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Part of the ZERO CARBON BRITAIN project

People, Plate and Planet

The impact of dietary choices on health, greenhouse gas emissions and land use.

Centre for Alternative Technology
Canolfan y Dechnoleg Amgen

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Acknowledgements

I would like to acknowledge my thanks and appreciation to Alice Hooker-Stroud for her support and supervision during both the research and write-up phase of this project. I would like to thank Alice Hooker-Stroud and Kit Jones for their editorial support and Graham Preston for the report's production. I would also like to thank my colleagues in the Zero Carbon Britain team and here at the Centre for Alternative Technology (CAT) for their encouragement and enthusiasm during this project. Finally, I would like to acknowledge the generous support of the Jam Today organisation, without which this report would not have been possible.

About this report

This report forms part of the 'Food and Diets' research done by the Zero Carbon Britain project through 2012-13. Although the focus was on low carbon diets in the Zero Carbon Britain scenario published in *Zero Carbon Britain: Rethinking the Future* (the third report from the Zero Carbon Britain project, launched in July 2013), this work concentrates on low carbon diets in the UK today.

There are two main differences between today and the *Zero Carbon Britain: Rethinking the Future* scenario that have an effect on environmentally conscious dietary or food purchasing choices.

One is that today (2014), our energy system is still responsible for a significant proportion – over 80% – of greenhouse gas emissions in the UK. This means that when food is transported, packaged, processed, refrigerated or cooked, these actions contribute to climate change. In *Zero Carbon Britain: Rethinking the Future*, our energy system is zero carbon, meaning that these actions do not contribute – it is only emissions 'on the farm' from food production that we have to think about.

The second difference is that today, our food system is a global system – we import about 42% of our food, and this contributes to greenhouse gas emissions and other environmental problems, as well as using land overseas. In the scenario in *Zero Carbon Britain: Rethinking the Future*, imports of livestock (meat and dairy) products and feed for livestock is not permitted, as this contributes most significantly to these problems globally; other imports are reduced also.

Therefore, our dietary decisions in the *Zero Carbon Britain: Rethinking the Future* scenario, and those we make today may be different. Though some rules carry, it is more complicated to make environmentally conscious decisions with respect to what we eat, and how it is produced today than it is in *Zero Carbon Britain: Rethinking the Future* as there are more factors to consider.

We hope that this report will form the basis for work to help us all make better decisions with respect to our diets and our purchases – from nutritional and environmental perspectives.

Please feel free to use the work in this report to support your own efforts towards a positive and sustainable future.

About the Zero Carbon Britain project

Zero Carbon Britain (ZCB) is an initiative from the Centre for Alternative Technology (CAT). The aim of the Zero Carbon Britain project is to demonstrate that integrated and technically feasible solutions to the climate problem do exist, in order to support and inspire the requisite action to achieve a positive zero carbon future.

About the Centre for Alternative Technology

Established almost 40 years ago, the Centre for Alternative Technology (CAT) is a leading research and educational charity which demonstrates practical solutions for sustainability. CAT aims to inform, inspire and enable people and society to achieve positive change.

CAT offers a wide range of practical and academic courses up to postgraduate level and a unique range of educational services for school groups, universities and educators. CAT also offers a free information service, backed by consultancy advice, and has published a wide range of books on sustainable technologies.

CAT's award winning educational facility – the Wales Institute for Sustainable Education (WISE) – and visitor centre are based in Machynlleth, mid-Wales.

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Key messages

Bill Ebbesen

- Kilocalorie, protein and nutritional recommendations can easily be met with a variety of different diets, including low-carbon diets.
- Simply eating how much is recommended (in terms of daily kilocalorie intake), reduces greenhouse gas (GHG) emissions and land use by about **15%** (the amount by which we currently overconsume).
- Following nutritional guidelines (including eating less) and simply moving towards a more healthy diet (on average in the UK) reduces GHG emissions associated with food by **19%**, and land use by about **50%**.
- Eliminating all animal products (both meat and dairy) is the most successful way of reducing GHG emissions (**43%** reduction) and land use (about a **70%** reduction, depending on the diet).
- A reduction (but not an elimination) of meat and dairy in the diet, and selecting lower-emitting options such as pig or chicken meat (rather than red meat), and yoghurt or milk over cheese, can still result in somewhere around a **34%** reduction in GHG emissions and a **65%** reduction in land use.
- Reducing the amount of meat products, fruit and vegetables bought from outside Europe significantly lowers GHG emissions (**8-13%** reduction depending on the diet), but has less of an overall impact than changing diets can have.
- Halving food waste reduces GHG emissions (**13-25%** reduction, depending on the diet) and land use (about a **16%** reduction), but has less of an overall impact than changing diets can have.
- Changing how we travel to the shop, how much packaging is used, and carrier bags have minimal effects on GHG emissions (only contributing about **2%** to GHG emissions in total), especially by comparison to changes in diet. They are, however, often related to other benefits – using fewer resources and materials, or having a more active lifestyle, for example.

Executive summary

This report sets out to integrate three important issues related to food. It asks what changes to our diets and food-related behaviours could:

- **Improve the 'healthiness' of the average diet of the UK population.**
- **Reduce emissions of greenhouse gases that contribute to climate change.**
- **Use less land globally.**

Anyone who is concerned with the health and wellbeing of people and planet should be interested in all three of these issues.

Diet has been linked to a range of diseases including obesity, heart disease and type II diabetes. All these diseases are affecting increasing numbers of people in the UK. Diet has also been shown to be a risk factor for some cancers, such as bowel cancer. In the UK today, 64% of adults are overweight or obese (Bates et al, 2011), and 71% of all deaths in the UK in 2010 were from the types of diseases mentioned here (WHO, 2013b). It is therefore more important than ever that we consider the impact of our dietary choices on our health.

What we eat here in the UK also has wider global implications. Climate change is caused by the emission of greenhouse gases such as carbon dioxide, nitrous oxides and methane. The current average diet in the UK is responsible for about 150-180 Mt CO_2e/UK population/year (Audsley et al, 2009a; Holding, Karr and Stark, 2011; Berners-Lee et al., 2012) based on 'life-cycle analyses' (LCA) from 'farm to fork' (not including emissions from land use change abroad) – 20-30% of UK consumption emissions (Audsley et al, 2009a). This means significant contributions to reducing UK greenhouse gas emissions could come from changes in diets and food production systems. Due to the risk of very serious impacts from global climate change (floods, droughts, heatwaves, sea level rise, ocean acidification, and others), preventing or mitigating climate change is extremely important, and anything that we can do to reduce our emissions is very valuable.

Land use for food production is important, but can put unnecessary pressure on natural systems. In this way, our diets are contributing to the continual worsening of a broad range of environmental problems, not just climate change – for example increasing levels of pollution and loss of biodiversity (Rockström and Klum, 2012). Because many of these issues are broadly proportional to how much land we use, and how intensively we use that land, reducing the amount of land needed to grow food can help. Leaving more space for nature, for example, is an important outcome in itself, but could also help reduce UK net GHG emissions. Restoring wetlands and planting forest on released land can lead to capture of carbon dioxide out of the atmosphere, and offers important habitats for biodiversity.

These three issues, therefore, are interlinked – what we eat has an impact on our health, climate change and other environmental issues related to land use.

The research

The nutritional qualities, GHG emissions from, and land use requirement of thirteen different average diets for the UK were modelled. To enable us to compare the impact of what we are eating today with what we could be eating, two of theses diets came from the National Diet and Nutrition Survey (NDNS) – the '**current average**' UK diet and the average UK diet among people on low incomes ('**LINDNS**'). The '**Livewell**' diet (taken from MacDiarmid et al, 2011) which aims at keeping food preferences similar to the UK average diet today, but lowers GHG emissions in line with UK government targets for 2020, is also modelled as a reference case.

All the other diets are idealised diets, each based on different restrictions:

- The '**ideal**' diet follows nutritional recommendations and aims to show the impact of eating healthily.

- The '**glutton**' (high calorie) diet aims to show the impact of eating too much.
- The '**high meat and dairy**' diet aims to show the impact of eating more meat and dairy than recommended, but otherwise following nutritional recommendations.
- The '**health conscious but high meat**' diet aims to show the impact of generally eating healthily, but with large quantities of meat.
- The two vegetarian diets – '**substitute vegetarian**' and '**light-lacto vegetarian**' – aim to show the impact of dairy produce (by removing meat from the diet, but keeping in line with nutritional recommendations).
- The two vegan diets – '**junk food vegan**' and '**vegan**'– aim to show the impact of eating healthily or not within a no meat and dairy diet.
- The '**gorilla**' diet shows the impact of a diet based purely on fruit and vegetables.
- The '**carbon minimiser**' diet shows the impact of eating foods in line with nutritional recommendations and with the aim of lowering GHG emissions – a carbon-conscious diet.

The study also compares the impact of these dietary changes to the impact of other food-related behaviours on greenhouse gas emissions and land use.

Findings

Greenhouse gas (GHG) emissions relating to our diets, and the amount of land required to produce the foods for each, can vary significantly. Making changes to what, and how much, we eat can help lower these emissions and the amount of land required to feed the UK population. In fact, the types and quantities of foods we consume have the greatest impact on emission reductions and the amount of land required for agriculture, and changes to the current average diet in the UK should be encouraged.

Shifting the diet of the UK more in line with health recommendations would have the positive benefit of reducing GHG emissions and freeing up land for other uses.

Our analysis shows that kilocalorie and protein requirements can be easily met with a variety of different diets, and that people can still eat a good balance of foods on a low carbon diet.

Eliminating animal (both meat and dairy) products from the diet altogether is the most effective way of reducing GHG emissions and land use, but these can still be lowered significantly with less dramatic changes in the foods that we eat.

Buying food produced in the UK – especially when buying meat products, fruits and vegetables – and reducing food waste should also be encouraged to reduce GHG emissions and land use relating to the food we eat, but have less of an overall effect than switching *what* it is we eat.

A closer look at eating different diets

A diet that is high in meat consumption, especially one that contains a lot of beef and lamb, is one that requires a lot of land, and has a lot of GHG emissions associated with it. This is due to the fact that these animals require grassland for grazing as well as some cropland to provide feed; and that GHG emissions related to land use (fertiliser etc) are proportional to the area of land used; and that the animals themselves (as ruminants) produce greenhouse gases. Lowering meat consumption would therefore help to reduce high land use burdens and GHG emissions.

However, the impact of following a vegetarian diet on GHG emissions and land use depends very much upon the amount of dairy in the diet. If vegetarians substitute eating meat with eating much more cheese, for example, then the GHG emissions of the vegetarian diet are in the same range as high meat diets.

Eliminating meat and dairy products from the UK diet (a vegan diet) entirely would bring about the greatest emissions reductions – approximately a reduction of **43%**, or 81 million-tonnes carbon-dioxide-equivalent ($MtCO_2e$) per UK population per year. This could be done in a way that would still supply the UK population with adequate kilocalories and protein and provide a good balance between food groups.

Large emissions reductions can still be achieved without the elimination of meat and dairy products from the diet altogether. Two different diets that

Rank	Ordered by energy	Ordered by protein	Ordered by NPS	Ordered by GHG emissions	Ordered by land use
1	Vegan	Vegan	Gorilla	Vegan	Gorilla
2	Light lacto-vegetarian	Light lacto-vegetarian	Vegan	Junk food vegan	Junk food vegan
3	Carbon minimiser	Substitute vegetarian	Light lacto-vegetarian	Carbon minimiser	Vegan
4	Junk food vegan	Carbon minimiser	Glutton	Light lacto-vegetarian	Light lacto-vegetarian
5	Ideal	Ideal	Carbon minimiser	Gorilla	Substitute vegetarian
6	Substitute vegetarian	Livewell	Ideal	Ideal	Carbon minimiser
7	Livewell	Health conscious but high meat	Health conscious but high meat	Livewell	Livewell
8	Health conscious but high meat	High meat and dairy	High meat and dairy	Health conscious but high meat	Ideal
9	LINDNS	LINDNS	Substitute vegetarian	Substitute vegetarian	Glutton
10	High meat and dairy	Current average	Junk food vegan	High meat and dairy	Health conscious but high meat
11	Current average	Glutton	Livewell	Current average	High meat and dairy
12	Glutton	Junk food vegan	Current average	LINDNS	Current average
13	Gorilla	Gorilla	LINDNS	Glutton	LINDNS

Summary table: All modelled diets, ranked in turn by the energy and protein they provide, their Nutrient Profile Scores (NPS) – a measure of 'healthiness', the GHG emissions associated with them, and the land required to produce them (1 = best; 13 = worst). **This shows that 'current average' UK diet and the 'LINDNS ' diet (those taken from data on what we eat today in the UK) rank low on almost all measures. The 'vegan' and 'light-lacto vegetarian' diets rank well on all measures, with the 'carbon minimiser' diet also relatively high up.**

model a reduction, but do not eliminate meat and dairy products from the diet altogether, reduce emissions by about **34%**, or 64 $MtCO_2e$/UK population/year. These reductions highlight the significant impact of selecting lower emitting foods such as choosing to eat more chicken and pig meat over that of beef and lamb, to limit cheese intake in favour of milk and yoghurt, and to increase the intake of meat and milk alternatives, pulses, nuts and seeds in their place.

Today's average UK diet has the third highest GHG emissions of all the diets modelled, and is the second worst diet in terms of nutritional recommendations and food group balance. Simply moving towards a healthier diet has the potential to reduce emissions by approximately **19%** – **35** $MtCO_2e$/UK population/year.

Diets focussing purely on being 'carbon-conscious' are not necessarily good from a nutritional health perspective. Even though there is some correlation between health benefits and GHG emission reductions, the two do not always go hand in hand. It is possible, for example, to eat a very unhealthy vegan diet that, although low in GHG emissions, does not meet all of the nutritional criteria.

Total consumption – how much we eat – is also an important consideration when attempting to reduce GHG emissions and land use. Another helpful thing we can do to lower GHG emissions is therefore to simply eat less. If we currently over-consume by almost **15%** in terms of energy needs, then reducing consumption across the board by this amount would reduce GHG emissions and the amount of land required by roughly the same.

A closer look at other food behaviours –waste, transport and cooking

Changing the mix of foods in the diet has the potential to have much more significant impact on GHG emissions and land use reductions than reducing food waste.

However, the amount of food waste varies significantly across different food groups. Reducing waste by 50% results in emissions reductions of between **13** and **25%** – depending on the diet. Reducing food waste has a larger effect on diets higher in fruit, vegetables, roots, tubers, fish, oilseed and pulses, due to their high waste percentages. As lower GHG emitting diets tend to contain more of these foods, emission reductions from reducing food waste are more significant in healthier and lower emitting diets.

The move to a vegan diet with the addition of cutting food waste by 50% would reduce total food-related carbon emissions by **57%**. Wasting less food also, very importantly, decreases demands for land.

Buying products from the UK can have a significant impact on GHG emissions and should be encouraged where possible. Buying everything we eat from overseas could increase our emissions between 23 and 34%, and buying only UK produce can reduce emissions from between **8** and **13%**, compared to the current mix of local and imported food. However, some of the significant differences in GHG emissions are not related to transport, but to different agricultural practices. It is not always the case that buying a particular food in the UK results in fewer GHG emissions. It is also worth noting that with the mix of foods in the current average diet it is not possible for everyone to buy food from the UK – we simply do not have enough agricultural land. In order for us to produce all (or much more) of our own food, we would have to change our diets.

Other 'food-related behaviours' such as refrigeration, cooking and travelling to the shop make up just over 40% of current UK food-related emissions. Reducing GHG emissions from these areas *could* therefore result in significant emissions reductions. Changing to more efficient appliances can help, but unless we change how our energy is produced (for example, switching from GHG emitting fossil fuels to renewables), making significant reductions here seems impractical and can be counter-productive (for example, not refrigerating produce may lead to more food waste).

How much packaging is used for produce, and whether or not we use carrier bags, have minimal effects on GHG emissions compared to changes in diet. Personal 'food-related behaviours' such as these may not therefore play such a significant role in emissions reductions.

Introduction

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This report looks at the impacts of different dietary choices in the UK today. Data has been collected on different food categories that are most commonly eaten, relating to:

- Nutritional health.
- Greenhouse gas (GHG) emissions.
- Land use requirements.

These food categories have been put together in various combinations to make up different diets so the reader can get an idea of the impact of different dietary choices. These diets have been modelled to answer some questions relating to food choices and, to a lesser extent, food-related behaviours. For example, what is the impact of eating lots of meat or dairy? If we in the UK were to reduce the amount of food that we waste, what affect would this have on our land use and GHG emissions? How much of an impact does shopping locally have on carbon emissions?

Firstly, this report explains what has been modelled and the methodology behind it. Secondly, the report defines the different diets and explains which foods have been increased, decreased or excluded. Thirdly, it goes on to outline the results of each diet modelled:

- How healthy it is.
- How much GHG emissions the diet is responsible for (this is on a consumption basis and so includes emissions from food items that have been grown overseas. It does not, however, include indirect land use change emissions – those related, for example, to clearing forested land for the production of various foods overseas).
- How much land is required.

Fourthly, it addresses the impact of food waste, favouring UK products over imported ones and the potential impact of our 'food-related behaviours'. Finally, it highlights some of the results and attempts to make some concluding remarks on the report as a whole.

What has been modelled and why

This piece of research set out to look at the implications of different diets on GHG emissions. They have also been modelled against various nutritional parameters to give the reader an idea of nutritional quality. Land use implications have also been considered. The model is based on a current population of just over 63 million people (ONS, 2010) and on the food categories from the National Diet and Nutrition Survey (NDNS) undertaken in 2001 (Henderson, Gregory and Swan, 2002). This survey takes a representative sample of the UK population and asks participants to fill out a seven day diet diary of all food that is consumed during this time. This survey gives us the most detailed insight into the eating habits of the UK population and the types of foods that are most commonly eaten.

Nutritional requirements

Making sure the diet meets all of our nutritional needs is very important for health. In the UK today, 64% of adults are overweight or obese (Bates et al, 2011), and 71% of all deaths in the UK in 2010 were from diet-related diseases (WHO, 2013b). With levels of obesity, heart disease and type II diabetes on the increase it is more important than ever that we consider the impact of our diets to our health. This means that moving to a healthier diet can reduce your chances of suffering from one of these diseases. Even certain cancers have now been linked to dietary health. Bowel cancer, for example, (one of the most common cancers in the UK today (CR UK, 2014)), has been shown to be related to nutritional intake due to low levels of fibre in the diet (BNF, 2014).

With this in mind, there were four elements we took into consideration for nutritional health: Nutrient Profile Scores (NPS), National Health Service (NHS) dietary recommendations on food balance, total energy intake and total protein consumption.

The World Health Organisation (WHO) defines nutrient profiling (and thus NPS) as "the science of classifying or ranking foods according to their nutritional composition for reasons related to preventing disease and promoting health" (WHO, 2013a). The NDNS food categories were 'profiled' to develop a scoring system that would give an indication of the healthfulness of each (DoH, 2011). NPS rate total energy intake, saturated fat, salt and sugar intake – i.e. all of the things that if consumed in large quantities can lead to diet-related diseases such as those described above – against fruit and vegetable, protein and fibre intake. If the food (or in our case food category) contains more of the 'bad stuff' (linked to diet-related diseases) than the 'good stuff' (that have in some cases, such as fibre and fruits and vegetables, been linked to lowering disease risk) it scores highly. If it contains a lot more 'good stuff' then the score becomes negative. Cheese and butter, for example, being high in both saturated fats and salt, had very high scores (23 and 25 respectively) whereas vegetables for example had very low scores (-9). Where this system was perhaps most useful, however, was amongst foods that are less easy to distinguish between. The scores between types of bread, for example, highlighted the difference between white and brown. Brown bread (containing more fibre) has a NPS of -3, whereas white bread scores 1. It can therefore be used to support and reinforce dietary guidelines. As NPS are designed to look at individual foods, however, within this report we have also multiplied them by the number of grams eaten per day and then added these scores together to provide a total NPS score for each diet. This type of scoring system on its own, however, does not always accurately reflect the overall dietary picture, which is why three other nutritional criteria were also used.

NHS recommendations on food balance were used to help to ensure that a good variety of foods are consumed. The food categories used to create each diet have been grouped into five broad food groups: starchy foods, fruits and vegetables, dairy products, meats and other high protein foods, and foods that are high in saturated fats, sugar and salt (HFSS) and are displayed visually for each diet in tables 1-5. These food groups help to determine whether or not each diet has a healthy balance of foods. Having a wide variety of foods in the diet is important for health and can also contribute to lowering disease risk. The NHS provides helpful information on this in the form of their 'Eatwell' plate (NHS, 2013). We have used the recommendations from the Eatwell plate to develop our own 'essential' and 'ideal' dietary criteria.

Essential criteria are as follows:

- 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 (not fried)).
- No more than 10% of daily energy intake (in kilocalories (kcal)) made up of unhealthy foods high in fats, sugar and salt (HFSS).
- No more than 70 grams (g) of red and processed meats eaten per day.

Ideal criteria are as follows:

- Wholegrain cereals (such as brown rice and bread) chosen where possible.
- More plant-based protein such as pulses (lentils, chickpeas and baked beans). These 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.

Every diet modelled has been scored based on these essential and ideal criteria. If the diet met the requirement it scored '1', if it didn't it scored '0'. The highest score a diet could receive, therefore, was 4/4 for the essential criteria and 5/5 for the ideal criteria.

Total energy intake (kcal) is also included as a separate parameter in order to attempt to avoid/regulate over-consumption. Over-consumption can lead to the body laying down fat in an attempt to store calories that are not required as energy, the result of which is that individuals become overweight and sometimes even obese. Being overweight or obese increases a person's risk of developing type II diabetes, heart problems and certain cancers (BNF, 2014). In modelling the diets for this report, therefore, an attempt has been made to provide only what is needed, rather than to match levels of food that may be supplied to the UK today.

The values for total protein intake were also included due to concerns placed on meeting recommended daily amounts (RDA) of 55g of protein per day whilst potentially limiting meat intake. Meat is a good source of protein. However, in the UK today total protein supply (as will become evident) is not really a concern for most people.

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Protein breaks down into amino acids, which are the building block for our muscles and other tissues. There are several amino acids which cannot be made in the body. These are known as 'essential amino acids' and must be supplied by the diet. The analysis in this report is not detailed enough to determine whether or not each diet modelled supplies all of the essential amino acids in the appropriate quantities, though we do monitor the total amount of protein provided. This would be an area of research that would benefit from further analysis.

Greenhouse gas (GHG) emissions

The release of GHG emissions into the atmosphere from human systems contributes to climate change. Due to the risk of very serious impacts from global climate change (floods, droughts, heatwaves, sea level rise, ocean acidification, and others), preventing or mitigating climate change is extremely important and anything that we can do to reduce our emissions is very valuable. It is estimated that the amount of GHG emissions attributable to the UK's food supply is about 150-180 Mt CO_2e/UK population/year (Audsley et al, 2009a; Holding, Karr and Stark, 2011; Berners-Lee et al., 2012) based on 'life-cycle analyses' (LCA) from 'farm to fork'. This is between 20-30% of the UK's total consumption emissions – those related to all that we buy and use in the UK (Audsley et al, 2009a). This does not include emissions from land use change abroad – those related, for example, to clearing forested land for the production of various foods overseas.

The scores for GHG emissions in this report are based on how many million tonnes (Mt) of carbon-dioxide-equivalent (CO_2e) each diet would produce, per year, if everyone in the UK ate this diet. Carbon-dioxide-equivalents have been used to reflect the importance of all greenhouse gases in the food system. Values therefore take account of nitrous oxide (N_2O) and methane (CH_4) emissions

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as well as those from carbon dioxide (CO_2). N_2O is emitted from soils, most commonly after fertiliser application. Methane emissions in the UK come primarily from cows and sheep as they digest grass for energy. As they chew, methane gases are belched from their mouths, as bacteria from the rumen (stomach) break down cellulose within the grass. A small amount of methane is also released from manure.

Each of the food categories (from the NDNS) have been attributed a GHG emission value. Emission values are based on 'life cycle analysis' (LCA) of a product from 'farm to fork' – 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 LCA of each product has been collected from three primary sources: the *How Low Can We Go (HLCWG)?* report (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. 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 believe to encompass about 56% of total emissions. Values based on this study have therefore been re-calculated to represent 100% of emissions. The Barilla study (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 study is based on LCA of a range of products sold in a UK supermarket. 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. Values from all studies used are given for 1 kilogram (kg) of product, and represent the amount of CO_2e (in kilograms) that would be emitted if 1kg of this food category was produced (including all emissions form farm to fork) (written as $kgCO_2e/kg$).

Values for each of the food categories were obtained by compiling averages of the different foods within each category. For example, the emissions value for vegetables in the UK (1.78 $kgCO_2e/kg$) is an average of 12 values from 12 different vegetables. All of these values are taken from the HLCWG report (Audsley et al, 2009a). The value for cheddar cheese (9.68 $kgCO_2e/kg$) was taken from an average of five different studies from the Barilla report, and represents studies conducted outside of the UK (Barilla, 2012).

Land use

Land use for food production is important, but can put unnecessary pressure on natural systems in doing so. Through use of land for food production, we have contributed to climate change, pollution, loss of biodiversity and other global and local problems (Rockström and Klum, 2012). Simply using less land for agriculture can be one way of reducing our impact and goes towards solving some of these issues.

Once all of the food categories had been assigned and GHG emission values and the nutritional data had been collected, the final component of the model was investigated. The current average UK diet was matched with actual known land use areas and production values and areas in the UK today. This ensured the model was an accurate reflection of how land in the UK is utilised. Land used abroad was estimated based on how much we import (tonnes) and world average yield values.

There were a number of things that were considered for the land use section. Firstly, the number of grams reported from the NDNS survey data is reported as prepared/cooked food weights, causing a mismatch between this and raw commodity yield/production data. Conversion factors were therefore used to adjust for this (Bowman et al, 2011). Pasta for example, once cooked, is a lot heavier than in its dry form as a lot of water is absorbed. A conversion factor of 0.38 was therefore used. This means that for a 210 gram (g) cooked portion of pasta, approximately 80g of dried pasta had to be used. Another example of this would be for sticks of raw carrot. Here, the prepared weight is less than the original weight as the carrot has been pealed, 'topped and tailed'. The conversion factor for carrots was 1.12, meaning that for every 80g of raw carrot consumed, the actual original weight of those carrots would have been 90g. Percentage values for food waste within the household were then also factored in. This gives us an estimation of the amount of product that would have been purchased in order for the original 80g of carrots to be consumed. The waste value for fruits and vegetables in the home, for example, is 13% (FAO, 2011). This means that in order to prepare a 90g portion of carrots, 102g of carrots would have most likely been purchased.

Following this, 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' compiled by the Food and Agricultural Organisation of the United Nations (FAO, 2013). The amount of waste thought to occur throughout the supply chain and on the farm was also factored in to the model. The number of grams needed at this point was also multiplied by the entire population (about 63 million) and for every day of the year (365.4). Values were then converted into number of tonnes rather than grams. Once the amount of each food category required was found, these could be divided by a 'yield factor' to tell us how much land (given in tonnes per hectare (t/ha)) would be needed for each diet. The yield factor for wheat, for example, is 7.7, meaning that 7.7 tonnes of wheat can be grown on one hectare of land. The yield factors for crops are taken from statistics from the UK Department for Environment, Food and Rural Affairs (DEFRA, 2012 and DEFRA 2011) and FAO statistics (for crops that can only be grown overseas) (FAO STAT, 2013); these factors were therefore easily sourced. Yield factors for livestock and fish were a little bit more complicated to work out. For livestock, yield factors were developed by dividing the current number of tonnes of meat produced by the amount of land currently used to rear the animals. In the case of cows and sheep, the amount of grassland needed for the cows and sheep to graze was used. Crops grown for feed were factored into the model separately and yield values for cereals are used. The amount of feed required today, and the amount of livestock in the current diet, was used to alter feed values in the other diets and decrease or increase them proportionally based on the amount of livestock present in each diet. Pigs and chickens are not assigned specific agricultural land. Their yield values are therefore calculated by the number of hectares of land used to grow their feed divided by the amount of meat (or eggs in the case of some chickens) that they provide. The same calculation was also done for fish. For obvious reasons, they do not have land assigned to them. Farmed fish, however, are fed 'fishmeal' which contains some plant sources (most commonly soya). The land used to grow this fishmeal is therefore divided over the amount of 'fish meat' that then can be consumed.

What are the different diets?

Thirteen diets were modelled in total, three of which are based on other reports and 10 of which have been generated 'in house'.

The first of the reported diets is called the '**current average**' diet. This is based directly on the NDNS data from 2001 (Henderson, Gregory and Swan, 2002). The results, which detail the number of grams consumed on average for each food category, are adjusted for under-reporting, which is believed to be around 25% (Henderson et al, 2002).

The second reported diet is also a nationally reported diet, but only families with low incomes are sampled (Nelson et al, 2007). This is called the '**LINDNS**' diet which stands for the Low Income NDNS.

The final diet taken from another report is the '**Livewell**' diet (MacDiarmid et al, 2011). This study created a diet for the UK population to aim towards. It meets the UK Governments greenhouse gas (GHG) emission targets for 2020, but is also based on NDNS data from 2001, so this diet also attempts to keep the new modelled diet as close to current taste preferences as possible. Unlike our study, this report made sure all recommended requirements of micronutrients (vitamins and minerals) were met. These are very important considerations for nutritional health and so would be a very valuable addition to our analysis. Their model does not, however, set the same restraints on over-consumption or food balance as our model,

	Starchy foods	Fruits and vegetables	Dairy products	Meat and other high protein foods	High fat, sugar and salt (HFSS) foods
Current average	Not enough.	Not enough.	More than 'ideal'.	More than 'ideal'.	Too much.
LINDNS	Not enough.	Not enough.	More than 'ideal'.	More than 'ideal'.	Too much.
Livewell	Not enough.	Same as 'ideal'.	More than 'ideal'.	More than 'ideal'.	Too much.

Table 1: Summary of the 'current average', 'LINDNS' and 'Livewell' diets in relation to the five Eatwell Plate food groups (recommended nutritional balance) and the 'ideal' diet created for this research.

	Starchy foods	Fruits and vegetables	Dairy products	Meat and other high protein foods	High fat, sugar and salt (HFSS) foods
Ideal	In line with nutritional recommendations.	In line with nutritional recommendations.	In line with nutritional recommendations.	In line with nutritional recommendations.	In line with nutritional recommendations.
Glutton	30% more than 'ideal'.	30% more than 'ideal'.	30% more than 'ideal'.	30% more than 'ideal'.	30% more than 'ideal'.
High meat and dairy	Same as 'ideal'.	Same as 'ideal'.	30% more than 'ideal'.	Meat and eggs 30% more than 'ideal'.	Same as 'ideal'.
Health conscious but high meat	Same as 'ideal'.	Same as 'ideal'.	Same as 'ideal'.	Meat and eggs 30% more than 'ideal'.	Same as 'ideal'.

Table 2: Summary of the 'ideal', 'glutton', 'high meat and dairy' and 'health conscious but high meat' diets in relation to the five Eatwell Plate food groups (recommended nutritional balance) and the 'ideal' diet created for this research.

meaning that in these respects it could be viewed as less than optimal. These three diets have been summarised in table 1.

The first of the modelled diets that was generated was the 'ideal' diet. This diet was created following recommendations from the NHS on healthy eating (the 'Eatwell' plate) (NHS, 2013).

The recommendations for fruits and vegetables are based upon five 80 gram portions (400g). This was the first section of the 'ideal' diet to be modelled as they are based on grams rather than kilocalories. As such they are the easiest food categories (and food group) to be modelled. The recommendation for total energy (kcal) is an average of 2200kcal. This means that the HFSS foods should not make up more than around 220kcal. This was the second category to be modelled. Starchy foods, high in carbohydrates, should make up a third of the diet. Many of the recommendations are based on portions rather than either kilocalories or grams. As the recommendations do not specifically state values for either metric, we assumed that this category should be no less than 734kcal (one third of 2200) or 400grams (as fruits and vegetables, by weight, should also make up 1/3 of the diet). Once this category was completed the remaining kilocalories were distributed among the final category – high protein foods (meat, fish, and dairy and meat alternatives such as soya, nuts and pulses). The resulting diet is one that contains a good balance of foods.

From this diet, several others have been modelled. The '**glutton**' diet was created by simply increasing the number of grams eaten in the 'ideal' diet in each food group by 30%. The '**high meat and dairy**' diet uses the 'ideal' diet values for all foods except for meat and dairy, which were modelled on the '**glutton**' dietary values. The '**health conscious but high meat**' diet is again modelled on the 'ideal' diet. This time, however, only the values for meat (and not dairy) are taken from the '**glutton**' diet.

The vegetarian diets are also based around the 'ideal' diet. The '**substitute vegetarian**' diet swaps calories from meat and fish categories to dairy products. The '**light-lacto vegetarian**' diet is based

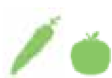
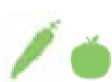
	Starchy foods	Fruits and vegetables	Dairy products	Meat and other high protein foods	High fat, sugar and salt (HFSS) foods
Substitute vegetarian	Same as 'ideal'. 	Same as 'ideal'. 	Calories from meat and fish replaced with dairy. 	No meat or fish. Other high protein foods same as 'ideal'. 	Same as 'ideal'. 
Light-lacto vegetarian	Same as 'ideal'. 	Same as 'ideal'. 	Low dairy, more milk alternatives. 	No meat or fish. More meat alternatives, pulses, nuts and seeds. 	Same as 'ideal'. 

Table 3: Summary of the 'substitute vegetarian' and 'light-lacto vegetarian' diets in relation to the five Eatwell Plate food groups (recommended nutritional balance) and the 'ideal' diet created for this research.

	Starchy foods	Fruits and vegetables	Dairy products	Meat and other high protein foods	High fat, sugar and salt (HFSS) foods
Junk food vegan	Same as 'ideal'.	Same as 'ideal'.	No dairy products. Only milk alternatives (levels modelled on 'light-lacto vegetarian' diet).	No meat, eggs or fish. Meat alternatives, pulses, nuts and seeds same as 'ideal'.	Too much.
Vegan	Cereals increased to make up lost calories.	Same as 'ideal'.	No dairy products. Only milk alternatives.	Based on 'light-lacto'. Nuts and seeds increased to make up lost calories.	Same as 'ideal'.

Table 4: Summary of the 'junk food vegan' and 'vegan' diets in relation to the five Eatwell Plate food groups (recommended nutritional balance) and the 'ideal' diet created for this research.

	Starchy foods	Fruits and vegetables	Dairy products	Meat and other high protein foods	High fat, sugar and salt (HFSS) foods
Gorilla	None.	Lots!	None.	None.	None.
Carbon minimiser	Lots of starchy foods included. Rice is reduced in favour of cereals that can be grown in the UK.	Slightly more than 'ideal' diet. UK grown is preferred over imported.	A small amount of dairy. More milk alternatives.	A small amount of meat fish and eggs. More pulses, meat alternatives, nuts and seeds.	Same as 'ideal'.

Table 5: Summary of the 'gorilla' and 'carbon minimiser' diets in relation to the five Eatwell Plate food groups (recommended nutritional balance) and the 'ideal' diet created for this research.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on lower dairy consumption due to the associated high GHG emissions that come with dairy products. Less cheese and yogurt etc is consumed and milk values are split between dairy sources and alternative milk sources such as soya. As these reductions did not supply the diet with enough kilocalories, meat alternatives and pulses were increased to make up for the lost calories from the meat, fish *and* dairy food groups.

Two vegan diets were also created. These diets are interesting to look at because they represent what kind of impact the diet could have on UK GHG consumption emissions if all livestock products were removed from the diet. In the '**vegan**' diet, all 'milk' is sourced from milk-alternatives. Values for soya and pulses remain the same as those for the 'light-lacto vegetarian'. Nuts and seeds and miscellaneous cereals (representing things such as couscous and bulgur wheat) were also increased to make up for the loss of calories. A '**junk food vegan**' diet was also developed. This diet took the number of calories lost from the '**ideal**' diet within the meat, fish and dairy food categories and replaced these calories with foods from the HFSS group. Milk alternatives were increased to the same levels as in the '**light-lacto vegetarian**' diet but every other category remained the same.

The '**gorilla**' diet is modelled on the implications of eating nothing but fruit and vegetables, as gorillas would do in the wild. This diet consists of eating almost 14 portions of fruit and vegetables a day as well as drinking a large amount of fruit juice. This diet was included as an experiment to see whether or not it was possible to get all our nutrition from 'low emitting' food stuffs, and whether or not this was in fact a 'low impact' diet as a result.

The eat-anything '**carbon minimiser**' diet was created for the Zero Carbon Britain project. Here, not only were healthier foods chosen over unhealthy foods in order to meet nutritional requirements, but all foods were considered from a GHG perspective as well. This means that products with lower GHG emissions are preferred (for example, seasonal vegetables over imported ones). It also means that foods that have high GHG emissions (such as cheese and beef) are only consumed in small quantities. An attempt was made to include some of every food category within the NDNS, including meat, fish and dairy products.

What are the results?

Nutritional recommendations

The 'current average' diet fails to meet most of the nutritional requirements: it does not meet any of the four 'essential' criteria and it only meets two of the 'ideal' criteria. It provides too many kcal and a lot more protein than recommended (Approximately 2,250 kcal and 55g are RDA of energy and protein respectively (COMA, 1991 and the FSA, 2007)). The NPS is both positive and high (3,324) which suggests that there is a high proportion of unhealthy foods in the diet and not enough healthy foods. This suggestion is reinforced by individual food group results: only 13% of the diet is made up of fruits and vegetables, for example, and starchy foods make up only 25%. These scores should both be around 33%. HFSS foods (which should make up no more than 10%) contribute 18% of the diet and high protein foods, 45% (this figure should be approximately 24%).

The 'LINDNS' diet also fails to meet nutritional recommendations. Fruit and vegetable consumption amongst this section of the population is lower than the 'current average'. HFSS foods make up a similar proportion of the diet (18%) as do starchy foods (24%). Most surprisingly, high protein foods make up a larger proportion (46%) of the diet, even though protein intake is not quite as high (85g/day as opposed to the current average of 94g/day), suggesting that the types of high protein foods consumed are of poorer nutritional quality. This, however, is still much higher than the current recommendation of 55g/day. The NPS is slightly higher than the 'current average' (3,347), suggesting again that the balance of foods between unhealthy and healthy products is weighted too much in the wrong direction. This diet matches the essential and ideal criteria of the 'current average' diet. Calorific intake, however, is significantly lower. The 'current average' diet provides 2,591 kcal/ person/day whereas the 'LINDNS' only provides 2,332 kcal/ person/day.

The nutritional results for the 'Livewell' diet are quite interesting. The original study guarantees that nutritional requirements are met for all micronutrients (such as vitamins and minerals), which have not been modelled here. Based on our criteria, however, this diet fails in some nutritional aspects. Firstly, it does not meet one of the essential criteria, as HFSS foods make up more than 10% of the diet (they make up 18%). It also fails to meet one of the ideal criteria, as wholegrain varieties are not eaten more regularly than other forms of cereals such as white rice and white bread. This is most likely due to the fact that an attempt was made to keep the diet as close to the 'current average' diet as possible (i.e. adhere more closely to current taste preferences) in order to make it easier for individuals to make the transition between the two (it is a target diet for 2020) (Macdiarmid et al, 2011). Secondly, it has the third worst NPS (-1,473), trailing only behind the 'current average' diet and the 'LINDNS' diets. This could be explained to some degree by the large proportion of HFSS foods in the diet (which have high NPS), and the relatively small amount of wholegrain varieties (which have lower NPS). It also provides 77g of protein which is, again, more than the amount advised.

The 'ideal' diet was created to meet all of the nutritional requirements designed for this report. It therefore meets all of the essential and ideal criteria. It provides 2,293 kcal and 76g of protein. Both of these values are still slightly high (particularly the protein score); reducing protein intake further, whilst maintaining all other nutritional requirements, was found to be very difficult. The NPS was -2,867, making it the 6th best NPS score of all the diets modelled.

As the exact proportions of the 'glutton' diet remain the same as the 'ideal' diet, this diet also met most of the nutritional recommendations. Essential and ideal criteria are met and the NPS score is even better at -3,728. This highlights one of the downfalls of combining the NPS to produce a

	Energy (kcal/ person/day)	Protein (grams/ person/day)	Nutrient Profile Score (NPS)	Balance criteria	
				Essential (4)	Ideal (5)
Current average	2591 (11)	94 (10)	3324 (12)	0	2
LINDNS	2332 (9)	85 (9)	3347 (13)	0	2
Livewell	2297 (7)	77 (6)	-1473 (11)	3	4
Ideal	2293 (5)	76 (5)	-2867 (6)	4	5
Glutton	2981 (12)	98 (11)	-3728 (4)	4	5
High meat and dairy	2385 (10)	82 (8)	-2721 (8)	4	5
Health conscious but high meat	2330 (8)	79 (7)	-2820 (7)	4	5
Substitute vegetarian	2294 (6)	71 (3)	-2354 (9)	4	5
Light-lacto vegetarian	2264 (2)	66 (2)	-3774 (3)	4	5
Vegan	2258 (1)	64 (1)	-4308 (2)	4	5
Junk food vegan	2277 (4)	54 (12)	-2132 (10)	3	4
Gorilla	608 (13)	19 (13)	-8222 (1)	3	1
Carbon minimiser	2276 (3)	72 (4)	-3149 (5)	4	5

Table 6: Results of nutritional analysis for all the diets modelled. Figures in brackets represent rankings (1 = best, 13 = worst).

total. As the amount of food increases, so does the score – both positive and negative scores. There is no penalty for eating too much in absolute terms. This diet provides 2,981 kcals, almost 750 kcal more than is recommended, and 98g of protein: the most of all the diets modelled. The rankings for these two categories, however, are not stated as being the 'worst'; diets that supplied less than the recommended daily amounts were given the lowest rankings due to their inability to supply the UK population with basic nutritional requirements.

The '**high meat and dairy**' diet meets the NHS food balance criteria despite the 30% increase in meat and dairy products. The NPS is slightly worse than the '**ideal**' diet, being equal to -2,721 (rather than -2,867). This is most likely due to the fact that both the meat and dairy categories contain products that have high NPS. Products such as meat pies, burgers and cheese, for example, have NPS of 19, 6 and 23 respectively. Total kcal consumption is also too high (2,385 kcal/person/day) as is protein consumption (82g/person/day). This diet is the third highest provider of energy and the fourth highest provider of protein.

The '**health conscious but high meat**' diet also meets NHS recommendations for food balance. It provides 2,330 kcal and 79g of protein, providing the 6th highest level of energy intake and the 7th highest level of protein intake per person per day. It has a NPS of -2,820, giving this diet the 7th best NPS.

The '**substitute vegetarian**' diet meets the NHS recommendations for health. It provides 2,294 kcals and 71g protein. This makes it the diet that is 6th closest to meeting the exact recommendations for kilocalories and the 3rd closest to protein requirements. It has a NPS of -2,354, however, making it the 9th 'best' score. This may be due to the large amount of cheese in the diet. As mentioned above, the NPS for cheese is one of the highest scores, making it one of the least healthy foods to

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consume in large quantities.

The 'light-lacto vegetarian' diet also meets all nutritional recommendations. It provides 2,264 kcal and is the diet that is the second closet to accurately matching kcal averages. Protein intake is 66g, which is still around 10g more than is recommended. As one of the most common arguments for meat intake is that is provides a better source of protein, however, it would be interesting to look at how this diet fares in providing all of our requirements for essential amino acids (which is the reason protein consumption is so important). This diet has a NPS of -3,774, which is the third best score of all the 13 diets modelled.

The 'vegan' diet is one of the best diets of all those modelled. It is the diet that matches the recommendations most closely. This diet provides 2,258 kcal and 64g of protein. It also has the second best NPS (-4,308) and is surpassed only by the 'gorilla' diet, which fails most of the other criteria for nutritional health.

The 'junk food vegan' diet, unsurprisingly, fails to meet the NHS recommendations relating to HFSS foods. This group makes up 24% of the diet. It also fails to meet one of the ideal criteria in that the amount of foods associated with providing 'bad fats' outweigh foods associated with providing 'good fats'. It provides 2,277 kcal/person/day but fails to meet protein intake recommendations, providing only 54g/person/day. It is one of only two diets that do not meet protein recommendations. This diet has a NPS score of -2,132, which ranks it fourth worst.

The 'gorilla' diet does not provide adequate nutrition. This diet only provides 608 kcal despite 14 portions (of 80 grams each) of fruit and vegetables being consumed every day. It also only provides 19g of protein which is just 35% of the RDA. It does however have the best NPS (-8,222). This is due to the fact that fruits and vegetables have the best NPS (the NPS for vegetables is the best score of all the food categories, equalling -9) and there are no

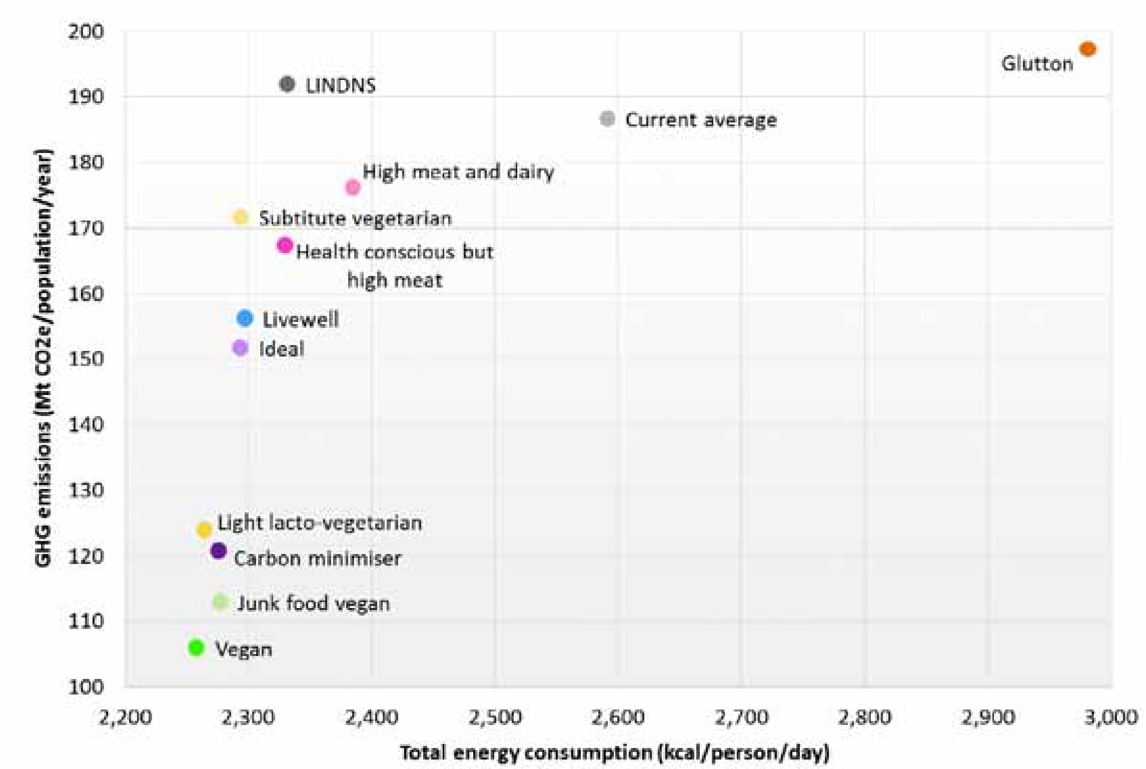

Figure 1: Total energy consumption (kcal/person/day) and greenhouse gas emissions ($MtCO_2e$/UK population/year) of 12 of the modelled diets. (NB The 'gorilla' diet is not present in this figure as the energy consumption is so low that the scale would have to be altered, making the distinctions between the other diets much harder to see).

other foods in the diet with bad scores. In terms of food balance it meets the recommendations for '5 a day' and, as this diet is only made up of fruits and vegetables, it does not contain more than 70g of red or processed meat and it does not exceed the recommendations for HFSS foods. This is why it scores three out of four on the essential criteria. This diet again shows the importance of having several dietary parameters in order to ensure they reflect each diet accurately.

Just as with the '**ideal**' diet the '**carbon minimiser**' diet was designed specifically to meet all nutritional requirements. As such it meets the NHS food balance criteria and ranks third best for kcal provision (as it provides 2,276 kcal/day) and fourth best for protein provision (supplying 72g protein/person/day). It also has the 5th best 'NPS:'-3,149.

GHG emissions

The '**current average**' diet has the third largest GHG emissions score: 187 $MtCO_2e$/UK population/year. The most significant sources of GHG emissions (rated here as anything over 10$MtCO_2e$/UK population/year) within this diet are: semi-skimmed milk, cheese, beef, chicken and butter.

The '**LINDNS**' diet is the second highest of all the diets in terms of GHG emissions (192$MtCO_2e$/UK population/year). Despite the fact that this diet contains fewer calories than the '**current average**' diet, and its protein content is less, it has higher emissions – approximately 5$MtCO_2e$/UK population/year more than the '**current average**' diet. Significant contributors are: cheese, beef and butter. These are the only three food categories in

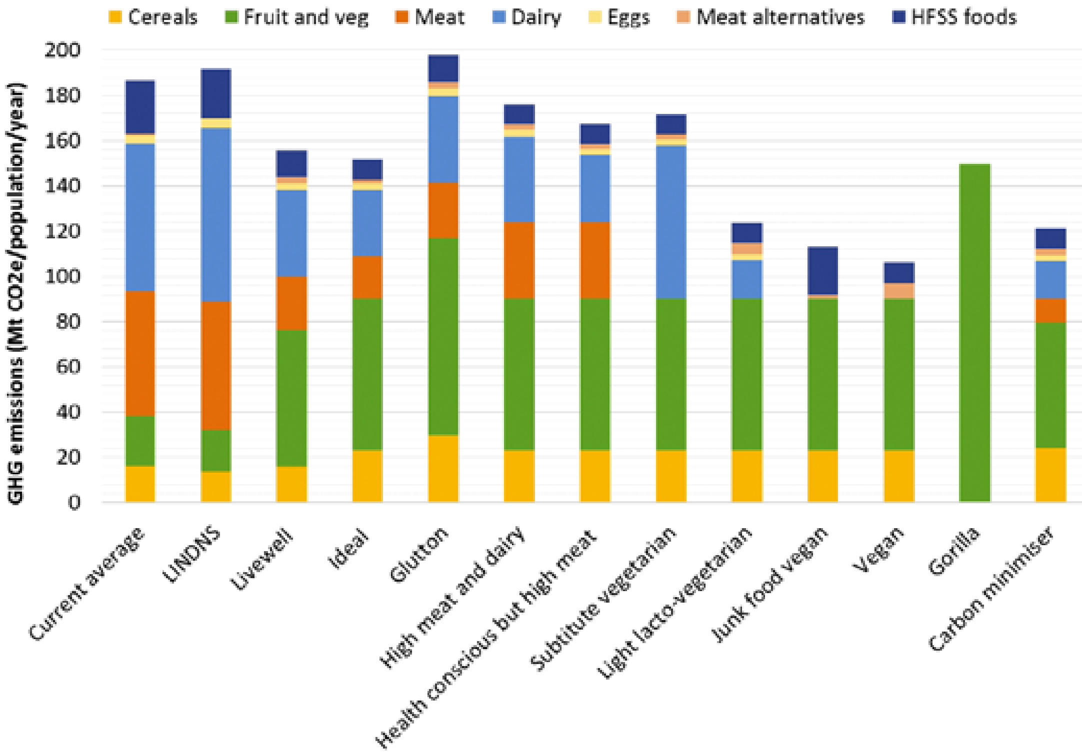

Figure 2: The breakdown of greenhouse gas emissions ($MtCO_2e$/UK population/year) between the food groups for each of the 13 diets modelled.

this diet that exceed the $10MtCO_2e$/UK population/year threshold. When compared with the 'current average' diet, these three food categories make up a significantly higher proportion of the diet's emissions. This suggests that small differences in the amounts of high GHG emitting foods can make a big difference in terms of the total GHG emission score of the diet.

GHG emissions from vegetables become significant (over $10MtCO_2e$/UK population/year) contributors in all other diets (see figure 2). This is because every diet, except for the 'current average' and 'LINDNS', meets fruit and vegetable recommendations.

The GHG emissions of the 'Livewell' diet are, however, much lower than that of the first two diets described here and rate 7th lowest amongst all the diets modelled (out of 13). Significant sources of emissions are from UK and imported vegetables, imported fruits, semi-skimmed milk and cheese. GHG emissions associated with milk in this diet are 13.7 $MtCO_2e$/UK population/year, compared with 16.4 $MtCO_2e$/UK population/year of the 'current average' diet. GHG emissions relating to cheese are also reduced in the 'Livewell' diet – by approximately 30%. This is the only diet where fruits are a significant source of GHG emissions. This is because the proportion of fruit being imported in this diet is a lot higher than the other diets and because imported fruits carry higher GHG emission values per kg.

The 'ideal' diet has the 6th lowest GHG emissions score, totalling 152 $MtCO_2e$/UK population/year. The only two categories to contribute

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significant GHG emissions of above 10 $MtCO_2e$/UK population/year were vegetables and cheese. Emissions associated with UK fruit production are 6.8 $MtCO_2e$/UK population/year, and 8.6 $MtCO_2e$/UK population/year is produced from imports (making a total of 15.4 $MtCO_2e$/UK population/year). Total emissions for fruit and vegetables combined are therefore relatively high, even though no one category produces significant emissions.

The following diets are variations of the '**ideal**' diet, and the values for GHG emissions for fruit and vegetable consumption remain the same in these diets. The '**carbon minimiser**' and '**glutton**' diets are the only modelled diets that vary in this respect.

The '**glutton**' diet is particularly interesting as you can see the effects of simply eating more food on GHG emissions. The GHG emissions relating to this diet are the highest of all the diets modelled (197 $MtCO_2e$/UK population/year). Emissions from the '**glutton**' diet are 6% higher than those of the '**current average**' diet today and add an additional 45 $MtCO_2e$/UK population/year than the '**ideal**' diet.

Total GHG emissions of the '**high meat and dairy**' diet are 176 $MtCO_2e$/UK population/year, which make this diet fourth highest in terms of emissions. Significant contributors are vegetables, skimmed milk, cheese and beef (values of 22, 12, 15 and 19 $MtCO_2e$/UK population/year respectively). The '**health conscious but high meat**' diet is responsible for 167 $MtCO_2e$/UK population/year, making it the sixth highest in terms of GHG emissions.

The '**substitute vegetarian**' diet GHG emission score is 172 $MtCO_2e$/UK population/year, making it the fifth worst diet of all those modelled. The results here may be a little on the extreme side, however. Even though an attempt was made to distribute the lost calories from meat and fish to dairy products evenly, a large amount of cheese was included (50g/day). This means that 50 $MtCO_2e$/UK population/year, 30% of total emissions, comes from eating cheese alone. Current cheese consumption is reported to be around 20g/day. This means that this diet increases cheese consumption by 2 ½ times today's average. This diet does, however, highlight the impact that high dairy product consumption can have on GHG emissions. In contrast, the '**light-lacto vegetarian**' diet has the fourth lowest GHG emissions, producing 143 $MtCO_2e$/UK population/year. Its only significant source of emissions is vegetables, which produce 37 $MtCO_2e$/UK population/year and thus contribute 26% of emissions. Emissions from fruit are the next highest, followed by milk, wholemeal bread and cheese.

The '**vegan**' diet has the lowest GHG emissions: 106 $MtCO_2e$/UK population/year. This suggests that removing livestock products from the food system is the most successful way of lowering GHG emissions. Within the '**vegan**' diet, fruits and vegetables make up 54% of all GHG emissions, producing 67 $MtCO_2e$/UK population/year. The '**junk food vegan**' diet has the second lowest associated GHG emissions of all the diets modelled. This highlights the fact that even though HFSS foods are bad for health, many of them (particularly sugary foods) are actually relatively low in GHG emissions (see figure 2). The only exceptions to this are dairy-based HFSS foods, none of which vegans eat. The HFSS group is only responsible for 21 $MtCO_2e$/UK population/year, which makes up only 19% of the total GHG emissions (113 $MtCO_2e$/UK population/year) in this diet.

Although the '**gorilla**' diet fails from a nutritional perspective it is also interesting to note that the GHG emissions associated with this diet aren't particularly good either. Total emissions for this diet are 150 $MtCO_2e$/UK population/year and there are four diets that have lower GHG emissions. If we had chosen to increase the amount of fruits and vegetables consumed until we had met kcal requirements the scores would have been considerably higher, making it one of the worst diets from an emissions perspective. Even then, the diet would have failed our nutritional requirements due to the lack of variation in food groups and thus food balance.

The '**carbon minimiser**' diet is responsible for 121 $MtCO_2e$/UK population/year. Unlike the '**ideal**' diet, the '**carbon minimiser**' diet was put together with the added constraint of choosing healthy foods that were also lower in GHG emissions. This diet has the lowest of all the GHG emissions except for the '**junk food vegan**' and '**vegan**' diet (discussed above). The difference with the '**carbon minimiser**' diet, however, is that it contains a small amount of nearly every food category within the NDNS (2001) data, including meat and dairy products. This means this diet has the potential to provide the UK population with much more flexibility and proves to some extent that the move to veganism, and thus removal of all livestock products from the UK diet, is not necessarily the only option.

This reduces food-related GHG emissions by 66 $MtCO_2e$ per year compared with the '**current average**' diet (which is a 35% emissions reduction). Vegetables (grown in the UK) are the only significant source of GHG emissions within this diet (all other groups are below 10 $MtCO_2e$/UK population/year). However, GHG emissions relating to fruits are 9.8 $MtCO_2e$/UK population/year for UK production, as most of the production is brought home. Total emissions from fruits (both UK grown and imported) are 10.9 $MtCO_2e$/UK population/year.

Land use

Figure 3 summarises the land use demands of each of the diets. It splits land up into two broad categories: cropland and grassland, but further subdivides cropland into areas used to grow crops to feed humans directly and areas used to grow crops to feed animals. It also splits up land use into that which is used in the UK and the rest of the world (RoW). This final division is probably the most difficult of the three to gain a truly accurate representation. Some products are easy to divide in this way. For example, we know we cannot grow soya beans and cocoa beans

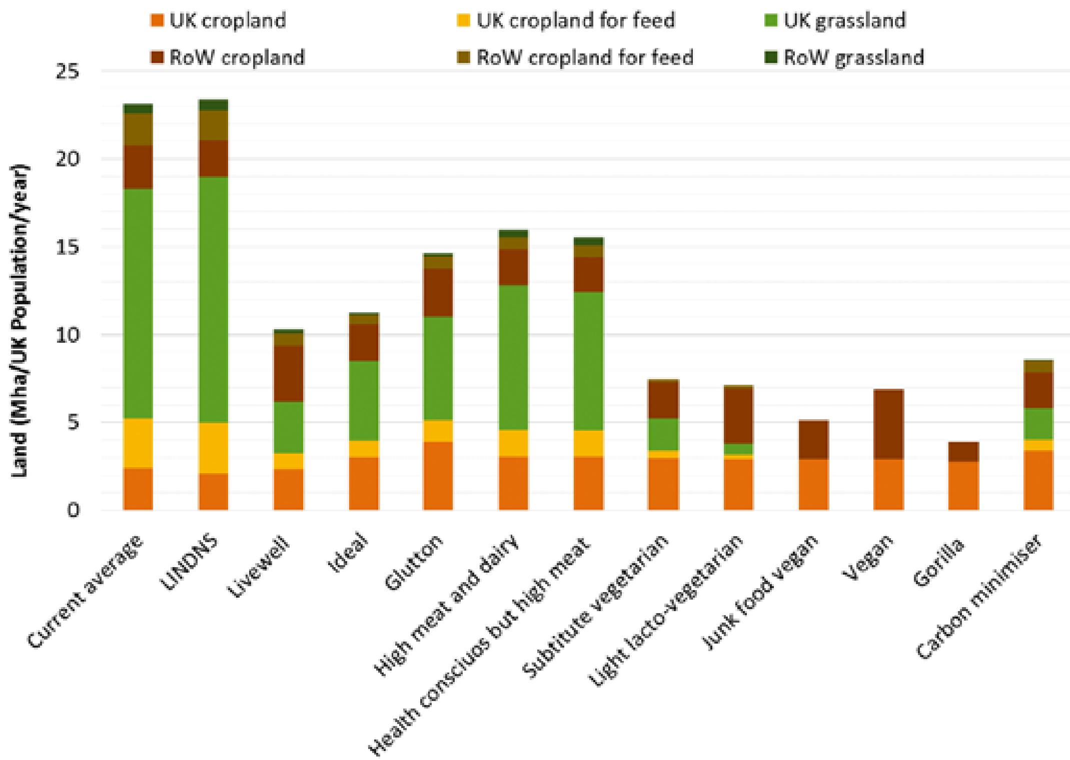

Figure 3: The amount of different types of land required (in million hectares (Mha)) to supply the whole of the UK population over one year for each of the 13 diets modelled.

in the UK so they can easily be attributed to cropland elsewhere. However, feed for cattle may be grown on land in many locations around the world, and it is difficult to ascertain what proportion of animal feed is made up of feed sourced from abroad and what proportion from feed grown in the UK. The same can be said for attributing grassland. To help with this, another study from Cranfield University was used (Audsley et al, 2009b). From this, proportions of imports for each food category could be estimated. As the model attempts to reflect how the system works today, it does not reflect simple changes that could be made to the system to produce more of our food in the UK. Sugar, for example, is a commodity which is currently imported from abroad, most commonly as sugar cane. Even though we cannot grow this in the UK, we could grow sugar beet instead. These sorts of options are not considered in this land use model.

The results are interesting, however, and highlight three key messages. Firstly, the two diets with the highest land use are the '**current average**' and the '**LINDNS**' diets. This is most likely due to both a larger calorie intake and high meat and dairy consumption. The difference in land use between the '**ideal**' diet and the '**glutton**' diet also shows the increase in land use required just to increase consumption (see figure 4). Secondly, high land use is related to meat consumption. The '**health conscious but high meat**' diet and the '**high meat and dairy**' diet both have significantly higher land use requirements than the '**ideal**' diet, despite consumption in the other food categories remaining the same. This is due to the amount of grassland cows

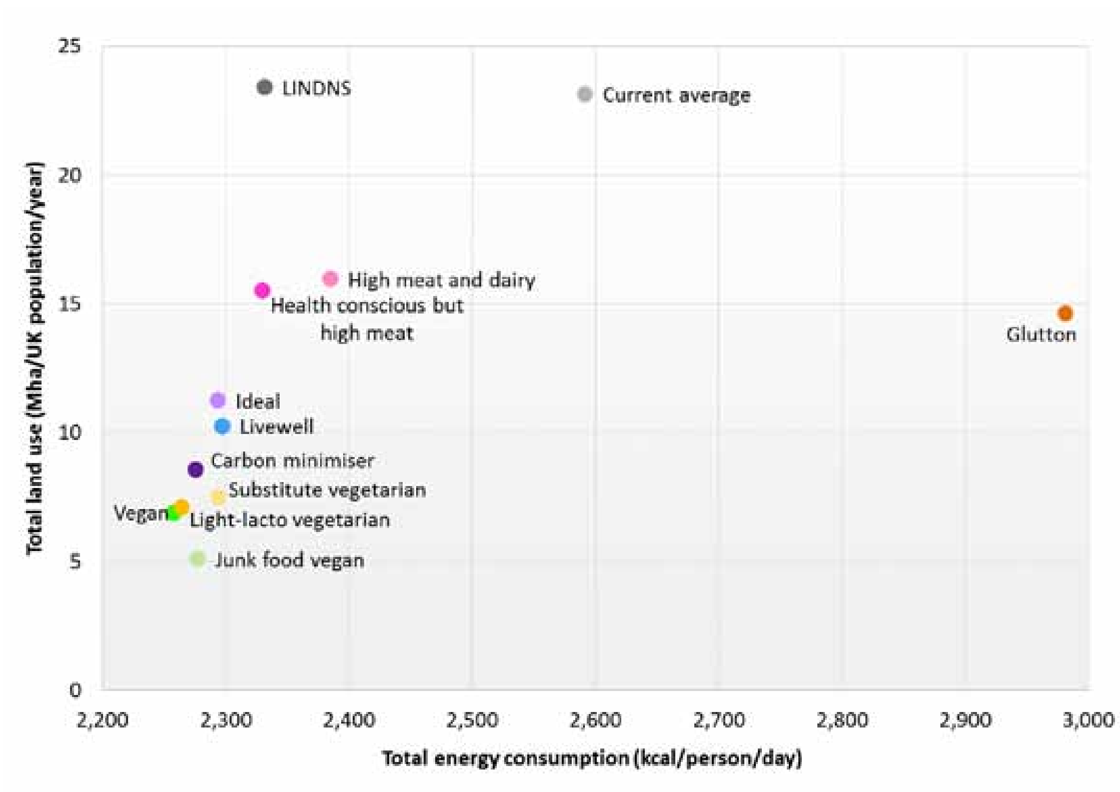

Figure 4: Total energy consumption (kcal/person/day) and total land use (Mha/UK population/year) of 12 of the modelled diets. (NB The 'gorilla' diet is not present in this figure as the energy consumption is so low that the scale would have to be altered, making the distinctions between the other diets much harder to see).

and sheep require for grazing as well as the cropland that is needed to grow food to feed all animals. Diets that have high meat consumption also have high land usage. Thirdly, the removal of livestock products, as shown in the '**vegan**' and '**junk food vegan**' diets, eliminates the use of all grassland, both here in the UK and overseas. Dairy products may be high in GHG emissions but dairy cattle do not currently require as much land as beef herds (Audsley et al, 2009b). The four vegan and vegetarian diets therefore, as well as the '**carbon minimiser**' diet show how land use requirements can be lowered with a range of different diets that have similar total calories. Less meat, however, would again be the central theme. The '**vegan**' diet also highlights an interesting point relating to land use: the levels of RoW cropland needed are much higher than that of UK land (see figure 3). This is because more products (such as soya, nuts and pulses) are included in the diet, none of which we currently grow in the UK. Whether or not growing some of these foods in the UK would be feasible is not considered in this report, but would be an interesting topic for further research.

Food-related behaviours

Food behaviours relate to the choices we make around the foods we buy rather than about the production and supply of foods themselves. Food behaviours encompass things such as whether we drive to the supermarket rather than walk, cycle or use public transport, how we cook our foods (if we cook them), how much food we waste, and whether

Commodity	Consumer waste	Supply chain waste	Total waste
Cereals	23%	12%	35%
Roots and tubers	10%	42%	52%
Oilseeds and pulses*	3-4%	16-18%	19-22%
Fruit and vegetables	13%	33%	46%
Meat	10%	12%	22%
Fish	8%	24%	32%
Dairy	6%	6%	12%
Average**	**11%**	**21%**	**31%**

Table 7: Summary table for European waste percentages of different commodities. [*Waste value for soya beans is also used here. These are based on waste figures from the FAO's North America, Oceania and Industrialised Asia waste category. **All figures have been rounded to the nearest whole number.]

or not we choose to buy our products seasonally from the UK only or all year round, importing them when necessary.

Food waste

The model we have used, as described above, allows for food waste. According to a recent FAO report (FAO, 2011) European countries waste an average of 31% of the food they produce (See table 7 for a breakdown of this average). 11% of this is wasted in the household (referred to as consumer waste). The remaining 21% is wasted throughout the supply chain. The amount of food waste does however vary significantly across different food groups. Roots and tubers (potatoes for example) have the highest food waste percentage. Just over half of all roots and tubers produced are wasted. Fruits and vegetables are the next highest at 46%; dairy, on the other hand, is wasted the least (12%). Every food category within the model is assigned one of 7 waste percentages, depending on which family of commodities it belongs to (cereals, roots and tubers, oilseeds and pulses, fruit and vegetables, meat, fish and dairy). Foods that we import from other countries have been assigned waste values for their production elsewhere in the world (not shown in table 7).

For this section of the report, the model has been altered, and waste levels have been reduced by 50% for all foods (imported and local), in line with European Union (EU) targets for 2030 (Forum Europe, 2013). This means that for dairy products, for example, only 6% of dairy products are wasted as opposed to the current 12%. Figure 5 shows the GHG emissions scores for each diet before and after waste reduction.

Figure 5 shows that reducing our food waste could have an impact on our GHG emissions regardless of which foods we are consuming or how much we choose to eat. Reducing waste by 50% could reduce GHG emissions in the UK without any dietary changes (i.e. based on the '**current average**' diet). This would reduce emissions from 187 $MtCO_2e$/UK population/year to 161 $MtCO_2e$/UK population/year. Reducing waste by 50% in the '**vegan**' diet results in annual GHG emissions of just 80 $MtCO_2e$/UK population/year. This is just 43% of the emissions from the '**current average**' diet.

Reducing waste by 50% results in an average of 19% lower emissions for the diets modelled. There are some variations between diets, however, as we waste higher levels of certain foods; if more of these are present in the diet then the reductions are greater. Emissions relating to the '**vegan**' diet and '**light-lacto vegetarian**' diet are cut by 25% and 22% respectively due to the high levels of fruits and vegetables and roots and tubers for example. By comparison emissions from the '**LINDNS**' diet and the '**current average**' diet are only cut by 13% and 14% respectively. This is most likely due to the high level of meat and dairy products in the diet, which

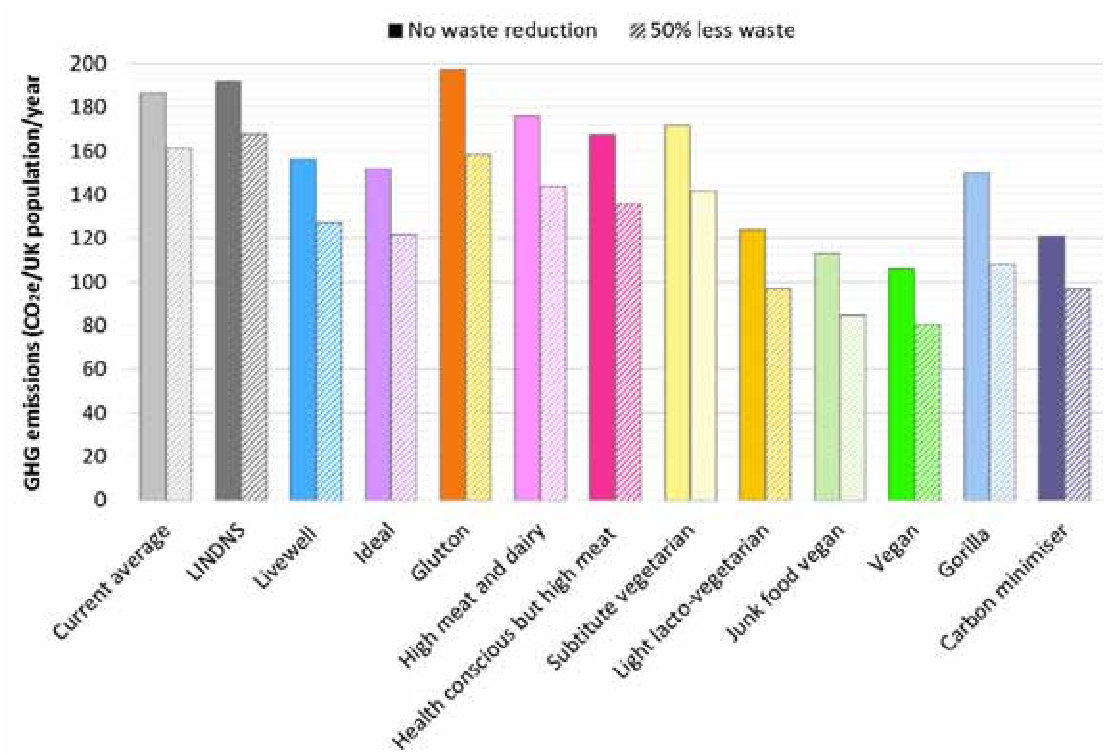

Figure 5: Greenhouse gas emission (Mt CO_2e/UK population/year) of each of the 13 diets, modelled both before and after a 50% reduction in food waste.

are associated with much lower levels of food waste (see table 7).

This suggests that if the diet of the UK were to improve and people began to choose/prefer foods that were both healthier and lower in GHG emissions, reducing levels of food waste would have a more significant impact on overall emissions reductions. The move to a '**vegan**' diet, with the addition of cutting food waste by 50%, would reduce total food-related carbon emissions by 57%. Wasting less food also decreases demand for land, which may also prove to be beneficial. Figure 6 shows the impact of reducing food waste by 50% on land use requirements.

As the number of tonnes that can be produced per hectare of land is generally high, land savings are not quite so pronounced as GHG emission savings. On average, the amount of land needed to provide the UK population with the food that it needs for 1 year could be reduced by just over 16% if food waste were reduced by 50%.

The largest benefit would be seen with the '**current average**' diet. A 50% reduction in food waste could free up 3Mha of land. The diets that are lower in meat, however, have much smaller reductions in land use needs (around 1Mha). This highlights the burden that meat places on the amount of land required for each diet, even though wastage of meat and dairy products is by comparison very low. This also means that, if the nutritional quality of the diet were improved, the percentage changes resulting from waste reduction would have less effect on land requirements. As the total amount of land required by these diets, however, is significantly less, changes to the mix of foods in the diet (mainly the reduction of meat) is a far more effective way of freeing up land than waste reduction. The land required by the '**substitute vegetarian**', '**light-lacto vegetarian**' and

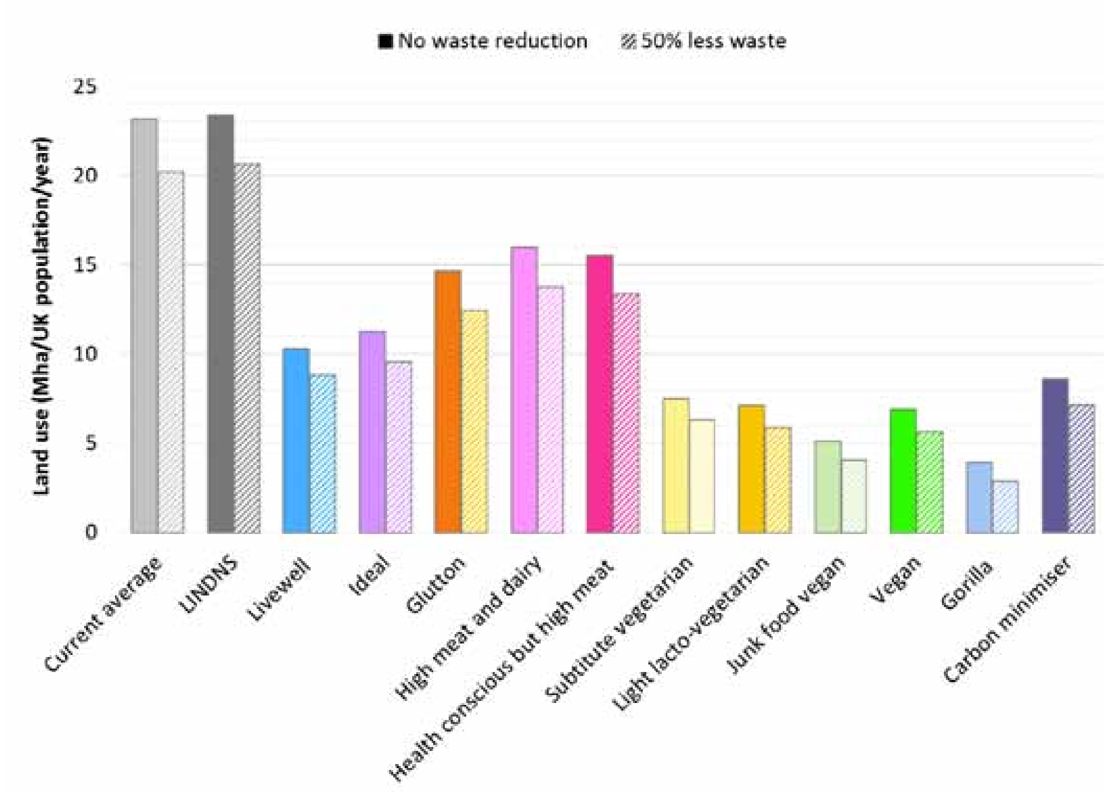

Figure 6: Land use requirements (Mha/year) of each of the 13 diets, modelled both before and after a 50% reduction in food waste.

'**vegan**' diets, for example, only use about a third of the land of that used by the '**current average**' diet. With a growing population, however, these smaller savings to land use requirements may become more significant and could ease possible future food production burdens.

Buying local (UK produce, rather than imports)

There are a number of campaigns in the UK today that recommend shopping locally. The benefits of shopping locally involve more than just carbon emission savings. They include things such as supporting local farmers and businesses, boosting the local economy and in some cases shortening the chain of supply. In terms of carbon emissions, reductions in travel are often cited as being beneficial to emissions reduction as well as reducing a reliance on imported food. Shopping locally, however, does not guarantee that the food is either grown locally or produced in the UK, so may not reduce food imports at all. As our model is only detailed enough to look at purchases of foods grown in the UK versus foods grown overseas, we aimed to model the impact of buying only crops that are grown in the UK and animals reared in the UK versus buying only imported products grown and reared outside of Europe.

In order to model the impact of only buying produce grown in the UK, GHG emission values from the HLCWG report were used (Audsley et al, 2009a). This report not only contains the values for food produced in the UK but also for food produced elsewhere in the world. Two different sets of GHG

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emission scores were therefore created: one based on UK values and one based on values from outside of Europe. Two of the diets were re-modelled with this new data: the 'current average' diet, to gauge the range of emission values that might be possible today and the 'ideal' diet to see what range of emissions are possible with a healthy diet that still encompasses all of the food groups and meets nutritional requirements. The HLCWG report does not contain data on overseas dairy emissions, nor on fish. UK emission scores for certain items we currently import, such as chocolate, also do not exist for obvious reasons – we cannot grow the cocoa required in the UK. There are therefore elements to each of the diets that remain the same. Figure 7 shows the results of these findings.

Despite the fact that some of the GHG emissions scores (from categories such as fish and dairy) remain the same, the results are still quite dramatic. This might be explained by the fact that significant changes to GHG emissions occur mainly in meat and fruit and vegetable purchases. The results show that, for the 'current average' diet, if everyone in the UK bought UK grown produce and UK bred meat products GHG emissions could be reduced to 171 $MtCO_2e$/UK population/year (a total reduction of 9%). If everyone chose to buy imported meat products and imported crops, GHG emissions relating to this diet could increase by as much as 23% from what it is today, to 230 $MtCO_2e$/UK population/year. The effects of buying only produce grown in the UK on the 'ideal' diet would be to reduce GHG emissions to 131 $MtCO_2e$/UK population/year (a reduction of 14%). Importing products from outside of Europe would increase emissions to 203 $MtCO_2e$/UK population/year – an increase of 34%.

It is also worth noting here that decisions regarding purchasing local or imported products can alter GHG emissions enough to change which diet has the lowest impact overall. In the original GHG emissions ranking the 'current average' diet was 11th (out of 13). The 'ideal' diet ranked 6th. As figure 7 demonstrates, however, a person consuming the 'current average' diet but buying UK products will be responsible for fewer emissions than someone consuming the 'ideal' diet but buying imported foods. This means that buying products that have been grown in the UK rather than from outside of Europe does have the potential to significantly

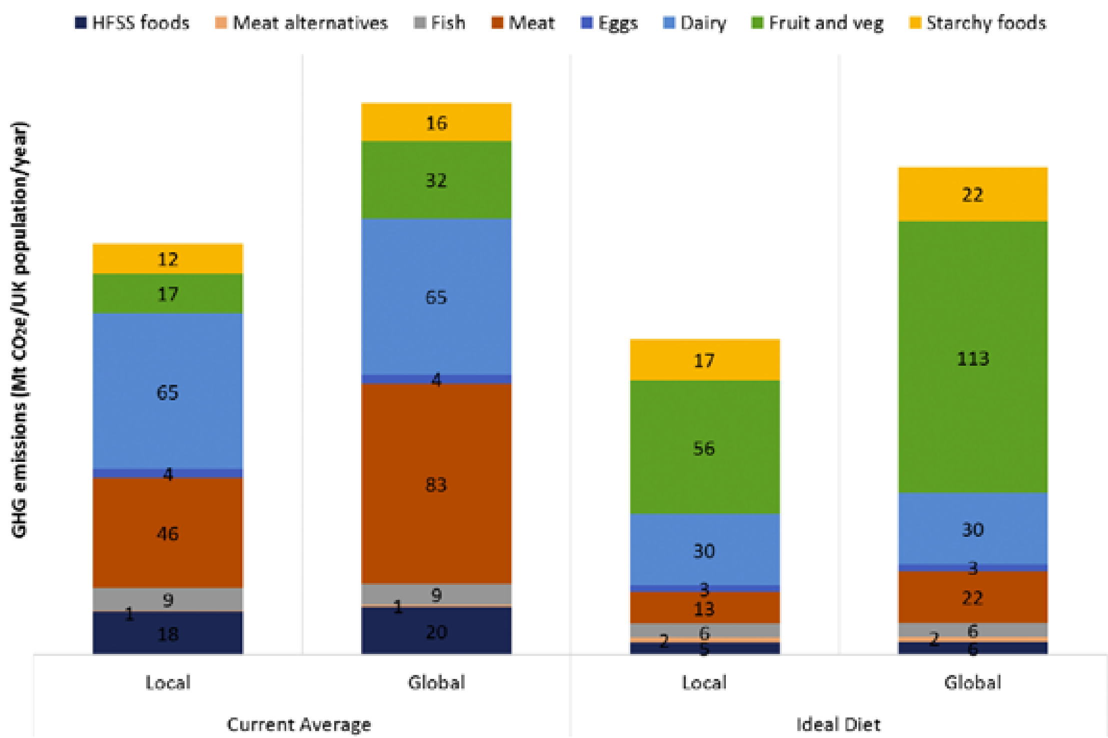

Figure 7: The difference in greenhouse gas emissions (MtCO_2e/UK population/year) between buying UK grown produce and produce imported from outside of Europe in the 'current average' diet and the 'ideal' diet.

reduce the GHG emissions associated with diets.

There can be significant differences between the GHG emissions associated with products grown or reared in the UK, and those overseas. Beef grown in Brazil, for example, has much higher emissions than that of UK beef, mainly due to the differences in practices that occur 'on the farm' rather than elsewhere in the supply chain. Transport emissions vary minimally in this instance (Williams et al, 2008). Emissions from transport, however, may contribute much more to a product's emission score if the product is flown to the UK (as is common with green beans and lettuces), rather than shipped or transported by road. Transport emissions can also make up a greater percentage of the total score if the emissions associated with growing that product are extremely low.

Although the analysis here does not detail the impact of buying from Europe, for almost all foods analysed, buying foods from the rest of Europe does increase GHG emissions (when compared to products from the UK), but not as dramatically as foods imported from further afield. There are also a few foods that can have lower associated emission scores when bought from within the rest of Europe, rather than from the UK. Tomatoes grown in Spain, for example, despite having to be transported over longer distances, have lower emissions as they are not grown in greenhouses that require a lot of extra heat and special lighting (ibid). Other foods that can also have lower emissions when imported from Europe are cucumbers, gherkins, peppers, chicory and lettuce. Understanding these variations is an important component to making more informed choices about what we eat and where in the world we buy it from.

Cooking, refrigeration, carrier bags and travelling to the shop

Cooking is responsible for approximately 10% of a product's total emission score. If we were to eat our food raw (and in many cases this is inadvisable!), we could therefore reduce the emissions from the '**current average**' and '**ideal**' diets to approximately 168 $MtCO_2e$/UK population/year and 136 $MtCO_2e$/UK population/year respectively.

Emissions relating to food storage, electricity and refrigeration (both at home and in shops and depots) are responsible for a further 17% of emissions. Removing these emissions from both diets would reduce dietary emissions to 156 $MtCO_2e$/UK population/year for the '**current average**' diet and 127 $MtCO_2e$/UK population/year for the '**ideal**' diet. This figure, however, represents food storage, electricity and refrigeration throughout the supply chain. It therefore does not give us a clear picture of the percentage of emissions that could be saved if people changed their personal food-related behaviours. It might also again be quite unpractical to do so. Moreover, saving energy through reducing the use of fridges and freezers, for example, may only increase levels of food waste and therefore effect emissions in other ways.

Emissions associated with landfill make up 3% of total emissions. Reducing these emissions would therefore result in total emissions of 182 $MtCO_2e$/UK population/year for the '**current average**' diet and 148 $MtCO_2e$/UK population/year for the '**ideal**' diet.

Packaging and carrier bags and takeaway containers make up a further 0.6% and 0.3% respectively, leaving emission totals relatively unchanged.

Travelling to the shops is also responsible for only approximately 1% of emissions. This means that walking or cycling to the shops rather than driving reduces emissions from the '**current average**' diet to 185 $MtCO_2e$/UK population/year and emissions from the '**ideal**' diet to 151 $MtCO_2e$/UK population/year. These savings therefore do not have a significant impact on overall emissions reductions, in comparison, for example, to dietary change, reduction in waste and buying locally-produced food. It does have other benefits, however. For example, it is much healthier to walk or cycle to the shops than it is to drive and so should be highly recommended as an alternative anyway.

Conclusions

GHG emissions relating to food and diets can vary significantly and making changes to what we eat can help to lower GHG emissions. Shifting the diet of the UK more in line with health recommendations would have the positive benefit of reducing GHG emissions and freeing up land. We have been able to show from our analysis that kilocalorie and protein requirements can be easily met with a variety of different diets and that people can still eat a good balance of foods. Eliminating animal products from the diet altogether is the most successful way of reducing GHG emissions (e.g. diets such as the '**vegan**' diet), but emissions can still be lowered significantly with less dramatic changes in the foods that are on offer (for example, by moving towards the '**carbon minimiser**' diet). The types and quantities of foods we consume, therefore, have the greatest impact on emission reductions, and changes to the '**current average**' diet should be encouraged. Buying food produced in the UK, especially when buying meat products and fruits and vegetables, and reducing food waste should also be encouraged.

The impact of changing our diets

GHG emissions

Today's '**current average**' diet has the third highest GHG emissions of all the diets modelled. Moving towards a healthier diet (such as the '**ideal**' diet modelled here) has the potential to reduce emissions by approximately 19%. This would reduce GHG emissions by 35 MtCO_2e/UK population/year. Individual food categories that make significant contributions to emissions are milk, cheese, beef and butter. Making smaller, individual changes such as limiting some/all of these foods (like in some of the other diets modelled) could reduce emissions by approximately 10%. Vegetables also make a significant contribution to emissions. This category is extremely broad, however, and encompasses many more food products. It is also a very important food category in terms of health, so selecting foods carefully from this category and buying seasonally, for example, should be encouraged in place of recommending reductions.

Eliminating meat and dairy products from the UK diet entirely would bring about the greatest reductions. The '**vegan**' diet shows that this could be done in a way that could still supply the UK population with adequate kilocalories and protein and provide a good balance between food groups. The move to a vegan population would reduce food-related emissions by approximately 43%. This would result in annual emission savings of approximately 81 MtCO_2e/UK population/year. It would, however, be advisable to be cautious about these results owing to the fact that a micronutrient analysis has not been undertaken in this research. Vitamins such vitamin B12 is particularly difficult to supply within a vegan diet and fortification for these nutrients are often relied upon. The amount of essential amino acids supplied by this diet would also require further research. Moreover, this may be limited in its success due to the lack of palatability of a vegan diet. The '**light-lacto vegetarian**' diet and the '**carbon minimiser**' diet, however, show that you can still achieve large emissions savings without the elimination of meat and dairy products from the diet altogether. Both these diets reduce emissions by about 34% eliminating approximately 64 MtCO_2e/UK population/year. These reductions highlight the significant impact of selecting lower emitting foods, such as by choosing chicken and pig meat over that of beef and sheep, limiting cheese intake in favour of milk and yoghurt, and picking meat and milk alternatives, pulses, nuts and seeds over all of the above, where possible.

The '**glutton**' diet suggests that total consumption is also an important consideration when attempting to reduce GHG emissions. Eating 30% more food than is advisable increases GHG emissions by the same amount, adding another 46 MtCO_2e/UK population/year (when compared to the 'ideal' diet). High emitting food categories, such as meat and dairy, are important food groups to consider in isolation, but some people may then assume that as long as these items are somewhat limited, any amount of anything else can be eaten in their place. The results from this report suggest that this is not the case and that one of the most helpful things we can do to lower GHG emissions is to simply eat less. Levels of obesity, diabetes, heart disease and other diet-related diseases could also be reduced with lower levels of total consumption.

The results of the 'substitute vegetarian' diet may be surprising, as vegetarian diets are generally thought of to be much lower in emissions. This idea, however, has been challenged in other papers (see Carlsson-Kanyama (1998) for example) as well as here. Essentially, it highlights the negative impacts of high dairy consumption. As stated in the results above, this is mainly due to a high consumption of cheese.

The 'junk food vegan' diet shows that diets based purely around what is good in terms of GHG emissions are not necessarily good from a nutritional health perspective. Even though there is some correlation between health benefits and GHG emission reductions (such as those for high red meat consumption (McMichael et al, 2007)) the two do not always go hand in hand. It is, however, the only one of the five diets that does not meet all of the nutritional criteria that is much lower in GHG emissions when compared to all of the diets modelled.

Land use

High land use is generally the result of two things. The first is a diet that has high meat consumption, especially one that contains a lot of beef and lamb. This is due to the fact that these animals require grassland for grazing as well as some cropland to provide feed. Lowering meat consumption would therefore help to reduce high land use burdens. The second is a diet that contains far more food than is required for a healthy balanced diet. Over-consumption not only places additional burdens on land use requirements but is also partly responsible for many diet related diseases seen in the UK population today. Reductions in both total food consumption and, specifically, high meat consumption are therefore recommended.

The impact of reducing food waste

Changing the mix of foods in the diet has the potential to have much more significant impact on GHG emissions reductions than reducing food waste. Reducing food waste has a larger effect on diets higher in fruit and vegetable, roots and tubers, fish and oilseed and pulse consumption due to their high waste percentages. As lower GHG emitting diets tend to contain more of these foods, emission reductions from reducing food waste are more significant amongst healthier diets. This may be an important consideration for the future, if the move to healthier average UK diet is achieved. These food waste savings represent waste values across the entire food chain. Household waste reductions alone would therefore not amount to the same levels of emissions reductions – waste would have to be reduced all along the supply chain.

The impact of buying UK products (instead of importing)

Buying products from the UK can have a significant impact on GHG emissions and should be encouraged where possible. The reductions in GHG emissions from two of the modelled diets are, however, not as high as the increases in emissions if imported foods are always consumed (buying from overseas can increase our emissions between 23 and 34% and buying only UK produce can reduce emissions from between 8 and 13%, compared to the current mix of 'foods brought locally, and those imported'). This suggests the UK population may already buy a lot of produce from the UK and that increasing the proportion of locally produced food in our diets can help reduce emissions further. The data presented above also does not look at the impact of importing foods from Europe, which may present different results.

There can be significant differences between the GHG emissions associated with products grown or reared in the UK and those overseas; however this depends greatly on the particular item, and is not necessarily to do with emissions from transport. Beef grown in Brazil, for example, has much higher emissions than that of UK beef, mainly due to the differences in practices that occur 'on the farm.' Transport emissions vary minimally in this instance (Williams et al, 2008). Tomatoes grown in Spain, however, despite having to be transported over longer distances, can have lower emissions as they are not grown in greenhouses that require a lot of extra heat and special lighting (ibid).

Buying locally produced food can have a more significant impact on GHG emissions related to food than changing the average UK diet – but this depends on what the average diet is changing to. Healthier diets, for example, containing more fruits and vegetables, make these types of choices much more significant.

One important aspect to note, however, is that with the mix of foods in the '**current average**' diet it is not possible for everyone to buy food from the UK – we simply do not have enough agricultural land (see figure 3 – the agricultural land area of the UK is currently about 18 Mha). In order for us to produce all (or much more) of our own food, we would have to change our diets to less land intensive ones, waste less and/or eat less than we currently do.

The impact of other food-related behaviours

The food-related behaviours presented in this section make up just over 40% of emissions. Reducing GHG emissions from these areas would therefore result in significant emissions reductions. The practicality of this, however, is less than clear and has not been addressed in this report. Reducing emissions from cooking, for example, would be rather difficult to do unless everyone in the UK became much more accustomed to eating raw foods – and to eating foods that were safe to eat raw. This seems neither practical nor likely. The solutions, therefore, are more likely to lie elsewhere for these areas of emissions. Switching to renewable sources of energy, for example, would all but eradicate these emissions without us having to change our eating behaviours in such an extreme way. A lot of food refrigeration, for example, also occurs throughout the supply chain and within the food and retail industries and not within the household. These emissions therefore do not reflect emissions savings that could be made on a personal consumer level and should not be interpreted as such. Travel to the shops, packaging and carrier bags have minimal effects on emissions, especially by comparison. Personal food-related behaviours such as these may not therefore play such a significant role in emissions reductions, though they are often related to other benefits – using fewer resources and materials, or having a more active lifestyle, for example.

Ranking of diets

By energy provision

	Energy (kcal/person/day)	Protein (grams/person/day)	Nutrient Profile Score (NPS)	Balance criteria		GHG emissions (MtCO$_2$e/UK population/year)	Land use (Mha/UK population/year)
				Essential (4)	Ideal (5)		
Vegan	2,258	64	-4,308	4	5	106	6.88
(Rank: 1 = best, 13 = worst)	1	1	2	All criteria met		1	3
Light lacto-vegetarian	2,264	66	-3,774	4	5	124	7.11
(Rank: 1 = best, 13 = worst)	2	2	3	All criteria met		4	4
Carbon minimiser	2,276	72	-3,149	4	5	121	8.45
(Rank: 1 = best, 13 = worst)	3	4	5	All criteria met		3	6
Junk food vegan	2,277	54	-2,132	3	4	113	5.12
(Rank: 1 = best, 13 = worst)	4	12	10	**Criteria not met**		2	2
Ideal	2,293	76	-2,867	4	5	152	11.12
(Rank: 1 = best, 13 = worst)	5	5	6	All criteria met		6	8
Substitute vegetarian	2,294	71	-2,354	4	5	172	7.50
(Rank: 1 = best, 13 = worst)	6	3	9	All criteria met		9	5
Livewell	2,297	77	-1,473	3	4	156	10.12
(Rank: 1 = best, 13 = worst)	7	6	11	**Criteria not met**		7	7
Health conscious but high meat	2,330	79	-2,820	4	5	167	15.07
(Rank: 1 = best, 13 = worst)	8	7	7	All criteria met		8	10
LINDNS	2,332	85	3,347	0	2	192	22.75
(Rank: 1 = best, 13 = worst)	9	9	13	**Criteria not met**		12	13
High meat and dairy	2,385	82	-2,721	4	5	176	15.51
(Rank: 1 = best, 13 = worst)	10	8	8	All criteria met		10	11
Current average	2,591	94	3,324	0	2	187	22.59
(Rank: 1 = best, 13 = worst)	11	10	12	**Criteria not met**		11	12
Glutton	2,981	98	-3,728	4	5	197	14.46
(Rank: 1 = best, 13 = worst)	12	11	4	All criteria met		13	9
Gorilla	608	19	-8,222	3	1	150	3.90
(Rank: 1 = best, 13 = worst)	13	13	1	**Criteria not met**		5	1

Table 8: A summary of all the results, ranked by energy provision.

By protein provision

	Energy (kcal/person/day)	Protein (grams/person/day)	Nutrient Profile Score (NPS)	Balance criteria		GHG emissions ($MtCO_2e$/UK population/year)	Land use (Mha/UK population/year)
				Essential (4)	Ideal (5)		
Vegan	2,258	64	-4,308	4	5	106	6.88
(Rank: 1 = best, 13 = worst)	1	1	2	All criteria met		1	3
Light lacto-vegetarian	2,264	66	-3,774	4	5	124	7.11
(Rank: 1 = best, 13 = worst)	2	2	3	All criteria met		4	4
Substitute vegetarian	2,294	71	-2,354	4	5	172	7.50
(Rank: 1 = best, 13 = worst)	6	3	9	All criteria met		9	5
Carbon minimiser	2,276	72	-3,149	4	5	121	8.45
(Rank: 1 = best, 13 = worst)	3	4	5	All criteria met		3	6
Ideal	2,293	76	-2,867	4	5	152	11.12
(Rank: 1 = best, 13 = worst)	5	5	6	All criteria met		6	8
Livewell	2,297	77	-1,473	3	4	156	10.12
(Rank: 1 = best, 13 = worst)	7	6	11	**Criteria not met**		7	7
Health conscious but high meat	2,330	79	-2,820	4	5	167	15.07
(Rank: 1 = best, 13 = worst)	8	7	7	All criteria met		8	10
High meat and dairy	2,385	82	-2,721	4	5	176	15.51
(Rank: 1 = best, 13 = worst)	10	8	8	All criteria met		10	11
LINDNS	2,332	85	3,347	0	2	192	22.75
(Rank: 1 = best, 13 = worst)	9	9	13	**Criteria not met**		12	13
Current average	2,591	94	3,324	0	2	187	22.59
(Rank: 1 = best, 13 = worst)	11	10	12	**Criteria not met**		11	12
Glutton	2,981	98	-3,728	4	5	197	14.46
(Rank: 1 = best, 13 = worst)	12	11	4	All criteria met		13	9
Junk food vegan	2,277	54	-2,132	3	4	113	5.12
(Rank: 1 = best, 13 = worst)	4	12	10	**Criteria not met**		2	2
Gorilla	608	19	-8,222	3	1	150	3.90
(Rank: 1 = best, 13 = worst)	13	13	1	**Criteria not met**		5	1

Table 9: A summary of all the results, ranked by protein provision.

By Nutrient Profile Score (NPS)

	Energy (kcal/person/day)	Protein (grams/person/day)	Nutrient Profile Score (NPS)	Balance criteria		GHG emissions ($MtCO_2e$/UK population/year)	Land use (Mha/UK population/year)
				Essential (4)	Ideal (5)		
Gorilla	608	19	-8,222	3	1	150	3.90
(Rank: 1 = best, 13 = worst)	13	13	1	**Criteria not met**		5	1
Vegan	2,258	64	-4,308	4	5	106	6.88
(Rank: 1 = best, 13 = worst)	1	1	2	All criteria met		1	3
Light lacto-vegetarian	2,264	66	-3,774	4	5	124	7.11
(Rank: 1 = best, 13 = worst)	2	2	3	All criteria met		4	4
Glutton	2,981	98	-3,728	4	5	197	14.46
(Rank: 1 = best, 13 = worst)	12	11	4	All criteria met		13	9
Carbon minimiser	2,276	72	-3,149	4	5	121	8.45
(Rank: 1 = best, 13 = worst)	3	4	5	All criteria met		3	6
Ideal	2,293	76	-2,867	4	5	152	11.12
(Rank: 1 = best, 13 = worst)	5	5	6	All criteria met		6	8
Health conscious but high meat	2,330	79	-2,820	4	5	167	15.07
(Rank: 1 = best, 13 = worst)	8	7	7	All criteria met		8	10
High meat and dairy	2,385	82	-2,721	4	5	176	15.51
(Rank: 1 = best, 13 = worst)	10	8	8	All criteria met		10	11
Substitute vegetarian	2,294	71	-2,354	4	5	172	7.50
(Rank: 1 = best, 13 = worst)	6	3	9	All criteria met		9	5
Junk food vegan	2,277	54	-2,132	3	4	113	5.12
(Rank: 1 = best, 13 = worst)	4	12	10	**Criteria not met**		2	2
Livewell	2,297	77	-1,473	3	4	156	10.12
(Rank: 1 = best, 13 = worst)	7	6	11	**Criteria not met**		7	7
Current average	2,591	94	3,324	0	2	187	22.59
(Rank: 1 = best, 13 = worst)	11	10	12	**Criteria not met**		11	12
LINDNS	2,332	85	3,347	0	2	192	22.75
(Rank: 1 = best, 13 = worst)	9	9	13	**Criteria not met**		12	13

Table 10: A summary of all the results, ranked by nutrient profile score (NPS).

By GHG emissions

	Energy (kcal/person/day)	Protein (grams/person/day)	Nutrient Profile Score (NPS)	Balance criteria Essential (4)	Ideal (5)	GHG emissions ($MtCO_2e$/UK population/year)	Land use (Mha/UK population/year)
Vegan	2,258	64	-4,308	4	5	106	6.88
(Rank: 1 = best, 13 = worst)	1	1	2	All criteria met		1	3
Junk food vegan	2,277	54	-2,132	3	4	113	5.12
(Rank: 1 = best, 13 = worst)	4	12	10	**Criteria not met**		2	2
Carbon minimiser	2,276	72	-3,149	4	5	121	8.45
(Rank: 1 = best, 13 = worst)	3	4	5	All criteria met		3	6
Light lacto-vegetarian	2,264	66	-3,774	4	5	124	7.11
(Rank: 1 = best, 13 = worst)	2	2	3	All criteria met		4	4
Gorilla	608	19	-8,222	3	1	150	3.90
(Rank: 1 = best, 13 = worst)	13	13	1	**Criteria not met**		5	1
Ideal	2,293	76	-2,867	4	5	152	11.12
(Rank: 1 = best, 13 = worst)	5	5	6	All criteria met		6	8
Livewell	2,297	77	-1,473	3	4	156	10.12
(Rank: 1 = best, 13 = worst)	7	6	11	**Criteria not met**		7	7
Health conscious but high meat	2,330	79	-2,820	4	5	167	15.07
(Rank: 1 = best, 13 = worst)	8	7	7	All criteria met		8	10
Substitute vegetarian	2,294	71	-2,354	4	5	172	7.50
(Rank: 1 = best, 13 = worst)	6	3	9	All criteria met		9	5
High meat and dairy	2,385	82	-2,721	4	5	176	15.51
(Rank: 1 = best, 13 = worst)	10	8	8	All criteria met		10	11
Current average	2,591	94	3,324	0	2	187	22.59
(Rank: 1 = best, 13 = worst)	11	10	12	**Criteria not met**		11	12
LINDNS	2,332	85	3,347	0	2	192	22.75
(Rank: 1 = best, 13 = worst)	9	9	13	**Criteria not met**		12	13
Glutton	2,981	98	-3,728	4	5	197	14.46
(Rank: 1 = best, 13 = worst)	12	11	4	All criteria met		13	9

Table 11: A summary of all the results, ranked by energy GHG emissions.

By land use

	Energy (kcal/person/day)	Protein (grams/person/day)	Nutrient Profile Score (NPS)	Balance criteria Essential (4)	Balance criteria Ideal (5)	GHG emissions ($MtCO_2e$/UK population/year)	Land use (Mha/UK population/year)
Gorilla	608	19	-8,222	3	1	150	3.90
(Rank: 1 = best, 13 = worst)	13	13	1	**Criteria not met**		5	1
Junk food vegan	2,277	54	-2,132	3	4	113	5.12
(Rank: 1 = best, 13 = worst)	4	12	10	**Criteria not met**		2	2
Vegan	2,258	64	-4,308	4	5	106	6.88
(Rank: 1 = best, 13 = worst)	1	1	2	All criteria met		1	3
Light lacto-vegetarian	2,264	66	-3,774	4	5	124	7.11
(Rank: 1 = best, 13 = worst)	2	2	3	All criteria met		4	4
Substitute vegetarian	2,294	71	-2,354	4	5	172	7.50
(Rank: 1 = best, 13 = worst)	6	3	9	All criteria met		9	5
Carbon minimiser	2,276	72	-3,149	4	5	121	8.45
(Rank: 1 = best, 13 = worst)	3	4	5	All criteria met		3	6
Livewell	2,297	77	-1,473	3	4	156	10.12
(Rank: 1 = best, 13 = worst)	7	6	11	**Criteria not met**		7	7
Ideal	2,293	76	-2,867	4	5	152	11.12
(Rank: 1 = best, 13 = worst)	5	5	6	All criteria met		6	8
Glutton	2,981	98	-3,728	4	5	197	14.46
(Rank: 1 = best, 13 = worst)	12	11	4	All criteria met		13	9
Health conscious but high meat	2,330	79	-2,820	4	5	167	15.07
(Rank: 1 = best, 13 = worst)	8	7	7	All criteria met		8	10
High meat and dairy	2,385	82	-2,721	4	5	176	15.51
(Rank: 1 = best, 13 = worst)	10	8	8	All criteria met		10	11
Current average	2,591	94	3,324	0	2	187	22.59
(Rank: 1 = best, 13 = worst)	11	10	12	**Criteria not met**		11	12
LINDNS	2,332	85	3,347	0	2	192	22.75
(Rank: 1 = best, 13 = worst)	9	9	13	**Criteria not met**		12	13

Table 12: A summary of all the results, ranked by land use.

Summary of all ranking

Rank	Ordered by energy	Ordered by protein	Ordered by NPS	Ordered by GHG emissions	Ordered by land use
1	Vegan	Vegan	Gorilla	Vegan	Gorilla
2	Light lacto-vegetarian	Light lacto-vegetarian	Vegan	Junk food vegan	Junk food vegan
3	Carbon minimiser	Substitute vegetarian	Light lacto-vegetarian	Carbon minimiser	Vegan
4	Junk food vegan	Carbon minimiser	Glutton	Light lacto-vegetarian	Light lacto-vegetarian
5	Ideal	Ideal	Carbon minimiser	Gorilla	Substitute vegetarian
6	Substitute vegetarian	Livewell	Ideal	Ideal	Carbon minimiser
7	Livewell	Health conscious but high meat	Health conscious but high meat	Livewell	Livewell
8	Health conscious but high meat	High meat and dairy	High meat and dairy	Health conscious but high meat	Ideal
9	LINDNS	LINDNS	Substitute vegetarian	Substitute vegetarian	Glutton
10	High meat and dairy	Current average	Junk food vegan	High meat and dairy	Health conscious but high meat
11	Current average	Glutton	Livewell	Current average	High meat and dairy
12	Glutton	Junk food vegan	Current average	LINDNS	Current average
13	Gorilla	Gorilla	LINDNS	Glutton	LINDNS

Table 13: A summary of all results ranked by energy, protein, Nutrient Profile Score (NPS), GHG emissions and total land use.

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