Food and diets model

Contents

Definition of terms

- Food group: Broad nutritional groupings: starchy foods, fruits and vegetables, dairy and meat etc
- Food Category: Group of similar foods represented as one category in the NDNS. The pasta group for example, consists of many different types of pasta and also includes things such as egg noodles. For a full list see Appendix P (DoH, 2011a).
- Food item: individual food such as an apple.
- Dishes: Made up of several food items such as rice and vegetables (dishes are grouped into different food categories based on the main component represented. A vegetable curry for example, would be included in the vegetable food category).

1 Nutrition

We started by designing nutritional parameters in order to be able to create a diet that would satisfy health recommendations. These were:

1. Nutritional profile score for a general score of the 'healthiness' of a food item, category, or diet.
2. Energy and protein intake to assess whether basic nutritional recommendations were met (or unhealthily surpassed).
3. 'Essential' and 'ideal' criteria to assess whether recommended balance between food groups was adhered to.

The latest National Diet and Nutrition Survey (NDNS) results show how much (grams per person per day) of 60 food categories are eaten by an average adult (19-64) in the UK (Henderson, Gregory and Swan, 2002). The most complete dataset relates to 2001 survey data. This dataset and its food categories were used as the basis for the dietary model. Appendix P of the NDNS study gives definitions of all the food items included in each category (DoH, 2011a).

1.1 Nutrient profile scores

The Nutrient Profile Score (NPS) of each food category was calculated using the WXY-AP11FVN.nut model (hereafter referred to simply as 'WXY model'), which is designed to 'rate' food items according to how rich in nutrients they are (Rayner et al, 2005). The scoring system works as follows (DoH, 2011b):
Elements associated with poor health if eaten in large quantities (known as 'A' nutrients) were deducted from elements in that are associated with health benefits (known as 'C' nutrients):

$$NPS = A - C.$$

The 'A' score is calculated as follows:

$$A = \text{Energy} + \text{sugars} + \text{saturated fat} + \text{sodium}$$

Each of the above were given a score out of 10 based on how much of each they contained per 100grams (g) of each food item. Energy was based on how many kilojoules were in 100g (kJ/100g) and the rest how many grams (g/100g). It was the four scores that were added together to make the 'A' score.

The 'C' score is calculated as follows:

$$C = \text{Fruit, vegetable \& nut content} + \text{fibre} + \text{protein}$$

Each of the values above were given a score out of 5 based on how much of each they contained per 100grams (g) of food.

The score for fruit, vegetable & nut content was based on a further calculation found in Scarborough et al. (2005) which derived the percentage of intake the fruit, vegetable & nut content (percentage intake per 100g). Two additional things were needed for this calculation:

a recipe for the food dish and the weights (in grams) of the different ingredients. Both were obtained with a 'Google search'.

Once both the 'A' and 'C' scores were obtained the 'C' score was subtracted from the 'A' score as stated above. This means that the healthier a food is, the lower the score will be. Very often healthy foods have negative scores. See table 1 below for an example of various NPS.

Table 1: An example of nutrient profile scores (NPS) from several different NDNS food categories over a range of different food groups.

NDNS food category	NPS
White bread	1
Wholemeal bread	-3
Cheddar cheese	23
Beef, veal and dishes	3
Bacon and ham	16.5
Oily fish	-0.5
Nuts and seeds	1.5
Salad and other raw vegetables	-6.5
Fruit	-3
Biscuits	13
Sugar confectionery	17
Chocolate confectionery	25

A range of food items within each NDNS food category (DoH, 2011a) were used to come up with an average NPS. Any scores for individual food items that had already been calculated were obtained from Rayner et al. (2005). For other foods, McCance & Widdowson's Composition of Foods Integrated Dataset (CoF IDS) data was used to calculate the NPS (FSA, 2010). The CoF IDS dataset provides details of total energy (Kilocalories (Kcal)), saturated fat content (g), total sugar content (g), levels of fibre (g), sodium (mg) and protein (g) and so provides all of the components needed for the calculation other than the score for fruit, vegetable & nut content.

1.2 Kilocalories and protein

Eating too much food can lead to obesity and an increased risk of many diet-related diseases, such as heart disease and type II diabetes (Friel et al, 2009). In the UK today, 64% of adults are now overweight or obese (Bates et al, 2011). Monitoring total calorific consumption was therefore included in our analysis. Total protein consumption was also included as this was believed to be a key component to monitor in the Zero Carbon Britain (ZCB) scenario diet. This was due to the perceived reductions in meat that would have to occur in order to reduce GHG emissions as much as feasibly possible. Recommended daily amounts (RDA) for both kcal and protein are 2,250 kcal and 55g respectively (COMA, 1991 and the FSA, 2007).

Values collected for kilocalories (kcal) and protein were also based on how much of each were present in 100g of food. As this data was collected for the NPS above, the same representation of several food items in each NDNS food category was included. There were some categories, however, that did not have these values present from the NPS calculations. In this case, new averages were taken directly from the McCance & Widdowson's Composition of Foods Integrated Dataset (CoF IDS). Each food category was given an average value per 100g.

1.3 Food group balance

Advice from UK government regulations on healthy eating was used to assess the 'balance' between food groups in the diet. The 'Eatwell Plate' (NHS, 2013) shows the types of food that should be eaten in which quantities. The 'Eatwell Plate' divides all foods into 5 broad food groups:

1. Bread, rice, potatoes, pasta and other starchy foods
2. Fruits and vegetables
3. Milk and dairy foods
4. Meat, fish, eggs, beans and other non-dairy sources of protein
5. Food and drinks high in fat and/or sugar (foods high in salt were added to this group)

The different food categories from the NDNS were allocated to the appropriate group and colour coded (see table 2).

Table 2: A table showing the five original food groups and each of the food categories assigned to each group. Groups are also colour coded to match those of the 'Eatwell Plate'.

Group 1 – Cereals	**Group 2 - Fruit and Vegetables**
Pasta	Greenhouse-grown tomatoes and cucumbers
Rice	Other UK - grown fresh salads
Other cereals	Seasonal UK vegetables
White bread	Imported vegetables
Wholemeal bread	Seasonal UK fruit
Soft grain	Imported fruit
Other bread	Fruit juice
High fibre breakfast cereals	**Group 3 - Milk and Dairy**
Other breakfast cereals	Milk (Whole, Semi-skimmed and Skimmed)
Oven baked potato products	Non-dairy milk
Other potatoes, potato salads and dishes	Cheddar cheese
Group - 4 Meat and high protein foods	Other cheese (e.g. camembert, goats cheese etc)
Eggs	Yoghurt
Egg dishes	Fromage frais and dairy based desserts
Beef, veal and dishes	**Group 5 - High fat, sugar and salt (HFSS)**
Lamb and dishes	Biscuits
Pork and dishes: of which	Buns, cakes, pastries and fruit pies
Bacon and ham	Puddings
Sausages	Dairy Ice cream
Chicken, turkey and dishes	Cream
Coated chicken and turkey	Butter
Liver and liver dishes	Margarine and other fats and oils
Burgers and kebabs	Savoury snacks (e.g. crisps, Bombay mix etc)
Meat pies and pastries	Savoury sauces, pickles, gravies and condiments
Other meat (game, offal, deli meats etc)	Soups
White fish coated or fried including fish fingers	Fried or roast potatoes
Other white fish, fish dishes and canned tuna	Sugars (table sugar, preserves, honey etc)
Shellfish	Sugar confectionery
Oily fish: salmon, herring, mackerel etc	Chocolate confectionery
Meat alternatives	Soft drinks (squashes, fizzy drinks etc)
Beans and legumes	Spirits and liqueurs
Nuts and seeds	Wine
	Beer, lager, cider and perry

One notable change was made, however, for this research. The meat group (group 4) was combined with the dairy group (group 3), and re-named the 'high protein' food group. This was considered to be one of the core nutritional elements of both groups and merging the

groups would better allow for the consideration of vegan, and low meat diets in the analysis. Therefore, four distinct food groups were left (see table 3 for food category allocations):

1. Starchy foods
2. Fruit and vegetables
3. High protein foods
4. High fat, sugar and salt (HFSS) foods

Table 3: A table showing the four adapted food groups and the food categories that are assigned to each. These groups are also colour coded to reflect those of the 'Eatwell Plate'.

Group 1 – Cereals	Group 2 - Fruit and Vegetables
Pasta	Greenhouse-grown tomatoes and cucumbers
Rice	Other UK - grown fresh salads
Other cereals	Seasonal UK vegetables
White bread	Imported vegetables
Wholemeal bread	Seasonal UK fruit
Soft grain	Imported fruit
Other bread	Fruit juice
High fibre breakfast cereals	**Group 3 - High protein foods**
Other breakfast cereals	Milk (Whole, Semi-skimmed and Skimmed)
Oven baked potato products	Non-dairy milk
Other potatoes, potato salads and dishes	Cheddar cheese
Group 5 - High fat, sugar and salt (HFSS)	Other cheese (e.g. camembert, goats cheese etc)
Biscuits	Yoghurt
Buns, cakes, pastries and fruit pies	Fromage frais and dairy based desserts
Puddings	Eggs
Dairy Ice cream	Egg dishes
Cream	Beef, veal and dishes
Butter	Lamb and dishes
Margarine and other fats and oils	Pork and dishes: of which
Savoury snacks (e.g. crisps, Bombay mix etc)	Bacon and ham
Savoury sauces, pickles, gravies and condiments	Sausages
Soups	Chicken, turkey and dishes
Fried or roast potatoes	Coated chicken and turkey
Sugars (table sugar, preserves, honey etc)	Liver and liver dishes
Sugar confectionery	Burgers and kebabs
Chocolate confectionery	Meat pies and pastries
Soft drinks (squashes, fizzy drinks etc)	Other meat (game, offal, deli meats etc)
Spirits and liqueurs	White fish coated or fried including fish fingers
Wine	Other white fish, fish dishes and canned tuna
Beer, lager, cider and perry	Shellfish
	Oily fish: salmon, herring, mackerel etc
	Meat alternatives
	Beans and legumes
	Nuts and seeds

From the advice surrounding the 'Eatwell Plate' (NHS, 2013) two sets of criteria relating to overall food balance were created. These were designated 'essential' and 'ideal' criteria. The essential criteria relate to things that have been proven to promote health and lower disease risk (see WHO, 2003 and Pan et al, 2012 for two specific examples). The ideal criteria are simply recommended for a healthy diet (FSA, 2007). These criteria are as follows:

Essential criteria:

- A minimum of five portions of fruit and vegetables per day.
- About a third of the diet made up of starchy foods (for example pasta, rice, bread and potatoes (fried potatoes (chips and crisps) are not included in this category. As they are high in saturated fats, they are included in the category below).

- No more than 10% of daily energy intake (kcal) made up of unhealthy foods high in fats, sugar and salt (HFSS).
- No more than 70g of red and processed meats eaten per day.

Ideal criteria:

- Wholegrain cereals (such as brown rice and brown bread) chosen where possible.
- Eat more plant-based protein such as pulses (lentils, chickpeas and baked beans), compared with what is currently consumed in the UK today (average adult consumption is currently 16g per person per day). Plant-based proteins are much lower in saturated fats than animal-based protein.
- More 'good fats' from foods such as oily fish, nuts, seeds and vegetable oils than 'bad fats' from foods such as butter, cheese, crisps, sweets, biscuits, cakes and chocolate.
- Less battered and fried chicken than other forms of chicken.
- Skimmed milk and semi-skimmed milk chosen rather than whole milk.

From this we developed a scoring system. If the diet met one of these recommendations it scored 1 point, if it didn't it scored 0. The healthiest possible diet therefore would score 4/4 from the essential criteria and 5/5 for the ideal criteria.

These scores were assigned as follows:

- A minimum of five portions of fruit and vegetables per day:
    - If the weight (g) of all fruits and vegetables consumed was over 400g per day, then a score of 1 was given. If the weight of all fruits and vegetables was over 320g per day, but an 80g or greater portion of fruit juice was consumed per day then a score of 1 was also given. Otherwise the score was 0.
- About a third of the diet made up of starchy foods (for example pasta, rice, bread and potatoes (not fried)):
    - If the sum of all starchy foods in the daily diet (kcal) was greater than the total number of daily kilocalories consumed divided by three (one third of the daily diet) then a score of 1 was given. If the score was less than 1/3, it received 0. There was no upper limit placed on cereals. As they are significant contributors to protein and energy intake, however, you cannot create a diet with too many without exceeding these totals or disturbing food balance.
- No more than 10% of daily energy intake (kcal) made up of unhealthy foods high in fats, sugar and salt (HFSS):
    - If the total number of kcal per day from the HFSS group was more than the total number of kcal in the total daily diet multiplied by 0.1 then a score of 0 was given. If it, then it scored 1.
- No more than 70g of red and processed meats eaten per day.
    - If the sum of all red meats in the diet (burgers and kebabs, meat pies and pastries, other meat (game, offal, deli meats etc), beef, veal, lamb, pork, bacon, ham and sausages) was greater than 70g per day then a score of 0 was assigned. If not, then it scored 1.

A similar 1, 0 scoring system was applied to the 'ideal' criteria:

- Wholegrain cereals (such as brown rice and bread) chosen where possible:
    - If the number of grams per day of wholemeal bread and high fibre breakfast cereals outweighed the number of grams per day of white breads and 'other breakfast cereals' then a score of 1 was given. If not, the diet scored 0.
- Eat more plant-based protein such as pulses (lentils, chickpeas and baked beans), compared with what is currently consumed in the UK today:
    - If the diet contained more than 45g of pulses per day then a score of 1 was given. If the diet contained less than 45g per day, it received a score of 0.
- More 'good fats' from foods such as oily fish, nuts, seeds and vegetable oils than 'bad fats' from foods such as butter, cheese, crisps, sweets, biscuits, cakes and chocolate:
    - If the sum of biscuits, buns, cakes, pastries and fruit pies, puddings, dairy ice cream, cream, butter, savoury sauces, pickles, gravies and condiments, sugar confectionery and chocolate confectionery was greater than the sum of white fish coated or fried including fish fingers, other white fish, fish dishes

and canned tuna, shellfish, oily fish, meat alternatives, pulses, nuts, seeds and margarine and other fats and oils the score was 0. If there was less of the former than the latter food categories in the diet (measured in grams per day), the score was 1.

- Less battered and fried chicken than other forms of chicken:
    - If the number of grams per day of battered and fried chicken outweighed other forms of chicken then the diet scored 0. If this was not the case or total consumption of both categories was less than 1g/day the diet scored 1. Overconsumption would have resulted in very high protein intake as chicken has the highest protein levels per 100g.
- Skimmed milk and semi-skimmed milk chosen rather than whole milk:
    - If semi skimmed milk (1.8% fat), skimmed milk and non-dairy milk consumption per day is more (in grams) than the sum of whole milk (3.8% fat) consumption per day then the score is 1. If consumption of whole milk is greater then a score of 0 is given.

1.4 Calculating the nutrition of a diet

When modelling the average diet today, the amount of food reported to be eaten was then corrected for under reporting, this is believed to be approximately 25% (Henderson et al, 2002). When modelling the scenario, the diet is based on actual consumption levels, rather than reported levels, so under-reporting is not considered in this case.

The number of grams reported for each food category was multiplied by the NPS for each category and the amount of protein and kcal per 100g of food. When all the protein and energy values for each food category were added together, this provided average daily amounts for the diet. The NPS and scores relating to food balance were also totalled. This allowed us to rate the diet from a nutritional perspective.

For a diet to be considered 'healthy' it had to have a negative NPS (the more negative, the better), it had to score 4/4 based on the essential criteria and 5/5 for the ideal criteria and it had to provide at least 55g protein and 2,250 kcal per person per day (based on RDA).

The current average diet, based on NDNS data, could only be profiled against these nutritional parameters. For the ZCB scenario diet, however, they were used to help create a new diet. NPS were used within food groups to increase healthier foods over less healthy ones and the food balance criteria was used to limit overconsumption of the different food groups and to ensure minimum nutritional requirements for fruits and vegetables, for example, were met. No official limit to protein and kcal was set for this new diet, but as over consumption is more common in the UK than under consumption, energy and protein content were monitored closely and limited to as close to the above figures as feasibly possible.

2 Greenhouse gas emissions

2.1 Life cycle analysis

Greenhouse gas (GHG) emission scores are usually based on how many kilograms (kg) of carbon-dioxide-equivalent (CO_2e) are released into the atmosphere for every kilogram of food that is produced (stated as kg CO_2e/kg). Carbon-dioxide-equivalents (CO_2e) are used to reflect the importance of other greenhouse gases in the food system. Values therefore take account of nitrous oxide (N_2O) and methane (CH_4) emissions as well as those from carbon dioxide (CO_2).

These CO_2e values are most commonly obtained by doing a life cycle analysis (LCA) on the food item in question. LCA determines the emissions of a product from producing it on the farm (for example soil emissions, emissions from animals and their manure and emissions from the use of fossil fuels in agricultural machinery), processing and retail emissions (such as packaging, refrigeration and transport) and household emissions (such as storage and

cooking). Data for the LCA of each product has been collected from three primary sources: the How Low Can We Go? report (hereafter referred to as HLCWG) (Audsley et al., 2009a), the Barilla study (Barilla, 2012) and a journal paper called 'The relative greenhouse gas impacts of realistic dietary choices' (Berners-Lee et al., 2012). The HLCWG report gives separate values for UK produced goods and goods produced abroad (that we import to eat). Most of their LCA values are based on raw commodities (for example wheat instead of flour or bread). Their analysis also only goes as far as the 'regional distribution centre' (RDC) which they state encompass about 56% of total emissions. Values based on this study have therefore been re-calculated to represent 100% of emissions. Barilla (2012) is based on a fuller LCA and so already represents 100% of emissions. Data is taken for UK emissions where possible, but some of these values may represent European averages, or averages from data gathered in other parts of the world. This will not represent the most accurate data for emissions in the UK, but as LCA is still relatively new, many products have simply not been analysed. The Berners-Lee et al. (2012) is based on UK food consumption GHG emissions. This study was particularly helpful in providing values for some of the more processed products (for example puddings, cakes and crisps) that would be difficult to gauge from the HLCWG raw commodity values.

GHG emissions factors for each of the food categories were obtained by compiling averages of the different foods within each NDNS category. For example, the emissions factor for vegetables in the UK (1.78 kg CO_2e/kg) is an average of 12 values from 12 different vegetables. All of these values are taken from the HLCWG report. The value for cheddar cheese (9.68 kg CO_2e/kg) was taken from an average of five different studies from Barilla (2012), and represents studies conducted outside of the UK.

A number of modifications were made to the GHG emissions factors various food categories to encompass specific issues. They were:

2.1.1 Weighted average adjustment for imports

Some of the GHG emission values used in the report are based on weighted averages. Import data from the FAO was used to assess how much we import from both the rest of Europe and the rest of the world (RoW) (FAO STAT, 2013a). Average GHG emissions for products both produced at home, and imported were then weighted based on the percentage of each that contributes to our end consumption.

2.1.2 Adjustment for different cuts of meat

Using the UK figures from the HLCWG report gives us GHG emission factors for 1kg of carcass weight. This means the weight of an animal without its skin and internal organs but with the bones and individual cuts of meat. In order to separate this value into several components, we worked out what proportions of the pig went to making each component (ham, sausages and pork). Values for liver were proportioned based on the amount of offal produced per animal (Farview Farm, 2013).

For cow meat, the Barilla (2012) value for minced beef was used to represent burger meat. These emissions were subtracted from the over all emissions to provide a value for beef meat.

2.2 Calculating the GHG emissions from a diet

The LCA emissions factors for each 'food category' were then used to calculate the total emissions for each diet being modelled. The amount of each food category (g/day) was multiplied through several modelled factors (see land use section below) in order to ascertain how much would need to be produced (tonnes per year) for the whole of the UK population (estimated to be approximately 63,181,775 people (ONS, 2010)). This value was then multiplied by the emissions factor (KgCO_2e/Kg) and divided by 1,000,000 to get the emissions associated with each food category (Mt CO_2e/ population/year for each food category). All of

the emission scores from the food categories were added up to give the total GHG emissions per diet on a UK population basis over one year ($MtCO_2e$/UK population/year).

The current UK diet was modelled first, using values for the current average diet from the NDNS (Henderson, Gregory and Swan, 2002) and current population, in order to see if predicted figures were inline with known estimates for UK food-related GHG emissions. Our model estimates that the amount of GHG emissions attributable to the UK's food supply is 187 Mt CO_2e/UK population/year. DEFRA statistics estimate emissions of 174 Mt CO_2e/UK population/year (Holding, Karr and Stark, 2011) The HLCWG report estimates these emissions to be somewhere between 152 and 159 Mt CO_2e/UK population/year (Audsley et al, 2009a) and the Berners-Lee paper estimates emissions of 167 Mt CO_2e/UK population/year (Berners-Lee et al., 2012). Our emissions are a little higher than these other estimates therefore, but were considered to be reasonable.

2.2.1 Changes to GHG emissions in the ZCB scenario diet model

To model a diet in our scenario (where emissions from energy-related processes (transport, refrigeration, processing, farm machinery) are dealt with in other sections – namely 'Power Up' and 'Power Down'), each GHG emission value needed to be divided in several components so that we could attribute the proportions of emissions associated with carbon dioxide, nitrogen and methane production. As the GHG emissions from transport and other industrial processes have either been removed completely or addressed in calculations elsewhere we needed to remove all emissions associated with these areas.

Williams et al. (2008) breaks down the proportions of emissions into several parts of the life cycle. It breaks down pre-Regional Distribution Centre (RDC) emissions factors into those 'on the farm' and 'post farm gate' emissions up to the RDC for seven different food items. These seven different food items were used to create proxy values for all food categories within the NDNS (see table 3).

Table 3: Proxies used to remove carbon dioxide emissions from total GHG emission scores per food category

NDNS Food Categories	Proxy commodity
Group 1 - Cereals	
Pasta	Potatoes UK
Rice	Potatoes UK
Other cereals	Potatoes UK
Bread	Potatoes UK
Breakfast cereals	Potatoes UK
Oven baked potato products	Potatoes UK
Other potatoes, potato salads and dishes	Potatoes UK
Group 2 - Fruit and Vegetables	
Greenhouse-grown tomatoes and cucumbers	Av Tomato Spain
Other UK - grown fresh salads	Potatoes UK
Seasonal UK vegetables	Potatoes UK
Imported vegetables	Potatoes Israel
Seasonal UK fruit	Apples UK
Imported fruit	Apples NZ
Fruit juice	Strawberries Spain
Group 3 - Milk and Dairy	
Milk (Whole, Semi-skimmed and Skimmed)	Beef
Non-dairy milk	Apples NZ
Cheese, Yoghurt, Fromage frais and dairy based desserts	Beef
Group - 4 Meat and high protein foods	
Eggs	Poultry
Beef, veal and dishes	Beef
Lamb and dishes	Lamb

Pork meat	Poultry
Chicken, turkey and dishes	Poultry
Burgers, kebabs, meat pies and pastries	Beef
Other meat (game, offal, deli meats etc)	Beef
Meat alternatives, Pulses, Nuts and seeds	Apples NZ
Group 5 - High fat, sugar and salt	
Biscuits, cakes and puddings	Potatoes UK
Dairy Ice cream, cream and butter	Beef
Margarine and other fats and oils	Potatoes Israel
Savoury snacks (e.g. crisps, Bombay mix etc)	Potatoes UK
Savoury sauces, pickles, gravies and condiments	Potatoes UK
Soups	Potatoes UK
Fried or roast potatoes	Potatoes UK
Sugars (e.g. table sugar, preserves, honey etc)	Potatoes UK
Sugar confectionery	Potatoes UK
Chocolate confectionery	Apples NZ
Soft drinks (squashes, fizzy drinks etc)	Potatoes UK
Spirits and liqueurs	Potatoes UK
Wine	Strawberries Spain
Beer, lager, cider and perry	Apples UK

These proportions vary significantly between different food categories. The HLCWG report gives a breakdown of post-RDC emissions. These two sources were used to apportion GHG emissions factors between those due to fossil fuel use (energy and transport), and others that would not be dealt with elsewhere in the report. The effect of this for the food and diets model was that any CO_2 emissions were reduced to zero.

Field emissions (representing nitrogen oxide release) were reduced by 38% (based on several studies: Akiyama, Yan and Yagi (2010), Di and Cameron (2012) and Liu, Wang and Zheng (2013)) due to the use of nitrogen inhibitors on soils. This gave us our new emission scores for the ZCB report.

After reading several journal articles relating to methane emissions it was decided not to include any methane reduction technologies in the final ZCB emission scores. The results of studies looking into methane reduction techniques are still producing highly variable results (Hongmin et al, 2011, Grainger and Beauchemin, 2011, Buddle et al., 2010 and Eckard, Grainger and de Klein, 2010). Successful techniques and implementation methods for these techniques are therefore very unlikely to occur by 2030. As one of the criteria for the ZCB research was to only include already proven technologies, methane reduction techniques were not considered to be far enough along in their development to be included. All of the methane emissions associated with the various food categories therefore remained.

The population figure was also increased in the ZCB scenario diet model. (Approximately 70,580,000 people are expected to be living in the UK in 2030 (ONS, 2010) so this is the figure used for the ZCB diet).

3 Land use

As our model is based around NDNS data – dietary surveys of the population, the amount of food reported represents what is consumed ‘on the plate’. This data was in the form of food that was reported to have been eaten in cooked weights, and whole dishes. This does not provide us with a value for how much food is *produced*. We therefore needed to convert what was reportedly eaten ‘on the plate’ to the associated production of agricultural commodities coming ‘out of the farm’. Various steps were necessary for this conversion:

3.1 Cooked to raw conversions

The number of grams reported from survey data is reported as prepared/cooked food weights. Conversion factors were therefore used to adjust for this. Pasta for example, once cooked, is a lot heavier than in its dry form as a lot of water is absorbed. Conversely, raw carrots would weigh more when bought as preparation of the carrot generally involves pealing and 'topping and tailing'. These conversion factors were taken from (Bowman et al, 2011), and applied to individual food categories.

3.2 Raw foods to commodities

Values were also obtained to convert foods as we would buy them (e.g. pasta) to their associated raw commodity (wheat). These values are taken from 'technical conversion factors' complied by the FAO (FAO, 2013), and applied to individual food categories.

3.3 Waste inclusion

Wasted food both at home and throughout the supply chain

Food waste figures were incorporated into the model and based on figures from the food and agricultural organisation (FAO, 2011). These figures are broken down into two separate categories: household waste and all other waste (i.e. on the farm and throughout the supply chain). All values for food waste were based on figures for European countries (who waste approximately 31% of food) with a few notable exceptions:

- Imported fruits and vegetables (based on an average between North Africa, West and Central Asia and South and South-East Asia – with an average wastage of 52%)
- Non-dairy milk and meat alternatives (based on averages from North America and Oceania and Industrialised Asia – with an average wastage of 20%)
- Pulses, nuts and seeds (based on averages from North America and Oceania and Industrialised Asia – with an average wastage of 20%)
- Cocoa beans (based on averages from North America and Oceania and Industrialised Asia – with an average wastage of 20%)
- Wine (an average between Europe, North America and Oceania and Industrialised Asia – with an average wastage of 49%)

The values were chosen to represent a range of other food waste figures of these products from around the world.

3.4 Yields

The amount of each food category required (based on the most common raw commodity per food category (see table 4)) can then be converted into the amount of land required to produce it using 'yield factors'.

Table 4: Raw commodities for each NDNS food category.

NDNS Food categories	Raw Commodities
Group 1 - Cereals	
Pasta	Wheat
Rice	Rice
Other cereals	Barley + Oats + Misc Cereals
Bread	Wheat
Breakfast cereals	Wheat + Other Cereals Average
Oven baked potato products	Potatoes
Other potatoes, potato salads and dishes	Potatoes
Group 2 - Fruit and Vegetables	
Greenhouse-grown tomatoes and cucumbers	Protected veg grown in UK
Other UK - grown fresh salads	UK grown 'salad' veg

Seasonal UK vegetables	UK grown veg
Imported vegetables	RoW grown veg
Seasonal UK fruit	UK grown fruit
Imported fruit	RoW grown fruit
Fruit juice	UK + RoW grown fruit
Group 3 - Dairy	
Milk (Whole, Semi skimmed and Skimmed)	Milk
Non-dairy milk	Soya
Cheese	Cheese
Yoghurt	Milk
Fromage frais and dairy based desserts	Milk
Group - 4 Meat and high protein foods	
Eggs and egg dishes	Layer Hens
Beef, veal and dishes	Cows
Lamb and dishes	Sheep
Pork and dishes	Pigs
Bacon and ham	Pigs
Sausages	Pigs
Chicken, turkey and dishes	Poultry
Coated chicken and turkey	Poultry
Liver and liver dishes	Poultry
Burgers and kebabs	Cows + Sheep
Meat pies and pastries	Cows + Sheep + Soya x2
Other meat (game, offal, deli meats etc)	Cows + Sheep + Soya x2
White fish coated or fried including fish fingers	Fish
Other white fish, fish dishes and canned tuna	Fish
Shellfish	Fish
Oily fish: salmon, herring, mackerel etc.	Fish
Meat alternatives	Soya
Beans and legumes	Pulses
Nuts and seeds	Nuts + Seeds
Group 5 - High fat, sugar and salt	
Biscuits, cakes and puddings	Wheat + Sugar + Oil + Eggs
Dairy Ice cream, cream and butter	Milk
Margarine and other fats and oils	Vegetable Oils
Savoury snacks (e.g. crisps, Bombay mix etc)	Wheat + Potatoes + Oil
Savoury sauces, pickles, gravies and condiments	Wheat + Sugar + Oil
Soups	Veg + Condiments + Potatoes
Fried or roast potatoes	Potatoes
Sugars (table sugar, preserves, honey etc)	Sugar
Sugar confectionery	Sugar
Chocolate confectionery	Cocoa
Soft drinks (squashes, fizzy drinks etc)	Sugar + Fruit
Spirits and liqueurs	Sugar + Fruit + Wheat
Wine	Grapes
Beer, lager, cider and perry	Barley + Apples + Pears + Wheat

The yield factor tells us how much of each food category can be grown per hectare of land (tonnes/hectare). The yield factors for crops are taken from DEFRA (2011 and DEFRA 2012) for produce from the UK; and FAO STAT (2013b) for crops that can only be grown overseas. Yield factors for livestock and fish were a little more complicated. For livestock, yield factors

were developed by dividing the current number of tonnes of meat produced (data taken from DEFRA, 2011) by the amount of land currently used to rear the animal (data taken from Audsley et al., 2009b). In the case of cows and sheep, the amount of land used was based on grassland only. Crops grown for feed were factored into the model separately (also using data from DEFRA (2011)) on the amount of cereal production is used currently in the UK for animal feed. For pigs and chickens, yield factors were developed by dividing the current number of tonnes of meat (or eggs) produced (data also taken from DEFRA, 2011) by the amount of land currently used to grow their feed (data taken from Audsley et al., 2009b). Land calculations are based on feed crops only as pigs and chickens do not have specific agricultural land assigned to them, as they do not graze on grassland as cows and sheep do. This calculation was also used for farmed fish as they are fed 'fishmeal' which contains some plant sources (most commonly soya) (MMO, 2013).

3.5 Calculating land use estimates for each diet

The land use portion of the model allowed us to convert grams consumed per person per day into tonnes required to feed the whole population per diet per year. Each food category went through each of the stages described above in order to enable this conversion. Cooked foods were converted to their raw equivalents to represent how they would be bought in the supermarket. These foods were then converted to a raw commodity agricultural equivalent. Wasted food both at home and throughout the supply chain was also accounted for. The amount of each food category required was then also multiplied by total population and by the number of days per year (365.4). Finally, grams per day values were converted to tonnes per year (by dividing by 1,000,000). Finally the number of tonnes required per year was divided by a 'yield factor' to work out how many hectares of land were required per food category. These values were then put into one of seven columns: UK arable land, UK arable land for feed, UK Grassland, rest of world (RoW) arable land, RoW arable land for feed, RoW Grassland and UK Greenhouses. These were then totalled to obtain data on all of the land required for each diet for the whole of the UK population.

3.5.1 Changes to land use in the ZCB scenario diet model

In our scenario, we assumed food waste would be cut by 50%. This is in line with UK targets for 2030 (Forum Europe, 2013).

Any food categories that contained food items that could be grown in the UK, but were currently imported (all or in part) were changed to UK production only. Some fruit and vegetables and some pulses were also included in UK glasshouse production.

In the ZCB scenario, the amount of crops grown for feed was reduced proportionally to the reduction of cows and sheep. The amount of food wasted in tonnes, within the ZCB scenario was also used to calculate how much food waste could be used as pig feed to save on cropland. This proportion was then deducted from the arable land in the scenario.

A further calculation was of the agricultural waste; that in the translation from food stuff to commodity – straw from cereal production then feeds into the 'Power Up' model to be used to produce energy through anaerobic digestion (AD).

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