Energy dependency and food chain security

FO0415

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Executive Summary

The UK agri-food supply chain is almost completely dependent on fossil fuel derived energy to maintain the supply of food to consumers. This report considers how that dependency is structured within the supply chain and the consequences that might occur as a result of increases in, or disruptions to the supply of energy. Energy use includes both direct and in-direct (embedded) energy from all energy sources and where quantified is a delivered (rather than primary) value. The supply chain is defined as starting with primary production (the agricultural stage including upstream embedded energy) and finishing at retail. This analysis excludes the consumer stage and waste operations. The results are reported under the four project objectives:

To summarise the energy use associated with producing, processing and distributing a range of food products

Energy use is very diverse and varies with commodity and product. A review of life cycle assessment (LCA) studies revealed that the energy used to produce simple products ranged between 2.2 MJ/kg (potato) and 51.3 MJ/kg (cheese). Energy use within the individual stages of the supply chain also varied greatly with primary production accounting for between 17% (yoghurt) and 63% (milk) and processing between 3% (rice and onion) to 64% (bread). Energy use within the transport phase is influenced by bulky items (potato; 40%) and distance (rice; 28%). Although data were available for many basic products, studies on multi-ingredient products were absent. This issue was addressed by undertaking original analysis on pasta sauce, soup and pizza which were considered to generic examples of different product types.

For these manufactured products, the choice of raw ingredients and packaging have the biggest impact on the overall energy content, ranging between 71% (restaurant pizza) to 92% (pasta sauce). Packaging formats are driven by food safety requirements, cost and consumer choice (in that order) and the main formats of glass jar, steel can and cardboard box are unlikely to change in the future. Energy reductions will be driven by continuing existing weight reduction programmes and similar initiatives, for example, WRAP. Manufacturing and logistics contribute relatively little to the overall energy use, however continuous efforts are being made to reduce energy use (and hence costs) by the major suppliers.

Based on the results from this study, it is likely that product energy values in the future will be influenced primarily by the embedded energy within ingredients and packaging rather than direct energy use within processing or logistics. The use of low energy nitrogen fertiliser and recycled packaging materials is likely to lead to greater savings in overall energy consumption compared to on-going efficiency activities or improved technological innovations within the processing and manufacturing sectors. Smaller savings will be motivated by on-going cost saving.

To examine trends in food production and consumption and highlight the energy implications if these trends continue

The population of the UK has increased over the last five decades, from 53 million in 1961 to 62 million in 2010; and is forecast to reach 66 million by 2020 (UN, 2010). This increase in population is likely to drive an increase in demand for domestic commodities and products. It seems likely that beef and veal, cheese, milk and poultry consumption will increase. The demand for bread and potatoes is more difficult to predict since substitute products (other breakfast items, rice, pasta) are readily available. To forecast energy use in the future means finding a balance between the likely increase due to greater demand for food (especially energy-intensive chilled and frozen products) and changes to diet against efficiency savings within the supply chain and reductions of food waste.

To determine which foods will be the most sensitive to increased energy prices

Demand elasticity analysis was used to examine how food consumption varied with product price and whether increases in the cost of energy (and therefore product price) would influence consumer purchasing decisions. The results suggest that fresh produce, bread and dairy products are inelastic with respect to real-expenditure; that is, demand does not respond to changes in expenditure. Meat products are elastic, that is sales may be detrimentally affected by increases in the price of energy.

It is difficult to draw any meaningful conclusions from this approach. Firstly because the cost of direct energy is a minor component of the price of many products; secondly because many of the products that would naturally substitute for one another, have similar high levels of energy use, chicken for beef and tinned salmon for fish fingers and thirdly, because manufacturers, especially those of non-branded products, may not wish to, or be able to, pass the costs of increased energy downstream. It is likely that demand elasticities is not a particularly useful analysis within this type of forecasting.

To examine how food businesses mange energy risks, both disruptions and price rises

A two-stage energy awareness survey was undertaken. The first stage, in conjunction with the Food and Drink Federation, was an on-line survey and was targeted at food business SMEs within the agri-food sector. This stage was characterised by a poor response rate (4%) so care is required in interpretation of the results. The second stage, recognising the high proportion of food supplied by large companies (as compared to SMEs), was conducted through interviews and factory visits with 22 major food businesses. The results from this stage are considered to be far more robust.

Respondents were aware of the general issues surrounding the supply and cost of energy but there was no widespread concern of the overall issue. From those food businesses surveyed there appears to be little concern over disruptions to supply of gas, but approximately half of respondents expressed concern over future electricity supplies. Anecdotal evidence suggests that individual companies, especially SMEs, do not feel sufficiently empowered to act on this awareness and therefore to engage with potential solutions. Overwhelmingly, respondents felt that Government had the responsibility to ensure that energy infrastructure was adequate but that the price of energy should be determined by the market. Respondents had concerns over the cost of energy but that was mitigated with the knowledge that any increases would be borne by the whole agri-food sector. Increased energy costs would eventually be passed on to the consumer, however retailer resistance to supplier price increases and consumers shifting to alternative food products were a common concern. Companies manufacturing low-value and own-brand products for the multiple retailers are in the most difficult position since it is more difficult for them to pass costs on. However, cost savings are not the biggest driver in the sector. Food safety is, and will always remain, the single most important factor in the production, processing and retailing of food. Any mistake can result in financial losses and perhaps, more importantly, damage to brand reputation. In comparison, the cost of energy is less important.

The results from this study suggest that the agri-food supply chain is polarised with regard to renewable energy. At one end are a small number of companies engaged with the green agenda that are driven by ideology and/or corporate responsibility to make investments in new technology. At the other end, for example, are farmers, smaller SMEs and own-brand producers, who have neither the capital nor tenure and for whom the pay-back period for is too long to be viable in such a competitive environment.

Summary

Although the food supply chain is hugely complex, its interactions with energy are relatively simple. At a basic level the UK's food supply is almost completely dependent on fossil energy; the type of energy may vary and its use may be direct or in-direct use, but any change to the supply of energy, whether that is a disruption or increase in price, will have serious consequences for the supply, and quality, of food.

A number of different factors will influence the requirement for energy within the agri-food sector in the future. These include an increasing population that will consume more complex foods, an increasing shift to convenience foods such as ready-meals which require some form of temperature control, a drive for ever increasing variety of foods and demand for all foods at all times, regardless of the season. It is likely that new technology and reductions in food waste will increase the efficiency of energy use within the agri-food supply chain but that these savings will not be enough to offset the demand for more energy-intensive products. In summary, it is likely that the agri-food sector will require more energy in the future.

Businesses will accept an increase in the price of energy if it is fairly apportioned across the whole supply chain, however, innovation and new technologies to increase use efficiency are being hampered by the majority highly competitive trading model. Businesses assume that Government will ensure the supply of energy and very few have contingency plans in place in case of disruptions to supply.

The DEFRA project FO0415 "Energy dependency and food chain security" explores energy use within the agri-food supply chain and considers how changes in the price of energy and potential disruptions to supply might affect the production and consumption of selected food products.

1. **To summarise the energy use associated with producing, processing and distributing a range of food products**. Firstly, a literature search of existing LCA studies was undertaken to understand the range and type of data that already available. This approach was supported by a secondary analysis which focused on processed foods, specifically highly consumed energy-intensive multi-ingredient processed foods (*e.g.* ready-meal or pizza). The overall aim was to examine how

and where energy is used within the supply chain and to identify 'hot-spots'; areas that use proportionally greater amounts of energy or where we considered that production was venerable to disruptions in supply.

2. **To examine trends in food production and consumption and highlight the energy implications if these trends continue**. Historical data (DEFRA, ONS, Eurostat and FAOstat) was used to identify trends in food production and consumption with a view to establishing future energy consumption patterns if the trends continued.
3. **To determine which foods will be most sensitive to increased energy prices**. An economic analysis was undertaken to establish the demand elasticities for selected products and their sensitivity to price increases was examined. The purpose was to establish whether food consumption is inelastic, as generally believed, or sensitive to energy price increases. The objective will assess whether consumption falls for selected products and whether product substitution should be expected.
4. **To examine how food businesses manage energy risks, both disruptions and price rises**. This was a wide ranging objective, taking in energy contracts and business attitudes to the costs of energy and potential disruptions to supply. Both SMEs and big businesses were targeted through on-line surveys and face-to-face and telephone interviews.

Introduction

The UK agri-food sector, defined here as pre-farm businesses (fertiliser and pesticide manufacture), farm businesses, food processors and manufacturers, logistics (warehousing and transport) and retail, is a large user of energy. Energy use was estimated at 20 million tonnes of oil equivalent (Mtoe) in 2006 and 18 Mtoe in 2009 and is unequally distributed between the different sectors: pre-farm and farm businesses (20%), processing and manufacturing (30%), logistics (24%) and retail (26%)[1].

Historically, oil prices have been relatively inexpensive at around $20 to $30 a barrel, in today's terms, and as a consequence the impact of the cost of energy on food prices has been mostly overlooked. However, more recently the price of oil (and gas) has fluctuated widely; in 2008 the price of crude oil almost reached $150 a barrel but at the time of writing (February 2012) had dropped back to $100 a barrel. It is likely that demand will continue to rise from an increasing and more affluent population which together with economic reality and political instability will keep prices around the $100 a barrel mark for the foreseeable future[2]. Given this situation, it is important to understand how energy is used within the agri-food sector, specifically how increases in the cost of energy influence the price (and quality) of food products and how robust the different sectors are to price increases and disruptions to supply. An understanding of the trade-offs involved between the different energy and food parameters should enable the resilience of the food supply chain to be assessed.

The UK agri-food sector is highly dependent on energy, principally oil and gas, and no part of the supply-chain is immune from either increases in the cost of energy or disruptions to supply (Woods et al., 2010). Given the length and complexity of the supply chain, different stages are vulnerable at different times, depending on energy type, with potentially

[1] Defra. Food Statistics Pocketbooks for 2007 and 2011. Defra, London.
[2] BP Energy Outlook 2030, London.

different consequences. This project explores energy use within the agri-food supply chain by examining product energy use and the consequences that might arise due to an increase in demand and cost for energy. It also examines the approaches that businesses adopt when dealing with these issues and their views of alternative energy generation. Energy use includes both direct and in-direct (embedded) energy from all energy sources and where quantified is a delivered (rather than primary) value.

Objective 1. To summarise the energy use associated with producing, processing and distributing a range of food products

Energy use in the production of food commodities

Approach

A literature search of the academic and grey literature was performed to assess the energy use associated with production of different food products; product choice within the study was based on data from Defra's Family Food Survey[3]. The search returned over 500 results relating to a wide range of products which allowed the calculation of an average value and an estimation of the variation due to different production practices to be included. Energy use was collated for five different stages within the supply chain: primary production, processing-manufacturing, packaging, logistics and retail-wholesale. This data was supplemented by other published data (Defra AC0401) which quantified the direct energy inputs into UK agriculture. The available data cover a wide range of food products from fresh fruit and vegetables to cereals, meat and processed foods, however, the bulk of the data relates to single products from primary production so as a consequence there is only a limited amount of data relating to processed foods.

Commodity Production Energy Use

The results show that there is a wide range of energy usage within the production of food products. The lowest value was for mineral water (2 MJ/kg) and the highest was for coffee (83 MJ/kg). Fresh produce tended to have the lowest values and meat the highest. The collated and ranked results are shown in Table 1.

Fresh produce (potatoes, onions, carrots, white cabbage and lettuce) require the least energy as they are field grown and may be consumed without undergoing further processing. Exceptions to this rule are fruits and some vegetables, for example, tomato, that require additional protection during production such as (heated) polytunnels and glasshouses. A wide range of values were found for tomato production since they are field crops in some parts of Europe but will need protection and additional heating in the UK depending on the time of the year. The fruit category is slightly more complicated since different fruits can be produced domestically or imported. Apples (5 MJ/kg) require almost three times less energy than strawberries (13 MJ/kg). Imported fruits tend to higher embedded energy values compared to domestically produced fruit.

The method of preservation (ambient, chilled or frozen) will also influence product embedded energy value. While freezing will increase the shelf-life of products it also increases the energy use. However, frozen produce has a relatively small market share so

[3] Defra Family Food Survey - www.defra.gov.uk/statistics/foodfarm/food/familyfood/

this method of conservation does not contribute a great deal to overall energy use within the agri-food supply chain although the popularity of chilled and frozen foods is increasing.

Meat products have high embedded energy contents. Pork, beef and chicken have values between 30 and 40 MJ/kg but the variation can be considerable, for example, beef can be between 17 MJ/kg and 74 MJ/kg. This variation can be explained by different production methods and the time required for the animal to reach maturity. By overall market share, the embedded energy content of meat products is high since both beef and chicken feature in the top five food products (Mintel, 2012).

Dairy products are represented a number of times within the results and illustrate well how energy consumption rises as the raw ingredient is further processed. Liquid milk requires 5 MJ/kg to produce but this value increases as the raw ingredient is processed. Cream, yoghurt and butter require 12 MJ/kg, 19 MJ/kg and 23 MJ/kg respectively, while the greatest energy is required to produce cheese, which on average requires on average 51 MJ/kg, a ten-fold increase on the basic ingredient.

While the embedded energy value of an individual product is interesting, it is the sector or total market value that has the most meaning as that is a clear indicator of how much energy is used to produce different food products that people consume. While coffee and prepared fish may have high individual values, the results are dominated by staple products such as meat, milk and bread.

Table 1. Embedded energy by product and market share

Product	**Average product energy use (MJ/kg)**	**Average product energy use ranking**	**Range of product energy use (MJ/kg)**	**Market energy use (TJ)**	**Market energy use ranking**
Apple	5.0	41	2.5 – 11.1	2,624	27
Banana	8.7	35	5.4 – 12.0	6,082	17
Bean (tinned)	18.0	18	16.0 – 20.0	6,205	16
Beef	34.4	8	17.0 – 74.2	36,498	1
Biscuit	25.4	11	23.0 – 27.2	13,296	8
Bread	9.0	33	3.7 – 15.8	19,214	6
Broccoli (fresh)	11.1	29	10.7 – 11.4	877	40
Butter	23.5	13	12.6 – 30.7	3,045	24

Cabbage (white)	4.4	42	3.7 – 5.1	548	44
Cake	16.8	20	11.6 – 21.0	8,151	15
Carrot (fresh)	3.3	45	2.6 – 4.1	1,155	37
Cereal & muesli	13.5	25	10.8 – 17.0	5,602	19
Cheese	51.3	4	35.7 – 65.0	19,278	5
Chicken (whole)	24.9	12	20.6 – 29.2	23,190	4
Chocolate	43.5	7	43.0 – 44.0	12,219	9
Cod (frozen)	61.9	2	45.0 – 78.8	1,604	31
Coffee	83.0	1	42.1 – 126.4	4,571	21
Cream	12.1	27	5.1 – 19.0	823	41
Crispbread	20.6	16	14.0 – 27.2	395	45
Eggs	29.2	10	27.2 – 31.3	9,320	12
Flour	3.6	43	1.7 – 5.2	735	43
Fruit juice	9.1	32	7.1 – 10.2	9,440	11
Grapes	8.8	34	7.8 – 9.7	1,620	30
Honey	3.5	44	1.3 – 5.6	67	48
Ice cream	16.4	21	14.0 – 20.2	8,766	14
Jam	11.7	28	8.0 – 16.0	933	39
Lettuce	6.3	39	3.5 – 9.1	744	42

Margarine	20.7	15	17.0 – 24.4	1,454	32
Milk	5.2	40	3.4 – 7.0	32,597	3
Oil	21.7	14	14.0 – 35.3	4,156	22
Onion	2.9	46	1.9 – 3.8	1,062	38
Oranges	8.1	36	6.8 – 9.4	1,267	35
Pasta	9.8	30	8.7 – 13.8	2,095	28
Peas (fresh)	16.3	22	8.2 – 24.4	264	46
Peas (tinned)	17.4	19	17.0 – 17.7	1,166	36
Pork	33.3	9	25.1 – 48.2	5,933	18
Potato	2.2	47	1.7 – 3.0	5,324	20
Raspberries	7.5	37		128	47
Rice	14.2	23	9.8 – 17.8	2,898	26
Salmon	57.0	3	54.5 – 59.4	1,846	29
Soft drinks	6.5	38	5.4 – 7.5	34,897	2
Strawberry	13.6	24	12.7 – 14.5	1,399	34
Sugar	9.8	31		2,909	25
Tomato	46.4	5	5.4 – 95.0	13,378	7
Tuna (tinned)	44.0	6		3,932	23
Water (mineral)	2.0	48		1,436	33
Wine	13.0	26	12.0 – 14.0	9,295	13

Yoghurt	19.4	17	13.7 – 25.1	11,313	10

Energy Use within the Supply Chain

Detailed analysis of energy use during the different stages of the supply chain cycle is shown in Table 2. Data is presented for selected commodities and shown for the different stages within the supply chain (primary production, processing, transport, packaging and storage/retail).

Table 2. Average and percentage energy use within the supply chain

Product	Average energy use (MJ/kg)	Primary production (%)	Processing (%)	Transport (%)	Packaging (%)	Storage/ Retail (%)
Apples	5.0	34	0	40	1	24
Beef	34.4	67	15	17	-	2
Bread	9.0	18	64	16	31	2
Cheese	51.3	53	27	12	3	5
Coffee	83.0	42	28	9	37	-
Milk	5.2	63	27	10	2	2
Pasta	9.8	39	21	31	-	9
Pork	33.3	72	9	9	12	8
Potato	2.2	48	14	34	11	14
Rice	14.2	48	3	28	32	6
Salmon	57.0	72	1	6	-	4

*This table is based on averages so row values will not add up to 100.

For most products, primary production consumes the most energy (42 to 72% of the total in this sample) and storage/retail the least (2 to 14% of the total) (Table 2). However, there are some products which do not fit this model. Bread is an obvious example since it requires a considerable amount of energy for processing (64% of the total) and packaging (31% of the total). Apple is another where its bulky nature ensures that the transport phase requires the most energy.

Summary of literature review

Energy use in food production (primary production, processing and manufacturing) is very diverse and varies with product. The review of life cycle assessment studies showed that energy used in production, expressed as MJ/kg, ranged between 2.2 (potato) and 51.3 (cheese) (Table 1). Energy use within the life cycle of products also varied greatly; primary production accounted for between 17% (yoghurt) and 63% (milk). Although data availability on energy usage within processing was sparse, the range is still considerable, being between 3% (rice and onion) to 64% (bread). Energy use within the transport phase was influenced by bulky items (apple; 40%) and distance (rice; 28%). Although life cycle assessment results were available for many basic products, studies on complex multi-ingredient products were absent highlighting a data gap.

Life cycle assessment of multi-ingredient processed foods

Approach

The majority of LCA studies examined in the review looked at single ingredient products; no studies were found that focused on commonly purchased multi-ingredient products containing meat (pies, quiches, pizzas, ready meals, etc.). The expectation is that these products use considerable energy within production and they all require cooling or freezing prior to sale. The absence of studies is not surprising as these products are complex and require the cooperation of the whole supply chain to generate robust results. This section addresses that data gap by examining the energy use to produce pasta sauce, pizza and soup; products selected because they contain very different and highly consumed ingredients including meat, vegetables and cheese which require a range of energy-intensive processing technologies.

Pasta Sauce Manufacture

Pasta sauce is a tomato-based product produced by mixing liquefied tomatoes with onions, garlic, lemon juice and a mixture of herbs. Recipe variants have additional items added such as peppers, pineapples with tomato purée mixed with the liquefied tomatoes to produce the required strength of flavour. Cheaper recipes used in own label offerings consist of tomato purée and water, sometimes with added corn starch to thicken up the mixture. The product is available almost exclusively in glass jars however, in the case of the some premium offerings; aluminium foil pack is also available. Pack sizes vary between 350g and 500g with the market leader being sold as 500g. The aluminium pack is sold as 380g. The product is mainly sold as an ambient item; however a small amount of chilled sauce is available in specialist outlets. A detailed breakdown of products is shown in Appendix 1 (Table 1).

The manufacturing process is comparable to a scaled up version of the same process used in home preparation with an added pasteurisation step. Ingredients are mixed according to the required recipe, heated to soften and to aid blending of the ingredients, filled and sealed in a glass jar prior to being pasteurised in a continuous oven. The jars are then cooled, labelled and packed in cases prior to despatch. For large-scale manufacture, raw materials will have been pre-treated prior to delivery at the factory. For example, onions will have been peeled and diced, tomatoes will have been pulped with skins and pips removed. There are two main areas of process control that guarantee product safety, these being the filling process and pasteurisation. During the filling process a small jet of steam is injected into the filled jar immediately prior to the cap being screwed onto the jar. This action expels any air in the headspace of the jar, and once the steam condenses, creates a vacuum thereby pulling the lid inwards; this produces the 'click' on opening the product. The pasteurisation process will usually consist of a continuous oven through which the jars pass on a moving belt. Close temperature and residence time monitoring of the oven ensures the product is properly pasteurised. A flow chart of a typical process is shown in Appendix 1 (Figure 2).

Supply Chain Energy Breakdown of Pasta Sauce

The energy requirement for the raw materials found in a typical recipe is highly dependent on the source of tomatoes. Spanish field grown tomatoes require an estimated 7 MJ/kg of energy for production, including transportation to the UK, whilst glasshouse UK tomatoes on the same basis require about 46 MJ/kg. As a consequence the energy requirement for pasta sauce will be between 10 and 40 MJ/kg, depending on sourcing choice of tomatoes. The assumption is that most pasta sauces use field-grown Spanish or Italian tomatoes.

The main energy requirement is the pasteurisation process. A manufacturing facility will use both gas and electricity, with gas being the predominant energy source for heating and pasteurisation. Indirect energy for non-product needs such as space heating, lighting etc. will add about 30-40% to the total energy requirement. An automated factory with good productivity levels should expect to have a total energy requirement no greater than 2 MJ/kg.

The main packaging format is glass jars with a metal lid. The energy requirement of a glass jar with a typical recycled content of 33% is about 12 MJ/kg. Using aluminium pouches the energy requirement falls to about 4 MJ/kg. One of the main reasons for this difference is the lower amount of packaging material required to hold the product. A typical 500g glass jar weighs 245g. An aluminium pouch weighs about 8g. Secondary packaging such as cardboard cases, shrink-wrap etc. add a negligible amount of energy to the total packaging requirement.

Being an ambient product, non-refrigerated transport and warehousing can be used. The total energy used will be mainly a function of fuel use in transport and the efficiency of truck loading; how much product can be put on to a truck. Glass jars usually have a good pallet loading capability and a truck can be filled to its weight capacity. However the high weight of packaging compared to product means that whilst the truck may be filled to its weight limit (about 28t for an ambient product), this only represents about 18t of actual product. Aluminium pouches do not have a good stacking capability due to their inherently unstable format so the reverse is true. Whilst nearly all of the pack is product, the poor stacking capability means the amount of product able to be loaded on a truck may be no better than that of the heavier glass jar. The energy required for product delivery will vary considerably of course depending on actual circumstances, however assuming an average delivery distance of 100 miles (*i.e.* UK sourcing), a full truck containing 18t of product will require energy of about 0.2 MJ/kg. The ambient nature of the product means the energy use in the retail environment is trivial. In-store refrigeration is not required and the only energy needed will be for general store lighting etc.

Energy Profile of Pasta Sauce

The energy required to make pasta sauce is summarised in Table 3. The lowest requirement would use field-grown tomatoes and an aluminium pack. The highest would use protected tomatoes and a glass jar. The majority of products are sold in glass jars using field-grown tomatoes, so a typical value would lie between the two. The energy profile of a typical pasta sauce is dominated by the sourcing of the tomatoes and packaging type. The manufacturing process, logistics and customer use are small in comparison.

Pizza Manufacture

A classic pizza consists of a dough base topped with tomato and cheese with optional toppings such as pepperoni sausage, olives, pineapple, etc. There are many variations on the basic concept, such as stuffed crusts, thick and thin bases etc. Packaging normally consists of a cardboard box or a cardboard base with a cellophane wrap for chilled products. Combinations of these formats are common along with cardboard boxes with cellophane windows, particularly for frozen pizzas.

The manufacturing process will vary with the size of the manufacturer. For a large manufacturer, dough is produced in a large batch mixer and conveyed automatically to a series of stretchers that form the dough into a sheet, simultaneously de-stressing the dough to avoid shrinkage at the later stages of forming. The de-stressed sheet passes under rollers that print out the required shape of pizza base. These rollers can be changed depending on the pizza shape required. All trimmings from this process are recycled back into the dough mix.

Printed bases are conveyed to a prover that maintains the bases at a controlled temperature and humidity for a set period of time. The proving parameters will vary depending on the specific recipe of the base. The prover will typically be a large insulated chamber with a continuous belt containing the bases passing through it using a multiple pass system. Bases are conveyed to a continuous oven where they are partially baked. The oven will typically be single pass and gas fired. The bases exit the oven and are passed under a tomato puree applicator, followed by a cheese applicator that completes the basic pizza manufacturing process.

The pizzas are conveyed through a continuous freezer before exiting to a topping area where specific toppings can be added by hand or by machine, depending on the variety being produced. The completed pizza passes through a further freezer before exiting to a shrink-wrap packaging machine, cartonner and case filler. The cases are palletised and moved to a cold store ready for customer delivery. Although there are many variations of this process, (in some cases toppings are added before baking for example), the basic dough forming, proving, and baking operations remain the same. Chilled pizza production is essentially the same as frozen. The process described above is for the industrial scale production of frozen Pizzas.

Smaller scale factories may have less automation, or employ a multiple- batch rather than a continuous operation in a part or their entire factory. Very small facilities will use static ovens and all operations will be on a batch basis. A small manufacturer will carry out most of the production process by hand. Dough will be prepared in simple mixer and manually formed into individual dough balls. The dough balls will be allowed to prove at room temperature or placed in a batch prover for about twenty minutes, prior to being placed in a cooler, allowing them to be kept for up to two days. When required the balls will be warmed back up to room temperature, and manually stretched into a pizza base. Tomato topping, cheese and variety toppings are applied by hand and the pizza baked in an oven for about nine minutes. Major ingredients will be delivered to the store in food service quantities; sacks for flour, large cans for tomato sauce and blocks for cheese. Toppings such as pepperoni, olives etc. will be prepared on site.

Major pizza restaurant chains will have a highly codified cooking procedure and portion control. 'Artisan' restaurants may have a greater variability in recipe control. A schematic of the Pizza manufacturing process is shown in Appendix 1 (Figure 3).

Supply Chain Energy Breakdown for Pizza

A typical pizza recipe will contain about 40% flour, 15% tomato, 20% cheese and 15% meat topping. There will be small amounts of yeast, salt and oil with water making up the rest. The typical recipe above will therefore have an energy requirement of between 15-21 MJ/kg (See Appendix 1, Table 3 for details of individual item energy content). This figure will be higher for a restaurant or retail operation as some of the raw material will have been pre-processed. Tomatoes, for example, are typically obtained from a food service can, meaning they have been cooked and sterilised. Depending on the format of raw material, the energy content could increase by a further 1-2 MJ/kg.

A large scale pizza manufacturer running at a high utilisation making frozen product will require approximately 2-2.5 MJ/kg energy; about 25% of the energy requirement is for refrigeration. This figure includes utilities and non-manufacturing items such as lighting etc. For a restaurant or pizza delivery operation, the large majority of energy will be consumed in the actual cooking of the pizza. An industrial oven run at full capacity will require about 4 MJ/kg of energy. Taking a sensible utilisation of say 50%, the actual energy usage will be closer to 8 MJ/kg, as the oven will be heated continuously regardless of whether the oven is filled.

Pizza is typically packed in a sturdy cardboard box, weighing about 200g for a frozen 1kg pizza, or one requiring home delivery from a restaurant. The embedded energy in high grade cardboard is about 32 MJ/kg of cardboard, or about 6 MJ/kg per kilo of pizza. Using recycled cardboard will reduce this figure to about 22 MJ/kg or about 4 MJ/kg per pizza. A truck carrying refrigerated product has less capacity than an ambient truck due to the weight of the chilling equipment and the requirement for insulated truck walls. These reduce the capacity from a typical 28 t to a maximum of between 22-24 t, depending on the specific truck design. Temperature controlled trucks require extra fuel to operate the refrigeration system. Assuming uplift in fuel requirement for cooling purposes, a figure of 1 MJ/kg would be reasonable when compared to an ambient product requirement of 0.2 MJ/kg (see section on pasta sauce). Storage of refrigerated product in an automated, efficient warehouse will require about 0.3 MJ/kg.

In store refrigeration varies between the relatively efficient in dedicated frozen food stores such as Iceland where freezer cabinets are insulated with doors and the more common unprotected freezers found in supermarkets where freezers are open to the atmosphere. A figure of about 0.5 MJ/kg has been assumed, based on storage cooling efficiency being significantly lower than that in a warehouse.

Soup Manufacture

Soup is an extremely versatile product and is effectively a mixture of liquidised and chopped foods such as vegetables, meat, fish etc. The recipe variations available are huge, allowing manufacturers to offer soups at all price levels. Soup tends to be a seasonal food, sold mainly in the winter months. The most popular varieties are vegetable, tomato and chicken. The product is sold in a wide variety of formats, including dehydrated powder and concentrated versions where the purchaser adds water. There is a small market for background broths where the purchaser adds chicken or similar, however most soup is sold as ready to eat after heating with no further preparation required.

There is a large variety of packaging offered. These include cans, Doy pack (flexible aluminium or plastic laminate pouches), cardboard boxes for dehydrated soup powders, paper sachets, plastic tubs etc. The most popular format remains the 400g can, however a wide range of can sizes are available between 290 and 800g. Most soup is sold as an ambient item in supermarkets, with some specialist outlets providing chilled soup with a very short shelf life. Soups come is different categories, each one with a slightly different manufacturing process. Cold blend soups (such as vegetable) are assemblies of recipe ingredients that are boiled for between 2-15 minutes depending on recipe, before being filled in cans, sealed with a lid and sterilised. Cans are labelled post sterilisation, consolidated into secondary packs, palletised and shipped. Puréed and 'Cream Of' soups emulsify the boiled ingredients to a paste prior to filling. More complex soups such as chicken and noodle require a two stage filling process where noodles are placed into a can followed by a slurry of chicken broth containing small chicken pieces. Condensed versions simply use a lower ratio of water to solids in the process.

There are a number of sub-processes supporting the production of soup. In many cases ingredients will have been peeled and diced by a co-manufacturer and delivered to the soup factory ready for immediate inclusion. For large use items such as carrots and potatoes larger factories will peel and dice the ingredients themselves. Other processes such as blanching of vegetables will take place where appropriate (for example beans). For a large manufacturer, the sterilisation process will take place in a hydrostatic steriliser. This is a high capacity, continuous steriliser using a combination of steam and high pressure (created by a head of water) which heats cans to the required temperature as they pass through the equipment. These can be highly efficient when highly utilised but are inflexible when treating cans with different diameters and/or having recipes that have different sterilisation parameters. Smaller companies (and larger ones requiring greater flexibility) will use standard retorts for sterilisation. A schematic of the soup manufacturing process is shown in Appendix 1 (Figure 4).

Vegetable soup is typically a blend of carrots, onions and celery in a background broth of vegetable stock, most of which is water. A typical recipe will require just over 2 MJ/kg of energy for raw materials. See Appendix 1 (Table 3) for more details. A large-scale manufacturer will use about 1.6 MJ/kg of energy to produce soup. The majority will be delivered from gas, accounting for up to 85% of the total site energy use. The sterilisation process is the main user of energy, consuming about 40% of site energy use, followed by the provision of hot water for blanching and other heating purposes at about 20%. Electricity is mainly used for lighting followed by packing machines and drives for process equipment, compressors and conveyors. Manufacturers are now acutely aware of the increasing cost pressures from energy price rises and the larger companies will often dedicate significant resources to energy reduction. Long-term energy use reduction targets are usually set at about 25%. The current level of 1.6 MJ/kg would therefore be reduced to about 1.2 MJ/kg if the target were achieved.

The main packaging format for soup is a standard 400g steel can which has an energy requirement of about 5 MJ/kg. An aluminium pouch will require slightly less at 4 MJ/kg. Being an ambient product, non-refrigerated transport and warehousing can be used. The total energy used will be mainly a function of fuel use in transport and the efficiency of truck loading. Steel cans have a good pallet loading capability and a truck can be filled to its weight capacity. The weight of packaging compared to product (about 1:7 including secondary packaging) means that a truck filled to its weight limit (about 28t for an ambient product), will transport about 24.5t of actual product. Aluminium pouches do not have a good stacking capability due to their inherently unstable format so although their packaging weight to product ratio is significantly better at between 15-20, the poor stacking capability means the amount of product able to be loaded on a truck may be no better than that of the heavier steel can.

The energy required for product delivery will vary but the assumption is that a full truck containing 24 t of product will require energy of about 0.2 MJ/kg. The ambient nature of the product means the energy use in these areas is trivial. The only energy needed will be for general store lighting etc. The energy required to make soup is summarised in Table 3. The normal energy profile uses a steel can.

Conclusions – Energy use for Pasta Sauce, Soup and Pizza Composite Products

The breakdown of energy values by life cycle stage is different for each product. For pizza, raw ingredients had the greatest energy requirement but it was the packaging stage that was dominant for pasta sauce and soup. Interestingly preparation of pizza required different amounts of energy; restaurant prepared pizza having a higher embedded energy value compared to factory prepared pizza, 28.0 to 23.3 MJ/kg; whether this near 5 MJ/kg saving for factory prepared pizza is nullified by home cooking is open to question. Between them, the choice of raw ingredients and packaging have the biggest impact on the overall energy content, ranging between 71% (restaurant pizza) to 95% (pasta sauce) of the total. The energy requirements are summarised in Table 3.

Table 3. Energy requirements for Pasta sauce, Soup and Pizza

MJ/kg energy	Pasta Sauce	Soup	Pizza (Frozen)	Pizza (Restaurant)
Primary production	10.0	2.0	15.0	16.0
Manufacturing	1.0	1.6	2.5	8.0
Packaging	12.0	5.0	4.0	4.0
Logistics /warehouse	0.2	0.2	1.3	N/A
Supermarket	Neg	Neg	0.5	N/A
Total	23.2	8.8	23.3	28.0
Assumptions	Field tomatoes, glass jar	Steel Can	Field tomatoes (canned for Restaurant), recycled cardboard, 50% utilisation of restaurant oven	

Packaging formats are driven by a combination of safety issues, cost and food consumer choice and the main formats of glass jar, steel can and cardboard box are unlikely to change in the future. Energy reductions are likely to be driven by weight reduction programmes and similar initiatives[4],[5],[6],[7]. Manufacturing and logistics costs contribute relatively little to the overall energy use, however continuous efforts are being made to reduce energy use (and hence costs) by the major suppliers. It is likely that reductions in energy use will be driven by raw material sourcing, rather than any other area of energy use. Innovation at the primary production stage has the potential to deliver the biggest savings, for example, low energy forms of nitrogen fertiliser.

The cost of energy in relationship to finished products varies with product and no general 'hard and fast' rules can be drawn. The cost of energy with respect to raw vegetables is minimal but can rise considerably in products which require energy-intensive

[4] FDF Policy Position on Packaging - www.fdf.org.uk/keyissues.aspx?issue=649
[5] IGD Packaging Reduction - www.igd.com/index.asp?id=1&fid=1&sid=5&tid=153&foid=70&cid=187
[6] WRAP Tools for Industry - www.wrap.org.uk/content/tools-help-grocery-sector
[7] Sainsbury's Reducing Packaging - www.j-sainsbury.co.uk/sainsburys-views/all-our-views/reducing-packaging/

manufacturing, for example, bread or products with sophisticated packaging, for example, tin cans. Rises in energy prices can disproportionally affect certain types of products: premium products will be least affected but economy products may have to increase their prices to allow manufacturers to retain their profit margins. In contrast to primary production, many processors and manufacturers are able to take advantage of forward buying and hedging with respect to energy.

Objective 2. To examine trends in food production and consumption and highlight the energy implications if these trends continue

Approach

The aim of Objective 2 was to examine trends in food production and consumption and combine the results from Objective 1 and forecast the embedded energy of food in the future (and therefore energy demand by life chain stage and food sector). Data on food consumption was extracted from government and EU sources and plotted against time and analysed for trends. The trend data was examined with respect to the energy use data to investigate what may happen in the future. The full analysis and figures is provided in Appendix 2. A summary by product is included here:

Beef - The production of beef has oscillated between 700,000t and 1,200,000t between 1961 and 2009 and given these conditions it is difficult to forecast future trends. However, the expectation is that production will show a slight increase based on global increased consumption, especially in emerging countries (Delgado, 2003).

Bread – Household bread consumption in the UK has decreased steadily since 1974 however that does not necessarily mean that the demand for flour is following the same pattern since the market for alternative baked morning goods is increasing and much of the bread purchased these days is part of ready-made sandwiches; this is not included in household consumption figures.

Milk – The production of liquid milk is fairly flat. Mintel forecast that retail sales of liquid milk will grow only slowly in the next decade. Market demand is likely to be based on the growth of milk powder and other processed products, for example, yoghurt and cheese.

Cheese – Growth has been positive since 1961 with a four-fold increase in production in forty years; imports show a similar trend. Mintel’s forecast of retail sales is equally positive and shows a steady increase in sales until 2015; from 300,000t in 2006 to more than 400,000t in 2012. It is possible that by 2020, the UK may produce 500,000t of a total market demand of 750,000t.

Potato – Production is fairly flat and difficult to predict. Although potato remains a simple and popular staple food, many starch alternatives are available, e.g. pasta and rice, at similar prices.

Chicken – The market for chicken (and other poultry) has shown year on year increases since 1961. Although the rate of increase is slowing the trend remains upwards.

Conclusions

The population of the UK has increased steadily over the last five decades, from 53 million in 1961 to 62 million in 2010; and is forecast to reach 66, 73 and 76 million by 2020, 2050 and 2100 respectively (UN, 2010). This increase in population is likely to drive greater demand for all food products and if combined with increasing exports might result in an increase in the overall size of the food market leading to a greater demand for energy. However, a lot of effort is currently being directed at reducing waste within the food chain (estimated to be as high as 50% for some fresh produce) to increase resource efficiency which could result in the demand for some food products falling. Certainly society should strive to reduce food waste which would deliver energy (and other resource) savings along the supply chain and provide benefits to all stages of the supply chain and energy generators. Given these opposing drivers, it is not possible to estimate the overall energy requirements for the agri-food supply chain but experience from the United States would seem to suggest that an increasing demand for more energy intensive products will outstrip any savings through greater efficiency and waste savings (Canning et al., 2010).

Individual product forecasts, based on trend analysis, suggest that beef, veal, cheese, milk and poultry consumption will increase. The trends for bread and potatoes are more difficult to interpret since other starchy substitutes are available. It is likely that consumers will oscillate between or completely replace the consumption of these products based on price, novelty, availability or ease of cooking. Forecasting under these conditions is problematical, for example, rice and potato are commonly substituted products but have very different embedded energy values; rice (14 MJ/kg) being seven times greater than potato (2 MK/kg). They also have completely different supply chains, and their energy demand is in different countries.

To forecast trends in food production and consumption requires an understanding of both population projections and dietary preferences. To extend the analysis to energy demand requires waste levels, new production development and energy pricing to be incorporated. Under these conditions, we suggest that forecasting based on sales is only partially helpful and that any interpretation should also consider an examination of energy use by new production processes and by country.

Objective 3. To determine which foods will be most sensitive to increased energy prices

Approach

Most UK studies examine the effects of energy price rises on the food supply chain from production perspective (Pretty et al., 2005). However, the consumption perspective is equally important, however, studies are more limited. This section examines if demand for food, calculated from own and cross price elasticities, can be influenced by price increases driven by higher energy costs. We examined if food consumption is generally inelastic, as generally believed, or sensitive to energy price increases that are reflected in the final prices consumers pay to purchase food (Piesse and Thirtle, 2009).The aim is to explore the relationship between increasing energy prices, the price of energy-intensive foods and food purchases/consumption. A second aim is to examine the potential to substitute high-energy foods with low-energy foods.

The empirical investigation utilised quarterly data on expenditure and prices of different goods over the period 2001 to 2008 (Defra Family Food Survey). Nominal prices were obtained by dividing the expenditure allocated to these goods by the respective demand quantity. The true cost of living (TCL) indices used in the first stage were obtained as follows. The prices of the goods belonging to a particular group were transformed in simple indexes. After that, these index prices were weighted by the expenditure share of these goods. A full explanation of the methodology employed and results is included as Appendix 3.

Elasticity is an indicator that measures relative changes of variables that are related. For example, the own price elasticity for apple is -0.751 which means that when the price of apple increases by 1%, the demand for this good decreases by 0.751%. Because this response is less than proportional, the demand for apple is considered as inelastic with respect to price. In contrast, the own price elasticity for chicken is -1.276. That is, when the price of chicken increases by 1%, the demand for this good decreases by 1.276%. Because this change is more than proportional, the demand for chicken is considered as elastic with respect to the price. Finally, note that lettuce is own price inelastic because its own price elasticity is -0.935, however, even when apple and lettuce are both own price inelastic, apple is even more own price inelastic than lettuce because the own elasticity of apple is smaller than that of lettuce in absolute value.

Results

Demand elasticities were estimated for lettuce, carrots, potato, tomato, apple, eggs, milk, butter, cheese, biscuits, bread, soft drinks, fish fingers, chicken, and beef. The results for own price elasticity reveal that demand for apple, lettuce, potatoes, milk, soft drinks, cheese, biscuits and white bread are inelastic (*i.e.* elasticity larger than 0.5, but smaller than 1.0 in absolute value); the demands for carrots, tomatoes, eggs and butter are very inelastic (*i.e.* elasticity smaller than 0.5 in absolute value); and the demands for chicken, beef and fish fingers are elastic (*i.e.* elasticity larger than 1.0). This means that the demands for apple, lettuce, potatoes, milk, soft drinks, cheese, biscuits and white bread have low degree of responsiveness with respect to their own prices. The demands for carrots, tomatoes, eggs and butter are very irresponsive with respect to their own prices. Finally, the demands for chicken, beef and fish fingers are strongly affected by changes in their own prices.

With regard to cross elasticities for complementary goods, it was found that grape is a complement for apple; tomato is a complement for lettuce; Brussels sprouts are a complement for carrots; cabbages, cauliflowers and rice are complementary goods for potatoes; cabbage is a complement for tomatoes; beef and other poultries are complementary goods for chicken; chicken, lamb and other poultry are complements for beef; salmon fresh, salmon frozen, herrings and other blue fish fresh or chilled, blue fish dried or salted or smoked, shellfish fresh or chilled, other tinned or bottled fish, and takeaway fish products are all complementary goods for fish fingers; sausages uncooked pork, ham and bacon are complements for eggs; coffee and chocolate drinks are complementary goods for milk; beers and lagers are complements for soft drinks; reduced fat spreads are complements for butter; reduced fat spreads and biscuits are complements for cheese; soft margarine, other margarine, reduced fat spread and white bread are complements for biscuits; and soft margarine, low fat spreads and biscuits are complementary goods for white bread. It is interesting to notice that most of the associated cross elasticities for these complementary relationships are very small (smaller than 0.6 in absolute value) revealing that the demand for these goods has low degree of responsiveness with respect to changes in the price of complementary goods. Even though, these complementary relationships were statistically significant.

With regard to cross elasticities for substitute goods, it was found that orange is a substitute for apple; potatoes and Brussels sprouts are substitute goods for lettuce; lettuce and pasta are both substitutes for potatoes; lamb and turkey are substitutes for chicken; other liver and turkey are both substitute goods for beef; white fish fresh or chilled, herrings and other blue fish frozen, white fish dried or salted or smoked, takeaway fish, and tinned salmon are all substitute goods for fish fingers; and reduced fat spread is a substitute for cheese. As in the case of complementary goods, the cross elasticities associated with substitution relationships are all small (smaller than 0.6 in absolute value). This means that the demand for these goods has low degree of responsiveness with respect to changes in the price of substitute goods.

Finally, it is possible to identify four groups of goods with respect to the real-expenditure elasticity. The first one is formed of goods whose demands are completely inelastic with respect to real-expenditure. That is, this group contains goods whose demands do not respond to changes in expenditure. This group is composed of apple and lettuce. The second group is composed of goods having very inelastic demands (elasticity between 0 and 0.5 in absolute value). These goods correspond to cheese and white bread. The third group is composed of goods whose demands are inelastic, but not as inelastic as the ones included in the second group. The goods included in the third group are potatoes, eggs, milk and butter. Finally, the last group includes goods with elastic demands with respect to real-expenditure. These goods are carrots, chicken, beef, fish fingers, soft drinks, and biscuits.

While this study was on-going, Defra commissioned a separate study on elasticities – DO010 ‘Estimating food and drink elasticities’ (Tiffin et al., 2011). This was a substantially bigger study and was specifically designed to provide up to date elasticity values for a range of food products. Although both studies adopted a similar approach, there were still some methodological differences and as a consequence the results are not comparable (details of the comparison can be found in Appendix 3).

The results suggest that fresh produce, bread and dairy products are inelastic with respect to real-expenditure; that is, demand does not respond to changes in expenditure. Meat products are elastic, that is sales may be detrimentally affected by increases in the price of energy. The full results are presented in Appendix 3, however, it is difficult to draw any meaningful conclusions from this approach. Firstly because the cost of direct energy is a minor component of the price of many products, for example, just 0.5% and 4.3% of the primary production of beef and milk, respectively; secondly because many of the products that would naturally substitute for one another, have similar high levels of energy use, chicken for beef and tinned salmon for fish fingers and thirdly, because manufacturers, especially those of non-branded products, may not wish to, or be able to, pass the costs of increased energy downstream. Manufacturers are under constant cost pressure to meet retail selling prices and margins and recipes can be changed to reduce high-value high-energy ingredients, e.g. meat and replace them with lower value and energy intensive substitutes. Some products might be affected by increases in the price of energy, for example, UK glasshouse tomatoes, but for the majority of commodities and products, we suggest that demand elasticities is not a particularly useful analysis within this type of forecasting.

Objective 4. To examine how food businesses manage energy risks, both disruptions and price rises

Energy use in primary production

Approach

This section is based on research undertaken by the Farm Energy Centre for this study and uses a mixture of confidential business data and interviews. The cost of direct (electricity, gas, diesel) energy is a fairly small component of most primary produce (this study suggests that the cost of direct energy use is typically less than 5% of commodity value; Table 4). However, the cost of indirect (fertilizer, pesticides) energy can have a greater influence, especially in crops with a high resource use. This section analyses how increases in the cost of energy (especially oil based) influence producer margin, product price and sales.

A range of energy supply contracts available to primary producers were analysed to assess how food chain businesses can best minimise the risk. In addition, energy purchase attitudes were also explored through consultation with a selection of food chain businesses, energy policy personnel in a selection of food industry trade associations and leading energy supply businesses. Together, these analyses provided information on the energy purchase related risk management tools that are available and the extent to which food businesses currently use them. The options for minimising the impact of energy supply disruptions were also assessed. This included the potential for standby generators or onsite electricity generation via CHP or renewables. Furthermore, the potential for fuel switching was examined where this may be advantageous in terms of energy cost and disruption management. To do this the key technologies and processes which are used by food chain businesses were examined and alternatives analysed. Where viable options are identified, the current uptake was determined. However, if the alternatives were found not to be in use, barriers to uptake were examined.

Energy use processes

The dominant energy use in primary production varies with commodity. The most commonly used fuels are diesel and electricity. The exceptions to this are chicken and tomato production where gas dominates due to the heating demand of the production systems used. The commodity also influences how vulnerable production is to disruptions to supply. A shortage of diesel within field production is not critical but the same cannot be said of dairy and chicken enterprises where the loss of electricity or gas could have major animal welfare implications.

Energy Costs of Production

The contribution that energy costs make to overall production costs was determined using Defra statistical data for production outputs and energy consumption data. Table **4**4 details the current energy costs and farm-gate values for the commodities studied. Ratios of energy cost to produce values (%) are also given. In all cases it is assumed that the production systems employed, and the efficiency of operation achieved, is in line with the current industry averages.

Table 4. Current energy costs and energy cost/produce value ratios

	Commodity									
	Potato	Apple	Milk	Lettuce	Wheat	Eggs	Chicken	Tomato	Carrot	Beef
Unit of Output	tonne	tonne	litre	tonne	tonne	case eggs	tonne	kg	tonne	tonne
Specific Energy Consumption (kWh/unit of output)	100	106	0.18	60	275	4.8	657	9.4	82	148.57
Typical Current Farm Gate Value (£/unit of output)	£220.00	£640.00	£0.26	£833.00	£185.00	£15.30	£1,380.00	£0.95	£380.00	£1,572.00
Current Energy Cost / unit of output (£/unit)	£7.64	£9.52	£0.0113	£4.70	£15.02	£0.47	£31.94	£0.22	£5.20	£7.68
Current Energy Cost / Farm Gate Value Ratio (%)	3.5%	1.5%	4.3%	0.6%	8.1%	3.1%	2.3%	23.5%	1.4%	0.5%

This analysis shows that, for the majority of the products, energy costs account for less than 5% of the farm gate sales value. The exceptions to this are tomato and wheat. For tomato, the production methods employed are particularly specialist as they rely on heated greenhouses to overcome the limitations of the UK climate. Domestic production of tomato is approximately 22% of the total fresh supply. The energy cost / produce value ratio for wheat is also worthy of note, especially how it is influenced by farm gate price. In March 2010, when this study started, the farm gate value of feed wheat was under £100/tonne[8] yet 14 months later the price had increased to over £220/tonne. Therefore, the market value of wheat has risen by more than 100% during this period and while energy prices also inflated over that period, the increases were modest compared to the changes in wheat price. This level of fluctuation severely influences the energy cost / produce value of wheat. The reported value of 8.1% is low as historically it has been more than 10%. The example of wheat also illustrates the greater issue of the influence of markets, whether global commodity or regional product, on wholesale price and where price pressure is unrelated to energy costs.

Reducing Energy Inputs in Primary Production

A number of options are available to producers that will reduce current energy inputs and help them manage the impact of energy cost increases in the future. There are numerous well developed and mature technologies which can be used to reduce the amounts of energy currently used to produce food commodities. These include improved insulation, better light sources, more efficient heaters, tractor engines with improved fuel efficiency, energy monitoring, reduction target setting and employee education.

In many cases the implementation of these methods is a “win-win” for the producer as the energy cost reductions achieved through implementation quickly repay the capital investment that is needed. In the majority of cases, a payback time of five years or less can be achieved, and for a significant proportion of the technologies the payback is three years or less. These payback times mean that some producers have already embraced energy efficiency technologies and reduced energy inputs accordingly. This uptake is best demonstrated by the impact of Climate Change Agreements in pigs, poultry meat, eggs and protected horticulture where energy use reductions of up to 40% have been achieved when compared to their base year energy use in 2000/2001 (personal comm.). The acceptance of payback times of between three and five years in primary production is a contrast to the manufacturing sector where two years is considered too long.

However, some significant barriers to uptake still exist; the largest being a lack of understanding of the savings that can be made through installing the upgrades and the availability of capital for investment. In addition some producers only consider upgrades at

[8] Defra API: Index of Purchase Prices of the Means of Agricultural Production; Monthly Data, November 2010.

times when new facilities are purchased or major refurbishments are carried out. This restricts the timeframe for making the improvements and acts as a barrier to widespread uptake. Overall, energy efficiency improvements still have significant potential to negate the effect of energy cost increases, especially in the short and medium term.

Agricultural advantages

The primary production sector is in an advantageous position when it comes to adopting alternative renewable energy technologies.

- Resources – many of the resources associated with renewable energy (wood fuels, oil seed fuels, wind) are readily and cheaply available to primary producers.
- Space – primary producers tend to have the space and planning freedom which is not available to urban developers. The installation of a small-scale wind turbine or solar array on a farm for instance, is not generally a problem from an accommodation point of view.
- Practical adaptation – farm businesses are used to adapting and integrating new technologies into their infrastructure. Primary producers are practical and skilled engineers and can readily take renewable technologies and make them operate effectively within their businesses.

Mitigation of price increases

Strategic energy purchases are an important mitigating influence on business resilience. For larger businesses which involve both short-term and long-term purchases, a degree of hedging is not uncommon. Most agricultural businesses do not engage in this. For bulk fuels, on-farm fuel storage is the most common method of ensuring continuous and cost effective fuel supplies when prices are high. Electricity and gas at the smaller end of the market (up to £30,000 per annum expenditure) are bought on contract on a one to five year basis. Some larger users will buy month or day ahead to achieve prices closest to the wholesale level. These businesses are more susceptible to the effects of short-term price volatility. Of the commodities considered here only tomato production is likely to be influenced by short-term price volatility through day or month ahead heating energy buying strategies. Energy supply utilities and consultancy firms offer risk management products which provide a mix of short and long-term pricing solutions to provide stability whilst delivering a competitive product.

Long term price volatility

An increase in energy prices has an effect on the viability of agricultural businesses, especially those that are energy intensive and in this respect UK agriculture may suffer more than agriculture in other countries, especially in situations where there is a disproportionate rise in UK energy prices. This might occur where energy availability becomes restricted (either through a lacking of refining capacity and/or logistical issues in road fuels) or because the UK is in competition with other countries for the same supply (natural gas and LPG).

Some UK sectors are especially vulnerable to this type of scenario. One example would be protected horticulture which can be dependent on the use of heating fuel. In this scenario, overseas producers with a warmer climate using ambient production methods will have an advantage. But this situation can be applied to all UK energy intensive operations where a general rise in international energy price would affect competitiveness. Other examples include the rearing of young stock, or where we produce more intensively than our competitors as is the case for intensive livestock.

Energy supply disruption

Energy supply disruptions can be categorised into short and long term. Short term disruptions are defined as anything from a few hours up to a week, and are likely to be caused by issues like weather or a major interruption to energy transport/network system. Medium and long term disruptions can be defined as a week up to two months. It is possible that they could come about from unforeseen natural cause, or extraordinary international events. Longer term interruptions over two months may be due to major international events like war or other dramatic unforeseen causes.

Mitigating techniques

Bulk fuels

For bulk fuels like oil, solid fuel or liquid petroleum gas (LPG), storage and purchase planning is the solution to most short to medium term supply interruptions. Most farms current have the facilities to cope with short term interruption as weather has long been known to cause this type of problem but it is unlikely that many farms have enough storage to cope with medium term disruption. For longer term disruptions, where extended storage is not viable, fuel substitution can be used. So, for instance, in the case of a boiler, a multi-fuel design is one solution. The use of renewable fuels which are locally sourced or rely on natural systems, like solar heat, will provide a better security of energy supply in some applications.

Gas and Electricity

In the case of electricity disruption, security can be provided by standby generation equipment. For short term disruption this can be cheaply provided from a tractor driven generator. For medium or long term disruption, more robust replacement generation equipment has to be considered. In some cases it is possible to engineer agricultural systems to be able to provide sustained replacement by technique substitution, for instance by replacing mechanical ventilation equipment by natural systems which use no electrical power. In cases of sustained disruption the key is to be able to separate essential elements of the agricultural process and selectively provide power from a generator. To be economical, power demand has to be low, so the engineering of the lowest energy system in any case is desirable. Dual fuel systems can be used to mitigate the effect of a gas supply interruption. Interchangeable oil and gas burner are an example of this. A supply of biogas from a local source will also supply some security.

Risk management attitudes and strategies

Management of risk in agricultural businesses in regard to energy costs and availability is largely determined by business size with larger businesses being more likely to have considered the implications of cost volatility or supply disruption. For the most part, small businesses are not proactive in managing risks from price volatility in other than the very short term. So, although a small to medium-sized farmer will endeavour to purchase his fuel intelligently at the time that a contract is renewed, there is little evidence to suggest that they consider the strategic balance between present cost and future risk.

Electricity and gas purchasing

The introduction of contracts based on one to five year terms has by its very nature removed a degree of short-term price volatility for those entering into these contracts. As contracts have fixed end dates, farmers in effect, do not have a great deal of choice when it comes to at what stage of the price curve they will buy. If they have a contract renewal date which falls at a trough in prices they will benefit from this for the next contract period they are involved in. However, should they fix their price at a high point in the curve then they are saddled with this for the contract period. For businesses which buy over £50,000 worth of electricity or gas per annum, various products are available which allow degrees of risk management through a mixture of short-term and fixed long-term price purchasing. Managing these can be complicated and farmers using this amount of energy often use energy consultants to guide them through the best buying strategies. The uptake of this type of product is quite low, probably only representing 2 or 3% of the total potential market.

Bulk fuels purchasing

Farmers of all sizes tend to use their storage capacity to, in effect, ‘buy time’ when choosing the right time to make an energy purchase. It is rare to find that farmers have access to energy market intelligence other than for ‘shopping around’ at any one point in time. Long-term bulk fuel contracts with price hedging are very rare and only used by the very largest users. The move towards specialised bulk fuels in the renewables sector has meant that users have had to take a more strategic view on securing supplies in the medium and long term. This is because the industry infrastructure for renewables is not fully developed, so if a producer wants to ensure a continued supply of feedstock he needs to consider long term contract arrangements with suppliers.

Energy supply outages planning

Most farm businesses are quite pragmatic about how they deal with emergency planning issues in connection with energy supplies. Outages caused by bad weather are the biggest driver to the formation of contingency plans. For enterprises like milk production or intensive livestock production where the loss of electricity supply can have an immediate effect on the production system or animal welfare, standby generation systems are common and procedures for the connection of equipment are well known by staff. Production systems with less critical energy needs do not generally have standby systems, as they can sustain a number of days without excessive loss. Such enterprises who do not have plans for dealing with long term outages so can suffer in the event of longer term (any more than a few days) supply disruption. Few businesses, other than very large operators in horticulture or intensive livestock production, will have plans and/or facilities to enable them to cope with long-term energy loss. The most common facilities installed to cope with such eventualities are alternative fuel systems (dual fuel boilers for instance) or permanent standby generation equipment.

Conclusions for Primary Production

Although the expectation is that energy prices will continue to rise (DECC, 2011) there is much uncertainty as to the size of the increase since lower than expected demand caused by depressed global economic conditions together with new reserves and supplies makes forecasting difficult. To some extent any increases are mitigated by the fact that direct energy costs in primary production account for less than 5% of the farm gate sales value for most commodities although wheat and tomato are exceptions to this rule. UK food retailing is highly competitive, and it is not clear if increases in the cost of primary production will, eventually, be passed onto consumers. Another important issue in this sector that this report does not seek to cover in detail is the possibility that rises in indirect energy costs, principally nitrogen fertiliser, could have a short-term impact on production costs.

There are already numerous well developed and mature technologies that can reduce the amounts of energy currently used to produce food commodities. Many technologies (e.g. heat exchangers and variable speed pumps) are “win-win” methods that can be implemented immediately and can achieve payback times of five years of less. These short paybacks mean that more producers are attracted to these new energy efficiency technologies. Some installations have shown that savings of up to 40% can be achieved when compared to their base year energy use. Farmers have advantages in the adoption of alternative renewable energy technologies; they have a wide availability of resources (such as wood fuels, wind and solar sites), and of space and they are used to practical adaptation. Energy efficiency still has a significant potential to negate the effect of energy cost increases, especially in the short and medium term. This study has not addressed in-direct energy costs in primary production, for example, nitrogen fertiliser, and these can contribute significantly to overall costs. This should be borne in mind when interpreting the results. The price sensitivity of UK commodities varies greatly according to timing and origin but this research shows that there are numerous alternatives that can be of use for farmers and that can bring great savings of energy, capital and negative environmental impact.

Energy use in processing and manufacturing

Approach

The agriculture, food and drinks manufacturing industry is an important sector of the UK economy. It employs over 3.7 million people and contributes 7% to the UK’s Gross Value Added[9]. Volatility in energy prices is a threat to both the continuing profitability and viability of the industry and it is vital that food companies are capable of surviving any major increase to energy prices or any threat to energy availability sources. This section examines the preparedness of the processing and manufacturing sector to meet such challenges, using a broad base of company inputs. A cost analysis is also presented, on specific food products, to examine the effect of energy price rises on likely finished product costs.

The results in this section are based on a two-stage energy awareness survey undertaken for the study and supported by research into the energy in packaging undertaken as part of a MSc project (Oswald, 2011). The first stage, in conjunction with the Food and Drink Federation, was an on-line survey and was targeted at food business SMEs within the agri-food sector. This stage was characterised by a poor response rate (4%) so care is required in interpretation of the results. The second stage, recognising the high proportion of food supplied by large companies (as compared to SMEs), was conducted through interviews and factory visits with 22 major food businesses. The results from this stage are considered to be far more robust.

[9] Defra – Food Statistics Pocketbook - www.defra.gov.uk/statistics/foodfarm/food/pocketstats/

Background

The processing and manufacturing sector is very fragmented in terms of products supplied, size of businesses and processes employed in manufacturing and distribution (IfM, 2010; ADAS, 2007b). A food manufacturer can therefore be anything from a small, local, family-run bakery to a huge multi-national making millions of cans of soup each day. Finding a common voice for such a disparate industry is difficult and there will always be exceptions to the majority position, however there are a number of common attitudes that can be found in all responsible food manufacturers:

- The priority of food manufacturers will always be the safety, quality and hygiene of their products. High prices can lead to lower profits and in the longer term end a business. In contrast, a quality problem can cause even a well-established brand to be killed off, practically overnight.
- Energy prices (and other inputs) are considered important (especially when prices are high) but are ranked in importance some way behind product quality.
- High quality conformance is seen as the responsibility of all employees, however energy use and sustainability are probably in the same position where Safety was a few years ago; the responsibility of a designated individual or senior manager with little widespread engagement being felt for the topic across the workforce.

Effect of energy price increases / Energy Security Awareness

This work has shown that companies awareness of the cost of energy and how it translates into product pricing has increased over the last few years; principally driven by spikes in prices. Until recently, most companies did not see energy management as a high priority and scenario analysis of the effect of energy price increases was limited. A more typical response has been to focus on reducing energy usage with actions ranging from basic metering to in-depth energy analyses from consultants. The effect on finished product selling price from energy price increases had generally not been evaluated in depth. The view was that energy price increases could be absorbed through efficiency improvements. Where prices could not be absorbed, for example in low margin products, selling prices would rise to protect producer margins or product portfolios would be modified, with unprofitable products being withdrawn from sale. Energy security concerns were usually linked to cost of supply. Contingency plans for interrupted supplies, if they existed, were based on short-term unavailability, for example, stand by generators, rather than prolonged or semi-permanent events. A common view was that ‘supplies may be interrupted, but the lights would not go out‘.

Drivers for energy awareness

Giving the disparity of manufacturing companies, a wide range of drivers exists. Some companies have investment policies that allowed projects classified as ‘sustainable’ to be accepted with longer pay back times than normal and in such cases capital funding was usually limited to an agreed percentage of the total capital expenditure spend for the year. There are examples, from those surveyed, of senior managers and/or owners being passionate about ‘doing the right thing’ regarding energy use and sustainability in general. This sometimes contradicted their investment criteria and led to a gap between strategic intention and practical actions. The strongest awareness of energy use and sustainability is where there was widespread engagement in the subject by the workforce as a whole, rather than it being delegated to a senior management group. Having a young workforce, who tend to be more actively interested in green issues generally, was quoted by one company as being one of the key factors in delivering a successful, sustainable business.

Micro producers

Micro food producers such as small bakeries and butchers are very susceptible to increases in energy prices. Energy forms a higher proportion of their operational costs than that in large companies, as their labour costs can be varied in line with the success of the business. Micro businesses are more restricted in their ability to replace old, inefficient equipment and are in competition with supermarkets who have the ability to under-cut them in price. In addition, they have no ability to hedge energy costs or use alternative energy supplies. A reduction in energy security, with the consequent spike in prices will leave many of them unable to absorb costs, requiring them to increase their selling prices, thereby reducing their ability to be competitive with large supermarkets which could put many of them out of business.

Typical Results from Food Manufacturing Energy Analyses

Studies carried out by several food manufacturers into their energy use were examined for common issues. Typical problems encountered were:

- A lack of a full understanding as to where energy was used, with little metering being employed. Base loads (*i.e.* power being used when all manufacturing was stopped) ranged between 40-80% of full load.
- Unaccounted energy losses, typically 30% of requirement.
- Lack of awareness of energy saving options such as heat integration.
- Old and inefficient equipment unable to be replaced due to financial constraints.
- Insufficient training provided on energy saving techniques– especially in smaller companies.

Food Branding and Energy Rise Impact

Increases in energy costs will eventually have an effect on food prices. The link between the two is, however, not a direct one. Much depends on the positioning of the product being manufactured. Food products are positioned differently at the point of sale. Basic products such as tomato soup, baked beans etc. are frequently offered at different price points, usually classified in terms such as super-premium, premium and economy or similar. Each offering will have a different cost structure, designed to deliver the required profit. Generally economy products are not supported by advertising and promotion funding, are unbranded or private label brands with no trade margin. Raw material costs are also lower with economy products being designed to have a low cost recipe. Economy tomato soup for example is formed from a tomato purée base, whereas super-premium offerings are formed from crushed tomatoes. Packaging costs can be identical or even higher in an own label operation, driven by bulk purchasing by powerful brand-owners. Own label manufacturers may compensate for this with slightly lower packaging offerings such as a can with no easy open end. Manufacturing costs (excluding energy and product waste) are likely to be lower in own label operations, mainly driven by lower wage rates, lower management overhead costs and using older, fully depreciated plant equipment.

Product Positioning and Energy Influence

Consumer goods can be further categorised into four broad sectors depending on their price/customer positioning (Economy to Super Premium) and the level of their brand awareness (Appendix 4, Figure 2).

High Brand Awareness / Premium – Super Premium

This sector typically contains the most familiar household products. Products in this sector are highly promoted through advertising, customer promotions and high trade margins given to supermarkets. Branded food manufacturers will generally make good margins from these products and these will form the core of their business. Increases in energy prices for products in this sector have the ability to be at least partially absorbed before being passed on to the customer, as levels of advertising etc. can be reduced in order to maintain price and/or profit margin and to stay competitive with similar branded offerings.

Low Brand Awareness / Premium – Super Premium

Whilst brand awareness may be low to the general population, the brand is very well known and patronised by a specific niche of customers. The marketing positioning tends to be one of exclusivity and luxury, with the ability to charge high prices and make high margins. Niche brands may have reduced promotional support, depending mainly on specific, targeted advertising to their chosen customer base. Energy price rises can be absorbed, at least temporarily, and if eventually passed on to the customer, may not affect the competitive positioning in this quadrant which is typically the least sensitive to price of the four.

Low Brand Awareness / Economy

This is the sector of the ‘value’ own label supermarket brands. They receive no brand support, may be withdrawn at short notice and are marketed solely on being low price. Generally priced at a level that branded manufacturers cannot match, they run on very tight margins and as such are highly susceptible to any change in cost structure such as a rise in energy prices.

High Brand Awareness / Economy

This sector can contain economy offerings from branded manufacturers as well as products that have a high brand presence despite receiving no specific brand support. Prices and hence margins are kept low by competition from own label offerings. Satisfactory margins are available here, although they will tend to be lower than those in the Super Premium – Premium quadrants. Selling prices will be sensitive to changes in energy and other variable costs, with increases being passed on to the customer very quickly.

Typical product cost structures

An example of the likely cost structure of Super Premium and Economy canned tomato soup offerings is shown below. The scenario analysis illustrated assumes a range of energy price increases. The impact on both product offerings has been examined, along with likely coping strategies.

Case Study – Tomato Soup

A typical super-premium product has a sale price of 82p for an individual 400g can. The trade margin given to the supermarket chain is a typical 25%, giving a Net Sales Value (NSV) per tonne of product sold of about £1,538. Raw material and packaging costs are estimated at about 35% of NSV with manufacturing and logistics costs at about 15%. There is a typical charge of about 27% of NSV for advertising and other product promotion and a management overhead cost of 15%. The product delivers a reasonable profit of about 10% of NSV.

A typical economy product has a sale price of 17p for an individual 400g can. The product is a supermarket own label and as such carries no trade margin. Recipe costs are minimised through recipe design and packaging costs (cans) are lowered by using a can without an easy open-end feature. Manufacturing costs are lower, driven by lower wage and maintenance costs, although energy costs are identical. Logistic costs are identical to the Super Premium offering but there is no advertising and promotion and management overhead costs are kept very low. The estimated profit is just over 2% of NSV.

A rise in energy prices will affect many parts of product costing. Producing and delivering raw materials become more expensive, packaging prices are driven higher, especially for energy intensive containers such as cans**.** Manufacturing costs are increased, as are costs in finished goods delivery and storage. Energy cost increases in these areas will produce a decrease in profit for both the Super-Premium and Economy offerings; however their ability to mitigate such increases will vary significantly.

Mitigation strategies

Results from this study show that companies employ a range of risk mitigation techniques when formulating their energy management strategies. These vary for capital projects and day to day running costs. Capital projects invest in equipment that is expected to reduce energy costs. These could include combined heat and power (CHP), waste heat recovery systems, etc. The cost of the equipment will be balanced against the expected savings to identify the benefit of the investment. Various techniques are employed to quantify the benefit, the most popular being payback time and internal rates of return (IRR). Most companies will require a payback of between 2-3 years, although larger companies will sometimes allow ‘green’ projects to pay back over a longer period. Small companies with little spare capital will require investment paybacks to be short and will be reluctant to invest in novel or unproven technologies. Running costs for energy can be controlled through the use of hedging, where energy is bought in advance for an agreed fixed price. Large companies will have in-house expertise; smaller companies will often use third party hedging providers. Companies unable or unwilling to hedge prices must accept the risk of uncertain prices.

In both cases risk can only be mitigated, it can never be removed. Even companies using sophisticated capital evaluation methodologies and hedging specialists can be caught out. Because all methods involve the prediction of future prices for energy, the risk of those predictions being wrong is always present. In the face of an energy price rise, companies wishing to maintain their profit margins could either attempt to pass on the price rise directly to their customer, or absorb the increase through improved efficiency in some area of their operations. In the case of the Super-Premium supplier, fully passing on the increase would mean about a 1% increase in final selling price for every 10% rise in energy cost. Faced with undoubted resistance from major suppliers, often leading to product delisting, a more likely scenario would be for the Super Premium branded supplier to at least partially absorb the increase through a reduction in advertising, management overhead and/or trade margin.

The options available to the economy producer would be limited. Costs could be mitigated by reducing recipe costs; however this may affect the taste or quality of the product. Economy producers typically run very lean operations and reductions in overheads etc. would be at best, modest. Their ability to maintain profit and stay viable would therefore depend on their ability to persuade their customers to accept price rises. In some cases this is possible if ‘open book’ relationships exist between producer and customer, in others, contracts allow price rises to be linked to indexed supply costs (usually restricted to raw materials), albeit with a time delay. The economy producer therefore would be faced with no option other than to try and pass on the price increase, leading to a rise in selling price of 18%. The consumer dependent on low cost products would therefore see a significant increase in their food costs, whereas the purchaser on Super-Premium products may see little or no change in price. Similar analyses have been carried out on bread, packed baked products and baked beans, all of which show the same trend.

Industry Trends

Sector carbon dioxide emissions decreased by approximately 11% between 1990 and 2007. These savings have continued as increasing focus is placed on energy savings and other sustainability issues by manufacturers. However, alongside these positive activities, there are numerous trends that could offset any improvements. These include supermarkets eliminating their warehouse stockholdings, forcing manufacturers to deliver smaller loads for immediate use; an ever increasing demand for food variety and out-of-season foods which have to be imported, smaller pack sizes being produced in response to obesity challenges; continuing use of BOGOF marketing techniques and the increase in both frozen and chilled prepared foods.

Conclusions

The priority of the food industry is the safety, quality and hygiene of the delivered product. Efficient energy use is generally seen as a priority only when prices are high rather than a pre-requisite. There is little preparedness for or awareness of potential food security issues. There is little long-term flexibility in energy sources and the use of alternative energy options, such as wind, has generally been discounted due to cost. The impact from energy price rises on final food costs will vary depending on the marketing positioning of products. Economy offerings having little ability to absorb energy cost increases and will suffer significant price inflation; Super Premium products will see lower inflation as costs are absorbed in areas such as advertising and overheads. Micro businesses are likely to be very badly affected by energy cost increases. Many could go out of business. There is little visibility of total energy costs in finished product cost structures. Most energy costs in a product cost structure are hidden. Further research in this area would be beneficial to food manufacturers and food scientists. Although there are areas of excellence in energy management within the industry, many manufacturers have little detailed understanding as to where their energy is used, a first step to making reductions. Training in energy saving techniques would increase awareness, especially in smaller companies.

Energy Use in Packaging

This section examines the energy use associated with packaging using typical materials: a glass jar, a steel can, an aluminium can, a rigid plastic container, a food carton and a pouch. The assessment takes into account the following aspects:

- Energy use associated with manufacturing (embodied energy of packaging material components and packaging manufacturing energy) while comparing packaging made of 100% virgin materials and materials containing a typical recycled content
- Energy use associated with packaging end-of-life treatment
- Product to packaging ratio of the packaging types studied

The product to packaging ratio is the weight of product against the weight of the packaging. A high ratio results in less material used and less packaging waste generated. Furthermore, it can also yield fuel and CO_2 savings in shipping, by reducing the shipping space required and hence increases the load of product that can fit on a truck. In the best case, it can reduce the number of truck trips required (SPC, 2006). Material choice can play an important role in reducing the environmental impact of a packaging. There is a strong correlation between packaging weight and energy use. Lightweight packaging such as the pouch and carton perform particularly well from an energy standpoint while recyclable packaging (besides steel) performs poorer. Considering energy use and product to packaging ratio at the same time, all recyclable materials perform low except for the lightweight aluminium can.

Increasing the recycled content of packaging material will further reduce energy requirements. Assuming a recycled content in glass of 73%[10] instead of 33%, reduces the energy of manufacturing from 6.33 MJ/500g to 5.39 MJ/500g. Increasing the recycled content of aluminium from 57% to hypothetical 80% would reduce the energy use from 5.67 MJ/500g to 3.46 MJ/500g. This emphasises that recycling of aluminium is indeed very important from an environmental perspective to reduce its high energy levels. Raising recycled material content in steel from 56% to hypothetical 80%, would further reduce the steel can's already low energy requirements from 1.67 MJ/500g to 1.29 MJ/500g. Overall, this shows that even if recycled contents are increased, glass and aluminium will not reach the low-energy use of plastics and composites. Steel however is already in the range of plastics and composites, even at current steel recycled content levels. Taking the energy use and the ratio together, none of the recyclable materials can compete with the low-energy lightweights. Although steel performs well from an energy perspective, it has only a medium-range ratio.

Packaging Design Choice

There are several functional and sustainability aspects, which determine packaging design. The most important is that the packaging works for its primary purpose. The results suggest that a focus on packaging lightweight can improve the energy performance of a packaging but also its product to packaging ratio. Reducing primary packaging weight, though, can lead to the fact that significantly more amounts of secondary and tertiary packaging are required to achieve the same level of protection. Also an increased recycled content, which is originally intended to reduce energy use, can result in a higher packaging weight because for example recycled plastics and paper will need to be thicker to achieve the same level of material performance (the reason why cartons are made of virgin materials in principle). The increased weight can in turn have adverse effects on the packaging's energy performance. These examples show that packaging properties are interconnected and a single focus on one environmental parameter can lead to unintended, adverse consequences in its environmental performance (Envirowise 2008). Therefore, it is important as a product/packaging designer to assess the packaging system as a whole and to make trade-offs between the desired packaging properties.

[10] UK industry average for green glass (WRAP, 2011).

Furthermore, the results on the energy uses should not be used as a single indicator for design. However, by having an overview of the different manufacturing energy requirements of packaging, designers can make informed decisions what packaging type could be most desirable at the conceptual design stage. For an environmental assessment it is rarely the case that one design option performs well in all design criteria. This study showed that a packaging might perform well from an energy and emissions perspective but on the other hand has a low recyclability. In this case, the designer should go for the option, which is in line with the key environmental objective, which is more desirable from a cost-benefit point or which enhances other functional benefits of the packaging.

Shelf-life is the duration that a product is suitable for sale and consumption and is an important consideration, which can affected by the packaging material decision. It is the duration a product is suitable for sale and consumption. Food in a metal can lasts unopened in ambient conditions for several years, while glass, pouches and cartons have shorter shelf-lives of one to two years[11]. The pasta sauce in the rigid plastic container was a fresh, cooled product, which turns bad after a couple of days.

Another aspect for packaging design is customer acceptance and perception. While customers are familiar with buying pasta sauce in a glass jar, they are not used to buy pasta sauce in a metal can for example. Packaging is also a means of communication with the customer: directly via the information provided on the container but also subliminally by conveying an association of product freshness. While cans are particularly bought because of their long-life, people would rather buy a cooled, uncooked product if they want a healthy meal. Hence, the cooled product in the plastic container would be a preferred option. In addition, packaging communicates a product image. A high quality wine is sold in a glass bottle for reasons of marketing (tradition and consumer expectation), even it is more environmentally friendly to pack it in a carton. On the other hand, a low-quality wine can be purposely packed in a carton to communicate to the consumer that it is a low-budget product.

Energy use in warehouses

In terms of operating temperature, warehouses can be split into three groups; ambient, chilled and frozen. Ambient warehouses typically can run with a wide temperature range without damaging the contents of the warehouse. There is therefore no provision made to control warehouse temperature during a power disruption.

Frozen warehouses are designed to keep product cold with a minimum of top up energy required to drive refrigeration systems. If power is lost, a frozen warehouse will maintain a low temperature for a considerable time without extra cooling, particularly if it is full, due to the thermal capacity of the product in the warehouse. To maximise the length of time the product can be protected, warehouses will close all doors and any other potential sources of heat-in leak. Chilled warehouses will require back up cooling quicker than a frozen facility. Common practice is to seal the warehouse similar to the process carried out for frozen in the expectation that the loss of power will be a short term one. A more detailed description can be found in annex 5.

The decision to provide permanent back-up generators for temperature control is made by the warehouse operator and the practice for doing so varies between facilities. Many warehouses operate with no back up, arguing that the infrequency of long term power cuts renders such provision unnecessary. Less frequently, operators will install diesel powered generators designed to maintain warehouse temperatures, even in the case of long term

[11] Based on the pasta sauce packaging studied.

energy failure. All warehouses, ambient, chilled, frozen, fully automatic and manually operated, will have provision for power back up to support emergency lighting, security, alarm systems, vital air conditioning etc. This is usually supplied by batteries and is a short term solution providing power for an hour or so. Where not available on site, longer term emergency backup for essential services can usually be provided within 5 hours of supply failure. In the case of a fully automatic warehouse, back up may be able to maintain warehouse temperatures, but is unlikely to allow normal operation of cranes etc.

Wind turbines are being used in the Netherlands to provide electricity to drive cooling compressors, effectively a method of storing generated electricity as cooling. No evidence has been found to suggest that this technique has been taken up in the UK yet.

Energy Awareness within Business

An awareness of energy issues is a prerequisite to taking action to reduce energy use or mitigate disruptions to supply. To explore the levels of energy awareness within the agri-food processing and manufacturing sector, a two-part investigation was undertaken.

1. A 12 part on-line questionnaire. This was directed separately at SMEs and bigger businesses
2. A detailed interview with selected businesses

The on-line survey was initially targeted to SMEs belonging to the Food and Drink Federation (FDF) but this was later extended to include all the members of their Climate Change Agreement scheme. The invitation to complete the survey was sent via the mailing list of the FDF and it included the link to the survey available on the University of Warwick website. The initial request was backed by an email reminder one month later. In total more than 600 companies were contacted between July and October 2011, out of which 24 survey responses were received (a 4% response rate). Twenty major companies were interviewed either by phone or via a factory visit. The companies chosen for the survey are recognised industry leaders and are involved in the manufacture of a wide range of products, using many different processes. Manufacturers of ambient, chilled and frozen food were included in the survey.

The response to the on-line survey was very disappointing and the lack of replies clearly limits the quality of the conclusions that can be drawn from the completed surveys. However, the response rate clearly demonstrates that, from those surveyed, most companies don't feel sufficiently concerned or motivated about energy issues to respond. Indeed, a number of SMEs stated that they were not interested in completing any survey on energy awareness despite the survey being distributed by their trade association.

Although the response was poor the replies were fairly consistent and demonstrate that respondents are aware of the general issues surrounding the cost of energy but there appears to be little concern over disruptions to supply. It is possible that individual companies, especially SMEs, do not feel sufficiently empowered to act on this awareness and therefore to improve their current situation. The overall impression is that current market conditions and regulatory framework make it difficult for any one company to influence energy supply and price which subsequently discourages individual action. Overwhelmingly, respondents felt that Government had the responsibility to ensure that energy infrastructure was adequate but that the price of energy should be determined by the market (within current regulation).

Respondents were concerned over the cost of energy but that concern is mitigated to some extent because any increases in the cost of energy will be borne by the whole agri-food sector. In the final analysis, increased energy costs will be passed on to the consumer. Companies manufacturing ‘basic’ low-value and own-brand products for the multiple retailers are in the most difficult position since it is harder for them to pass the costs on; the strategy to lower their cost base will be to use cheaper less-nutritional ingredients which will subsequently may affect the health of their customers. Companies producing branded products are likely to pass the cost on.

Many companies would like to ‘go green’. However, the competitive nature of the industry means that for the majority, the pay-back periods for alternative forms of energy production are too long to consider. It is likely that the agri-food supply chain is polarised with regard to new sources of energy: at one end are the companies driven by the green agenda who are ideology driven and are selling a premium branded product and at the other are the multiple retailers who control the majority of the supply chain; they have the capital but are shackled by their financial model and the competitiveness of their market place. In the middle is everyone else; many would consider renewable energy within their own sustainability agendas but are unlikely to provide much take up in the current financial situation (both general economy and targeted grants).

The detailed interviews revealed that there is widespread concern in the food industry over the increasing cost of energy, particularly from non-branded or own label manufacturers (the interview process illustrated that respondents are far more open and willing to provide information compared to trying to collect it through an on-line survey). However respondents do not feel that Government has a responsibility to cap prices, rather taking the view that their key role is the provision of adequate infrastructure and to ensure that a competitive environment exists between energy suppliers. The impact of an energy price increase on manufacturing and logistics costs is well understood, however, the relationship between energy costs and raw materials less so, particularly in factories processing a wide range of ingredients. The relationship between energy costs and packaging was poorly understood. Controlling energy costs was a major priority for all respondents. Common actions included the provision of basic training in energy saving techniques across the workforce, hedging energy purchasing and gaining an understanding of energy usage in their factories through metering etc.

In terms of energy availability, gas supplies were felt to be more secure than electricity with only a third of respondents feeling supplies could be at risk. Electricity supplies were felt to be more vulnerable with about half of those interviewed expressing concern over supply continuity. In both cases a sizeable minority claimed to have no concerns over supply, indicating a clear difference of opinion between manufacturers.

All respondents had considered using alternative energy sources. About half of respondents had either installed a form of alternative energy or were considering doing so. Most popular installations were Anaerobic Digestion (AD) systems (either owned or third party) followed by Combined Heat and Power and wind turbines. Solar Power was the least popular of those considered, with most respondents rejecting installation on cost grounds. Heat pumps and solar heating were the least well-known options with a third of respondents not having examined their potential. Energy reduction initiatives were invariably driven by the opportunity to save costs. It is reasonable to expect that the focus will reduce should energy prices fall, however in a few cases (usually branded market leaders), the motivation for such activities was more altruistic – ‘doing the right thing’, ‘supporting the corporate agenda’, etc. About half or respondents were also responding to retailer pressure to adopt a ‘green agenda’. The full results are available in Appendix 4.

Food Company Benchmarking

Twenty companies were interviewed in order to examine their approach to sustainability, energy reduction and energy security. The companies interviewed included major manufacturers of processed meat, coffee, bread, ready meals, soups, sandwiches and pizzas. A major retailer and logistics company were also interviewed.

Energy usage

In all cases factories used gas and grid electric for their major power sources. The split between gas and electric (where known) was quoted as being about 60-75% in usage terms (gas: electric) and 25-40% in terms of cost. There were no cases where energy supplies were protected by a specific non-interruptible supply contract. It was assumed that the availability of energy would always be secure, with the biggest risk being on securing energy supplies at an advantageous or at least predictable price. There was consequently a focus on energy procurement, with all companies reviewed using hedging techniques for their purchases. In most cases energy procurement was out-sourced (see also ‘mitigation strategies’, below).

Alternative renewable energy technologies

The use of alternative renewable energy technologies decouples the link between energy cost and international fossil fuels based wholesale markets. Costs are loaded towards capital repayments rather than the continual revenue stream required to support the purchasing of energy. Therefore if a business chooses to integrate renewable energy technologies into the business, it is likely to isolate the business, to some extent, from the ups and downs of the energy market. Alternative energy sources such as wind, solar etc. had been examined by all companies interviewed. However it was clear that in some cases the examination was done in order to be seen ‘to be doing something about green issues’ rather than as a part of a serious alternative energy supply strategy.

Wind: In most cases electricity generated from wind turbines had been examined and quickly dismissed as being inconsistent with company financial payback constraints. Wind power was being implemented in one case studied, using a third party supplier who installs and runs a turbine on site, delivering electricity at a price guaranteed to be below grid prices in exchange for the value of the Renewable Obligation Certificates produced.

Solar: Small-scale solar projects had been implemented by those companies with a keen interest in pursuing a green agenda. They were implemented as a learning exercise rather than as a project to deliver significant savings. Most companies had dismissed this form of energy source after a quick cost/benefit analysis and had no plans to re-examine the option until the payback time for investment could be reduced.

Combined Heat and Power (CHP): CHP had been examined by most of the companies surveyed and installed by two of them (one small scale). The ratio of heat to power produced from CHP proved to be a hurdle in some processes and in others financial constraints could not be overcome.

Anaerobic digestion (AD): AD was installed in one company and was being seriously examined in another. Constraints to installation were quoted as payback time and insufficient fuel source.

Other: The level of investigation into green alternatives for energy supplies was linked to the enthusiasm in general for green issues found in the company. Companies where there appeared to be large scale engagement on sustainability issues from management and/or the workforce in general, tended to be more tenacious in their attempts to install green technologies and quoted examples such as wood burning boilers, LPG trucks, tri-generation, burning of waste bi-products etc. Those companies were usually active supporters of other sustainability initiatives such as packaging reduction, water usage management etc.

The larger the company, the more funds are likely to be available for experimentation and carrying out projects ‘to learn’ rather than ‘do’. Similarly large companies may use sustainability initiatives primarily to meet consumer demands as part of a broader marketing story. Small and micro companies rarely have the financial flexibility to try unproved technologies, or those that are unlikely to offer a satisfactory payback.

Energy flexibility – ability to change energy source

All companies had the ability to change the energy source for their main boilers from gas to oil. Similarly short-term production of electricity using stand-by diesel powered generators was common. The ability to change major process equipment such as gas ovens etc. was generally absent. Equipment choices were based primarily on process and financial criteria rather than use of energy or flexibility of energy source. Full details and results of the energy awareness survey and interviews can be found in Appendix 4.

Conclusions for Objective 4

The first step in being prepared for any increase in energy prices or reduction in energy availability is to gain an understanding as to where energy is used and how big an impact energy costs have on the viability of a business. In both areas the response of the food industry is patchy. Whilst this could be expected in such a disparate industry, there is no link between the size of a business and its response to the energy challenge. The research showed that small businesses are far ahead of their larger counterparts in tackling the issue and even amongst industry leaders great differences exist in levels of training and general awareness. Awareness education and technical training programmes are an on-going need to bring the subject to as wide an audience as possible within the industry. The challenge now facing the industry is how to deliver the same change in attitude towards energy and sustainability that has been successfully done with safety, which are now accepted in the same way as quality always was – a pre-requisite for responsible food manufacturing.

The impact of energy prices on product selling prices is often obscured. In the examples examined in this study, the Super-Premium offering had a visible energy cost of about 1.2% of NSV. However hidden costs of energy in areas such as raw materials, packaging production costs etc. lifted the total impact to an estimated 7% of NSV. In the economy offering the impact is even more dramatic with the visible energy cost of 4.5% NSV being increased to a significant 17% NSV.

Overall Project Conclusions

Although the food supply chain is hugely complex, its interactions with energy are relatively simple. At a basic level the UK's food supply is almost completely dependent on fossil energy; the type may vary and its use may be direct or in-direct use, but any change to the supply of energy, whether that is a disruption or increase in price, will have serious consequences for the supply, and quality, of food.

An examination of the embedded energy values of different food types confirms what is already known from other resource use studies. Different food types require different levels of resources to produce and simple foods (fresh fruit and vegetables) require less resources to produce compared to more intensive and complex foods (meat and processed products). A diet which favours fresh fruit and vegetables requires less energy that one which is high in meat or processed foods. However, diet is not judged on energy intensity but on many other parameters and more thought could be given by the industry in general to promoting products with small energy footprints, coupled with maximising financial return..

Business rarely knows the quantity and cost of in-direct energy either upstream or downstream of their own operations. Exceptions to this are completely vertically integrated businesses (e.g. farm shop) or those who have an agreement with other parts of the supply chain (e.g. liquid milk industry) where the data is used to guarantee a 'fair' return.

Food and drink business know the cost of direct energy since it is a quantified input into their business and can affect their financial performance. However, as the survey demonstrates, the cost of energy is rarely the most important factor within business thinking. The food industry's position is, quite rightly, dominated by quality and safety concerns which over-ride all others. Only at the value and own-brand end of the market does the cost of energy become an important factor and when this happens, the quality of ingredients declines to maintain a financial margin. Any increase in the cost of energy will, in the long term, be passed on to the customer and therefore affects all businesses. Businesses generally have no concerns over the supply of energy and rely on Government to provide the necessary infrastructure to ensure supplies. Only a very limited number of businesses (mainly farms with animal welfare concerns or companies with cooled or frozen supply chains) have either back-up generation or alternative forms of generation. Where an alternative supply is not critical, the capital cost, extended payback period or lack of financial security prevent firms from investing in alternative and new technologies. There is no doubt that the very competitive nature of the food industry and the short term nature of investors and the capital markets make long-term business planning in energy very difficult.

Forecasting is an inexact science but there is no doubt that UK production of food is likely to increase in the future. The drivers are clear: the UK has an increasing population and is only 72% self-sufficient in indigenous food[12]. Given the current debate on food security,

[12] Defra – Agricultural Statistics in your pocket 2009

and even in the absence of an official policy, it is unlikely that Government would want to see that level of self-sufficiency fall. The result must be an increase in production and therefore demand for energy. This demand is likely to be magnified since food products are becoming more energy intensive, both in their processing and packaging stages, where innovation can extend shelf life. The increase in demand for energy will be spread across all stages of the supply chain and from both in-direct and direct sources but is unlikely to be even.

In percentage terms, and for most products, primary production requires the largest amount of a product's embedded energy value. Nitrogen fertiliser and then diesel fuel account for the majority of energy use but making efficiency gains in these areas will be difficult if greater production is required to meet an increased demand. The energy required to produce a unit of nitrogen fertiliser has fallen consistently with the introduction of new technology and processes but the capital costs are high and the current economic situation makes large-scale investments more difficult to justify. Sustainable intensification is seen as the key to greater production while using the same or less resource but will be difficult to achieve when production must be balanced against competing uses for land. It is likely that further agronomic efficiencies are possible but these are being hampered by a lack of applied research and development.

There is still great potential to save direct energy within the processing and manufacturing sectors but the easy gains have already been made and further savings will require investment in new technologies and capital equipment. Anecdotal evidence suggests that savings of between 10 and 20% are possible but only likely to be realised in a more stable economy, and perhaps less competitive market, where more businesses are able to take a longer term view on returns on investment.

The high price of road fuels has driven efficiencies in the road transport sector and while there are still undoubtedly savings to be made, they are becoming more difficult to fine. Again there is anecdotal evidence that supermarket promotions have actually worsened the position in recent years and that some of the original savings in this sector have been compromised. The just-in-time delivery model combined with aggressive promotions may actually be detrimental to both energy savings and stocking rates as it has become increasingly vulnerable to disruptions in fuel supplies.

The last twenty to thirty years have seen great advances in energy efficiency within the industry but savings are now harder to find at a time when demand is forecast to increase. It is likely that we are reaching another milestone when efficiencies cannot keep ahead of increased demand for energy and that as we go forward, we will need to ensure that the supply can keep up with demand. While Government can introduce measures to influence demand their primary role is to ensure adequacy of supply. All businesses consulted as part of this study indicated that they regard the Government as having a dual role: to enable the energy industry to work within a structured market and to ensure infrastructure is in place.

Recommendations for Future Work

- To integrate this area of research into Defra and WRAP's Product Research Forum to provide a joined up approach to product development and energy saving. A number of respondents commented on the number of related initiatives and suggest that a common forum was required. They recognised the value of this and other similar work but felt that its value to industry was undermined by a lack of an overarching structure through which results could be communicated and change could be made. One suggestion was to feed the results of research through the existing Product Sustainability Forum. The Food Supply Chain Mitigation Working Group could also be considered.
- To update the embedded energy values for nitrogen fertilisers and determine how the source of these fertilisers contributes to the UK's energy consumption. This research has demonstrated the very large contribution that the manufacture of nitrogen fertiliser makes to indirect energy use but the actual values used in these types of study are mostly based on a single source – Jenssen and Kongshaug (2003). It is known that embedded energy values per fertiliser type have been declining as a result of increased efficiencies in production and it is likely that current estimates are too high. It is also important to understand how UK production, and therefore energy requirement, compares with imported fertiliser.
- To quantify the energy 'saved' by importing energy intense products and commodities and explore the contribution made to global greenhouse gas emissions. The UK imports a considerable amount of its food and drink requirements and therefore 'saves' energy compared to a higher level of self-sufficiency.
- To explore how manufacturing inflexibility, new product development, food safety, logistics and customer preference influence packaging formats. This is a hugely complex area but every one of these parameters will influence not just the embedded energy value of a product's packaging but will interact with other aspects of the supply chain (logistics especially) and influence their energy use as well. It would be useful to commission a project to investigate a number of case studies to establish the relationships between these parameters how optimum solutions can reduce energy use across the whole supply chain.
- To explore the possibility of promoting reuse, rather than recycling, of glass jars and determine the energy requirements in comparison to using virgin materials. A life cycle assessment should be undertaken to quantify the energy use of different packaging types and how they vary between the use of virgin materials, reuse of existing packaging formats and recycling of packaging materials. The principal material is glass and this would fit into WRAP's remit.
- To investigate the relationship between 'value' own-label products, energy cost, product cost and the nutritional quality of food. As a society we tend to judge value from a financial or economic basis but other approaches are possible, perhaps even desirable. To examine whether the continuing pressure of prices, especially within the 'value' sector, has resulted in the nutritional 'value' of food declining as cheaper and less nutritional ingredients are specified.
- To understand the strategic nature of food production in relation to the supply of natural gas. The production of certain key food items, principally bread and other baked items, relies on gas fired ovens. If shortages or disruptions to supply where to become common, it is important to understand how this affects production and consequently supplies to consumers. Bread is one of our staple foods and has a relatively short shelf and eating life and would be affected disproportionally should gas supplies be interrupted.

- To investigate the consequences that would arise from disruptions in the supply of diesel to primary production and just-in-time logistical systems. It is important to understand the effect of disruption to primary production and distribution. The potential impact was perhaps illustrated best in the 2004 blockade of fuel distribution centres with a reminder in 2012 when the threat of industrial action by tanker drivers caused temporary shortages of some road fuels. Although both the big transport companies and farms hold stocks of diesel, these could be exhausted quickly at busy times of the year so it will be important to understand where the pinch-points in the supply are.
- To review the relationship between major companies and SMEs and how best-practice is disseminated with the agri-food sector. SMEs, for a number of good reasons, do not, or are unable to, adopt industry best practice very quickly even though many organisations and routes exist for dissemination of information. We recommend that a case study review is undertaken to explore why best practice is not adopted quicker by SMEs and to identify solutions where by big business can assist the SME sector.
- To investigate the motivation of companies with regard to the adoption of alternative energy generation and explore how changes to regulation might encourage greater adoption of new technologies in the future. Food and drink businesses have, in general, been slow to adopt alternative forms of energy generation. To encourage a greater take up of new technologies it is important to understand the barriers to adoption that exist and how they may be overcome. We suggest a project to survey a range of businesses which will describe the barriers to adoption and highlight those companies that are trend setters in the adoption of alternative technologies.

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