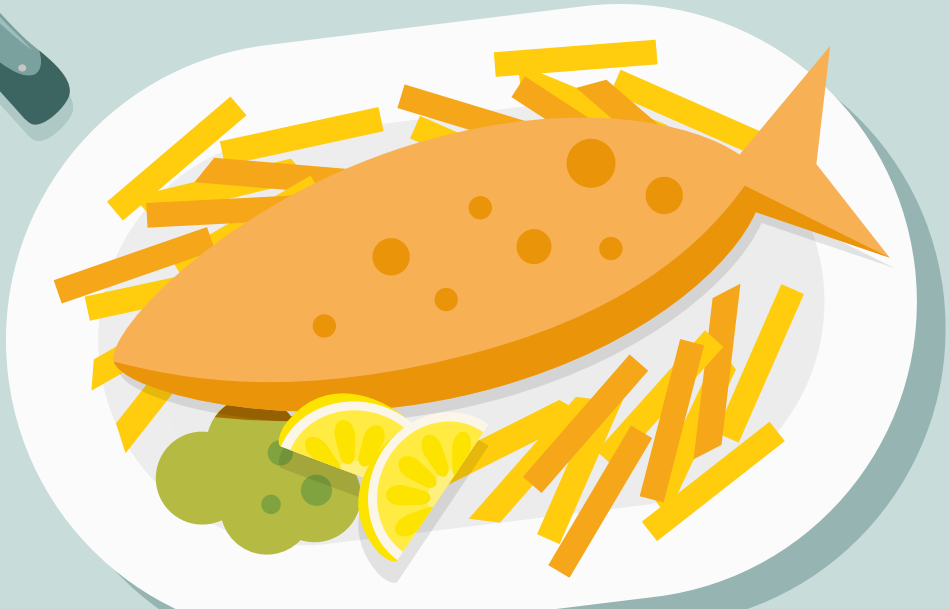
DO IT FOR YOUR PLANET

FOOD IN A WARMING WORLD

THE CHANGING FOODS ON THE BRITISH PLATE



Food in a warming world:

- The changing foods on the British plate

Executive Summary

Our climate is changing at an alarming rate, with 2015, 2016 and 2017 confirmed as the three warmest years on record. The international Paris Agreement has been created to limit the greenhouse gas emissions that are causing climate change, and it recognises the breadth of activities that contribute emissions. The role of the food we eat has come into the spotlight in addressing climate change, and it is now evident how much we can all do to help global efforts by adapting our diets.

This report takes the example of four iconic, classic UK dishes: chicken tikka masala, fish and chips, ploughman's lunch, and cawl, Wales' famous lamb stew. We consider where the ingredients come from and how much the different ingredients contribute to carbon footprint. For comparison, one example result shows that the emissions for the ingredients and preparation of one chicken tikka masala meal are equivalent to boiling a kettle 89 times to make a cup of tea. In doing so, we consider how the footprints of these meals compare to the 'carbon budget' we need to have adopted by 2030 to meet the Paris Agreement.

But the climate and our food is a two-way street. We have identified twenty risks posed by climate change to our classic British dishes, some affecting food production overseas, while others emerging on home shores. Example impacts include lower yields for global commodities like rice and soybeans; heat stress disrupting livestock productivity; warmer, wetter conditions leading to pest invasions and proliferations; and water shortages threatening age-old production regions.

There is plenty of evidence that climate change is already affecting our food system. Imports of avocados, coffee and courgettes have already been squeezed, and UK farming has been battling with flooded fields and new pest problems.

This Earth Hour, WWF is asking people to make a #PromiseForThePlanet, a pledge to make one change in their own lives to reduce their environmental footprint. The promises include becoming a flexitarian and reducing the amount of meat we eat, refusing plastic cutlery and carrying a reusable coffee cup. The promises have been chosen as examples of small behaviour changes people can make that collectively will have a big impact.

We hope this report helps to think about the two-way street between the climate and their food, and to choose to eat food that is good for both their health and for the planet.

Introduction

We know climate change is happening, and we know that it is caused by our actions. The Earth's atmosphere is warming faster than it probably ever has. In some cases weather patterns, climates and natural environments are changing quicker than wildlife or people can adapt.

The current median trajectory for climate change is a 3.2 degree rise by 2100, which would be devastating for many ecosystems and vulnerable human populations. The 'COP 21' Paris Climate Change Agreement aims to reduce man-made greenhouse gas emissions to a level that limits the global average temperature rise to well below two degrees, compared to pre-industrial levels, with an aspirational goal of 1.5 degrees. Globally, 20% of direct greenhouse gas (GHG) emissions are from food and agriculture, so clearly diets have a critical role in supporting the international mission to minimise anthropogenic emissions and limit the most severe effects of climate change.

Wherever food production takes place, the systems are dependent on the environment, whether wild fish caught at sea, sheep grazing on our hillsides or potatoes maturing in the soils beneath our feet. This report delves deeper into this dependency, to examine the relationship between food and the climate by looking at four much-loved, iconic British dishes and how they are threatened by climate change. We consider how our food can contribute towards the problem of climate change, but also how climate change threatens the supply of ingredients we take for granted. The results show there is a 'two-way street' between the climate and our food, insomuch as each is directly affected by the other.

Our food provides great pleasure, but is also essential fuel for our bodies. Dietary choices are key to influencing exactly what is grown, and how much is needed. That is why this Earth Hour WWF is asking people to make a promise for the planet and eat more sustainably. We're asking people to make small lifestyle changes and cut back on the amount of meat, fish and dairy they eat rather than cutting back altogether. By doing this, we can all play our part in helping resolve some of the issues in our food system, reduce our carbon footprint and future-proof our best-loved dishes.

Iconic British dishes

The UK has a diverse food landscape, shaped by its history and multiculturalism, and enabled in the last 30 years by the consistent availability of high quality, affordable ingredients sourced from a dynamic, complex global food system. Ingredient sourcing moves between countries dependent on the season, market prices, and supplier relationships and so on - for example, fresh UK tomatoes are supplied from Morocco, Spain, Egypt, The Netherlands and domestic producers. The popularity of television food programmes, social media sharing and the burgeoning of new food outlets and delivery channels are all revolutionising the types of food that UK consumers recognise and want to eat.

Despite these changes, some classic British dishes have retained their draw to the present day. Given that 22 million take-aways are eaten every week and almost half of Brits go to the pub at least once a week, we have selected four iconic British dishes that are popular pub-grub and typical take-aways. These much-loved meals all have interesting origins – one dates back to the 11th century – and comprise a range of different ingredients through which we can explore links to the environment and climate.

FISH & CHIPS, with mushy peas

- A prominent meal in British culture, the culinary fusion of fish and chips first appeared in the UK in the early 1860s. 'Chippies' serving the dish quickly spread around the country, with meals served in old newspapers to keep prices low. The development of steam trawling boats secured a steady supply of white fish from the North Sea, and the number of chippies in London peaked in 1927 with 35,000 - today, the number is closer to 10,000, although the dish is also firmly established on pub menus nationwide. Fish and chips became an iconic meal and national institution; during the First World War the government refused to ration the dish and ensured its availability to boost morale and combat hunger.
- **Major ingredients**[1]
    - **UK-sourced:** Cod, potatoes, peas, wheat flour for batter
    - **Imports:** Lemon (Spain), sunflower oil for frying (France).
- **Pub meal cost:** £8.25
- **Protein choice:** consumption[2] of seafood stands at 177g per person per week, of which 25g is for cod. But cod remains the most popular fish eaten out of home, with 126 million servings recorded annually.

[1] For the purpose of this report we have specified single source countries that are significant suppliers of the ingredients. However, actual sourcing will vary and often be from more than one country at any one time. Appendix 1 lists details of all ingredients for each dish.

[2] Protein data taken from recent industry sources Seafish, AHDB and Diary UK. Figures are generally higher than NDNS data from 2010 used in 'Eating for 2 degrees', which are self-reported and recognised as potential underestimates.

CHICKEN TIKKA MASALA, with rice and naan bread

- The origins of chicken tikka masala are debated. Various accounts credit an Indian restaurant in Glasgow for creating the dish in the 1960s when a patron complained that his Chicken Tikka was too dry. The chef reportedly added tomato soup, spices and yogurt and eventually added this concoction to his menu as "Chicken Tikka Masala." Other reports claim that the dish was a spin-off of butter chicken or a solution to tone down the spiciness common in other Indian dishes for British palates. At the other extreme, some claim that it originated in the 1500s with the Mughal empire in India! No matter the dispute about its origins, in 2001 the Foreign Secretary called it a "true British national dish," highlighting its popularity and cultural importance.
- **Major ingredients**
    - **UK-sourced:** Chicken, cream, yoghurt, butter, onion, wheat flour and rapeseed oil.
    - **imports:** Rice (India), tomato (Spain), coriander (Spain), lemon (Spain), spices (various)
- **Pub meal cost:** £8.29
- **Protein choice:** demand for chicken has risen rapidly, and it is now the most popular meat consumed in the UK representing 36% of the market, with consumers eating on average 670g per person per week.

PLOUGHMAN'S LUNCH, with egg and bread

- Reference to a traditional meal of bread, cheese and beer dates back to 14th century manuscripts. Rural labourers relied on this in the fields, and it could be found served in pubs and inns across the UK. However, the 'Ploughman's lunch' was not officially named until the 1950s, when the Cheese Bureau began advertising the concept in pubs to promote the sale of cheese. In the 1960s, the Milk Marketing Board began promoting the meal and its name nationwide.
- **Major ingredients**
    - **UK-sourced:** Cheese, egg, onion, apple, celery, radish, butter, and wheat flour.
    - **imports:** Tomato (Spain)
- **Pub meal cost:** £8.50
- **Protein choice:** given that 10 litres of milk are needed for 1kg of Cheddar, cheese makers are a key market for dairy farmers, and UK consumers eat an average of 190g of cheese per person per week. An average of 3.8 eggs are eaten per person per week.

CAWL (lamb stew)

- Dating back to the 11th century, cawl (rhymes with 'owl') is considered one of Wales' national dishes. This traditional country one-pot stew was developed to feed working men and women using whatever ingredients were available. A shortage of grain and vegetables resulted in a dependence on meat, and the meat was often reused for broth for cawl. "Cawl twymo" means second eating, and the original pot of cawl was often bulked up with added ingredients over the following days. In the 18th and 19th centuries, there was a meat shortage, so the stew was often bulked with potatoes and leeks. Traditionally, the cawl is served with bread and butter, and often also with cheese. A popular choice is Caerphilly, a hard cow's milk cheese made from unpasteurised milk and animal rennet and matured for just a couple of months before being sold.
- **Major ingredients (all UK-sourced):** Lamb, potatoes, leeks, onion, parsnip, swede, cheese, butter, and wheat flour.
- **Pub meal cost:** £8.95
- **Protein choice:** sales of lamb are in decline, with average consumption now at 90g per person per week, reportedly because it is less convenient to prepare and cook than other proteins, and is less present in international foods such as Italian, Mexican and Chinese that constitute a significant part of the modern UK diet.

Just under half of the food consumed in the UK is domestically produced, with imports particularly high for certain food groups such as fruit and vegetables. For our four iconic dishes, the higher proportion of ingredients listed from UK sources may be because they originate from a time when fresh imports where much less readily available. However, nowadays 90% of cod consumed in the UK is from overseas, and although most livestock is UK-reared, there is still high dependency on imported feeds.

Responsible consumers are conscious of where food comes from, and although the 'food miles' focus has waned (as impacts from deforestation and livestock digestion have gained prominence), local provenance and supporting British farmers are still considered to be important to shoppers in the UK. Perhaps in recognition of these preferences, we are seeing the major UK retailers and many restaurants make explicit consumer commitments to British sourcing, particularly for fresh meat.

THE PRESENT

How our food affects the climate

Food production and processing is a significant portion of our contribution to climate change, with 20% of UK's greenhouse emissions attributed to feeding the population. The scale and precise sources of greenhouse gas emissions depend on factors such as the agricultural production methods, input and structures of the supply chain. In broad terms, greenhouse gas emissions can be categorised as follows:

AGRICULTURE

- **Land conversion** – where natural land-use such as forests or peat soils are converted for agriculture – particularly for soy, oil palm and beef production – leading to the release of stored carbon to the atmosphere
- **Fertilisers** – these are needed for plant nutrition, but generally have high impacts in manufacture and from the soil where they are applied to the fields
- **Livestock digestion** – particularly from ruminants such as sheep and cattle, leading to the release of methane which is a potent greenhouse gas in the atmosphere
- **Rice cultivation** – high levels of methane, a potent greenhouse gas, occur from growing rice in flooded fields
- **Animal manures** – particularly for intensive livestock systems, concentrated piles are major emitters of methane and nitrous oxide gases.
- **Farm fuel and energy** – farm machinery such as tractors and irrigation pumps, and onsite processes such as refrigeration require energy which is typically derived from fossil fuels

SUPPLY

- **Transportation** – from farms to processing sites; to distribution centres; and then out to retailers and food service
- **Food processing** – energy for cooking, chilling, freezing and packing goods in the supply chain.
- **Packaging** – product packaging, with energy and other resource needed for making plastics, steel, aluminum and card.

CONSUMPTION

- **Consumer travel** – journeys from homes to supermarkets and restaurants.
- **Food preparation** – to refrigerate, prepare and cook our food, whether at home or in food service

By compiling the agricultural production and processing required for each of our four dishes, we have calculated their carbon footprints to understand the climate change impact – see Appendix 2 for details on the methodology. Results are reported in 'kilograms of carbon dioxide equivalents', or $kgCO_2e$, which bundles all greenhouse gases such as methane and nitrous oxide to a single unit to enable comparisons. The table below shows the carbon footprint for each of the major[3] ingredients and total for each dish.

[3] Individual ingredient values are shown for all ingredients ≥3g CO_2e.

Ingredients list		Carbon footprint ($kgCO_2e$)		
	CHICKEN TIKKA MASALA	FISH and CHIPS	PLOUGHMAN'S	CAWL (LAMB STEW)
Apple	-	-	0.05	-
Butter	0.05	-	0.20	0.20
cheese	-	-	1.28	0.83
chicken	0.77	-	-	-
Cod	-	0.91	-	-
Cream	0.39	-	-	-
Egg	-	-	0.35	-
Lamb	-	-	-	4.51
Lemon	0.03	0.09	-	-
mustard			0.03	
palm oil	0.03	-	-	-
Peas	-	0.09	-	-
Pickle	-	-	0.23	-
Potato	-	0.10	-	-
Radish	-	-	0.04	-
rapeseed oil	0.07	-	0.06	-
Rice	0.33	-	-	-
rice flour	0.03	0.03	-	-
sunflower oil	-	0.17	-	-
tomato	0.07	-	0.07	-
wheat flour	0.06	0.11	0.14	0.10
yoghurt	0.07	-	-	-
Other	0.16	0.05	0.16	0.29
TOTAL	**2.0**	**1.5**	**2.6**	**5.9**

Key: Yellow 100 to 250g CO_2e; orange 250 to 500g CO_2e; bright red 500g to 2kgCO_2e; dark red > 2kgCO_2e.

Higher carbon footprint values mean higher greenhouse gas emissions, exacerbating the problem of climate change, which in turn effects the conditions needed for producing our food. The average daily footprint in the UK is currently 35.6kg CO_2e which includes travel, home heating, and so on. The average diet related carbon footprint is 5.17kg CO_2e – but this needs to shrink to 4.09kg CO_2e by 2030.

The iconic dish with the highest footprint is for cawl, at 5.9kg CO_2e per serving, of which three quarters derive from the lamb, largely due to the enteric fermentation of sheep digestion that leads to methane release. The second highest carbon footprint dish is the ploughman's lunch at 2.6kg CO_2e, because the 124g of cheese in the recipe causes 1.3kg CO_2e, this time because of the methane emissions from cow digestion. Chicken tikka masala is the third highest at 2.0kg CO_2e, with chicken, cream and rice being major contributors. The lowest footprint meal is fish and chips at 1.5kg CO_2e, in part because the cod protein is wild-caught and there are no other animal products in the recipe.

So, how do these numbers for our dishes compare to other activities? For each of our dishes, we can compare the footprint to other common items and daily activities:

Equivalent to[4]:	CHICKEN TIKKA MASALA	FISH and CHIPS	PLOUGHMAN'S	CAWL (LAMB STEW)
Number of 500ml PET plastic bottles	25	19	31	71
Days of LED lightbulb being switched on	22	17	28	65
Times boiling the kettle for one cup of tea	89	67	113	258
Miles driving in average UK car	11	8	13	31
Number of full charges for a smartphone	249	188	316	722

How the climate affects our food

The relationship between the climate and our food is interdependent. While what we grow and eat can contribute to climate change due to the differing carbon footprint as shown above, the changing climate can also directly affect our food production and supply.

Forecasts for climate change are extremely complex – with different conditions predicted in different parts of the world and even across the UK. The global trend is for warmer average temperatures with more energy in the atmosphere leading to increased frequency of more severe events such as droughts, heat waves, hurricanes, flooding and tidal surges. UK projections include increases in precipitation in winter, spring and autumn for most regions, as well as more frequent short duration, "extreme" precipitation events. This is evident from Met Office reports, with the 2013/4 winter the wettest for 250 years and December 2015 the wettest month ever recorded, both of which caused widespread flooding.

Extreme weather events have occurred historically, but due to the improving science of event attribution it is now sometimes possible to attribute likelihood as well as intensity of a single weather event to climate change. For example, it has been calculated that the occurrence of the 2003 European heat wave when thousands of people died was twice as likely as a consequence of climate change.

Precisely how severe weather events impact food production depends on various factors such as the type of crop, timing, location, local vulnerability, and so on. The ultimate impact on food *supply* also depends on factors such as global trade, particularly if there are simultaneous supply issues elsewhere in the world, which can be unrelated. The mechanisms by which severe weather impacts food production include:

Event	Potential impacts
Heavy rainfall	Waterlogged land prevents access and harvest; reduced yields; increased disease risks
Flooding	Soil erosion; kills plants; washes away livestock; long term yield loss
Drought	Reduced yields; water shortages for livestock; supplementary feed requirements
Heat wave	Heat stress for livestock; crop losses
Storms	Loss of leaves/blossom; crop damage from hail or wind; supply chain disruptions

For many weather events there are also indirect impacts. This is true for pests and diseases – such as insects, bacteria, and viruses – which have lifecycles that can be dramatically affected by the environmental conditions. When the weather is warmer, wetter or windier, new or larger populations of pests can emerge that infect both crops and livestock. And over the long term, weather events such as wind and rain can cause soil erosion that reduces the productivity and resilience of future crops. Other indirect impacts relating to human activities, such as port closures stopping shipments or power outages affecting key food operations, can cause as much disruption to supply as direct impacts on agriculture.

Food production has always been at the mercy of the elements, and inclement conditions and severe events have impacted food supply since records began. However, observed climate change appear to be consistent with direct experiences for some of our key imports, as well as for UK agriculture:

- **Avocados**

[4] Calculations use Defra's UK grid average electricity emissions factor. 'Average car' from SMMT 2016, with emissions of 120gCO_2e/km

The cost of "smashed avo' on toast" increased during the first half of 2017, as the price of avocados in supermarkets in the UK had increased by at least 50%. Global supplies dwindled due to a late harvest in Mexico, exacerbated by a workers' strike and floods in Peru. Mexico and Peru alone account for 37% of global avocado production. Increased demand from emerging markets, like China, where consumption has doubled annually for several years, contributed to these higher prices. In the United States, several years of drought in California resulted in a harvest of about half of the usual amount and combined with fewer imports from Mexico, doubled the retail price of avocados. Despite higher prices, global demand for avocados continues to increase. The market is likely to experience more chaotic years like 2017 as most avocadoes consumed in the UK are grown in the warm climates of developing nations which can be more vulnerable to climate change events.

- **Coffee**
  More than 60 countries produce coffee in the 'bean belt', with Arabica coffee — 60% of global output — growing in tropical highlands and performing best at an average temperature of 18-21 degrees Combined changes in temperature and precipitation are the main avenues through which climate change affects coffee production, and rising temperatures tend to force growers upslope to track suitable climates. Where coffee was previously grown up to 2,200m in Ethiopia, the level has now risen to 2,600m – the productive area in Ethiopia, coffee's original homeland, could fall by up to 60% through the century. Growing regions in India have already suffered substantially lower yields due to one third decrease in rainfall, higher temperatures, and pest problems.
- **Courgettes (and other imported vegetables)**
  UK imports of lettuce, courgette and other produce from southern Spain were disrupted in early 2017 because of flooding, unseasonal frost and snow. These conditions ruined harvests and severely limited transportation, leading to retailers imposing purchasing limits on items. Prices skyrocketed with courgette prices up by 60%, aubergines by 132% and tomatoes by 45%. UK retailers resorted to air freighting lettuces and other items from the US to plug the gap.
- **Costs to UK agriculture of 2014 winter flooding**
  From mid-December 2013 to February 2014, the UK experienced a series of intense winter storms and the largest rainfall on record. This resulted in extensive flooding, with saturated soils worsened by poor drainage. The flooding had a £6.9 million agricultural economic impact and resulted in £19 million in damages. Over 80% of the damages were to the livestock sector. Two poultry farms in North Lincolnshire that supplied major UK retailers were hit by a tidal surge, costing the company half a million pounds in lost stock and damages. Cereals and break crops suffered the greatest loss at 20%, while potatoes and root crops saw a 10% reduction in yield.
- **Pests and disease threatening UK livestock**
  The presence and spread of many pests and disease are exacerbated by warm, wet weather that enable faster growing cycles and survival over winter. Bluetongue virus, which infects sheep and cattle via a biting midge, arrived in the Netherlands in 2006 and was first confirmed in the UK in 2007. A vaccine was developed and deployed in 2008 which prevented major livestock losses. Similarly, during the mild winter of 2012, severe rumen fluke infections in cattle were reported for the first time in the UK and were attributed to warmer weather. The control of pests and disease – and particularly if faced with new exotic species that require warmer environments – presents an arms race for veterinarians and farmers to control infections, all of which requires additional investment and management by the industry.

The interconnected, global nature of modern day food supply also means that impacts in one region have spillover effects elsewhere in the world. And when two or more events coincide, the combined effect can be amplified to cause real shocks to the global supply and market prices. We are already seeing these 'amplification' effects ripple through the global system, and these are likely to become more frequent. The 2007-8 food price crisis was attributed to factors including droughts in grain-producing countries, oil price rises and competition for land with biofuel production. The effects were dramatic, with price increases in commodities of wheat by 130%, soy by 87% and rice by 74%. The cost of tinned foods in the UK increased by 15%, and fruit and vegetables were up by nearly a third. The effects in developing countries were more severe, with widespread rioting in response to food unaffordability – for example, common food items in Haiti were 50% higher in 2008 than the previous year. It is clear that the combination of a changing climate and supply chain pressures are leading to disruption across the globe, affecting all aspects of our food system.

At each stage of the food chain, individuals and organisations can take steps to adapt to climate change, whether that be new crop varieties that cope with different growing conditions; techniques to preserve the soil; or new ventilation to reduce temperatures in livestock enclosures. However, in many cases – and particularly when facing extreme weather events – the forces of nature are just too powerful, and will have devastating effects irrespective of the preparations.

THE FUTURE – 2030 & Beyond

Climate risks to iconic dishes

What might climate change mean for the future iconic British dishes? Although it is impossible to predict exact impacts, there is evidence of risks to our dishes based on recent climate-related events, as well as threats from future conditions expected as a consequence of manmade climate change . The table below lists twenty risks from climate impacts to major ingredients. While it is by no means exhaustive, it shows how different climate impacts could affect ingredient supply.

Climate Impact	Ingredients affected					
Heat wave causing heat stress	Chicken	Milk	Lamb	Tomatoes		
Water shortage and droughts	Potatoes	Peas	Wheat			
Warmer, wetter conditions favouring pests	Rice	Onions	Peas	Wheat	Lamb	Potatoes
Climatic change reducing growth rates	Soy (for chicken & dairy feed)		Tomatoes	Cod	Apples	Rice
Unseasonal weather events	Lemons					
Soil losses to erosion	Wheat					

Many ingredients face multiple challenges, and these combine to present a range of risks for each of our four dishes. The following sections describe potential impacts, and summarise what these could mean for our dishes:

Chicken tikka masala – Rising costs from rising temperatures

Potential impacts from climate change

- **Heat stress affecting chicken welfare and impacting growth rates**
- **Disruption to soymeal market, giving rise to use of alternative feeds such as insects and algae.**
- **Rice could be one third more expensive in 2050**
- **Onion growers battling fusarium soil fungus**
- **Extreme rainfall and heat waves hitting tomato growing regions, driving up prices**

- **Chicken**
  - Heat stress in livestock is not a common problem under normal climate conditions in the UK, but is a growing threat under more frequent heat waves forecasted with climate change. High temperatures induce heat stress, which can affect feed intakes, growth rates, fertility, immunity to diseases and pests, and overall welfare. For poultry, heat stress occurs from mid-twenty degrees and these effects can reduce chicken meat quality and/or yields. Heat stress in poultry was a cause of concern in the summer of 2012, when temperatures as high as 30 degrees disrupted poultry health and productivity. One vulnerability in chicken supply chains is transportation to slaughter, when controlling the temperature on trucks can be more difficult than in rearing sheds. If a heat wave coincided with journey delays there could welfare impacts as well as productivity losses.
  - Poultry feed in the UK is about one fifth soyameal, and the UK bought 2.3 million tonnes of soyameal in 2010 (including from rapidly expanding Argentinian soy production where harvests are encroaching on vulnerable ecosystems) of which 1.15 million tonnes were used for poultry feed. Higher temperatures and changing rainfall patterns have been shown to reduce soy yields by 30% for the largest global producer, the United States, and this could also affect those countries which export soy products to the UK. Chicken feed is carefully managed to optimise growth, with particular amino acids in soy protein being a vital constituent. If soy costs increase markedly – as they did for a period during the 2008 food price spike with an increase of 87% – or availability declines, 'alternative feeds' such as insects and algae may become more cost competitive. All in all, these changes point towards upward pressure on the currently cheap price of chicken protein.

- **Rice –** Rice is an increasingly important grain in the UK diet, and in 2013 the UK imported almost 600,000 tonnes. Rice prices are highly volatile and soared ten years ago in the 2008 'Global Rice Crisis', triggered in part by major droughts in Australia reducing global grain supplies. Forecasts for the future are for the

majority of climate change impacts on rice to be to be negative: water shortages and irregular rainfall patterns will increase the intensity of diseases such as brown spot and blast, and rice-weed competition, while extreme weather events have recently led to dramatic rodent population outbreaks in Asia due to unseasonal cropping. The net effect is a forecast that by 2050 rice prices will increase by up to 37% as a result of climate change, and that rice productivity will reduce by at least 10% in Asia and Africa.

- **Onions –** Onions are widely cultivated around the globe and are the second most valuable crop after tomatoes. Production is valued at £110 million per year in the UK and £9.5 billion globally. One threat to onion production is Fusarium Basal Rot (FBR), a soil-borne fungus that causes the bulbs to rot in the ground or while sitting on store shelves. In 2012, higher than normal temperatures in the UK were linked to losses costing an estimated £11 million. FBR is forecast to worsen with climate change projections for warmer and wetter conditions, so the UK risks more losses in our onion fields.

- **Tomatoes** – Marketable tomato yields have been shown to decrease with increasing temperatures. The UK imports more than 80% of the tomatoes it eats, primarily from The Netherlands and Spain. Almost all Spanish export tomatoes are grown in the semi-arid southeast, Almeria and Murcia, and its cultivation requires significant amounts of water, especially when plants experience high temperatures. During the 2014-2015 season, temperatures of more than 40 degrees severely damaged more than 60% of the tomato plants in the main growing towns of Águilas and Amzarrón. The next season, 2015-2016, the region suffered from severe flooding, further affecting produce yield, including tomatoes, leading to shortages and higher prices in export markets like the UK.

Fish & chips – Under threat from acid oceans

Potential impacts from climate change

- **Warming, acidified oceans disrupting cod habitats and reproduction**
- **Potato growers moving from the East of England and struggling to water crops in dry years**
- **Pea beetle's arrival from mainland Europe, compounding bacterial blight and water stress**
- **Droughts leading to farmer protests, lemon shortages and prices spikes**

- **Cod** – Both rising sea surface temperature and ocean acidification pose a real threat to maintaining economically and biologically viable cod stocks. The North Sea is reported to be warming twice as fast as the world's other seas and oceans. North Sea cod – which over the last two decades have been recovering in numbers – are migrating to cooler waters. A temperature rise of 1 degree has seen cod shift their range further north and southern species, like anchovies and sea bass, are replacing indigenous fish populations. With increasing temperatures, this trend will continue. Evidence from the Atlantic has shown that in cod's spawning waters of the Gulf of Maine, where temperature has increased markedly, cod are less likely to reach maturity. The expected effects of ocean acidification have been recreated in the laboratory, and show the doubling of mortality of newly-hatched cod larvae under the predicted acidification levels for 2100.

- **Potatoes** – Potatoes are a water-thirsty crop, and water shortages are already affecting key UK growing regions in the South and East of England. Many producers have constructed on-farm winter-filled reservoirs for water storage, but with forecasts for 75% decrease in rainfall, droughts still pose a risk. The more drought-resistant Maris Piper is the most popular UK-grown spud, but the future may see increases in other resistant varieties such as King Edward, or Russet Burbank.

- **Peas** – The UK is the largest producer and consumer of frozen peas in Europe, but changing temperatures may introduce new and changing pests, diseases and weeds. Milder winters without frost acclimation risk damages from aerial diseases and bacterial blight, resulting in lower yields as pests are not eliminated. The pea beetle's range is expected to extend further north from France to the UK, and temperature changes may also increase powdery mildew, affecting yields and plant health. Dry years lead to increased root disease; water stress lowers yields; and the sowing and growing seasons may be affected.

- **Lemons** – The UK imports about £150 million of lemons and limes, which from May to September come from the southern hemisphere (Argentina and South Africa), and the rest of the year from southern Europe, primarily the water-stressed Spanish region of Murcia which produces about 40% of all Spanish fresh fruit and vegetable exports to the UK. In 2016, a three-year drought period led to farmers protesting with the regional government to declare a 'drought crisis', to enable them to use drought wells to save their dehydrated crops. Murcia´s lemon production is Europe´s largest, but experienced a 30% drop in fruit development and harvest in 2017 due to water shortages, leading to price increases.

Ploughman's lunch – Production disruptions in the south

Potential impacts from climate change

- **Dairy farmers need to manage herds to avoid heat stress in hot summers**
- **Water shortages and soil losses undermine quality and yields of wheat from the south east**
- **Warmer conditions lead to softer apples, with orchards moving northwards**

- **Milk** for cheddar cheese – dairy farming in the UK is concentrated in south-west Wales, south-west England, western Midlands and south-west Scotland. Although these hillier areas are subject to fewer heat waves than the south-east of England, high yielding dairy cows are particularly susceptible to heat stress which impacts health and milk production. Higher humidity and temperatures coupled with low air flow in buildings can cause up to a 15% decrease in milk production. If temperatures rise above 25 degrees, milk yields can fall by 20% and there is a greater chance of infertility, causing problems and additional costs for farmers. During the 2006 heatwave, there were report of cows in the southeast UK which had decreased milk yields of 30%.

- **Wheat** for bread– Wheat is the highest value (£1.6 billion) and largest planted area (1.8 million hectares) of all British crops. Globally, yields are expected to decrease due to increasing temperatures and droughts, although for the UK the medium-term forecast to 2050 is for warmer temperature that could increase production, if other factors (such as precipitation and disease) remain constant. However, severe weather events such as intense precipitation or droughts impact quality, delay harvests and lead to reduced yields and/or value of the final crop. Pests and disease also threaten production, with stem rust, Fusarium head blight and powdery mildew all expected to increase in the UK due to climate change. In the medium-term, drier conditions exacerbating soil loss (erosion) in the major wheat growing regions in the east of England pose a potential risk due to reductions in soil fertility.

- **Apples:** Fruit trees take several years to mature and can be productive for 20 years or more, meaning that orchard locations are high value, long-term investments. For apples to develop each year, the trees require sufficient cold days over winter to 'wake up' and begin budding in the spring. With warming temperatures, existing orchards are under threat as winters may no longer be cold enough, resulting in buds falling, abnormal flowering, and lower yields of poor quality. It is estimated that in Europe for every 1.5 degrees increase in temperature, apple orchards will need to move at least 50km north. And these changes will affect taste too, with research showing that warmer temperatures lead to softer and sweeter apples. In addition to average temperature changes, extreme events such as heavy rainfall and particularly hail can be devastating during spring when trees are flowering, as well during early fruit development.

Cawl (lamb stew) – New challenges for Welsh farmers

Potential impacts from climate change

- **Frequent flooding risking sheep welfare in the uplands and lowlands**
- **Northward march of Colorado Potato Beatle risks potato crop devastation**
- **Weather fluctuations adding volatility for dairy farmers, from feed sourcing and welfare conditions**

- **Lamb**: Since sheep are extensively managed in the outdoors, UK sheep are expected to be exposed to some climate vulnerability, including drought and heat stress reducing fertility and forage quality. Too much precipitation can also be a problem, with flooding that can wash sheep away. After the 2016 floods, almost half of vets in the flooded areas reported loss of livestock, poor welfare or flood-related lameness, with sheep being the worst hit. Standing in water and mud exposes sheep to diseases, such as foot rot, or parasites like liver fluke, which are spread by snails. Although management options and good husbandry can mitigate some of these problems, as more intense rainfall events are projected these may take a toll on herd productivity and animal welfare costs.

- **Potatoes** are susceptible to pest infections, and with warmer temperatures pests can persist and thrive at more northerly latitudes. UK potatoes are at risk from the potato cyst nematode, which already causes losses of approximately £50 million/year, and are expected to rise with higher air and soil temperatures. The most destructive pest for potatoes is the deadly Colorado Potato Beetle which can destroy the entire crop. Although widespread in continental Europe, there have been only a few UK cases, but with a warmer climate it is feared this Beetle will become a much greater pest for UK producers.

- **Milk for Caerphilly cheese:** Welsh dairy farms are predominantly in the lowlands areas of the southwest, southeast, northeast, coastal regions and river valleys, and represent about one third of the output of Welsh agriculture. However, the average dairy farm business income fell by 40% from 2015 to 2016, and like the rest of the UK, volatility in the dairy sector has impacted Wales. Exposure to feed price fluctuations, such as a 42% rise in soyameal costs in 2011 attributed to the US drought, have been cited as a factor, with milk outputs also reduced by unusual weather as witnessed during the second wettest summer on record in 2012.

Coping with climate change

In this report we have identified twenty risks from climate impacts to major ingredients which illustrate the breadth of threats to the ingredients used in our four dishes. Given the complexity of the food system and the variable nature of climate change impacts, it is extremely difficult to forecast exactly *what* will happen, *where* or *when*. If we look at the consequences of climate change on UK production, there may be some effects – such as warmer temperatures leading to longer growing seasons and elevated atmospheric carbon dioxide concentration – that could even increase crop fertility and average yields in the short term. It is also the case that when facing adversity humans don't 'stand still', but will innovate in response to changing conditions. For example, producers can take adaptive measures to buffer impacts, such as selecting more resilient crop varieties, erecting hail nets, installing irrigation systems and so on.

However, despite these uncertainties and our abilities to respond, the prospect of unpredictable, extreme events still pose significant threats to the food system. This is because adaptation measures often carry significant additional costs, and more importantly because many climatic events will be either not as predicted, or of such scale to overwhelm even the very best defences. For example, protracted droughts, tidal surges or new species of pests can devastate food production, irrespective of the attempts made to prepare and respond.

The net effect is that we need to be prepared for impacts to our food system that could include:

- Degradation and loss of land from agricultural production, particularly in exporter countries
- Financial pressures on the supply chain – particularly farmers – in the wake of severe events
- Fluctuations in quality of ingredients, as producers cope with suboptimal conditions
- Temporary periods of unavailability of ingredients on supermarket shelves
- Higher cost of food ingredients and meals for consumers

What can we do?

The impacts of climate change will be felt in our food system in the short and long term. For farmers and food businesses, these impacts will present economic and operational challenges, and for consumers these challenges will flow through as higher prices and even periods of unavailability of certain ingredients.

Despite the complexity of forecasting precise impacts, one key determinant of the severity of these conditions is the concentration of greenhouse gases in the atmosphere. So, although globally we are already facing some disruptions from elevated greenhouse gas emissions, now is the time to act to minimise the scale of long term climate change.

Given that the food system is responsible for approximately 20% of the UK's total carbon footprint, and we are all contributors, there is much that we can do to reduce the impacts of the food that we eat. WWF recently calculated that our individual 'carbon budgets' for the food we eat need to reduce by 8% from 5.17 kg CO_2e per person per day today to 4.77 kg CO_2e per person per day in 2020 in order to be on target to meet the Paris climate agreement in 2030. Following a Livewell diet has the potential to achieve an 18% reduction to 4.25kg CO_2e per person per day in 2020. To put this in context, the footprints of each of our dishes are:

- Chicken tikka masala – 2.0 kgCO_2e
- Fish and chips – 1.5 kgCO_2e
- Ploughman's – 2.6 kgCO_2e
- Cawl (lamb stew) – 5.9 kgCO_2e

This report provides context for individual dishes in a carbon-conscious future, and the need for moderations to meal choices, frequencies and portion sizes to contribute to eating for 2 degrees.

But there are reasons to be hopeful. Swelling support in 2018 for 'Veganuary' (being vegan in January); burgeoning plant-based food and milk products from retailers; and an increase to 29% of evening meals now being meat-free, all indicate encouraging shifts in eating patterns. These changes make a huge contribution to meeting the UK's commitment to limiting climate change to a 1.5 degree rise.

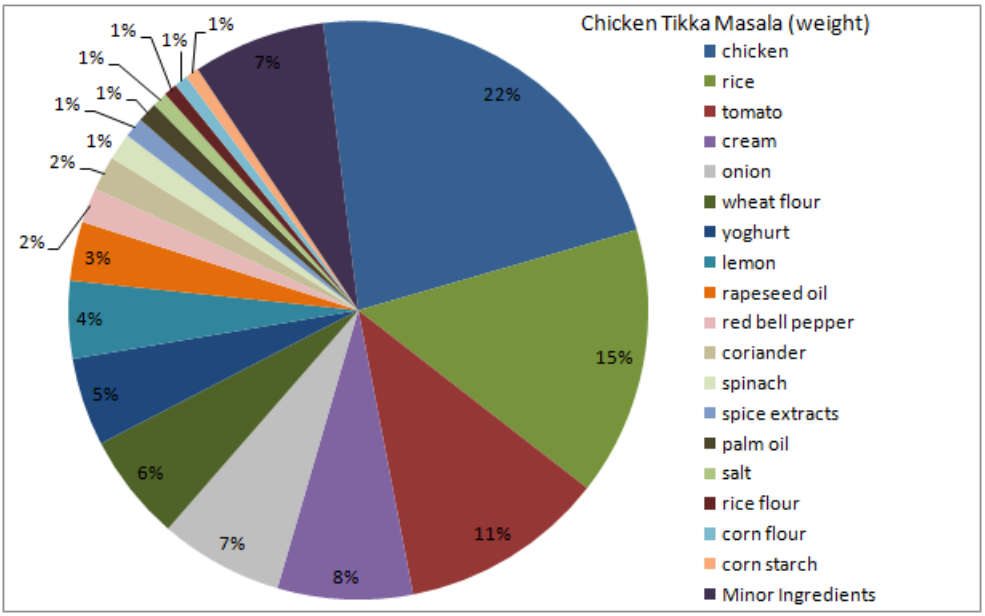
To help inform consumers about diets that are good for the planet and good for their health, WWF has developed six principles people can follow to ensure their diet is healthy as well as being sustainable and good for the planet. And by making an Earth Hour #PromiseForThePlanet this year, WWF hopes to encourage people across the UK to consider the part their diet has to play in affecting the environment and the small steps we can all take to reduce our individual carbon footprint.

Appendix 1 – Meal ingredients and footprints

Chicken Tikka Masala w/ Rice and Naan Bread

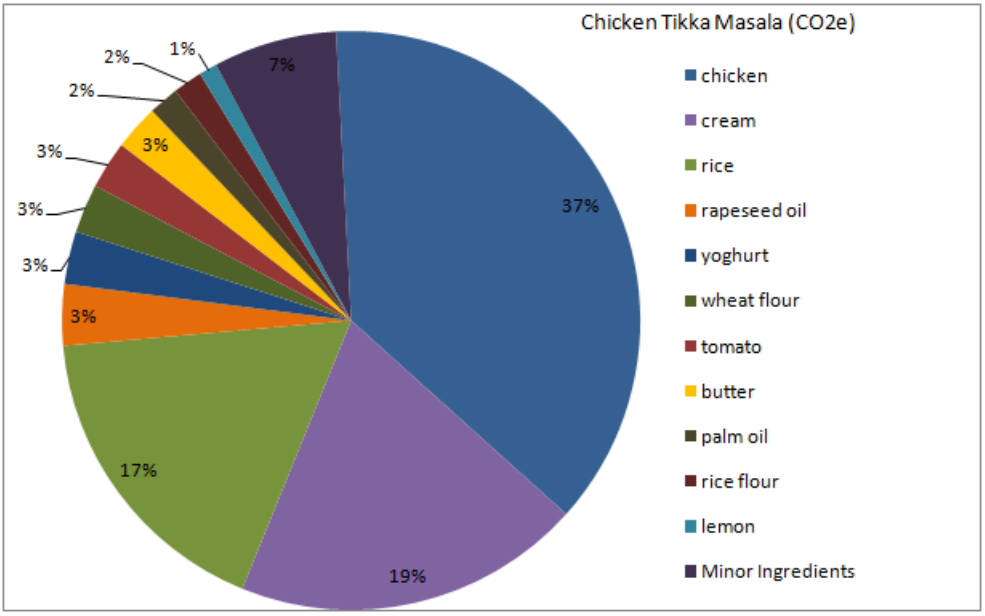
List of main ingredients by weight (more than 5g), excluding water.

		Quantity (g)				
Ingredient	%	TOTAL MEAL	MARINATED CHICKEN	SAUCE	RICE	NAAN BREAD
chicken	22%	**150**	150	-	-	-
rice	15%	**100**	-	-	100	-
tomato	11%	**77**	38	38	-	-
cream	8%	**50**	-	50	-	-
onion	7%	**46**	-	45	1	-
wheat flour	6%	**40**	-	-	-	40
yoghurt	5%	**33**	33	-	-	-
lemon	4%	**29**	-	29	-	-
rapeseed oil	3%	**22**	-	15	-	8
red bell pepper	2%	**13**	-	-	13	-
coriander	2%	**13**	3	10	0	-
spinach	1%	**10**	-	10	-	-
spice extracts	1%	**8**	2	5	1	-
palm oil	1%	**8**	8	-	-	-
salt	1%	**6**	1	1	3	1
rice flour	1%	**5**	-	-	5	-
corn flour	1%	**5**	5	-	-	-
corn starch	1%	**5**	-	5	-	-
Minor Ingredients	7%	**50**	10	19	10	12
CHICKEN TIKKA MASALA w/ RICE and BREAD TOTAL		**668**	**249**	**227**	**132**	**60**



List of main ingredients by footprint (more than 1%), excluding water.

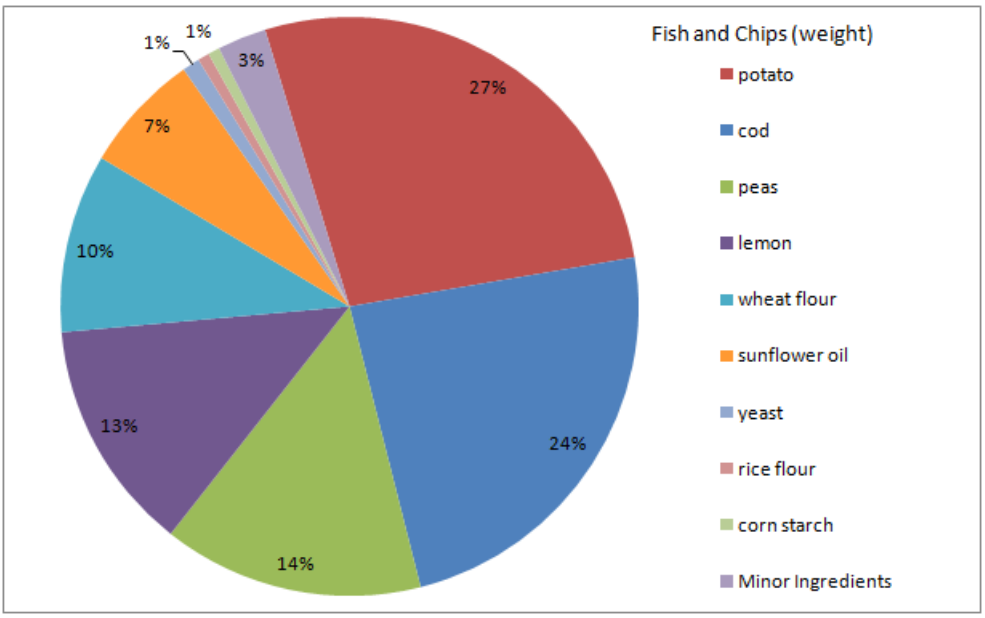
		Footprint ($kgCO_2e$)				
Ingredient	%	**TOTAL MEAL**	MARINATED CHICKEN	SAUCE	RICE	NAAN BREAD
chicken	38%	**0.768**	0.768	-	-	-
cream	19%	**0.389**	-	0.389	-	-
rice	16%	**0.329**	-	-	0.329	-
rapeseed oil	3%	**0.065**	-	0.043	-	0.022
yoghurt	3%	**0.065**	0.065	-	-	-
wheat flour	3%	**0.057**	-	-	-	0.057
tomato	3%	**0.071**	0.036	0.036	-	-
butter	2%	**0.050**	-	0.050	-	-
palm oil	2%	**0.031**	0.031	-	-	-
rice flour	1%	**0.030**	-	-	0.030	-
lemon	1%	**0.027**	-	0.027	-	-
All other ingredients	8%	**0.162**	0.025	0.067	0.034	0.035
CHICKEN TIKKA MASALA w/ RICE and BREAD TOTAL		**2.04**	**0.93**	**0.61**	**0.39**	**0.11**



Fish and Chips with Mushy Peas

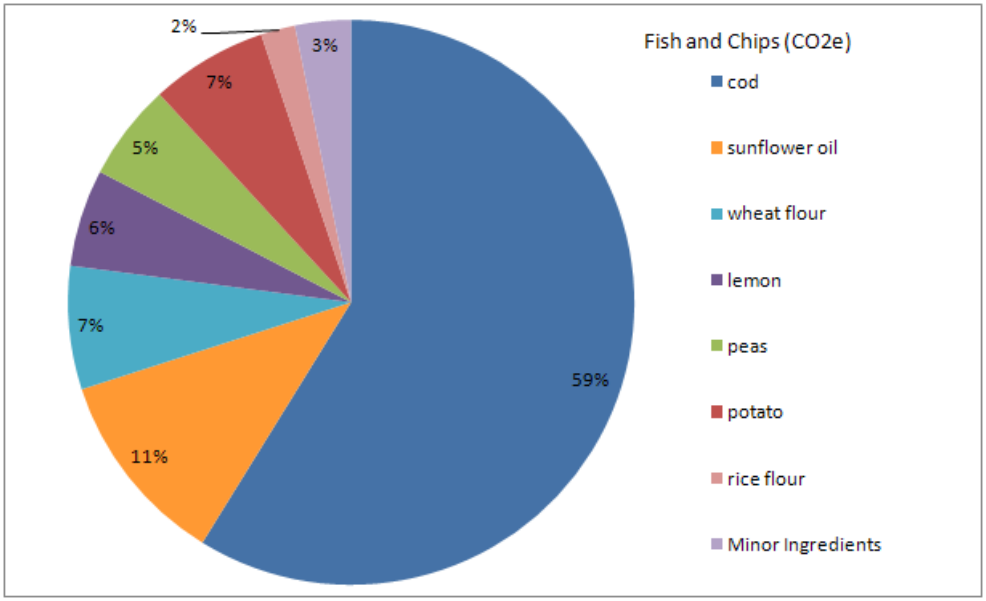
List of main ingredients by weight (more than 5g), excluding water.

		Quantity (g)				
Ingredient	%	**TOTAL MEAL**	FISH	CHIPS	BATTER MIX	MUSHY PEAS
potato	27%	**208**	-	208	-	-
cod	24%	**183**	183	-	-	-
peas	15%	**113**	-	-	-	113
lemon	13%	**100**	100	-	-	-
wheat flour	10%	**77**	-	26	51	-
sunflower oil	7%	**52**	-	52	-	-
yeast	1%	**8**	-	-	8	-
rice flour	1%	**5**	-	5	-	-
corn starch	1%	**5**	-	5	-	-
Minor Ingredients	3%	**21**	-	7	11	3
FISH and CHIPS w/ MUSHY PEAS TOTAL		**772**	**283**	**303**	**70**	**116**



List of main ingredients by footprint (more than 1%), excluding water.

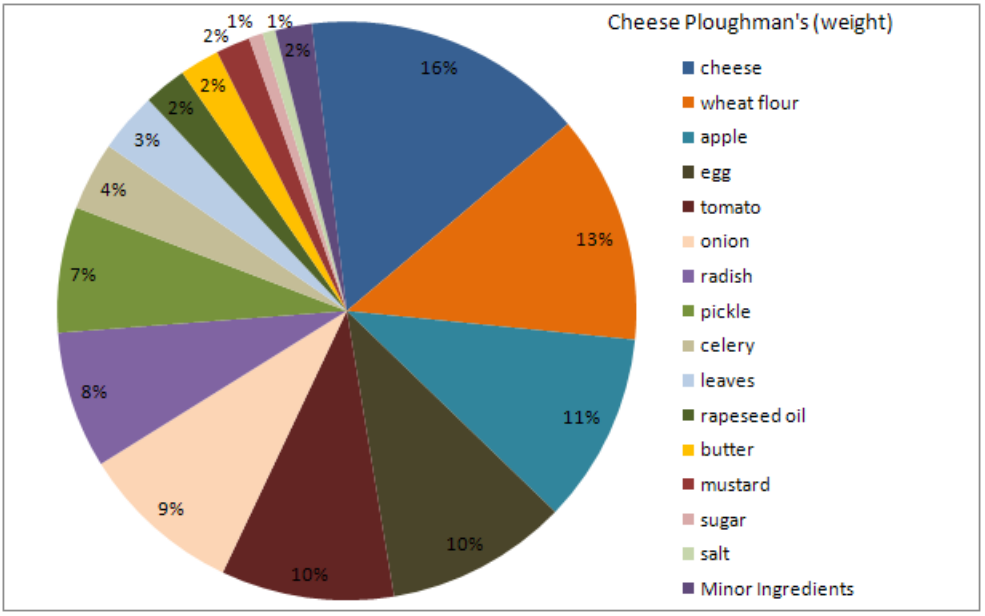
Ingredient	%	Footprint ($kgCO_2e$) TOTAL MEAL	FISH	CHIPS	BATTER MIX	MUSHY PEAS
cod	59%	**0.907**	0.907	-	-	-
sunflower oil	11%	**0.173**	-	0.173	-	-
wheat flour	7%	**0.109**	-	0.036	0.073	-
lemon	6%	**0.086**	0.086	-	-	-
peas	6%	**0.085**	-	-	-	0.085
potato	7%	**0.103**	-	0.103	-	-
rice flour	2%	**0.030**	-	0.030	-	-
All other ingredients	3%	**0.049**	-	0.027	0.018	0.004
FISH and CHIPS w/ MUSHY PEAS TOTAL		**1.54**	**0.99**	**0.37**	**0.09**	**0.09**



Cheese Ploughman's

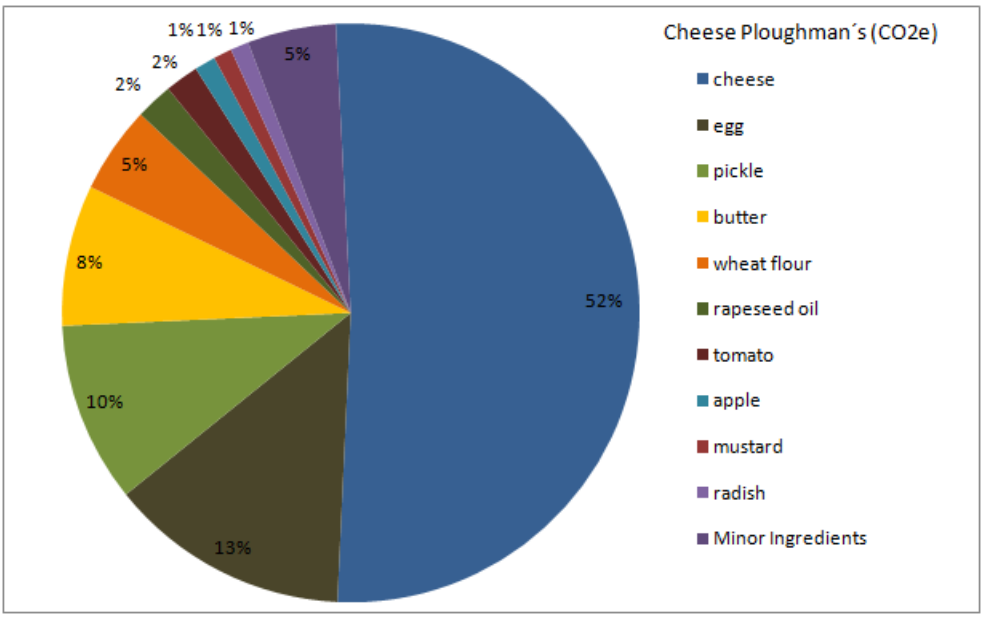
List of main ingredients by weight (more than 5g), excluding water.

		Quantity (g)			
Ingredient	%	**TOTAL MEAL**	CHEESE & BUTTER	SALAD	BREAD
cheese	16%	**124**	124	-	-
wheat flour	13%	**100**	-	-	100
apple	11%	**83**	-	83	-
egg	10%	**80**	-	80	-
tomato	10%	**76**	-	76	-
onion	9%	**71**	-	71	-
radish	8%	**60**	-	60	-
pickle	7%	**55**	-	55	-
celery	4%	**30**	-	30	-
leaves	3%	**26**	-	26	-
rapeseed oil	2%	**19**	-	-	19
butter	2%	**18**	18	-	-
mustard	2%	**15**	-	15	-
sugar	1%	**6**	-	-	6
salt	1%	**4**	-	3	2
Minor Ingredients	2%	**16**	-	5	12
CHEESE PLOUGHMAN'S TOTAL		**784**	**142**	**504**	**138**



List of main ingredients by footprint (more than 1%), excluding water.

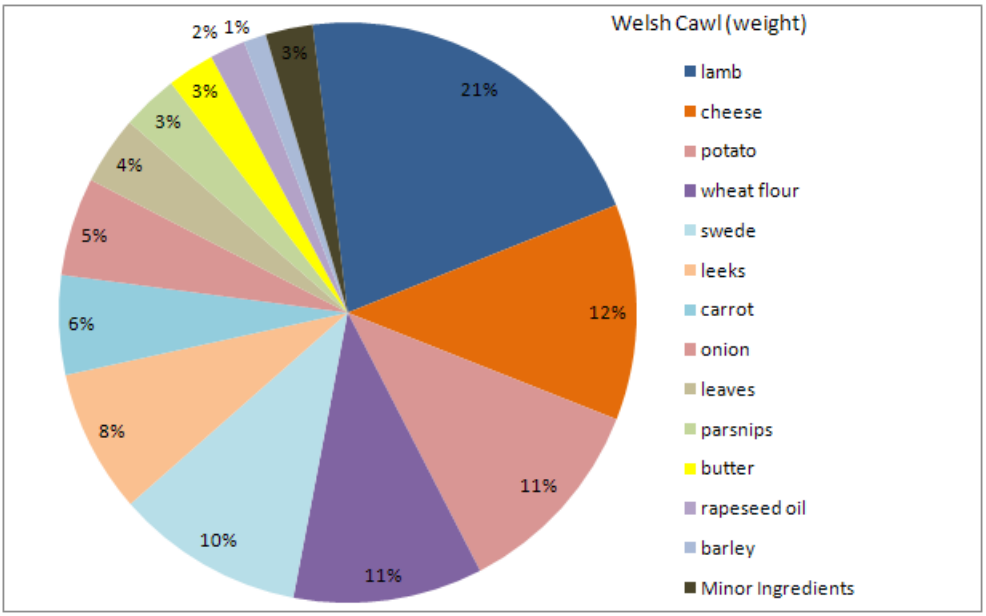
		Footprint ($kgCO_2e$)			
Ingredient	%	**TOTAL MEAL**	CHEESE & BUTTER	SALAD	BREAD
cheese	50%	**1.283**	1.283	-	-
egg	13%	**0.347**	-	0.347	-
pickle	9%	**0.233**	-	0.233	-
butter	8%	**0.196**	0.196	-	-
wheat flour	5%	**0.141**	-	-	0.141
rapeseed oil	2%	**0.055**	-	-	0.055
tomato	3%	**0.065**	-	0.065	-
apple	2%	**0.050**	-	0.050	-
mustard	1%	**0.026**	-	0.026	-
radish	1%	**0.035**	-	0.035	-
All other ingredients	6%	**0.159**	-	0.085	0.074
CHEESE PLOUGHMAN'S TOTAL		**2.59**	**1.48**	**0.84**	**0.27**



Welsh Cawl w/ Caerphilly Cheese and Bread

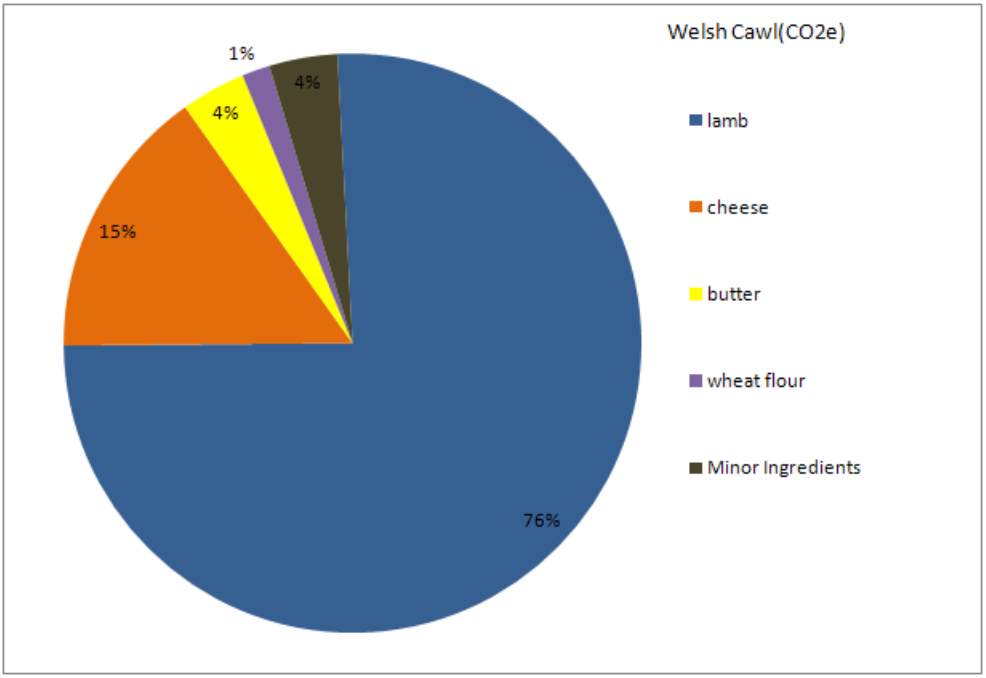
List of main ingredients by weight (more than 5g), excluding water.

		Quantity (g)			
Ingredient	%	**TOTAL MEAL**	STEW	CHEESE & BUTTER	BREAD
lamb	21%	**138**	138	-	-
cheese	12%	**80**	-	80	-
potato	11%	**76**	76	-	-
wheat flour	11%	**70**	-	-	70
swede	11%	**70**	70	-	-
leeks	8%	**53**	53	-	-
carrot	6%	**37**	37	-	-
onion	5%	**36**	36	-	-
leaves	4%	**25**	25	-	-
parsnips	3%	**21**	21	-	-
butter	3%	**18**	-	18	-
rapeseed oil	2%	**13**	-	-	13
barley	1%	**8**	8	-	-
Minor Ingredients	3%	**17**	4	-	14
WELSH CAWL w/ CHEESE AND BREAD TOTAL		**663**	**469**	**98**	**97**



List of main ingredients by footprint (more than 1%), excluding water.

		Footprint (kgCO2e)			
Ingredient	%	**TOTAL MEAL**	STEW	CHEESE & BUTTER	BREAD
lamb	76%	**4.510**	4.510	-	-
cheese	14%	**0.828**	-	0.828	-
butter	3%	**0.196**	-	0.196	-
wheat flour	2%	**0.099**	-	-	0.099
All other ingredients	5%	**0.286**	0.196	-	0.090
WELSH CAWL w/ CHEESE AND BREAD TOTAL		**5.92**	**4.71**	**1.02**	**0.19**



Appendix 2: Streamlined approach for carbon footprint assessments

The purpose of this report is to raise awareness about the links between food and the climate. As such, the footprint assessments of the four meals were one component only. The objective was to create representative footprints to inform the discussion rather than highly detailed, accurate assessments. This appendix explains the approaches taken to achieve this aim using a streamlined approach, and details the assumptions made.

Farm to plate carbon footprints were carried out to determine the global warming contributions of four iconic British dishes: chicken tikka masala with naan bread, fish and chips with mushy peas, cheese ploughman's with bread and butter, and Welsh cawl with bread and Caerphilly cheese.

A theoretical recipe was constructed for each of the four plates, combining ingredient types and weights from several publicly available recipes. Emission factors to farm gate derived from academic literature. The methods published in WWF's Eating for 2 degrees – *new and updated Livewell Plates* report were adapted and used for energy use in distribution centres; supermarkets; and for average distances transported. Cardboard and plastic packaging weights were assumed to be a percentage of ingredient weight, not least because formats would vary between delivery channel. Consumer in-home energy use was derived from the Product Sustainability Forum applied to each ingredient based on assumptions on home storage and cooking method.

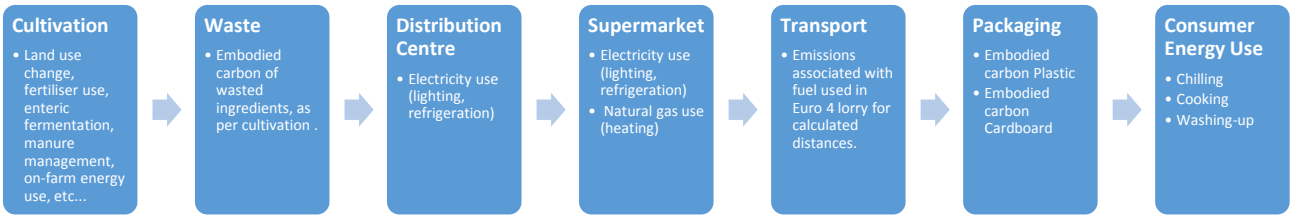


Figure 1: Lifecycle stages of four iconic British dishes.

Cultivation

Several food websites were used as sources for the four recipes. Sites were chosen based on the existence of the four recipes. For chicken tikka masala and Welsh cawl recipes from allrecipes.com, goodfood.uktv.co.uk, jamieoliver.com, and bbc.co.uk were used. For fish and chips recipes from goodfood.uktv.co.uk, jamieoliver.com, and bbc.co.uk were used. For cheese ploughman's recipes from culinaryginger.com, and bbc.co.uk were used, along with a recipe defined by the researchers. The meals weigh between 660 and 790 grams, excluding water.

Some recipes report ingredient quantities by units of produce or in volume and not weight, so the necessary conversions were made.

Table 1: Weight of ingredients in grams for each of the four dishes

Ingredients (more than 5g)	CHICKEN TIKKA MASALA	FISH and CHIPS	PLOUGHMAN'S	CAWL
apple	-	-	83	-
barley	-	-	-	8
butter	-	-	18	18
carrot	-	-	-	37
celery	-	-	30	-
cheese	-	-	124	80
chicken	150	-	-	-
cod	-	183	-	-
coriander	13	-	-	-
corn flour	5	-	-	-
corn starch	5	5	-	-
cream	50	-	-	-
egg	-	-	80	-
lamb	-	-	-	138
leaves	-	-	26	25
leeks	-	-	-	53
lemon	29	100	-	-
mustard	-	-	15	-
onion	46	-	71	36
palm oil	8	-	-	-
parsnips	-	-	-	21
peas	-	113	-	-
pickle	-	-	55	-
potato	-	208	-	76
radish	-	-	60	-
rapeseed oil	22	-	19	13
red bell pepper	13	-	-	-
rice	100	-	-	-
rice flour	5	5	-	-
salt	6	-	4	-
spice extracts	8	-	-	-
spinach	10	-	-	-
sugar	-	-	6	-
sunflower oil	-	52	-	-
swede	-	-	-	70
tomato	77	-	76	-
wheat flour	40	77	100	70
yeast	-	8	-	-
yoghurt	33	-	-	-
Other Ingredients	50	21	16	17
TOTAL	**668**	**772**	**784**	**663**

Emission factors were selected from Clune (2017)[5] for the following ingredients: apple, barley, basil, butter, carrot, chicken, cheese, cod, coriander, cream, egg, fennel, ginger, ginger puree, green chilli puree, lamb, leaves, milk, onion, paprika extract, peas, pimento, potato, red bell pepper, rice, spinach, swede, tomato, turmeric, and yoghurt.

The Product Sustainability Forum Final Report (2013), *An initial assessment of the environmental impact of grocery products* was used to obtain emission factors for ingredients not present in Clune *et al*., particularly for: black pepper, calcium, carbonates, cardamom, celery seed, cinnamon, clove, cumin, garlic powder, garlic puree, grilled onions, honey, iron, leeks, lemon, niacin, nutmeg, onion powder, onion seed, parsnips, radish, pickle, red pepper, spice extracts, thiamine, and white pepper.

For the remaining ingredients and components of the carbon footprint several sources for emissions were used including Ecoinvent, case studies (Kingsmill Bread), PhD theses, amongst others. The components are: cardboard,

[5] 'Systematic review of greenhouse gas emissions for different fresh food categories'. *Journal of Cleaner Production*. 140:2, 766-783

colour, corn starch, corn flour, dextrose, electricity, wheat flour, natural gas, lorry, mustard, palm oil, packaging film, rapeseed oil, rice flour, salt, sugar, sunflower oil, water, and yeast.

Waste

Waste volumes across the supply chain were assumed to equal 5% of total ingredient weight. This uplift was used not only to calculate embodied emissions from the actual food wasted, but was also applied to ingredients stored in distribution centres and transported to supermarkets. Emissions from landfilling or composting waste food are not included in the analysis.

Distribution Centre

Data from WWF's *Eating for 2 degrees – new and updated Livewell Plates* (2017) report were used to calculate emissions arising from distribution centres. Ingredients were categorised by storage temperature and the following electricity use was applied:

- Lighting – 0.04 kWh/kg
- Cold Storage - 0.05 kWh/kg
- Frozen Storage - 0.09 kWh/kg

Emissions associated with refrigerant use are not included.

Supermarket

As with distribution, data from WWF,(2017), were used to calculate emissions arising from supermarkets. Ingredients were categorised by storage temperature and the following electricity use was applied:

- Lighting (all ingredients) – 0.036 kWh/kg
- Cold Storage - 0.03 kWh/kg
- Frozen Storage - 0.05 kWh/kg

Additionally, ambient heating for customers was included in the analysis and assumed to be provided by natural gas.

- Heating (all ingredients) – 0.079 kWh/kg

Emissions associated with refrigerant use are not included.

Transport

As with distribution and supermarkets, data from WWF(2017), were used to calculate emissions arising from transport. A Euro 4 16-32 tonne lorry was assumed to be the method of transport. Distances were assumed to be as follows:

- Non-animal farm products to supermarket – 170km
- Animal farm products to supermarket – 320km

Emissions from refrigerated transport are not included.

Packaging

Packaging was assumed to equal 5% of meal weight and assumed to be half plastic and half cardboard. The embodied carbon emissions from the production of core board and low density polyethylene packaging film were calculated from Ecoinvent data and applied to the packaging weights.

Consumer energy-use

Data on tonnes of CO_2e associated with different stages of the food life cycle from the Product Sustainability Forum were used to determine uplifts for home energy use required for storing and preparing food.

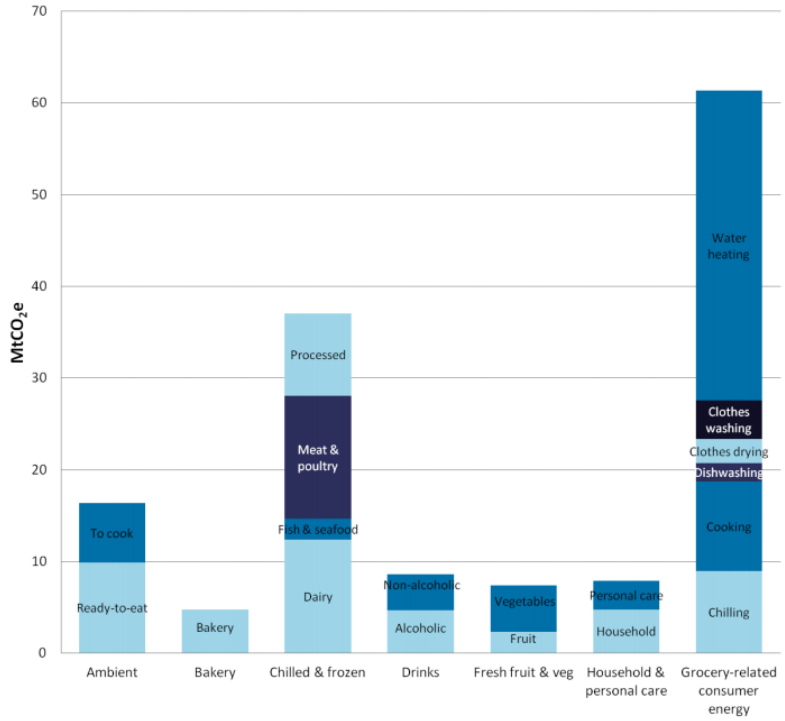


Figure 3.3 Breakdown of annual cradle-to-retail grocery GHG emissions by category[23,24]

Uplifts of 14% for cooking, 11% for chilling, and 2% for washing-up were applied to the meals to determine energy use in the home.

Results

Results by the lifecycle stages described in this method are shown in table 2, below.

Table 2: Results by life-cycle stage

	Footprint ($kgCO_2e$)			
lifecycle stage	CHICKEN TIKKA MASALA	FISH and CHIPS	WELSH CAWL	PLOUGHMAN'S
Cultivation	1.460	1.045	4.475	2.055
Supply chain waste	0.073	0.052	0.224	0.103
Distribution Centre	0.036	0.046	0.029	0.039
Supermarket	0.041	0.050	0.037	0.047
Transport	0.023	0.027	0.023	0.023
Packaging	0.066	0.077	0.066	0.078
Consumer energy-use	0.344	0.245	1.065	0.245
TOTAL	**2.04**	**1.54**	**5.92**	**2.59**

Results by lifecycle stage show that cultivation and consumer use in the home represent the highest portion of emissions. Where the method used relied on assumptions – notably packaging and waste – the figures are low, and may represent an underestimate. However, conducting a detailed analysis of the supply chains – and given the variability in delivery channels – these figures are deemed acceptable for the illustrative purpose of this report.

Appendix 3: References

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