A SUMMARY OF FOOD AND LAND USE POLICIES PROPOSED IN

THE ZERO-CARBON BRITAIN SCENARIOS.

*I am indebted to Laura Blake for much of the data in this article.*

The food we choose to consume is responsible for about one fifth of the UK’s carbon emissions, or 152MtCO2e. This is a sector of the economy where the overall goal of ‘zero emissions’ cannot be fully achieved, yet we need to aim at something like 20MtCO2e. This is a very large reduction. How can it be done?

The total breaks into three parts (see Figure 1):

Figure

* production on UK farms,
* processing, distribution and consumption
* imports

The processing component is almost entirely due to energy requirements, and this is reduced to zero by the processes described in the rest of this report. That is the easy part!

In the UK, agricultural emissions amount to 63.4 MtCO2e. Of these emissions, 16.2 MtCO2e are released in the form of carbon dioxide (CO2), 18Mt CO2e are released as methane (CH4) and 29.2 MtCO2e are released as nitrous oxide (N2O) (UK Environmental Accounts, 2012). The proportion of emissions that is not related to carbon dioxide therefore, especially when compared to other sectors, is unusually high. This presents a unique challenge, since the non-CO2 greenhouse gases are much harder to reduce.

Figure

The approach adopted is a systematic shift of balance from high-emitting to low-emitting foods, and this inevitably entails a change in the pattern of UK diets. The same approach also reduces emissions from imports. The result is shown in Figure 2.

A change in the balance of foods immediately raises the question of whether the resulting altered diets are adequate in terms of quantity and quality. In particular, are they healthy?

CREATING A BETTER DIET

The food we eat has a strong impact on our health and wellbeing. Consumption of an unhealthy diet over the long term can lead to many diet related diseases such as diabetes, obesity and heart disease (Valela-Silva *et al*, 2007). The scenario aims to identify dietary patterns that are healthier than those of today, while generating much lower levels of GHGs at the production stage. Is this possible?

The method used to test this is fairly simple. The UK government collects dietary statistics in the form of the National Dietary and Nutrition Survey, using about 50 basic food categories. A wide range of scientific studies has analysed these categories in terms of both their health implications and greenhouse gas emissions (GHGE). The list (which we modified very slightly from the original) is given in the sidebar on the next page.

These food categories, and their health and GHGE scores, are the key tool. They generate a statistical ‘average’ British diet against which we can measure different kinds of actual diets, or theoretical extreme or idealised diets. It is fairly easy to represent specific kinds of diets by altering the quantities of different foods. These altered quantities of course generate their own health and GHGE values, and these guide the search for ‘new’ diets that are both healthy and low-emitting.

It is useful to represent some of these results in the form of a ‘scattergram’. In this graph, carbon emissions are higher towards the top, while health scores are higher towards the right. The average UK diet today is shown in yellow.

The GHGE scores are represented in terms of the implications for the whole UK emissions “if everybody ate that diet”. The ‘average diet’ therefore represents the total emissions of the UK food system as shown in Figure 1: production, processing and imports, about 150MtCO2e a year.

Figure

The nutritional value scores are derived from a nutritional profiling system developed by the Food Standards Agency. This generates both positive (less healthy) and negative (more healthy) scores. As an extra check each diet is assessed for energy and protein content to insure that it would in principle be a viable human diet. A yet further check is to ensure a reasonable balance among the four different food groups in the NDNS list, approximately following the recommendations of the ‘Livewell Plate’ (MacDiarmid et al)

Here are some comments on these results. The most important observation is that diets with a higher proportion of livestock products have higher carbon emissions. This is a widely-observed effect and not really a surprise. But it is striking that on the whole the low-livestock diets also score better in terms of nutritional health. The overall result is that there is a fairly strong negative correlation between health and emissions. This is been noted before (Poli, 2009) but is not widely accepted as a useful generalisation.

|  |
| --- |
| Pasta |
| Rice |
| Other cereals |
| White bread |
| Wholemeal bread |
| Soft grain (White) |
| Other bread (Brown) |
| High fibre breakfast cereals |
| Other breakfast cereals |
| Oven baked potato products |
| Other potatoes dishes |
|  |
| Greenhouse-grown salads |
| Other UK - grown fresh salads |
| Seasonal UK vegetables |
| Imported vegetables |
| Seasonal UK fruit |
| Imported fruit |
| Fruit juice |
|  |
| Whole milk (3.8% fat) |
| Semi skimmed milk (1.8% fat) |
| Skimmed milk |
| Cheddar cheese |
| Other cheeses  |
| Yoghurt |
| Fromage frais and dairy based desserts |
| Non-dairy milk-like products |
|  |
| Eggs |
| Egg dishes |
| Beef, veal and dishes |
| Lamb and dishes |
| Pork and dishes |
| Bacon and ham |
| Sausages |
| Chicken, turkey and dishes |
| Coated chicken and turkey |
| Liver and liver dishes |
| Burgers and kebabs |
| Meat pies and pastries |
| Other meat (game, offal, etc) |
| White fish including fish fingers |
| Other white fish and canned tuna |
| Shellfish |
| Oily fish |
| Meat alternatives |
| Beans and legumes |
| Nuts and seeds |
|  |
| Biscuits |
| Buns, cakes, pastries  |
| Puddings |
| Dairy Ice cream |
| Cream |
| Butter |
| Margarine and other fats and oils  |
| Savoury snacks  |
| Savoury sauces, pickles, condiments |
| Soups |
| Fried or roast potatoes |
| Sugars, and preserves |
| Sugar confectionery |
| Chocolate confectionery |
| Soft drinks  |
| Spirits and liqueurs |
| Wine |
| Beer, lager, cider and perry |

While ‘lower livestock’ is a good rule of thumb, it does not necessarily imply vegetarianism. What we called the ‘substitute vegetarian’ diet that simply replaces meat with an equal quantity of eggs and dairy products, was not much better than average. The ‘Junk-Food Vegan’ by definition avoids all livestock products, but if the diet consists mainly of snack foods and sugary drinks, health will deteriorate. At the other extreme what we called the ‘Gorilla Diet’ (consisting entirely of fruit and vegetables) seemed much healthier but did not contain enough protein to be a viable human diet. This is therefore coded black in the graph: all other diets are adequate for survival.

The exercise also modelled the effects of over-eating and moderate eating, but with average proportions of food categories. The ‘Glutton’ eating 20% more, and ‘Eating Less’ with 20% less showed strong effects on both emissions and health. Finally we modelled a hypothetical ‘carbon aware’ consumer who as well as making low-carbon food choices, reduced processing and other post-production emissions by various behavioural means. There was a four-fold difference in emissions between this ‘Best Behaviour Minimiser’ diet and the ‘High meat and Dairy’ diet at the other extreme.

There is noticeable cluster of diets in the bottom right quarter of the graph, pointing the way to further explorations. They are all low-livestock-product diets, but not necessarily ‘vegetarian’.

Why should livestock products have a disproportionate effect on the emissions associated with diets? It is because, for physical reasons of energy-conversion they tend to be relatively unproductive compared with crop products. This is summarised in Figure 4, where the green bars represent output, the black bars GHGE per unit of production. It is immediately obvious that the crop commodities (shown at the top) have high outputs and low emissions, while the livestock commodities (bottom) tend to show the opposite pattern. There are some exceptions: rice is a relatively high emitter on account of methane emissions; protected (greenhouse) crops are high emitters on account of the need for heating, currently done with fossil fuels. A food-decarbonisation scenario needs to take all these factors into account.

Figure 4

Figure 5

It must be remarked that measuring agricultural commodities simply in terms of raw yields could be misleading, since not all have equal nutritional value. However the meaning of ‘nutritional value’ is imprecise: it could refer to dry matter, to calories, to protein, or to a wide variety of other metrics. A composite nutritional metric is used below, and if this is used as a measure of unit output Figure 4 looks much the same.

Figure 5 summarises the same data in a different way. The disparity between productivity and emissions of livestock versus crop commodities is very striking.

LOW-CARBON DIETS IN A WORLD OF DECARBONISED ENERGY

Using the insights gained from modelling the situation today, how can we model low-carbon diets in a Zero-Carbon Britain scenario set twenty years in the future? The key difference is that the energy system is presumed almost 100% decarbonised, and therefore virtually all emissions ‘after the farm gate’ are reduced to zero. We are left with the production emissions only, currently consisting of 63MtCO2e in the UK and 29MtCO2e overseas.

Food production emissions come in the form of three greenhouse gases, CO2, methane CH4 and nitrous oxide N2O.

Carbon dioxide is emitted from fossil fuels used agricultural machinery and vehicles to transport goods, as well as from other things such as refrigeration and fertiliser manufacture. Only 7% of UK agricultural emissions are produced from burning fossil fuels. This amounts to 4.6MtCO2e per year (UK Environmental Accounts, 2012) and can be discounted in the scenario.

CO2 also arises from soils according to their treatment, especially when there is a permanent change of use, for example converting pasture to arable land by ploughing.

Methane (CH4) gas is released from cows and sheep as they digest grass and forage, and from the manure they produce. These processes account for 24% of the UK’s agricultural emissions (UK Environmental Accounts, 2012). UK agricultural emissions are higher than the global average, as much more of our agricultural land (61%) is used for grazing.

Methane is also released during paddy rice production. This makes up about 5% of global agricultural emissions (Millstone and Lang, 2008) and at present rates of consumption in the UK is responsible for about 2MtCO2e per year.

42% of the UK’s agricultural emissions come from direct N2O released from soils (UK Environmental Accounts, 2012). Most of this is derived from mineral nitrogen fertilisers applied to increase crop yields. Not all nitrogen fertiliser that is used is taken up by the crops it is intended for. What remains is broken down by bacteria in the soil and releases nitrous oxide (N2O) into the atmosphere (Di and Cameron, 2012).

Nitrogen fertilisers are used on grassland for grazing, on feed crops, and on crops for direct consumption. Nitrogen is also provided by the use of legume crops such as clover and field beans, but this nitrogen too can be released as N2O, so unfortunately switching to ‘organic farming’ practice does not solve the problem. N2O is also released during the production of nitrogen fertilisers, and by animal manures.

In the light of these observations, is it possible to design an ‘ideal dietary range’ for the future? From a GHGE perspective:

* Reduce the proportion of livestock products overall, and especially beef, lamb and dairy products
* Reduce the quantity consumed to a healthy optimum
* Increase proportions of fresh vegetables and fruit, especially seasonal
* Increase plant-based protein sources
* Increase proportion of UK-grown cereals, and reduce rice consumption

From a health perspective:

Solutions to diet-related poor health outcomes:

* *Reduce over-all food intake*

Essential criteria (adapted from NHS recommendations)-

* provide enough fruit and vegetables to meet with 5-a-day recommendations,
* that cereals make up a third of the diet
* that unhealthy foods that are high in fats, sugar and salt to not exceed 10% of the daily calorific intake,
* that red and processed meat do not exceed 70grams per day

Ideal criteria (adapted from NHS recommendations)-

* that wholemeal cereal varieties are favoured where possible
* to increase *plant* protein sources such as beans and pulses, which are much lower in saturated fats
* that fat intake from foods such as oily fish, nuts and seeds and vegetable oils outweigh intakes from foods such as butter, cheese, crisps, sweets, biscuits, cakes and chocolate
* that battered and fried chicken consumption is less than other forms of chicken

It is notable that, as expected, the health and emission criteria overlap.

THE ZCB DIET

The ‘new average diet’ that emerges from the above guidelines has the following characteristics:

2400kcal per day for an estimated 71m population

89g per day of protein (relative to a guideline level of 60g)

Good balance between different food groups

A Nutritional Profile score of -3880

The average diet within the ZCB scenario has been designed to meet all nutritional standards. Within this scenario, Nutritional Profile Scores (NPS) were used as a guide to decide which food groups the UK diet mix could contain less of. The levels of unhealthy (high scoring) foods were decreased. Among the recommendations regarding a balanced diet, the proposed diet meets four out of four ‘essential’ criteria and five out of five of the ‘ideal’ criteria. The current average diet of the UK only meets one out of the four essential criteria (the criteria for cereals) and two out of the five ideal criteria (for more information on this see the solutions section above). The total nutrient profile score for the current UK diet is 2542; whereas the ZCB scenario average diet scores -3882 (negative scores are healthier). When broken down by category the score for the current diet and the ZCB scenario diet are as shown in Table 1. Note that the conventional five categories have been replaced by four, since ‘dairy’ and ‘meat’ and ‘meat substitutes’ have been combined into single category of high-protein foods.

Table

|  |  |  |
| --- | --- | --- |
|  | Current diet | ZCB scenario diet |
| Cereals | -34 | -213 |
| Fruit and Vegetables | -1283 | -3645 |
| High Protein Foods | 1256 | -873 |
| HFSS Foods | 2603 | 848 |

The balance of the categories in the scenario is shown in Figure 6. In general this follows the pattern of a ‘wonky CND symbol’ and almost any ideally healthy diet will be close to this pattern.

Figure

The diet within this scenario is not meant to be prescriptive. It is an *average* diet, and is compared against the *average* UK diet from the 2001 National Diet and Nutrition Survey (NDNS). These average figures do not reflect the differences in recommended intake between men and women for example, or between those of different age groups. It can, however, still be used as a guide to promote good health and highlight best practice.

Around this ‘average diet’ an infinite variety of personal choices can be made.

ALTERNATIVE DIETS IN ZCB3

It is fairly easy to determine that the new average diet is healthy. But translating it into carbon terms is more difficult. The reason for this is that Carbon Emission Factors for foods as consumed are calculated on the basis of today’s data and include all the processing emissions. We have data for the production of farm commodities, but it is not always straightforward to match complex mixed foods on a plate to raw commodities back on the farm, where the scenario emissions are now exclusively located.

Nevertheless this process has been attempted, and allows us to create a provisional scattergram for diets in the scenario (Figure 7).

This chart is similar in some ways to Fig 3, but there are also dramatic differences.

* *All* diets have lower emissions on account of background decarbonisation of the energy system, and other measures
* The new average is around 17 MtCO2e, with a range of “good” diets clustered round it
* The new average has half the emission level of the 2010 average, and is markedly healthier.
* “Bad” diets are still possible—any diet is possible—but would be constrained by scarcity and prices
* It is easily possible to be ‘better’ than the average, especially in terms of health, but these would be individual choices
* Apart from the new average, two new diets are modelled:
	+ New average with provision for a weekly traditional ‘Sunday roast’
	+ ‘Laura’s Diet’, a nutritionist’s calculation of best practice

Figure

LAND IMPLICATIONS

At this point we are confident that healthy and very-low-carbon diets can be created. The unanswered question is whether the UK agricultural system can deliver them. In particular, what are the land implications?

Crudely there is a simple question: is there enough land? More significantly, is there enough land *of the right kind*? In a shift away from grazing and towards arable cops there is a danger that grassland, with its large stores of organic carbon, will be ploughed up to provide more arable land. The loss of carbon in the ensuring twenty years or so can be very large and negate at least part of the benefits of the switch from livestock to crop products.

Unfortunately it is quite difficult to match raw commodities with food as consumed, since the pathways are so varied and complex, and since materials and water are constantly being combined, added and subtracted. It is problematic to say that commodity mix *x* can ultimately generate consumed food *y*; or conversely that consumed food mix *x* can be supplied by commodity mix *y*.

Nevertheless this linking must be attempted or the scenario cannot be fully credible. Very broadly, the quantitative flow of biomass through the UK system, including imports, is represented by figure 8. There are considerable losses as biomass moves from stage to stage.



Figure 8: Flow of biomass through UK food feed and timber systems

In attempting to assess areas needed we have created two models, one working from the foods consumed back through to required commodities, the other working from modified commodity outputs to generate adequate levels of calorie, protein and other nutritional requirements. Making allowance for considerable uncertainties, the two sets of land use estimates in kilohectares match fairly well (Table 2)

Table : Areas required (kha) for various commodity types according to two methods of calculation

|  |  |  |
| --- | --- | --- |
|  | Forward from commodities | Backward from foods consumed |
| Cereals | 1870 | 1600 |
| High-Protein foods | 530 | 300 |
| Fruit and Vegetables | 1390 | 1300 |
| Oils | 600 | 200 |
| Grazing land | 2270 | 2800 |
| Overseas area | 1100 | 1200 |

Both show that an excellent diet can be obtained from the existing arable area of the UK, and that there is no need to convert pasture to arable land. Both scenarios allow a certain amount of imported food, but this consists largely of ‘luxury’ items such as tropical fruits, coffee tea and chocolate, and some items that can be produced less carbon-intensively overseas.

Figure 9: Total food area about 8 million hectares

The approximate allocation of areas to uses in the scenario is shown in Figure 9

About half of this land is allocated to crops, and half to livestock. As it happens there is enough existing arable land in the UK to meet all the requirements without having to convert grassland to arable.

The net result of these changes is that the UK can meet its food needs with only half the present agricultural area.

The greatly reduced allocation of land for food frees up around 8Mha for other purposes in the scenario: for woodland, recreation, ecosystem services, carbon sequestration, industrial feedstock and energy crops. The ‘residual’ level of GHGE from the food system is around 20MtCO2e, assuming that no special measures are taken to reduce emissions further.

Could emissions be further reduced? They almost certainly could, but that would depend on the success of various technical measures now being explored. A thoroughgoing decarbonisation programme would concentrate research in these areas, and it seems reasonable to expect a certain degree of accelerated progress.

The two most important processes are the reduction of methane emissions from ruminants, and the reduction of nitrous oxide emissions from soils. These are the principal sources of residual GHG. Considerable research is being undertaken in feed additives and other measures that already report reductions of over 10% enteric methane. Meanwhile nitrification inhibitors are reported to reduce N2O emissions from soil by a similar amount. If research continues on these processes, it is likely that reductions of emissions from the food sector would be at least 25% lower than those calculated now, and probably more.

Incorporating some of these technical advances into the existing scenario could mathematically reduce agricultural emissions down to about 12 MtCO2e/year, but this remains speculative.

CONCLUSION

We have demonstrated that thet UK population could have a diet in the future that is both healthier and far lower in GHGE. The UK could also increase its self-sufficiency, importing only 22% of food products rather than the current 45%. This would also reduce demand for land in other countries which could help prevent further increases in global food-related emissions due to land-use changes. It also shows that the UK could provide its population with enough food without incurring further carbon penalties from domestic land use changes.