DO IT FOR YOUR PLANET

EATING FOR 2 DEGREES
NEW AND UPDATED LIVEWELL PLATES

Revised edition

Cover photo
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Note on revised edition

As a result of a query about inconsistencies between the carbon footprint breakdown and the figures in the composition tables presented in *Eating for 2 degrees – new and updated Livewell Plates* (May 2017), a miscalculation error has been identified which led to incorrect values across the Livewell Plates being published. Although the suggested consumption of various products is affected by this, in particular beef and veal, poultry and processed meat, it does not affect the overall conclusions of the report.

Blonk Consultants

About WWF

WWF is the world's leading independent conservation organisation. We're creating solutions to the most important environmental challenges facing the planet. We work with communities, businesses and governments in over 100 countries to help people and nature thrive. Together, we're safeguarding the natural world, tackling dangerous climate change and enabling people to use only their fair share of natural resources.

Food is at the heart of many key environmental issues WWF works on. Growing, producing and importing food contributes substantially to climate change. It's a driving force behind habitat and biodiversity loss. And it's a huge drain on water resources. That's why helping to develop a sustainable food system for healthy people and a healthy planet is one of WWF's priorities.

Find out more about our work at **wwf.org.uk/food**

About Blonk

Blonk Consultants helps companies, governments and civil society organisations put sustainability into practice. Our team of dedicated consultants works closely with our clients to deliver clear and practical advice based on sound, independent research. To ensure optimal outcomes we take an integrated approach that encompasses the whole production chain.

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PREFACE

The newly modelled Livewell Plates presented in this report illustrate the dietary changes we need to make by 2020 and 2030 in order to keep the average global temperature rise well below 2 degrees, as agreed at the Paris climate conference in December 2015.

Below are the key elements of our research framework.

THE PARIS AGREEMENT

The Paris Climate Change Agreement adopted at the Conference of the Parties in December 2015 (COP21) entered into force on 4 November 2016. This landmark agreement aims to reduce man-made greenhouse gas (GHG) emissions to a level that limits the global average temperature-rise to well below 2 degrees compared to pre-industrial levels, with an aspirational goal of 1.5 degrees. These targets have been agreed by the international community and endorsed by companies, and their policies will be geared towards achieving them.

Changes to the food system will need to be part of the solution. WWF is committed to working with all stakeholders within the food sector to understand how it can contribute and what steps need to be taken to keep the rise well below 2 degrees.

UK CARBON BUDGETS

The Paris Agreement commits all parties to build on their efforts to keep global warming well below 2 degrees, and aim to achieve 1.5 degrees. In the UK, the Committee on Climate Change has advised the government to reduce territorial emissions by 61% from 1990 levels. For this report we've rounded this down to 60%.

It's important to note that this scenario should be considered a conservative estimate of the contribution required to uphold the Paris Agreement [i].

REDUCTION FROM THE FOOD SECTOR

To analyse the changes required in the food sector we've assumed it needs to make the same level of contribution as the rest of the economy, in other words a reduction in emissions of 60%. Rather than a prescriptive target, this is an exercise to help start the conversation about mitigation efforts within the food sector.

Within the food system mitigation efforts can be split between producers and consumers. Producers can improve resource efficiency and reduce emissions, while consumers can adopt a climate-smart diet such as the Livewell diet presented in this report. Our core analysis focuses on consumption[ii].

SPLIT BETWEEN CONSUMPTION AND PRODUCTION

In order to establish the necessary emissions reductions from the food system – and taking into account a lack of research relating to consumption's 'fair share' in achieving this – we've developed three scenarios:

- A 50/50 split between consumption and production, which leads to a 30% reduction in consumption related GHG emissions;
- A 70/30 split between consumption and production, which leads to a 42% reduction in consumption related GHG emissions; and
- A 30/70 split between consumption and production, which leads to a 18% reduction in consumption related GHG emissions.

[i] UK carbon budgets are currently aiming for 2 degrees and will need to be strengthened to achieve the 'well below' 2 degrees target.

[ii] The analysis is based on projected food consumption in the UK, which includes a mix of imported goods and domestic production. For formal accounting purposes, the emissions reductions related to imported food would be accounted for in the exporting countries, whereas the emissions reductions of domestic food production would be accounted for across the economic sectors considered in the life cycle analysis.

While our reduction targets were 25% by 2020 compared to 1990 levels in *Livewell: a balance of healthy and sustainable diets* and our LiveWell for LIFE project (in line with WWF's One Planet Food programme goal), we need to work within the global context of the Paris Agreement when developing our new Livewell Plates. We've also included a scenario approach in the hope that it'll start a discussion on how best to approach the split between consumption and production in achieving the reductions we need.

LAND OCCUPATION

Apart from global warming, loss of biodiversity is the other major global environmental concern addressed in this report. Loss of biodiversity is closely linked to the conversion of natural habitats, such as tropical rainforest being cleared for agricultural land. The world's forests and other natural habitats are also important carbon sinks.

Our model works on the basis that the adoption of the Livewell Plates brings no increase in land converted for agriculture – in particular grassland and cropland, and especially in vulnerable regions such as Latin America and Southeast Asia[iii]. The projected growth in the world's population means that the share of available agricultural land for each individual will decrease over time.

[iii] West PC, Gerber JS, Engstrom PM, et al. (2014) Leverage points for improving global food security and the environment. Science (80-.). 345, 325–328.

FOREWORD

When we first started working on sustainable diets in 2010, we were told it was confusing and even impossible to define a diet that linked health and environmental outcomes.

Duncan Williamson
Food Policy Manager, WWF

We questioned this perceived wisdom, and after speaking with leading academics we decided to see what we could do. This lead to Livewell – a healthy, sustainable diet that's good for people and the planet. Livewell was based on the government's own healthy eating advice, the Eatwell Plate, and demonstrated how a nutritious diet that can also lead to a reduction in carbon emissions from the food supply chain.

Since then sustainable diets have moved up the agenda. It's no longer niche. Eating Better champions coordinated civil society work; the Eat Foundation has arrived and joined us in the call to make sustainable diets mainstream. We have The Protein Challenge 2040 and the World Resource Institute's work on sustainable diets. Even retailers and the food service sector are taking an active role – just look at Sodexo's Green and Lean offer!

External development and feedback from expert stakeholders – including farmers, business leaders and health experts – meant it was time to update our Livewell work. When identifying the environmental constraints for the research it was clear to us that the basic tenet would have to be the Paris Agreement. We've also included water and land metrics for the first time. And we've looked at diets for different ages: adults, teenagers and the elderly. We've even produced a Plate for vegans. This shows the flexibility of sustainable diets. We can eat a huge variety of dishes, including meat and cake if we so wish.

Of course, our work doesn't stop here. As policy, science and evidence progress, we'll include further nutritional and environmental constraints to our research. From an environmental point of view, the Plates presented in this report illustrate the absolute minimal dietary changes needed to reach a 2 degree target. We need tighter environmental constraints if we want to reach the well below 2 degrees target, or even the aspirational 1.5 degree target.

And we want to continue to illustrate that sustainable diets are appropriate for all age groups across the globe. So we hope to develop additional Plates. This may well include one for infants and primary school children as well as country specific Plates in the global North and South.

This work is about more than what we eat. It is about linking consumption to production. That's why we advocate the role of credible certification – including MSC/ASC, RTRS and Fairtrade – as a way to identify how our food has been produced. We need to respect the rights of workers as well as ensure that sustainable diets are available, accessible and affordable for all people. We need producers to get involved and recognise that this agenda supports their long-term goals.

That's why we need the UK government to engage. It is not about nanny stateism (after all the government has a hand in all our food decisions from farming and fishing policy, to taxes, nutritional advice and public procurement). It about joined up policy making that puts health and sustainability at the heart of our food, farming and fishing industries. With Brexit we have a unique opportunity to refresh the food sector to deliver health and environmental outcomes. This is a new frontier for UK food. We know diets cross boundaries, we've seen the spread the western diet and its associated problems. Now's the opportunity for the UK to lead the way delivering a sustainable food system.

We've had a lot of support developing this work. Thank you too everyone who participated in our expert consultation, we have taken your advice on board. And a special thank you to Tara Garnett, Wendy Russell and Tim Lang for reviewing this work.

EXECUTIVE SUMMARY

OVERVIEW

This paper is a summary of the research carried out in 2016 by Blonk Consultants to update WWF's work on sustainable food consumption. Our Livewell work started in 2010 in response to scientific evidence demonstrating the need for a systemic approach to a sustainable food system. In 2011, we published our first Livewell report *Livewell: a balance of healthy and sustainable food choices*, which included the Livewell Plate.

Livewell Plates are representative diets that meet national nutritional requirements while reducing the environmental footprint of the food system that produces them: they're diets that are good for both people and planet.

The research presented in *Eating for 2 degrees* aimed to produce updated versions of the Livewell Plate by using additional environmental criteria – such as water use and land footprint – and to produce individual Plates for four separate groups: adults, adolescents, the elderly and vegans. Whereas the original Livewell Plate was for adult women only, each Plate presented here is an average Plate for each demographic. They include the latest nutritional data, environmental metrics and an estimate of costs; and are compared to current average diets for each demographic.

Historical changes in eating habits since 1961 are also analysed and the consequent health and environmental impacts are mapped.

As will be described in detail below, Blonk Consultants found that it's indeed possible to eat a sustainable, nutritious diet that contributes to the future health of the planet and its population, without significant increases in costs.

BACKGROUND

Globally, 20% of total direct carbon emissions are from food and agriculture. When land-use change is factored in, this figure rises to 30%. Around 70% of all fresh water withdrawn is used for agricultural irrigation, which in many cases has a major impact on water quality. And agriculture is the most significant cause of deforestation – and hence loss of biodiversity – around the world.

What we eat and how it's produced have consequences for the whole planet. By changing our diets and by improving production efficiency in the food system we can make a major contribution to the environmental performance of the food system. Indeed, now that the Paris Agreement is in force we have binding commitments to reduce carbon emissions, and in the UK, the Committee on Climate Change has advised the government to reduce territorial emissions by 61% from 1990 levels by 2030. For this report we've rounded this down to 60%.

Changes in the food system will have to be part of the solution, and this report assumes the food sector needs to make the same level of contribution as the rest of the economy as a whole. Mitigation efforts can be divided between producers and consumers, and – while we've also explored other proportions – we've based our modelling on a 50/50 split. Our core analysis focuses on consumption.

GLOBALLY, 20% OF TOTAL DIRECT CARBON EMISSIONS ARE FROM FOOD AND AGRICULTURE.

PROCESS

Blonk Consultants carried out the analysis using Optimeal 2.0, a bespoke optimisation tool that uses quadratic programming. In simple terms, it works by taking the overall nutritional requirements of a given group, then finding a division of food products that will meet these needs while also respecting various environmental constraints agreed by the research team (limited carbon footprint in line with national reduction targets, equal individual shares of the world's current agricultural land, and so on). A detailed account is given below.

A great amount of rigour was required when creating the databases on which the optimisation process depends. From creating food product groups to calculating nutritional outputs and the environmental footprints of product life cycles, our researchers used a wide range of approved sources to build realistic and measurable solutions that reflect the complex and interlinked nature of today's food system.

The goal was to create Livewell Plates whose composition was as close as possible to the current average diet for each group in the UK. A range of other metrics – from cost to blue water footprint – was also detailed in each case.

RESULTS

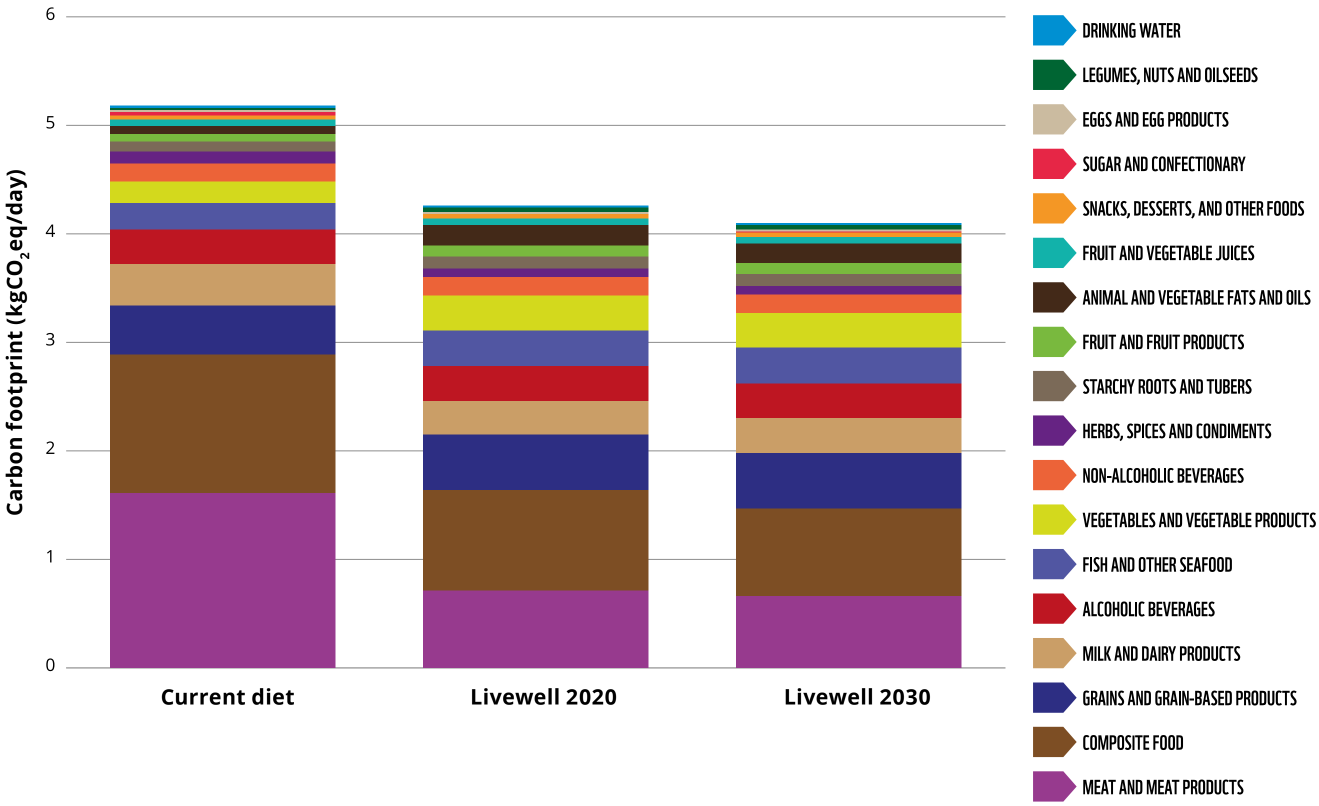
We updated the 2020 Plates and created four new Livewell Plates for 2030. All the Plates meet national nutritional and environmental needs, without significant cost increases.

While each of the Plates is different and is described individually below, it's possible to make some general points on their composition.

Carbon footprint

First, the carbon footprint of the average diet has reduced considerably since 1990 – almost exclusively through improvements in production. When nutritional requirements alone are fed into the Livewell Plate model, the carbon footprint of each diet falls further. The vegan Plate has the lowest carbon footprint of all.

Breakdown of carbon footprint (GHG emissions) of the current UK diet and adult Livewell Plates



Changes in diet

Notable increases are clear in meat replacers (such as soy and Quorn); legumes, nuts and oilseeds; fats and oils; vegetables; and aquaculture fish. Fish is nutritionally important, but for environmental reasons the optimisation model didn't permit an increase in wild-caught fish. Aquacultured fish, like salmon, is therefore increased in order to meet the Eatwell Guide[iv] requirement of two servings of 140g of fish per week. The types of fish in the Livewell Plate are all available with either a Marine Stewarship Council (MSC) or Aqualculture Stewarship Council (ASC) label.

The most obvious difference between all Livewell Plates and current diets is a significantly lower amount of meat. Beef and lamb have high carbon footprint primarily related to the enteric fermentation in the gut, leading to methane emissions. Reducing beef and lamb is therefore far the most less effective.

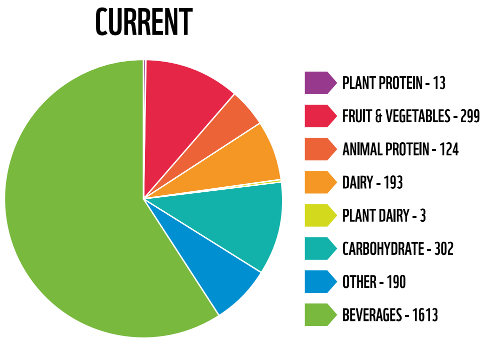
However, in order to allow beef and lamb to remain on the Plate all other meat groups are also reduced. This reduction in meat supports our Livewell principle (see below) that people need to moderate their meat consumption – red and white – and not eat more white meat to compensate for the reduction of red meat.

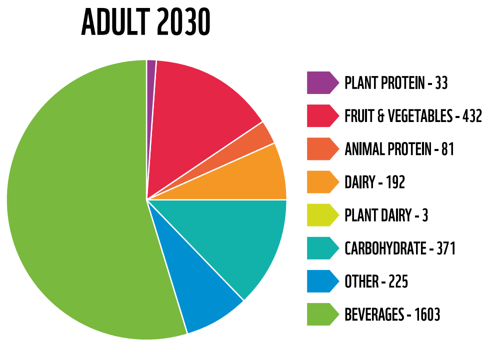
Cheese is reduced, but other dairy – one of the most important sources of iodine in the UK diet – increases on the adult Plates. This was also the case in the original Livewell Plate for the UK.

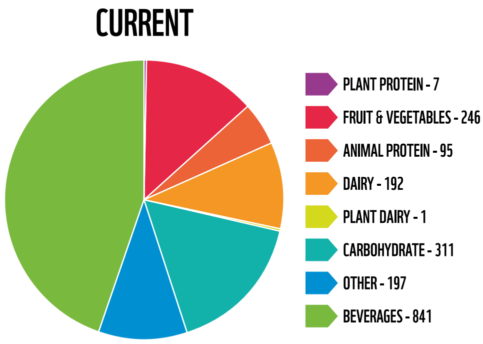
The maximum limit of 5% of total energy from added sugar set by the Scientific Advisory Committee on Nutrition proved challenging and caused a a significant reduction of *sugar and confectionery*. But there is an increase of food in the *snacks, desserts and other food category*. It's important to note here that in spite of the UK government's levy on the sale of sugary drinks (to be implemented by April 2018) and a target to reduce the amount of sugar in food products by 20%, a large amount of hidden added sugar remains in our everyday products. This will need to be tackled if we want to reduce the overall amount of sugar we consume on a daily basis.

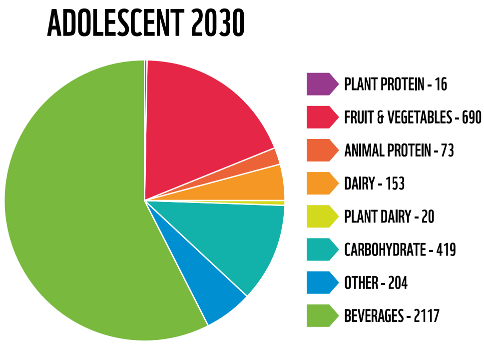
It's also important to remember that every change on our plates has real-world consequences, and the results reflect how complex this can be. So while reducing meat consumption means less grassland is needed for pasture and less cropland is needed to grow animal feed (such as soy and maize), it may also mean that more cropland is needed to provide increased amounts of legumes, or vegetable oil. These in turn may require increased land occupation and produce a higher blue water footprint – but there's a huge difference between repurposing existing agricultural land and clearing rainforest to create more. In short, all these results need to be seen in their overall context to truly reflect the complex inter-relationships that define the consumption and production of food.

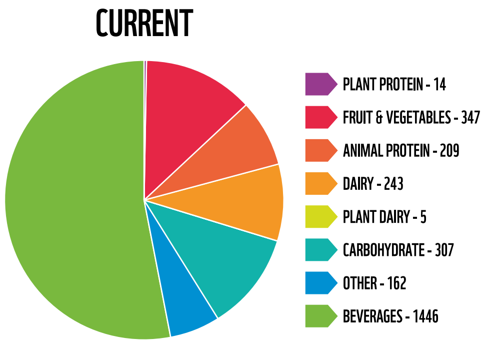
[iv] The Eatwell Guide (formerly the Eatwell Plate) is a visual communications tool created by the UK Food Standards Agency to promote nutritionally healthy diets https://www.gov.uk/government/publications/the-eatwell-guide

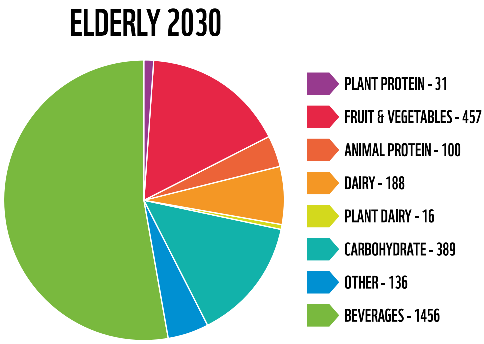


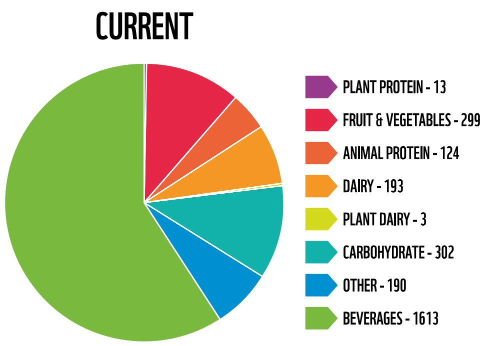


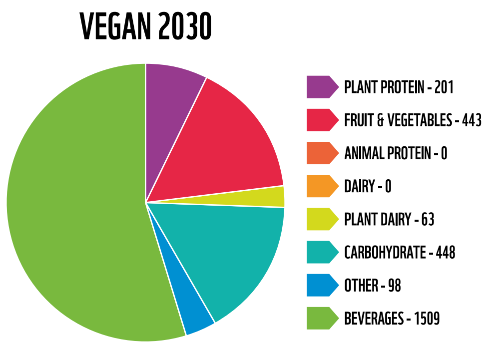












Pie-charts of the composition of the current adult diet (NDNS) and the adult Livewell Plate for 2030. Amounts are in grams/day.

Please note: *Animal protein* includes meat, fish and egg; *Plant protein* includes legumes and meat replacers; *Plant dairy* includes soy drink and soy yoghurt; *Carbohydrate* includes grains and grain-based products, starchy roots and tubers, and sugar and confectionery.

Cost

There are small cost increases in Livewell Plates in comparison to the current diet, which are mainly due to higher amounts of healthy products like fish and vegetables. However, it's possible that the apparent increases could be due to under-reporting of current dietary habits, which is higher than the suggested cost increase. Although this is an approximation and there's no clear indication that those on lower incomes couldn't afford Livewell Plates, it's important to note that food costs are predicted to go up over time, with costs for high input foods – such as those based on animal feed – rising faster and further than those for the low-impact foods in the Livewell diet.

Historical trends

In terms of historical trends since 1961, the results are mixed. An increased availability of calories is very likely to have been responsible for an increase in obesity, while a shift from animal fats to vegetable oils and an increase in fruit consumption are both positive trends. Composition of diet hasn't had significant environmental effects, but there has been a dramatic improvement in production efficiency leading to a considerably reduced carbon footprint. The production system continues to have an important part to play in the overall mitigation effort, while consumption lags behind.

NEXT STEPS

Food is at the heart of many of the key environmental issues WWF works on; that's why helping to develop a sustainable food system is one of WWF's priorities. We believe the findings in this report support our six Livewell principles as the basis of a sustainable diet and a well-functioning food system. Together with key stakeholders we'll use this report to shape policymakers' thinking around our food system. We'll continue to work with corporate partners to support sustainable consumption through innovative and far-reaching partnerships. And we'll work to strengthen the case linking food, feed, nutrition and biodiversity.

To achieve our vision of a sustainable food system, we call on:

- The UK government to request advice from the Committee on Climate Change on setting a goal to reduce emissions from the food system, including overseas emissions resulting from UK consumption.
- The UK government to develop healthy eating advice (in the form of the Eatwell Guide) that incorporates sustainability.
- The UK government to develop an integrated food policy with a centralised responsibility for implementation.
- The farming and processing sector to develop a demand-led strategy to increase consumption of fruit and vegetables, support improved consumer health, and deliver growth for the UK horticulture and potatoes sector.
- Retailers and the food service sector to reformulate recipes and develop menus that will increase the range of food products that contain fruit and vegetables – particularly ready-to-go products and ready meals.

Through our own work, partnerships and involvement with various coalitions, we welcome the chance to work with the horticulture, farming and fishing industries; the UK government; and corporate partners to deliver this path to 2 degrees and to explore other scenarios and mitigation potential. Adjustment and innovation within these sectors will enable farmers and food businesses to set the UK on the path to become a leader in delivering sustainable diets.

LIVEWELL PRINCIPLES

EAT MORE PLANTS

Enjoy vegetables and whole grains.

EAT A VARIETY OF FOODS

Have a colourful plate.

WASTE LESS FOOD

One third of food produced for human consumption is lost or wasted.

MODERATE YOUR MEAT CONSUMPTION, BOTH RED AND WHITE

Enjoy other sources of proteins such as peas, beans and nuts.

BUY FOOD THAT MEETS A CREDIBLE CERTIFIED STANDARD

Consider MSC, free-range and fair trade.

EAT FEWER FOODS HIGH IN FAT, SALT AND SUGAR

Keep foods such as cakes, sweets and chocolate as well as cured meat, fries and crisps to an occasional treat. Choose water, avoid sugary drinks and remember that juices only count as one of your 5-a-day however much you drink.

GLOSSARY, ACRONYMS AND ABBREVIATIONS

AFP: Agri-footprint®, a database with environmental impacts of agricultural products

ALA: Alfa-linoleic acid (essential omega-3 fatty acid)

EAG: Estimated average energy requirement

EFSA: European Food Safety Authority

Blue water footprint: sum of the amount of freshwater consumed to irrigate crops and grassland during the whole life cycle of a product (indicator of water stress with a high level of uncertainty)

BSE: Bovine spongiform encephalopathy

CHD: Coronary heart disease

COMA: Committee on Medical Aspects of Food and Nutrition Policy

Composite food: is a product that contains more than one food group. Defined in European Union legislation as a "foodstuff intended for human consumption that contains both processed products of animal origin and products of plant origin and includes those where the processing of primary product is an integral part of the production of the final product"

COP21: Conference of the Parties number 21 which took place in Paris in December 2015

DHA: Docosahexaenoic acid (omega-3 fatty acid from fish)

ECFCD: EFSA Comprehensive Food Consumption Database

EFSA: European Food Safety Agency

EoL: End of life

EPA: Eicosapentaenoic acid (omega-3 fatty acid from fish)

EU: European Union

Fair share: equal share for all world citizens – in this context, of a global environmental impact

FAO: Food and Agricultural Organisation of the United Nations

FBS: Food balance sheets

GHG: Greenhouse gas

GHG emissions: Greenhouse gas emissions (environmental indicator for climate change), includes direct emissions

IPCC: Intergovernmental Panel on Climate Change

Kg CO_2 eq: kilo of carbon dioxide equivalent. This is a standard unit converting greenhouse gas emissions to measure carbon footprint

LCA: Life cycle assessment

Life cycle inventory: data required in LCA models

Linear programming: a mathematical optimisation technique that finds the optimal combination of foods within a set of constraints (such as nutrient requirements)

Land occupation (environmental indicator): square metres of land used in the production of a food, irrespective of the type of use

Land-use change: the conversion of natural habits such as rainforest into agricultural land; a process responsible for the release of CO_2. Also known as indirect greenhouse gas emissions

m^2a: land use measurement in LCA, measuring area used multiplied by time it's used

NDNS: National Diet and Nutrition Survey

Optimeal: diet optimisation tool developed by Blonk Consultants

PHE: Public Health England

PEF: Product environmental footprint

Quadratic programming: a mathematical optimisation technique that finds the optimal combination of foods within a set of constraints relative to a starting point (such as current diet)

RNIs: Recommended nutrient intakes

SACN: Scientific Advisory Committee on Nutrition (UK)

SAFA: Saturated fatty acids

INTRODUCTION

The original Livewell project started in 2010 in response to scientific evidence demonstrating the need for a systemic approach to a sustainable food system. In 2011, WWF published its first Livewell report, *Livewell: a balance of healthy and sustainable food choices*. The report included a Livewell Plate for the UK – a visual representation of a diet that is good for both people and the planet. The Plate was an adaptation of the UK Food Standards Agency's Eatwell Plate which illustrates the proportions of major food groups to be included in a healthy diet.[1,2]

This initial report was followed by LiveWell for LIFE – a €2.1 million European Commission-funded project which aimed to demonstrate how a healthy, sustainable diet can help us achieve a 25% reduction in GHG emissions (in line with our One Planet Food Programme at the time) from the European Union (EU) food supply chain. The project looked at health, nutrition, carbon and affordability, and developed Livewell Plates for three EU member states – the project's pilot countries France, Spain and Sweden.[3]

The Livewell work[4,5] was very successful in putting the topic of sustainable diets on the agenda of governments, food companies and health organisations, as well as demonstrating that it's possible to incorporate sustainability in dietary recommendations.

Building on this success and the recently produced Eatwell Guide[6] WWF decided it was time to produce an update of its Livewell Plate, including more material on environmental impacts like deforestation and freshwater use. They selected Blonk Consultants to perform the diet modelling required for these updates, and the results are presented in this report.

The report has the following structure:

- Chapter 2 presents the main research questions addressed in the project;
- Chapter 3 gives a brief overview of the methodology applied in modelling the Livewell Plates; and
- Chapters 4 and 5 present the results and the conclusions.

Interested readers may wish to refer to the annexes for more details on the methodology used:

- Annex 1 provides details on how the environmental reduction requirements for GHG emissions and land occupation were derived;
- Annex 2 contains the background of nutritional data and nutrient requirements used in modelling;
- Annex 3 provides information on the methodology and data applied in the calculation of environmental impacts of foods included in the diets;
- Annex 4 contains technical details on the settings applied in the optimisation of Livewell Plates;
- Annex 5 is a report capturing the key comments and recommendations put forward by WWF's stakeholders at their Livewell meetings in London and Edinburgh in February 2017; and
- Annex 6 provides an overview of how our current food system links to key WWF policy areas: water, forest, seafood, meat and soy.

OBJECTIVES AND RESEARCH QUESTIONS

WWF's Food Programme aims to reduce the global environmental and social impacts of food production and consumption. GHG emissions, water use and biodiversity loss are the most significant challenges. To meet global demand for food and reduce our food footprint we need to look at the whole food system, including production efficiencies and the types of food we eat.

This most recent project is an update and extension of the previous Livewell work developed for the UK. The main objectives of our research were to:

- Extend the analysis of food consumption to include drinks;
- Revisit and update the original Livewell Plate for the UK;
- Include additional environmental metrics, such as water use and land footprint;
- Create additional Plates based on specific dietary needs; and
- Calculate the cost of the revised Plates relative to the current diet.

In close cooperation with WWF, we further defined the scope of this research project. For instance, for water use and land footprint there are common metrics in the life cycle assessment (LCA) methodology such as blue water footprint (fresh water use), land-use change, and land occupation. We agreed which to include in our environmental impact assessment and how to weigh their importance, taking into account data quality and the limitations of each methodology. This meant we were able to formulate the following additional tasks:

Develop or update Livewell Plates for the UK with the latest nutritional data, including:

- Age groups: adults (aged 18-64), adolescents (aged 10-17), elderly (aged 65-84) and vegans (aged 18-64);
- Agreed metrics for carbon footprint, land footprint and water footprint: respectively direct GHG emissions and indirect GHG emissions by land use change, land occupation, by type of agricultural land use, and freshwater consumption (blue water footprint);
- Show how the composition of the Livewell Plate depends on how the mitigation effort is divided between reduction requirements for food consumption and food production: 50/50, 30/70 or 70/30;
- An estimate of diet costs based on current prices in mid-range supermarkets;
- A comparison with the Eatwell Guide, aiming for a 30% reduction in GHG emissions; and
- Explore how eating habits have changed since the 1960s, map the health and environmental impacts of these changes, and compare with changes as suggested in Livewell Plates.

By performing these tasks, we aimed to answer the following research questions:

1. Can we develop Livewell Plates that respect national climate change mitigation commitments, stop deforestation and reduce the impact of freshwater consumption at the same time?
2. Is it possible to reproduce the carbon footprint and size of the segments of the Eatwell Guide?
3. Are the Livewell Plates still affordable for people with lower incomes?
4. Can we show how eating habits have changed since the 1960s, and explain how this might have influenced both health and environmental impact? How do the trends compare with those suggested by Livewell? Has a change in food consumption contributed to lower GHG emissions?

METHODOLOGY OVERVIEW

The Livewell Plates presented in this report were developed with the help of the Optimeal 2.0 optimisation tool[10,11], applying a technique called quadratic programming. The main concept – and how it contributes to the creation of healthy and sustainable Livewell Plates – is explained below. A more comprehensive description of the methodology is given in the annexes.

STEPS IN DERIVING HEALTHY AND SUSTAINABLE DIETS BY OPTIMISATION

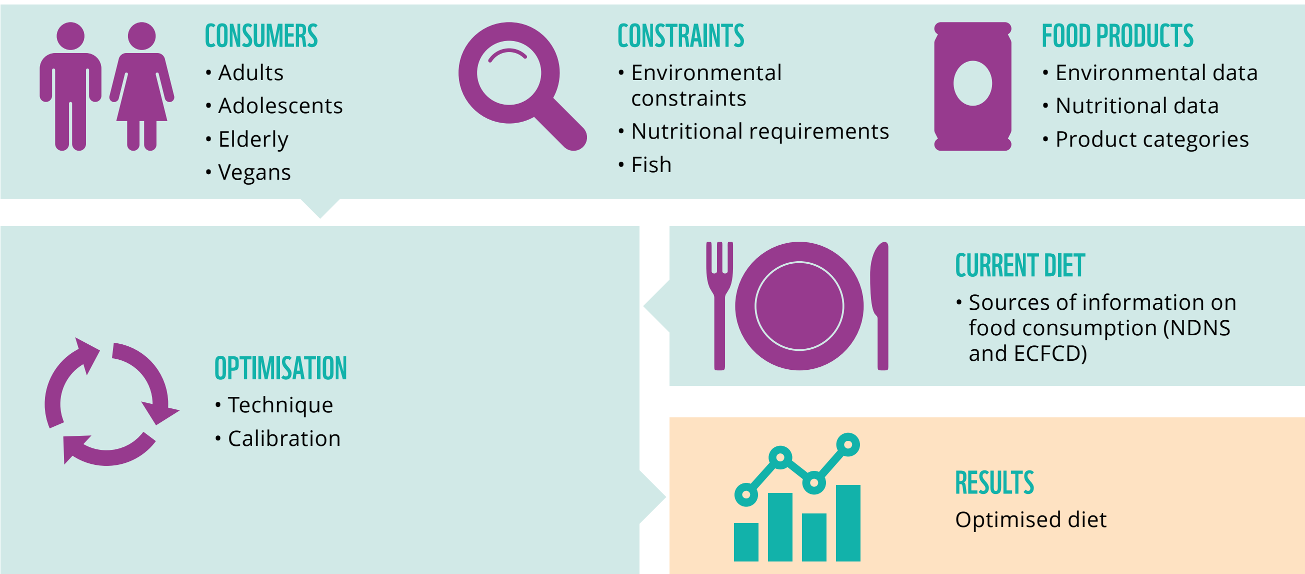


Figure 1: Steps taken in the optimisation process of Livewell Plates.

CONSUMER GROUPS

Whereas the original Livewell Plate was for adult women only, the Livewell Plates here were developed for adults (aged 18-64), adolescents (aged 10-17), elderly (aged 65-85) and vegans (adults). Each group has specific nutritional requirements, so we tailored their Livewell Plates accordingly. Each represents an 'average' diet, making no distinctions for gender or activity level.

CONSTRAINTS

The optimisation process requires quantifiable targets that define a healthy and sustainable diet. These are referred to as constraints or boundaries, and include upper boundaries (maximum) and lower boundaries (minimum). The environmental reduction requirements are upper boundaries, which mean that they need a solution which stays below them. The nutritional boundaries can be either lower or upper depending on the nutrient.

Environmental constraints

The following environmental impacts were taken into account in creating the new Livewell Plates. These were included as constraints in the optimisation process:

- GHG impact without land-use change, or carbon footprint;
- Total land occupation;
- Grassland occupation; and
- Cropland occupation.

Together, the different land occupation metrics give a good indication of potential loss of biodiversity. Land occupation and land transformation are key drivers of biodiversity loss[12]. An increasing amount of land used to grow food for the diets in the UK would increase loss of biodiversity directly by higher land occupation and indirectly by a higher risk of land transformation.

Table 1: Environmental reduction requirements for Livewell Plates for 2020 and 2030

An overview of the environmental constraints used for the Livewell Plates is shown in Table 1.

	1990	2020 LIMIT	2030 LIMIT
Total carbon footprint ($MtCO_2$)	152	117.9 (-23%)	106.5 (-30%)
Individual carbon footprint (kg CO_2eq)		4.77	4.09
Land occupation (m^2*a)		17.7	16.1
Grassland (m^2*a)		12.1	11.1
Cropland (m^2*a)		5.0	4.6

Other environmental metrics that are measured but not used as limits in the optimisation are the blue water footprint and the carbon footprint including land-use change. Both metrics are harder to interpret and to set limits on. The blue water footprint is actually a measurement of all freshwater (tap water and irrigation water) used during a product's life cycle. It does not explain the impact of this use. To understand this impact the local water scarcity situation should be taken into account. The carbon footprint of land-use change is an indicator of what happened over the past 20 years: it can be used in examining current land transformation practices but not to analyse future developments.

The reduction requirements and the limits for each indicator are further explained below.

Reduction of GHG impact (carbon footprint)

To keep the average global temperature rise well below 2 degrees – as agreed at COP21 – the Committee on Climate Change has advised the UK government to reduce territorial emissions by 61%, but as stated above we've rounded this down to 60%. This forms the basis of the reduction requirements for the UK Livewell Plates for 2020 and 2030.

As established in *How low can we go? An assessment of greenhouse gas emissions from the UK food system and the scope for reduction by 2050*, we estimate that the supply of food and drink (excluding land-use change) for the UK resulted in a direct emission equivalent of 152 $MtCO_2$ in 1990[16] not just the emissions from the UK food chain that arise in the UK. The study comprises an audit of the GHG emissions arising from the UK food economy and an examination of the scope for substantial reductions of these emissions. The aim of this short and preliminary study conducted over a few months in 2009 is to stimulate debate about the full GHG impact of the UK food chain and the scope and options for reducing GHG emissions in line with wider climate change policy. The study is theoretical, in effect a thought experiment based on detailed inventories of emissions and the use of LCA or 7.28kg CO_2e/day per UK citizen.

After applying the 50% share to the overall target of -60%, we derive a reduction requirement of -30% for UK food consumption in 2030: 106.5 $MtCO_2e$. The intermediate target for 2020 is 117.9 $MtCO_2e$, assuming a linear reduction path of 11.4 Mt per 10 years. This is the basis for the limits shown in Table 2 under Results.

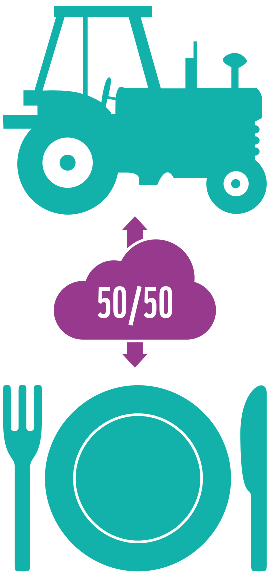
For the 2030 scenarios explained above, we've assumed that the food system should contribute at the same level as the economy-wide average. We've also assumed that food consumption and food production should contribute equally (50/50) to the reduction of GHG emissions in the food system. Alternative shares were 30/70 and 70/30. All the scenarios meet the requirements presented in Table 1.

Limits for land occupation

We've made the assumption that Livewell Plates should not increase global agricultural land occupation, nor promote a shift from grassland towards more cropland. However, because a diet consists of raw materials sourced from all over the world, it's very difficult to define national limits for land occupation per individual. Instead, we divided all currently available agricultural land equally between all world citizens living in 2020 and 2030, to obtain an equal share of total agricultural land, grassland and cropland for everybody.

Nutritional requirements (defining upper and lower limits)

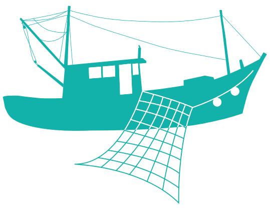
Each age group has its own estimated average energy requirement, recommended nutrient intakes (RNIs) and safe upper limits for nutrients. These are defined by



FOOD CONSUMPTION AND FOOD PRODUCTION SHOULD CONTRIBUTE EQUALLY (50/50) TO THE REDUCTION OF GHG EMISSIONS IN THE FOOD SYSTEM.

national public health authorities or the European Food Safety Authority (EFSA). (See Table 15 in Annex 2 for an overview of all nutrient constraints implemented in the modelling of Livewell Plates).

On top of that the Eatwell Guide provides guidelines specifying minimum or maximum amounts of foods recommended for a healthy diet in the UK[6]. One example is the recommendation to consume at least five servings of fruit and vegetables per day. (See Table 16 in Annex 2 for an overview of implemented food-based dietary guidelines).



90% OF THE WORLD'S FISH STOCKS ARE FULLY EXPLOITED OR OVER-FISHED.

Together, the upper and lower constraints in the optimisation model define a healthy diet. The model will always find a solution that meets these requirements, unless there is simply no solution possible. The latter was the case for vegans who couldn't meet the RNI for iodine. The requirement was therefore removed from the model (see Results).

Constraint on fish

Current fish consumption is below the recommended level in the UK. However, around 90% of the world's fish stocks are now fully exploited or over-fished leaving little room for expansion under current management approaches. Consequently, we limited wild-caught fish to the level of intake found in the current diet. This meant that the extra requirement could only be met by introducing more aquacultured fish.

FOOD PRODUCTS IN THE OPTIMISATION

A diet consists of food products, each with specific nutrient content and environmental impacts. The goal of the process is to find a diet with the fewest possible changes relative to the current diet, while meeting all restrictions imposed by the optimisation model. Changes are measured in grams of product.

Product categories

Food-based dietary guidelines are often given at the level of food groups, so we used FoodEx, a food classification system developed by EFSA[21], to categorise each food into a food group. In total we used 26 product groups; where necessary we added more detail:

- *Meat and meat products* were subdivided into beef/veal, lamb, meat replacers, poultry, pork, and processed meat. Meat replacers include soy and Quorn (this distinction was made because these products are very different in nutrient composition and environmental impact).
- *Milk and dairy products* were subdivided into traditional dairy products such as milk and yoghurt, cheese, and dairy replacers such as fortified soy drink and soy yoghurt.
- *Fish and other seafood* was subdivided into wild-caught fish and aquacultured fish. Wild-caught fish was limited to the current intake in order not to increase overfishing.

Environmental impacts of food products

To enable quantification of the environmental impact of the Livewell Plates, LCA were performed on 79 food products, including both whole foods such as bread, onions, sugar and potatoes, and processed foods like mayonnaise, cola and orange juice. The LCAs were performed by filling existing LCA-models developed by Blonk Consultants for the Dutch government[22] with country-specific life cycle inventory data which included a mix of home produce and imports. Among the data sources were AgriBalyse[23], Agri-Footprint[24] and FAOSTAT[25]. By using some of the products as a proxy for other products, we were able to include 125 food products in the calculation of the Livewell Plates. As an example, white bread serves as a proxy for other types of bread and pizza, the latter made by combining sausage, cheese and white bread.

Nutritional data on food products

The sources of data on the composition of all foods included in this research were available from McCance & Widdowson's[27]. However, because it lacked data on chicken liver and water (tap, still mineral water and sparkling mineral water) these were adopted from the French Ciqual[26].

Added sugar was included as an extra property. This included all sugars except those in fresh fruit, vegetables and dairy.

[v] http://livewellforlife.eu/wp-content/uploads/2013/05/Adopting-healthy-sustainable-diets-report.pdf

CURRENT DIETS

There are many barriers to adopting healthier and more sustainable diets[v], and we want the Livewell Plates to stay as close as possible to the current average diet. For this report, it meant we needed a definition of the average current diet in each age group to serve as a starting point for the optimisations, which we created using data compiled by EFSA[(28)] in the EFSA Comprehensive Food Consumption Database (ECFCD) and National Diet and Nutrition Survey (NDNS) Rolling Program Years 1-3[(30)].

One point we need to mention here is underreporting. This is a recognised problem in dietary surveys[(31)] because all other nutrients must be provided within the quantity of food needed to fulfill the energy requirement. Thus if total energy intake is underestimated, it is probable that the intakes of other nutrients are also underestimated. Under conditions of weight stability, energy intake equals energy expenditure, which rely on self-reporting of food intake by subjects. Typically subjects are more willing to report foods perceived as “good” than those perceived as “bad”. This differential reporting makes it difficult to correct for underreporting in estimations of nutrient intake, as well as in estimations of diet cost and environmental impact.

We mention this here so readers are aware of the limitations of the data, and understand why the energy content of Livewell Plates needed to be increased relative to the current diet. The extent of energy underreporting can be estimated by measuring the difference between reported energy intake and the estimated average requirement based on age, physical activity level, gender and bodyweight of each subject. Among the groups in this study average energy underreporting was between 11% and 28%[(29,32)] compared to the energy requirements we’ve applied (see Table 15).

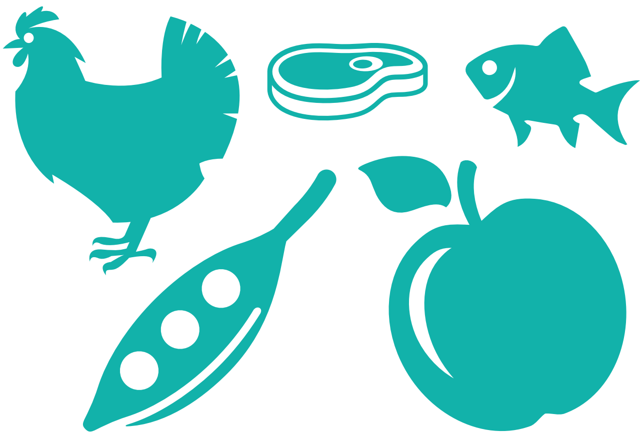
SELECTION OF OPTIMISATION ALGORITHM AND CALIBRATION

In this study we used quadratic programming as our optimisation technique. Previous Livewell Plates were obtained by linear programming[(1,3)]. Blonk’s optimisation tool Optimeal provides both options. There are subtle differences in the outcome of the techniques. Quadratic programming typically makes small changes to almost all foods in the diet, whereas linear programming makes large changes in a limited amount of foods and leaves the rest the same. Researchers developing the latest Dutch food-based dietary guidelines[(33)] compared the techniques and found that quadratic programming gave more attainable suggestions. This confirms our own experience[(34,35)].

After importing the data into Optimeal, we performed several test runs of the optimisation as a sense-check on the outcome and to trace potential problems. We found that some nutrient requirements were very difficult or even impossible to fulfil with the available foods.

In the case of vegans, the requirement for iodine prevented Optimeal from finding a solution. This meant we had to disable the lower limit for iodine.

A sensitivity analysis on the choice of algorithm or the impact of variability in data and constraints was outside the scope of this project.



THE GOAL OF THE PROCESS IS TO FIND A DIET WITH THE FEWEST POSSIBLE CHANGES WHILE MEETING THE RESTRICTIONS IMPOSED.

RESULTS

LIVEWELL PLATES

Adults 2020 and 2030

Based on the LCAs we performed on the foods in the current diet, we estimate that the current diet of UK adults has a carbon footprint of 5.17kg CO_2eq/day per individual (Table 2), compared to the 1990 level of 7.28 CO_2eq/day(1,41). Considering the limited environmental impact consumption changes have had since 1961 (see Historical trends in diets) this suggests a large decrease related to production efficiencies has taken place. However, this might well be an underestimation of the actual value, due to an underreporting of calorie intake by this age group of almost 22% in the NDNS[32].

The Livewell Plates for UK adults provide the required amount of calories, 2,388 kcal/day, as well as meeting all national nutrient requirements and the food-based dietary requirements of the Eatwell Guide[6] (see Annex 2 for all nutritional requirements), such as a minimum of five portions per day of fruit and vegetables, two servings of fish per week, and a maximum of 70 grams per day of red and processed meat.

As well as a lower carbon footprint, the Livewell Plates have lower GHG emissions including land-use change, and lower land occupation.

Grassland use in particular is much lower, due to reductions in beef and lamb production (Table 3). Although still well below the limit, the required amount of cropland is increased for 2020 due to more vegetables and vegetable oils in the Livewell Plates, which are needed to meet Eatwell Guide and nutrient requirements. The blue water footprint of the Livewell Plate is fractionally higher, but this is highly uncertain due to issues with data quality.

Increases in grain-based products, aquacultured fish, vegetables and fruit mean the estimated cost of the Livewell Plates was somewhat higher than the cost of the current diet. This is an approximation, due to the limitations of the method applied to collect existing food costs and the potential underestimation of the current cost due to underreporting.

Table 2: Environmental indicators and diet cost per day for current diet and adult Livewell Plates for 2020 and 2030.

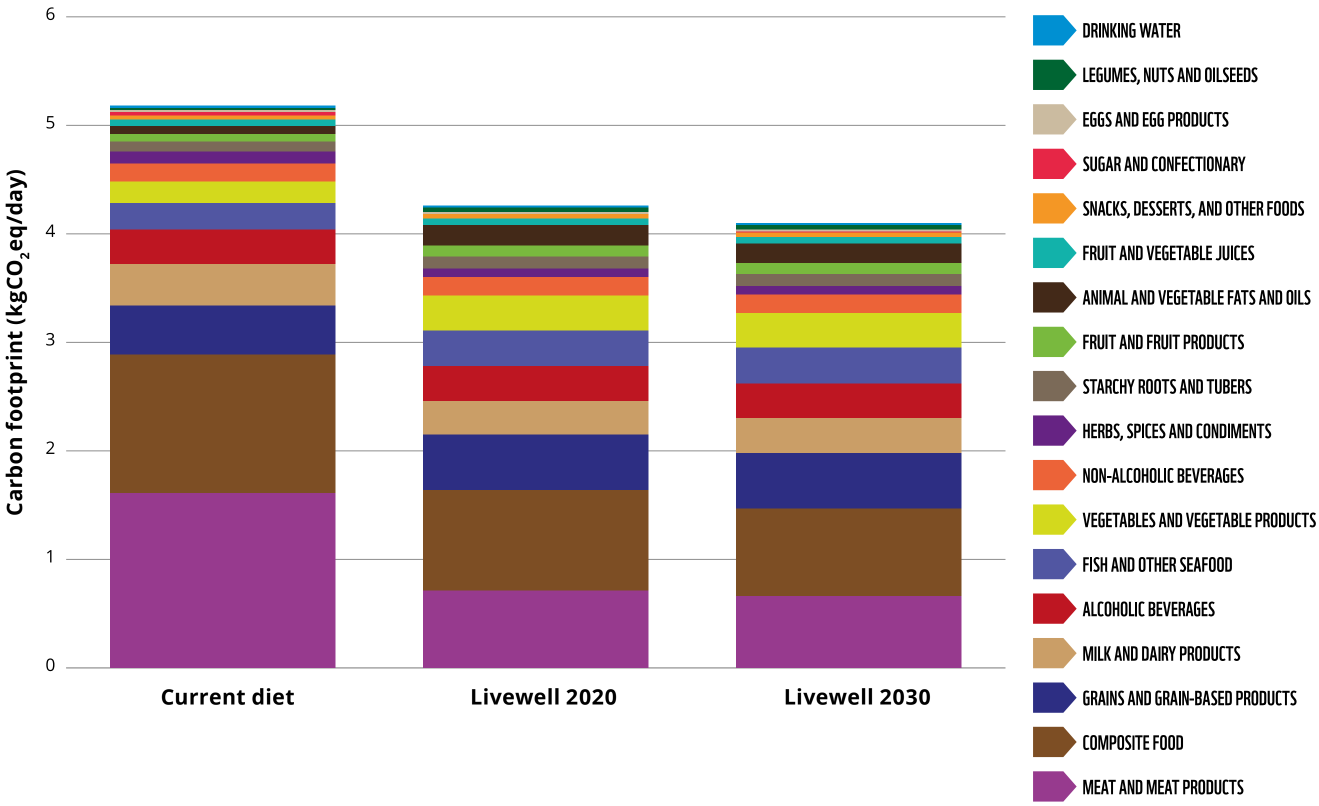
	1990	CURRENT	LIVEWELL 2020	LIMIT	LIVEWELL 2030	LIMIT
Carbon footprint (kg CO_2eq)	7.28	5.17 (-29%)	4.25 (-42%)	4.77	4.09 (-44%)	4.09
GHG including land-use change (kg CO_2eq)		5.79	4.67		4.51	
Land occupation (m²*a)		6.4	5.3	17.7	5.06	16.1
Grassland (m²*a)		3.2	1.87	12.1	1.67	11.1
Cropland (m²*a)		3.2	3.43	5	3.39	4.6
Blue water footprint (m³)		0.16	0.19		0.19	
Cost (£)		3.89	3.95		3.95	

Note: the percentage reductions on this row relate to the carbon budget divided by number of citizens, with projected population growth taken into account. See Appendix 1 for further information.

Figure 2 shows the breakdown of the overall carbon footprint in food groups for each Plate. It illustrates that *meat and meat products* and *composite food* (which includes meat-based dishes) make by far the highest contributions to the footprint of the current diet. These groups are reduced in the Livewell Plates because other foods can provide the same essential nutrients with much less environmental impact, particularly in terms of carbon footprint. We explain the differences between the current diet and the Livewell Plates in more detail below.

Table 3 shows the composition of the current UK diet and Livewell Plates on the level of food groups, with extra subdivisions in groups like *meat and meat products* and *fish and other seafood*. Due to methane emissions, meat from ruminants like cattle and sheep (lamb) has a higher carbon footprint, especially if these animals are farmed exclusively for their meat. In the case of lamb, this is further worsened by the low yield of meat, resulting in a carbon footprint that is more than double that of beef: 87kg CO_2eq/kg of prepared lamb versus 34kg CO_2eq/kg of prepared beef.

Figure 2: Breakdown of carbon footprint (GHG emissions) of the current UK diet and adult Livewell Plates



Reducing consumption of beef and lamb is therefore most effective; however, in order to allow beef and lamb to remain on the Plate all other meat groups are also reduced.

Another reason to reduce meat – in particular beef, lamb and pork – and cheese is saturated fatty acids.

Although the absolute amount of meat replacers added to these Livewell Plates is modest, the increase is significant. The reason could be their zinc content, as we deduced from contributions to the vegan Livewell Plate, discussed elsewhere in this report. The intake of zinc from the current diet was below the RNI (see Annex 2 for an overview).

Table 3: Composition of Livewell Plates for UK adults compared to current (NDNS)

	CURRENT	LIVEWELL 2020		LIVEWELL 2030	
Product group	**g/day**	**g/day**		**g/day**	
Legumes, nuts and oilseeds	11	28	147%	28	144%
Fruit and fruit products	92	131	43%	131	43%
Beef and veal	18	4	-78%	4	-80%
Pork	7	6	-20%	5	-30%
Lamb	6	4	-29%	4	-37%
Poultry	30	8	-73%	9	-70%
Processed meat	29	12	-59%	12	-58%
Meat replacers	2	6	210%	5	177%
Fish wild-caught	19	19	0%	19	0%
Fish aquaculture	7	21	199%	21	199%
Dairy	179	187	5%	186	4%
Cheese	14	5	-67%	6	-57%
Dairy replacers	3	3	-5%	3	2%
Eggs and egg products	8	8	-1%	7	-2%
Sugar and confectionery	19	3	-85%	3	-85%
Fats and oils	13	49	265%	49	261%
Fruit and vegetable juices	61	68	12%	68	11%
Non-alcoholic beverages	608	598	-2%	598	-2%
Alcoholic beverages	280	280	0%	280	0%
Drinking water	725	726	0%	726	0%
Herbs, spices and condiments	30	30	-2%	30	-2%
Composite food	129	126	-2%	122	-6%
Snacks, desserts, and other foods	17	24	43%	25	46%
Grains and grain-based products	193	261	35%	262	36%
Vegetables and vegetable products	146	232	59%	232	59%
Starchy roots and tubers	90	106	18%	106	18%

Several of the shifts from the current diet can be attributed to underreporting of energy in the NDNS, and to inadequacies in the current diet with respect to intake of certain macro- and micronutrients – among these were mono- and poly-unsaturated fatty acids, dietary fibre, iron, potassium and iodine. This is the reason for increases in vegetable oils (energy, mono- and poly-unsaturated fatty acids), legumes (energy, fibre, and so on), grains (energy, fibre, zinc, iron) and nuts (energy, poly-unsaturated fatty acids). Some of the increases also compensate for energy and beneficial nutrients from foods that were reduced in quantity.

THE TYPES OF FISH IN THE LIVEWELL PLATE ARE ALL AVAILABLE WITH EITHER AN MSC OR ASC LABEL.

Last, the food-based dietary requirements from the Eatwell Guide also force certain shifts. Aquacultured fish, like salmon, was increased in order to meet the Eatwell Guide requirement for two servings of 140 grams of fish per week. As previously stated, it's of some reassurance that the types of fish in the Livewell Plate are all available with either an MSC or ASC label. Considering the ecological impact of the requirement, it's regrettable that it wasn't reduced to one serving per week, as a recent Dutch Health Council review of the scientific evidence concluded that there's no additional benefit in eating two instead of one servings of fish per week[36,37].

Cheese was reduced, but other dairy was increased slightly. This was also the case in the previous Livewell Plate for the UK[2]. One of the reasons is that dairy is the most important source of iodine in the current UK diet, and the intake of this trace element is currently below the requirement. Dairy is often perceived as a product group with a high carbon footprint, while in fact on a per volume basis it has a carbon footprint very similar to many plant-based foods, such as bread, fresh orange juice or certain vegetables. In areas like this, the balance between environmental impact and contribution to the provision of essential nutrients is important. In the case of dairy there appears to be enough nutritional benefit to justify the amount of environmental impact.

Some of the nutrient requirements proved harder to meet than others, among them dietary fibre and iodine. The Livewell Plates shown in Table 3 supply exactly the required amount of these nutrients but not more, as is the case for most other nutrients.

The maximum limit of 5% of total energy from added sugar set by Scientific Advisory Committee on Nutrition (SACN)[42] also proved challenging and caused a massive reduction of *sugar and confectionery*.

These results can also be compared to the groups mentioned in the Eatwell Guide, which are shown in Figure 3. Both Livewell Plates contain more *starchy foods*, *fruit and vegetables* and *oils and spreads*. *High sugar/high fat* foods were lower, for the reasons explained above. The difference in protein is related to the reduction of all types of meat on the Livewell Plates.

Figure 3: Results translated to Eatwell Guide groups

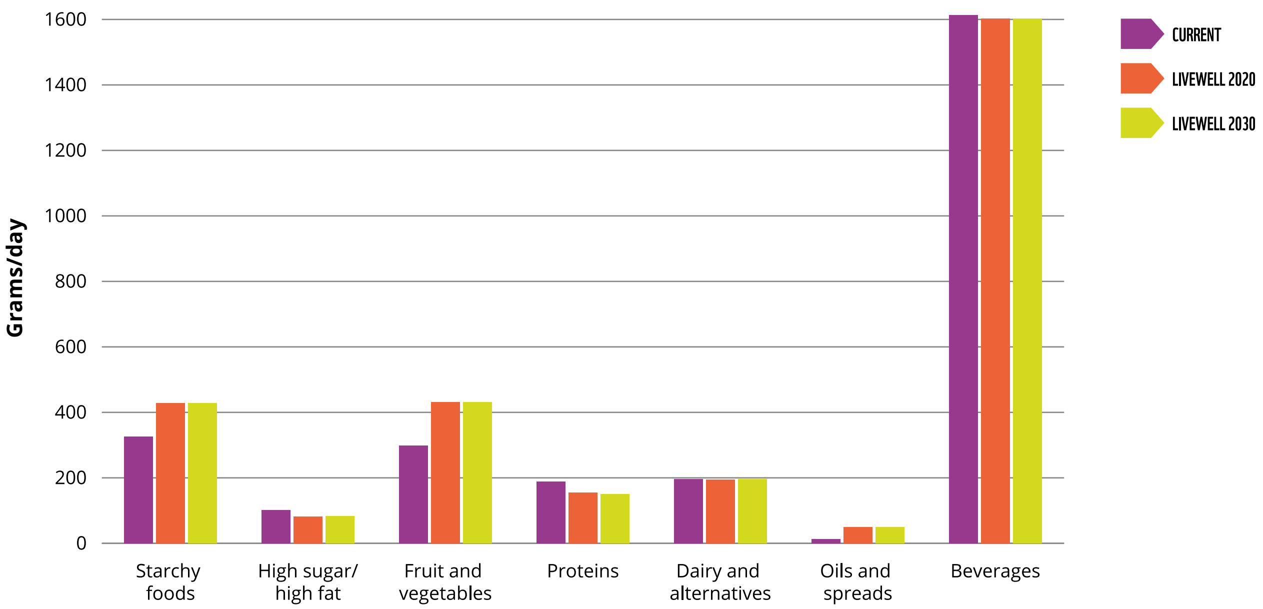


Figure 4 also summarises the results in a more aggregated form. The proportion of *Beverages* decreased in relative terms, but the absolute amount was constant. Also *animal protein* decreased, for the reasons explained above.

As previously mentioned, one of the baseline assumptions in this report is that the mitigation effort required of the food system as a whole is shared equally by consumption and production (50/50). However, this is just an assumption and it's open to debate whether it's the most realistic and attainable option. Therefore we also tested two other shares. Table 4 compares the composition of Livewell Plates with the default (50/50) and alternative shares: 30/70 and 70/30. The different shares produce different reduction requirements for the overall carbon footprint of the diet in the model.

For a better overview, changes relative to the current diet of more than 10% are marked with either a minus (-) or a plus (+), whereas smaller changes are marked with a zero (0). Although the extent of changes may differ, their overall similarity is clear. Some changes, for instance those in *fish aquaculture* and *fats and oils*, are independent of the carbon footprint target and are made for health reasons or to increase the energy content to the required level.

The amount of *lamb* and *beef and veal* are most dependent on the carbon footprint target: consuming less of these is an effective option for mitigation of GHG emissions which can be achieved by consumers. This also applies to *composite foods*, the second largest contributor to the overall carbon footprint of the current diet (Figure 2) behind *meat and meat products*.

Figure 4: Pie-charts of the composition of the current adult diet (NDNS) and the adult Livewell Plate for 2030. Amounts are in grams/day.

Please note: *Animal protein* includes meat, fish and egg; *Plant protein* includes legumes and meat replacers; *Plant dairy* includes soy drink and soy yoghurt; *Carbohydrate* includes grains and grain-based products, starchy roots and tubers, and sugar and confectionery. See Table 3 for the full composition of the adult Livewell Plate.

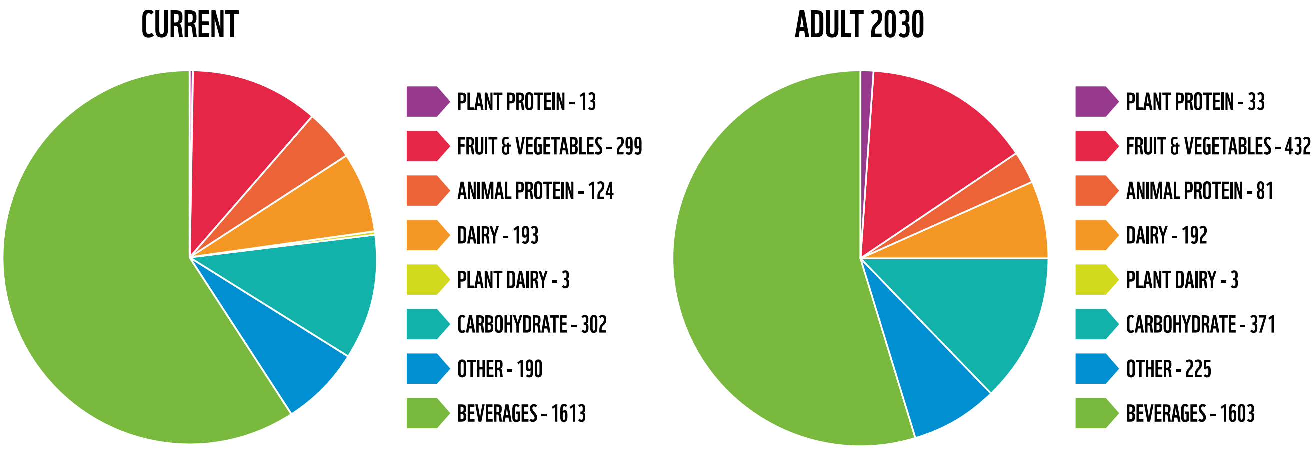


Table 4: Composition of the adult Livewell Plate 2030: sensitivity to how the mitigation effort is shared between consumption and production. Default is a 50/50 share. Changes larger than 10% are indicated with + or -.

	Current	Livewell 2030	Livewell 2030	Livewell 2030	
Share		**50/50**	**30/70**	**70/30**	**Trend**
CF Target		**4.09 $kgCO_2eq$**	**4.73 $kgCO_2eq$**	**3.30 $kgCO_2eq$**	
Product group	**g/day**	**g/day**	**g/day**	**g/day**	**(>10%)**
Legumes, nuts and oilseeds	11	28	28	22	+++
Fruit and fruit products	92	131	131	134	+++
Beef and veal	18	4	4	0	---
Pork	7	5	5	5	---
Lamb	6	4	4	4	---
Poultry	30	9	8	15	---
Processed meat	29	12	12	13	---
Meat replacers	2	5	6	0	++-
Fish wild-caught	19	19	19	18	000
Fish aquaculture	7	21	21	22	+++
Dairy	179	186	187	184	000
Cheese	14	6	6	6	---
Dairy replacers	3	3	3	3	000
Eggs and egg products	8	7	7	9	00+
Sugar and confectionery	19	3	3	5	---
Fats and oils	13	49	48	50	+++
Fruit and vegetable juices	61	68	68	68	+++
Non-alcoholic beverages	608	598	598	595	000
Alcoholic beverages	280	280	280	270	000
Drinking water	725	726	726	725	000
Herbs, spices and condiments	30	30	30	22	00-
Composite food	129	122	125	98	00-
Snacks, desserts, and other foods	17	25	25	25	+++
Grains and grain-based products	193	262	262	266	+++
Vegetables and vegetable products	146	232	233	230	+++
Starchy roots and tubers	90	106	106	104	+++

COMPARISON TO THE EATWELL GUIDE

The sizes of the segments of the Eatwell Guide correspond with the quantity of food recommended by Public Health England (PHE). The Eatwell Guide also claims a 30% lower carbon footprint than the current UK diet. We attempted to reproduce these findings.

In order to define the size of the segments of the Eatwell Guide PHE used linear programming[43], a mathematical optimisation technique like the quadratic programming which was used to calculate the Livewell Plates in this report. PHE used the current diet (NDNS) as the starting point and modelled the fewest possible changes needed to achieve a diet meeting the updated Eatwell Guide recommendations. A study by the Carbon Trust found that Eatwell Guide diet model had a 30% lower carbon footprint[44] than the current diet.

Further details about the methodology weren't communicated, making it very difficult to compare the results of our model with those found by PHE and the Carbon Trust. In order to make a fair comparison all nutritional requirements were kept similar to those applied to calculate the Livewell Plates for adults (Annex 2). We then applied both linear and quadratic programming to find two diets (**A_qdr** and **B_lin**) with the fewest possible changes relative to the NDNS diet – these optimisation techniques differ in how they measure changes to the current diet.

The results of this analysis are shown in Table 5. We were unable to reproduce either the size of the segments or the 30% carbon footprint reduction found by PHE and the Carbon Trust. The differences can't be attributed to the use of linear programming instead of quadratic programming, as we find only small differences between the two when applied to the same dataset and requirements.

Some differences in segment size are minor. Relatively large differences are found in *oils and spreads* and *dairy and alternatives*. The latter make up 15% of the two healthy diets we modelled, but only 8% of the Eatwell Guide[45].

In contrast to the Eatwell Guide, we found a negligible to small increase in carbon footprint, depending on the type of algorithm we applied.

Without knowing the details on foods and nutrient requirements included in Eatwell Guide modelling, it's difficult to give an explanation for these observations. It just demonstrates that the outcome of diet modelling is very sensitive to differences in data, requirements and model.

Table 5: Comparison of Eatwell Guide to current and optimised diets

Eatwell Guide groups	CURRENT	A_QDR**	B_LIN	A_QDR	B_LIN	EATWELL
	g/day	g/day	g/day	segment	segment	segment
Starchy foods	326	428	353	34%	28%	38%
Fruit and vegetables	299	432	429	34%	34%	40%
Proteins	188	150	153	12%	12%	12%
Dairy and alternatives	196	196	202	16%	16%	8%
Oils and spreads	13	49	34	4%	3%	1%
Beverages	1613	1603	1613			
High sugar/high fat	101	83	114			
Carbon footprint (kg CO_2eq/day)	5.17	3.93	4.09			

****Note:** This is the 2030 Livewell Plate as presented in Figure 3.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Adolescents 2030

On the one hand, UK adolescents consume less fruit and fewer fish and vegetables than UK adults. On the other hand, they consume more fruit juice and sugary products. The carbon footprint of their current diet is lower than that of adults (Table 2 and Table 6), mainly because they consume less meat. As is the case with adults, the impact of the current diet is very likely underestimated due to severe underreporting of energy – in adolescents the apparent intake of energy was 28% less than the estimated average requirement[32].

Underreporting also affects the comparison of cost and environmental indicators. Apparently, the Livewell Plate for UK adolescents requires less grassland, but a minor increase in cropland. Overall cropland and blue water footprint also seem higher; although as previously stated this is a highly uncertain estimate.

The lower amount of grassland required for the Livewell Plate is due to the reduction of beef and lamb. In the *meat* product group, some beef, pork and poultry remained.

One of the reasons for the higher use of cropland and freshwater is an increase in the quantity of vegetable oils compared to the current diet. These are needed to increase the amount of unsaturated fatty acids to required levels.

Table 7 shows the contents of the current diet and the 2030 Livewell Plate for UK adolescents.

The Livewell Plate contains more legumes, nuts, fruit, aquacultured fish, grain-based products and vegetables whereas there's a decrease in beef and veal, poultry, processed meat, dairy and cheese.

Some of these changes were necessary to meet the requirements of the Eatwell Guide, others to meet energy and nutrient requirements. *Sugar and confectionery* sees a notable decrease due to the strict maximum limit of 5% of energy from added sugar set by SACN[42]. That said, the amount in the current diet seems low: this could be due to underreporting of "bad" foods.

Among other nutrients in the current diet, unsaturated fatty acids, dietary fibre, iron, zinc, potassium and iodine were below the requirement. Eatwell Guide requirements for fruit and vegetables and for fish were not met either. Increasing the amount of fruit and vegetables helps to improve the intake of fibre, iron and potassium; while more fish contributes to the intake of unsaturated fatty acids and iodine.

Table 6: Environmental indicators and diet cost per day for current diet and adolescent Livewell Plate

	1990	CURRENT	LIVEWELL 2030	LIMIT 2030
Carbon footprint (kg CO_2eq)**	7.28	4.16 (-43%)	3.4 (-53%)	4.09
GHG including land-use change (kg CO_2eq)		4.68	3.67	
Land occupation (m^2*a)		5.15	3.63	16.1
Grassland (m^2*a)		2.55	0.71	11.1
Cropland (m^2*a)		2.6	2.91	4.6
Blue water footprint (m^3)		0.14	0.21	
Cost (£)		2.94	3.26	

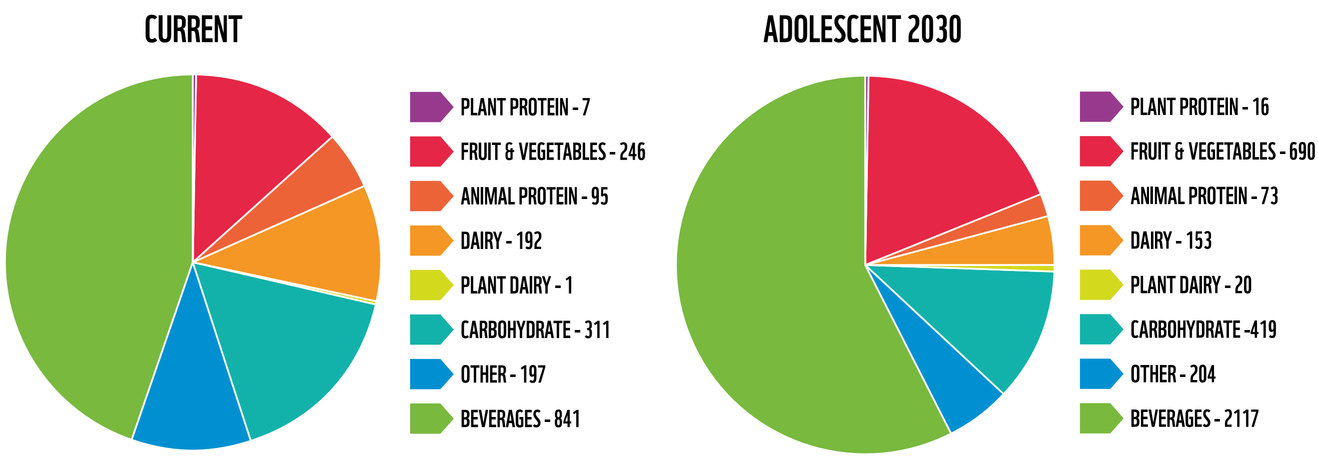
Note: the percentage reductions on this row relate to the carbon budget divided by number of citizens, with projected population growth taken into account. See Appendix 1 for further information.

Table 7: Livewell Plate for UK adolescents compared with their current diet

	CURRENT	LIVEWELL 2030	
Product group	**g/day**	**g/day**	
Legumes, nuts and oilseeds	6	14	118%
Fruit and fruit products	62	200	223%
Beef and veal	12	3	-75%
Pork	5	4	-18%
Lamb	4	3	-24%
Poultry	26	9	-67%
Processed meat	29	10	-66%
Meat replacers	1	2	269%
Fish wild-caught	12	5	-54%
Fish aquaculture	2	35	1408%
Dairy	180	150	-16%
Cheese	12	3	-72%
Dairy replacers	1	20	3016%
Eggs and egg products	5	4	-16%
Sugar and confectionery	24	9	-60%
Fats and oils	11	34	225%
Fruit and vegetable juices	98	150	53%
Non-alcoholic beverages	350	368	5%
Alcoholic beverages	16	0	-100%
Drinking water	475	1748	268%
Herbs, spices and condiments	27	52	90%
Composite food	126	42	-67%
Snacks, desserts, and other foods	33	75	131%
Grains and grain-based products	198	230	16%
Vegetables and vegetable products	86	340	294%
Starchy roots and tubers	90	180	101%

Figure 5: Pie-charts of the composition of the current adolescent diet (NDNS) and the adolescent Livewell Plate for 2030. Amounts are in grams/day.

Please note: *Animal protein* includes meat, fish and egg; *Plant protein* includes legumes and meat replacers; *Plant dairy* includes soy drink and soy yoghurt; *Carbohydrate* includes grains and grain-based products, starchy roots and tubers, and sugar and confectionery. See Table 7 for the full composition of the adolescent Livewell Plate.



Legumes are nutrient-dense; eating more of them is an efficient way to improve the intake of several nutrients, including fibre.

The increase in *fats and oils* is due to the need to replace saturated fat by mono- and poly-unsaturated fatty acids. This is associated with lower blood cholesterol and a reduced risk of heart disease[46].

In the Livewell Plate for adolescents dairy, cheese and egg were decreased. As mentioned earlier, one of the reasons for keeping dairy is iodine, which is difficult to obtain from ordinary plant-based foods. An alternative source would be seaweed; iodised table salt can also be used, although according to the British Dietetic Association it's not as common in the UK as in many other countries[47].

Although egg is animal-based, it's a reasonably environmentally-efficient source of nutrients with a carbon footprint of only 2.7kg CO_2eq/kg, so it was kept in the Livewell Plate.

Elderly 2030

The high carbon footprint of the current diet of the UK elderly is similar to that of UK adults (Table 8 and Table 2), mostly because of their high consumption of *meat and meat products* and *composite food*. In comparison to younger adults, the UK elderly consume more fruit, fish, dairy, non-alcoholic beverages and vegetables.

Achieving the reduction target meant overall land occupation and grassland were reduced, while there was a minimal decrease in cropland. These indicators of agricultural land occupation stayed well below their respective targets based on an equal share for all world citizens living in 2030.

Overall the blue water footprint remained unchanged, but olive oil, rice and orange juice became its highest contributors.

During the NDNS, underreporting of energy intake among the elderly (65+) was significant at 18%, but still lower than in both other age groups discussed in this report[32].

Many of the differences between the current diet of the elderly and their Livewell Plate for 2030 have the same causes as the differences for younger UK adults.

Table 9 shows the total composition of the Livewell Plate for the UK elderly.

Compared to the current diet it contains more legumes, nuts, fruit, vegetable oil, grain-based products and vegetables. Dairy replacers also increase, and meat replacers are introduced.

On the other hand, all types of meat, composite foods, cheese and dairy were reduced. There's little change in other food groups.

Fish consumption among the UK elderly is closer to the Eatwell Guide recommendations than among younger adults, which is a positive sign from a health perspective. *Meat replacers* are increased, as is the case in the Livewell Plate for UK adults.

Table 8: Environmental indicators and diet cost per day for current diet and elderly Livewell Plate

	1990	CURRENT	LIVEWELL 2030	LIMIT 2030
Carbon footprint (kg CO_2eq)**	7.28	5.18 (-29%)	3.37 (-54%)	4.09
GHG including land-use change (kg CO_2eq)		5.79	3.73	
Land occupation (m^2*a)		6.52	4.02	16.1
Grassland (m^2*a)		3.44	0.97	11.1
Cropland (m^2*a)		3.08	3.05	4.6
Blue water footprint (m^3)		0.14	0.11	
Cost (£)		3.69	3.63	

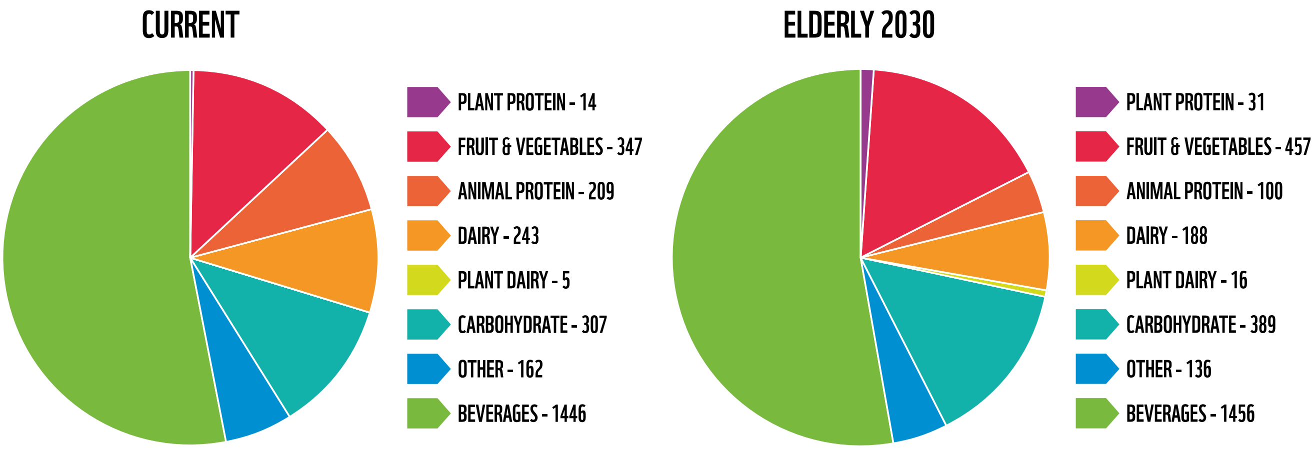
Note: the percentage reductions on this row relate to the carbon budget divided by number of citizens, with projected population growth taken into account. See Appendix 1 for further information.

Table 9: Livewell Plate for the UK elderly compared with their current diet

	CURRENT	LIVEWELL 2030	
Product group	**g/day**	**g/day**	
Legumes, nuts and oilseeds	14	27	96%
Fruit and fruit products	129	162	26%
Beef & veal	32	5	-84%
Pork	19	8	-58%
Lamb	14	5	-64%
Poultry	45	11	-75%
Processed meat	51	23	-55%
Meat replacers	0	4	925%
Fish wild-caught	24	19	-17%
Fish aquaculture	14	21	42%
Dairy	228	183	-20%
Cheese	15	5	-67%
Dairy replacers	5	16	254%
Eggs and egg products	11	8	-25%
Sugar and confectionery	14	12	-17%
Fats and oils	17	46	170%
Fruit and vegetable juices	46	52	12%
Non-alcoholic beverages	649	656	1%
Alcoholic beverages	187	186	0%
Drinking water	611	614	0%
Herbs, spices and condiments	24	20	-16%
Composite food	106	55	-48%
Snacks, desserts, and other foods	16	15	-1%
Grains and grain-based products	193	252	30%
Vegetables and vegetable products	172	243	41%
Starchy roots and tubers	100	126	26%

Figure 6: Pie-charts of the composition of the current elderly diet (NDNS) and the elderly Livewell Plate for 2030. Amounts are in grams/day.

Please note: *Animal protein* includes meat, fish and egg; *Plant protein* includes legumes and meat replacers; *Plant dairy* includes soy drink and soy yoghurt; *Carbohydrate* includes grains and grain-based products, starchy roots and tubers, and sugar and confectionery. See Table 9 for the full composition of the elderly Livewell Plate.



Vegans 2030

The NDNS data[28,32] we applied in this research doesn't contain information about vegan diets in the UK, so the current diet of ordinary UK adults was used as a reference diet in the modelling. Elsewhere, vegan diets in the UK were studied as part of the research on a pan-European cohort[48] of fish-eaters, vegetarians and vegans in the UK. Subjects were participants in the EPIC-Oxford cohort study. The diets of 2,041 vegans, 15,751 vegetarians, 8,123 fish-eaters and 29,589 meat-eaters aged 20-79 were assessed using a validated food frequency questionnaire. Comparable GHG emissions parameters were developed for the underlying food codes using a dataset of GHG emissions for 94 food commodities in the UK, with a weighting for the global warming potential of each component gas. The average GHG emissions associated with a standard 2,000 kcal diet were estimated for all subjects. ANOVA was used to estimate average dietary GHG emissions by diet group adjusted for sex and age. The age-and-sex-adjusted mean 95 % confidence interval, which found a carbon footprint of 2.89kg CO_2eq/day per individual.

At first Optimeal could not find a solution for vegans. The limiting factor was the requirement for iodine of 140mcg/day. In the UK, the main dietary sources of this trace element are dairy and fish. Unlike in other countries, it isn't common to use iodised table salt or iodised salt in bread baking in the UK[47]. UK vegans are at risk of iodine deficiency, and the Vegan Society suggests supplements are the most reliable source to achieve the right amount of iodine. However, seaweed (such as kelp) is a good source of iodine from plants.

Interestingly, the optimised Livewell Plate for UK vegans has a carbon footprint below the limit of 4.09kg CO_2eq/day set in Optimeal. This implies that this target isn't difficult for vegans to attain with the choice of foods available in the model.

If a large proportion of the population adopted a vegan diet, it would have far-reaching implications for the food system. There would be large shifts in land occupation and the international trade in agricultural commodities. As Table 10 shows, the requirement for grassland would be negligible, because products from grazing animals are eliminated from the diet. The requirement for cropland is more uncertain. We see a minor decrease in the amount of cropland needed for the UK Plate, but this is very sensitive to national nutritional requirements and the selection of particular products such as olive oil, which has high land occupation due to low yields.

Table 10: Environmental indicators and diet cost per day for current diet and vegan Livewell Plate

	1990	CURRENT (UK ADULT)	LIVEWELL 2030	LIMIT 2030
Carbon footprint (kg CO_2eq)**	7.28	5.17 (-29%)	2.33 (-68%)	4.09
GHG including land-use change (kg CO_2eq)		5.79	2.51	
Land occupation (m^2*a)		6.40	3.17	16.1
Grassland (m^2*a)		3.20	0.00	11.1
Cropland (m^2*a)		3.20	3.15	4.6
Blue water footprint (m^3)		0.16	0.15	
Cost (£)		3.89	3.48	

****Note:** the percentage reductions on this row relate to the carbon budget divided by number of citizens, with projected population growth taken into account. See Appendix 1 for further information.

If the potential of grassland to produce food is not utilised, there will be an increase in the demand for cropland to supply the same amount of calories and nutrients. The question is whether this is compensated for by a lower demand for cropland used to produce animal feed. The results shown above suggest that both effects are almost in balance.

The Livewell Plate for UK vegans contains 64 food products. The detailed composition is shown in Table 11. Apart from the animal-based foods, fruit and *sugar and confectionery* were also lowered.

The highest increases are seen in *legumes, nuts and oilseeds, meat replacers*, dairy replacers and vegetable oils.

Nutrients associated with animal-based products, like vitamin B12 and vitamin D, are provided by soy drink and soy yoghurt; whereas iron and zinc come from vegetables, meat replacers and grain-based products.

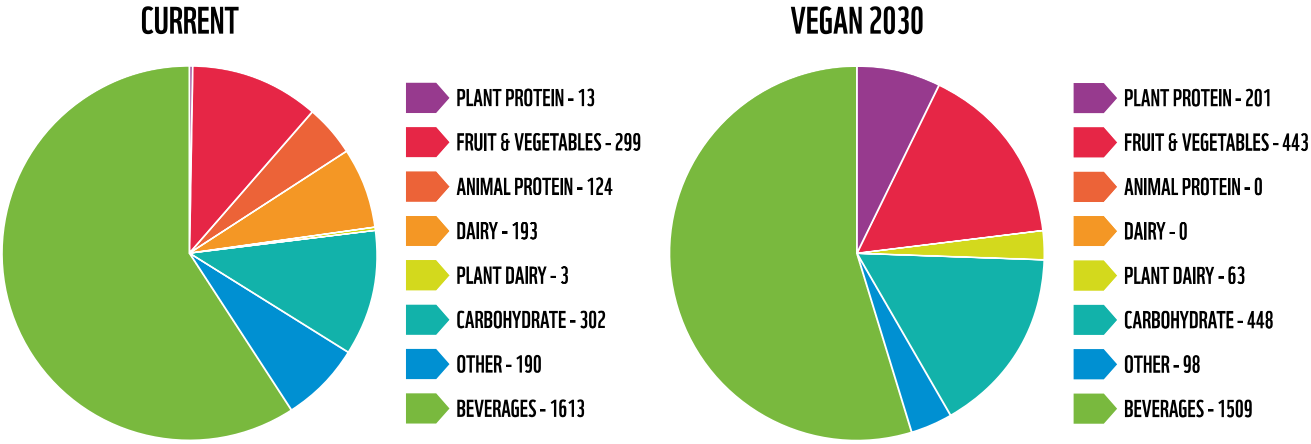
The reduction in fruit was compensated for by a large increase in vegetables in order to reach the recommended five portions a day, reflecting the fact that vegetables are richer in nutrients. Implicitly, this change suggests that it's quite hard to find a solution with the available set of foods, as fruits don't contain nutrients that are perceived as unhealthy, apart from sugar.

Table 11: Livewell Plate for UK vegans compared with the current diet of UK adults

	CURRENT	LIVEWELL 2030	
Product group	**g/day**	**g/day**	
Legumes, nuts and oilseeds	11	123	975%
Fruit and fruit products	92	55	-40%
Beef and veal	18	0	-100%
Pork	7	0	-100%
Lamb	6	0	-100%
Poultry	30	0	-100%
Processed meat	29	0	-100%
Meat replacers	2	78	4244%
Fish wild-caught	19	0	-100%
Fish aquaculture	7	0	-100%
Dairy	179	0	-100%
Cheese	14	0	-100%
Dairy replacers	3	63	1779%
Eggs and egg products	8	0	-100%
Sugar and confectionery	19	4	-80%
Fats and oils	13	43	220%
Fruit and vegetable juices	61	60	-2%
Non-alcoholic beverages	608	565	-7%
Alcoholic beverages	280	216	-23%
Drinking water	725	728	0%
Herbs, spices and condiments	30	0	-100%
Composite food	129	24	-82%
Snacks, desserts, and other foods	17	32	86%
Grains and grain-based products	193	372	93%
Vegetables and vegetable products	146	328	125%
Starchy roots and tubers	90	72	-19%

Figure 7: Pie-charts of the composition of the current diet (NDNS) and the vegan Livewell Plate for 2030
Amounts are in grams/day.

Please note: *Animal protein* includes meat, fish and egg; *Plant protein* includes legumes and meat replacers; *Plant dairy* includes soy drink and soy yoghurt; *Carbohydrate* includes grains and grain-based products, starchy roots and tubers, and sugar and confectionery.



COST OF LIVEWELL PLATES

One of the goals of this research was to investigate the financial implications of adopting the Livewell Plates, which are healthier and more sustainable than current diets. We wanted to establish whether the Plates are as affordable as what people eat today, especially for those on a lower income.

While there were some limitations in the process, we analysed the cost of each Livewell Plate consumed at home only, and compared it to the estimated cost of the current diet (rather than the recommended diet). For each food in the database, we collected prices from mid-range supermarkets and converted these to the cost per 100 grams of consumed product.

As mentioned earlier, underreporting may also have caused an underestimation of the cost of the current diet. This means the results presented below are indicative only. Also, the cost increase is substantially lower than the percentage of underreporting of energy intake, indicating that the actual differences might be much smaller.

In the Livewell Plates for adults, the higher costs are mainly due to higher amounts of fish, grain-based products, dairy and vegetables (Figure 5). The contribution of meat, the most expensive food group in the current diet, is reduced.

The Livewell Plates for adolescents cost more than the current diet. This is also mainly due to considerable increases in healthy products such as fish and vegetables. Again, this might be compensated for by the error in the estimated cost of the current diet created by underreporting.

HISTORICAL TRENDS IN DIETS

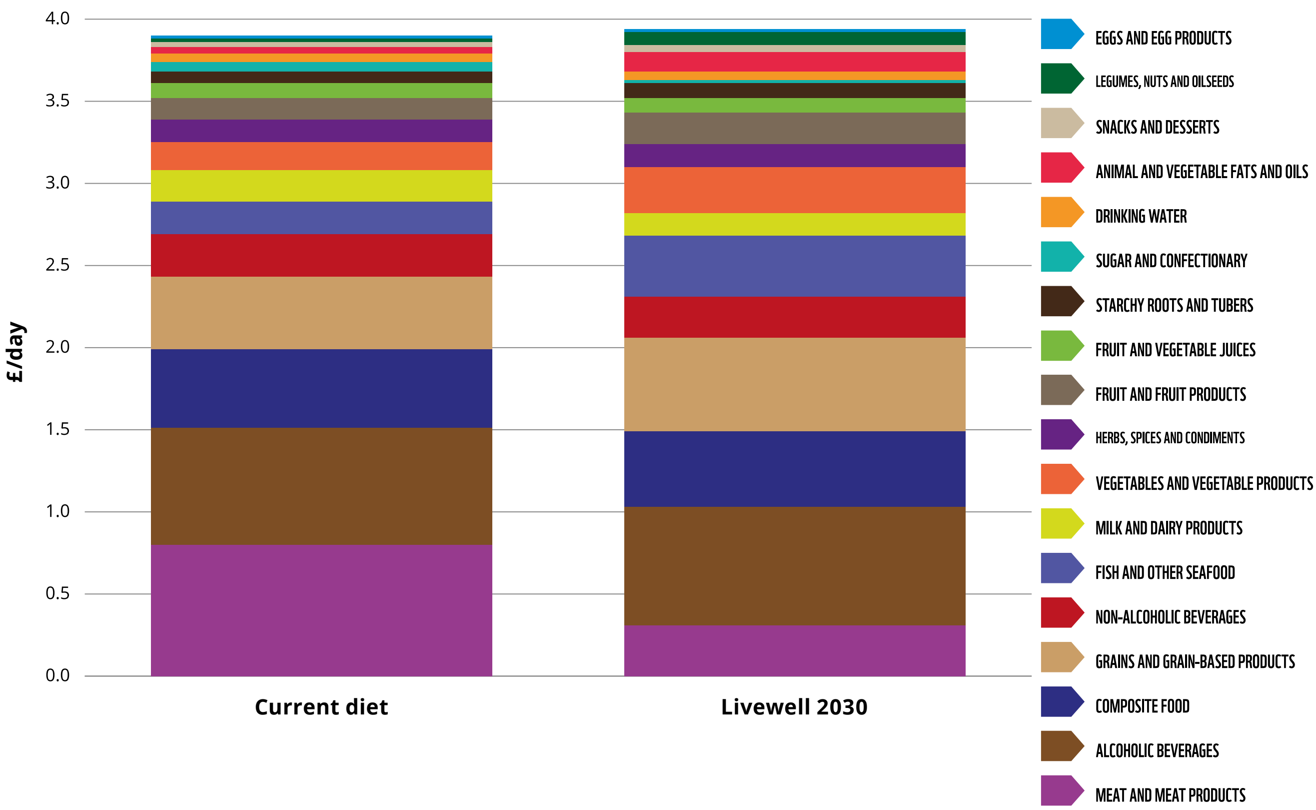
Eating habits change over time, and our current Western diet – characterised by eating large amounts of meat and food high in fat, salt and sugar – has a negative impact on both health and the environment. By analysing historical trends, we wanted to establish whether we could identify positive or negative trends in either respect, and if these corresponded with the changes suggested in Livewell Plates. Another goal was to find out whether past changes in food consumption already contributed to mitigation of GHG emissions.

How diets have evolved and influenced health and the environment is illustrated by an analysis of historical data on the food supply in the UK from 1961 until today.

This analysis was based on Food Balance Sheets (FBS) of the Food and Agricultural Organisation of the United Nations (FAO)[9] from 1961 until 2011. The FBS also provide a detailed annual overview of the food supply in each country. We analysed trends in the supply of calories and the supply of specific food groups related to health outcomes. Based on this analysis we determined if changes in food consumption and food production in the past have contributed to decreasing the impact of the food system.

Trends in the supply of most food groups aren't very distinct in the UK. The amount of vegetables increased from around 160 grams/day in 1961 to around 250 grams/day in 2011. Fruit consumption also increased, mainly due to a higher supply of oranges (from 26g to 104g), apples (from 27g to 75g) and bananas (from 18g to 42g). From a public health perspective, these are positive trends.

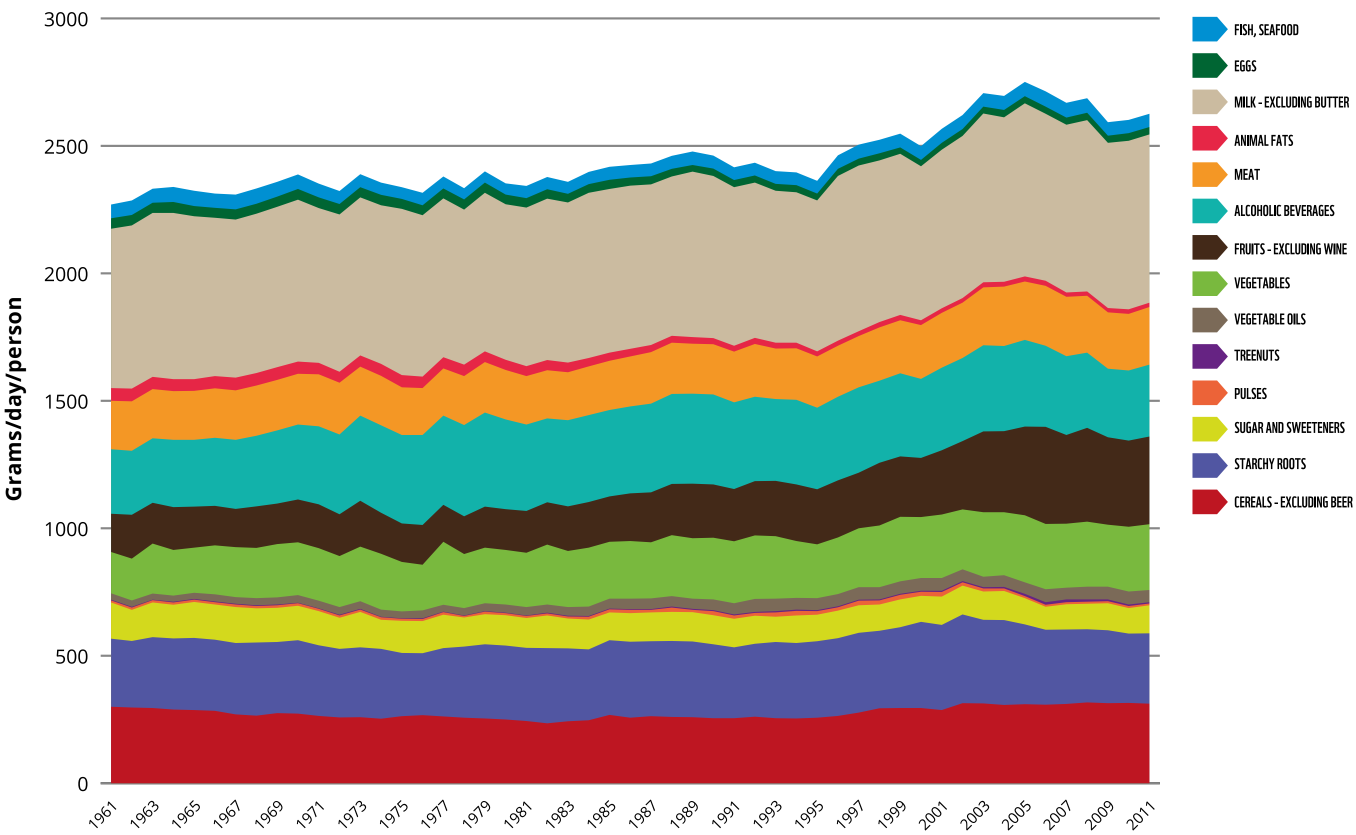
Figure 8: Breakdown of the price of the Livewell Plate for UK adults compared to the current diet



The composition of fat in the UK diet was another area which showed a positive trend, moving from animal fats towards vegetable oils, which are richer in unsaturated fatty acids. Replacing saturated fatty acids with unsaturated fatty acids has a positive effect on blood cholesterol(49) and reduces the risk of heart disease(46). Surprisingly, the supply of sugar seems to have decreased.

The supply of other food groups remained relatively unchanged, although the amount of cereal products initially decreased before later recovering. The trends noted above indicate a positive direction of travel with respect to public health, and correspond with suggestions in the Livewell Plates.

Figure 9: Historical trends in foods available for human consumption in the UK: grams/day



The supply of calories (Figure 10) has increased over the past four decades from around 3,200 kcal/day to 3,400 kcal/day, which is likely to be responsible for a higher incidence of overweight and obesity. For comparison, the Livewell Plates supply between 2,100 and 2,500 kcal/day; with the highest contributions coming from cereals, meat, vegetable oils and milk (including cheese).

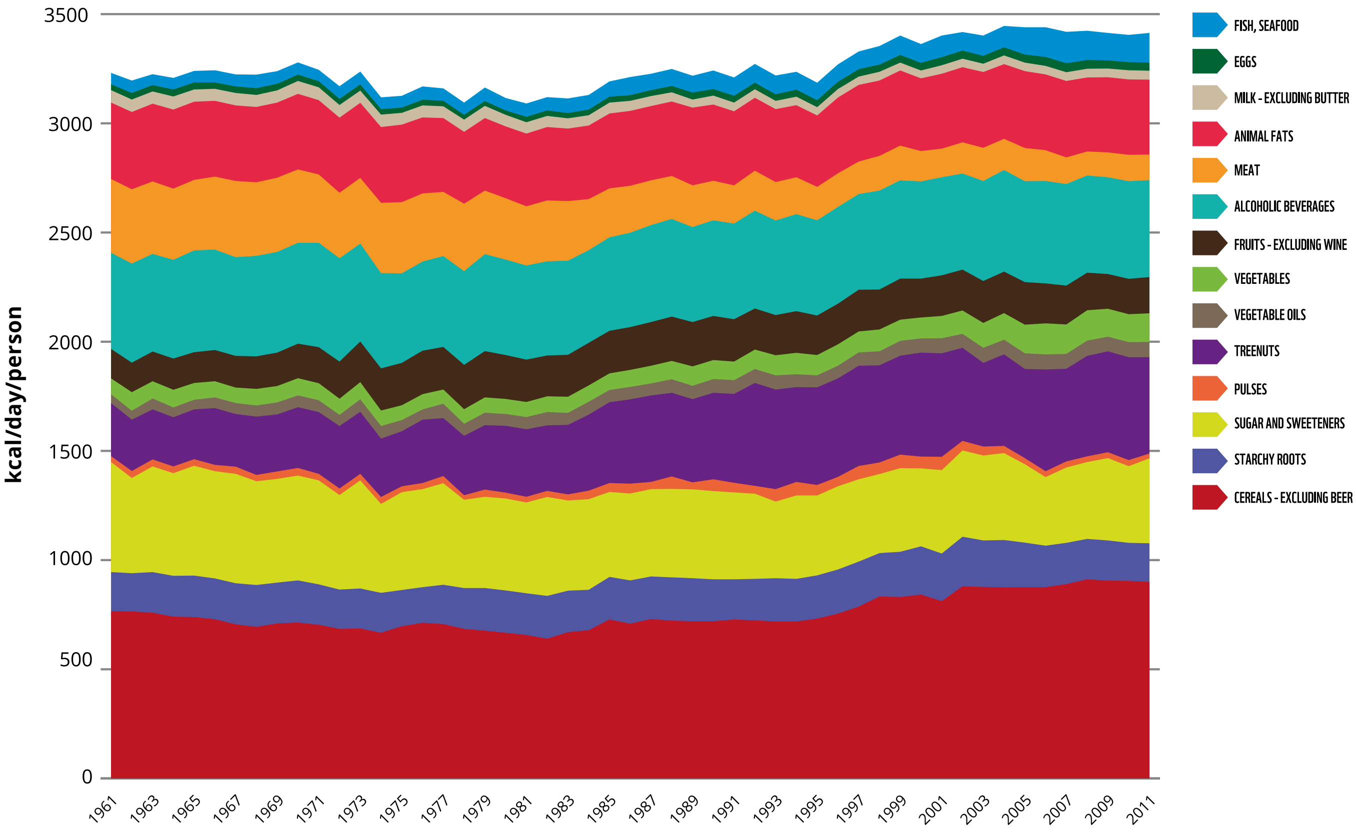
Food supply statistics can only provide a limited picture, but alternative methods also have their limitations. Food consumption surveys tend to underestimate actual energy intake due to underreporting by subjects, a tendency which is most severe in obese subjects[31].

Calories from vegetable oils increased, mainly due to large increases in the supply of soybean oil (from 21 kcal to 107 kcal) and rapeseed oil (from 1 kcal to 205 kcal). At the same time calories from animal fats decreased. This is in line with the trends visible in Figure 9.

The climate change potential of the UK diet, shown in Figure 11, is dominated by *bovine meat* (beef), *mutton and sheep meat* (lamb), and *milk – excluding butter* (dairy and cheese). Figure 11 shows a slight decrease due to positive changes in food consumption. The estimate for the most recent year (2011) was 5.39kg CO_2eq/day/person, close to our estimate for the current diet. Due to the BSE crisis (bovine spongiform encephalopathy commonly known as mad cow disease) the consumption of beef was at a low during the mid-1990s, but later recovered, before declining again after 2007. 1996 marks the first case of variant Creutzfeldt-Jakob disease[51] – a rare and fatal disease related to BSE – while the latter decline is probably due to the financial crisis.

Other ruminant meat, like lamb, also has a high climate change potential due to the emission of methane formed during enteric fermentation. Consumption of lamb has decreased (from 32g to 13g) since 1961, while the consumption of poultry meat

Figure 10: Historical trends in the supply of dietary energy in the UK: kcal/day



(such as chicken) has increased (from 17g to 84g). The lower amount of both meats is the main factor in the overall decrease in carbon footprint seen in Figure 11.

Also visible here is the decrease in the supply of animal fat, mainly butter. Butter has a carbon footprint three to seven times higher than vegetable oil, depending on the type of oil.

From an environmental perspective decreased consumption of beef, lamb and butter is a positive shift. Even without compensating for the improved eco-efficiency of production the graph shows a decreasing trend, from 7.1kg CO_2eq/day per person in 1961 to 5.4kg CO_2eq/day in 2011. Among the factors contributing to improvements in efficiency are increased crop yield per hectare and better feed conversion rates by farm animals. If these are taken into account, the graph shows an even sharper decrease, as illustrated below.

Figure 11: Historical trends in the relative contribution of food groups to the climate change potential of the UK diet: kg CO_2eq/day

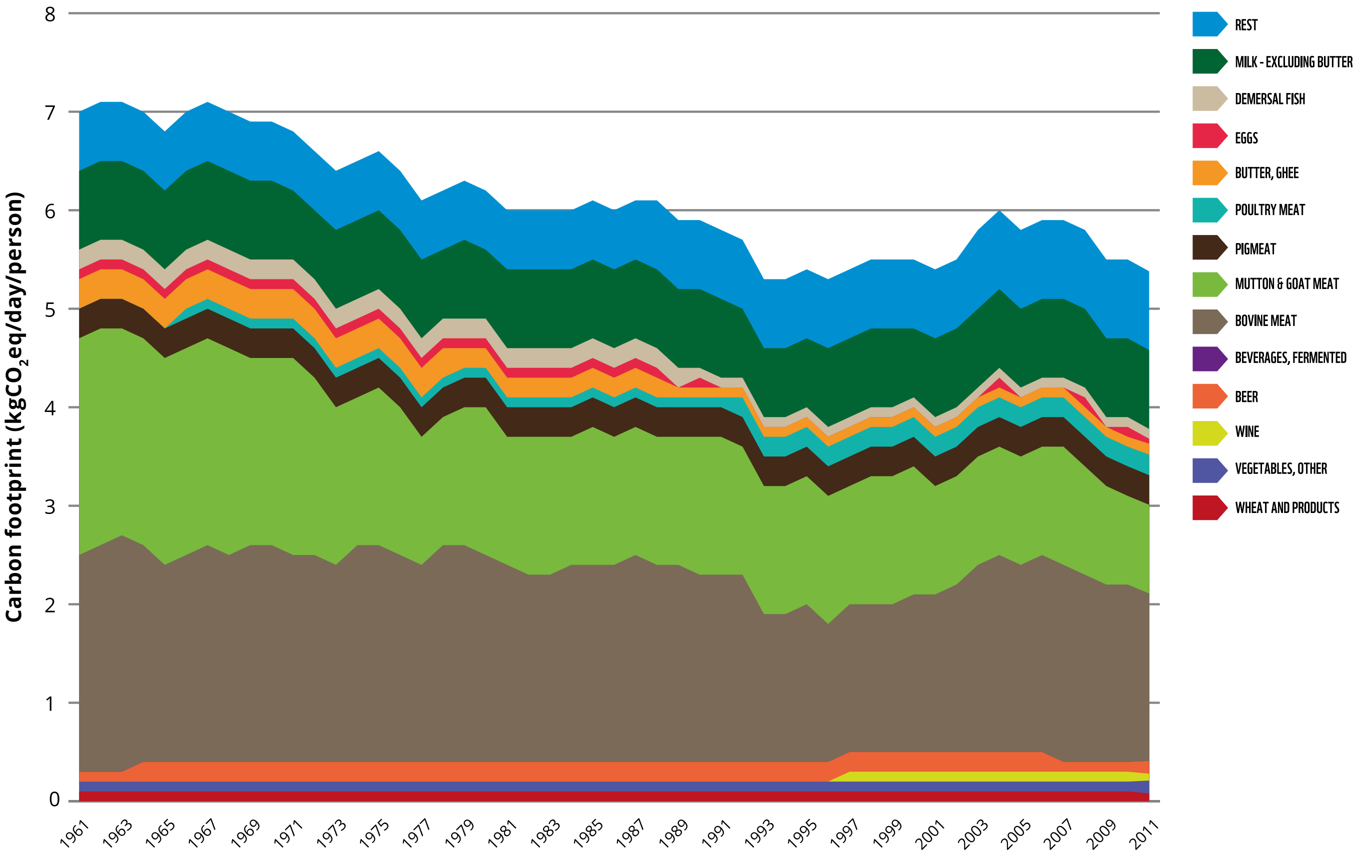
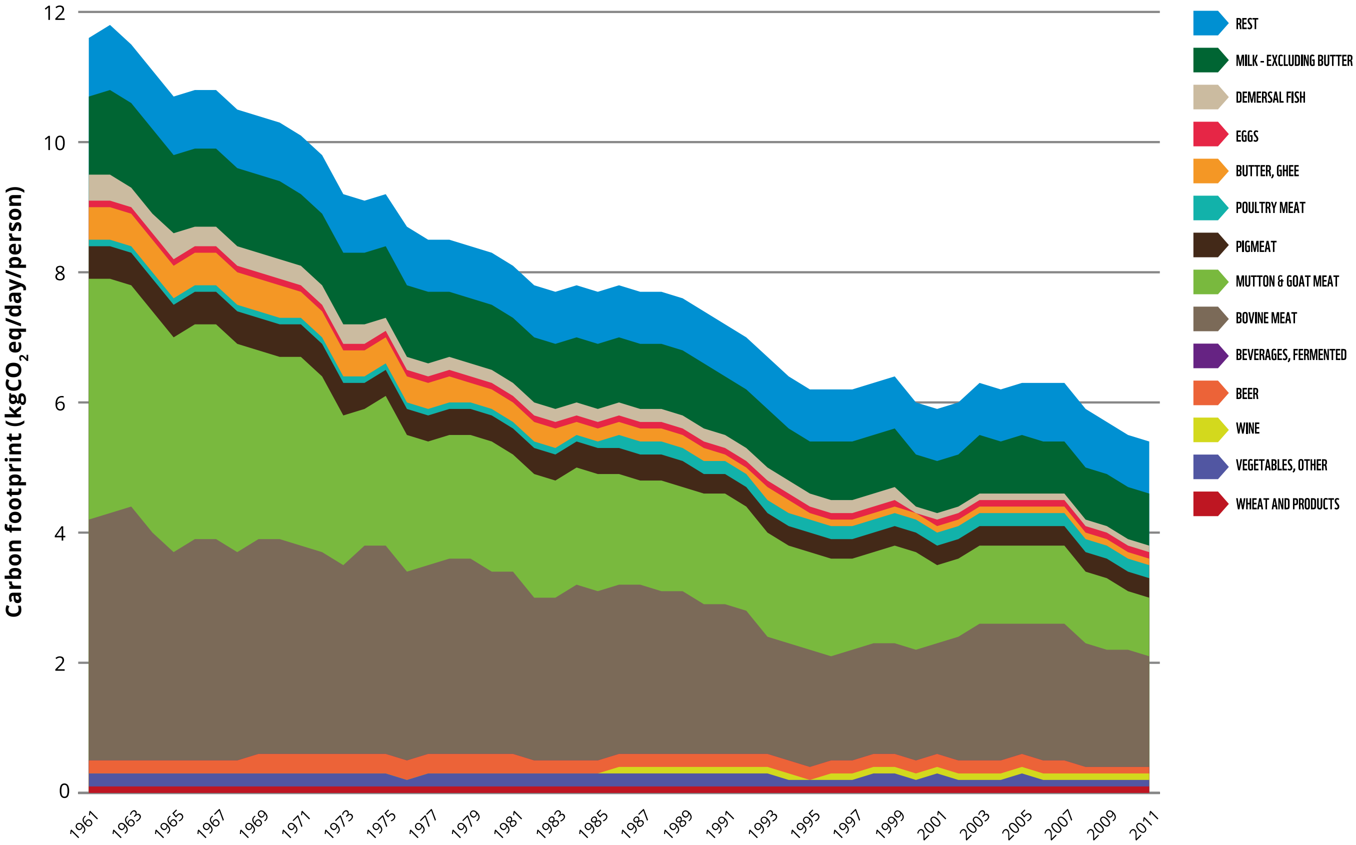


Figure 12 shows what the historical trend in carbon footprint would look like if we assumed a 1% annual increase in efficiency (based on the available studies this is a conservative estimate – see Annex 2 for references). The estimate for 1961 changes to 11.7kg CO_2eq/day.

Whichever set of results we use, it's safe to assume that the carbon footprint of an individual's diet in the UK has been halved over the past five decades, mainly by improvements in food production – although the data suggests that changes in food consumption also played a role.

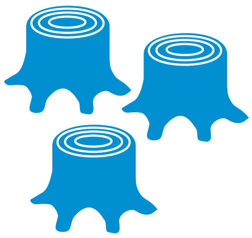
Overall, the results for the UK paint a positive picture when it comes to the environmental impact of our diet. With respect to health, an increase in fruit consumption could be beneficial; however, this should come from whole fruit rather than from juices.

Figure 12: Historical trends in carbon footprint of the UK diet with 1% annual improvement in efficiency



CONCLUSIONS

This report presents new and updated Livewell Plates for the UK. Our main goals were to develop Livewell Plates for a broader part of the population and to include more environmental impacts, such as agricultural land occupation, loss of carbon stocks through deforestation, and freshwater use (blue water footprint). The previous Livewell Plate was for adult women only and focused solely on the diet's carbon footprint. Implicitly the Plate assumed that the mitigation effort required of the food chain had to come exclusively from changes in food consumption, when in fact in this latest report, we assume that shifts in food production can also play an important role in GHG mitigation. This would create more space for a varied diet, with a substantial reduction in the amount of meat and other products with a higher environmental impact.



LIVEWELL PLATES DO NOT PROMOTE FURTHER DEFORESTATION AND OTHER CONVERSION OF NATURAL HABITATS, INCLUDING THAT OF GRASSLAND.

We've shown that it's possible to include targets for GHG emissions in the Livewell Plates, drawing on national carbon reduction commitments and a mitigation effort shared equally between the consumption and production sections of the food sector. Whether this 50/50 share is the most realistic and attainable option, however, is open to debate. It's worth emphasising again that the UK's 60% reduction figure can also be debated, as it's an illustrative rather than prescriptive target. In any case, the UK government should request advice from the Committee on Climate Change on setting a goal to reduce emissions from the food system, including overseas emissions resulting from UK consumption.

With respect to the main research questions, we can conclude the following:

LIVEWELL PLATES RESPECT GLOBAL BOUNDARIES

- The Livewell Plates developed in this study respect the UK's national carbon budget and assume that the food system contributes at the level of the economy-wide average. Targets for the carbon footprint of 2030 Livewell Plates were 4.09 CO_2eq/day, and 4.77 CO_2eq/day for 2020.
- Current adult diets in the UK have an estimated carbon footprint of 5.17kg CO_2eq/day, well above the world average of 3.45kg CO_2eq/day. When GHG emissions due to land-use change are included, our estimates for current diets are even higher at 5.8kg CO_2eq/day. This accounts for losses of carbon stocks due to deforestation over the past 20 years.
- Livewell Plates do not promote further deforestation and other conversion of natural habitats, including that of grassland. By allocating a fair share of all currently occupied agricultural land to each world citizen living in 2020 and 2030 and allowing no further increase, we defined limits for total land occupation, grassland use and cropland use.
- The land occupation of all Livewell Plates was well within this equal share, implying that the carbon footprint target is their most significant environmental constraint.
- The most effective mitigation options are to lower amounts of beef and lamb in the diet: both have a high carbon footprint due to the methane emitted during the animals' enteric fermentation of feed. However, in order to allow beef and lamb to remain on the Plate all other meat groups are also reduced.

  In addition to health benefits, a reduction in the current over-consumption of discretionary food will also have a positive mitigation effect. Other options are far less effective.
- Because they reduce the amount of beef and lamb, Livewell Plates require less grassland. Albeit not straightforward, the areas of grassland freed up, mainly in Europe, could be converted back to natural habitats. Though semi-natural grasslands have nature conservation value, natural habitats have a higher capacity for carbon storage (carbon sequestration) than grassland.
- Some Livewell Plates have an increased requirement for cropland in comparison to the current diet. The required amount is still below the global equal share. Some of the grassland freed up in Europe could be converted to cropland. Any change will result in some soil carbon losses.

IN GENERAL LIVEWELL PLATES CONTAIN MORE PLANT-BASED FOODS, IN PARTICULAR THOSE WITH A HIGH NUTRITIONAL QUALITY SUCH AS VEGETABLES, WHOLEGRAIN CEREAL PRODUCTS, NUTS, LEGUMES AND VEGETABLE OILS.

- Due to poor data quality we were unable to draw conclusions on freshwater use (blue water footprint) for Livewell Plates. This indicator is dominated by only a few products, such as olive oil.
- In general Livewell Plates contain more plant-based foods, in particular those with a high nutritional quality such as vegetables, wholegrain cereal products, nuts, legumes and vegetable oils. This confirms the conclusions of earlier Livewell projects. Most of these trends are linked to nutrient requirements and food-based dietary requirements.
- In contrast to earlier Livewell Plates, the new versions presented in this report include beverages. In general, in order to meet the requirement of a acceptable diet, these aren't reduced significantly.
- Livewell Plates for adolescents and the elderly differ slightly from the adult plates due to differences in current dietary patterns and dietary requirements. Estimates of the impact of the current adolescent diet in the UK (NDNS) are uncertain due to underreporting of food and energy intake in both surveys.
- The vegan Livewell Plate has a carbon footprint far below the limit. It also saves large areas of grassland, mainly in Europe. With respect to cropland conclusions are uncertain. Potential increases in area can be offset by conversion of a small part of the freed up grassland. This is an interesting topic for future research.

LIVEWELL PLATE VERSUS EATWELL GUIDE

- We were unable to reproduce results to back up the claim that eating according to the Eatwell Guide reduces the carbon footprint by 30%. The size of the segments of the Eatwell Guide and the Livewell Plate differ slightly, mainly in the amount of dairy and alternatives. There could be several explanations, but due to a lack of information about the methodology applied in defining the Eatwell Guide we weren't able to investigate them.

AFFORDABILITY OF LIVEWELL PLATES

- Due to the limited scope of our survey of supermarket prices and underreporting of food intake in dietary surveys, we have to be careful in comparing the cost of the current diet with the cost of Livewell Plates. Drawing conclusions on the affordability of Livewell Plates for people on lower incomes is particularly difficult. However, apparent increases in cost are generally lower than the error created by underreporting.

HISTORICAL TRENDS IN FOOD CONSUMPTION SINCE THE 1960S

- As part of this study we analysed historical trends in food consumption in the UK. These were based on FAO's FBS. With respect to health outcomes the conclusions are mixed. The increased availability of calories, for instance, is very likely to be associated with the increased incidence of obesity and overweight in the UK since the early 1960s. Positive trends included an increase in vegetable consumption. Trends are visible in the Livewell Plates presented in this report.
- By linking current generic carbon footprint data to each product in the FBS we were able to show how trends in food consumption affected the carbon footprint of the whole diet. Beef, lamb and dairy (including cheese) had the largest contributions. The estimates for the most recent year (2011) were 5.39kg CO_2eq/day/person. Given the uncertainty in data, this is not too far off the values we estimated for the current diets.
- Changes in food consumption over the past five decades didn't result in significant changes in the environmental impact of the diet. Our results suggest the composition of the UK diet showed improvement, however, this doesn't take into account improved production efficiency.
- When we corrected for improvements in production efficiency, we found a decrease in carbon footprint of at least 40-50% per individual. Over the past decades, the amount of GHG emitted per unit of product has decreased dramatically, proving that food production has played an important part in the overall mitigation effort and will continue to do so. Consumption seems to lag behind.

ANNEX 1 DEFINITION OF LIVEWELL GHG TARGET

TARGET FOR GHG EMISSIONS

The Committee on Climate Change has advised the government to reduce territorial emissions by 61% from 1990 levels by 2030. For this report we've rounded this down to 60%. Audsley et al[16] estimated that direct GHG emissions from the UK food system made up 19.6% of this total: 152.183 $MtCO_2e$ or 7.28kg CO_2e per UK citizen (Table 21). This means the budget for direct emissions from the food system in 2030 is 60.87 $MtCO_2e$.

It's unrealistic to assume that all of this must be achieved by changes in food consumption (diet). Food production must also contribute, for instance by reducing waste, increasing farm efficiency and using sustainable energy sources. We recommend dividing the 60% reduction equally (50/50): 30% from changes in consumption and 30% from changes in production. For the former, the corrected budget for food consumption in 2030 is 106.5 $MtCO_2e$ and the intermediate budget for 2020 is 117.9 $MtCO_2e$. When dividing this budget between all UK citizens, projected population growth has to be taken into account, increasing the challenge per individual to a 44% reduction compared to the 1990 level (Table 12).

LAND OCCUPATION

The baseline assumption in this project is that Livewell Plates do not increase global agricultural land occupation, nor promote a shift towards more cropland. When taking population growth into account, this means there will in fact be a reduction of the share of each type of agricultural land available for each world citizen, and this was reflected in our calculations (Table 13).

Table 12: Livewell GHG emissions budget for the diet of UK individuals in 2020 and 2030

YEAR	UK POPULATION A	BUDGET UK FOOD CONSUMPTION	INDIVIDUAL BUDGET
1990	57.2 million	152.2 $MtCO_2e$ (100%)[b]	7.28kg CO_2e/day (100%)
2020	67.8 million	117.9 (-23%)	4.77kg CO_2e/day (-35%)
2030	71.8 million	106.5 (-30%)	4.09kg CO_2e/day (-44%)

Sources: a) ONS[56] b) Audsley 2009[16]

Table 13: Data used to define the global boundaries for land occupation

		2010	2020	2030
World population	(bn)	6.92	7.70	8.42
Available				
Grass/pasture	(Gha)	3.40	3.40	3.40
Crop	(Gha)	1.40	1.40	1.40
Permanent crops	(Gha)	0.16	0.16	0.16
Agricultural land use	(Gha)	4.96	4.96	4.96
Fair share				
Grass/pasture	(m^2/p/d)	13.5	12.1	11.1
Crop	(m^2/p/d)	5.6	5.0	4.6
Permanent crops	(m^2/p/d)	0.6	0.6	0.5
Agricultural land use	(m^2/p/d)	19.7	17.7	16.1

Sources: FAOSTAT 2010, FAO 2011

ANNEX 2: DATA SOURCES – HEALTH AND NUTRITION

CURRENT DIETS

We applied dietary survey data that was compiled by EFSA[28] in the EFSA Comprehensive Food Consumption Database (ECFCD) from the NDNS Rolling Programme Years 1-3 (UK). This dataset contains four levels of detail, L1 to L4, with L1 being the most aggregated level (20 groups). Foods are coded in a standard way, through FoodEx. We used L3, in which 752 food products were recorded. The age groups were adults (aged 18-64), adolescents (aged 10-17) and the elderly (aged 65-85).

Due to restrictions in the number of foods on which LCAs could be performed, we had to prioritise some to decrease the work load. From each group we selected the most frequently consumed foods. Together, these covered 89% of the mass consumed in average adult diets in both countries. To make up for the foods omitted, the selected foods are multiplied by 1005/89%. The L1-groups *products for special nutritional use* and *food for infants and small children* weren't considered relevant and were therefore omitted, which caused a maximal error of 1.3% (UK adolescents).

Table 14: Composition of current diets as reported by EFSA

	ADOLESCENTS	ADULTS	ELDERLY
FoodEx L1	**g/day**	**g/day**	**g/day**
Grains and grain-based products	198	193	193
Vegetables and vegetable products	68	128	157
Starchy roots and tubers	90	90	100
Legumes, nuts and oilseeds	25	31	30
Fruit and fruit products	62	92	129
Meat and meat products	77	92	81
Fish and other seafood	14	26	38
Milk and dairy products	192	196	248
Eggs and egg products	5	8	11
Sugar and confectionery	24	19	14
Animal and vegetable fats and oils	11	13	17
Fruit and vegetable juices	98	61	46
Non-alcoholic beverages	350	608	649
Alcoholic beverages	16	280	187
Drinking water	475	725	611
Herbs, spices and condiments	27	30	24
Food for infants and small children	0	0	0
Products for special nutritional use	*24*	*9*	*3*
Composite food (including frozen products)	126	129	106
Snacks, desserts, and other foods	33	17	16
Total Included	**1914**	**2748**	**2657**
Original	**1890**	**2738**	**2654**
Error	1.3%	0.3%	0.1%

To prevent unrealistic increases in certain foods, we set a limit on the maximum amount in the Livewell diets of the mean plus five times the standard deviation[28]; except for vegan diets, where more fortified soy products were needed to meet certain nutrient requirements.

There might be slight differences with current diets reported in earlier Livewell reports, for three reasons:

1 This study used more detailed consumption data (more products, more product groups). Also the original data was processed to fit in the uniform data format of EFSA, which meant that parts of the mixed dishes were separated into their components;

2 Products were categorised in different ways (FoodEx versus EPIC); and

3 This study presents an average for adults, whereas the previous Livewell projects focused on women only.

NUTRIENT REQUIREMENTS

The Livewell Plates we developed are for an average person, either an adult, an elderly person or an adolescent. Nutrient requirements were averaged for both genders.

We took the requirements for energy, protein and micronutrients from a compilation published by the British Nutrition Foundation[64]. The bodyweights needed to calculate the protein requirement were from the Health Survey for England[65]. For total fat, mono- and poly-unsaturated fatty acids, omega-3 and omega-6 we used limits set by the Committee on Medical Aspects of Food and Nutrition Policy (COMA)[66].

The model implements SACN advice that added sugars[42] should make up a maximum of 5% of dietary energy. The SACN also recommend that carbohydrate intake should be at the current level of approximately 50% of total dietary energy. As a lower limit we adopted the 47% limit set by COMA[66]. Requirements for protein and fat will naturally limit the upper level.

Table 15: Nutrient and other dietary requirements applicable in the UK

		ADULTS		ADOLESCENTS		ELDERLY		VEGANS	
		Lower	**Upper**	**Lower**	**Upper**	**Lower**	**Upper**	**Lower**	**Upper**
Energy	kcal	2388	2389	2492	2493	2096	2097	2388	2389
Protein total	0.75g/kg bw/day	59		44		57		59	
Fat total	≥33en%	88		91		77		88	
SAFA	≤10en%	0	27	0	28	0	23	0	27
Monounsaturated fatty acids	≥12en%	32		33		28		32	
Polyunsaturated fatty acids	≥6en%	16		17		14		16	
Fatty acids n-3	≥0.2en%	0.5		0.6		0.5		0.5	
Fatty acids n-6	≥1en%	2.7		2.8		2.3		2.7	
Carbohydrates	≥47en%	281		293		246		281	
Added sugar	≤5en%	0.0	29.9	0.0	31.2	0.0	26.2	0.0	29.9
Fibre	g	30		25		30		30	
Retinol eq.	µg	650	3000	625	2300	650	3000	650	3000
Vitamin B1	mg	0.9		0.9		0.9		0.9	
Vitamin B2	mg	1.2		1.2		1.2		1.2	
Niacin	mg	15		15		14		15	
Vitamin B6	mg	1.3		1.2		1.3		1.3	

Folate eq.	µg	200	1000	200	700	200	1000	241	1000
Vitamin B12	µg	1.5		1.4		1.5		1.5	
Vitamin C	mg	40		38		40		40	
Vitamin D	µg	0	100	0	100	0	100	0	100
Calcium	mg	700	2500	900		700	2500	700	2500
Phosphorus	mg	550	3000	700		550	3000	550	3000
Iron	mg	11.1	25.0	13.1		8.7	25.0	11.1	25.0
Sodium	mg	1600	2400	1600	2400	1600	2400	1600	2400
Potassium	mg	3500		3300		3500		3500	
Magnesium	mg	285		290		285		285	
Zinc	mg	8.3	25.0	8.6	20.0	8.3	25.0	12.4	25.0
Selenium	µg	68	300	55	225	68	300	68	300
Copper	mg	1.2	5.0	0.9	4.0	1.2	5.0	1.2	5.0
Iodine	µg	140	600	135	475	140	600	0	
Juice	g	0	150	0	150	0	150	0	150
Fruit and vegetables	servings	5		5		5		5	
Water, coffee, tea	g	900		900		900		900	
Fish	g	40		40		40		0	0
Oily fish	g	20	80	20	80	20	80	0	0
Red and processed meat	g	0	70	0	70	0	70	0	0
Alcoholic beverages	servings	0	2	0	0	0	2	0	2

The requirement for iodine meant that Optimeal was initially unable to create a solution for vegans, so we had to disable it.

FOOD-BASED DIETARY GUIDELINES

The recently-updated UK food-based dietary guidelines are summarised in the Eatwell Guide[6]. The accompanying documentation mentions a few quantitative recommendations, which we implemented in the model.

For all fruit and vegetables we applied a generic portion size of 80g, except for fruit juice where we used 150ml. The upper limit for alcoholic beverages is expressed in units, where the amount of units per beverage depends on alcohol percentage and the size of the glass[69]. These were converted to units per 100g of consumed product. One unit is equivalent to 8g of alcohol. The limit is the same for men and women. For adolescents we restricted the number of alcohol units to 0.

Table 16: Implemented Eatwell Guide food-based dietary guidelines

FOOD GROUP	LIMIT	QUANTITY
Smoothies and fruit juice	max	150 ml/d
Water, lower fat milk, sugar free drinks, coffee, tea	min	6 x 150 ml/d
Fruit, vegetables, smoothies and fruit juice	min	5 portions/d
Fish	min	2 portions of 140g/w
Oily fish	min	1 portion of 140g/w
Red and processed meat	max	70 g/d
Alcoholic beverages	max	14 units/w

FOOD COMPOSITION

We use McCance & Widdowson's[27] food composition data. Items from the survey were matched with similar products on the tables. Because McCance & Widdowson's lacked data on chicken liver and water (tap, still mineral water and sparkling mineral water) these were adopted from the French Ciqual[26]. For the UK *added sugar* was included as an extra property. This included all sugars except those in fresh fruit, vegetables and dairy.

COSTS

The costs presented in this report are based on prices from Tesco as an example of a mid-range supermarket in the UK. We didn't undertake a sensitivity analysis but matched each product in our dataset with a typical representative product from the online range. Due to high variability, selection was tricky: the results are no more than indicative, and should be treated with caution. We attempted to select items with an average price (per kg or litre), which we then converted to prices per 100g of consumed product, with corrections for edible parts and 'raw to cooked ratio'.

HISTORICAL TRENDS

Typically food consumption surveys are held too infrequently to enable analysis of the trends they reveal, so researchers often rely on statistics collected by national statistics offices and FAO. Statistics on food supply were based on FAO's Food Balance Sheets[9] and generic environmental data from Optimeal and the Agri-Footprint life cycle inventory database[70].

Food Balance Sheets report the per capita supply of food items available for human consumption. Data on per capita food supply are expressed either in grams or dietary energy value (kcal).

Food supply is not the same as actual consumption. Typically, food supply statistics overestimate actual consumption (they don't correct for food waste and other losses), while consumption surveys tend to underestimate energy intake (underreporting).

Amounts of typical food groups give an indication of the healthiness of a diet. For example, increased consumption of fruit, vegetables and fish is considered a positive sign, whereas increased consumption of animal fats, alcoholic beverages and sugar can be correlated to a higher incidence of non-communicable diseases, such as coronary heart disease (CHD) and diabetes. Another indicator that can be derived from the Food Balance Sheets is the total amount of dietary energy (calories) and sources of energy. A larger supply of dietary energy increases the incidence of overweight and obesity.

A diet's GHG emissions have to be regarded with caution, because underlying trends in the evolution of the impact per unit of produce aren't taken into account. Present day impacts could easily be 50% lower than in the 1960s due to improvements in efficiency along the whole food chain, including increased crop yield per hectare, better storage and better feed conversion rates by farm animals. We're not aware of studies on this subject with respect to food systems in the UK. We've relied instead on the Dutch food system as a model, to illustrate the potential of improved efficiency: for Dutch dairy we found a 31% reduction in carbon footprint between 1990 and 2012[71], for Dutch pork 26%[72] and for Dutch poultry 40%[73]. Even conservative estimates expect these trends will continue in the future[74].

ANNEX 3: LCA METHODOLOGY AND DATA

In this annex we describe the methodology and data sources for the LCA applied in this study. All foods were linked to either generic or country-specific life cycle inventories, including the impacts desired by WWF – climate change, climate change due to land-use change, land occupation (cropland, pasture) and blue water footprint.

SCOPE

This section examines the products for which life cycle inventories have been developed, as well as the functional unit, system boundaries, methods, allocation, intended use, limitations and critical review employed. The products analysed are listed in Table 17.

Table 17: List of food products for which life cycle inventories have been developed

FOOD PRODUCT
Apple (Malus domesticus)
Bananas (Musa × paradisica)
Beans (Phaseolus vulgaris)
Beans, green, without pods (Phaseolus vulgaris)
Beans, with pods (Phaseolus vulgaris)
Beef liver
Beef meat (Bos spp.)
Beer and beer-like beverage
Beer, regular
Beetroot (Beta vulgaris subsp. vulgaris)
Biscuits (cookies)
Black tea, infusion
Broccoli (Brassica oleracea var. italica)
Butter
Carrots (Daucus carota)
Cauliflower (Brassica oleracea var. botrytis)
Cereal flakes
Cheese, Camembert
Chicken liver
Chicken meat (Gallus domesticus)
Cider
Cod and whiting (Gadus spp.)
Coffee drink, café américano
Cola beverages, caffeinic, low calorie
Cola beverages, caffeinic
Courgettes (Zucchini) (Cucurbita pepo var. melopep)
Cow milk

Cream
Cucumbers (Cucumis sativus)
Cultivated mushroom (syn. Button mushroom) (Agaric)
Custard
French fries
Head cabbage (Brassica oleracea convar. capitata)
Herring (Clupea)
Ice cream, milk-based
Juice concentrate, Oranges
Juice, Orange
Leek (Allium porrum)
Lentils (Lens culinaris syn. L. esculenta)
Lettuce, excluding Iceberg-type lettuce (Lactuca s.)
Mackerel (Scomber)
Mandarins (Citrus reticulata)
Margarine, normal fat
Mayonnaise < 25% oil
Mayonnaise > 50% oil
Meat imitates
Milk chocolate
Mutton / lamb liver
Mutton / lamb meat (Ovis aries)
Oats, grain
Olive oil
Onions, bulb (Allium cepa)
Oranges (Citrus sinensis)
Pasta (Raw)
Pastries and cakes
Peanut (Arachis hypogea)
Pear (Pyrus communis)
Peas, green, without pods (Pisum sativum)
Peppers, paprika (Capsicum annuum, var. grossum an)
Pork / piglet meat (Sus scrofa)
Pork liver
Potato baked
Potato boiled
Potato crisps
Quark
Quorn (mycoprotein)
Rapeseed oil
Rice
Salad dressing 25 - 50% oil
Salmon and trout (Salmo spp.)
Shrimps (Crangon crangon)
Soya drink
Soya yoghurt
Soybeans

Still mineral water
Sunflower oil
Table grapes (Vitis euvitis)
Tap water
Tea (Infusion)
Tomato ketchup
Tomatoes (Lycopersicum esculentum)
Tuna (Thunnus)
Turkey meat (Meleagris gallopavo)
Unleavened bread, crisp bread and rusk
Veal meat
Walnuts (Juglans regia)
Wheat bread and rolls
Wheat
White sugar
Whole egg, chicken
Wine
Yoghurt, cow milk, plain

FUNCTIONAL UNIT

The functional unit of the life cycle inventories is 1kg of food product.

SYSTEM BOUNDARIES

The system boundaries of the life cycle inventories with examples from the Netherlands are presented in Figure 13 and Figure 14.

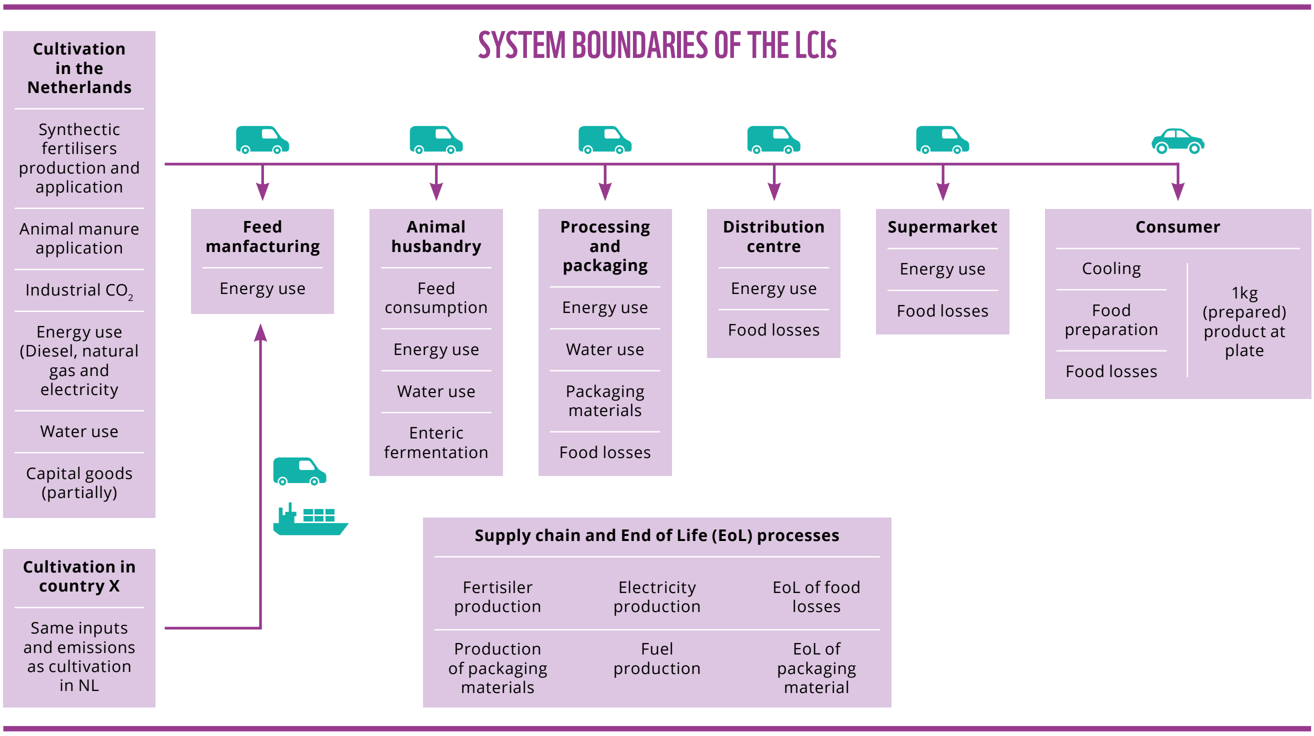


Figure 13: System boundaries of life cycle inventories of dairy- and animal products

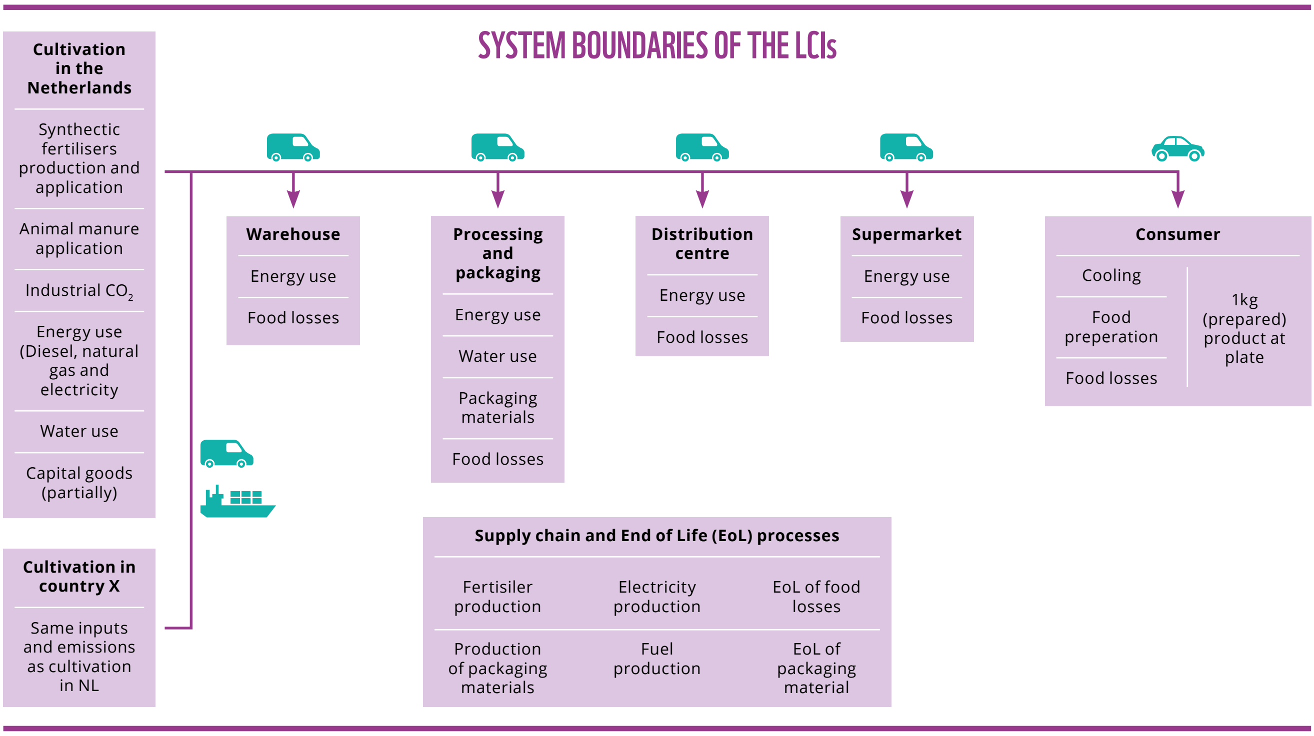


Figure 14: System boundaries of life cycle inventories of fruits, vegetables and other products

The following processes are outside the scope of the life cycle inventories:

- Pesticide production and use is excluded. Data for Dutch cultivations is available in KWIN (75–77) but its quality and completeness is uncertain. Ideally pesticide use would be included. Pesticide production makes only a minor contribution to total environmental impact, but the use of the pesticides is one of the main contributors to toxicity impacts;
- Seed production;
- Disinfectants (such as sodium hypochlorite) in the processing phase;
- Refrigerant use and losses; and
- Secondary and tertiary packaging materials.

The life cycle inventories are based on an attributional approach. This means that the results give an impression of the environmental impact of a product in the current situation.

INCLUDED IMPACTS

GHG emissions

Calculation of direct GHG emissions was straightforward[78].

GHG emissions by land-use change

Deforestation is one of the major issues facing the global agriculture production system, with as much 8% of global CO_2 emissions being attributable to land-use change. A well-known example is the clearing of forest for the cultivation of crops such as soybean and palm oil. Many publications have rightly focused on this issue and have provided solid global or country-specific estimates of CO_2 emissions due to land-use change based on statistics and/or satellite imagery. To address this challenge we developed the Direct Land-use Change Assessment Tool[79]. The tool provides a predefined way of calculating GHG emissions resulting from land-use change, based on the most up-to-date data from FAOSTAT covering a large set of crops from various countries.

LAND OCCUPATION

Apart from total agricultural land occupation, we specified two types of land occupation: grassland/pasture and cropland/arable land.

Impact on freshwater use

After a discussion with WWF's expert on water scarcity, we decided to only report on blue water footprint, an indicator on inventory level, which is the total of all water consumed for irrigation. Together we concluded that impact assessment methods for water scarcity published so far had serious limitations, especially when applied to a whole diet.

Therefore, our aim was simply to quantify the amount of irrigation water used for the whole diet, without drawing further conclusions on the implications for water scarcity.

COMPLIANCE TO LIFE CYCLE IMPACT ASSESSMENT METHODOLOGIES

The elementary flows in the life cycle inventories are compliant with ReCiPe [80] and ILCD[81] [82].

We used economic allocation for allocating the environmental impact to specific co-products. Currently the allocation rules in animal husbandry are the subject of debate in the European Commission, regarding the development of the product environmental footprint (PEF). The conclusion to this debate may have an impact on the allocation rules applied for future analyses and the environmental impact of products.

INTENDED USE

The life cycle inventories can be used for the purpose described in the introduction, but they're not suitable for comparative assertions to be disclosed to the public. Before using these life cycle inventories for other LCA studies the data quality should be considered and the data should be updated accordingly, as during this project we found that the data quality varies between food products.

LIMITATIONS

Crop rotation

Crop rotation is not integrated in the life cycle inventories. The impact of this omission is assumed to be minor because the main aspect of crop rotation – in other words the use of animal manure and its positive effects on soil fertility – is included by the animal manure application method[83].

Surface albedo change

Not only do GHG emissions contribute to changes in the Earth's energy budget, but a change in surface albedo caused by land-use change can also contribute. In some cases replacing pasture land on uplands with trees will lead to carbon reductions, though the amount will depend on the local climate. A case study[84] has shown that the change in surface albedo could offset a major part of the GHG emissions. This change in surface albedo is not taken into account in this study because it is not usually included in agricultural LCAs.

Regionalisation

Characterisation factors of impact categories with a local impact such as eutrophication and acidification are not regionalised in the impact assessment. This should not be part of a life cycle inventory, but has to be integrated in the characterisation factors of the LCA instead.

Data variation

Including data variation was not possible due to a lack of data.

Transport from supermarket to the consumer home

The transport of the food products from the supermarket to the consumer's home has not been included. Consumer transport can be a hotspot, but it also varies a great deal. In addition, it is not product-specific: the product does not determine the way in which the consumer decides to go shopping.

LIFE CYCLE INVENTORY

Our starting points have been the Agri-footprint (APF) database, Agribalyse[23] and the life cycle inventories which we have developed for the Dutch National Institute for Public Health and the Environment. These life cycle inventories have been adapted at specific points for the UK. Points of adaptation are for instance the countries of origin for cultivation, transport distances and energy sources for the production of heat and electricity. We determined relevant origins by making balances of data from FAOSTAT[85] on import, export and production.

Agri-footprint

Some of the food products were already modelled in the AFP[86,87]. No new data have been collected for these ingredients. The life cycle inventories of these ingredients have been reported in the reports mentioned. The reports can be found at www.agri-footprint.com.

Life cycle inventory databases developed for the Dutch National Institute for Public Health and the Environment

Some ingredients were previously modelled in the life cycle inventory database developed for the Dutch National Institute for Public Health and the Environment[88–91]. No new data have been collected for these ingredients. The life cycle inventories of these ingredients have been reported in the reports mentioned.

Other food products

Some of the other food products have also been covered in earlier projects[92–96].

The recipes of some products – like cereal flakes, pastries and cakes, biscuits, pasta, bread, meat imitates, tomato ketchup, mayonnaise, salad dressing and margarine – have been approximated based on food labels of an average product in the specific category. The ingredients of these food products were mostly modelled before in earlier projects.

For some products earlier studies were not available, and it was not feasible to search for data within this project. The life cycle inventories of these products are based on the life cycle inventories of other food products, which are used as proxies. This is the case for:

- Beef liver – based on beef meat;
- Cider – based on beer;
- Turkey meat – based on chicken meat;
- Cola beverages, caffeinated, low calorie – based on cola;
- Lamb liver – based on lamb meat;
- Juice concentrate – based on orange juice;
- Pork liver – based on pork;
- Potato baked – based on potatoes;
- Quorn – based on meat imitates;
- Soya yoghurt – based on soy drink;
- Black tea, infusion – based on tea;
- Unleavened bread, crisp bread and cracker-bread – based on wholemeal bread; and
- French fries – based on potato chips.

Distribution centre

An electricity use of 90kWh/ton is attributed to products that are stored as frozen products, alongside 50kWh/ton for cooled products. In addition, an electricity use of 40kWh/ton is assumed for lighting [97]. As mentioned earlier, emissions of refrigerants are not included.

Supermarket

An electricity use of 50kWh/ton is assumed for all frozen products, as well as 30kWh/ton for all cooled products. In addition, lighting electricity is assumed at 36kWh/ton. Finally, for heating we assumed an energy use of 284.4MJ/ton[98].

Consumer phase

It's important to note that the 'at consumer' phase consists of four consecutive phases, leading to a functional unit of 1kg on the plate. In the first phase, the products are transported from the supermarket to the consumer. Second, products are stored either on a shelf, in a fridge or in a freezer. Third, some products are cut, which results in cutting losses. Fourth, products are cooked. The order of these process steps is quite important since high cutting losses will influence both the impact transport and the storage for 1kg on the plate. A different order would lead to different results, because losses will occur earlier or later, changing the mass balance of the processes.

The cutting losses are assumed to be zero for all dairy and meat products.[vi] For eggs, we assumed that the shell accounts for approximately 8% of the total weight.

Electricity-use for fridge/freezer is calculated with a model we created for Milieu Centraal[99], applying the following three assumptions:

- A-label fridge/freezer;
- 50% is used directly; and
- The other 50% is stored for 18 days in a freezer or five days in a fridge.

For preparation at home, we assumed that 40% of consumers used electricity and 60% natural gas. We applied the following formula for boiling:

E_tot (kWh/kg)= (E_use [kwh/kg]* (Edible part [kg]+ AddedWater [kg]) + (Power [kw]* Ctime [h]))/ Edible part [kg]

The total energy for cooking (Etot) consists of two parts. The first part describes the energy use for heating the edible part and added water to its boiling point. The second part describes the energy use of actual cooking. The sum of these two parts is divided by the edible part to obtain the energy use per 1kg of cooked product. According to measurements by Blonk Consultants in 2012, using natural gas requires approximately 35% more final energy than using electricity.[vii]

Food losses through the life cycle

We assumed that losses during cultivation were already included in the yields. The other estimated losses were:

- A variable percentage depending on the recipes used in the processing;
- 0.7% cutting losses for cheese during packaging;
- 1% for transport and at the distribution centre;
- 5% at the supermarket;
- losses at the consumer (=edible parts) (100);
    - 2% for eggs;
    - 5% for dairy; and
    - 6% for meat.

All food losses are assumed to be fed to animals so no environmental impact is associated with the end of life (EoL) of these losses (allocation cut-off). The reasoning is almost in line with how the EoL of packaging materials is modelled, except that no credits (for example energy recovery) are taken into account.

Transport through the life cycle

The applied transport distances are shown below. In general, all transport is assumed to be by a EURO 4 truck with a size of >20 tons and a load factor of 50%.

Table 18: Transport distances used in the different processes and life cycle stages

LIFE CYCLE STAGE	DESCRIPTION	DISTANCE
Animal husbandry and slaughterhouse	Animals from farm to slaughterhouse	100km
Distribution	From farm to warehouse within country	250km
Distribution	From warehouse/processing to distribution centre	20km
Supermarket	From distribution centre to supermarket	50km

[vi] One could argue that for example pork chops contain bone, which should be accounted for as a cutting loss. However, accounting for these bones in food losses but not in allocation at the slaughterhouse would lead to illogical results. Ideally allocation at the slaughterhouse would be extended to incorporate bones. Currently this data is not available.

[vii] On the other hand, cooking on natural gas requires approximately 25-30% less primary energy.

ANNEX 4: OPTIMISATION

Optimeal 2.0 is a generic diet optimisation tool developed by Blonk Consultants in cooperation with the Netherlands Nutrition Centre.[101][102]

Based on the default Excel templates in Optimeal, we developed a country-specific database for the UK.

Type of algorithm: Quadratic programming

Unit: Grams

Deviation criterion: Absolute

ANNEX 5: EATING FOR 2 DEGREES – NEW AND UPDATED LIVEWELL PLATES: MEETING NOTES

On Tuesday 7 February 2017, the Food Team at WWF met with 23 external stakeholders in London to share and discuss the finding in this report.

This meeting was followed up by a separate meeting in Edinburgh on Friday 10 February 2017, attended by 36 external stakeholders representing a wide variety of sectors, including business, local government and farmers.

The objectives of the meetings were to:

- get the stakeholders' feedback on our research;
- raise awareness of WWF-UK's continued commitment to sustainable diets in order to:
- strengthen existing collaboration;
- create opportunities for new collaboration;
- introduce Livewell to a wider stakeholder group;
- allow stakeholders to network.

Overall, the delegates welcomed WWF's continued commitment to our sustainable diets work and the opportunity to provide feedback on the updated Livewell research. Below is an amalgamation of the discussions which took place.

The Food Team facilitated discussions around the following three questions:

1. LIVESTOCK

Question for discussion: for those who want to eat meat, how can they include this in a healthy, sustainable diet in 2030?

General discussion

There was a general agreement that we need to eat more plant protein, and produce and eat less meat. This is an important message which the meeting participants believe livestock farmers and people need to understand – however unpalatable some might find this.

Overall, the participants felt that WWF shouldn't hold back on the research findings in fear of bad headlines as all the evidence points in the same direction: we need to keep and consume less livestock if we are to meet climate and biodiversity targets. We shouldn't ask consumers to change, but rather focus on 'mainstreaming' Livewell meals supporting an effortless transition to a healthy, sustainable diet.

Going forward

Consumption

The discussions focused around how we can reach the wider public, whether it's through spokespeople, practical support or positive messages.

We need external support to challenge the popular belief that meat is essential for a healthy diet. This could be done by recruiting a high achieving sporty vegan – such as an ultra-runner – as a spokesperson, or though up-skilling chefs across the board. The more people who talk about and provide a sustainable diet, the more people we'll reach.

There's a strong sense that we need a more practical application of the Livewell Plate. Suggestions included creating meal/dish options and linking these to shopping lists. Could we develop a score based system? Can we produce an app so people can decide the make-up of their own Livewell diet or allow them to clearly see what the diet could look like in a week or month? Tools like these can enable people to visualise a healthy, sustainable diet and empower them to choose what this should look like.

Hand-in-hand with this would be the development of more alternative Livewell Plates:

- Low cost Plate for adults;
- Weekly Plate for adults;
- Children and young people Plate (5-9);
- Soldier Plate;

A Plate for mental health or dementia.

Another practical solution could be the development of a quality plant-based protein label. However, the delegates agreed there is too much on-pack information already.

Positive messaging around meat and vegetable consumption is also important to reach a wider audience. The stakeholders welcomed the idea of integrating celebration food – or 'meat as a treat' – into the sustainable diet debate, but highlighted the need to remain culturally sensitive as some religions don't allow certain types of food, such as pork, shellfish and beef.

On a daily basis, messages around the consumption of meat should focus on increasing the proportion of vegetables – rather than decreasing meat – but also using meat as a flavour rather than the centrepiece. This could be aligned with efforts to challenge the myth that meat should be cheap.

Some delegates felt WWF should have stronger messages on meat, from encouraging people to eat a wider variety, eating less and better meat, raising awareness about meat production, to actively supporting the right production systems in the right places. WWF should also clarify the link between food, feed and biodiversity.

Production

The delegates focused on how we can frame future discussions on livestock production and agreed that our main challenge is how we engage farmers in the UK in a nuanced debate. Some expressed an interest in WWF convening a cross-sector forum (as our previous Livestock dialogues).

In terms of content, future discussion will need to include an honest assessment of land quality and use. Some participants challenged the argument that land currently used for beef and sheep farming is only suitable for this type of farming. More research is needed to identify the environmental potential this land has if restored.

Another challenge is to compare production systems and identify the opportunities to move away from poor systems, whether this is poor management (extensive/intensive) or poor location (upland/lowland). Can WWF include this is a future Optimisation analysis?

Finally, some delegates discussed sustainability in animal feed and aquaculture. Identified solutions were to:

- Provide more sustainable options to the industry;
- Increase supply chain understanding of the issues and provide incentives;
- Put the right market base mechanisms in place to increase adoption of sustainable practices;
- Improve understanding of land use.

2. HORTICULTURE

Question for discussion: what opportunities exist within the horticultural sector to increase healthy, sustainable food consumption by 2030?

General discussion

The meeting participants believe there's a cultural aversion among businesses to develop plant-based options because of a perceived lack of consumer demand; however it was noted that this is slowly beginning to change – Pret's veg-only shops being one example. The food industry is also slowly promoting educational initiatives, such as the successful 'eat the rainbow' campaign and Tesco's free fruit offer to school children.

Celebrity influencers – including Jamie Oliver and the DIY SOS presenter Nick Knowles – were seen as important actors to help boost vegetable consumption. Increased mainstream media attention on people following meat-free or 'flexitarian' diets was also highlighted as a positive development.

We noted the challenges in influencing people's choices when options are near limitless. It can be easier for contract caterers who have a captive audience to edit choices than it can be for high-street chains who pursue a 'more-is-better' approach. Linked to this were discussions around the architecture of the high-street and urban expansion. Delegates felt we need to improve the access independent specialists and small businesses have to consumers and public institutions. In turn, improving access needs to be supported by better infrastructure for local supply chains.

Going forward

Consumption

Marketing is essential to increase consumption of vegetables and plant protein. We need coherent and positive messages – implemented by a number of actors – and get the media on board.

Messages need to be simple and focus on normalising the place plants have on our plates, improve understanding of what a recommended portion size is, and encourage greater knowledge about how to prepare vegetables and plant protein. People need greater cooking skills and confidence in trying new things! We need to look at how we can move the population away from the 'meat and two veg' approach – and the associated meat-equals-energy perception – towards using vegetables to enhance dishes and meat as flavouring, for example meat croutons or lardons in dishes.

We need to acquire a greater understanding of the nutritional link between land, agricultural output and the future needs of the population. This will need to include growing- and rearing-cycles as well as land use. Can we establish a link between the nutrient density of foods and production systems and reward systems that produce nutrient dense foods?

We also need better public information about the nutrient benefit of plants, including frozen vegetables – which are both cheaper and less wasteful. Could we commission a paper profiling fresh and frozen, focusing on nutrition, environmental impacts and waste, as well as comparing microwaved vegetables to stove-top looking at nutrition and carbon footprint?

Increased focus on food in education was also highlighted. Food can be taught across subjects from geography and history (where our food comes from and our changing tastes) to science (growing and cooking) to maths (measurements) and languages.

Although some influencers exist, the delegates agreed that much more can and must be done by our food service providers to improve menu options and make these more appealing; kids menus tend to focus on chips, nuggets and fish. Retailers also have a huge part to play in how they communicate with their shoppers. Currently, the majority of retailer offers, such as a meal for 2 for £10, is meat based. The stakeholders believe these actors can play a role in educating shoppers through choice-editing and by rewarding behaviour change. We need to work with food service providers and retailers to help them re-jig their meal offers to include vegan and vegetarian options which are not pizza or pasta based, as well as meat as flavouring options. We want to explore whether we can brand vegetables as has been successfully done for meat and other food products.

Chefs and product developers were also identified as key influencers. We need to train these to put plant protein at the centre of the plate and not see it as an afterthought or the compulsory vegan or vegetarian options. Following on from this, should we support a qualification in community growing? And should there be greater emphasis on horticulture training in Agri-Tech colleges, small-holding courses and in large scale farming? Most of these are currently dominated by livestock and husbandry.

Finally, participants emphasised WWF's role in this field and suggested adding advice to the Livewell messages, for example:

- Eat a variety of food – this includes meat, fish and vegetables.
- Eat less meat – lamb once a month, fish twice week.

Production

The discussions relating to production within the horticultural sector presented fewer suggested ways forward, but highlighted a number of issues participants felt WWF should consider.

Access to labour was addressed as a potential issue for the sector; however we felt the discussion needs to move away from a narrow focus on seasonal, migrant workers to address how to ensure a sustainable supply of labour and fair wages to all. Jobs in this sector need to be more attractive for farmers and workers over generations, regardless of their nationality.

The delegates agreed that the horticultural sector needs to expand if we're to meet our climate change targets. We must move away from the expansion of crops that are used for non-human needs like maize (used for fuel, feed and sugar), and think differently about how we use existing space. One example highlighted is how the UK cherry tomato industry is growing 10% if its crop next to British sugar factories using its waste heat and energy to power greenhouses. Finally, we need to move the debate forward around issues stuck in the past, such as aquaculture and GMOs.

The delegates felt that Brexit poses a real threat to the horticultural sector. To date, the sector receives fewer subsidies, and other than issues relating to immigrant workers, it is less represented by the NFU and receives less media attention.

The participants discussed risks facing the horticultural sector following the decision for the UK to leave the EU. One is the potential free-trade deals with non-EU countries (the US in particular) which could lower standards and make UK growers unable to compete with large-scale overseas growers. This could see farmers drop out of an already contracting sector. Tariffs imposed on EU fruit and vegetable imports could also have an impact on UK prices and a negative knock-on effect on consumption given our reliance on fruit and vegetable imports.

However, the delegates also agreed Brexit gives us an opportunity to shift subsidies away from the livestock sector; we must use post-CAP subsidies to incentivise the production of healthy, sustainable produce, support small growers, and push for greater transparency on where subsidies go. This could be the fertile ground needed for the British horticulture sector to flourish.

3. BUSINESS

Question for discussion: what are the blockers for business to be engaged in t his area?

General discussion

Delegates identified the current agricultural set up as a barrier for business engagement. Scottish farming is dominated by providing ingredients for the whisky industry, export markets and more extensive livestock than they can eat, whereas English farming is increasingly dominated by livestock, cereals, sugar and crops for livestock feed. Both landscapes are dominated by extensive livestock to the detriment of other things wild and cultivated. We need to create natural landscapes not just farmed ones. This will create fertile climates for businesses to change.

The delegates agree there's no one-size-fits-all approach to business engagement and that it's more challenging to engage with non-purpose driven businesses than with those that have a strong sense of environmental responsibility.

For a business with purely financial KPIs, a major blocker would be to recognise the urgency of sustainable diets. In this case, they might need to be presented with a business case for sustainable diets that demonstrates consumer demand and opportunities for higher turnover and profitability. Such a business might also benefit from wider engagement around the environmental and social issues and risks facing the food industry.

Going forward

For businesses with a stronger environmental commitment, the delegates focused on the role civil society organisations and government can play to help address the blockers.

Although civil society organisations are working increasingly well together, the meeting participants felt there's plenty of room for improvement in their engagement with the corporate sector. Businesses know how to promote products and what people purchase; they don't slavishly follow consumer demand (although it can drive their decisions in many cases). The delegates felt organisations can be more supportive and openly positive about advancements made by businesses. They should also capitalise on a business' expertise, help them make the right decisions and prepare them for the future.

It was suggested that civil society organisations need to be smarter in identifying strategic decision makers and actors of change, from buyers and culinary teams to external affairs, press, and corporate responsibility. Civil society need to provide corporate responsibility with the evidence they can use to push for actions internally.

Further, civil society organisations need to recognise that competition law is a barrier and help corporations seek collaborative ways to address challenges. Businesses need to be brought together to share precompetitive information;

we need to develop a database of case studies – successes and failures, from environmentally driven businesses and from companies with purely financial KPIs – that any business, whatever size, can learn from. The technology to generate global data exists, as do global data for nutrition, we just need to collate environment data.

Retailers are in a particularly strong position to influence positive consumer behaviour. They should use their insight and in-house technology – achieved for example through clubcards – to identify people's needs, provide alternatives, and communicate this across their stores, for example by positioning food with health books and fitness equipment.

Government plays an important role in removing barriers for business engagement, and the recent sugar tax levy was highlighted as an example of regulatory action with wide-ranging, positive consequences. The levy has already achieved more than voluntary measures in incentivising drinks' suppliers to reformulate their products. Businesses knew what was coming and that they would benefit from adopting more sustainable practices. Drawing on this example, the delegates felt it was space for government to implement similar measures to reduce consumption of saturated fats and increase consumption of plant protein. To achieve this, we'll need strong regulation from government that moves us in the right direction, for people, planet and profit.

The other role government can play is to provide certainty for businesses – through offering public sector contracts and subsidies for healthier food – and provide them with a level playing field. Can the food industry learn from the development of transport policies, such as sliding scales for road taxes based on emissions, which act as incentives for companies and citizens to factor sustainability into operational and purchasing decisions?

Finally, the delegates mentioned the role investors can play in putting pressure on companies to take environmental issues more seriously. We need investment funds to look beyond the obvious risks, such as fossil fuels, and consider risks associated with unsustainable food systems.

4. OTHER

In addition to the above, the delegates provided us with the following thoughts and recommendations:

The meeting participants supported the views that any dietary recommendations need to be positive, culturally acceptable – the Plates need for instance to include all major food groups currently consumed – and cost effective. It was noted that NDNS suffers from under-reporting and therefore an under-estimation of the cost of the current diet. Comparing the cost of the Livewell diet with current consumption is therefore highly indicative.

WWF needs to diversify its engagement with the farming sector. A growing number of farmers are taking measures to reduce flock numbers to reduce costs, and diversify into other foods and species such as pigs, chickens, agro forestry or even garden plants. Civil society organisations shouldn't kowtow to the NFU or NFUS, but challenge them in coalition with other farming groups and land users.

In terms of the Livewell research, the stakeholders recommended WWF creating better links to and reviewing existing studies in this area. They also suggested making the Livewell Plates food rather than nutrition based as has been done in Brazil.

We'd like to thank all the meeting participants for their time and comments. The Food team have taken a number of your recommendations on-board and amended the research criteria to ensure the Livewell Plates are widely acceptable. Other comments and recommendations will be taken into consideration as the team plans its on-going work in the sustainable diets field.

ANNEX 6: FOOD AND WWF POLICY AREAS

WATER

Only 2.5% of the water on the planet is freshwater, and approximately 70% of all the freshwater withdrawn is used for agricultural irrigation[viii]. This use of freshwater for crop irrigation is referred to as the blue water footprint, and has been quantified in this report.

We know that in order to fully assess the link between our food choices and freshwater systems we'd need to look at both the quantity and quality of water use. Unfortunately there are serious limitations to existing work on water scarcity and it's therefore too difficult to assess the link between dietary choices and the impact on freshwater. Moreover, a higher water footprint doesn't necessarily mean higher impact.

Nonetheless, we believe it's reasonable to conclude that a change in diet can lead to water quality improvements. Consequently, we focus on quantifying the amount of irrigation water used for the whole diet, without drawing further conclusions on water scarcity.

River flows

Agriculture is by far the largest user and consumer of water globally, accounting for 70% of water withdrawals and around 90% of water consumption[ix]. It's the main cause of over-depletion of rivers globally. However, the impact this has on water scarcity is difficult to assess for the following reasons:

a) Consumption of rainfall

The main impact of agriculture on river flows is from irrigation taken from rivers or groundwater. This is the blue water footprint. But crops – whether for direct human consumption or for animal feed – also consume rainfall. This is the green water footprint. To thoroughly assess the impact of agriculture on river flows, we'd need to include the green water footprint by comparing rainfall consumption of a specific crop with an alternative land-use, either another crop or the natural vegetation for that area. But an agricultural crop can often consume a smaller fraction of the rainfall than the naturally occurring vegetation, which could be preferable from both a terrestrial and freshwater ecosystem perspective. Therefore the absolute volume of rainfall consumed is not a good indicator for the water impact of that crop.

b) Impact of irrigation

Within a defined geographical area, the total volume of water consumption in agriculture from irrigation (the blue water footprint) is a better indicator of the impact on river flows. Irrigation with surface flows also has the added impact of requiring infrastructure in the river (dams, barrages and so on) that can affect its continuity in terms of flow, sediment and species migration.

However, comparing the blue water footprint of one food to another on a per weight basis is not useful for determining their relative impact on freshwater ecosystems. There are a number of reasons for this:

- The impact on flows from a particular crop depends on the total consumption of water within the catchment. A crop with a high water footprint per unit of weight might be having a low impact on flows if there is only a small area being grown.
- In areas of high water stress, crops with a relatively low water footprint per unit of weight may have a significantly higher impact on river flows than a high water footprint crop in a water-abundant area.

[viii] Food and Agriculture Organisation (FAO) AquaStat. http://www.fao.org/nr/water/aquastat/data/query/results.html

[ix] The distinction between water use/withdrawal and water consumption is an important one. The former refers to the amount of water taken out of surface or groundwater systems. However, domestic and most industrial processes return a large proportion of this water back to the same catchment from which it was withdrawn, therefore making it available for downstream uses. Water consumption refers to the amount of water removed from a catchment through the processes of evaporation or transpiration, and is therefore not available for downstream uses.

c) Landscape use

There is a landscape-scale argument for keeping agricultural water use within sustainable limits: in each river basin/ catchment water allocations and total consumption in agriculture should explicitly recognise environmental flow requirements. The question then is whether a top-down policy-driven shift towards a lower-meat diet would help to support this objective. In other words, does a lower overall demand for a specific crop help us achieve basin-specific limits on water consumption?

Given the sunk-cost investment in infrastructure required to make land irrigable, and the generally higher profit margins of the resulting crops, it's likely that any land currently used to grow irrigated feed crops could be used to grow the same crop for direct human consumption or another irrigated crop. Although it's an untested hypothesis, it's not unreasonable to expect that marginally profitable land would go out of production rather than the irrigated land – this would most likely be rain-fed agriculture, which is generally not significantly depletive of river flows.

In addition, we'd need to assess the current levels of irrigation in feed crops. The areas where the UK gets its main feed crops (wheat, maize, soybeans) are relatively low irrigators[x]. We'd also need to consider that the global irrigated area is increasing, but the rate of increase seems to be slowing.

Water quality

In global terms it's reasonable to expect that lower consumption of meat protein in favour of a more plant-based diet would result in reduced water quality impacts, given that where livestock consume feed crops there is a greater overall biomass/ land requirement, with associated agrochemical use and soil erosion. These water quality impacts from animal rearing are in addition to those caused by growing the feed. Their extent depends on the different types of production systems, however; and the water quality impacts from low-density, extensively-grazed livestock may be lower than for the equivalent amount (in calorie or protein terms) of some crops.

Finally it's important to note that, even if there were no widespread river flow benefits from a shift to plant-based diets, such a move would be likely to improve water quality in addition to its land-sparing and carbon benefits.

[x] Exceptions would likely be soybean from the US, maize from Bulgaria, and some French maize (van der Velde et al 2009 suggests around 40% of French maize is irrigated) but the actual degree to which these crops are irrigated is largely unknown: http://voices.nationalgeographic.com/2015/02/10/corn-remains-king-in-usda-irrigation-survey/ says 79% of US maize is rain-fed.

FORESTS

The world's forests are home to over half the species that live on land[xi]. While 300 million people actually live in forests, more than 1 billion people depend on them for their livelihoods[xii,xiii]. In fact, we all depend on forests. Forests play a vital part in our battle to avoid dangerous climate change by re-balancing the flow of carbon dioxide into the atmosphere. Only the world's oceans store more carbon. The destruction of forests is one of the biggest sources of man-made carbon dioxide emissions. Moreover, many of the products we use today have their roots in the forest – from cosmetics and medicine to rubber and tonic water.

If you care about forests, you care about where your food comes from: the fates of food and forests are intertwined.

The expansion of commercial agriculture is the most significant cause of deforestation around the world, and has been a serious environmental issue for decades. The threat is particularly acute in the tropics where highly biodiverse rainforests are being destroyed by farms and ranches. WWF has identified 11 deforestation fronts across the world where we expect that most of the forest loss up to 2030 will take place. On seven of these fronts, large-scale agriculture is a primary cause of forest loss, and it is a secondary cause in three others. Small-scale agriculture is also a primary cause of forest loss in many of the 11 fronts.

Despite our current trajectory, WWF envisions a world where forest loss has been brought to zero. Our *Living Forest Report* set out how this could be achieved by 2020[xiv]. It would require, among other things, significant changes to the way land is governed, how we generate energy, how we harvest wood, and – yes – the production and consumption of our food. In fact, a shift to a more sustainable diet is essential to deliver on the vision. We must do this while respecting the fact that agriculture is a route out of poverty and into food security for many millions of people.

International pressure on companies trading in the major commodities has led to a series of commitments to change. Dozens of major businesses in the food supply chain now have commitments to eliminate any deforestation linked to their supply chain. Many are buying commodities certified by third parties as sustainably produced, although the market share of certified commodities is still small.

Recent research has shown that the tide may be beginning to turn. Deforestation is slowing on average across the world[xv], and resulting emissions have reduced slightly – in fact, agriculture itself is now emitting more through direct operations than through the land-use change it requires[xvi].

But there remains a long way to go: companies have been slow to implement their promises, and others have yet to make any commitments at all[xviii]. We have more to do to ensure the food we eat does not contribute to deforestation. Considering changes to your diet and buying responsibly could help relieve pressure on forests – you can find out how well companies are doing in their sourcing policies in the WWF scorecards.

[xi] http://www.unep.org/forests/AboutForests/tabid/29845/Default.aspx

[xii] Millennium Ecosystem Assessment, (2005). In WWF Living Planet Report 2014

[xiii] FAO, State of the World's Forests, 2014

[xv] http://wwf.panda.org/about_our_earth/deforestation/forest_publications_news_and_reports/living_forests_report/

[xvi] FAO, Global Forest Resource Assessment, 2015

[xvii] Tubiello et al. (2015) The Contribution of Agriculture, Forestry and other Land Use activities to Global Warming, 1990–2012, Global Change Biology, vol 21, p2655–2660

[xiv] Climate Focus. 2016. Progress on the New York Declaration on Forests: Eliminating Deforestation from the Production of Agricultural Commodities – Goal 2 Assessment Report. Prepared by Climate Focus in cooperation with the NYDF Assessment Coalition with support from the Climate and Land Use Alliance and the Tropical Forest Alliance 2020.

DEFORESTATION PRESSURES

	LIVESTOCK	LARGE-SCALE AGRICULTURE	SMALL-SCALE AGRICULTURE AND COLONIZATION	UNSUSTAINABLE LOGGING	PULP PLANTATIONS	FIRES	CHARCOAL AND FUELWOOD	MINING	INFRASTRUCTURE	HYDROELECTRIC POWER
AMAZON	Red	Red	Red	Yellow		Orange		Orange	Red	Red
ATLANTIC FOREST/ GRAN CHACO	Red	Red		Orange	Orange	Orange	Orange	Orange	Red	Yellow
BORNEO		Red	Orange	Orange	Orange	Orange		Orange	Yellow	Orange
CERRADO	Red	Red					Yellow	Yellow	Orange	Yellow
CHOCÓ-DARIÉN	Red	Red	Red	Orange				Red	Red	
CONGO BASIN	Yellow	Orange	Red	Orange			Red	Orange	Orange	
EAST AFRICA	Red	Yellow	Red	Orange		Red	Red	Orange	Orange	
EASTERN AUSTRALIA	Red		Yellow	Orange				Yellow		
GREATER MEKONG		Red	Orange	Orange	Orange		Yellow		Yellow	Yellow
NEW GUINEA		Red	Orange	Orange	Yellow	Yellow				
SUMATRA		Yellow	Red	Orange	Orange	Orange				

Figure 15: The most common pressures causing deforestation and severe forest degradation are: large and small-scale agriculture; unsustainable logging; mining; infrastructure projects; and increased fire incidence and intensity. New roads can have a small direct impact but a large indirect effect through opening up forests to settlers and agriculture. Poor forest management, destructive logging practices and unsustainable fuelwood collection degrade forests and often instigate an increasing spiral of degradation that eventually leads to deforestation ("death by a thousand cuts").

- Red: Primary cause of forest loss and/or severe degradation
- Orange: Important secondary cause of forest loss and/or severe degradation
- Yellow: Less important cause of forest loss and/ or severe degradation
- White: Not a cause of forest loss and/or severe degradation

SEAFOOD

The oceans and other aquatic environments are a vital source of food and livelihoods. Over 250 million people are employed in the seafood industry, and more than 3 billion people depend on seafood as a major source of protein. Seafood is an important contributor to global food security, and over the past five decades the global supply of fish for human consumption has increased at a faster rate than population[xviii].

Over the past 50 years, the average consumption of seafood per person per year has increased from less than 10kg in the 1960s to more than 20kg in 2015. This increase in demand has resulted in nearly 60% of fisheries being fished to their sustainable limits, while more than 30% are overexploited. The pressure on the oceans along with technological advances has meant that aquaculture production has increased rapidly. In 2014, the contribution of aquaculture to the supply of fish for human consumption was for the first time higher than that of wild-capture fisheries.

The increased production in seafood globally has not come without problems. Pressures affecting wild-capture fisheries include overexploitation of fish stocks; discards; by-catch of endangered, threatened and protected species; illegal, unreported and unregulated fishing; as well as climate change. Challenges in the aquaculture sector include disease; the use of fishmeal and fish oil in feed; escapes; and pollution from chemicals and nutrients. However, aquaculture makes an important contribution to feeding a rapidly growing global population, and if properly managed can be a sustainable option with lower impacts than other forms of animal protein.

WWF is involved in a variety of areas in the seafood sector including markets, governance, investment and regional work around the world. We help companies to reduce their environmental and social impacts, improve their supply chains, increase transparency, and work towards the high sustainability standards set by the Marine Stewardship Council and Aquaculture Stewardship Council.

Everyone can play their part to ensure a secure and sustainable future for our waterways and oceans. WWF advises that if you eat seafood, make sure the products you buy are certified sustainable by the Marine Stewardship Council (MSC) or Aquaculture Stewardship Council (ASC). If you're a business involved in the seafood industry, then you should download the WWF Seafood Charter guide for companies to find out more about the pathway towards sustainable seafood.

[xviii] http://www.fao.org/3/a-i5555e.pdf

MEAT

When we look at food and how to shift to a sustainable diet it is impossible not to talk about livestock, especially meat. Livestock can be beneficial to our health; it makes use of land that can't be used for growing crops; and it provides benefits to ecosystems and society. We've used it for food, fuel, clothing and as a symbol of wealth ever since we first domesticated the cow. However, we now know this comes at a cost. The evidence is increasingly clear that in some parts of the world we're eating too much, far more than we need for our health, and the current production systems and numbers are having a huge impact on the planet. Livestock needs large amounts of land, water and energy, and in general the footprint of meat and dairy products is much higher than that of other foods.

Globally 20% of total direct emissions are from food and agriculture, and with land-use change this rises to 30%[xvi]. Livestock is the most significant driver of these emissions through the production of animal feeds and from grazing animals[xvii]. The livestock industry generates 14.5% of GHGs – even more than transport[xviii]. In the EU, livestock production is responsible for 15% of GHGs, and in the UK it's responsible for about 8.5%. However, this figure doesn't take into account emissions resulting from land-use change.

The majority of land-use change and deforestation is a result of livestock production, either directly for the provision of grazing and crop land for animal feed, or indirectly through increasing the overall demand for agricultural land. One-third of the world's cereal harvest and over 75% of soya is used for animal feed, despite inherent inefficiencies of conversion:[xix] it takes around 15-25kg of animal feed to produce 1kg of beef, 4.5-5.5kg of feed to produce 1kg of pork, and 3-4kg of feed to produce 1kg of poultry meat.

While soybeans can be eaten directly by humans, most are crushed to produce protein-rich soy meal and soybean oil. The meal is used primarily as livestock feed. Increasing meat consumption is the main driver behind soy's continuing expansion. Around three-quarters of soy worldwide are used for animal feed, especially for poultry and pigs. Between 1967 and 2007 pork production rose by 294%, egg production by 353% and poultry meat by 711%[xx]; over the same period, the relative costs of these products declined. As the world's second largest source of animal feed after maize, soy is a key component of the industrial farming model that has enabled this change.

When trying to quantify the impact of meat you need to go beyond a simple gram for gram comparison, which will undoubtedly show that lamb is a lot worse than chicken. You need to be aware of and take account of all the inputs and their potential costs or benefits. A cow raised on lowland pasture may be using land that cannot be farmed, contributes to carbon sequestration and only takes water from the surrounding environment; while a chicken in a shed is being fed on soy and grain which has caused significant land-use change. Added to this complexity is the total produced: according to the FAO there are 21 billion chickens on the planet at any one time, with approximately 60 billion being produced for food each year.

So, there's a clear need to move away from business as usual. WWF's Living Forests project[xxi] showed that our goal of zero deforestation can only be achieved with a reduction in the total amount of meat consumed globally by the rich (and a small increase in consumption among the lower income groups in in South Asia and Africa), and a move towards extensive and sustainable livestock production.

[xvi] http://newclimateeconomy.report/land-use/

[xvii] Steinfeld H, et al. (2006) "Livestock's Long Shadow" UN Food and Agriculture Organization

[xviii] Seijan V, et al. (20150 "Global Warming: Role of Livestock" http://link.springer.com/chapter/10.1007%2F978-81-322-2265-1_10

[xix] FAO 2006 Livestock's long shadow environmental issues and options

[xx] FAO 2011

[xxi] http://wwf.panda.org/about_our_earth/deforestation/forest_publications_news_and_reports/living_forests_report/

Figure 16: The amount of soy required to produce some of our foodstuffs (hiddensoy.panda.org)

SOY

High in protein and energy, soy is one of agriculture's 'wonder crops' and is a key part of our global food chain. Soybeans contain 38% protein (twice as much as pork and three times as much as eggs), a wide range of essential amino acids, and a high proportion of unsaturated fat: it's an excellent food stuff and should be a key part of a healthy and sustainable diet.

Most soy, however, is not eaten by humans directly but is crushed into soybean meal and used to feed animals that are reared for meat and dairy products. With 75% of the soy grown globally used as animal feed, it's a 'hidden' ingredient in our food. On average, European consumers eat approximately 61kg of soy per year, most of it embedded within animal products like chicken, pork, beef and farmed fish species like salmon as well as in eggs, milk, cheese and yogurt.

Soy produces more protein per hectare of land than any other major crop, so it's extremely important in the battle for global food security. However, with a growing global population and an increasing shift to a more Western style diet with more meat and dairy products, demand for soy is predicted to nearly double by 2050: this threatens large areas of important habitats.

Much of the soy produced globally is grown in South America, and far too often it's grown at the expense of natural ecosystems such as the Amazon rainforest, the Atlantic Forest and the vast savannahs of the Cerrado. The area of South America devoted to soy grew from 17 million hectares in 1990 to 46 million hectares in 2010 and it continues to expand. To put the consequences in perspective, consider the Cerrado, the largest savannah region in South America and one of the most threatened and over-exploited ecosystems in the world. It's home to 5% of all living species and has over 10,000 species of plants, half of which are found nowhere else on Earth. Half of the Cerrado has been converted to agriculture since the 1950s, with soy and cattle production as the main drivers of this conversion. In destroying this habitat we release huge quantities of stored GHG emissions and lose some of the vital services it provides like clean water and healthy soil, as well as threatening the way of life of many indigenous people who rely on these lands for their livelihoods.

As a high-protein crop, cutting out soy from our diet is not the answer, nor is it very easy to do. Many of us, however, over-consume the products that contain 'hidden' soy, mainly meat and dairy products, and so a good step to take is to consume less and consume better. Reducing consumption of meat, eggs and dairy products in favour of vegetable proteins like pulses, peas and other green vegetables can lessen the demand for soy and can also help us get closer to a healthier and more sustainable 'Livewell' diet.

Consuming better can involve buying good quality meat from known sources. Shopping with retailers and brands who have committed to responsibly-produced, deforestation- and conversion-free soy throughout their supply chains will help to transition the soy supply chain to be responsible and to stop immediate habitat loss. Ask your favourite retailers and brands to act now if they haven't already.

Lastly, reducing food waste by planning shopping and meals carefully can also help avoid the loss of valuable proteins.

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