Report

Sustainable Development Commission

$100 a Barrel of Oil

Impacts on the sustainability of food supply in the UK

A report by ADAS, commissioned by the SDC

November 2007

Preface

This study asks a simple question: what would be the impact on food of oil prices rising to $100 a barrel? When the SDC commissioned this research, oil was nearly half the price it is at the time of publication, and then it seemed almost fanciful to consider such Olympian price heights. Yet as I write, the price is almost there,[1] and petrol prices for motorists have breached the £1 a litre psychological beachhead. Oil vulnerability is the subject of mainstream political analysis and discussion.[2] This rapid price shift is raising issues of risk, resilience and security not just within the food sector but beyond. The UK's experience of the lorry strike in 2000 reminded planners and decision-makers how dependent the food system is upon oil.[3,4]

In a society where the average distance between home and the food shop is around 5 miles (beyond the distance most consumers walk, especially carrying bags), public interest about oil prices centre particularly on fuelling the car. At the SDC, we are equally concerned about how the food gets to the shops in the first place. Oil underpins both how food is produced, how consumers access it and (if they use electricity) how they cook it.

Even though this debate about oil and food is now 'hot', we would do well to remember that it has deep roots. For decades, policy analysts have pointed out that modern food systems' efficiencies have been reliant upon use of cheap fossil fuels.[5] But today, attention is rightly focussed on the impact of consuming fossil fuels: both the impact of climate change, and whether we are at, near or past the moment when oil supplies peak. Food and drink has emerged as one of the most significant sources of greenhouse gases in the EU, accounting for 31% of our climate change impact and 20-30% of total environmental impacts of European consumption.[6] There is now an important debate about which sectors within the food and drink economy have greatest impact with meat, meat products and the dairy sector identified as the most significant. Such details are becoming central to food companies' attempts to face and reduce their carbon footprint.

The impact of rising oil prices on food prices is uncertain. Cheap food has been deemed a sign of a successful economy: the less money spent on food, the more there is to fuel other sectors of the consumer economy. Keeping food prices down has been one of the benchmarks of the post World War II production-oriented policy. By and large, this has been hugely successful. Average household expenditure on food has dropped from a quarter of disposable income in 1950 to less than a tenth by 2005. However, this trend has stalled and food prices have begun to creep up. The large food retailers who take pride in their consumer products being good value-for-money and affordable, are now under pressure. They in turn are putting pressure back down the supply chain, to logistics, processors, farmers, growers and traders.

Although the SDC commissioned this study for its modelling, we now have the benefit of seeing how the model measures up against reality. The study was conducted by ADAS, and the model's assumptions, data analysis, implications and extrapolations are ADAS'. Undoubtedly, the model used here will require modification and commentary, as events and experience unfold, and both the authors and the SDC would very much welcome feedback. In particular, we recognise there are wider sustainability issues that are not covered by this study which will have huge importance, such as greenhouse gas emissions and water. The large-scale shift to biofuels, too, will have a serious impact on supply chains and prices. Combined with normal fluctuations and climate-related shortfalls the problem of sustained and severe food price inflation will be made a great deal worse by the arrival of $100 barrel oil. Another factor not covered here is the cultural drive to support organic, seasonal and local foods. Price is not the only determinant of food or shopping behaviour.

Nevertheless, price is very important. A core finding of the study was that food prices are not likely to rise as dramatically as some of the more apocalyptic thinkers might suggest. The figures presented suggest rises in food prices of 5% or 10% when oil reaches $100 a barrel. Such rises might seem comparatively small. For a food culture which has been built on assumed access to plentiful and ever cheaper food, even slight reversals can have profound effects. One possibility is that the psychological significance might be greater than the financial impact. Equally, consumers might be phlegmatic and take the upward pressures – now happening - in their stride. They might adapt and refine their spending patterns. Such issues deserve to be considered and debated, not least by health specialists, already concerned about the impact of many cheap calories on the nation's waistlines and subsequent ill-health.[7] Another impact is likely to be that the food supply chain will redouble efforts to reduce energy use as part of its core business strategy for containing costs and maintaining competitiveness.

Finally, on behalf of the SDC, I offer my sincere thanks to all who have contributed to this study. Many people in and beyond Government and the food sectors gave their time, thought and energy to refining and revising the project. We are extremely grateful to them.

Tim Lang

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Agriculture and Rural Issues
(& Professor of Food Policy, City University, London)

8 November 2007

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1 Closing price on 7 November 2007 was $96 (http://www.iea.org/)

2 Flood C (2007). *Oil rises with $100 target in view*, Financial Times, 8 November www.ft.com/cms/s/0/08075c78-8dec-11dc-8591-0000779fd2ac.html?nclick_check=1

3 Defra, *Food Security and the UK: An Evidence and Analysis Paper*. Food Chain Analysis Group. 2006, Department for Environment, Food and Rural Affairs – Food Chain Analysis Group. London http://statistics.defra.gov.uk/esg/reports/foodsecurity/foodsecurity.pdf

4 Peck, H., *Resilience in the Food Chain: A Study of Business Continuity Management in the Food and Drink Industry.* Final Report to the Department for Environment, Food and Rural Affairs. July 2006. 2007: London: Defra

5 Leach, G., *Energy and food production.* 1976, Guildford: IPC Science and Technology Press for the International Institute for Environment and Development.

6 Arnold Tukker, Gjalt Huppes, Jeroen Guinée et al (2006). *Environmental Impact of Products (EIPRO): Analysis of the life cycle environmental impacts related to the final consumption of the EU-25.* EUR 22284 EN. Brussels: European Commission Joint Research Centre. p.15

7 Foresight (2007). *Tackling Obesities: Future Choices.* London: Government Office of Science.

The $100 Barrel of Oil: Impacts on the Sustainability of Food Supply in the UK

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Abbreviations

Abbreviation	Meaning
ACP	African, Caribbean and Pacific (states)
ADAS	ADAS (UK) Limited
CAP	Common Agricultural Policy
CARD	Center for Agricultural and Rural Development
Cranfield	Cranfield University
Defra	Department for Environment, Food and Rural Affairs
ECU	European currency units
ESU	European Size Units
EU	European Union
FADN	Farm Accounting Data Network
FAPRI	Food and Agricultural Policy Research Institute
FISS	Food Industry Sustainability Strategy
FTE	Full-time Equivalent workers
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GOR	Government Office Region
GVA	Gross Value Added
IEA	International Energy Agency
LCA	Life Cycle Assessment
MBS	Manchester Business School
NFU	National Farmers Union
NZ	New Zealand
OECD	Organisation for Economic Co-operation and Development
OPEC	The Organisation of the Petroleum Exporting Countries
QUB	Queens University Belfast
SDC	Sustainable Development Commission
SDC	Sustainable Development Commission
SFP	Single Farm Payment
SME	Small and Medium Enterprise
SMP	Skimmed Milk Powder
SSFF	Strategy for Sustainable Food and Farming
TPES	Total Primary Energy Supply
UK	United Kingdom
US/USA	United States of America
WMP	Whole Milk Powder

Executive summary

The overall objective of this study is to provoke greater debate on the potential impact of increased energy prices on the ability of UK agriculture to be a successful market-based industry. It considers the likely direct impact of an oil price of $100/barrel of oil on UK agriculture and on the wider food supply chain. The work was undertaken by a consortium of researchers, led by ADAS; Cranfield University led the work on energy components of agriculture using Life Cycle Analysis while Queens University Belfast modelled macro-level changes in land use and reviewed the impact of biofuels.

Key findings are as follows:

- The energy component of food production is significant and when the cost of energy is doubled by moving from an oil price of $50 to $100 per barrel, the impact of production cost is in the order of 3-13% of farm-gate price.
- With a total cost increase per MJ of £0.0042, this gives an increase in household food expenditure of around £3 billion if the oil price rises from $50 to $100 a barrel and all costs are passed on to consumers. That represents a 4% increase in household expenditure on food within a total spend of £79 billion. We might expect an increase in household expenditure of between roughly 5% to 10% if all costs are passed on to consumers and secondary impacts are allowed for.
- The economic modelling in this research (AGMEMOD) assumes prices changes from an earlier study by Defra using Aglink, an OECD model. This forecast cereal and oilseed price increases of approx. 20-40% under $100 barrel oil, with meat prices rising by approx. 10-20% and dairy product prices by 5-10%. It indicated that by 2015, UK cereal production for feed/food would reduce and oilseed rape would increase marginally; there was an overall fall of 4% in land use by modelled crops. Livestock sectors are forecast to decrease by up to 4%, with the exception of pigs, which showed a 3% increase. These findings reflect the relative position of costs and returns across the sectors in an EU context. These forecast price impacts do not include any impact of changes in the biofuels market resulting from an increase in the oil price to $100 per barrel, which is beyond the modelling capability of this study.
- When the price rise used in the AGMEMOD model was doubled, the scale of impact was changed to a small extent but the direction was largely maintained. This suggests that decisions on the production of commodities in the UK is not very sensitive to the cost or price changes which may accompany $100 barrel oil.
- In terms of regional impacts, Northern Ireland, Scotland and Wales will be hit most hard due to their reliance on livestock and distance from processing or markets. While Scotland could benefit from better returns from the cereal sector via growth in the biofuel sector, Northern Ireland and Wales will not. The poultry sector (notably in Northern Ireland and some England regions) and the pig sector are vulnerable to higher feed costs and competition from imported product. Eastern regions of England and Scotland may become a focus for intensive beef finishing (using biofuel by-products), reducing transport costs and allowing extensification of grassland areas.
- With regard to competitive position, the LCA analysis of UK and international competitors for the six commodities demonstrated that higher energy prices are not necessarily detrimental to the UK when taking into consideration transport costs from exporting countries to the UK. Wheat, chicken and beef will be more

competitive though this does not change the wider position of having higher production costs than many third countries.

- Extensive and organic production systems in the UK are less severely affected by energy prices than intensive systems but lower output per unit area means that these systems will need to continue to have low costs or secure market premiums to prosper.
- Along the food supply chain, farmers are most vulnerable to higher energy costs, as historically, rising production costs are not rewarded from the market in the short term. Over time, this will impact on supply and in a growing market, buyers will adjust prices to encourage more supply. However, much depends on the global balance of supply and demand (and world stocks).
- The response of farmers will depend on the net financial impact on different sectors; cereal and oilseed crops benefiting from biofuel-led price increases may not feel pressure to reduce energy use while those crop and livestock sectors which are most impacted will seek to reduce costs. This may take the form of restructuring, technology uptake and energy efficient practices. However for many it will also involve better linkages with the processing and retail sector in order to reduce waste and transport costs.
- As energy use in food processing is generally the second highest next to agricultural production in most selected commodities, we would expect that food processors would be impacted greatly by the rising energy prices. They need to look for energy efficiencies and product innovation.
- Food retailers have most market power, dealing directly with consumers. They are best placed to pass on the costs either upstream or downstream along the supply chain to ease the impact from higher energy costs. While this can be negative in that suppliers are forced to find cost savings and rationalise, retailers can drive positive change in the UK food supply chain and in the longer-term deliver competitiveness through efficiency and innovation. A partnership approach is essential and this is already being seen in the growth of dedicated supply chains.

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1. Introduction

ADAS was commissioned by the Sustainable Development Commission (SDC) to research the economic implications of increased energy prices upon UK farm businesses, the wider impacts on the UK food supply chain, and the implications of this for the UK agricultural industry. While there are discrete outputs in terms of estimates of quantitative economic data, the broader aim of the project is to provoke greater debate on the potential impact of increased energy prices on UK agriculture. As such, the research has also considered the high level impacts of a potentially smaller industry, reliant on renewable energy markets as well as food and with a significant remit to deliver environmental public goods.

The brief was as follows:

The overall objective of this study is to provoke greater debate on the potential impact of increased energy prices on the ability of UK agriculture to be a successful market-based industry.

Based upon the premise of oil prices reaching $100/barrel of oil, it should explore:

- **The direct impact of increased energy prices upon UK farm businesses, with consideration to the potential for a change in farm practice**
- **The wider impact of increased energy prices on the UK food supply chain, and hence the competitiveness of the UK agricultural industry**

This chapter considers the requirement for the study; section 2 considers the policy context and section 3 sets out the research tools employed. Section 4 details the research findings with discussion of the impact of the biofuel sector. Section 5 considers the aggregate findings and section 6 sets out key conclusions and recommendations.

1.1 Approach

Following the inception meeting in January 2007, the methodology proposed by the ADAS team was refined, and the workplan revised to take account of the specific requirements of this commission. The following criteria were agreed:

- **Commodities and potential international comparisons chosen: feed wheat (Hungary); oil seed (Eastern Europe); milk (New Zealand); beef (South America); Poultry (Poland); and lamb if at all possible.**
- **The study will include a commentary on the relevance for the Devolved Administrations, and English regions, based upon the generic commodity results.**
- **The baseline will use 2005 data. It will assume the current CAP reforms to date, although the study might highlight the potential differences that could arise from further CAP reform**
- **Whilst not reflective of the real world, the study will assume that the farmer is driven by the market and will produce an economically rational response.**

Particular requests from the SDC and Defra were as follows:

- **A transparent approach, in which the various assumptions and challenges are clearly identified and discussed**

- **An approach that is robust**
- **The whole farm model to take into account wider on-farm energy efficiency savings in addition to a reduction in fertiliser use e.g. rotation and use of machinery**
- **Exploration of the change in production systems e.g. organic vs. conventional**
- **Exploration of the impact of farm sizes upon the profitability of a business and the extent to which efficiency savings can be made**
- **Part two to identify those areas of energy use in the supply and retail chain that are of greatest significance**

1.2 Workstreams

There are five key workstreams:

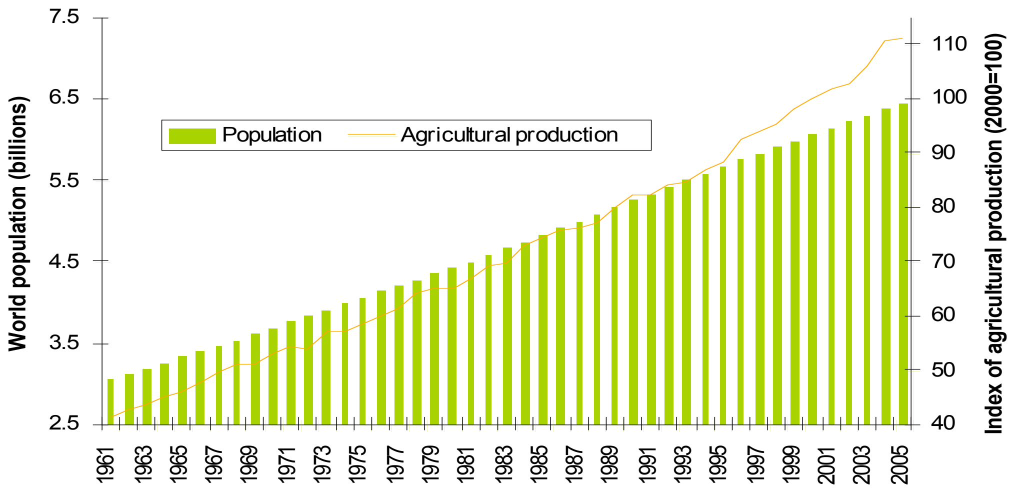
1. **Economic impact at farm level**. Using the LCA data on energy components of food production to estimate the first level impact on production costs.
2. **Competitive position**. Using the LCA data on energy components of food production in competitor countries to estimate the first level impact on production costs and to compare the effect against the UK position
3. **Producer response**. To assess how producers might respond to higher energy prices by looking at the differential impacts across sectors and between systems. We also consider opportunities for energy saving through technology uptake
4. **Macroeconomic response.** To use an established macroeconomic modelling tool to assess the impact of $100 barrel oil price on levels of production of commodities in the UK and Europe. This will include a review of the impact of the biofuel sector
5. **Food supply chain impacts**. To what extent is the food chain impacts beyond the farm gate and to what extent will this lead to a shift in the processing sector to overseas locations

Project progress was reported back to the Steering Group on a regular basis and Defra analysts were consulted on the methodology at an early stage.

1.3 Context for the work

Analysts predict that ‘peak oil’ will be reached this century; this is the point at which half of global oil production has been consumed, and beyond which extraction goes into irreversible decline. Higher prices may reduce consumption in the West but a growing global economy may increase demand and prices of $100 per barrel or more could be reached. This may be significant for the UK agricultural industry for two reasons. Firstly, there will be direct cost impacts on factors of production related to energy components e.g. fertilisers and pesticides, as well as direct fuel and heating energy use. Secondly, the biofuels sector may develop significantly, based not only on government policies aimed at reducing global warming or improved energy security but also on improved market returns (high energy prices). In this context, land may be taken out of food production to grow biofuels, adding further pressure on food prices. The context for this is also continuing word population growth (Figure 1).

Figure 1: World population and agricultural production 1961-2005



Source: FAO, State of food and agriculture

For the UK, which considers food security in European terms, there is little risk of food shortages but a real issue of food price inflation. Further, reduced trade protection in the EU as part of the WTO process means that more competitively priced imports from third countries could displace home production. This might be exacerbated by a move by retailers to manage food price increases in the short term. The European focus on environmental outputs (landscape, biodiversity, water quality etc.) and climate change (renewable energy, managing waste) could realistically see a shift in land use away from food production. Combined with a move to manage consumer prices, there may be a real threat to the UK food and drink sector, if not to UK farming.

This research does not aim to forecast the gross impact of oil price at $100 per barrel, which would include secondary impacts on the cost of other factors of food production such as labour and land and ultimately on other costs through inflation impacts on the wider economy. Instead it considers the first level impact of oil price change, based on component energy inputs. This raises the issue of how sensitive (elastic) food consumption is to price.

While there is discussion on the potential response to a rapid change in oil price, the analysis relies on comparing $100 per barrel oil costs to a baseline, rather than possible 'shock' impacts in the interim. The latter are discussed on the basis of past experience of significant oil price rises in 1973 and 2001.

Finally, the report considers a response to the prospect of $100 barrel oil energy prices. Over 50% of world oil use is consumed in transportation, and world demand for oil is forecast to increase by 37% by 2030, driven in large part by transport needs[1]. This begs the question of whether the current global food market is sustainable at higher energy prices.

[1] http://news.bbc.co.uk/1/hi/business/5099400.stm

2. Energy in the UK Food and Drink Supply Chain

Energy is a key component of food production and consumption and the impact of a $100 barrel oil price would depend critically on which processes are most energy-intensive and efficient. The response would include opportunities to exploit new technology or improve energy efficiency. This section reviews the policy context and available data on energy use as a basis for considering the impact of an increase in energy price.

2.1 Policy Context

The key areas of policy relevant to this work are sustainability in the food and farming sectors, climate change and UK energy policy.

The **Sustainable Farming and Food Strategy (SFFS)**[2]**,** published in December 2002, set out how industry, Government and consumers can work together to secure a sustainable future for farming and food industries. Key areas of action included reconnecting the food supply chain, reducing the environmental damage caused by agriculture and the wider food chain and enhancing the positive impacts, reform of the CAP and investment in skills and new technology. A review of progress in 2006[3] (Forward Look) introduced the concept of "One Planet Farming" to develop a profitable and competitive domestic farming industry which is a positive net contributor to the environment, while reducing the environmental footprint – at home and abroad – of our food consumption. The latter emphasises the key role of consumers in ensuring that patterns of consumption respect environmental limits. Another of the five priority themes 'Climate change & agriculture' recognises that while agriculture contributes to UK Greenhouse Gas (GHG) emissions, it also has a major role in the production of bioenergy and other non-food crops which can help to reduce overall UK carbon emissions.

The **Food Industry Sustainability Strategy (FISS)**[4] looks at sustainable food production practices beyond the farm-gate. It sets out how those involved in the food industry (manufacturers, wholesalers, retailers and food service providers) can, through widespread adoption of best practice, help achieve sustainable development. It also covers the role that Government and industry can play to inform sustainable consumer choices better and influence current patterns of consumption. The FISS recognises that environmental impacts arise across the whole food chain – overseas as well as in the UK. The strategy's environmental ambitions are for the industry as a whole to:

- reduce its carbon emissions by 20% by 2010 against a 1990 baseline;
- reduce water use by 10-15% by 2020 and by 20-25% in the south east of England;
- significantly reduce the environmental and social costs of its domestic food transportation by 2012; and

[2] Defra (2002) Strategy for Sustainable Farming and Food. Available from: http://www.defra.gov.uk/farm/policy/sustain/pdf/sffs.pdf
[3] Defra (2006) SFFS: Forward Look. Available from: http://www.defra.gov.uk/farm/policy/sustain/pdf/sffs-fwd-060718.pdf
[4] Defra (2006) Food Industry Sustainability Strategy. Available from: http://www.defra.gov.uk/farm/policy/sustain/fiss/pdf/fiss2006.pdf

- for the food manufacturing sector to reduce its food waste by 15-20% by 2010

Industry-led Champions Groups have responded to Government and set out how they can make progress towards these ambitions[5].

In recent years, food security has become increasingly discussed as a matter of concern in some developed countries, including in the UK. Two main triggers appear to be at work:

1. In the UK, the self-sufficiency ratio of domestic production to consumption has been in noticeable decline over the last decade. The ‘decoupling’ reforms of the CAP, together with the prospect of trade liberalisation in agricultural products, are expected to reduce domestic agricultural production in the UK and Europe.
2. In the context of climate change, international energy concerns, geopolitical tensions and international terrorism, a growing sense of the potential for disruption to domestic food supplies in an uncertain world.

Together with other factors this has prompted a review of Food Security by Defra[6] which concluded that the UK is, and has long been, ‘food secure’ and that a more relevant priority is strengthening energy security. As such, there is no national policy to maintain or increase UK food production although food and drink is a priority at regional level in terms of employment and Gross Value Added (GVA). In this context, a policy of promoting renewable energy crops will increase competition with food markets, which will seek to secure supplies from imports and/or minimise cost impacts.

In terms of addressing climate change, the UK has introduced a number of initiatives, such as the Climate Change Levy and agreements, Renewables Obligation and Energy Efficiency Commitment. Government has set a domestic target to reduce carbon dioxide emissions by 20 per cent below 1990 levels by 2010 as part of a wider Climate Change Programme[7].

Specific industries have agreements to improve the industry energy performance in line with objectives of the **Climate Change Levy**[8]. These agreements commit the industry to implementation of measures to meet specific targets from a base year for performance (1999). It is useful to initially note these figures as they provide an indication of the overall processing energy levels per functional unit in a range of standard UK food commodities (table 1).

Table 1: Energy use in food manufacturing for red meat, poultry meat and dairy products

Association	Target (MJ /tonne)	1999 base
British Egg Industry Council	3,490	
British Meat Federation	1,997	2,025

[5] Defra (2007) Final submissions of the Champions’ Groups, available from: http://www.defra.gov.uk/farm/policy/sustain/fiss/index.htm
[6] Defra (2006) Food Security and the UK: An Evidence and Analysis Paper
[7] Defra (2006) http://www.defra.gov.uk/environment/climatechange/uk/ukccp/index.htm
[8] DEFRA Climate Change Agreements Sectoral Energy Efficiency Targets http://www.defra.gov.uk/environment/ccl/pdf/etsu-analysis.pdf

British Poultry Meat Federation	2,344	2,675
Dairy Industry Federation	1,599	1,762
Food and Drink Federation	3,236	3,758
Maltsters Association of Great Britain	4,331	4,698

The Government's report on the **Energy Review**[9], 'The Energy Challenge' sets out the two major long-term challenges in UK energy policy and what response is needed:

1. need to tackle climate change by reducing carbon dioxide emissions; and
2. need to deliver secure, clean energy at affordable prices, as we move to increasing dependence on imported energy

A key action for industry is 'measures to reduce carbon emissions in large non-energy intensive business'.

Other relevant policies are the **Renewable Transport Fuels Obligation**[10] and the **Energy White Paper**[11]. These set out Governments long-term goal to reduce carbon dioxide emissions. Biofuel production is already a part of the EU policy and the policy sets indicative targets that by 2010, 5.75% of energy in the EU will need to be from renewable resources. This means that either part of food (mainly rapeseed and wheat in the EU) or part of land for the food production may be used for energy purpose and subsequently agricultural production and marketing may be restructured for this policy alone. Higher crude oil price may trigger more use of the renewable to be substituted for the fossil fuels.

In March 2007, European Union leaders agreed to adopt a 10% minimum target on the use of bio-fuels in transport by 2020, which is binding.

2.2 Energy use in the Food Supply Chain

Energy is used at all stages of the food supply chain, from manufacture of farm inputs and food production to processing, packaging and distribution. At the retail and consumption stages, transport and refrigeration also consume considerable amounts of energy.

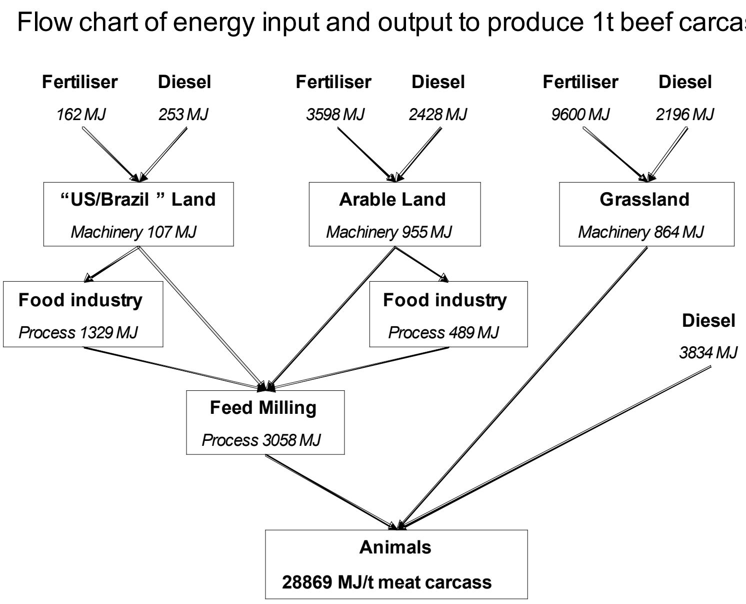
Cranfield University undertook a major study for Defra[12] to quantify the environmental impact of a number of farm commodities using Life Cycle Assessment (LCA). It quantified the resource use (including energy use) and environmental burdens arising from the production of ten key commodities: bread wheat, potatoes, oilseed rape, tomatoes, beef, pig meat, sheep meat, poultry meat, milk and eggs. Organic production systems were analysed, as well as variations on non-organic production.

[9] DTI (2006) The Energy Challenge. Energy Review Report 2006. Available from: http://www.berr.gov.uk/files/file31890.pdf
[10] DTI (2006) The Energy Challenge. Energy Review Report 2006, Chapter 6. Available from: http://www.dft.gov.uk/pgr/roads/environment/rtfo/chpt6energyreview

[11] DTI (2007) Energy White Paper: meeting the energy challenge. Available from: http://www.berr.gov.uk/files/file39387.pdf
[12] Williams, A.G., Audsley, E. and Sandars, D.L. (2006) Determining the environmental burdens and resource use in the production of agricultural and horticultural commodities

All inputs into on-farm production for each commodity were traced back to primary resources such as coal and crude oil. Farm level energy inputs and outputs are illustrated for beef production in figure 2. This shows a breakdown of the inputs of energy in diesel, fertiliser and machinery manufacture to grass and arable land in the UK and overseas, and process energy in industry which goes in to the systems of production which result in 1t of beef.

Figure 2: Flow chart of energy input and output of farms



Results are summarised at table 2. Poultry and pigs consume high volumes of feed and effectively live on arable land, as their nutritional needs are overwhelmingly met by arable crops (produced both in the UK and overseas). Ruminants can digest cellulose and so make good use of grass, both upland and lowland. Much of the land in the UK is not suitable for arable crops, but is highly suited to grass. It is expressed in the table in terms of grade 3a land equivalents.

Table 2: Energy use arising from the production of field and protected crops

Commodity	Unit	Primary energy use (GJ)	Land use (ha)
Bread wheat (0.7%)	Tonnes	2.5	0.15
Oilseed rape (0%)	Tonnes	5.4	0.33
Potatoes (1%)	Tonnes	1.4	0.03
Tomatoes (3.6%)	Tonnes	130	0.003
Milk, (1%)	$10m^3$ milk	25	1.2
Beef (0.8%)	tonnes of carcass	28	2.33
Sheep meat (1%)	tonnes of carcass	23	1.4

Pig meat (0.6%)	tonnes of carcass	17	0.74
Poultry meat (0.5%)	tonnes of carcass	12	0.64
Eggs, (1%)	20,000 eggs	14	0.67

Current organic share shown in parenthesis

Organic production, which usually requires less energy input but lower yields and higher inputs into fieldwork may offset the large reduction in energy used by avoiding synthetic N production, only accounts for a small percentage across various agricultural sectors. .

In 2005, Manchester Business School (MBS) undertook a review of a 'shopping basket' of food items to consider their environmental impacts (including energy use) using LCA and related approaches[13]. The review found a dearth of research post farm-gate but used evidence from both UK and international studies to draw the following conclusions:

- significance of packaging in the life cycle, particularly for bottled drinks
- organic food chains are not necessarily less energy demanding per unit of output
- energy requirements can vary widely between different production systems, notably fruit and vegetables
- high energy requirements for all meats due to reliance on feed inputs
- the growth of refrigeration as the 'default' method of food preservation and storage throughout the production-consumption system will exacerbate energy use

[13] Manchester Business School (2006) Environmental Impacts of Food Production and Consumption. Report for Defra

3. Research tools

In order to undertake this study a number of research tools have been employed. These are considered in turn and limitations of each approach considered.

The analysis of the (long-term) price of inputs when the oil price is $100 is based on the calculation of the primary energy needed for production and delivery of the input calculated by the Cranfield LCA model. The agreed baseline for the research was 2005 and impacts should be measured from that point, assuming other variables remain largely constant. Energy price in 2005 has been assumed at $50 per barrel of oil.

3.1 Life Cycle Assessment

We have employed the Life Cycle Assessment method to capture the energy requirements and therefore the impact of higher energy costs for agricultural production and the wider supply chain. LCA is an instrument that provides a quantitative estimate of all flows of materials and energy related to producing a product, providing an evaluation of the environmental compatibility and end result of each productive choice. It can be applied to agricultural production to examine the environmental impacts/burdens of producing agricultural products by considering both of inputs (relates to energy use) and outputs (relates to emissions) in energy terms.

Based on the LCA approach, two levels of impact are examined, one of which is the farm level impact on production costs and the other is the impact on the food supply chain. In terms of food production, international competitiveness is also examined on the basis of available LCA studies on production costs and food supply chain.

Farm level impact

LCA is used to quantify changes in production costs due to higher oil prices for selected agricultural commodities. There are three forms of inputs for agricultural production that can be directly or indirectly affected by increased oil prices. They are:

- direct energy inputs (including diesel, petrol, electricity and natural gas);
- indirect inputs in the forms of fertilisers, chemicals and animal feed, and
- the capital inputs which include farm equipment, machinery andbuildings.

When crude oil prices increase, the production costs for agricultural products will increase through these direct and indirect links with energy inputs. The LCA method traces all these inputs back to primary resources, including crude oil, and through price transmission by converting oil price to energy per MJ price, it quantifies the necessary increases in agricultural production costs.

Prices can also increase due to economic opportunism, such as the large increases seen in the price of bread ‘due to’ small increases in the price of wheat, and equally can fail to increase because of economic pressures. In addition many companies will have long-term fixed price contracts, which in the short term insulates them from increases. It can also mean that the spot price for oil is a poor estimate of the actual price being paid for energy. In the longer term however, in a competitive market, price increases can be expected to accurately reflect the longer-term increases in costs of production.

We would anticipate that the degree of impact of oil price increase depends on the level of reliance on energy and energy efficiency in production. By breaking down costs to their components for each of the selected commodities, each primary energy component needed for its production is known and hence the increase in price of the component due to higher oil prices can be estimated.

Based on LCA studies and price transmissions from crude oil to agricultural inputs, the production costs under the $ 100 per barrel oil have been estimated for the UK. By comparing these results with reviews of production costs for selected agricultural commodities of competing countries, the impact of higher oil prices on the relative international competitiveness of UK is examined in terms of production costs.

Note that labour costs are a major input to agricultural production costs, but their increase due to the increase in oil price and its effect on the cost-of-living, and other costs, due to $100 oil is taken as a second order effect and ignored.

Food Supply Chain

LCA methodology is also applied to study the impact of higher energy cost on the food supply chain. Energy inputs (electricity and fuel consumption) in the life cycles of food items can vary from 2 to 220 MJ per kg due to a multitude of factors related to animal or vegetable origin, degree of processing, choice of processing and preparation technology and transportation distance[14]. Comparisons of life cycle energy inputs for stages in food supply chains therefore give a good indication of where problems may arise if oil prices increase.

3.2 Economic Modelling

To examine the economic responses, Queen University Belfast (QUB) has used the AGMEMOD model to examine the impact on agricultural production and commodity prices of higher oil prices at the aggregated level. The AGMEMOD model is an econometric, dynamic, multi-product partial equilibrium model that allows us to make projections and simulations to evaluate the national level impact on agricultural production and prices when oil price increases to $100 per barrel.

The AGMEMOD project is a collaboration of European research partners to develop a model of the agricultural sectors. Each partner builds a model of their own country using central guidelines. Within a country's model, agricultural sectors are linked through land restrictions, price linkages, and relative profitability of one commodity against another. The arable and livestock sectors are linked through the grain demand for livestock feed. The agricultural price equations are set in the country with a dominant position in that commodity, but include the aggregate supply and demand of all countries. Grain and cheese prices are set in France, butter and meat prices are set in Germany (with the exception of lamb: Ireland), potato and SMP prices are set in the Netherlands, and the WMP price is set in the UK. Commodity prices in each country are then linked to those "central" prices. The price of rapeseed, however, is linked directly to the world market price in all country models.

The first step was to establish a baseline of the agricultural sector for the period 2005-2015. The macro-economic assumptions on exchange rates and GDP were taken from projections. Agricultural policy is assumed to continue; agreed arrangements for the projection period are incorporated. The AGMEMOD model provides a reliable

[14] Carlsson-Kanyama, A. *et al*., (2003). Food and Life cycle energy inputs: consequences of diet and ways to increase efficiency. Ecological Economics 00 (2003) 1-15.

baseline that can be used to compare alternative policy scenarios. This baseline has been tested for robustness by several research partners.

The impact of $100 oil price on the world price of agricultural commodities was modelled by Defra in 2006 using the Aglink model, as developed by OECD. The model takes into consideration the potential impacts of the emerging substitutional energy-biofuels market. It treats the EU15 as a single producing and trading entity. It was found that, in general, the prices of agricultural commodities rise as a direct result of higher production and transportation costs. These price rises ranged from around 10% for beef to nearly 60% for vegetable oil for the period 2002-04 to 2014. The historic time series differ slightly between the AGMEMOD and Aglink models. Including the Aglink baseline world market prices into the AGMEMOD model would disturb the steady path of AGMEMOD baseline projections and new market equilibrium would be established. To resolve this difference, the relative change in Aglink projected prices were applied to the AGMEMOD projected prices.

The increase in world prices is offset by the higher production costs within the EU. Changes have been made to the production decisions by reducing the price impact according to the rise in energy costs. The latter information was taken from two sources: agricultural production handbooks, such as Nix (2005) for the UK, and the Farm Accounting Data Network (FADN). The advantage of the former source is that it provides energy costs for arable or livestock produce on a typical farm. The FADN data categorises sample farms that cross different arable or livestock enterprises. For example, the farm type “specialist granivores” includes breeding pigs, fattening pigs, broiler, laying hens and turkeys.

For arable production, the production decisions that were augmented with increased energy costs were generally harvested area and yield. Changes were only made if these production decisions were already driven by an output price or expected return. For livestock production, most production decisions used a production costs index to deflate the price. In other words, if the energy costs increase, the deflated price falls. As mentioned earlier, variations in model structure between countries and commodities meant that a variety of adjustments were made for each individual equation.

3.3 Farmer Response

There are three levels at which farmer response is considered:

1. **Country level** – changes in country level production from the economic model results will prompt a consideration of where production of a given commodity will expand or contract. This involves a regional analysis and an assessment of energy efficient production systems and trends.
2. **Farm enterprise** – the Cranfield LCA analysis was used to assess likely changes in returns and absolute terms and relative to key competitor countries. These economic signals will drive production at farm level. Secondly the Cranfield Agricultural Land Use model, which determines the optimising response of farmers to given gross margins and costs, was used to indicate the land use response to the (European) prices indicated by the economic model.
3. **Sector level** – ADAS technical experts have reviewed the evidence from the overall analysis of energy impacts to validate the farmer response. This includes key opportunities for energy efficiency and technological change.

The challenge in terms of gauging farmer response is the complex of national and international actions which drive the economics of an industry, from Government subsidies to labour markets and regulation frameworks. Thus while the UK may operate an enterprise with very low energy input or a high degree of energy efficiency, the market signals at production level may lead to a decline in the sector. For example, environmental stewardship schemes may encourage extensive production systems e.g. sheep or market prices may be driven by the cost of imports from third countries with lower labour or regulatory costs e.g. poultry.

The approach taken in this study is to consider the headline first-level impacts and to set in the context of a wider policy and market environment.

3.4 Supply Chain Impact

In order to examine the impact of high energy prices across the food supply chain, we have adopted a 'sampling' (or- bottom up) approach, selecting four food commodities to represent overall consumption, to be consistent with previous sections of this study. The commodities are:

1. Milk/dairy products
2. Wheat/oilseed
3. Beef/Lamb
4. Chicken

Given the short timeframe, a cursory assessment of the supply chain has been completed for each commodity above from port or farm gate up to retailing. There is a distinct lack of data on energy use within the individual sector supply chains and the analysis is based on available information. However, each representative supply chain provides a basis for discussion of the potential impacts of $100 barrel oil.

We have considered:

- relative use of energy along the supply chain; energy inputs (transport, processing, etc.) within each post-production supply chain have been assessed to identify the points of greatest impact from high energy prices
- first order impact on supply chain costs
- whether this might encourage more processing to be exported to country of production
- opportunities for cost cutting or substitution

The analysis is highly dependent on secondary published research.

We have also considered the aggregate national impact on the food supply chain in terms of household spend. Defra provided data on energy use and the price effect has been applied to this to give an overall first level impact. It also gives some indication of where, along the supply chain, the impact is most significant.

4. Research findings

This section presents the results of the various research activities undertaken, as outlined in the previous section. It provides an initial analysis for each component in the context of the research questions and includes a review of the biofuel sector in section 4.5. An overview of all the components is brought together in section 5.

The analysis of the (long-term) cost of inputs at an oil price of $100 is based on the calculation of primary energy needed for production and delivery of the input as calculated by the Cranfield LCA model. Thus, as a barrel of oil contains 6100MJ, at $100 per barrel the cost of energy is 0.0084 £/MJ. Clearly this ignores the various fractions of oil, which have different values and concentrates on the middle range or major products. We also assume that this cost presents the basic price of all other energy sources such as gas, nuclear, hydro. History suggests that the price they can obtain is more or less driven by the price of oil.

Taking nitrogen fertiliser as an example, the LCA analysis shows that this requires 41 MJ/kgN fossil energy. It should be noted that this includes the energy for the production and delivery of the feedstock to the production process AND the energy for the delivery of the product to the user. In the past with the oil price around $25 per barrel, the fertiliser price has been 35p/kgN; this includes many other costs such as marketing, delivery, packaging and profit. Adding the $100 increase in oil price to the portion of the fertiliser price due to energy cost, the resulting estimate of the $100 fertiliser price is 61p/kgN.

Recently with the oil price at $50/barrel, the fertiliser cost has increased to 45p/kgN. Using the price linkage starting from an oil price at $50, the fertiliser price at $100 is 62p/kg, and starting from an oil price of $25, the $50 fertiliser price estimate is 44p. This suggests that this method of oil price transmission is quite robust (See details in Table 3).

Table 3: Estimation of the cost of fertiliser at $100/barrel

	Energy cost (£/MJ)	Fertiliser energy (MJ/kgN)	Fertiliser price (£/kgN)
Base price $25	0.0021	0.09	0.35
Base price $50	0.0042	0.17	0.45
New price @ $50 from 25	0.0042	0.17	0.44
New price @ $100 from 25	0.0084	0.34	0.61
New price @ $100 from 50	**0.0084**	**0.34**	**0.62**

Assumptions: barrel of oil is 159 litres and has energy content of 6,100 MJ
Fertiliser uses 41 MJ/kgN
$1.00 = £0.51

4.1 First level impact on agricultural production costs

This research examines the situation in which oil price increase is the only driver of change, relative to a baseline position. We thus assume that labour costs for example, are unchanged and all costs and prices are calculated at current values.

Thus the first level impact of $100 barrel oil assumes that direct cost impacts are taken into account but not indirect impacts (e.g. on labour cost) and that there is no response in terms of production systems.

The Cranfield LCA model has been used as the basis for this analysis across the six commodities identified by SDC. The results are set out in Table 4 and Table 5. The costs are expressed as a percentage of the commodity price since this best reflects the total costs of production, including labour and in the case of livestock the costs of rearing the cows and ewes.

Table 4: Breakdown of income and costs for wheat and milk

Nix (2007)	Wheat @ 8.25 t/ha		Milk @ 7000 l/cow
Price	£75/t		18ppl
Income	620		1260
Area payment	184		92
TOTAL INCOME	**804**		**1352**
Variable costs	261	Replacements	67
		Concentrates	254
		Forage	95
		Vet, medical, other	139
Labour (paid)	95		670
Machinery	175		350
Rent	140		190
General overheads	70		170
TOTAL COSTS	**781**		**1245**

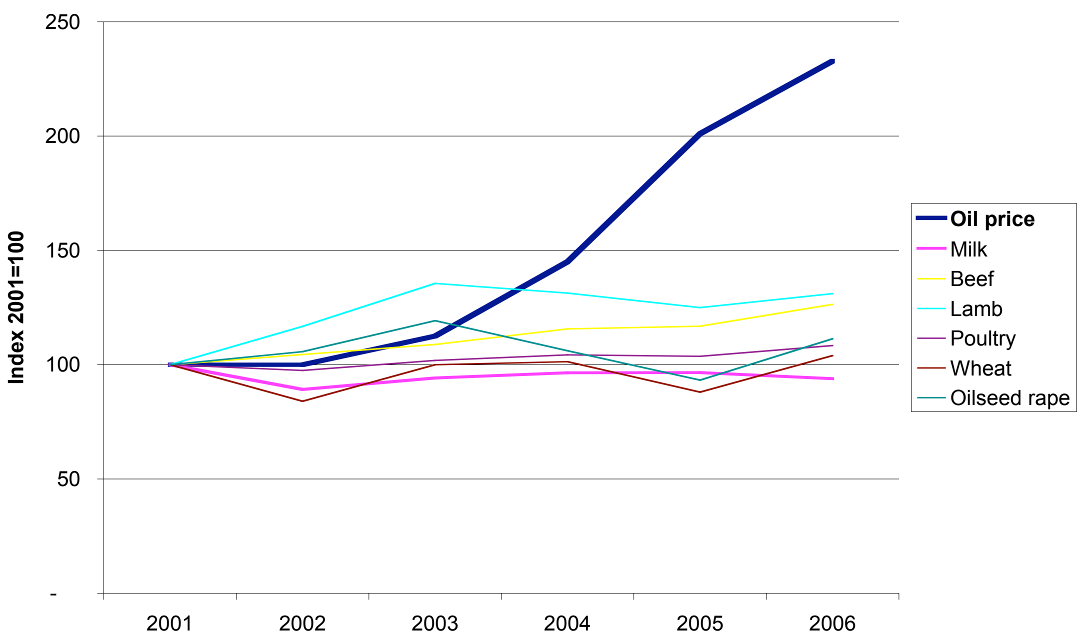
It should be noted that wheat price represents typically 13% of the price of a loaf of bread. The corresponding figures for chicken, beef and milk are 30%, 46% and 30%. Thus farm prices typically represent less than 2% of any increases in retail prices due to $100 oil. However since farm energy represents in the order of 20% of total retail product energy, this would suggest an overall retail price increase of the order of 10%, which if it occurred in one year would be a substantial rate of inflation.

Table 5: First Level Impacts of $100 barrel oil on UK production costs

	Units	Energy (MJ)	Baseline Farmgate price (£)	Increase in production costs (£/unit)	As % of commodity price	As % of retail commodity
Wheat	tonne	2,194	69	9	13%	1.7%
Oilseeds	tonne	5,388	154	20	13%	-
Poultry	1000 kg dwt	14,882	1,260	63	5%	1.5%
Beef	1000 kg dwt	26,870	2,260	113	5%	2.3%
Sheepmeat	1000 kg dwt	25,477	3,567	107	3%	1.5%
Milk	10,000 litres	25,757	2,160	108	5%	1.5%

Part or all of the cost increase may be passed onto the market, depending on the elasticity of demand, availability of lower priced imports and other factors such as increased competition for land for bioenergy feedstock crops. Evidence from the recent increase in oil price from $28 per barrel in 2001 and to $65 per barrel in 2006 suggests that the market has not passed much of the associated production cost increased back to farmers. Figure 3 shows the price trends over the same period for the six commodities observed in this study and the apparent lack of a correlated short-term response. However prices have increased over the period by an amount which is consistent with the values determined in Table 5.

Figure 3: Oil price compared to farmgate prices 2001-2006



Source: Defra AUK

In this context, the supply chain does not demonstrate a short-term response to energy cost increase on the scale of oil price increase. However, there is a modest response, commensurate with the 3-13% cost increase due to energy inputs, estimated in table 5. Any shortfall will require producers to secure efficiency savings through better allocation of resources or technological innovation. For some sectors such as beef, there is considerable scope for cost saving while for others such as poultry, the industry is already highly concentrated and efficient, with limited scope to reduce costs. The latter will need to add value to output through product innovation and differentiation as a means of recouping additional costs.

4.2 First level impact on agricultural commodity margins

In the absence of reliable trend data, the longer-term impact of a substantial oil price increase on farm commodity prices has been estimated by economic modelling. Defra has undertaken some work using the OECD Aglink-Biofuels model. It considered the impact of oil price on commodity prices through higher production costs and also through increased biofuel demand. While the results indicated that further increases in oil price would not lead to large shifts in production or consumption, it did forecast a significant rise in world commodity prices.

The Aglink model predicts an increase in wheat price at $100 oil price from £78 to £101/t, an increase of almost 30%. This can be combined with the LCA-based estimates of production cost changes from Table 5 to give an overall impact on enterprise margin. The impact on a typical UK gross margin for milling wheat is shown in Table 6; this is based on England data where most milling wheat is grown. Some regions with good soils and adequate rainfall can achieve substantially higher yields, but NPK input would be proportionally higher.

Table 6: Forecast margin for milling wheat at $50 and $100 per barrel oil

		@ $50		**@ $100**		
Yield, t/ha	8.14					
Price, £/t @ $50			78		78	101
OUTPUT (£/ha)			**635**		**635**	**824**
		Price (£/kg)	**£/ha**	**Price (£/kg)**	**£/ha**	**£/ha**
N, kg/ha	192	0.45	86	0.61	117	117
P, kg/ha	48	0.36	17	0.43	21	21
K, kg/ha	48	0.21	10	0.24	12	12
WOHerbicide	10	2.04	20	2.19	22	22
Seed, kg/ha	155	0.24	37	0.31	48	48
Other inputs			80		86	86
Additional fuel costs					24	24
Additional machinery costs					12	12
INPUT (£/ha)			**251**		**342**	**342**
Margin (£/ha)			**384**		**294**	**482**
Margin change (£/ha)					*- 91*	*98*
Margin change (£/tonne)					*- 11*	*12*

The baseline margin based at $50 barrel oil prices is £384/ha. Adjusting for the prices of inputs due to $100 oil price (including fuel and machinery prices), this falls to £294/ha, a fall of £11/t. However, if the predicted wheat price increase of 30% is included, there is a net increase in margin of £12/t. Note that while the cost increases of fuel and nitrogen fertiliser are felt within a year, machinery cost increases will not take effect immediately as they only take effect as machinery is replaced. Overall, the profitability of wheat production will increase due to biofuels.

Note that the cost changes only reflect the energy component, with no secondary impacts on the other factors of production.

The process has been completed for a range of crops and results are shown in table 7. Again, this relates to England data but the direction and scale of impact would be similar for other UK regions, where for example, both yields and inputs might be lower.

Table 7: Forecast margin changes for crops at $50 and $100 per barrel oil

	Milling Wheat		W Barley		S Barley		Oilseed rape	
Yield, t/ha	8.1		6.7		5.2		3.5	
	Old	New	Old	New	Old	New	Old	New
Price (£/t)	78	101	63	73	73	85	143	225
Sales	635	824	422	490	380	441	500	786
Other	0	0	66	66	56	56	0	0
OUTPUT (£/ha)	**635**	**824**	**488**	**556**	**436**	**497**	**500**	**786**
Inputs								
N, kg/ha	86	117	73	99	43	58	86	116
P, kg/ha	17	21	14	17	13	15	18	21
K, kg/ha	10	12	8	9	7	8	9	10
WOHerbicide	20	22	20	22	0	0	0	0
Seed, kg/ha	37	48	34	44	40	51	23	23
Other inputs	80	86	42	46	59	62	42	46
Fuel		24		24		23		26
Machinery		12		12		11		11
INPUT (£/ha)	**250**	**342**	**191**	**273**	**162**	**228**	**178**	**253**
Margin (£/ha)	385	482	297	283	274	269	322	533
Change (£/ha)		*97*		*-14*		*-5*		*211*
Change (£/t)		*12*		*-2*		*-1*		*61*

Note that the Aglink price effect varies by crop, from 16% for barley to 57% for oilseed rape based on $100 barrel oil (see Annex 4 for Aglink assumptions). For barley, the price increases predicted by the Aglink model are largely balanced by the predicted increases in costs due to oil price and thus the crop margin is largely unchanged. Oilseed rape prices are predicted by Aglink to increase substantially resulting in an increase in net margin of £61/t even after increases in fuel and machinery. The margin is considerably higher than that of bread wheat. This is driven within the model by the increased demand for oilseed rape for biodiesel.

The Defra paper on the Aglink model recognises that the assumption that biofuels are not traded is unrealistic because it is expected that the EU will source some of its biofuel needs from other countries, e.g. cheaper Brazilian ethanol. Therefore the effects of biofuel growth on European feedstock demand are likely to be 'slightly overstated'. As such the wheat and oilseed prices used in the modelling in this study are also likely to be overstated.

When these crop gross margins were applied at the farm level using the Cranfield Agricultural Land Use model, the results were anomalous, due to the significant impacts on margins of wheat and rape, relative to other land use options. In practice all agricultural production and prices would be impacted by higher energy prices and land use change in the longer run will depend on the competitive position of the UK and changes in global demand.

4.3 Impact on international competitive position

The extent of trading in both food and biofuel feedstock will depend not only on EU level impacts but also on the EU and UK competitive position against third countries. In particular countries with lower production costs for grains, oilseeds and proteins are likely to be further advantaged by higher oil prices, relative to the EU.

The starting point for this analysis is the relative use of energy in overseas production systems. LCA data has been used for this purpose where available, e.g. New Zealand milk and lamb production and Hungary for wheat, but for other commodities a more indirect approach has been used. Thus, the cost impact of oil price on cereals and proteins has been used to estimate beef and poultry impacts in Brazil and imported palm oil has been used as a competitor product for oilseed rape. The LCA analysis of UK and competitor country production is detailed in Annex 2 and summarised in table 8.

Table 8: First Level Impacts of $100 barrel oil on UK production costs

Commodity	Unit	Competitor country	Increases in production costs (£/unit)		UK Competitive position (£/unit)	Change in UK cost as % price (%)
			UK	Competitor		
Wheat	tonne	Hungary	9	12	+3	+4%
Oilseed rape	Tonne of oil	Malaysia (palm oil)	36	16	-20	-5%
Chicken	1000 kg dwt	Brazil	96	116	+20	+2%
Beef	1000 kg dwt	Brazil			+58 to +81	+3-4%
Lamb	1000 kg dwt	New Zealand	107	66	-41	-1%
Milk	10,000 litre	New Zealand			-0.1 to -0.2 ppl	-1%

Wheat

Based on the increased cost of energy from $50/t to $100/t, the increased cost of the energy component of production is estimated at £9/t for the UK and £12/t for Hungary. In all cases however, the competitiveness of the UK has increased by £1-4/t due to lower crop yields in Hungary. UK wheat competes with Black Sea ports for exports to other countries and has an advantage when transport (sea and land) is considered. This is relatively less significant than production cost impacts at about £1 per tonne.

Oilseed rape

In terms of oil production, one of the major competitors is the oil palm. This is the most productive of all oil crops but has significant environmental impacts. The comparable energy input figure for oilseed rape after allocation to the protein meal fraction is £20/t more for oilseed rape oil relative to sustainable palm oil.

Milk

New Zealand has a small domestic dairy market with 95 percent of all milk produced being exported and represents a key competitor for UK milk producers in home markets. Production is based on an extensive outdoor system and is focused on commodity markets. LCA data from New Zealand suggests an increase in competitiveness relative to the UK at $100 barrel of oil, ranging from 0.06 to 0.20 ppl after transport.

Lamb

The New Zealand study of food miles calculates the energy cost of both home produced and UK lamb. As the analysis made a number of worst case assumptions about UK production, Cranfield data has been used. The increased cost of energy at $100 barrel oil will add £66 and £107 to the cost of producing one tonne of lamb carcass from New Zealand and the United Kingdom respectively. This represents a 1% reduction in competitiveness of the farm gate price, and considerably less in terms of the retail price.

Beef

UK beef is produced largely from grass while in a hot country such as Brazil, grass is unreliable and cattle are kept 'indoors' in feedlots. The bulk feed is maize silage plus concentrates. In lieu of actual data on a Brazil feeding system, a ration was calculated using maize silage and soyameal which provided the same intake of metabolisable energy and protein as the whole UK beef system per tonne of beef meat. The UK benefits from a much lower energy requirement for grazed grass than maize silage. The increase in competitiveness of UK against Brazilian beef is estimated at £81/t or 3.8% of the price of beef, based on a $100 versus $50 barrel of oil.

Poultry

Brazil (and Thailand) is a key competitor to the UK for poultry production, targeting frozen chicken. The industries are very modern having increased largely over the last few years and thus technically are very similar to our own industry. The major differences are in the feed used which are more based on a maize and soyameal diet where the UK uses wheat and soyameal. The analysis is based on comparative diets and transport impacts of $100 barrel oil. The cost of UK poultry meat increases by £96/t compared to £116/t for Brazilian chicken, giving a reduction in competitiveness of Brazilian poultry meat of £20/t, compared to a typical farm-gate value of poultry meat of £1200/t.

The impacts for all sectors need to be seen in the context of overall competitive position. For example, in the poultry sector, recent analysis from the Netherlands has shown that western European broiler costs of production (production and processing costs combined) are broadly similar at around 126 Euro cents / kg ready to cook weight. In the USA, total costs of production calculated on the same basis are around 90 Euro cents. In Brazil, where large quantities of the UK's chicken imports come from, total costs of production are less than 75 Euro cents / kg – around 40% cheaper than the UK's combined production and processing costs of production. Processing costs alone in Brazil are 35% cheaper than in the UK.

The position for many of these commodities is similar; relative changes in competitive position due to energy costs are less significant than overall competitiveness. As such, the UK still relies on EU trade protection or consumer preference to secure its markets.

In summary, it is anticipated that an increase in oil price to $100 per barrel would not significantly change the UK competitive position, relative to a $50 price. Instead, changes in UK production due to overall economic returns at higher oil price or competition for resources from biofuels in the UK or abroad is likely to be more significant. A further consideration is the consumer response to food price inflation triggered by an oil price rise e.g. substitution of white meat for red or reduced overall consumption of meat. A mitigating factor is that the % of total household final consumption expenditure on food has been falling in recent years. This is in part due to low food inflation; 1998 food prices have risen by only 14 per cent while prices of all items have increased by 27 per cent. While there would be consumer resistance to higher food costs, there is scope for adjustment.

4.4 Farm level response

The commentary in this section is based on the evidence from previous sections but also on a practical knowledge of the production systems for the six key commodities studied. ADAS experts have contributed to the likely sector responses and the possibilities which technology might offer in mitigating high energy prices.

However, a recent report on energy efficiency policy[15] highlighted the low price elasticity of energy demand compared to many other goods and the importance of behavioural factors in limiting the uptake of energy efficiency measures. The farm sector has a long history of reliance on Government support and the extent of response to energy efficiency can be affected by policy initiatives.

4.4.1 Energy reliance and efficiency

The adjustment of existing production systems to a $100 barrel oil price relies on the energy intensity and efficiency of the production process but also on the commodity price response. In principle the former favours low energy input and/or highly energy efficient production processes. However, the limited availability of land for agricultural production, together with a competing demand for land for building, recreation and particularly for bioenergy crops means that land-intensive systems may also be favoured. This may be at odds with low energy input or less intensive systems. However, for the UK, wider production economics and environmental constraints e.g. under the EU Nitrates Directive[16] and the Water Framework Directive[17], may limit more intensive systems.

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[15] NERA Economic Consulting and Enviros (2006) Policy Options to Encourage Energy Efficiency in the SME and Public Sectors. Report for Defra

[16] http://www.defra.gov.uk/environment/water/quality/nitrate/nvz.htm 55% of England was designated as a Nitrate Vulnerable Zone (NVZ) in 2002 but this is likely to be extended. This requires farmers to restrict the application of organic manure to crop needs and imposes overall limits for nitrogen use.

[17] http://ec.europa.eu/environment/water/water-framework/index_en.html requires all inland and coastal waters to reach "good status" by 2015

The second key driver is commodity price; if the price response is significant it may actually encourage intensification of production, particularly if this is also relatively energy efficient. An example of the latter might be large-scale meat production with on-site processing and use of anaerobic digestion to convert animal manure and waste into energy or heat. However, intensive production relies on the use of feed grain (or its by-product equivalent) and this will have an inflated value based on its potential as a renewable feedstock for biofuel production. It can therefore be argued that a high degree of efficiency is key.

Much depends on the relative use of energy and the significance of energy as a cost, relative to other inputs e.g. land and labour. Table 9 sets out some key components of UK production systems and likely price response for each of the commodities.

Table 9: Commodity production resource use and price impacts

	Energy intensity	Energy efficiency	Price impact
Wheat	High	Moderate	High
Oilseeds	High	Moderate	High
Poultry	High	High	Moderate
Beef	Moderate	Low	Moderate
Sheep meat	Moderate	Low	Moderate
Milk	High	Moderate	Moderate

Wheat and oilseeds will be favoured by high oil prices due to the likely impact on price from increased biofuel demand. In contrast the livestock sectors are likely to benefit from a more moderate price impact as higher international grain prices will impact on all meat prices and may reduce consumption in Europe. There may also be substitution of more extensively produced red meat by intensively produced white meat on a cost basis (the differential will increase under higher oil price). The evidence from the recent increase in world oil price is that producers have struggled to recoup increased production costs from the market; retail prices did respond but primarily to meet additional distribution costs at retail and processing levels.

The evidence from the Cranfield and MBS studies also indicates that milk, beef and lamb are land intensive as well as energy intensive. This favours a move to more intensive systems, where increased output per animal can offset high production costs or to more extensive systems to reduce production costs and energy dependence. In practice, it is likely that both responses will be valid, depending on the availability of suitable land and the economics of such systems. In the UK there is already evidence of a polarisation of the milk and beef sectors to intensive and extensive systems.

There will be incentives to reduce energy use and improve efficiency across all commodities.

4.4.2 Organic production.

The Cranfield study considered key responses to energy costs including organic production. About 27% less energy was used for organic wheat production compared with non-organic, but there was little difference in the case of potatoes. The large reduction in energy use by avoiding synthetic nitrogen is offset by lower organic yields and higher inputs into fieldwork. Most organic animal production reduces primary energy use by 15% to 40%, but organic poultry meat and egg production increase energy use by 30% and 15% respectively. The benefit of the lower energy needs of organic feeds is over-ridden by lower bird performance. Table 10 compares the impact on organic and non-organic production.

Table 10: Relative impact of oil price on organic and non-organic production costs

	Milk	Lamb	Beef	Poultry	Wheat	OSR	Potatoes
Non-organic, MJ/t	26,085	25,961	27,354	15,533	2,400	4,852	1,507
Increase in costs, £/t	110	109	115	65	10	20	6
Organic, MJ/t	17,691	10,953	16,325	17,243	2,019	4,990	1,668
Increase in costs, £/t	74	46	69	72	8	21	7
£/t advantage to organic	**35**	**63**	**46**	**-7**	**2**	**-1**	**-1**
Price (non-organic)	2,115	3,227	2,098	1,180	75	155	155
% increase in competitiveness of organic (relative to non-organic price)	**1.7%**	**2.0%**	**2.2%**	**-0.6%**	**2.1%**	**-0.4%**	**-0.4%**

Milk production costs increase by £110 and £74/t per 10,000 litres for non-organic and organic production respectively. This represents a relative increase in competitiveness of organic milk of 0.35ppl (2% of non-organic price). The impacts for lamb and beef are very similar, with a small advantage to organic production. However for poultry, where the production system is very different, organic systems use more energy per tonne of meat produced and thus are disadvantaged by the increase in oil price.

Similarly for arable crops, organic wheat has an advantage of about 2% of the price over non-organic wheat. However oilseed rape (which is not normally grown organically) and potatoes show a disadvantage for organic of 0.4%.

While these results suggest a positive outcome for organic production, the scale of the impacts are modest and may be offset by the wider impact of higher distribution costs or general food price inflation, following a significant increase in oil price. They need to be seen in the context of current growth in demand for a wide range of premium products. Carbon credentials may become the new organic; this will be demand rather than supply driven.

4.4.3 Technology response

Technology can respond to economic drivers by producing more productive genotypes, more efficient use of resources (streamline process) or innovation in energy source (e.g. solar energy, reuse of heat, biogas production). An overview of possible technological responses for the six commodities is set out in Table 11.

Technology, in the form of genetic improvement and energy efficiency innovation, will be given a boost by higher oil price. For example, a new variety of wheat that increases yield by 20% could reduce energy use by 9%. Retailers will also drive efficiency as part of their carbon neutral strategies and this will lead to more dedicated supply chains, a smaller but more highly utilised processing sector and reduced transport and waste.

Livestock systems (dairy, beef and sheep) will become more polarised between large finishing units (feedlots) and low input grassland systems to reduce seasonality of production and allow higher utilisation of UK processing plant. They might also benefit from increased reliance on nitrogen-fixing legumes in grass-based systems and treatment of straw in intensive systems, with by-products from the biofuels industry as a feed[18]. Continued payment of environmental stewardship in the hills and uplands will allow some farmers to continue to ignore market signals for food production.

Table 11: Possible technology response to $100 barrel oil

	Genetic improvement	**Energy saving / efficiency**	**Other**
Wheat	Plant breeding to increase useful components of yield for different markets. GM technology?	Min-till and precision application of inputs	Economies of scale through rationalisation and collaboration.
Oilseeds	Plant breeding to increase useful components of oil yield. GM technology?	Min-till and precision application of inputs	Economies of scale through rationalisation and collaboration.
Poultry	Limited. Industry uses purpose bred 'broilers'	Limited. Use of solar panels for heating houses	Product innovation and differentiation to compete with cheaper imports. Anaerobic digestion to produce bio-gas and bio-fertiliser
Beef	Increased reliance on key breeds to produce consistent product	Collaboration of producers into dedicated supply chain groups, led by retailers. More multi-species abattoirs serving regional markets	Increased use of treated cereal straw as forage and biofuel by-products in beef feedlot systems. Others will move to extensive grass-clover based systems

[18] Leng, R.A (2002). Future directions of animal production in a fossil fuel hungry world. Livestock Research for Rural Development. 14 (5)

Sheep meat	Increased reliance on key breeds to produce consistent product, including new breeds.	Collaboration of producers into dedicated supply chain groups, led by retailers	Move to less seasonal production to reduce reliance on exports and imports.
Milk	Limited capacity to breed for milk yield without welfare problems. Use of sexed semen to reduce Holstein male calves.	Increased use of robotics	Economies of scale through rationalisation and collaboration. Anaerobic digestion to produce bio-gas and bio-fertiliser

4.5 The impact of biofuel crops

A literature review was undertaken to consider the impact of higher energy prices on the demand for biofuel crops. This is necessary for following reasons:

a) biofuel production is already a part of the EU policy, which mandates that by 2010, 5.75% of fuels in the EU should be from renewable resources. This means that, either part of food commodity production (mainly rapeseed and wheat in the EU), or part of the land resource for food production, may be used for energy purposes, and subsequently agricultural production and marketing may be restructured.

b) higher crude oil price may trigger more substitution of fossil fuels for renewables.

Renewable energy can be from different sources; in 2005, the breakdown of renewable energy produced in the EU by source include biomass (66.1%), hydropower (22.2%) wind power (5.5%), geothermal energy (5.5%) and solar power (0.7%)[19]. As biofuel production can use agricultural products as feedstock, our analysis will focus on this specific area. The impact of substitution of biofuels for fossil oil requires an energy sector model; it would need to be based on a break-even analysis for the substitution and is beyond our ability in this study.

The main findings in the review include:

1. **Biofuel production is more politically and environmentally than economically driven.**

The recent expansion of biofuels is a response to increased concerns about energy security, partly as a result of international political climate change and demand from emerging countries such as China, India and Brazil. Also, many developed countries such as EU and USA have used biofuel production as a way to overcome difficulties in agricultural policy, particularly in dealing with surplus commodity food production and farm support. Finally, biofuel production has been supported by evidence of its carbon saving effects, with CO_2 emissions the main contributor to global warming.

[19] http://europa.eu/scadplus/leg/en/lvb/l27065.htm

Because of political motivation, biofuel production is mainly concentrated in the USA, EU and Brazil. Almost all major studies have assumed that crops are the main feedstock for biofuel production (the so-called first generation of biofuels). At current oil price levels ($50-60 per barrel), sugar cane in Brazil is the only commodity found to be economically viable without subsidies. In the EU, no crop-based biofuel production is viable in the absence of subsidies but this may change with the second generation of biofuels.

Biofuel production still only accounts for a very small proportion of transportation fuel (less than 2% in the case of ethanol production at the global level). A continuous increase in biofuel production will eventually reach a level to moderately influence oil market prices, though the price impact is still not visible at the moment.

As biofuel is policy driven, particularly for energy security purposes, national policies in different countries are based on promoting domestic production rather than importing from other countries, although imports of biofuels and feedstock cannot be excluded. Such policy is often associated with dangers of excessive government intervention in terms of infrastructure investment or supply side subsidies, which are not economically sustainable. Theoretically, national costs for this security purpose need to be consistent to the level of 'risk'.

2. The main driving force in the long run for biofuel production is technology

Technology here refers to the conversion of biomass to either ethanol or biodiesel. It is likely that biofuel production is going to move from the first generation to the second generation of biofuels. The latter will continue to derive biofuels from any lignocellulosic or hemicellulosic matter that is available on a renewable basis, and will comprise a whole new range of crops. The advantage of the second generation of biofuels is that the tension between food and energy will be reduced and it will also have a smaller carbon footprint because the amount of energy-intensive fertilisers and fungicides will remain the same but output of useable material will be higher. In the UK, sunflowers and fodder maize are recommended (Tomkinson, 2006).

In the short run, development of biofuel production will depend on supply and demand side factors. On the supply side, both processing capacity and feedstock availability can be a constraint on biofuel production. On the demand side, there are many constraints, as Schmidhuber (2007) indicated. These include factors related to the marketing and consumption, such as bottlenecks in the distribution system, technical problems in transportation, blending systems' insufficient conversion capacities, and delays in engine adjustments and development.

As biofuel production is not viable without subsidies in the EU, Government policy is the major driving force for expansion at present. The main factors determining private investment in the sector are subsidies for biofuel production at different government levels, "parity price" of agricultural feedstock and the expected oil price. As the feedstock accounts for more than 80% of total biofuel production costs, when a large bulk of agricultural products is used in biofuel production, the agricultural market will be integrated with the energy market. As a result, agricultural price will follow the changes in the energy market. In other words, break-even (parity) price, i.e. an equilibrium price level in which using agricultural products in the biofuel production is no longer economically viable will be dictated by oil price.

There are still differing views on the future of oil price movement as the current price is largely subject to controls of the oil cartel OPEC. The optimists tend to believe that oil price surges in recent years are a combination of different factors such as political unrest in the Middle East and general inflation. They claim that allowing for inflation, the current price is even lower than the first oil crisis period and with technical progress and more substitution of other types of fossil and renewable resources in a relatively long period (20 years), oil price will fall back and stabilise to a relatively low level. The pessimists are looking at the issue in an even longer timespan; EIA (2007) suggests that oil price will continue to increase simply because strong demand from emerging countries and the fact that fossil oil is by far the cheapest way to produce, though production costs increased over time.

3. **Biofuel is more an intermediate demand similar to many cash crops rather than food demand.**

As a derived demand, its impacts include:

a) effects will be reflected via commodity prices. In absolute terms, agricultural prices tend to increase with total demand for agricultural products.

b) different impacts for different commodities and regions are expected, and there will be winners and losers in the process. It is expected that energy crops will be the winners due to increased demand from biofuel production and its relative price to other crops will increase.

c) effects will also impact on prices for agricultural inputs such as land values, and these impacts will also be transmitted to the later stage of food supply chain.

d) in the agricultural sector, the effect of derived demand will be realised via land reallocation with respect to changes in relative prices of agricultural commodities.

e) different regional effects may appear with different advantages or disadvantages in energy crop production and marketing.

f) there are food security implications.

This review only provides a framework for analysing the impact of biofuel production in the agricultural sector. A comprehensive analysis of biofuel impact has proved difficult for a number of reasons. First, biofuel production is still relatively new and small scale and the biofuel market is still regional and not integrated. An economic analysis is constrained by data availability and appropriate tools. Second, as discussed previously, the biofuel sector is mainly driven by government policies. In most cases, government policy on biofuel is uncertain in the long run. Finally and probably most important, the long run perspective of technological progress in the sector is not yet clear.

In this study, only the impacts of high energy price on production costs are considered.

4.6 Sector level response

Table 12 shows the results of the Defra analysis using OECD's Aglink-Biofuels model of a $100 oil price on world market prices, compared to the baseline, for 2006, 2010 and 2014 (see Annex 4). It shows that all prices increase as a result of higher production and transportation costs; the extent and the speed of the price rise depends on the energy dependency of global agricultural production and trade, and the market response of individual commodities. Large increases in price, such as for oilseeds, occur where the model assumes substantial increases in consumption.

The historic time series differ slightly between the AGMEMOD and Aglink models. Also, the projected prices vary, as both models have different underlying assumptions.

An extreme case is demonstrated in Figure 4, which plots the barley world price according to the AGMEMOD baseline, and the Aglink baseline and $100 scenario. To resolve this difference, the relative change in Aglink projected prices were applied to the AGMEMOD projected prices.

Table 12: World price changes under $100/barrel scenario against the baseline

Commodity	2006	2010	2014
Wheat	+1.8%	+27.3%	+27.0%
Barley	+2.2%	+22.5%	+22.4%
Maize	+3.7%	+37.6%	+37.5%
Oilseeds	+1.5%	+37.5%	+36.5%
Raw Sugar	+6.8%	+59.0%	+126.3%
Beef	+0.4%	+11.3%	+12.5%
Pigmeat	+0.4%	+16.9%	+18.6%
Poultry	+0.9%	+19.7%	+19.6%
SMP	-0.2%	+2.8%	+4.6%
WMP	+0.3%	+7.1%	+7.0%
Cheese	+0.4%	+6.8%	+6.7%
Butter	+1.5%	+16.3%	+10.6%

Source: Defra

It is evident that the AGMEMOD baseline projects a steady rise in the world market price from 2006 onwards, whilst Aglink baseline projections show a constant price level for that period. The $100-scenario, compared to the Aglink baseline, leads to a higher barley world price that again stabilises after 2010. When the relative rise in world market prices from the Aglink model is applied to the AGMEMOD baseline, its $100-scenario will also continue to rise.

Figure 4: Barley world price: AGMEMOD baseline, Aglink baseline and $100 scenario

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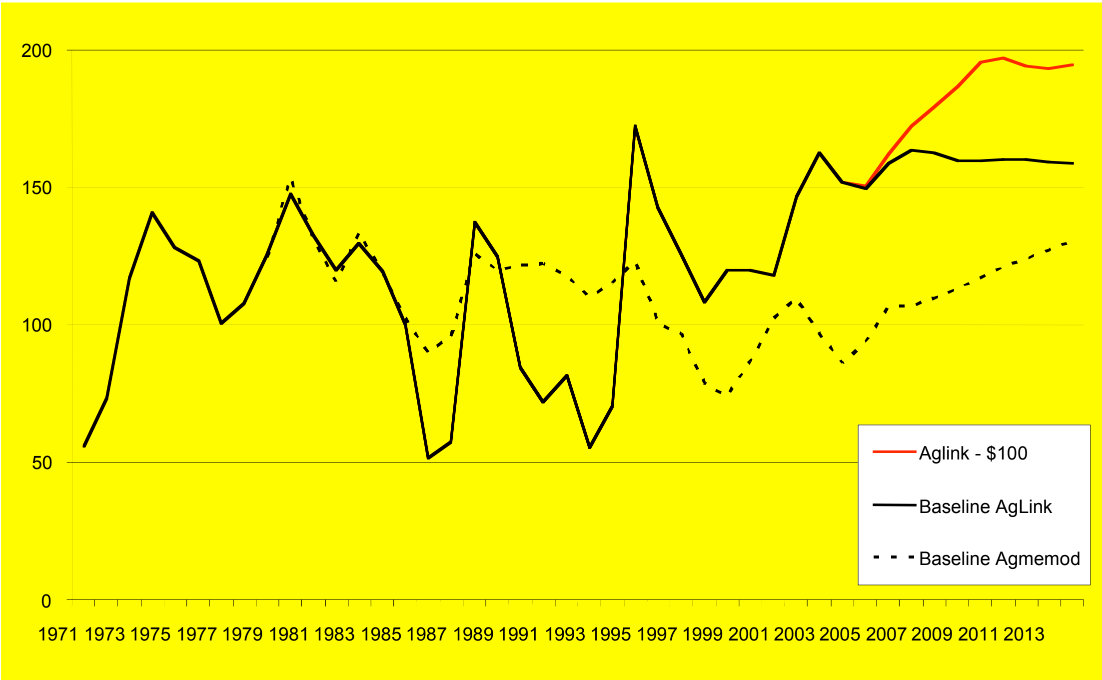

Table 13 shows key findings of the baseline and the $100 oil price scenario using AGMEMOD with Aglink projected world prices and energy costs adjustments made to production decisions. The reported effects are composites of the higher production costs – causing a reduction in supply – and the higher world market price, which drives higher production levels. There are additional effects of the relative price rise and increase of production costs between different countries and different sectors, and the link between higher grain prices and animal feeding costs. The relative world price rises are not fully passed through to EU countries. For example, the world market price for soft wheat is projected to increase by 27% in 2014 while the UK price in 2015 only increases by 5.9%. This reflects the relatively low dependency of the EU on imports and the openness of the market in general. As is the case for the world market prices, differences in the market prices to a certain extent reflect the relative energy dependency of different agricultural products at the EU level. The barley price increased more than the soft wheat price, which is mainly due to the fact that energy costs of EU barley production are higher than those for soft wheat. The reduction in the soft wheat area for 2015 is relatively small, which reflects the fact that the energy costs of UK wheat production are lower than those of the EU average.

Table 13: Key findings of the AGMEMOD model with Aglink projected world prices

	2006			*2010*			*2015*		
Variable	*Baseline*	*$100 scenario*	*Relative Change (%)*	*Baseline*	*$100 scenario*	*Relative Change (%)*	*Baseline*	*$100 scenario*	*Relative Change (%)*
Crop prices (€/tonne)									
Soft wheat	117.3	117.7	+0.3	120.3	127.0	+5.6	122.3	129.5	+5.9
Barley	89.1	89.4	+0.4	94.6	100.9	+6.7	100.2	110.0	+9.7
Potato	12.7	12.7	+0.0	5.4	5.3	-1.6	6.3	6.3	-0.2

Crop area ('000 ha)									
Soft wheat	1.707	1.696	-0.7	1.709	1.641	-4.0	1.716	1.690	-1.5
Barley	1,190	1,185	-0.4	1,158	1,065	-8.1	1,114	988	-11.3
Rapeseed	420	421	+0.2	416	421	+1.1	410	411	+0.2
Potato	162	162	-0.0	162	160	-1.0	161	159	-1.5
Sugar beet	189	189	+0.0	189	189	+0.1	189	189	-0.0
Other crops	77	77	-0.0	77	77	+0.0	122	122	+0.1
Total Area	**3.745**	**3.730**	**-0.4**	**3.711**	**3.553**	**-4.3**	**3.712**	**3.559**	**-4.1**
Livestock prices (€/100kg)									
Cattle (dw)	253.1	253.3	+0.1	258.0	266.2	+3.2	270.2	278.3	+3.0
Sheep (dw)	228.8	228.8	-0.0	220.9	223.5	+1.2	210.4	214.1	+1.8
Pig (lw)	114.4	114.7	+0.2	128.2	142.5	+11.1	131.4	144.5	+9.9
Poultry (lw)	168.4	168.4	+0.0	163.0	167.2	+2.6	152.6	157.4	+3.1
Milk	24.3	24.3	+0.0	24.0	24.4	+1.7	24.6	25.5	+3.5
Livestock ('000 head)									
Suckler	1.851	1.848	-0.2	1.848	1.848	+0.0	1.804	1.797	-0.4
Ewes (min head)	15.0	15.0	-0.1	14.8	14.3	-3.5	14.6	14.1	-3.6
Breeding sows	483	481	-0.4	504	519	+2.9	502	517	+3.0
Dairy cows	2,096	2,095	-0.1	1,983	1,952	-1.6	1,874	1,847	-1.4
Poultrymeat ('000t)	1,720	1,720	+0.0	1,846	1,827	-1.0	1,976	1,948	-1.4

Energy prices are assumed to start to rise in 2005; the oil price will reach the $100 level in 2009 and will stay at that level thereafter. Some sectors take a few years to establish a new price-supply equilibrium. Areas and livestock numbers (breeding animals, except for poultry) react to (relative) prices. These prices are corrected for additional energy costs. So countries/commodities will have further price impacts on intensity of production through yield and slaughter weight, but not through change in use of inputs. There is no substitution of inputs (i.e. from energy dependent to independent). The Aglink model takes into account US/Brazil biofuel production.

Note that the area of sugar beet hardly changes even though the world market price more than doubled. This is a result of the EU policy of quotas. Livestock numbers fall across the board, with the exception of breeding sows. This indicates that the pig price rise overcompensates for the additional fuel-related production costs.

There is a strong response in the area of wheat at first, falling by 4% in 2010, but then recovers to 1.5% over by 2015. The area of rapeseed rises initially from a smaller area of cereals, but then stabilises in 2015 to the same level as the baseline. The total area of crops falls by 153 thousand hectares or 4% of the total modelled area in 2015. This land can be used for grazing livestock, set-aside, non-modelled arable crops, non-agricultural use or for biofuel crops. The impact of $100 oil price on the area of biofuel crops cannot be modelled, as these crops are not included in AGMEMOD, nor are economic incentives and policies regarding bio-fuel production included in other crop models as an alternative production. There may also be further substitution between fuel crops and other non-modelled land uses.

All livestock sectors, with the exception of the pig/pork sector, decline with the rise of the oil price up until 2009 and show a modest long-run fall by 2015. Breeding sow numbers fall initially, but then start to recover under a higher pork price. The long-run projected effect is an increase of 3.6% compared to the baseline. This indicates that the pork price rise outweighs the higher production costs. Note that livestock sectors are not only hit by higher energy costs, but also higher feed costs derived from the increases in grain and oilseed prices.

Table 14 compares the long-run (2015) changes in area and livestock numbers between the UK, France and Germany. In the model, national output prices are linked to a particular country with a dominant position in a particular commodity. The observed differences are in effect the results of the relative energy dependency. For example, the barley area in the UK falls significantly, whilst it stays more or less constant in Germany. This indicates that in Germany, the rise in market prices compensates for the increase in production costs. At the same time, the area of barley rose in France, suggesting that the price rise exceeded the higher energy costs. A reverse situation occurs for the rapeseed area, which remains stable in the UK but drops in France and Germany.

Table 14: Comparison between UK, France and Germany (baseline vs. $100, 2015)

Variable	UK	France	Germany
Soft wheat area (‘000 ha)	-1.5%	-1.5%	1.1%
Barley area (‘000 ha)	-11.3%	3.0%	-0.1%
Rapeseed area (‘000 ha)	0.2%	-10.0%	-2.3%
Suckler cows (‘000 head)	-0.4%	-0.3%	-0.1%
Breeding ewes (‘000 head)	-3.6%	0.6%	-0.1%
Breeding sows (‘000 head)	3.0%	0.7%	1.6%

Suckler cow numbers fall in similar proportion across the three countries. This suggests that the energy dependency, and therefore the production methods of beef production, are similar. The number of breeding ewes fell in the UK, remained stable in Germany, and increased slightly in France. In all three countries, the number of breeding sows rose, with the highest relative rise observed in the UK, indicating that with higher energy price the UK has a comparative advantage in pork production.

In order to test the sensitivity of the world market price derived from the Aglink project, we have re-run the AGMEMOD model a second time with doubled price changes due to $100 barrel oil. The results with the new prices are reported in Table 15. This shows the results under three different scenarios of world market price changes. The first scenario assumes no world price changes; the only changes to AGMEMOD are the additional fuel costs, and as such can be regarded as a local energy tax scenario. The second scenario is that with the Aglink projected prices, whilst the third scenario assumes a doubling of the price rise as projected by Aglink. These successive scenarios of higher output prices will compensate for the increase in production costs.

Table 15: Key outputs in 2015 from world price scenarios

Variable	Baseline	No WP change	Aglink projection	Double WP rise
Soft wheat price (€/tonne)	122.3	122.3	129.5	136.8
Barley price (€/tonne)	100.2	101.2	110.0	119.0

Potato price (€/tonne)	63.2	63.2	63.1	63.0
Soft wheat area (‘000 ha)	1,716	1,703	1,690	1,679
Barley area (‘000 ha)	1,114	942	988	1,031
Rapeseed area (‘000 ha)	410	407	411	415
Potato area (‘000 ha)	161	158	159	159
Sugar beet area (‘000 ha)	189	189	189	189
Other modelled crop area (‘000 ha)	122	122	122	122
Total modelled arable area (‘000 ha)	3,712	3,521	3,559	3,596
Cattle price (€/100kg dw)	270.2	270.3	278.3	287.8
Sheep price (€/100kg dw)	210.4	210.8	214.1	217.0
Pig price (€/100kg lw)	131.4	131.6	144.5	159.8
Poultry price (€/100kg lw)	152.6	152.8	157.4	161.9
Milk price (€/100kg)	24.6	24.6	25.5	26.4
Suckler cows (‘000 head)	1,804	1,782	1,797	1,808
Breeding ewes (‘000 head)	14,613	14,517	14,084	13,736
Breeding sows (‘000 head)	502	489	517	552
Poultry production (‘000t)	1,976	1,958	1,948	1,938
Dairy cows (‘000 head)	1,874	1,867	1,847	1,831

Without a change in the world market prices, the UK agricultural commodity prices rise rather modestly. This is the result of the additional energy costs, which have a downward effect on supply. Once the world market price starts to rise, there is a recovery in the reduced output. With the exception of the rapeseed area, even a doubling of the Aglink projected world price rises still results in a reduction in the harvested areas compared to the baseline. The doubling of the Aglink projected world price rise results roughly in a similar rise in UK prices.

The results in the livestock sector are less straightforward. The Aglink projected price rises for livestock products were relatively smaller than those observed in crops. Also, grains and oilseeds are used as livestock feed; an increase in these prices means higher costs for livestock production. This explains the continued fall in poultry production, breeding ewes and dairy cows from the baseline through the three increasing world price scenarios. Both suckler cow numbers and breeding sows recover from the additional energy costs through higher output prices.

4.7 Food supply chain impact

The analysis of food supply chain impacts relies on the same method as the farm production section. For first level impact we have used published data on energy use in four key supply chains and adjusted the cost element on the basis of $100 barrel oil energy cost. The data is much less robust than the farm-level data for the following reasons:

- Data on energy use is less available
- Less consistent process – large range of processes, products and packaging

- Range of routes to market – from national supermarkets to small scale local

The latter two issues have significant impacts on energy use. For the purpose of this study we have used published data and qualified the supply chain(s) it relates to.

4.7.1 UK food production

Britain is a net importer of both beef and lamb. In 2005 fresh/frozen and processed imports accounted for 40 per cent of total United Kingdom beef consumption and 35 per cent of total sheep meat consumption[20]. Although the UK is largely self-sufficient in milk, the value of UK exports of milk products is significantly lower than the value of imports and in 2005 the UK had a trade deficit of £893m in dairy products[21]. In the poultry sector, total production and processing costs are generally lower in third countries and in the former Eastern bloc countries than in the UK. For example, cheap imports of turkey meat have decimated the UK turkey sector in recent years; the number of turkeys produced in the UK has more than halved in the last 10 years.

In this context, rising production costs for energy (direct and indirect) and higher feed prices, impacted by biofuel markets, may lead to reduced UK food production, with an increase in imports from countries with a more favourable production context (climatic, economic or regulatory). Much depends on the global balance of supply and demand and the ability of supply chains to pass these higher costs onto consumers.

4.7.2 Foods supply chains and overall impact

For the purpose of this study we have used published data and qualified the supply chain(s) it relates to, to estimate increases in energy costs. However, additional difficulties arise from using published evidence in reaching a consensus estimation as various studies are based on different approaches and assumptions and sometimes have different classifications of food chain stages which lead to inconsistency and a lack of comparability between studies. Table 16 compares the results of a range of studies in this area, including an extensive review study and a study on energy use in the US food supply chain.

Energy consumption in farming is estimated to account for from 16% to 46% of total energy in various studies. Percentage of energy use in processing varies from 10% to more than 30%. However, we can still identify that farming as well as transport and processing will be impacted most by higher energy prices as most of the studies suggest they are responsible for a significant proportion of energy use in the food chain.

Table 16: Comparison of key studies reviewed on energy consumption.

Sector	Energy use (% of total excl. home and	U.S energy use (% of total use in food supply	Defra Data[24]: bottom up LCA approach	Defra Data ESI[25]: I-O approach (% of total use)	Fuelling a food crisis report[26],

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[20] MLC (2007) The Beef and Lamb Cuts Balance Sheet February 2007
[21] http://www.defra.gov.uk/foodrin/milk/dairyindustry.htm
[22] Rebecca White, ECEEE 2007 SUMMER STUDY: Carbon governance from a systems perspective: an investigation of food production and consumption in the UK.

	catering)[22]	chain)[23]			
Farming	26.8	33.9	16*	46**	-
Transport	*24.8*	22.6	12*	*5***	27.6
Processing	31.5	25.8	21*	10**	51.5***
Packaging	11.7	11.3	-	-	11.3
Storage	0.8	-	-	-	0.0
Retail	4.4	6.5	-	7**	9.6
Total (excluding home and catering) (PJ)	***514.7***	**-**	***650***	**-**	***1021***
Total for food and farming	***780***	**-**	***780***	**-**	***1521***
Total UK (PJ)	***7206***	**-**	**-**	**-**	***7214***

Data Source: Rebecca White, ECEEE 2007 SUMMER STUDY which syntheses the results from a range of literature including DEFRA studies (2005, 2006)[27], MTPROG (2005)[28], DEFRA and AEA Technology Environment (2005)[29], Tremove (2005)[30], Dutilh & Kramer (2000)[31], Gerbens-Leens (2003)[32], Jones (2001)[33], Select Committee (2005)[34] and etc.

* Figure does not add up to 100%, as some of the categories in the Defra study are not included in this table.

** Figure does not add up to 100%, as some of the categories in the Defra study are not included in this table.
***It includes both agriculture and food processing

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[23] Data source: M. Heller and G. Keoleian, Life-Cycle Based Sustainability Indicators for Assessment of the U.S. Food System (Ann Arbor, MI: Center for Sustainable Systems, University of Michigan, 2000), p.42.
[24] Detailed break-down data in CO2 emission made available from Defra Statistics for this $100 per barrel oil study.
[25] Data source: Environmental Statistics and Indicators, Defra.

[26] Data from the “Fuelling a food crisis” report prepared by Caroline Lucas, Andy Jones and Colin Hines, which syntheses results of two studies: INCPEN (2001) Towards Greener Households: Products, Packaging and Energy. ISBN 1 901576 50 7 June 2001 and AEAT (2005) The Validity of Food Miles as an Indicator of Sustainable Development. Final Report produced for DEFRA JULY 2005 ED50254 Issue 7 AEA Technology.
[27] DEFRA, 2006, Food Industry Sustainability Strategy; DEFRA, 2005, Estimated total emissions of UK ‘basket’ greenhouse gases on an IPCC basis; DEFRA, 2005, European Union Emissions Trading Scheme, National Allocation Plan (Phase 1);
[28] Market Transformation Programme, 2005, Sustainable products 2005: Policy analysis and projections, Didcot, Market Transformation Programme.
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[33] Jones, A., 2001, Eating oil, food supply in a changing climate, Sustain and the Elm Farm Research Centre, UK.
[34] Select Committee on Science and Technology, 2005, Annex 1.1 Industry Indicators: progress report October 2004. http://www.publications.parliament.uk/pa/ld200405/ldselect/ldsctech/999/4110304.htm

Table 17: Detail energy use data of Defra study

	Energy Use (PJ)	%
Total UK agriculture and fish	124	16%
Total emissions embedded in imports	109	14%
Total transport overseas and to UK	143	18%
Total food manufacturing	167	21%
Total food services	146	19%
Transport within UK pre-purchase	92	12%
Total	**780**	**100%**

From the Defra study (see Table 17 for breakdown use of energy), it is estimated that 650 PJ of energy out of the total of 780 PJ is dedicated to food supply in terms of household consumption. With a total cost increase per MJ of £0.0042, this gives an increase in household food expenditure of around £3 billion if the oil price rises from $50 to $100 a barrel and all costs are passed on to consumers. That represents a 4% increase in household expenditure on food within a total spend of £79 billion.

For the highest estimate of energy use made by the Green Party in the "Fuelling a food crisis" report, following the same method of calculation, the increase in household expenditure on food would be 9%.

Therefore we might expect an increase in household expenditure from roughly 5% to 10% if all costs are passed on to consumers, which represents the worst case of shocks for consumers as it assumes no others along the food chains could absorb some of the shocks. In practice it is likely that some of this cost will be offset through efficiencies but secondary impacts of oil price change will add to the first level impact.

4.7.3 Detailed Analysis of Food supply chains of selected commodities:

This section summarises the data available for the four key supply chains researched, namely milk, red meat, poultry and wheat. The full analysis is detailed at annex 3. As data on detailed energy use for different supply chains are limited, this study is mainly based on a review report done by Manchester Business School which explores extensive LCA studies and provides an synthesis of results for various food supply chains.

Milk supply chain

Data on liquid milk, cheese and yoghurt processing are available from the Manchester report. These highlight the three key elements of energy use, transport, processing and packaging. The data is summarised in table 18.

Table 18: Energy use in milk processing

Energy use (MJ per 10,000 litres)	Transport	Processing	Packaging	Total
Liquid milk	1,000	2,000	5,000	8,000
Yoghurt	1,000	35,000	42,000	78,000
Cheese	1,000	70,000	20,000	91,000

Packaging is a major component of milk manufacturing and represents a key opportunity to make efficiencies in terms of energy use. It is also clear that the more highly processed products consume more energy and will be most affected by an increase in energy price. The liquid milk sector is highly concentrated and there has been considerable investment in new plant over recent years. The perishable nature of liquid milk, combined with the lack of a significant import trade and low price elasticity, suggests that this sector will be able to pass much of the energy cost increase on to consumers over the medium term. Recent retailer initiatives, such as the 4-6 ppl (20-35%) increase announced by Tesco, are evidence of this.

Commodity cheese production is much more competitive with substantial levels of imports. While competitiveness is largely dependent on the wholesale price of milk, the process is energy intensive and large-scale modern plant is also important. For other fresh products such as yoghurt, the energy costs associated with packaging are significant but these are high value added and costs can be passed to consumers. Due to the perishable nature of these products they are only imported from Europe but energy costs associated with refrigerated transport would favour UK processing if oil price was high.

Red meat supply chain

The UK is the fourth largest producer in the EU-25, at more than 750,000 tonnes of beef per year. It is the largest producer at 325,000 tonnes of sheep meat in the EU and is also the biggest exporter. More than 70 per cent of the 110,000 tonnes imported comes from New Zealand, which is the world's biggest exporter at some 360,000 tonnes a year. UK consumers eat an average of 17.3kg of beef a year and 5.8 kg of lamb.

Detailed data is less available for red meat but the evidence suggests that it takes 23,000 MJ to produce 1 tonne of lamb and 44,000 MJ to produce 1 tonne of beef across the whole supply chain. However, more than half of this relates to farm production with an estimated 10% at the processing stage. Refrigeration and transport are key components of this and the key opportunities to improve efficiency rely on addressing these stages. However, due to the largely extensive nature of beef and lamb production in the UK, the focus must be how the supply chain is organised, limiting journeys and reducing waste. The issue is compounded by over-capacity in the slaughter sector and the use of dedicated abattoirs by the main supermarkets.

Poultry supply chain

The poultrymeat sector is more integrated with feed mills, production and processing facilities all within a very short distance of each other. This can be seen, for example, in East Anglia where over 30% of the UK's meat birds are housed. The slaughterhouse process is estimated to consume only 700 MJ energy per 1,000kg whole chicken. The research review gives an estimated 1,080 MJ for transport of live birds to slaughter and 3,010 MJ for process and packaging.

The key issue with chicken is the extensive use of chicken fillet, much of which is imported and the use of frozen chicken. This reflects a more substantial lack of price competitiveness in the UK, which will continue irrespective of oil price.

Feed cereal supply chain

The feedstuffs supply chain is concentrated with a small number of large compounders producing feed from UK and imported grain. Recent rationalisation of the supply side through growth of integrated grain co-ops should drive efficiency gains and build supply chain relationships. Prices are driven by world supply and demand as evidenced by the fact that UK feed prices have risen by 30% in the last year. Global wheat supply was met in 2007 but stocks are expected to fall to their lowest for over 25 years. The sector is getting used to fluctuating prices and a market will always be found but efficiency is key to a competitive UK livestock sector. Growth in the UK biofuel sector may dampen the need to further improve energy efficiency.

4.7.4 Energy price impacts

The impact of $100 barrel oil on the processing sector is linked to both the energy use at that point in the supply chain and the impacts on production. For example, if the cost of milk production were disproportionately affected, relative to third country exporters, the processing sector would also be affected, regardless of its comparative efficiency in terms of energy use.

The first order impacts on cost caused by rising oil prices can be estimated. This is based on the sum of the energy consumption within each supply chain for each commodity studied and the current average commodity prices. Due to increasing energy cost within supply chains, a 4-6% increase in commodity price can be expected for milk and cheese, 2-3% of red meat and 4% of poultry and 4% for bread wheat. Table 19 to 21 set out the detailed first level impacts.

Table 19: Energy use to the point of retail - dairy products

	Milk	Cheese
	MJ/l	MJ/kg
production	3.6	37.5
processing	4.0*	11
transport	0.5	-
Retail	0.05	3
Total energy (MJ/unit)	8.15	51.5
Increase in energy cost (p/unit)	0.42	0.42
Product cost increase (£/unit)	0.03	0.22
Retail price (£/unit)	0.50	4.75**
Increase as % retail price	5.9%	4.6%

Source: Impacts of Food Production and Consumption: A report to the Department for Environment, Food and Rural Affairs. Manchester Business School. Defra, London.

* Energy use in packaging is a component, but varies greatly from 0.46 to 3.7 MJ/litre.
** Data from MDC statistics: http://www.mdcdatum.org.uk/RetailerDataPrices/ukretailprices.html

Table 20: Energy use to the point of retail - red meat and white meat

	Beef	Chicken
	MJ/kg	MJ/kg
Production	28.00	6.52
Processing	4.21	5.44
Transport	-	6.98
Retail	2.20	18.73

Total energy (MJ/kg)	**34.41**	**37.67**
Increase in energy cost (p/kg)	0.42	0.42
Product cost increase (£/kg)	0.14	0.16
Retail price (£/kg)	4.90	4.20
Increase as % retail price	2.9%	3.8%

Source: Impacts of Food Production and Consumption: A report to the Department for Environment, Food and Rural Affairs. Manchester Business School. Defra, London.

Table 21: Energy use to the point of retail - bread

	Bread (MJ/kg)[35]
Production	2.10
Processing	0.70
Transport	1.20
Total energy (MJ/kg)	**4.00**
Increase in energy cost (p/kg)	0.42
Product cost increase (£/unit)	0.02
Retail price (£/unit)	0.50
Increase as % retail price	4.0%

Source: Impacts of Food Production and Consumption: A report to the Department for Environment, Food and Rural Affairs. Manchester Business School. Defra, London.

The review raises several key issues around the competitiveness of the processing sector in the UK. These include:

- The UK should be competitive with its EU competitors for fresh dairy products, but processed commodities such as cheese and milk powder are both energy intensive and uncompetitive with third countries. As the dairy sector contracts, economic pressure will force rationalisation of cheese processing capacity. Packaging, processing and transport are the most energy intensive stages within the conventional dairy supply chains. There will be strong pressures to innovate and add value as well as to rationalise supply chains and improve energy efficiency.

- For lamb and beef, seasonality of production and lack of product consistency in the UK are key contributors to energy inefficiency, through additional journeys and poor utilisation of processing plant. The main threat to lamb is not just overseas competition but product substitution by more efficient and integrated white meat supplies. Continued reliance on environmental stewardship payments and decoupling of subsidies may lead to a small reduction in the UK flock size; this will

[35] Data source: Impacts of Food Production and Consumption: A report to the Department for Environment, Food and Rural Affairs. Manchester Business School. Data are from Swedish study.

exacerbate processing overcapacity problems. In terms of processing, there is a strong need for vertically integrated plants, which can also deal with other species. In terms of beef production, there is considerable opportunity to improve the consistency and seasonality of supply through growth of intensive feedlot systems, located in proximity to grain and biofuel by-product supply. Sector size will be driven by the scale of the dairy herd and an economic beef cow enterprise, although store cattle could be imported from western areas of the UK and Ireland for finishing in grain-growing areas.

- Poultry processing is a highly efficient process with relatively low waste and energy use. The key issue with chicken is the extensive use of chicken fillets, much of which is imported and the use of frozen chicken. The opportunity for UK processors is to innovate in terms of product and process; this may actually increase energy use but is perhaps the only way to compete with cheaper imports in the longer run.
- For the cereals sector, the opportunity is to rationalise and simplify the supply chain so that processes are more efficient and transport and waste are reduced. The recent growth of large farmer coops to store and market grain is an important development in driving this process.

4.7.5 Differential Impact - past evidence

From previous overall impact analysis, it is anticipated that farming, processing and transport will be impacted most due to rises in energy cost. Retailers are the most influential actors along the food supply chains; they have largest market power and could pass on costs either upstream or downstream without being impacted heavily by cost increase. In the past few years, when food supply chains have been experiencing rising energy costs, retailer margins have not been negatively affected and some even have increased their returns, with retail prices always increasing faster than wholesale and farmgate prices.

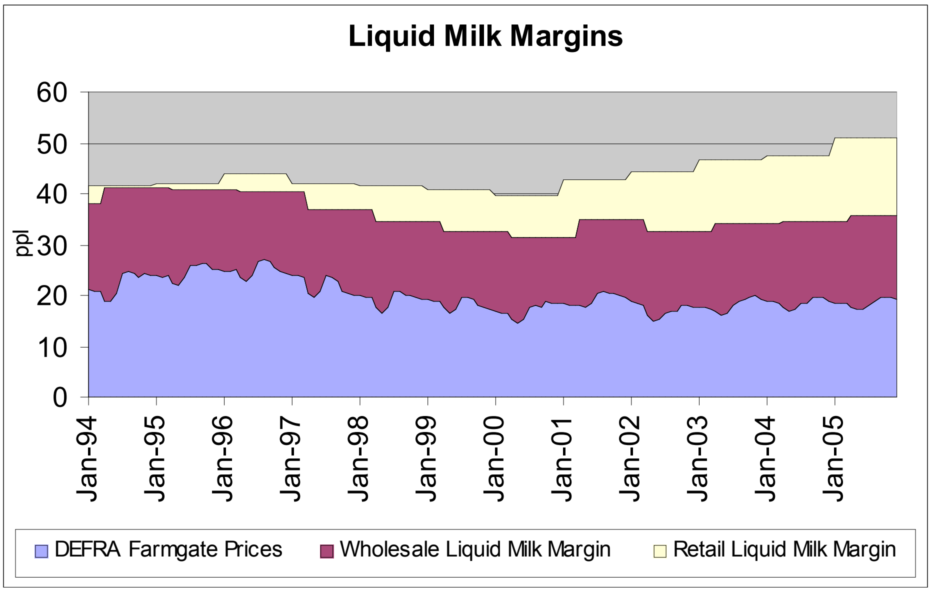
As information on costs and margins of food supply sectors is limited, we have used the dairy sector as an example for analysis. This is based on the MDC supply chain margin report. Between 2005 and 2006, oil price went up from $41/barrel in Jan 2005 and moved towards $80/barrel in 2006. In the MDC study of dairy supply chain margins of 2005-2006[36], it is pointed out milk processors have been impacted as transport and packaging costs increase with crude oil price increasing. Although gross margins were maintained or improved, their profits were hit by the consequences of higher input costs. Milk processors managed to negotiate some price increase from retailers in early 2006 to cover some of the increased costs, but farmers were excluded from this and no price increases were passed back to them to cover the rising costs in fertiliser and energy.

Retailers in the milk market have been experiencing a continuous increase in retail margins since 1995 (Figure 5). After 2005, the retail price increased in early January 2006, was cut in March 2006, and increased again in July 2006 (MDC 2006). The net effect of these changes has been that the price of a 4-pint poly bottle has increased

[36] Milk Development Coucil (MDC), October 2006: Dairy Supply Chain Margins 2005 – 2006: Who made what in the dairy industry and how it has changed.

from £1.03 to £1.11 over the past 18 months, and retail margins have again increased[37].

Figure 5: Liquid milk margins in the UK from Jan 1994 to Dec 2005.



Source[38]: Farmgate-DEFRA; Wholesale-MDC; Retail-TNS.

For milk processors, they have been unable to increase profits because production costs increased faster than gross margin increases, which accounted for the wholesale price increase during early 2006.

As pointed out in the MDC report, it is difficult to calculate the exact profitability in 2005 as gross margins were likely to be higher due to higher whey powder prices, while costs will have also increased. However, according to the comments made by the two largest cheese processors in the UK, Dairy Crest and Milk Link, the cheese businesses appear to generally be performing at least satisfactorily.

From the experience of dairy industry, we can see that farmers are most vulnerable along the food supply chain and their rising costs due to the energy price increases were not rewarded from the market in the short term. Over time, this will impact on supply, and, in a growing market, buyers will adjust prices to encourage more supply. However, much depends on the global balance of supply and demand (and world stocks).

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37 MDC, October 2006. Dairy Supply Chain Margins 2005 – 2006. http://www.mdcdatum.org.uk/PDF/MDCDairySupplyChain2006.pdf

38 Liquid milk processor gross margins are based on the difference between the wholesale price milk (as estimated by MDC Datum) of liquid milk and the DEFRA farmgate price; Retail Liquid milk retail gross margins are based on the difference between the wholesale price of liquid milk (as estimated by MDC Datum) and the average supermarket retail price of liquid milk (fully weighted from TNS data).

5. Overview of impacts

To date we have considered 5 key elements of a $100 barrel oil price, namely:

(i) the first level impact of increased energy price on farm production costs

(ii) the relative impact of the competitive position of UK farm commodities

(iii) the farm-level response and key energy efficiency options

(iv) changes in the level of production of commodities in the UK

(v) downstream impacts on the UK food supply chain

In this section, we bring these impacts together to assess the aggregate impact. For this we have suggested a framework for how the component effects might interact.

5.1 Aggregate impact

There are three key components of change that we might expect from an increase in oil price:

1) **Balance of land use** – overall reallocation of land use between food production enterprises based on an economic response to costs and prices. This might also include growth in biofuel crops and/or fallow land

2) **Intensity of land use** – depending on the realignment of costs and prices, farmers may move up or down the production response curve. This will depend not only on the cost of inputs such as fertiliser and pesticides but also on the demand for land as a resource. Historically, unsupported livestock sectors such as pigs and poultry have become industrialised with a focus on production efficiency and supply chain integration. With decoupling of farm support for other sectors, this could also happen to some extent in the dairy and beef sectors and to a lesser extent in lamb production. Any such change would release land for crops and extensive livestock production systems.

3) Downstream impacts on the UK food supply chain – this relates to changes in what is produced, how much is produced and where it is produced. The interdependence of food production and processing together with a need for increased supply chain efficiencies dictates that more dedicated supply chains and increased market focus are likely.

Below we consider the extent to which the evidence from this study informs these questions.

5.1.1 Land Use

The evidence from the economic modelling indicates that the impact of the energy price in the EU is smaller than the international market, though the gap may be reduced with deepening trade liberalisation. There are several reasons behind this. First, although a big player in the international agricultural market, the EU market is still relatively isolated from the international market, thanks to economic and technical trade barriers. In other words, the EU price is still very much internally determined and price transmission between the EU and international market is limited. Second, the EU still has a large production and supply potential including set aside land and the new member states.

The model predicts a strong short-run response in the area of wheat, falling by over 7%, which then recovers to a long-run price drop of 1.5%. The area of rapeseed benefits from this large initial drop, but then stabilises in 2015 to the same level as the baseline. The total area of crops falls by 153 thousand hectares or 4% of the total modelled area in 2015. The land can be used for grazing livestock, set-aside, non-modelled arable crops, non-agricultural use or for fuel crops. There may also be further substitution between fuel crops and other non-modelled land uses.

5.1.2 Farm sectors

The impact on crop margins from impacts on costs is significant at about £10/t for wheat but there is likely to be a greater price impact from the increased demand for biofuels (typically increasing wheat margin by about £10/t). The position is similar for oilseeds. The competitiveness of the UK wheat increases by £1-4/t relative to the Ukraine but again this will only impact at the margins. While cereal and oilseed prices will be driven by a growing UK and EU market for biofuels, imported bioethanol or raw palm oil will displace them at some point.

Livestock sectors are negatively impacted by the biofuel effect on cereal and oilseed prices. Together with other direct and indirect energy cost impacts, production costs are likely to increase by an estimated 3-5% of commodity price. While this is not disastrous, the reduction in returns relative to the crop sector is likely to see an increase in crops at the expense of grassland and livestock production. The dairy and beef sectors are most likely to decline as they are already under economic pressure, compete with crops for land and are dependent on more expensive feed input. The latter will also increase economic pressure on the poultry sector.

$100 barrel of oil would increase the competitiveness of New Zealand lamb under any assumptions, but by less than 3% of the farm gate price, and the competitiveness of milk products by only 0.2 ppl. It will cause a reduction in competitiveness of Brazilian poultry meat of £20/t, compared to a typical farm-gate value of poultry meat of £1200/t, and increase the competitiveness of UK beef by £81/t or 3.8% of the price of beef. These gains or losses are relatively minor and will only affect the scale of UK farm sectors at the margin; as sectors decline, buyers become more dependent on imports and in turn this can increasingly drive pricing. The medium and long term price of cereals and oilseeds will dictate whether UK farmers continue to favour cropping land or increase their reliance on environmental stewardship payment on marginal land to meet other Government sustainability targets.

The impacts of energy price for different agricultural commodities are modest except for rapeseed for which the EU is a big net importer. Relatively speaking, impacts are stronger in the short term (knock on) than in the long term and stronger in the crop sector than livestock production, resulting in land moving from non-energy crops to energy crops.

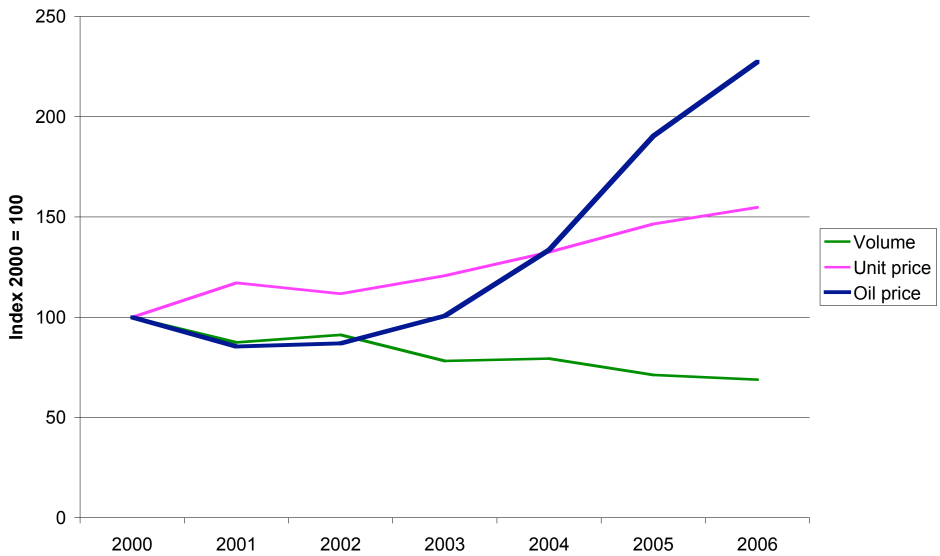
5.1.3 Production systems

The key driver for changes in production systems will be an initial attempt to reduce costs through more efficient use of inputs – nitrogen rates have reduced (figure 6) and this can be expected to happen to a further extent. However, a medium term increase in cereal and oilseed price may partly or fully offset this, depending on the economics. Fertiliser use will also be limited by environmental constraints e.g. Nitrates Directive and this will limit the scope to substantially increase crop yield through plant breeding.

We can also expect to see an increase in 'economically efficient' systems rather than 'low input' systems. This might include min-till cultivation or use of technology to better match plant needs and inputs; this is consistent with the longer-term move to larger, more specialised arable units, managing land on behalf of others in addition to their own. In contrast, organic cereal production is likely to continue to struggle to compete with a buoyant non-organic sector. While some large growers will convert part of the farm to organic productions, much of the area will continue to be based on mixed farms, driven by returns from an organic livestock enterprise.

The long-term decline in spring cropping is also expected to continue as growers aim to maximise cereal yields for a market that is not demanding on quality or spring rainfall and as such is less risky. This, together with a significant increase in industrial oilseed rape grown on set aside land, does pose a threat to the biodiversity gains from set aside. Environmental stewardship prescriptions may need to alter to recognise these economic drivers; this becomes more significant as monies move from single payment to Pillar II.

Figure 6: Fertiliser N use in response to oil price change 2000-2006



Source: Defra AUK

5.1.4 Supply chain impacts

The evidence from the analysis of energy use in food supply chains indicates that increased energy prices will only exacerbate existing economic opportunities and threats. The threats are based around a lack of price competitiveness at production and processing levels where lack of integration within the supply chain means that animals/product travels too far and lives with processing overcapacity based around dedicated plants (by species and buyer) and seasonal production. Given the impact of energy costs and an environmentally focused Government policy on food and farming, the livestock sectors are likely to contract further. This will exacerbate pressure and lead to more radical restructuring. The availability of imports of processed product will allow this to happen.

The opportunity is for energy efficient innovation in product, process and packaging. This is likely to be driven by the retailers and processors in a bid to add value as well as to save cost.

The relative power of multiple retailers is both a threat and an opportunity in terms of the wider supply chain. While supply is good, they can drive down costs and to some degree deliver productivity growth and innovation along the supply chain, including their own purchasing and distribution. Where this is via reliance on imports, there is a risk that UK production capacity and/or infrastructure is lost. When supply is less available, retailers can quickly increase prices to increase supply.

The impact of rising energy costs on farmgate prices and on supermarket shelves will depend ultimately on the market. The imminent end of a period of overproduction in the European Union, together with growth of the biofuels sector suggest that markets will be reasonably responsive to cost change in the short to medium term. However, there will also be a drive to cut cost out of the supply chain and improve efficiency.

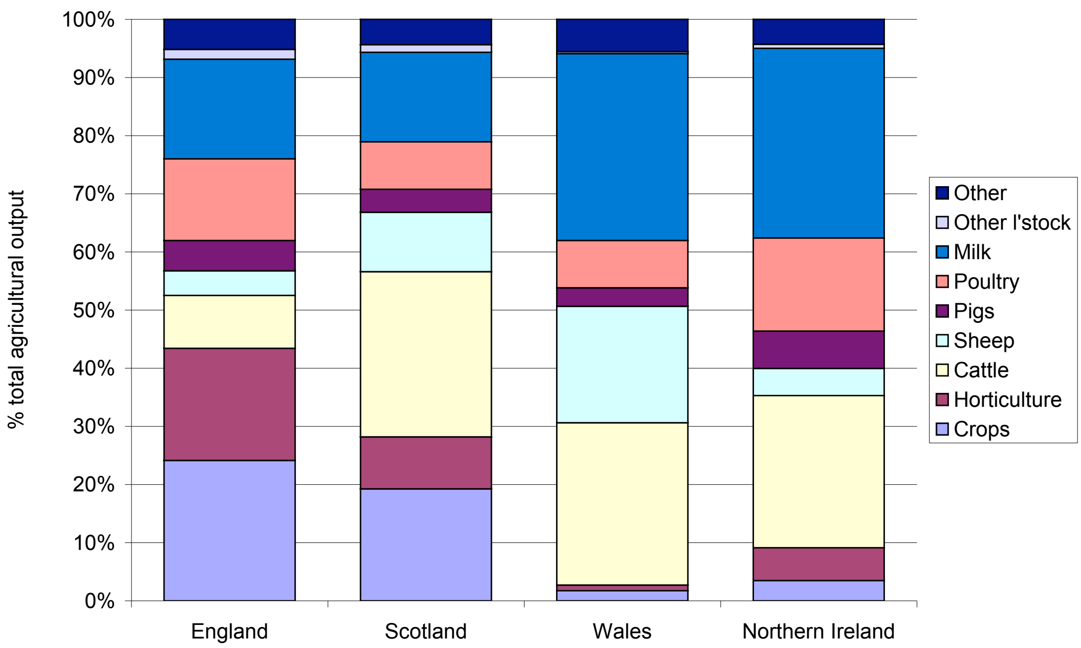
Alternative, localised supply chains have gained in popularity in recent years and where they are genuinely locally based, they should also be energy efficient, based on minimal transport and reduced waste and storage. However, many small-scale supply chains involve considerable transport in small volumes, with low vehicle utilisation and hence are not energy efficient. The premiums available in these markets are often absorbed in higher costs rather than providing returns on innovation.

Country level impacts

The UK is characterised by a wide range of production systems and farm sizes, reflecting topography and climate but also the economic and cultural development of the UK regions. While energy price changes will apply across the UK, impacts will vary according to the dependence of the regions on different sectors, production systems and farm sizes, which predominate.

Figure 7 sets out the percentage of production for each commodity by UK region from the June 2006 census.

Figure 7: Gross Output from key agriculture sectors by UK region (2005)



Source: Defra Statistics

It highlights the reliance on milk and cattle in Wales and N Ireland, cattle in Scotland and the more balanced output across England. However, the latter varies considerably across the English Government Office regions (GOR) as shown in Figure 8.

This spatial concentration of sectors is often based on some competitive advantage and associated with more developed production and processing infrastructure. The case for continued concentration is likely to be enhanced by high oil prices in order to reduce supply chain costs. The two key questions are therefore:

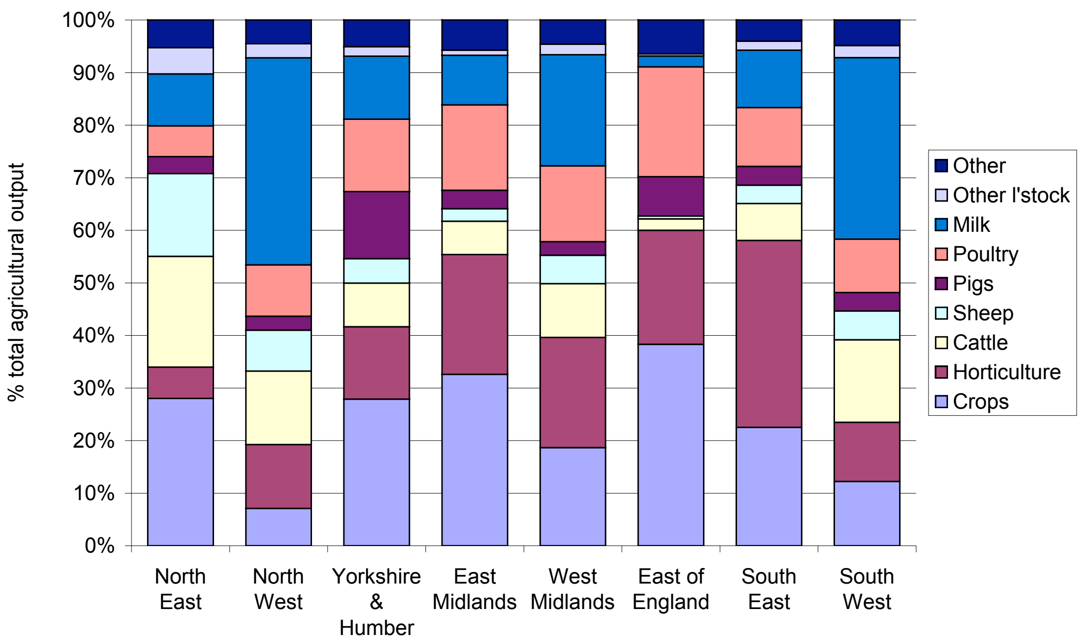
(i) **Which enterprises are vulnerable overall under high oil prices, and consequently, what is the threat to regions that specialise in these sectors?**

Pig production and dairying are two sectors that are capital intensive and relatively energy intensive; both also rely on dedicated processing capacity. Poultry production is a highly concentrated and efficient sector but is very vulnerable to production cost increases, especially in the context of increased environmental restrictions. All three of these sectors could contract but the regional economies where they are most significant are least likely to be impacted due to increased concentration.

(ii) **Which regions of production are marginal in terms of vulnerable enterprises and as such may become uncompetitive relative to clusters of production and processing elsewhere?**

Milk production in the eastern regions of England and in much of Scotland could be limited to small-scale, local supply chains. Conversely, pig and poultry production could virtually disappear from many regions, again apart from small-scale, local supply chains.

Figure 8: Gross Output from key agriculture sectors by English region (2005)



Source: Defra Statistics

We might also expect a differential effect based on farm size, particularly where economies of scale exist. A recent report by the University of East Anglia[39] found that this varied across farm types, concluding that 'cereal, sheep and general cropping farms exhibit decreasing returns to scale whilst dairy and mixed farms display increasing returns to scale; beef, poultry and pig farms exhibit constant returns to scale'. Scale economies relate to efficiency gains and do not change the basic principle that farms need to be of a minimum size to generate an income and widely held farmer attitudes that scale offers longer-term viability.

Farms are classified in terms of European Size Units (ESU), with 8 ESU representing the threshold for a full-time farm[40]. The size groups are set out in table 22 along with the number of full-time equivalent (FTE) workers.

Table 22: Farm Size classified by number of FTE and ESU

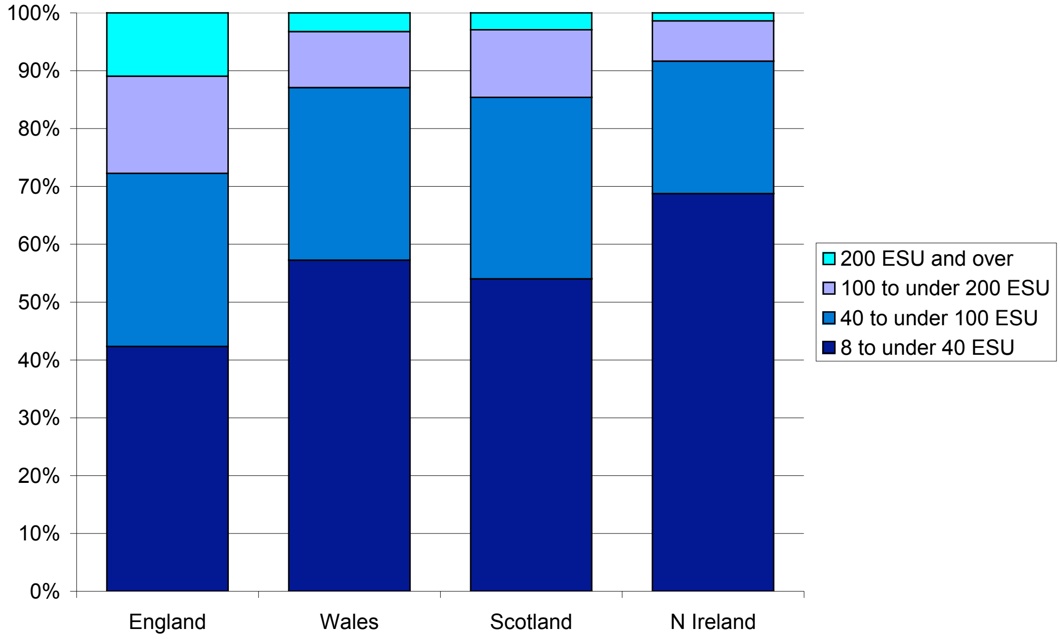
Size Band	ESU	FTE
Very Small- Spare Time Agricultural Business	<8	<0.5
Very Small- Part Time		0.5>1
Small	8 <40	1-2
Medium	40 <100	2-3
Large	100 <200	3-5
Very Large	200 and over	5+

Figure 9 highlights the variation in farm size across the UK regions. Of particular note is the predominance of smaller farms in N Ireland and larger farms in England.

[39] University of East Anglia (2006) Efficiency and Productivity at the Farm Level in England and Wales 1982 to 2002. Report to Defra

[40] This is defined in terms of total standard gross margin (average value 1987 to 1989), with 1,200 ECU (European currency units) of standard gross margin corresponding to one ESU (European Size Unit)

Figure 9: Distribution of full-time farms by size in UK regions



While there are implications in terms of the extent of restructuring of agriculture across the UK regions which might be driven by high oil price, the overall balance of land use and intensity of land use would not be prejudiced in the longer run. Issues of critical size of certain sectors may be relevant where downstream supply chain costs are also affected e.g. pig processing sector in N Ireland, Scotland and Wales.

It is important to distinguish oil price effects from ongoing rationalisation and restructuring in farming, a process which has been recognised for some time. Table 23 summarises the likely impacts by UK region and England GORs, based on the premise that cereals and oilseeds will be net beneficiaries from higher oil prices while livestock sectors will suffer a net increase in costs.

Table 23: Regional impacts of $100 barrel oil

	Dairy Farms	Cattle and Sheep - LFA	Cattle and Sheep - Lowland	Cereals	General Cropping	Specialist Pig	Specialist Poultry
N Ireland	✗✗	✗✗	✗			✗✗	✗✗
Scotland	✗	✗✗	✗	✓		✗✗	✗
Wales	✗✗	✗	✗			✗✗	✗
England	✗	✗	✗	✓		✗	✗✗
East Midlands	✗	✗	✗	✓		✗	✗✗
East of England	✗	✗	(✓)	✓		✗✗	✗✗
North East	✗	✗✗	✓	✓		✗	✗
North West	✗	✗✗	(✓)	(✓)		✗	✗
South East	✗	✗	✗	✓		✗	✗
South West	✗	✗	✗	(✓)		✗	✗
West Midlands	✗	✗	✗	✓		✗	✗✗
Yorkshire and The Humber	✗	✗	✓	✓		✗✗	✗✗

✓ = positive impact on sector

✗ = negative impact on sector

Regions that specialise in intensive sectors such as dairy, pigs and poultry will be particularly impacted due to higher costs and import competition. However, they will become more important, relative to regions with low sector presence, which have less-developed infrastructure and incur higher transport costs. Northern Ireland and Wales, with small dairy farms and distant from processing/markets will be most affected. The impact will be partly offset by lower reliance on concentrate feed.

For the less intensive livestock farm types e.g. cattle and sheep LFA, higher production costs and lack of proximity to finishing and processing infrastructure will reduce presence. Northern Ireland and Wales are more remote from processing/markets, while North East and North West England will also be impacted by higher transport costs. However, the latter along with Yorkshire and the Humber may benefit in terms of lowland production where access to by-products from the biofuel sector through growth in beef feedlots. This effect is less likely to apply to sheep production.

Broadly, all cereal growing areas should benefit for the biofuel effect more than offsetting higher costs due to $100 barrel oil; while contracts for UK wheat and rape feedstock will be concentrated in the regions where processing plant is located, the need for relative parity with feed markets should ensure an even effect across the country. General cropping farms will be impacted both positively (prices for cereals and oilseed rape) and negatively (growing costs for other crops).

5.1.5 N Ireland

The agriculture sector is dominated by the livestock sectors, notably Cattle and Sheep (LFA), dairying and poultry. In the LFAs, there is unlikely to be any change in enterprise but higher energy costs will reduce fertiliser use and stocking rates while reliance on export markets for beef (UK and Europe) and lamb (France) will reduce net returns. The same issues apply to dairy farms but energy use is more intensive; much will rely on the demand for processed dairy products on world markets e.g. milk powder. The high number of part-time farmers means that these businesses have a secondary source of income and are less responsive to economic signals; as such limited change is likely although there may be significant restructuring.

The poultry sector is very significant and is concentrated in the hands of two large processors, with reliance on the UK and EU markets. This is a very efficient sector and already relies on imported feed. The future of the sector relies heavily on the ability to recoup additional (energy-based) costs from the market. **The poultry sector is vulnerable.**

Cereals and General cropping farms are not significant in Northern Ireland and the region is not expected to benefit from growth in the biofuels market.

5.1.6 Scotland

Grazing land comprises over 79% of the total agricultural land in Scotland (2006 Agricultural Census), and approximately 47% of holdings in Scotland are involved in livestock farming. Beef production is the largest sector of the agriculture industry in Scotland, estimated to contribute almost 26% of gross agricultural output in 2006. **For the beef and sheep sector, remoteness from processing/markets is the biggest challenge with transport costs being impacted by oil price as well as production costs**. Livestock numbers would be expected to decline on this basis, with potential issues of destocking in remote hill areas.

Dairying is concentrated in the South West of Scotland, with dedicated processing and reasonable proximity to markets. Feed and fertiliser costs will impact on the sector output and much will depend on the balance of world markets for dairy products. A move to cereal production is not an option for most livestock farmers, due to climate and soil limitations.

The cereal sector in Scotland is also significant and should benefit from higher returns, driven by biofuels. Development of the latter will provide by-products which, together with access to straw in cereal growing areas, could develop an intensive beef-finishing sector, helping offset some of the costs of the rearing sector and adding value within the region.

5.1.7 Wales

Cattle and sheep (LFA) farms almost 30% of Welsh holdings with Dairy and Cattle and sheep (non-LFA) next most significant at around 10%. Milk and milk products represent the single largest share of gross output at 29% of total Welsh Agriculture.

Remoteness from processing and markets for milk and livestock products is a key issue in addition to higher feed and fertiliser costs. Seasonality of lamb supply has led to a reliance on exports of lambs to southern Europe; this trade may be badly impacted by high transport costs. Livestock numbers would be expected to decline on this basis, with potential issues of destocking in remote hill areas.

Cereals and General cropping farms are not significant in Wales and the region is not expected to benefit from growth in the biofuels market.

5.1.8 England

The picture across England varies considerably across the regions, with cereal growing areas in the east more likely to benefit from expansion of the biofuel sector and livestock sectors impacted by higher costs (feed, fertiliser, transport) which are not fully reflected in prices. As such grazing livestock numbers in the west and especially in more remote LFAs can be expected to reduce. This may be offset by an increase in intensive finishing units in arable areas, especially in proximity to biofuel plants, if by-products are available to the feed industry e.g. North East and Yorkshire and the Humber.

The pig and poultry sectors are concentrated in eastern regions and in the Midlands. Their future depends heavily on the price response to $100 barrel oil at a global level. We have already noted that the poultry market is under pressure from imports and has limited capacity to become more efficient; a similar statement can be made about pigs. Ultimately, these meats are cheaper than beef and lamb and there may be some substitution, which will allow costs to be recouped. The economic modelling suggested that pig production might expand, despite higher cereal prices. Any reduction in the pig and poultry sector is most likely to affect those smaller units in areas remote from processing capacity and markets.

5.2 Implications for sustainability

Sustainability needs to be considered in the context of Government policy. Table 24 shows the key indicators of sustainability as set out by Defra in the Strategy for Sustainable Farming and Food.

Table 24: Defra indicators of sustainability

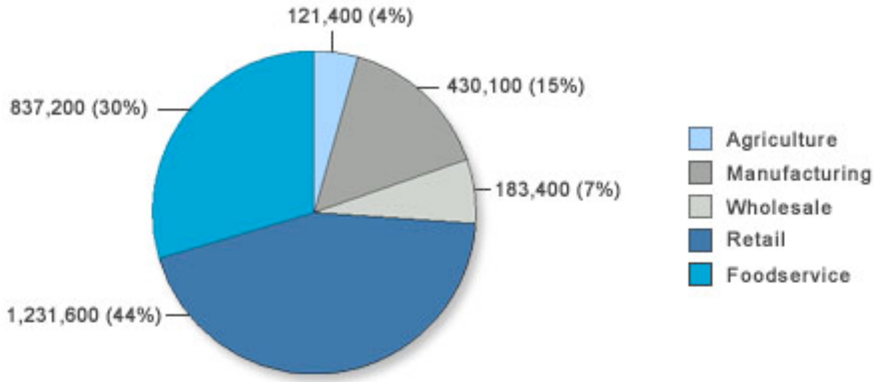
	Economic	Environmental	Social
1	A farming sector focussed on the market	Reduced pollution from food and farming	Improved landscape and biodiversity
2	Greater competitiveness of the total food chain	Better use of natural resources	Better public health
3	Reduced burden on taxpayers		Higher animal welfare
4			More cohesive and productive rural communities

5.2.1 Economic

High oil prices will help drive market focus and competitiveness in the wider food chain, as retailers will wish to limit increases in food price. The supply chain will seek efficiencies and will need to evidence ‘sustainability’ as part of increased consumer awareness of this issue. It is likely that the initiatives already announced by major retailers will apply more widely and will drive the move to more dedicated supply chains.

Employment in retail and foodservice represents almost three-quarters of total supply chain total (see Figure 10). It is likely that the long-term trend of falling employment in farming will be continued or hastened. The downward trend in food manufacturing is also likely to continue, due to limited growth of domestic food and drink consumption and strong productivity growth in food and drink manufacturing. The latter will also be exacerbated by increased energy costs.

Figure 10: Employment in the UK food and grocery chain



Source: ONS / IGD Research 2004

5.2.2 Environmental

The greenhouse gases implicated in global warming are nitrous oxides, methane and carbon dioxide. UK agriculture as a whole contributes 67% of nitrous oxides (arable cropping – 64%) and 43% of UK methane emissions (mainly livestock). Less than 1% of UK carbon dioxide emissions comes from agriculture. Overall, agriculture accounts for 80% of UK ammonia emissions.

There are three scenarios in terms of the impact of high oil prices:

(i) UK agriculture contracts and consequently the environmental impact is reduced (but exported overseas)

(ii) UK agriculture is maintained at current levels and inputs (fertiliser, pesticides and cultivations) are maintained on the basis that economic returns are improved

(iii) UK agriculture is maintained at current levels but inputs (fertiliser, pesticides and cultivations) are reduced through more energy efficient practices

On the basis of the analysis in this study, it is likely that the area of land cropped will be maintained or increased, partly to supply a buoyant biofuel market. Livestock numbers will fall due to competitive disadvantage relative to other countries and because more extensive systems will be favoured by high cereal and protein prices. More set aside land is likely to be cropped for biofuel and more marginal arable land will grow longer-term energy crops such as SRC.

A review of the environmental impact biofuel crops by HGCA[41] concludes that cultivating set-aside has overall a negative impact. There is little difference in the environmental impact of growing crops such as wheat and oilseed rape for food or biofuel use, but there may be some scope to reduce impacts if biofuel buyers accept different quality and grain protein specifications to allow some inputs, such as nitrogen, late fungicides and insecticide applications to be reduced.

Organic farming and extensive systems will be mainly encouraged by high oil prices but the former is dependent on reasonable market premiums. These may come under some pressure if overall food prices increase in response to high energy prices or consumers see carbon neutrality as a competing premium 'brand'.

5.2.3 Social

A reduction in breeding livestock and promotion of extensive systems under higher oil price represents a threat to landscape and biodiversity in upland and hill areas; there may also be social impacts with fewer jobs in farming and impacts on tourism from high fuel prices. It is difficult to see a positive contribution to more cohesive and productive rural communities.

More specialised farming in lowland areas and the growth of intensive livestock finishing systems in clusters around processing facilities will be favoured. This is unlikely to promote animal welfare at one level but reduced movement of livestock and use of markets would reduce travel times and related stress.

The one social sustainability indicator which is likely to be enhanced is public health, as livestock supply chains will need to become much more market led in order to secure economic and energy efficiencies e.g. through improved feed conversion efficiency. We might expect more homogenous genetic breeding stock and production systems and a focus on more delivering healthy products. If meat is significantly more expensive, overall intakes are likely to reduce and may also have health impacts.

[41] HGCA (2005) Environmental impact of cereals and oilseed rape for food and biofuels in the UK

6. Conclusions and recommendations

6.1 Conclusions

On the basis of the research undertaken in this study, a number of conclusions have been drawn. These have been set out under the research questions in the brief.

1. **The on-farm implications of an increase in energy costs if oil prices rose to $100/barrel**

   Oil price will impact directly and indirectly on farm production costs. This varies between and within commodities depending on the production system. Moving from $50 to $100 barrel oil would increase production costs of the livestock products considered in this study by between 3 and 5%, and crops by 13% of commodity price. While this is significant and would cause short-term pressure on incomes, it is expected that commodity prices would also increase, partly in response to the cost response but largely due to the impact of increased demand for biofuels.

   Based on the Defra paper, using the OECD Aglink model, the price response might range from 10% for beef to nearly 60% for vegetable oil for the period 2002-04 to 2014. In turn these price rises would help mitigate higher production costs; the arable sector (cereals and oilseeds) would be impacted to a lesser extent than livestock and the latter sectors are expected to contract.

   We can expect a differential impact across the UK regions with N Ireland, Wales and western areas of Scotland and N England, where there is a minimal arable sector and a reliance on livestock, to be impacted most severely. This is based on a more limited market response to costs and high reliance on transport to markets.

   Overall, farm-level impacts would be modest in the long-term but a dramatic increase in oil price to $100 per barrel or more would cause some short-term shocks. These would be offset to some extent by the reliance of farmers on other income streams e.g. Single Payment, agri-environment schemes, diversified enterprises.

2. **Responsive changes in farm practices and related energy and cost savings – both potential and anticipated**

   The impact of energy price increases on the price of fertiliser and pesticides may prompt producers to reduce use of inputs or turn to relatively cheap substitutes; unless they have expectation of that the product price will also increase to offset the impact of increasing input price. Reduction in agricultural inputs may cause falling agricultural production, if production technology remains unchanged. This may result in higher market price and in turn encourage more production in the next stage.

   There are three short-term responses, first to recover the additional costs from the market, secondly to change the scale and management of the enterprise to mitigate cost impacts, and thirdly to discontinue production. The scale of the first-level impact of the oil price change is perhaps less than expected and we are unlikely to see any sectors discontinued. Instead, we will see a polarisation of production systems with extensive systems producing at low cost and limited inputs and a growth in intensive systems, using economies of scale and technology to offset higher levels of input. The latter does not exclude energy saving practices such as the use of min-till in the arable sector and solar panels for intensive meat or milk production.

Technology will be a key element of a positive response to energy prices, not only in terms of energy-efficient vehicles and solar panels but also in term of plant and animal breeding. This is the one way that the UK can compete with lower cost third countries.

Finally, increased integration of farming with the food supply chain as part of a 'security of supply' approach by retailers may standardise some farm practices.

3. **Overall – how an increase in energy costs to $100/barrel of oil would impact upon overall farm costs in the UK in the next 1, 5 and 20 years**

   The impact of energy costs has not been detailed in terms of absolute levels in 1, 5 and 20 years. The economic model has instead offset prices with increased energy costs as part of the process. Thus we have price impact and forecast sector changes within a 1-year and 10 year timescale. It was agreed that as 10 years was the current horizon for policy development, there was little merit in looking beyond this period.

   The 1 and 10 year forecasts indicate an initial reaction to oil price change, which is often different over a longer timescale.

4. **Extent to which increased costs will be reflected in the farm output costs**

   In principle, higher production costs due to energy price can be passed on to the market but the evidence from the recent increase in fuel price (from $28 to $65 between 2001 and 2006) is that little of this cost was recouped. The first priority for the downstream supply chain (retailers and processors) is to recoup their own cost increases due to fuel price change. In the medium to long term, costs may be recouped to some extent but it is much more likely that the industry will be required to absorb or mitigate much of the cost increase. In time it is likely to be achieved though energy efficiency and new technology.

   Where increased farm costs lead to a shortfall in supply, the market will respond by increasing prices or seeking alternative supplies. The combination of increasing world consumption, higher global production costs and competition for land to grow biofuels may mean that supplies are not always available from third countries and that markets will move to secure domestic supplies e.g. for milk products.

5. **Impacts overseas, including relative use of energy compared to international competitors**

   The LCA analysis of UK and international competitors for the six commodities demonstrated that high energy prices are not necessarily detrimental to the UK. While the UK is relatively intensive in terms of crop inputs (fertilisers / pesticides and cultivations) it is also efficient in terms of yield for cereals and oilseeds; this means that it gains competitive advantage relative to less intensive systems e.g. in Hungary, in terms of unit output.

   The capacity to grow grass also offers an opportunity to gain competitive advantage in the livestock sector as competitors face rising feed costs (from energy costs of inputs and biofuel market growth). While this is borne out in the analysis – beef and poultry gain competitive advantage relative to intensive production in Brazil – the scale of this is nominal and the much larger cost advantage enjoyed by third countries will drive production there and reduce UK production.

Extensive and organic production systems in the UK are less severely affected by energy prices than intensive systems but lower output per unit area means that these systems will need to have low costs or secure market premiums to prosper. The current growing market for organic and premium foods suggests that this sector would enjoy a degree of continued growth, despite overall increases in food prices resulting from oil price changes. The latter, together with competition from a buoyant cropping sector for land, would limit growth at some point.

6. Implications of increased oil prices for imports and exports

It is anticipated that food production in the UK (and the EU) will reduce on the basis of a combination of more expensive inputs and wider economic drivers in terms of decoupling / reduction of subsidies and trade liberalisation. As such, it is clear that in aggregate terms more food will be imported and less exported. This will vary by sector and it may be that some sectors decline e.g. dairy, beef and poultry, where there is very competitive overseas production. In contrast, others will be maintained or expand, notably wheat and oilseeds, due to demand for biofuels.

The market will drive technological change in terms of crop yields, and together with increased use of set aside land for biofuels (mainly oilseed rape), UK crop output will be maintained or increased. If livestock numbers decline, it is quite possible that the UK will export more feed-grade wheat while importing biofuel feedstock from, for example Brazil (bioethanol) and Malaysia (palm oil).

A detailed balance sheet of imports and exports has not been compiled but the six commodities considered in this study, the expected trend is as follows:

Wheat	static imports of milling wheat as producers chase biofuels and feed markets but increased exports of feed wheat as plantings increase and yields increase
Oilseeds	increased UK production as plantings increase and yields increase but focused on UK biodiesel production
Milk	increased imports as UK production declines due to high feed costs and other economic / regulatory pressures
Beef	increased imports as UK dairy and suckler herds decline; high feed costs linked to biofuel sector growth limit capacity to compete with imports
Lamb	little change in production or imports / exports; sector driven by need to manage hill/upland areas and minimal fertiliser/feed input
Poultry	reduced production and increased imports due to high feed costs and other economic / regulatory pressures

7. Impacts of higher transport costs

Transport is a key component of the energy used in the food chain, although this largely relates to the retail and consumption stages. Recent Value Chain Analysis studies have highlighted the fact that it is not just the distance between nodes in the supply chain which add cost but numerous instances of inefficient process, which require additional journeys and increase waste. IGD's report 'Rising Energy Costs: Implications for the Grocery Supply Chain' (2007) further informs opportunities for efficiency gains, including transport.

An analysis of the energy costs of different modes of transport using LCA data indicates that energy use for a large sea-going bulk carrier is only one tenth of that for bulk lorry transport and one thirtieth that for a small delivery vehicle. Thus food miles represent a poor indicator of energy use and the impact on small-scale local food systems will be just as significant as on boat loads of grain from Baltic ports or lamb from New Zealand. All journeys will need to backload to ensure transport costs are contained.

At production level, farmers will be increasingly tied into dedicated supply chains, which minimise journeys and allow efficient logistics. Processors will be part of this process but capacity will need to be shared across a number of supply chains to ensure high utilisation and reduce food miles. Collaboration will need to apply both vertically and horizontally to allow this to happen. This can readily be driven by the multiple retailers but is much more challenging for the many small and medium-sized independent supply chains in the Foodservice sector.

8. Overview of the wider supply chain implications of an increase in energy costs to $100/barrel of oil

From the Manchester Business School report, energy used in the food production stage for most shopping basket items represents over 30% of total energy requirements. As such, the impact on consumer food prices would be substantial if all additional costs were passed on. Also, in the context of a highly concentrated and consumer-focused retail sector, the supply chain will have to absorb a significant proportion of these costs. The options for achieving this include:

(i) source more cheaper raw materials i.e. imports from third countries and Eastern Europe; this is consistent with a fall in UK (and Western European) production and a need to drive efficiency gains in UK supply chains

(ii) improve supply chain efficiency and drive out cost through price pressure, simplifying / shortening supply chain and rationalising processing capacity, especially in the red meat sector. There is limited scope for efficiency gains in the poultry sector, which is highly integrated and efficient and to a lesser extent the pigmeat sector but there is considerable scope in other commodity supply chains

(iii) investment in innovation and technology to reduce energy use in processing, packaging and distribution. The recent commitment of major retailers to carbon neutral trading indicates a willingness to invest in sustainability and significant progress can be expected

There is potential conflict between consumer choice – food is becoming increasing differentiated with a growing 'premium' market – and energy efficiency. The latter requires scale and investment in technology and it is likely that the premium market will increasingly be supplied through mainstream commodity market channels. Where 'local' food supply chains can operate at a genuinely local level, with minimal transport, these may also prosper.

6.2 Recommendations

On the basis of this work, there are some significant gaps in our understanding of how future rises in oil price might impact on the UK food supply chain. These are listed below as recommendations for further research.

R1. Undertake further to modelling work to isolate the impact of EU farm support mechanisms on the responsiveness of UK farm production to oil price change. Biofuel production is key to assessing high energy price impacts but there are still many uncertainties in providing a reasonable outlook. The energy and agricultural policy, subsidies, technology of biofuel production and trade policy for biofuels can dictate the future of the UK production.

R2. Undertake additional research on the likely socio-economic and environmental impacts of a significant decline in key livestock sectors such as dairy, beef and poultry, both in the UK and overseas. It should consider regional impacts in particular areas of reliance e.g. dairy in N Ireland, beef in Scotland and poultry in the East of England. It should also consider the loss of critical mass in infrastructure for these sectors in other regions.

R3. Further studies in the biofuels are required. There is potential for biofuel production in the UK through increasing use of set aside land for rapeseed production and increased yields. However due to its natural, technical and economic restrictions, in the long term a large proportion of the UK biofuels market will be met by imported feedstock if we still mainly rely on food crops as feedstock for biofuel production.

R4. Engage with industry to consider how the supply chain efficiencies highlighted in this report might be tackled. Where Government can play a role in this, it should do so, notably in the areas of research and technological development. Ultimately, a smaller farming and food sector might reduce sustainability impacts at home but is only likely to export them.

Annex 1: LCA Model Description and Assumptions

LCA analyses production systems systematically to account for all inputs and outputs that cross a specified system boundary (see Figure 11). The useful output is termed the functional unit, which must be of a defined quantity and quality, for example 1 tonne of breadmaking wheat. There may be co-products or waste products like straw, together with emissions to the environment, for example nitrate (NO_3^-) to water and nitrous oxide (N_2O) to the air. All inputs are traced back to primary resources, for example electricity is generated from primary fuels like coal, oil and uranium. Ammonium based fertilisers use methane as a feedstock and source of energy. Phosphate (P) and potassium (K) fertilisers require energy for extraction from the ground, processing, packing and delivery. Tractors and other machinery require steel, plastic, and other materials for their manufacture, all of which incur energy costs, in addition to their direct use of diesel. The minerals, energy and other natural resources so used are all included in an LCA. Allowances should also be made for making the plant used in industrial processes (factory or power station) as well as the energy used directly.

Figure 11: Interaction of agricultural production systems and the environment

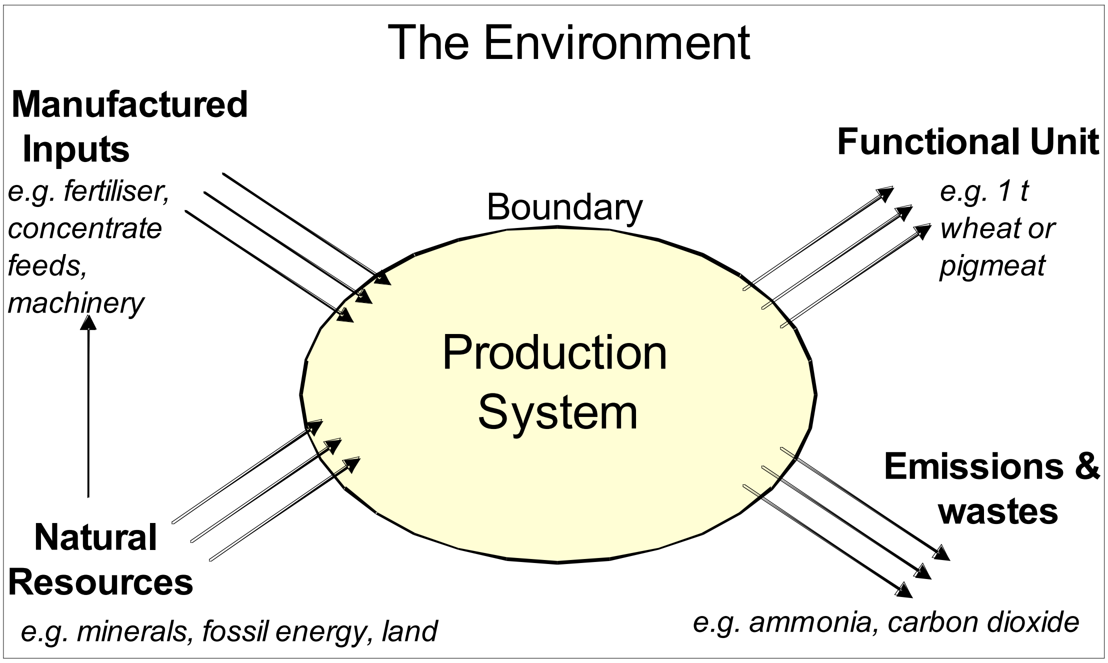


Table 25 estimates the increase in production cost for a tonne of wheat in response to an oil price change from $25 to $100 per barrel of oil. It assumes constant levels of input use and as such is a first level impact. We would expect farmers to respond to such production cost increases by adjusting inputs to the new economic optimum but at this stage we do not know how the international price of wheat will adapt to the new scenario.

Table 25: Calculation of adjusted production cost for wheat

		@ $25 per barrel oil		@ $100 per barrel oil	
Inputs	Use kg/ha	Prices £/kg	Cost £/ha	Prices £/kg	Cost £/ha
N	192	0.35	67.2	0.61	117
P	48	0.32	15.36	0.43	21
K	48	0.2	9.6	0.24	12
Water	0	0.3	0	0.3	0
WO Herb	10	1.97	19.7	1.97	20
Seed	185	0.29	53.65	0.29	54
Other			77		86
Total			243		308

Assumptions: Yield of primary product 8.14 t/ha
Yield of secondary product 3.75 t/ha

The price of machinery will also rise in response to oil price change and will also impact on production cost. Table 26 sets out the first level impact of energy cost increase associated with $100 barrel oil on a range of key agricultural equipment.

Table 26: Estimation of price of machinery at $100/barrel

Machinery	Baseline Price (£)	Machine (kg)	Sundries (kg)	Machine (MJ)	Sundries (MJ)	Price increase (£)	Price (£) at $100 barrel oil
Tractor	35,825	4,299	4,777	584,664	554,132	7,180	43,005
Sprayer	15,500	1,000		107,000		675	16,175
Combine	109,376	12,380	5,626	1,683,680	601,982	14,411	123,787
Sugar Beet Harvester	31,500	4,000	4,000	464,000	428,000	5,624	37,124
Potato Harvester	48,500	4,000	3,383	464,000	392,428	5,400	53,900
Baler	18,000	1,800	2,813	192,600	300,991	3,112	21,112
Maize header	16,000	1,000	1,000	107,000	107,000	1,349	17,349

This is the first step to enable us to examine the cropping on an individual farm and how this would change as the gross margins change. The other pieces of information needed for this is the price of the crop products. An alternative to determining the external prices is to calculate what prices are needed by the farm in order to maintain an equivalent cropping. The objective is then to compare these price changes with the equivalent from abroad to determine whether UK farming is better or worse off in competing.

The methodology based on the primary energy requirement can also be applied directly to the individual crops based on the total MJ required for their production taken from the LCA, which includes all the inputs and their inputs back to their source. Table 27 lists the increases for arable crops and Table 28 for livestock products.

Table 27: Energy input and production costs for crops at $100 barrel oil

	Bread Wheat	Feed Wheat	Oilseed rape	Soya	Potatoe s	Maize	Forage maize
N use (kg/ha)	208	192	915	0	170	120	100
Yield (tonnes)	7.58	8.05	3.29	2.57	52.14	7.2	11.2
MJ/t	2369	2194	5388	2837	1507	2163	1645
By source:							
Crude Oil, %	34%	36%	38%	69%	31%	41%	34%
Natural gas, %	53%	50%	50%	12%	29%	42%	46%
Coal, %	7%	7%	6%	10%	24%	9%	6%
Nuclear, %	5%	5%	5%	7%	14%	7%	5%
Renewable, %	1%	1%	1%	1%	2%	1%	9%
By use:							
Field diesel	21%	24%	25%	51%	21%	25%	27%
Machinery manufacture	11%	12%	12%	22%	6%	13%	11%
Crop store & process	5%	6%	3%	6%	49%	13%	2%
Pest manufacture	8%	7%	8%	12%	5%	7%	2%
Fertiliser manufacture	55%	52%	52%	9%	19%	42%	58%
Change in cost (£/t)	10	9	20	12	6	9	7
Change in cost (£/ha)	75	74	67	31	330	65	77
Change in cost %)	13%	13%	13%	-	7%	11%	-

Table 28: Energy input and production costs for livestock products at $100 barrel oil

	Quantity	Units	Energy (MJ)	Increase in production costs (£/unit)	As % of price of commodity
Pig meat	1,000	kg dwt	21,208	89	9%
Poultry	1,000	kg dwt	14,882	63	5%
Beef	1,000	kg dwt	26,870	113	5%
Sheep meat	1,000	kg dwt	25,477	107	3%
Milk	10,000	l	25,757	108	5%
Eggs	20,000	no	13,527	57	9%

To analyse overseas production an important piece of information is the increase in the cost of transport. This can be derived from the data in Table 29.

Table 29: Primary energy data on transport.

Item	Quantity	Reference Unit	Primary Energy used (MJ)
Large sea-going bulk carrier	1	t km	0.118
Boat, ocean going	1	t km	0.200
Transport, freight, rail/CH S	1	t km	0.316
Boat, coastal	1	t km	0.503
Rail	1	t km	0.518
Transport, freight, rail/RER S	1	t km	0.720
Bulk lorry transport	1	t km	1.105
Medium sized lorry	1	t km	2.432
Small delivery vehicle	1	t km	3.647

The MJ analysis can be carried out for overseas areas where this is available. For example we have the NZ milk study (and lamb) as detailed in Table 30. From this we can calculate the increase in production and delivery costs of NZ milk to the UK to compare with the above UK production cost increase. The NZ study assumes shipping uses 0.114 MJ/t.km and a fully loaded articulated truck uses 0.419 MJ/t.km.

Table 30: Primary energy requirements for milk from New Zealand and UK studies

	NZ study	UK study
Milk (kgMS/ha)	819	968
cows/ha	2.7	
Diesel (MJ/ha)	2,483	10,429
Contractors (MJ/ha)	861	
Electricity inc irrigation (kWh/ha)	545	4,053
N	4,678	9,685
P	864	203
K	560	382
S	312	
CA	173	1,05
Chemicals	1,515	1,091
Concentrates	189	7,522
Fodder	542	4,320
Dairy shed	431	606
Storage	590	400
Fences / Races	228	1
Irrigation / Water supply / Effluent	268	

Annex 2: LCA Competitor Country Analysis

Feed Wheat

Data on energy use in UK wheat production is available from the Cranfield LCA model. This can be broken down into its constituent parts of fieldwork, energy cost of inputs and energy cost of production of inputs. A work study by Palonen (1993)[42] lists the tasks used in producing winter wheat in Finland, Sweden, Denmark, Germany, Hungary and the Netherlands. Although there are some differences, it is clear that many of them are more due to the standards and methods used in carrying out the work study in the different countries, than substantive differences in the fuel use of tractors and harvesters when carrying operations. They attempted to use a model to remove some of the differences but found it was not satisfactory. It seems clear however that the use of Hungary as a proxy for the same data from the Ukraine is valid.

Table 31 shows the energy use in wheat cultivation for the UK and Hungary. The first column shows the data from the Cranfield LCA model, which gives 2194 MJ/t wheat. The fuel use of 141 l/ha is comparable to the German value of 124 l/ha in the Palonen study so the data.

The second column uses the assumptions:

- only half the pesticides are used
- the 156 kgN/ha from the Hungarian data are applied
- the yield is 5 t/ha.

This results in an estimate of 2839 MJ/t.

The third column uses the fuel use per hectare estimated by the Hungarians in the work study, which was at the lower end of the country estimates. This results in a very similar 2801 MJ/t.

The Hungarian fertiliser input seems high for the yield obtained, even on the assumption of using mainly urea, (which loses about 11% of the nitrogen as ammonia after application). The fourth column uses fertiliser calculated on a yield pro-rata basis with the UK fertiliser, which reduces the energy to 2572 MJ/t.

Finally as the data is from 1990, it is likely that, as with UK yields, the current yield has increased from this value. Thus the final column assumes that the yield has increased to 6 t/ha (and the fertiliser is again pro-rata with the UK). This is just over 1% per year. The energy required is 2343 MJ/t.

Based on the increased cost of energy from 25$/t to 100$/t, the increased cost of production ranges from £14/t for the UK to a maximum of £18/t for Hungary. In all cases however the competitiveness of the UK has increased by £1-4/t.

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42 Palonon, J.; Oksanen, E.H. (1993) Labour, machinery and energy data bases in plant production. Work Efficiency Institute, Helsinki

Table 31: Energy use in winter wheat cultivation in the United Kingdom and Hungary

	UK from Cranfield LCA model	**Hungary based on reduced pesticide, fertiliser and yield**	**Based on Hungarian fuel use**	**Based on fertiliser pro-rata with UK rate of fertiliser**	**Based on Hungarian yield of 6 t/ha**
Cultivation	3487	3487	5611	5611	5611
Spraying	636	318			
Fertiliser App	471	471			
Harvest	1515	1515			
Grain proc	978	0			
Pest manufacture	1237	618	618	618	618
Fert manufacture	8935	7260	7260	6157	7388
Allocated total	17259	13669	13489	12386	13617
Per tonne after seed	2194	2839	2801	2572	2342
£/t increase in production cost	**13.8**	**17.9**	**17.7**	**16.2**	**14.8**
Additional increase in E Europe, £/t		4.1	3.8	2.4	0.9

UK wheat competes with Black Sea port for exports to other countries. Table 32 shows the energy costs of transport by different forms. Sea transport is cheapest and an advantage of UK wheat is the closeness of all our ports. This probably reduces land transport by at least 100km over the Ukraine. In addition the distance to Gibraltar is about 1000km versus 2000km from Ukraine, which is an advantage unless exporting to North African countries. This amounts to 228 MJ/t, which is within the range of values but worth about £1/t.

Table 32: Energy cost of different forms of transport

Item	Quantity	Reference Unit	Primary Energy used (MJ)
Transport			
Bulk lorry transport	1	t km	1.1053
Medium sized lorry	1	t km	2.4317
Small delivery vehicle	1	t km	3.6475
Large sea-going bulk carrier	1	t km	0.1177
Boat, coastal	1	t km	0.5028
Rail	1	t km	0.5180

Oilseeds

In terms of oil production one of the major competitors is the oil palm (table 33)

Table 33: Oil crops

Crop	Production ('000 t)	Oil/ha/year (t)	Area (million ha)	(%) of total area
Soyabean	25 483	0.46	55.398	63.48
Sunflower	9 630	0.66	14.591	16.72
Rapeseed	14 237	1.33	10.704	12.26
Palm Oil	21 730	3.30	6.563	7.52

The oil palm has the distinction of being the most productive of all oil crops with an average yield in major producing countries of about 3-4 tonnes of mesocarp (palm) oil/ha/year. In addition, oil palm also produces c. 0.5 tonne/ha/year of kernel containing c. 47% kernel oil. The kernel and mesocarp oils differ in fatty acid composition and hence have different uses, including both food and non-food. The kernel meal or cake is also of economic value as a source of animal feed protein.

The oil palm, a C3 crop, is a perennial and has a relatively high photosynthetic capacity. At a commercial spacing of 130-150 palms/ha, under good conditions a full canopy cover is obtained by the 5-6th year after planting when the leaf area index (LAI) is around 6. By ten years, 96 % of photosynthetically active radiation (PAR) is intercepted. Being a tropical perennial crop with continuous year-round fruit production it is able to fully exploit resources provided limitations such as water deficits and pest and disease attacks are minimal.

Large plantation schemes require good soil drainage, level terrain and large amounts of fertilisers. Although setting up these schemes requires large inputs of energy, the lifespan of the commercial crop is 20 to 30 years, considerably spreading the energy costs per tonne of oil produced. One problem in comparing systems is that, for example fertiliser spreading techniques range from a labour-intense wheelbarrow to a technical-intense aircraft with GPS system. In general a plantation demolishes huge areas of tropical forest and generates considerable emissions to the environment; thus environmentalists generally regard them (including the factory) as undesirable. It has to be noted that the soil initially will have considerable reserves of nutrients (thus emitting carbon to the atmosphere) which means that crops can initially be grown without additional fertiliser and, spreading the wastes back on the land will tend to delay the need for fertiliser. Where plantations are replanted, the degrading old palm trees can supply a substantial part of the required nutrients for the first few years. Nevertheless the proper LCA approach is to analyse the energy requirements in terms of those needed to replace those removed.

Setting up a plantation requires Nursery Establishment (site clearing with biomass disposal, drainage & irrigation, planting and maintenance of seedlings), Field Establishment (clearing and disposal, and transplanting), Maintenance (fertiliser application, use of control agrochemicals), Harvesting (harvesting and transportation of FFB), and finally Replanting or Abandonment. Thus apart from setting up costs which are spread over 25 years, the main crop production energy inputs are for spraying, fertiliser, irrigation and harvesting and transport. Yields commence in year 3, rising to a peak in year 10 and declining after year 15.

The oil palm requires large amounts of mineral fertiliser – 500-1000 kg/year (Caliman et al)[43]. It has been estimated that for Malaysian soils between 0.5 and 1.1 kg/palm /year of N, 0.7 and 1.1 kg/palm/year of P_2O_5, and 0.5 to 2.0 kg/palm/year of K_2O are needed to make good the shortfall in soil nutrient supply after taking into account expected losses of the applied nutrients (Tarmizi, 2000)[44]. For a yield of 25 t Fresh Fruit Bunch (FFB), a replacement rate of fertiliser is (Wahid et al)[45] 120kgN/ha, 16 kgP/ha, 286 kgK/ha, 22 kg Mg/ha. There are attempts to improve the 'sustainability' of oil palm production with irrigation using the factory waste water and fertilising using the waste products after oil extraction.

There are several embryonic LCA studies of palm oil plantations but none found that have been completed. In any case, we are only interested here in the use of energy in production, rather than the emissions of nitrate and pesticides and soil erosion. A lower estimate of energy required is 612 MJ/t FFB, where a major factor is fertiliser. Depending on the amount of irrigation required this could easily double. The meal, which is only from the small kernel fraction, has little value and can be ignored. This corresponds to 2656 MJ/t oil. After transport to the UK this becomes 4969 MJ/t oil. Where pumped irrigation is required this will add 1000MJ/t oil per additional 100 ha.mm of irrigation.

The comparable energy input figure for oilseed rape after allocation to the protein meal fraction is 8678 MJ/t. Thus the $100 oil price will add up to £23/t more to the price of oilseed rape oil relative to sustainable palm oil. This should be compared with a rapeseed oil price of £323/t rising to £378/t to cover production costs with the $100/barrel oil price.

Milk

New Zealand represents a distinctive competitor for UK milk producers. Whereas over half of UK milk goes to the liquid milk market and highly perishable products such as yoghurt, NZ competes with supplying the less perishable products, butter and cheese, and milk powders. Since there is thus little need for an all-year round supply, the vast majority of the dairy herd is fed from grass for 10 months of the year and dried-off for the two months of the NZ winter. In the UK, producer contracts range from those based on payment for liquid milk supply to those based on payment solely for protein and butterfat, typically for cheese makers. Different contracts can also attach more or less importance to a balanced all-year round supply.

The NZ food miles study (Saunders, 2006) considered milk production, as well as lamb production. The NZ data is based on a comprehensive study by Wells (2001), which concludes that milk production requires 22317 MJ/t milk solids (MS). Milk solids are protein plus fat and being the main ingredients of butter and cheese are the measure used in New Zealand statistics. Milk yield *per se* is not used.

As Wells (2001)[46] noted, the surveyed farms have a very different production of MS/cow to the national average, implying that the survey referred to the, in some

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[43] J.P. Caliman, Elikson Togatorop, Budi Martha, and R. Samosir Aerial Fertilization of Oil Palm Better Crops International Vol. 16, No. 2, November 2002

[44] Tarmizi, A M and Mohd Tayeb, D Nutrient demands of tenera oil palm planted on inland soils of Malaysia Journal of Oil Palm Research vol. 18 June 2006 p. 204-209

[45] M. B. Wahid, S. N. A.Abdullah and I. E. Henson Oil Palm – Achievements and Potential. Proceedings of the 4th International Crop Science Congress Brisbane, Australia, 26 Sep – 1 Oct 2004 www.cropscience.org.au

[46] Wells, C. (2001) Total Energy Indicators of Agricultural Sustainability: Dairy Farming Case Study Technical Paper 2001/3,Dept of Physics University of Otago ISBN: 0-478-07968-0 ISSN: 1171-4662

sense, ‘most productive’ farms. He attempted to ‘correct’ the bias in his surveyed farms but with little success. His detailed data suggest that the high yields are due to the smaller farms and that his larger farms were similar to the national average. An estimate on the basis of the national average would be 702 kgMS/ha. It is of course unclear how this would affect the average inputs to all the NZ farms. For example the error could be due to the small farms using other forage land where a small error would have a large effect. However using the worst case assumption, the energy input would be 26033 MJ/t milk solids.

To these values must be added transport (2030 MJ/t) and refrigeration (1000 MJ/t.30 days). Butter is 15% water and cheese is 40% water. Powder does not need refrigeration. Exports are in the ratio 3:3:8, not necessarily to the EU. Thus the total energy cost is 25323 MJ/t milk solids or at worst 29039 MJ/tMS.

The Cranfield LCA model calculates the energy required for 10,000 litres of milk as 25550 MJ, Table 34. Milk solids is not a number regularly used in UK milk production. The NZ study, which also calculated a value for UK milk production, derived a value of 844 kgMS per 10000 litres. The source of this value is not clear as their quoted data source gives the sum of protein and fat as 740 kg. This range of assumptions results in a range of 30273-34527 MJ/tMS energy use. The production methods assumed in the analysis provide all year round milk and an alternative basis would be to consider just spring calving, even though this would not be desirable from the point of view of keeping factories in year-round production. In this case the range is 27293-31527 MJ/tMS.

Converting these to a pence per litre (ppl) basis using the oil price, New Zealand have an increase in competitiveness ranging from 0.09 to 0.29 ppl with the $100 barrel of oil.

With the increase in fertiliser prices, it is likely that the rate of fertiliser use will fall. This depends on the ratio of output to input prices. The analysis suggests that there will be about a 10% change in output prices, versus 61/35 increase in fertiliser. The grass model in the LCA suggests that average fertiliser use for silage will fall from 317 kgN/ha to 279 kgN/ha. The model calculates that the energy required for 10,000 litres of milk thus falls to 24,950 MJ, which does not have a material effect on the conclusions.

Table 34: Comparison of New Zealand and UK Life cycle analyses for milk production

New Zealand			UK		
Milk	818.9	kgMS/ha	Milk	10000	Litres
cows/ha	2.7		Pro-rata milk solids	844	kgMS
Diesel	4084	MJ/tMS	Diesel, General, MJ	2066	MJ
Electricity incl irrigation, parlour (160kWh/cow)	5426	MJ/tMS	Electricity, UK, MJ	5911	MJ
N, 72kgN/ha @65	5713	MJ/tMS	Grass, 9222kg DM	9118	MJ
P, 57.6kgP/ha	1055	MJ/tMS	Maize silage, 417 kg DM	686	MJ
K, 56kgK/ha	684	MJ/tMS	Concentrates, 2989 kg	9310	MJ
S, 62.4kgS/ha	381	MJ/tMS	Straw, 994 kg	251	MJ
Lime, 289kg/ha	211	MJ/tMS	Small delivery vehicle	153	MJ
Chemicals	1850	MJ/tMS	Building, dairy cattle	247	MJ
Concentrates, 83kg/ha eg grain	231	MJ/tMS	Manure	-181	MJ
Fodder, 389kg/ha eg maize silage	662	MJ/tMS			
Capital items	2021	MJ/tMS	Total	25550	MJ/10000litres
Total	22317	MJ/tMS		30273	MJ/tMS
MJ	18275	MJ/ha		16699	MJ/cow
	6769	MJ/cow			
			Spring calving	23035	MJ/10000litres
Transport	2397	MJ/tMS		27293	MJ/tMS
Refrigeration	609	MJ/tMS			
TOTAL	25323	MJ/tMS	Assuming 740 kgMS	34527	MJ/tMS
TOTAL @ 702 MS/ha	29039	MJ/tMS		31128	MJ/tMS
MS=protein+fat, typically standard litre is 3.3% and 4.1% respectively					
Cheese=25%protein, 35% fat, 45% water					
Butter=82% fat, 15% water			Difference in pence per litre	All year	Spring
			844 kgMS	0.26	0.09
			740 kgMS	0.29	0.10

Table 35: Predicted Production Indicators for the 'National Average' Dairy Farm

Indicator	Actual National Averages	Predicted 'National Average' Dairy Farm
Effective Milking Area (ha)	91	86 ± 8
Cows in Milk (1 December)	229	234 ± 23
Milk Production (t MS/annum)	61.3	70.9 ± 8.1
Stocking Density (cows/ha)	2.7	2.8 ± 0.1
Production Intensity (kgMS/ha)	684	835 ± 39
Milk Production (kgMS/cow)	256	299 ± 10

Source: Wells, 2001

Lamb

The Cranfield LCA model indicates that raising lambs in the UK consumes 25,496 MJ/t lamb carcass weight of which 16,817 is attributable to grazing, 7291 to concentrates and 1,798 to diesel. About 12,000 of the grazing is attributable to nitrogen fertiliser. In addition the system produces about 275kg mutton per 1000kg prime lamb meat.

The NZ study of food miles calculates both the energy cost of NZ and UK lamb. The calculated value for the UK is 45859 MJ/t carcass, but in doing so they have made a number of worst case assumptions about UK sheep growing, all of which seriously inflate the figure. We will therefore assume the Cranfield figure is correct.

However it is reasonable to assume that their data on New Zealand lamb production is valid. But there are a number of areas where their figure needs to be adjusted to be comparable to the UK numbers and also to agree with some New Zealand national statistics. It should also be noted that their figures refer to just 9 farms in New Zealand and, as in the UK where there are mountain, hill and lowland farms, there are a large range of farm types in very different circumstances in NZ.

Their data state an output of 8.2 'lambs and ewes' per hectare on the basis of 9 farms. As farms have both beef and sheep their values are based on the principle of allocation at the rate of 47%. They calculate 1628 MJ/ha of energy input to the sheep system. Some of the figures are clearly not based on LCA principles of mass balance, notably the requirement for K. Their nitrogen energy cost is much higher than in the UK (65 versus 41 MJ/kg N), but apparently very little is applied. It seems reasonable to take the figure as a first best estimate of their production system.

NZ national statistics state that fecundity is 1.129 raised lambs/ewe. Data on mutton production agree with the idea of 1/5th of ewes replaced each year plus at least 5% mortality which represent typical performance figures for sheep herds. Applying these data to their figures (see details in Table 36) suggests their farms had 7.84 ewes/ha and an output of 115kg lamb/ha with 28.2kg mutton/ha. This gives 12309 MJ/t lamb meat. Transport to the UK accounts for an additional 2030 MJ/t using their figures for shipping 17840 km. This requires refrigeration for the journey. We have an estimate of 1GJ/t.30 day for refrigeration. Frozen storage is quoted as less than this. Assuming that 30 days represents the approximate additional time that the lamb has to be kept cold, then the total energy required is 15339 MJ/t lamb meat. Note the weight of lamb products exported is a little less than the original weight of the lamb carcass, so the MJ for transport could be 2500 MJ.

It is reasonable to assume that all other energy costs post farm gate are identical for UK and NZ lamb, and thus can be ignored.

Based on the increased cost of energy from the $100 barrel of oil, this will add £97 and £161 to the cost of producing one tonne of lamb carcass from New Zealand and the United Kingdom respectively. This should be compared with the value of £2340/t lamb carcass at the farm gate. In other words a 2.6% reduction in competitiveness of the farm gate price, and considerably less in terms of the retail price.

Nitrogen fertiliser is by far the largest factor in the energy use of non-organic agricultural commodities. The low requirement for fertiliser in the data is perhaps feasible in clover-based extensive grazing. However the comparable data for milk production state a requirement of 72 kgN/ha. On the same basis, the sheep would require 17.7 kgN/ha (they remove less N for the same grazing and so required less to balance the removal in meat). This increases the energy required to 21650 MJ/t meat and the cost increase to £136, which is a 1% reduction in farm gate price competitiveness.

Table 36: New Zealand lamb production system

Ewes/ha	7.84	
Lambs/ewe	1.13	From NZ national stats
Lambs/ha	8.85	
Lambs output /ha @ 1/4th replacement	6.64	
Ewes output per ha	1.568	remainder mortality
Total output	8.21	
kg lamb meat/ha	115.4	
kg mutton /ha	28.2	106kt mutton and 427 kt lamb cwt
MJ/1000kg lamb	14107	
Mutton/1000kg lamb	244	i.e. very similar to UK ratio
Allocation in UK	0.873	
Allocation to lamb	12309	MJ/ t lamb meat
Transport	2030	
Refrigeration	1000	
Total MJ	15339	

$100 barrel of oil would increase the competitiveness of New Zealand lamb under any assumptions but by less than 3% of the farmgate price.

Beef

Whereas beef in the UK is produced largely from grass with some indoor barley and silage beef, in a hot country such as Brazil, grass is not a major option and thus systems need to be of a type where cattle are kept ‘indoors’ (feed lots). The bulk feed is maize silage plus concentrates. In lieu of actual data on a Brazil feeding system, a ration was calculated using maize silage and soyameal which provided the same intake of metabolisable energy and protein as the whole UK beef system per tonne of beef meat.

The comparable Primary Energy requirements of the systems (see details in Table 37) were 26932 MJ/t for the UK and 46117 MJ/t for Brazil including transport to the UK. The UK benefits because in terms of bulk fodder, grazed grass for beef has a much lower energy requirement than the comparable maize silage. In addition the UK system makes extensive use of by-products from the cereal processing industry such as wheatfeed, which by allocation have a low primary energy requirement versus soyameal which by allocation as a higher requirement than soyabeans. Using the lowest estimate of energy requirement which is for the production of the soyabean with no processing, milling etc, then the Brazilian primary energy requirement becomes 38792 MJ/t.

The increase in competitiveness of UK versus Brazilian Beef is £81/t or 3.8% of the price of beef, based on a $100 versus $50 barrel of oil. Using the minimum soyabean requirement this reduces to £58/t or 2.8%.

Table 37: Brazilian Beef production system

	kg dm	MJ/kg dm	MJ	MJ/t beef
Grass	11,315	0.44	4,978	26,932
Silage	5,594	1.36	7,626	
Barley mix	2,320	2.58	5,992	
Beef concentrates	2,183	2.41	5,259	
FYM reducing need for fertiliser			-1,298	
Diesel			4,374	
Maize silage	18,885	1.64	31,066	44,278
Soya meal	2,527	5.01	12,655	
FYM reducing need for fertiliser			-2,451	
Diesel			3,008	
Using soyabean MJ/kg dm	2,527	2.84	7,169	38,792

Poultry

As with milk, the poultry industry in Brazil (and Thailand) targets a specific sector of our industry, in this case the frozen chicken meat section of the UK market because it would be impossible to transport fresh chickens that distance economically. The industries are very modern having increased largely over the last few years and thus technically are very similar (or better!) to our own industry. The major differences are in the feed used which are more based on a maize + soyameal than a wheat + soyameal based diet as in the UK. However the main issue with chicken diets is blending protein sources to achieve the correct balance of amino acids, so no ration is going to be exclusively two components.

The report, http://www.fao.org/DOCREP/004/Y2638E/y2638e08.htm, quotes Brazilian yields of soya and maize as about 2.5 t/ha and 3.2 t/ha respectively, but rising every year. The latter seems low in comparison with the former, but perhaps reflecting lack of fertiliser and soil fertility. Similar values for North Central Kansas are 2 and 5 t/ha (Kansas Farm Management and Marketing Handbook, Dept of Ag. Econ, Kansas State University). One would expect values of 2.5 and 7.5 t/ha, even 10t/ha with irrigation of maize (Clemson Extension Enterprise Budgets, South Carolina). In some areas of Brazil there is the additional economic advantage of being able to achieve double-cropping in a year, but as the crop still needs planting, fertilising and harvesting this is unlikely to have a big effect on the energy cost of production.

Our LCA model (ref.) indicates 2.00 GJ/t for maize at a yield of 7.2t/ha. With a no till system and 50% yield, this rises to 2.5 GJ/t. This compares to wheat at 2.19 GJ/t and soya at 2.84 GJ/t. However as it seems likely that as economic conditions improve, so Brazilian yields will continue to rise to their potential, we will assume that they can achieve an energy efficiency of 2 GJ/t for maize production. Note that by comparison we assume a UK feed wheat yield of 8t/ha, which is conservative by some modern standards.

To calculate the energy input to poultry meat production in Brazil using the LCA model, one must first remove the transport element from the soyameal. The analysis assumes that the soya is still pressed to remove the oil and the meal used for animal feed, but after allocation of the energy used between the oil and meal, the energy per tonne of meal is almost unchanged, so the assumption is not critical.

Secondly, since maize contains a lower level of protein, the level of soyameal needs to be adjusted. Rather than attempt to calculate a full ration, we make the assumption of a pure maize-soyameal ration which contains the same level of overall protein as the current chicken ration based mainly on wheat and soyameal. The ratio which provides the same level of protein is 60% maize to 40% soyameal. The resulting energy required to produce 1t chicken meat is then 16479 MJ/t in Brazil, which compares with 15222 MJ/t in the UK. Adding in the refrigerated transport, the Brazilian chicken requires 18318 MJ/t.

This means an increase in the cost of UK poultry meat of £96/t versus £116/t for Brazilian chicken, giving a reduction in competitiveness of Brazilian poultry meat of £20/t, compared to a typical farm-gate value of poultry meat of £1200/t. Thus although Brazil will be made slightly less competitive the difference is negligible.

Annex 3: Food Supply Chain Analysis

Milk supply chain

Milk forms the basis of a number of dairy products including yoghurt, cheese, cream, ice cream and butter. Highly processed dairy products such as cheese and milk powder have the highest average energy inputs compared to that of yoghurt, cream and milk[47]. In fact these energy inputs are close to that of meat making some dairy supply chain stages such as processing particularly vulnerable to rises in oil price. The national mass of dairy products from the industry is provided in Agriculture in the UK[48]. Approximately 60% of the national milk production goes towards manufactured non-liquid sales.

In early 2005 profitability of both dairy farmers and producers were hit by higher prices in oil and oil related costs[49]. This and many more forecasted oil price rises presents serious ramifications for the dairy industry within the UK. It is useful, therefore to assess where the most oil/energy dependant stages are within the milk/dairy product supply chain in an effort to identify any opportunities to improve efficiencies in energy consumption. Within the UK over half of UK milk goes to the liquid milk market and highly perishable products such as yogurt. Producer contracts range from those based on payment for liquid milk supply to those based on payment solely for protein and butterfat, typically for cheese makers. Different contracts can also attach more or less importance to a balanced all-year round supply. Milk is in excess in the market due public regulations (quotas) and milk production is within certain limits independent of the market demand. Hence, a marginal demand for milk ex dairy farm does not influence the extent of milk production processes at the dairy farm[50,51].

Energy Inputs

Packaging, processing and transport are the most energy intensive stages within the conventional dairy supply chains (Figure 12)[52]. There are a number of milk LCA studies that present results across the supply chain for different countries[5354] and others that look at specific aspects of the supply system[55]. From this research a cursory breakdown of energy (MJ per 1L of Milk) can be estimated for each major stage of the milk supply chain. In the UK cheese accounts for 23% of milk utilisation and there has been one in depth LCA study of cheese and a number of other studies

[47] Carlsson-Kanyama, A., et al. Food and life cycle energy inputs: consequences of diet and ways to increase efficiency. Ecological Economics 00 2003 1-15, Article In Press

[48] DEFRA Agriculture in the United Kingdom 2005

[49] Dairy Supply Chain Margins, 2005-06. Milk Development Council.

[50] Jensen JD and Andersen M (2003). Working paper no. 08/2003 (in Danish).

[51] Weideman B (2003). Market information in life cycle assessments. Technical report, Danish Environmental Protection Agency (Environmental Project no. 863).

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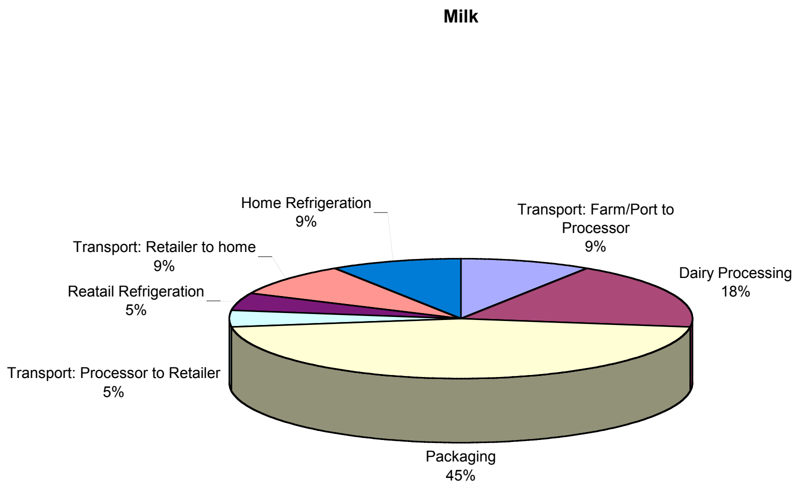
[53] Cederberg, C. and Mattsson, B., (2000), Life cycle assessment of milk production – a comparison of conventional and organic farming, Journal of Cleaner Production, 8, pp.49-60.

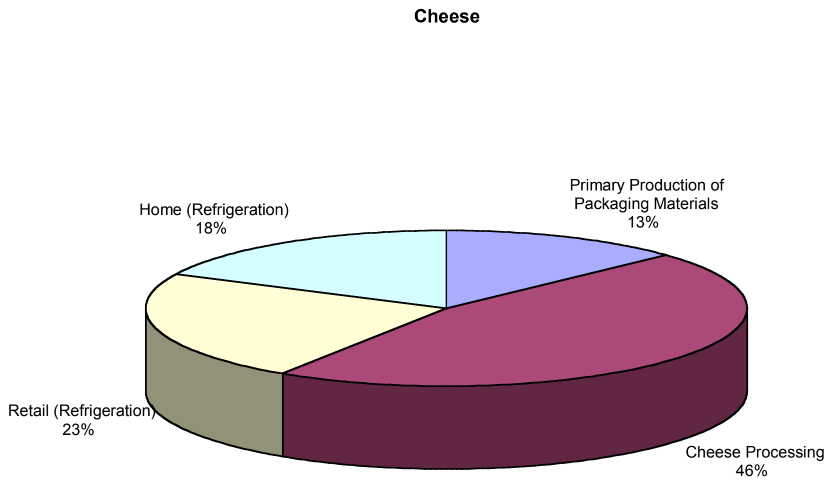
[54] Hospidio, A., Moreira, M. and Feijoo, G., (2003), Influence of farm size on the uncertainty of milk cycle inventory data, available at http://www.lacenter.org/InLCA2004/scale.html

[55] Competition Commission (1999), Milk: A report on the supply in Great Britain of raw cows' milk – http/www.competition-commission.org.uk/rep_pub/reports/1999/429milk.htm#full

that have looked at cheese in addition to other products[56]. Yoghurt on the other hand accounts

Figure 12: Energy Consumption across the conventional milk supply chain





[56] Berlin, J., (2002), Environmental LCA of Swedish Hard Cheese, International Dairy Journal, 12, pp. 939-953.

for 2% of total milk utilisation in the UK, but some 10% of the total sales revenue for milk and milk product[57]. Although there are no complete LCA studies of yoghurt, there are studies that have looked at specific life cycle stages[58][59].

Milk production in the UK is concentrated in Shropshire, Cheshire, Lancashire and the West Country and most milk is processed by dairies located near urban areas[60] where UK milk purchasers buy milk from dairy farms and sell it to processors. There are 130 Milk Purchasers in the UK but the industry is dominated by three large firms: First Milk, Dairy Farmers of Britain and Milk Link[61]. Bulk Milk tankers transport milk at a rate of 120 L per vehicle kilometre[62] and from Manchester University calculations average energy consumed is 96MJ/1000 litres milk.

In response to rising oil prices there is scope to achieve greater efficiencies in transportation of milk through recommendations developed by the Milk Task Force. According to previous studies the type of primary packaging for milk used can increase the energy consumption associated with milk's manufacture, processing and transport by over seven times[63]. Research suggest that the energy consumption of milk packaging varies at the manufacturing stage between 0.5 MJ per L Milk for linear low-density polyethylene flexible pouches and 3.7 MJ per litre Milk for glass bottles.

Production of plastic containers for milk requires significant quantities of resources, primarily fossil fuels, both as a raw material and to deliver energy for the manufacturing process. It is estimated that 4% of the world's annual oil production is used as a feedstock for plastic production and an additional 3-4% during manufacture[64]. One logical step to reduce the energy use within the liquid milk supply chain, therefore, is to encourage a greater uptake or recycled polyethylene. Within the UK the recycling of plastics is in its infancy but over time this could potentially grow given improvements in infrastructure and technology[65]. A report on the production of carrier bags made from recycled rather than virgin polythene concluded that the use of recycled plastic resulted in the following environmental benefits: reduction of energy consumption by two-thirds; production of only a third of the sulphur dioxide and half of the nitrous oxide; reduction of water usage by nearly 90%; reduction of carbon dioxide generation by two-and-a-half times. A different study concluded that 1.8 tonnes of oil are saved for every tonne of recycled polythene produced[66].

Packaging represents the largest single sector of plastics use in the UK. The type of packaging and the number of units transported per 'trip' also affect significantly the transport stage between the milk processors and the retailers as most dairies are

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[57] DEFRA (2005b) UK Dairy Industry
[58] Keoleian, G.A. and Spitzley, D.V., (1999). Management of milk packaging, Journal of Industrial Ecology, 3 (1), pp.111-126
[59] DEFRA (2205b). Life cycle assessment of polyvinyl chloride and alternatives: Summary Report.
[60] DEFRA 2001, Milk Task Force Report, available at http://www.defra.gov.uk/science/Project_Data/DocumentLibrary/ER02003/ER02003_2494_FRP.pdf
[61] London Economics 2003
[62] Competition Commission (1999), Milk: A report on the supply in Great Britain of raw cows' milk – http/www.competition-commission.org.uk/rep_pub/reports/1999/429milk.htm#full
[63] Keoleian, G.A. and Spitzley, D.V., (1999). Management of milk packaging, Journal of Industrial Ecology, 3 (1), pp.111-126
[64] http://www.wasteonline.org.uk/resources/InformationSheets/Plastics.htm
[65]http://www.wasteonline.org.uk/resources/InformationSheets/Plastics.htm://www.bpf.co.uk/bpfindustry/process_plastics_recycling.cfm
[66]http://www.wasteonline.org.uk/resources/InformationSheets/Plastics.htm://www.bpf.co.uk/bpfindustry/process_plastics_recycling.cfm

close to urban areas and milk is transported directly from dairy to retailer[67]. Furthermore packaging increases waste volume which results in a greater amount of oil/energy being used to collect, manage, dispose and recycle used milk packaging.

After the production of packaging materials, the processing of milk at dairies is the most intensive part of the liquid milk supply chain in terms of energy use. Efficiency largely depends on the on the size of processing operations, with considerable economies of scale. Dairy processing has become increasingly a concentrated sub-contractor of the dairy industry where, in 2000, the five largest dairy firms accounted for around 60% of milk processed: Dairy Crest, Express Dairies, Glanbia, Aria and Wiseman[68].

Commodity cheese production is much more competitive with substantial levels of imports. While competitiveness is largely dependent on the wholesale price of milk, the process is energy intensive and large-scale modern plant is also important.

For other fresh products such as yoghurt, the energy costs associated with packaging are significant but these are high value added and costs can be passed to consumers. Due to the perishable nature of these products they are only imported from Europe but energy costs associated with refrigerated transport would favour UK processing if oil price was high.

Implications of Rising Oil Prices

With a drastic rise on oil price a number of responses could potentially occur within the Milk supply chain in the UK.

- Significant cost increase in the overall consumer price of milk and dairy products.
- Local suppliers will be forced to source greater volumes of locally sourced milk to save on transportation costs.
- Greater uptake of clean fuel such as biodiesel and renewable forms of electricity used in various stages of the liquid milk supply chain.
- Imports of highly processed dairy products such as cheese and milk may increase.
- Re-Location and upgrade of dairies, processors and suppliers to reduce transport costs and improve energy efficiency.

It is emphasised that the above is purely theoretical and it is recommended that further research and detailed economic modeling will need to be completed to investigate such scenarios.

Because milk is uneconomical to transport long distances in its liquid form it is unlikely that higher processing costs due to an oil price increase will force processing offshore as these costs will still be relatively similar, driven by energy prices. The only potential cost saving by relocating processing plants offshore, however, will be labor costs. New Zealand represents a distinctive competitor for UK milk producers. Whereas over half of UK milk goes to the liquid milk market and highly perishable

[67] Competition Commission (1999), Milk: A report on the supply in Great Britain of raw cows' milk – http/www.competition-commission.org.uk/rep_pub/reports/1999/429milk.htm#full
[68] London Economics, 2003; KMPG, 2003.

products such as yoghurt, NZ competes with supplying the less perishable products, butter and cheese, and milk powders. Since there is thus little need for an all-year round supply, the vast majority of the dairy herd is fed from grass for 10 months of the year and dried-off for the two months of the NZ winter. In the UK, producer contracts range from those based on payment for liquid milk supply to those based on payment solely for protein and butterfat, typically for cheese makers. Different contracts can also attach more or less importance to a balanced all-year round supply.

Beef/Lamb Supply Chain

To describe the Beef and Lamb Supply chains we have detailed the stages in Table 38. In 2004, 301,000 tonnes of beef were sold in the UK and sales are expected to rise by 3% by 2009[69]. The livestock and meat industry within the UK is made up of a complex network of individual companies of all sizes. They are all involved in the production of meat from farm to plate and work within specific supply chains.

Table 38: Functional Stages of Supply Chain of Beef and Lamb

Functional stages of supply chain	Detailed stages of supply chain
Primary Processing	Abattoirs Cutting plants Minced meat and meat preparation plant Cold stores Integrated plants carrying out more than one of these functions
Secondary Processing	Catering butchers Retail packers Plants preparing meats and recipe products e.g. sausages, burgers, reformed products Manufacturing plants for cooking, curing, canning, ready meals Integrated plants carrying out more than one of these functions
Distribution	Meat wholesalers e.g. meat suppliers, depots, traders, importers, exporters, specialist foodservice suppliers Supermarkets Traditional butchers Independent grocers Direct sale outlets e.g. farm shop, farmers market, delivered/box scheme Foodservice companies supplying both the private and the public sector

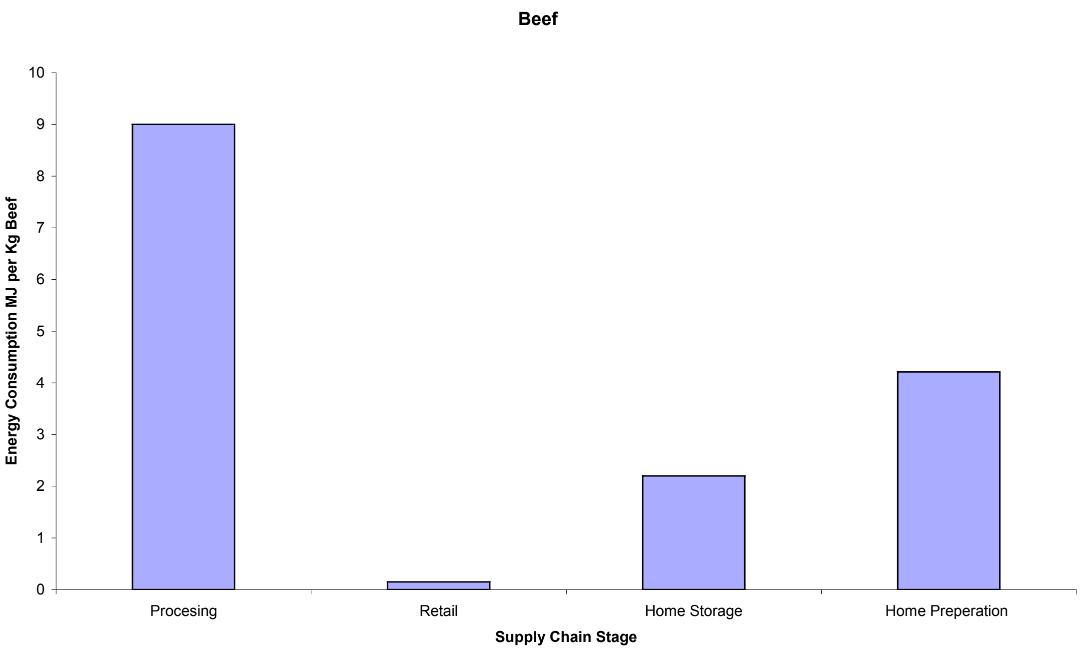
Source: Environment Agency[70]

Energy Inputs

It should be noted that 64% of energy expenditure on beef is through primary production. Minimal work of the entire life cycle of beef, however, has been done. Manchester University has recently compiled data from various sources to construct a simplistic supply chain for beef that excludes transportation (Figure 13).

[69] Mintel, 2005
[70] http://publications.environment-agency.gov.uk/pdf/GEHO1205BJZI-e-e.pdf?lang=_e

Figure 13: Energy Consumption across the beef supply chain



Similarly, only a handful of LCA studies could be found that examine the energy expenditure of the lamb supply chain[71][72] apart from one that examined environmental burdens of production[73][74]. It is estimated however that it takes 23MJ to produce 1kg of lamb compared to that of 44 MJ for 1kg of beef. It should also be noted that when considering the beef life cycle that there is a complex interconnected relationship between beef and milk production, with surplus calves and meat for culled dairy cows being an important contributor to the beef supply chain.

It is acknowledged, however, that the supply chains of beef and lamb have the same three functional stages, Primary processing, Secondary processing and Distribution. Detailed LCA is needed to examine UK beef and lamb supply chains to gauge a deeper understanding of what stages will be the most effected.

A general indication of where energy is being consumed at the abattoir and meat processing stage is provided by the Environment Agency. In terms of electricity refrigeration accounts for 65% of usage followed by 17% for packaging. Heating fuel is much more spread across supply chain stages, where scalding, singing and portioning and trimming account for the bulk of oil consumption (Figure 14).

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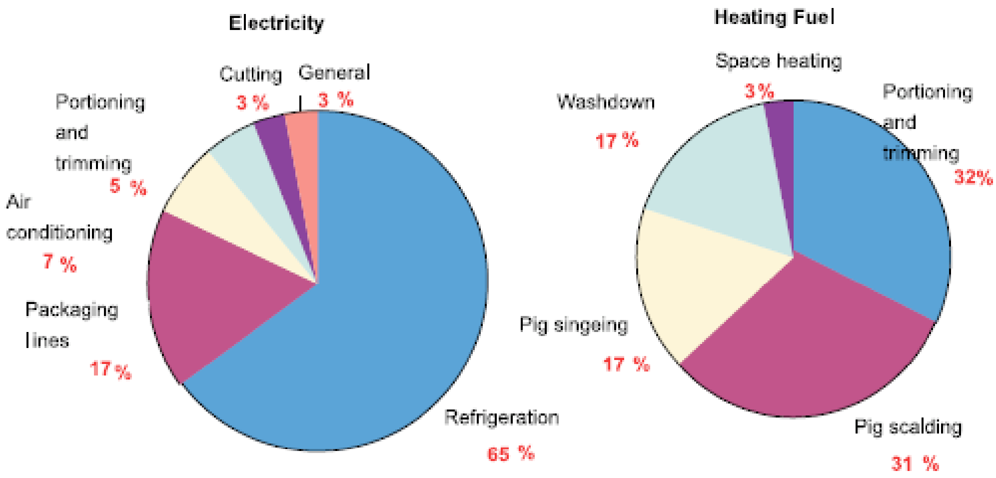
[71] Carlsson-Kanyama & Faist (2000).'Energy Use in the Food Sector: A data survey'.
[72] Pimental, D & Pimental, M. (1996) 'Food, Energy, Society'. University Press Colorado.
[73] Williams, A.G., Audsley, E. and Sandars, D.L. (2006). Determining the environmental burdens and resource use in the production of agriculture and horticulture commodities. Main Report. Defra Research Project ISO205. Bedford. Cranfield University and Defra.
[74] http://www.foodchaincentre.com/NEW%20foodchainfiles/Cutting%20Costs%20-%20Adding%20Value%20in%20Red%20Meat/x)%20Case%20Study%20-%20Better%20Business%20-%20Improving%20Organic%20and%20Conventional%20Lamb%20Production.pdf

Figure 14: Electricity and heating fuel consumption at a typical mixed species abattoir



Source: Environment Agency[75]

Implications of rising oil prices

With a drastic rise on oil price a number of responses could potentially occur within the Beef/Lamb supply chain in the UK.

- Significant cost increase in the overall consumer price of beef/lamb products passed down the supply chain to the consumer.
- Local suppliers will be forced to source greater volumes of locally sourced beef/lamb to save on transportation costs.
- Greater uptake of clean fuel such as biodiesel and renewable forms of electricity used in various stages of the beef/lamb supply chain
- Imports of highly processed dairy products such as cheese and milk may increase.
- Re-Location and upgrade of abattoirs, processors and suppliers to reduce transport costs and improve energy efficiency.

It is emphasised that the above is purely theoretical and it is recommended that further research and detailed economic modeling will need to be completed to investigate such scenarios. The 'Cutting Costs - Adding Value in Fresh Produce' whole chain work completed by the Red Meat Industry Forum[76] highlights process in-efficiencies in post production supply chain (Table 39).

[75] http://publications.environment-agency.gov.uk/pdf/GEHO1205BJZI-e-e.pdf?lang=_e
[76] http://www.redmeatindustryforum.org.uk/content.output/29/29/Post-Farm%20Projects/Projects/Whole%20Chain%20Work.mspx

Table 39: Potential for improving energy efficiency in the UK beef and lamb supply chain

Abattoir/ Processor	Inefficiencies in machine operation: No orders to work on (lack of sales); Machine broken down or running too slowly. Equipment taken down for routine maintenance. Bottleneck elsewhere in the plant. Most processing plants have bottlenecks that constrain output, e.g. holding chillers, boning or cutting facilities. Seasonality and weekly cycles can result in different bottlenecks.
Distribution	Distribution assets can be energy in-efficient owing to: Vehicles not fully loaded. Delays in loading vehicles. Long journey times because of delays or bad route planning. Delays at the destination. Problems in unloading, e.g. because of incorrect paperwork. Empty vehicle on the return journey. Vehicles sitting idle. Poor fuel consumption. There are many root causes behind these problems, for example: Pack sizes vary and do not always fit neatly into a crate for transportation. Traffic problems are unpredictable and cause delays. Vehicles are assigned delivery slots at the retailer's warehouse. If they miss that slot, it can be a long wait before they can be attended to and unloaded.
Shop	Prime retail space is expensive and so empty shelves are a waste of this

With rises in oil prises another response could be a shift to work harder at making these stages more efficient and less wasteful.

Poultry Supply Chain

Most poultry processors carry out slaughtering, cutting, and portioning at the same site. In general, the anticipated lifetime of poultry processing plant is about 25 to 40 years. Plants that wish to export their meat within the European Community must meet the criteria and standards laid down in European Council Directive 64/433 as amended. These include specifications for process plant design and building finishes. The throughput at a typical poultry processing plant is relatively constant throughout the year and shows little seasonal variation.

Energy Inputs

Studies of chicken using an LCA approach are few in number. It has been noted within the literature, however, that 'commercial feed producers maintain a high degree of confidentiality occur actual ingredient mixes'. That commercial sensitivity appears to pervade the rest of the chain. The best information available concerns primary production.

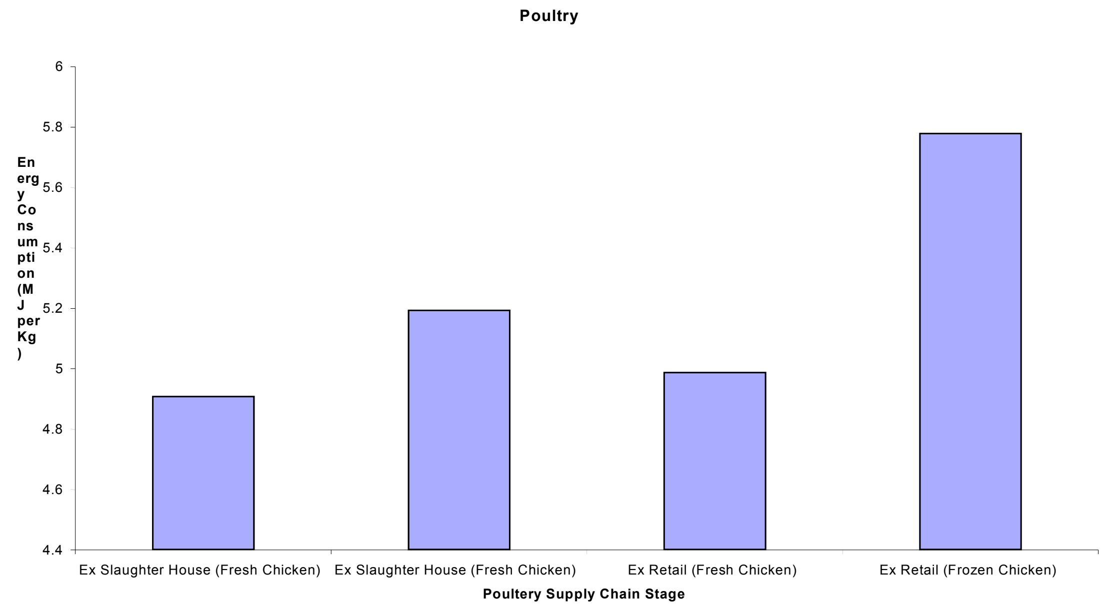
Although the chicken industry is highly vertically integrated with the same firm undertaking the rearing, slaughtering and processing of chicken meat, these activities are not necessarily co-located. Nevertheless the literature does not suggest that travel will make a major contribution to overall energy consumption. The RAC report[77] provides some information on the distance travelled by broilers, indicating that the distance travelled per bird is 0.07km, and that for a bird with an average live weight of 2.2kg this would be 0.03km/kg for a live bird and 0.044km/kg for fresh meat. Elligsen and Aandondsen[78] (P 62) who investigated farm processing impacts also claim that transport has only minor levels of energy consumption.

The literature indicates that processing chicken is a highly efficient process with limited waste of resources including energy. The Danish LCA Food database indicates that to produce 1 kg of chicken after slaughter will need 1.37kg of chicken on the farm, 9 litres of water and 0.7MJ electricity at the slaughterhouse[79]. The RAC Report notes that to within the Broiler processing stage, to produce .26kg 1.6MJ is needed.

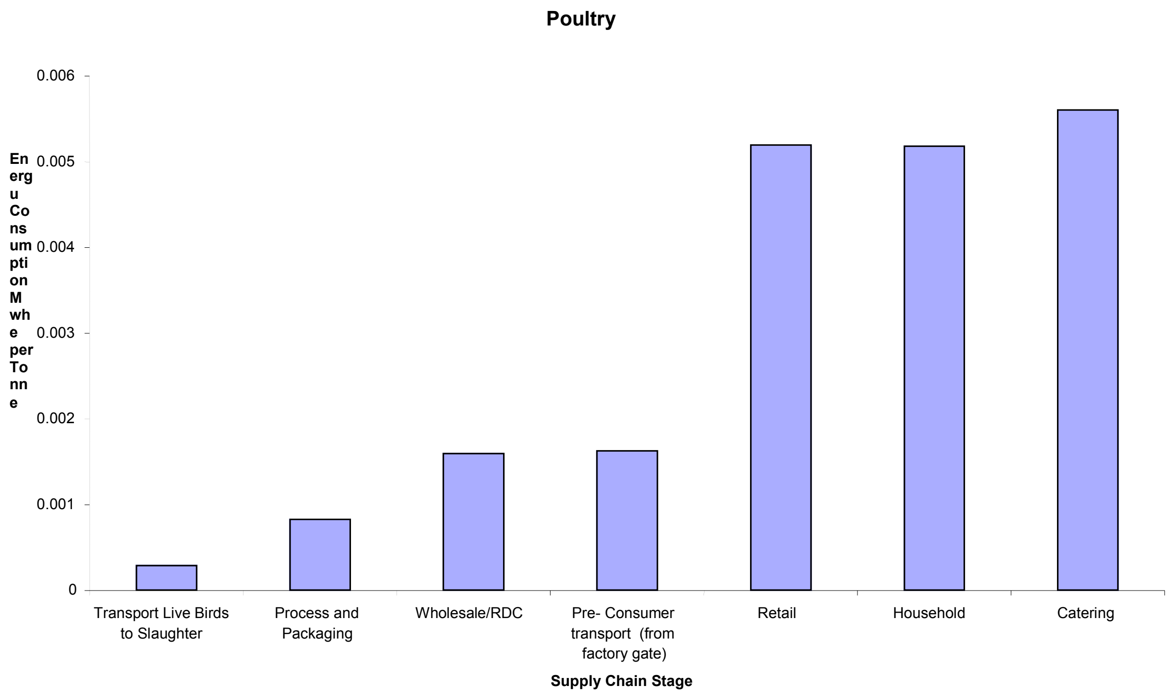
The impact assessment results in the Danish LCA Food Database reveal that in terms of its energy consumption there is only a very marginal difference for a fresh chicken between its leaving the slaughterhouse and leaving the supermarket. Much more significant difference arise, however, when comparing fresh with frozen chicken and when comparing fresh with frozen chicken leaving the slaughterhouse and supermarket[80]. In terms of Post-processing, however, there is very few studies on the topic apart from the attempt to provide a system-wide view of the UK chicken industry that is contained in the NHFO7 Energy Model Assumptions and Scenarios. Here larger energy consumption levels are highlighted in the life cycle after processing. Wholesale, transport, retailing, households and catering all emerge as significant users of energy (Figure 15).

[77] RAC Environment Ltd. Undated. Poultry UK. Mass Balance of UK Poultry Industry.
[78] Ellingsen and Aanondsen 2006. Environmental Impacts of Wild Caught Cod and Framed Salmon – A Comparison with Chicken. Int J LCA 1 (1) 60-65 (2006).
[79] Danish LCA Food Database (2003 or later) www.lcafood.dk
[80] Environmental Impacts of Food Production and Consumption. A Research report completed for Defra by Manchester Business School December 2006.

Figure 15: Energy Consumption across the poultry supply chain



Source: BNF07 Energy Model Assumptions and Scenarios, Market Transformation Programme



Implications of Rising Oil Prices

With a drastic rise on oil price a number of responses could potentially occur within the Poultry supply chain in the UK.

- Significant cost increase in the overall consumer price of beef/lamb products passed down the supply chain to the consumer due to incase in cost of post farm supply stages.
- Local suppliers will be forced to source greater volumes of locally sourced poultry to save on transportation costs.
- Greater uptake of clean fuel such as biodiesel and renewable forms of electricity used in various stages of the poultry supply chain.
- Imports of highly processed chicken products such as chicken nuggets may increase.

Feed (Wheat/Oil-seed) Supply Chain

Within the poultry, beef and pork industries feed (wheat/oil-seed) is an important contributor to overall production. Major feeds are produced from oil-bearing crops (e.g. rape, soya, sunflower, palm kernel) and cereals (e.g. fractions of milled wheat). Oilseed press cake is widely used in the manufacture of animal feeds. Normally the press cake is seen as a by-product of the edible oil manufacturing. Competitor products from overseas include meal from soya, sunflower, palm kernel and other commodities. The supply chain for Oilseed Cake and Wheat are independent until they are incorporated into the feed ration.

In background information to their LCA study, UK-focussed, SRI (2005) have distinguished further the different constituents of feed, suggesting that wheat is the biggest constituent by far[81].

We have looked at the feed wheat supply chain based on expert opinions on post-farm energy consumption and LCA study results of Cranfield University on energy use at production stage (which accounts for 52% of total energy use, see figure 16. Most energy use in feed wheat supply chain lies in the production stage. The second biggest is processing at the milling factories.

The majority of animal feed is processed in mills, with the rest being home fed, with little processing, expect for crushing. Values for general feed processing on farms and mills (rolling, flaking, pelleting) have been documented in the literature[82].

The majority of animal feed is processed in mills, with the rest being home fed, with little processing, expect for crushing. Values for general feed processing on farms and mills (rolling, flaking, pelleting) have been documented in the literature[83].

[81] Silsoe Research Institute SRI (2005) ‘ Determining the environmental burdens and resource use in the production of agricultural and horticultural commodities’ Draft report for DEFRA Research project ISP”)%, unpublished.

[82] William, A.G., Audsley, E. and Sandars, D.L. (2006) *Determining the environmental burdens and resource use in the production of agricultural and horticultural commodities*. Main Report. Defra Research Project ISO205. Bedford: Cranfield University Defra. Available on www.silsoe.cranfield.ac.uk

[83] William, A.G., Audsley, E. and Sandars, D.L. (2006) *Determining the environmental burdens and resource use in the production of agricultural and horticultural commodities*. Main Report. Defra Research Project ISO205. Bedford: Cranfield University Defra. Available on www.silsoe.cranfield.ac.uk

Figure 16: Energy Use in Feed Wheat Supply Chain.

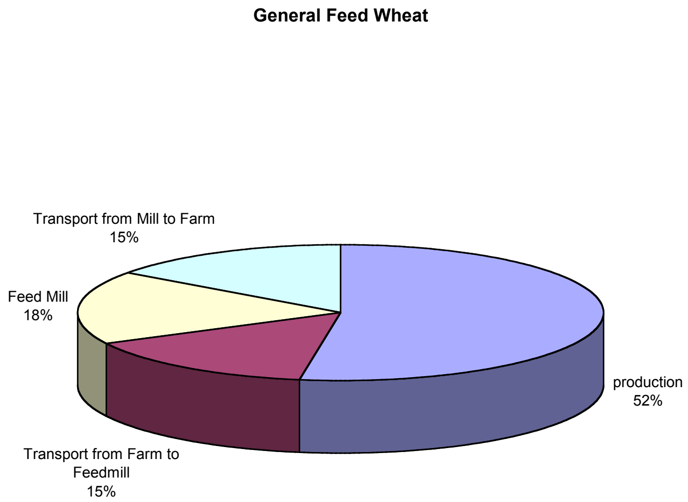
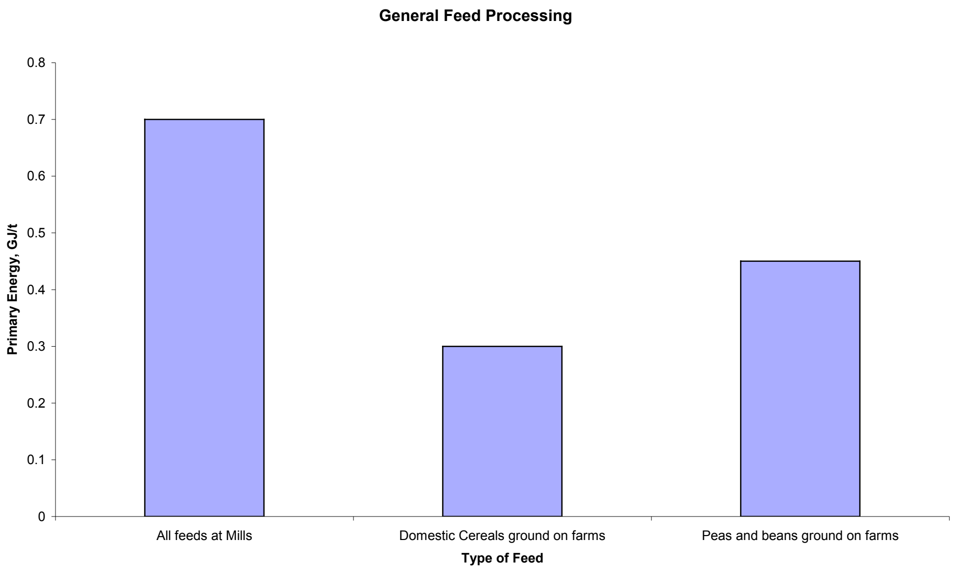


Figure 17: Energy Consumption in general feed processing (excluding oil extraction)

Energy Inputs

(Source: Defra Research Project ISO205).



Oil extraction

Envirowise provides energy inputs for stages of food processing for oilseed processing this requires 200kg (500 MJ) steam per tonne of oil seed processed (30% oil).[84] The oilseed cake makes up the remainder. Typical ratios of processed oil to cake are 27/73.[85] The energy source is class D or G fuel oil. If the energy in processing is allocated equally to the oil and the press cake production then the energy provided by the steam is 342MJ/tonne. There is a further thermal efficiency of 83% the boiler equipment the give an energy requirement of 413MJ/tonne.

25-50 kWh electricity per tonne of oil seed processed (30% oil). If the energy in processing is allocated equally to the oil and the press cake production then the electrical energy provided is 127MJ/tonne. There is a further generation efficiency of 27% the boiler equipment to give an energy requirement of 457MJ/tonne. The total energy input into oil extraction is therefore 870 MJ/tonne.

Feed milling and the production of the ration that includes oilseed press cake can be defined as a unit process that has boundaries of the intake to the process and the output of the mixed product. The inputs are the wheat and other ingredients. This includes the energy in feed manufacture, which is assumed to apply to the wheat and the other ingredients plus that energy flow from the extraction of the oil. The energy from the other ingredient flows are not included. For a poultry ration that contains 27% oilseed cake then the overall energy requirement is calculated as shown in Table 40.

Table 40: Energy in Feed Ration Manufacture

	Mass kg	Energy MJ/tonne		% of Total Energy Burden
		Component	Product	
Manufacture of Cereal Based Ration	1000	700	700	75%
Oil seed extraction element	270	870	235	25%
Total energy			935	

The extraction element of the oilseed makes up 25 % of the manufacturing energy burden. Thus with a doubling of price of energy the cost of this element may increase the cost of production by 25%. Counter to this is there is a likelihood that at the enhanced price for biodiesel will result in more press cake by product entering the market. This may in turn depress the price of press cake which then may lead to a displacement a proportion of the imported soya and other press cakes.

Implications of Rising Oil Prices

With a drastic rise on oil price a number of scenarios could potentially occur within the wheat/oil-seed supply chain in the UK.

- Significant rise in the overall cost of white meat production as a result of increase in energy cost for ingredients and processing (70% of production cost). Significant

[84] Envirowise Food and drink sector: energy use KPIs
[85] Ewing W.N. The Feeds Directory Context products Ltd ISBN 1-899043-01-2

cost increase in the overall consumer price of meat products as a consequence of the increase in demand for wheat to produce bioethanol. .

- The demand for biodiesel may lead to greater availability of co products like press cake. This may lead to a reduction in the price of these ingredients. Within this scenario the costs for extraction will increase but it is likely that the burden of this cost will be allocated in a greater proportion to the biodiesel.
- Cost increases in wheat/oilseed passed down the post farm supply chain to the consumer.
- Suppliers will be forced to source greater volumes of locally sourced poultry to save on transportation costs.
- The extraction element of the oilseed makes up 25 % of the manufacturing energy burden. Therefore with a doubling of price of energy the cost of this element will increase the cost of production by 25%. Counter to this is the likelihood that at the enhanced price for biodiesel that will result in more press cake by product entering the market so depressing the price of press cake. This in turn will also displace a proportion of the imported soya and other press cakes.
- The manufacturing element including wheat milling will also increase accounting for 75% of the rise in cost of feed manufacture.

Annex 4:QUB Model Description and Assumptions

AGMEMOD assumptions and limitations

Several assumptions were made during the modelling of the impact of $100 oil price as a result of constraints of the model, exogenous data and the time scale of this research project.

CAP policy instruments are fixed at 2005 level; in other words set aside and production quotas for milk and sugar are kept in place.

The oil price does not appear directly in AGMEMOD. At the global macro-economic level, an increase oil price will have an impact on exchange rates, gross domestic product (GDP) and economic growth. The impact depends on each country's and each industry's dependency on oil and their ability to reduce this dependency. It was not possible to quantify the $100 oil price impact on the exogenous macro-economic variables in the model; they are assumed to equal those of the baseline.

At the consumer side, a high oil price can create a dramatic shift in consumption patterns. There will be both an increased demand for products and services that depend less on energy, but there will also be a smaller available budget. It is assumed that the structure of demand equations will not change, nor the responsiveness to agricultural prices.

A $100 oil price will increase the production costs of all commodities that use energy in its manufacturing. In addition, the costs of transporting commodities to their markets will also increase. For processed products, further costs increases can be passed onto the customer through the price. It is clear that the price of nearly all products will increase. In the model, additional energy costs have been included at the farm-level only. The increased costs of transport and processing could lead to a higher demand for local produce. It is not possible to quantify this effect on trade in agricultural commodities.

There could be an increase demand for fuels from crops, i.e. bio-ethanol and biodiesel. It is expected that the area of crops for biofuels will increase. At the same time, a smaller area of land is available for food crops; thus their prices will rise further. The production of bio-fuels is a recent phenomenon and, within the EU, relies heavily on subsidies. It is therefore difficult to estimate the response in the area of fuel crops. It is assumed that the area of crops for bio-fuels does not alter from the baseline scenario.

Information on agricultural production costs in other EU countries have not been incorporated into their production decisions. As a result, they will face the higher output prices without the additional energy costs and therefore will increase their production. The inclusion of energy costs for these countries' models would further reduce the aggregate EU supply and increase the output price. The models that did include these costs, including the UK model, will therefore overestimate production changes.

Aglink assumptions and limitations

Energy cost shares are calculated from production cost data for only two countries. US data is applied for all OECD countries, while Argentinean data is applied for all Non-OECD countries. Most cost calculations are subject to a considerable degree of uncertainty. Cost estimates in the literature vary widely, and their applicability to other regions introduces some degree of uncertainty. The assumptions used in OECD's

Aglink-Biofuels model will not be the same assumptions as those used in the SDC study. This inconsistency needs to be borne in mind when prices from the Defra analysis, based on the Aglink-Biofuels model, are used in conjunction with other models for the SDC project.

Biofuels are assumed not to be traded, therefore increases in demand for biofuels are modelled to be sourced within the region itself. As such the impact of national biofuels policies on national prices will probably be overstated. This needs to be borne in mind when national prices (e.g. US prices) are used as an indicators for the level of the 'world price'.

The modelling is based on 2005 OECD Outlook baseline. Recent developments in commodity markets are therefore not included in the analysis, ie the recent increases in demand for cereals and oilseeds for biofuel production are not included in the baseline.

Indirect impacts of the oil price on agricultural markets through the biofuel markets are modelled but the modelling is only partial in its geographic coverage and there are uncertainties and limitations related to the modelling. The modelling is limited to five regions (US, EU15, Poland, Brazil and Canada). Also the modelling draws on data from a 2005 paper. The biofuel market is evolving at great speed and some of the assumptions will be out-of-date. In addition, the biofuel market is still at an early stage and therefore there is a lack of data e.g. on elasticities of demand and supply with relation to the oil price and commodity prices.

Biofuel demand and supply is largely policy driven – some of the policies have changed since 2005 and more changes are ahead. There are market implications through the food demand side of the economy, which are ignored in the analysis. With higher crude oil prices GDP growth is likely to be lower in most countries, while it may be higher in oil producing ones. This may have an impact on food demand.

For more detailed description of the assumptions and limitations see http://www.oecd.org/dataoecd/58/62/36074135.pdf

Assumptions and Limitations of combination of Aglink and AGMEMOD

The AGMEMOD model includes only agricultural sectors of EU15 countries. World market prices are treated as exogenous. Without the results from Aglink modelling on the impact of a $100 oil price on world market prices of agricultural commodities, AGMEMOD would only be able to model the impact of a rise in production costs on agricultural sectors in EU15 countries (See Table 4).

The descriptions of the AGMEMOD and Aglink models above demonstrate that there are some differences in the methodology and assumptions. Also, there were differences in the historical data series, as well as in the projected baselines. The relative change in world market prices from the Aglink $100 scenario compared to the Aglink baseline were applied to the AGMEMOD baseline. This may impact the results in levels, i.e. prices, areas and livestock numbers, but the relative changes will be similar.

The world market prices in Aglink are the result of international trade in commodities. However, they are exogenous after being imported into AGMEMOD, There is no further interaction between the aggregate net-trade position of the EU15 and international commodity prices. In other words, the projected net-trade of AGMEMOD should converse to that of Aglink.

Annex 5: A Review of Biofuel Studies

The key issues relating to biofuel development are discussed in this annex and provide the context for the overview in section 4.5 in the main report. The policy context is first considered at international level, then at European Union level and UK level; economic and technology drivers are then considered and finally the linkage between energy and food policy.

International perspective of biofuel production

- **Dramatic increase in the biofuel production**

Biofuels include ethanol and biodiesel derived from organic matter such as sugar cane, vegetable or corn oils. Not all ethanol is suitable to be used as a motor fuel blend. Biofuels have developed as an alternative of fossil oils, along with other sources such as solar, wind, hydro and nuclear energy.

In the period between 1973, when the first oil crisis occurred, and 2004, world total primary energy supply (TPES) increased from 3762 mt to 5506 mt.. Oil, coal and gas account for more than 80% of total primary energy supply in the world in 2004, compared to over 90% in 1973. In the period the share of combustible renewable and wastes only increased from 2.3% to 3.4% of TPES (IEA, 2006).

Biofuel production increased dramatically worldwide after 2004. World ethanol production increased from about 10.77 billion gallons in 2004 to 12.15 billion gallons in 2005 (US Department of Energy, 2007), while biodiesel production increased even more rapidly. In USA, total biodiesel production increased from 0.5 million gallons in 1999 to 25 million gallons in 2004, 75 million gallons in 2005 and about 200 million gallons in 2006 (National Biodiesel Board, 2007). In the EU, this figure increased from 1.9 million tonnes in 2004 to 3.2 million tonnes in 2005 and about 6 million in 2006 (EEB, 2006). The International Energy Agency (IEA, 2006) predicts ethanol alone has the potential to make up 10 percent of world gasoline use by 2025 and 30 percent in 2050, up from around 2 percent at present.

The expansion of biofuel however is not without constraints. On the demand side, Bioethanol is still very much used as an additive to gasoline as its energy value is only two thirds of standard gasoline. A full substitution of ethanol for gasoline would require change in engine design for motor vehicles. In other words, the current market for the bioethanol may soon be saturated without changes in the engine side. On the supply side, biofuel production is still very much dependent on food crops as feedstock. Many empirical studies suggest that biofuel production is not economically viable in competing with fossil oil unless subsidies are provided. Increasing biofuel production implies that uses of food for biofuel production will increase. Subsequently prices for the food will also be increased and costs to produce biofuel will increase further.

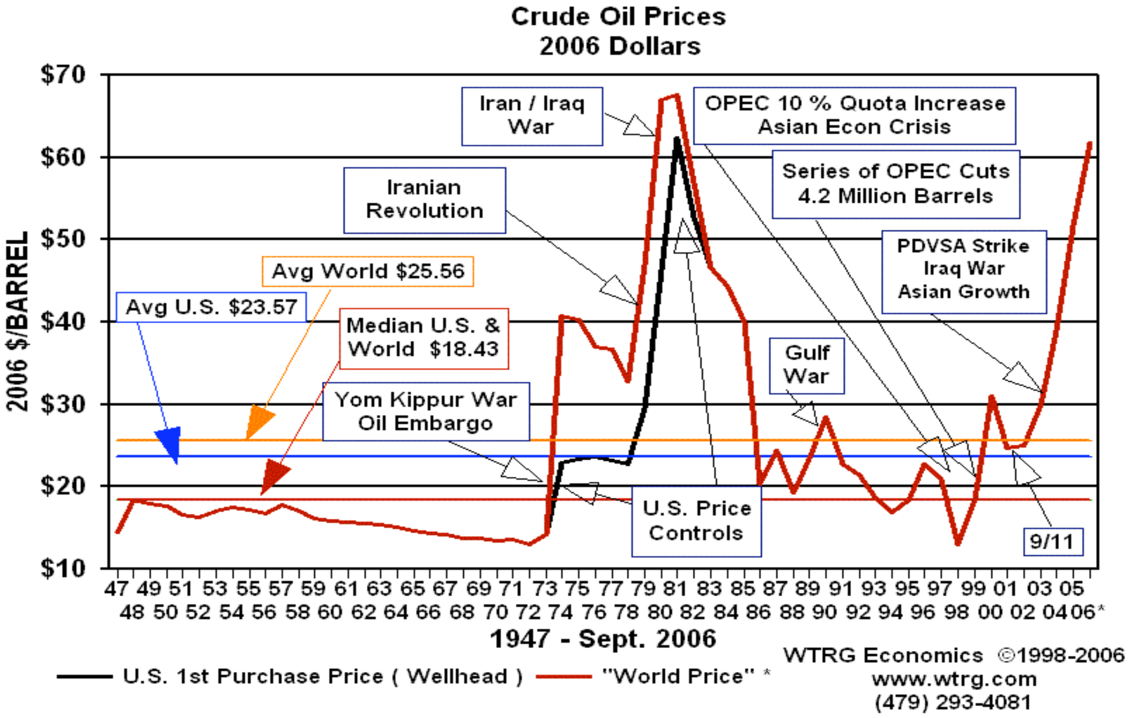
- **Energy security is the main reason behind the change**

Several reasons are behind these changes. First, sudden expansion of biofuels relates to increased concerns over energy security, partly as a result of international political change and emerging of countries such as China, India and Brazil. Second, many developed countries such as EU and USA have used biofuel production as a way to overcome their difficulties in the agricultural policy particularly in dealing with food surplus and farm supports. Finally, biofuel production has been supported on the evidence of its carbon saving effects. It further links to climate change in the past two centuries. With CO_2 emission regarded as the chief culprit of the global warming, biofuel production is justifiable from an environmental aspect.

- **Change is directly linked to the crude oil price**

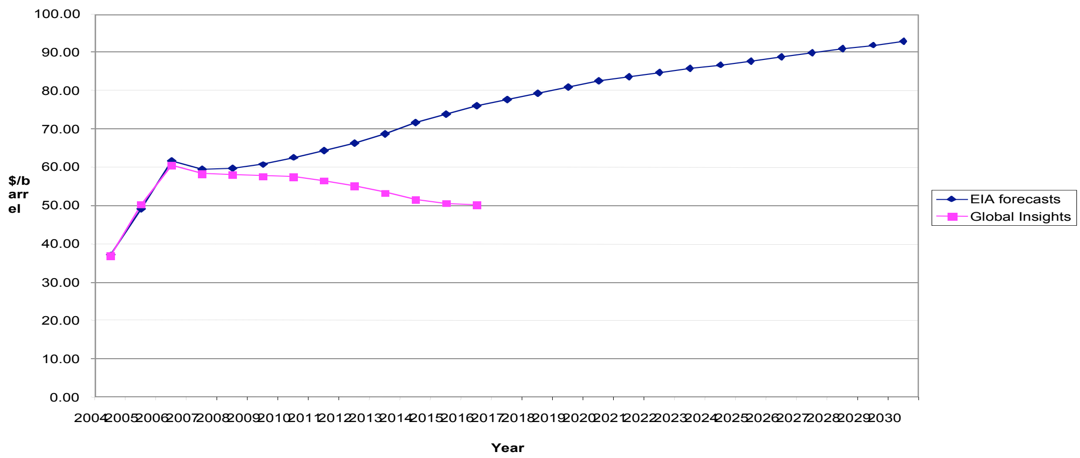
This change has been closely related to the world crude oil price (figure 18). Measured in Europe Brent spot price, crude oil price increased from $24.99/barrel in 2002 to $28.85/barrel in 2003, $38.26 in 2004 and to $54.57/barrel in 2005. In 2006, it reached a new high of $65.16/barrel.

Figure 18: Crude oil price and world events



There are still remarkably different views for the future price of crude oils. Some forecasting agencies predict that oil price will fall after 2007. However, others believe that in the long run the price will continue to go up. The figure below shows recent forecasts of future changes of crude oil price by the Energy Information Administration (EIA) and Global Insights. The forecast of the EIA suggests that by 2030, the crude oil price will reach $93 /barrel while Global Insights forecasts a decline in the oil price in the future (figure 19).

Figure 19: Forecasting for Crude Oil Prices 2005 ($ per barrel)



Sources: EIA (2007) and FAPRI (2007)

Note: EIA price is the imported crude oil price at 2005 in US dollars and the Global Insights price is the refiners' Acquisition Cost.

There are still many uncertainties in predicting long run oil prices as oil price is to a large extent subject to control by the oil cartel OPEC. Oil policy and strategy in the main oil supply countries particularly the OPEC countries and that in the main importing countries will impact on the long run oil price movements. For example, if oil price keeps an increasing trend in the long run, uses of the alternatives and substitutes of fossil oil may increase dramatically and new technology for new energy sources will be developed. This in turn will reduce the reliance of the world on fossil oils.

EIA (2007) compared oil price projections by different organisations available in the public and governmental domains. The results are reported in the table 41 below.

Table 41: Oil price projections from different organisations

Projection	2010	2015	2020	2025	2030
AEO2006 (reference case)	48.72	49.24	52.24	55.72	58.69
AEO2007					
Reference	57.47	49.87	52.04	56.37	59.12
Low price	49.21	33.99	34.10	34.89	35.68
High price	69.21	79.57	89.12	94.40	100.14
GII	57.11	46.54	45.06	43.21	40.25
IEA (reference)	51.50	47.80	50.20	52.60	55.00
EEA	56.94	49.80	47.42	45.16	NA
DB	39.66	40.11	39.73	39.95	40.16
SEER	44.21	45.27	45.87	46.23	46.60
EVA	42.28	42.35	45.76	49.45	NA

Source: Table 19 in EIA (2007)
Note: AEO here stands for Annual Energy Outlook.

Two different trend projections are shown in the table. Two of the six long-term projections— Global Insights Inc (GII) and Economic and Environmental Analysis, Inc.(EEA) anticipate that oil price will fall while other four -_Deutsche Bank AG (DB), Strategic Energy and Economic Research, Inc. (SEER), and Energy Ventures Analysis Inc (EVA) and EIA —expect that world oil prices will surge in the long run with EIA's projection increased much quicker than others.

Excluding the AEO2007 high and low price cases, EIA (2007) found four distinct views proffered by the comparative series beginning in 2010. " (1) prices moderate by 2015 before beginning a steady increase; (2) prices do not moderate over the mid-term but increase toward the end of the projection; (3) prices decline throughout the projection; and (4) prices remain relatively flat throughout. In the AEO2007 reference case, prices decline from about $57 per barrel in 2010 to $50 per barrel in 2015 and rise steadily to $59 per barrel in 2030 (all prices expressed in real 2005 dollars)".

- **Different countries have a different emphasis**

Biofuels have been produced in almost all countries. However, different countries seem to have different emphasis in terms of biofuel production. Bioethanol is currently the world's leading biofuel while biodiesel, until recently only produced in significant quantities in the EU, is second. Biogas comes third and has so far made a breakthrough only in Sweden. In 2005 world production of bioethanol for fuel use was approximately 26.9 million tonnes. This represents around 2% of global petrol use (EC, 2006).

Brazil is the world's largest biofuel producer and is based on sugar cane (table 42). It produces about a half of world biofuels (about 16 billion litres a year of which 1.5 billion litres is exported). The United States is the second-largest biofuel producer after Brazil. The bulk of the bioenergy produced in the USA is bioethanol from corn (maize). More than 12 percent of the US corn crop was used for ethanol in 2006. The US Senate Energy Committee's bill has set production milestones for ethanol as follows: 4 billion gallons in 2006, 4.7 billion in 2007, 5.4 billion in 2008, 6.1 billion in 2009, 6.8 billion in 2010, 7.4 billion in 2011, and 8 billion in 2012.

Table 42: Bioethanol Production in the world

Country	2004	2005	Country	2004	2005	Country	2004	2005
Brazil	3,989	4,227	Ukraine	66	65	Guatemala	17	17
U.S.	3,535	4.264	Canada	61	61	Cuba	16	12
China	964	1,004	Poland	53	58	Ecuador	12	14
India	462	449	Indonesia	44	45	Mexico	9	12
France	219	240	Argentina	42	44	Nicaragua	8	7
Russia	198	198	Italy	40	40	Mauritius	6	3
South Africa	110	103	Australia	33	33	Zimbabwe	6	5
U.K.	106	92	Japan	31	30	Kenya	3	4
Saudi Arabia	79	32	Pakistan	26	24	Swaziland	3	3
Spain	79	93	Sweden	26	29	Others	338	710
Thailand	74	79	Philippines	22	22			
Germany	71	114	South Korea	22	17			

Source: EIA, http://www.eia.doe.gov/

European Union

EU Policy

As discussed earlier, biofuel production in the EU plays a multiple role: it is used to mitigate global warming and reduce GHG emission, to increase energy security and to enhance rural diversification and rural development. In terms of climate change, the Commission has already set the objective of limiting the increase in the earth's average temperature to 2 degrees Celsius (compared to the pre-industrial level), To reach this objective, the Commission proposes that developed countries should cut their greenhouse gas emissions by 30 per cent by 2020 (compared to 1990 levels) and set the target for the EU to commit to reduce EU greenhouse gas emissions by at least 20% by 2020 as compared to 1990 levels. Two important objectives are set: (1) by 2020, the European Union should obtain 20 per cent of its overall energy mix from renewable sources and (2) biofuels should account for at least 10 per cent of our transport fuel usage.

Biofuel production and marketing in the European Union is subject to Common Agricultural Policy (CAP) and relevant biofuel directives. Reforms in the CAP in 2003 and recent reforms in the sugar regime appear to have important impacts on biofuel production. Under the 2003 CAP reforms, EU farmers are required to set aside 10% of their land and to meet compulsory compliance regulations for the single farm payment (SFP). The set-aside land can be used to grow oilseeds as long as it is for a bioenergy market. A special payment of €45/ha is available for energy crop production, which is also subject to a ceiling of 1.5Mha at the European level. Recently this ceiling has been increased to 2Mha, with the payment extended to the New Member States and to other perennial energy crops.

A recent reform of the sugar sector agreed in the late 2005 has eliminated the intervention system, cut the internal support price by 36% and total sugar quota, while sugar used for biofuel is no longer included in sugar production quota. It is likely the reform will further productivity gains, lower the domestic sugar price and increase sugar imports from ACP, EBA and Balkan countries. For biofuel production, it means that feedstock costs will be reduced; however the amount of sugar beet available for biofuel production is also reduced (Defra, 2006).

EU biofuel directives have regulated biofuel use, taxation and quantity. In the 2003 Biofuel Use Directive, the EU, in an attempt to reduce greenhouses gases in line with its Kyoto Protocol obligations, set a non-binding target of 2 percent of biofuels in 2005, increasing by 0.75 annually to 5.75% in 2010. The 2005 target was not achieved (biofuels only attained 1.4%) and on current projections, the target of 5.75% for 2010 is also at risk: it is likely the EU will only achieve 4 per cent at best. (Boel, 2007).

In the Energy Taxation Directive, the EU has allowed the Member States to grant tax reduction and/or exemptions in favor of renewable energy and set the ceiling for the reduction being no less than 50% of the normal exercise duty. The Fuel Quantity Directive, however, requires a limit on biodiesel blending of no more than 5% share by volume for technical reasons.

The Current State of biofuel sector

The main biofuel produced in the EU is biodiesel from rapeseed. In 2005 EU production of biofuels was 3.9 million tonnes with biodiesel accounting for 81.3%. This represented less than 1% of EU petrol and diesel consumption. The current state of EU biofuel sector is reported in Table 43.

Apart from France, sugar beet is the main feedstock (about 75%) for bioethanol production. Spain, Germany, Sweden, and France are the leading EU producers of bioethanol, mainly because of feedstock. The leading consumer is Sweden, which takes about 80% of the quantities imported, mostly from Brazil.

Table 43: EU biofuel sector

	Bioethanol	**Biodiesel**	**Total**
2004 Production	491	1933.4	
Feedstock used	1.2mt of cereals (0.4% of EU total), 1mt of sugar beet (0.8% of total)	4.1m rapeseeds (40% of total). 58% of rapeseed in 2006	
Land used for feedstock			2.8mh (3% of EU total arable land)
Support used			0.9mh on setaside, 0.6mh on energy crop regime

Sources: Smeets, et al (2005); Boal (2007);

Some 80 percent of EU's biodiesel comes from rapeseed oil, with soybean oil and a marginal quantity of palm oil from Asian palm oil exporters such as Malaysia and Indonesia making up the rest. Germany, France, Italy, and the Czech Republic are the main producers for the biodiesel (see Table 44). Processing capacity is regarded as a main constraint for the production at the moment.

Table 44: EU Biofuel production

EU production of biofuels (1 000 tonnes)[12]				
	Biodiesel		Bioethanol	
	2005	2004	2005	2004
Germany	1 669	1 035	135	20
France	492	348	115	102
Italy	396	320	6	-
Austria	85	57	-	-
Spain	73	13	243	194
Denmark	71	70	-	-
UK	51	9	-	-
Sweden	1	1.4	123	52
Finland	-	-	10	-
Czech Republic	133	60	-	-
Slovakia	78	15	-	-
Hungary	-	-	28	-
Lithuania	7	5	6	-
Poland	100	-	51	36
Slovenia	8	-	-	-
Estonia	7	-	-	-
Latvia	5	-	10	-
The Nederlands	-	-	6	-
Greece	3	-	-	-
Malta	2	-	-	-
Cyprus	1	-	-	-
Belgium	1	-	-	-
Portugal	1	-	-	-
Wine intervention stocks*	-	-	-	87
EU-25	**3 184**	**1 933.4**	**730**	**491**

Sources: EBB (biodiesel), EurObserv'ER 2005 (bioethanol 2004), eBIO (bioethanol estimations for 2005).

*In 2005, the production based on wine intervention stocks purchases (about 185.000 tonnes) is included in the production of each country.

Table 45: EU Biodiesel Capacity

EUROPEAN UNION 2005 AND 2006 BIODIESEL CAPACITY*

Pays/Countries	2005	2006
Allemagne/*Germany*	1 903 000	2 681 000
Italie/*Italy*	827 000	857 000
France/*France*	532 000	775 000
Royaume-Uni/*UK*	129 000	445 000
Espagne/*Spain*	100 000	224 000
Rép. tchèque/*Czech Rep.*	188 000	203 000
Pologne/*Poland*	100 000	150 000
Portugal/*Portugal*	6 000	146 000
Autriche/*Austria*	125 000	134 000
Slovaquie/*Slovakia*	89 000	89 000
Belgique/*Belgium*	55 000	85 000
Danemark/*Denmark*	81 000	81 000
Grèce/*Greece*	35 000	75 000
Suède/*Sweden*	12 000	52 000
Estonie/*Estonia*	10 000	20 000
Slovénie/*Slovenia*	17 000	17 000
Hongrie/*Hungary*	0	12 000
Lituanie/*Lithuania*	10 000	10 000
Lettonie/*Latvia*	5 000	8 000
Malta/*Malta*	2 000	3 000
Chypre/*Cyprus*	2 000	2 000
Total UE/*EU*	**4 228 000**	**6 069 000**

Source: Biofuel Barometer, 2006

At present, there are three major supply sources identified to meet the extra demand for biofuels; diverting land used for compulsory setaside for energy crops, reduction of EU cereal exports and feedstock imports. In the long run however, the EU will have to rely on efficiency improvements based on new technologies in both production and consumption.

The UK position

The UK is one of the countries seriously devoted to the green policy in the Europe. In January 2000, the UK Government announced a target that 10% of the electricity supplied in the UK will be generated from renewable energy sources by 2010. In the Energy White Paper published in February 2003 the UK government has pledged to reduce GHG emissions by 20% in 2020. By 2015, 15% of UK electricity consumption need will come from renewable resources; this will increase to 20% by 2020. In the recently published Climate Change Bill, the UK government has further set the UK's targets for a 60 per cent reduction by 2050 with a 26 to 32 per cent reduction by 2020 legally binding.

However, UK is not a major biofuel producer. The main reason for this has to do with its climate constraint and low feedstock availability mainly due to relatively high crop production costs and structure. Because of the high costs, the UK may not have its comparative advantage in producing biofuel in the current way, particularly when energy price increases. This has been reflected from the major feedstock used for biofuel production in the UK.

To achieve the target, several policy measures have been used in promoting biofuel production.

(1) Fuel Duty

Fuel duty is the main support available in supporting the longer-term growth of the UK Biofuels industry. A 20 pence per litre duty cut on biodiesel has been in place since July 2002, and a similar duty incentive for bioethanol introduced from 1 January 2005. The incentive is extended in the 2007 budget.

(2) Bioenergy Capital Grant Schemes

The scheme supports the installation of biomass-fuelled heat and combined heat and power projects in the industrial, commercial and community sectors. It provides a variable rate up to a maximum of 40% of the difference in cost compared with installation of a fossil fuel alternative, with minimum award of £25,000 and the maximum single award £1m.

(3) Enhanced Capital Allowances

It will allow the costs of capital assets to be written off against a business's taxable profits. 100% first-year enhanced capital allowances (ECA) allow a business to write off the whole cost of qualifying capital assets against the taxable profits of the period during which the expenditure is incurred. From the 2004 budget, the Government has taken the application in the case bases. However, this policy is still under consultation.

Total sales of biofuels in the UK in 2004 are estimated at 20,990,000 litres, whilst total road fuel sales were approximately 48 billion litres. As a percentage of total road fuel sales, biofuels contributed about 0.04% (UK Government, 2005).

Feedstock for biofuel production

Feedstock for UK biofuel production include re-cycled cooking oils, agricultural by-products (e.g. tallow and possibly straw) and mainstream agricultural crops (e.g. cereals and root crops for bioethanol and oilseed crops for biodiesel). Imports could include straight bioethanol and biodiesel as well as biodiesel feedstock including tropical products such as palm oil. Most biodiesel was sold in a blend, the majority at or below the 5% level, which is in line with the European Road Fuel Diesel Standard EN590 (http://www.dft.gov.uk/consultations/archive/2004/tuksb/ukreporttothecommissiononbio2048).

In 2004, the UK consumed 161 million tones of oil equivalent energy. Of this, domestic and transportation uses account for 30% and 36% respectively. The transport sector includes subsectors of road, air, water and rail transport. Road transport in the UK represents some 73.5 % of total transportation energy uses with air transport consumed another 23% in the same year.

Table 46: UK energy projection (UEP) by DTI

	1990	2000	2010	2020
Cars vehicle group				
Fuel demand (Mtoe)	25.1	25.8	28.8	30.0
Motor spirit share (%)	94	88	73	63
Diesel share (%)	6	12	27	37
Commercial vehicle group				
Fuel demand (Mtoe)	13.7	15.2	16.5	17.2
Diesel share (%)	80	90	96	96
Total				
Fuel demand (Mtoe)	38.8	41.1	45.3	47.2
CO_2 emissions (MtC)	30.1	32.0	34.6	36.2
Of which impact of the existing VA package to improve vehicle efficiency (MtC)	0	0	-2.3	-3.1

Source: DTI (2006), http://www.dti.gov.uk/files/file26363.pdf

A commissioned study (Turley et al 2003) suggests that to meet the 2010 targets for biofuel substitution (5.75% of all road transport fuels), up to 1.06 million hectares (see Table 47) of land in the UK (about 20%) would need to be directed to biofuel production to meet the 2010 targets.

Table 47: Land required for 5.75% transportation fuel target in the UK

Feedstock	Fuel required (million tonnes)	Feedstock area (thousand ha)	% of current crop area
Waste fats/oils	0.10		
Rape oil (RME)	0.70	459	102
Wheat grain	0.40	173	11
Sugar Beet	0.40	98	55
Wheat straw	0.25	*	-
Miscanthus	0.20	100	-
Short Rotation Coppice	0.50	229	-
Total:		**1,059**	

* sourced from wheat grain area

Source: Turley, et al (2003)

Other studies have calculated the UK biofuel potential asset out in table 48.

Table 48: UK Biofuel Potential

UK Biofuel Potential			
	Wheat	Sugar Beet	Oilseed Rape (OSR)
Area (000,000 ha)[1]	1.87	0.15	0.59
Average yield (t/ ha)[1]	7.96	57.3	3.2
Biofuel Type	Bioethanol	Bioethanol	Biodiesel
Process	Fermentation	Crush/ mash & fermentation	Crush followed by transesterification
Volume Biofuel (t/ha)	2.21	3.95	1.18[2]
By-product	Dried grain & solubles. Straw	Sugar beet pulp/ dried residues	Glycerine/ Rapeseed cake

[1] http://statistics.defra.gov.uk/esg/default.asp
[2] Oilseed rape contains approx. 40% recoverable oil. Assumes 100% conversion to biodiesel

Source: http://www.nnfcc.co.uk/Newsletter_Issue6.pdf

Table 49: Land required by transportation fuel targets in 2015 and 2020

	2005	2015	2020
Total fuel required (MT) - petrol		20.67	19.59
- diesel		25.58	27.61
Targets in biofuels (MT)- petrol		1.78	2.94
- diesel		1.47	2.76
1. Yields staying 2005 levels			
Areas required (MH)			
Wheat (2.21 T/H)		0.81	1.33
Sugar beet (3.95 T/H)		0.45	0.74
Rapeseed (1.18 T/H)		1.25	2.34
2. Yields increasing by the trend			
Conversion ratios (T/H)			
Wheat	2.21	1.87	1.71
Sugar beet	3.95	3.48	3.23
Rapeseed	1.18	1.17	1.18
Areas required (MH)			
Wheat		0.68	1.03
Sugar beet		0.40	0.61
Rapeseed		1.24	2.34

Note: Total fuel demand figures from DTI (2006); conversion rates from Table 44

Moving from the first generation to the second generation of biofuels

An OECD study on biofuel (Van Lamp, 2006) indicates that without subsidies, most biofuel production using crops, except of sugarcane based production in Brazil, will not be economically viable even when oil price reached $60 per barrel. A break-even analysis of ethanol production (Elobeid, et al 2006) suggested that without subsidies, break-even price for corn is $1.14 per bushel when oil price is $40/barrel and when oil price increases to $80/barrel, its break-even price is $3.90 per bushel. As higher oil price means higher production costs for crops, different countries have moved to the second generation of biofuels.

The second generation of biofuels will continue to derive biofuels from any lignocellulosic or hemicellulosic matter that is available on a renewable basis. It will look at a whole new range of crops rather than energy crops as in the first generation of biofuels. The advantages of the second generation of biofuels are that tension of food and energy will be reduced and it will also have a smaller carbon footprint because the amount of energy-intensive fertilisers and fungicides will remain the same but output of useable material will be higher. In the UK, sunflowers and fodder maize are recommended (Tomkinson, 2006).

Technical, environmental and economic justifications for biofuel

Technical justification here refers to energy efficiency of biofuel production, i.e. to measure energy input/output coefficients. The environmental effect of biofuel production is more to do with carbon footprints particularly CO_2 emissions and whether biofuel production will increase or reduce CO_2 emissions in comparison with fossil fuels or between biofuels. The economic effect looks at whether biofuel production is economically viable by comparing with other ways of delivering fuel supply. Life Cycle Energy Assessment (LCA) has been used mainly for analysing technical and environmental effects of biofuel production.

There are limited studies available on the economic efficiency of biofuel production. Two studies, one carried out by OECD (Van Lampe, 2006) and another by CARD of ISU (Eloibed, et al, 2006), were relevant to the economic impact of biofuel production at the international level. Although slightly different in approach and emphasis, both studies were looking at two areas of biofuel economics: economic feasibility of biofuel production and impact on market prices of agricultural products.

In Van Lampe's study, the economic feasibility of biofuel was based on an earlier study of Smeets et al (2005), in which the production costs of ethanol and biodiesel were calculated[86]. It suggests that in 2004, with regional supply costs (RSC) for gasoline stand at $0.311/litre (equivalent to $39 per barrel of crude oil price), without a subsidy; only boiethanol from sugar cane in Brazil is economically viable. In the EU-15 all ways of biofuel production are not economically feasible, while production costs of ethanol from maize seems to be more close to regional supply costs of ethanol than any other biofuel production. Production costs of ethanol from maize in Poland are $0.337/litre while that of the EU-15 is $0.448/litre in 2004. Based on assumptions on

[86] For comparability, all production costs are converted to gasoline equivalent by dividing production costs per litre of fuel by the energy content relative to gasoline, i.e. 0.66 for ethanol, 0.89 for biodiesel and 1.11 for petrol-based diesel. Area requirements calculated from average regional crop yields and oil extraction rates in 2000-2004, assuming the following biofuel yields per ton of feedstock: wheat 362 l/t, maize 396 l/t, sugar cane 85 l/t, sugar beet 98 l/t, vegetable oil 1048 l/t.

fixed production technology for agriculture and biofuels, it calculates land required for producing 10% of transport fuels from biofuels for the major countries. It concludes that shares of land required for US, Canada, EU, Brazil and the world are respectively 30%, 36%, 72%, 21.6% and 9%. By using the Aglink model, this study has also analysed three different biofuel scenarios: (1) constant biofuel scenario (at 2004 level), (2) policy target scenario, and (3) $60 oil price scenario.

Two major works were carried out in the study of Elobeid et al (2006). First, by considering current production technology of producing bioethanol from corn and assuming reasonable production margin, they have calculated a breakeven price for an economically viable ethanol production, i.e. when corn price is sustained at $4.05/bushel. Then, a multi-commodity, multi-country system of integrated commodity models is used to estimate the impacts for agricultural market at different price levels. They conclude that higher energy price will lead to increase in bioethanol production, result in additional land to be used for corn production, while this will mainly come from reduced soybean acreage. Wheat markets would adjust to fill the shortage of feed grain caused by alternative uses of corn for bioethanol. Corn exports and production of pork and poultry would all be reduced in response to higher corn prices and increased utilization of corn by ethanol plants.

Implication of biofuel production for the agricultural market

Biofuel impacts and analysis

The impact of biofuel demand on agricultural market and production is more to do with the fact that biofuel demand is an extra demand for crops used for biofuel production, and demand itself is more an intermediate demand similar to many cash crops rather than food demand. In other words, it's a derived demand of other industries (transportation, heating, fertiliser etc.). In the sense, an inverse demand function can be used for partial equilibrium analysis. Eventually, a proper estimation of the demand requires a global energy model.

Here biofuels act more as leverage to lower oil price with its substitutional effect in the oil market. In the agricultural market, however, demand for biofuels represents a significant and growing source of extra demand for agricultural commodities. It increases absolute and relative prices of agricultural commodities of most suitable for biofuel production, alters land use structure between cropland and grassland and between crops suitable for biofuel production and other crops, and even increases uses of marginal and setaside land. There is also a possibility that it may increase the input intensity (in which energy input is part of it) in the production. Given the land quantity restriction in agricultural production, it may be reasonable to conclude that the biofuel demand will also affect the absolute prices for non-biofuel crops (food and feed crops).

There are three complications in assessing impacts of biofuel demand. First, as part of the by-products from biofuel production such as soybean meals and rapeseed meals can still be used as animal feed, to certain extent it will affect feed crop prices and even change feed crop structure. Second, Government policy will have a critical impact on production, consumption and international trade of biofuels. The current EU and UK policy has been supportive to biofuels mainly through tax rebates. Finally, the short run knock-on impact may very much differ from a long run impact as technological effects are seen. In the long run, higher prices for agricultural products (in relation to other products) will lead to an increase in land rent and land value. To a certain extent, this increase is a transfer of the value of fossil fuels such as coal mines and oilfields.

The key to the assessment is technology for agricultural and biofuel production. As von Lampe (2006) indicated, in the longer run, however, modern technologies to produce ethanol from cellulosic and ligno-cellulosic material or synthetic fuels from biomass (BTL) may change the economics of biofuel supply significantly. Therefore a long run study will need to be based on a sound technological review of biofuel production.

In modeling biofuel production, two alternatives can be used. The first approach is quite popular in calculating land requirement with certain targets. In the approach, the biofuel target can be directly incorporated by assuming that all targets will be achieved. In this way, possible use of the energy in the future will be predicted. From that the total requirements of bioenergy contribution can be calculated. Following the technical relationships between feedstock of food and oils and biofuel production and production function (yield) we will be able to calculate land required for the targets. The main problem here is that to calculate land requirement, we will need to assume certain structure of feedstock (in most cases we assume the current structure will remain unchanged in the future). As the feedstock structure can be changeable with changes in relative prices and technology, this approach is a static one.

The second approach takes biofuel demand as an extra demand on land. So with viable economic conditions, biofuel will compete with food demand for certain crops such as wheat and oilseeds in the EU. The difficulty in using this approach is with the construction of the demand function for feedstock of biofuel production. As time series data on biofuel production is very short in the most cases, a reliable estimation on price response is almost impossible. Because of this, many studies in this area have adopted a two-step approach, i.e. to first look at economic viability via so called break-even analysis. If it is viable then to look at processing capacity as it is quite often a constraint for the production. In the Europe, as many previous studies suggest, on the average without subsidies it is not viable to produce biofuels from food and oil crops. However, it can’t exclude production in certain areas or from the stock or lower quality commodities. The latter two are usually associated with a lower price (cost). Using a processing capacity based approach may be acceptable in a short run but in a long run what is determining the process is the fundamental relative prices.

With assumptions and proper revisions, the current AGMEMOD UK model can be used to evaluate the knock-on impacts of biofuel production on UK agricultural market under different oil price scenarios.

Energy Price and Agriculture

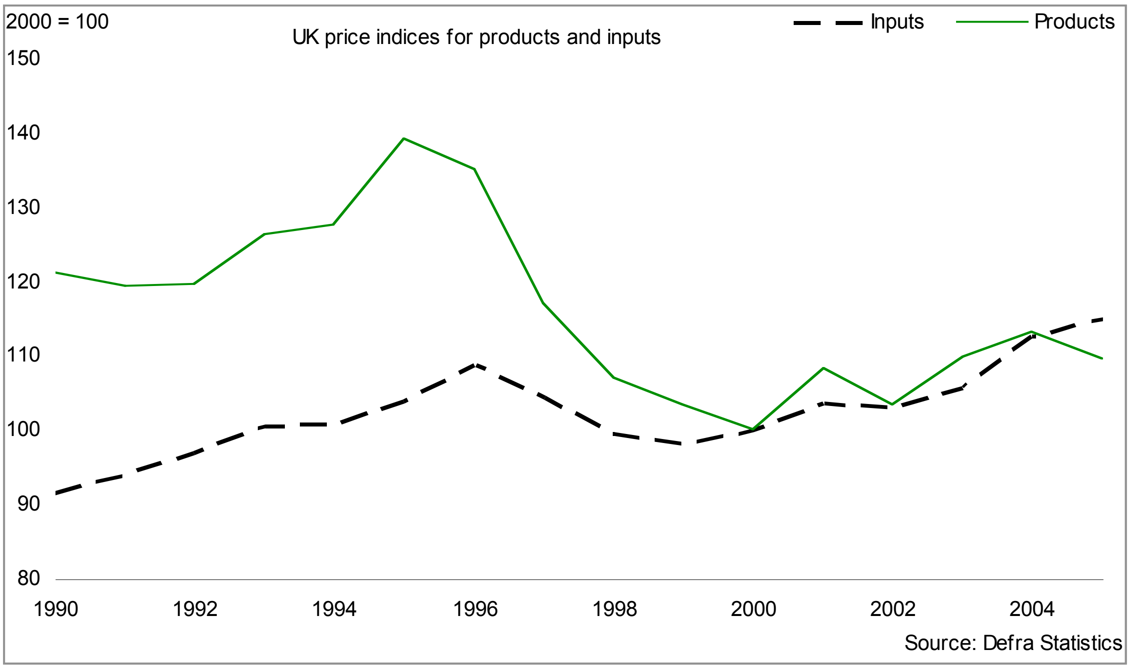
One of direct impacts of the high oil price is the substitution of biofuels for oil-based fuels. At present, the use of biofuels is very limited as the production costs of biofuels are relatively high and investments in developing technologies for producing and using biofuels are low. With energy policy favouring uses of biofuels and higher oil prices, it is likely more biofuels will be used.

High energy price affects agriculture in two ways: (1) Direct implications through higher production costs in agriculture and (2) Indirect implications through higher biofuel production. As the indirect impact has been discussed in the earlier section, we will focus our discussion in this section on the direct impact.

Energy is a part of cost of production and marketing of agricultural products. Increases in energy price implies that prices for agricultural inputs such as fertilizer, pesticides, heating costs and transportation costs will be increased and subsequently food production and marketing costs will also be increased. Due to technical constraints and different market situations for these inputs, price changes of these inputs and price response (of producers and consumers) can be different. For example, when energy price increases, prices for fertilizer and pesticides may increase though increases may not be proportionate to the share of energy costs to produce them. Facing a higher input price, producers may reduce uses of inputs or turn to relatively cheap substitutes; unless they have an expectation that the product price will also increase to offset the impact of increasing input price. Reduction in agricultural inputs may cause falling agricultural production, if production technology remains unchanged. This may result in higher market price and in turns encourage more production in the next stage. However, the impact of price shocks like this tends to gradually die out in the production process. Figure 20 shows UK price indices for agricultural inputs and outputs from the period between 1990 and 2005. Clearly price for the output continued to fall though input price tended to increase in the period.

Two factors, technological progress and substitution between inputs, have contributed to this process. Technological progress allows output to increase with the same level of inputs and substitution between inputs allows for producers to choose relatively cheaper input substitutes to minimize production costs.

Figure 20: Trends in Product and Input Prices



Source: Defra AUK