



# FCRN foodsource

A free and evolving resource to empower informed discussion on sustainable food systems

## Chapter 3.

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### Food systems and greenhouse gas emissions

# Contents

<b>Why should you read this chapter?</b>	<b>3</b>
Key points	3
<b>3.1 What is the food system's contribution to the global GHG emissions total?</b>	<b>4</b>
3.1.1 The food system contributes 20-30% of global GHG emissions	4
3.1.2 GHG contributions from agricultural production are particularly significant	5
3.1.3 Post-production GHG emissions are on average lower	7
3.1.4 The UK as an example of food-related GHG emissions in developed countries	8
<b>3.2 What are the main GHG contributions to agricultural emissions?</b>	<b>10</b>
3.2.1 Livestock is by far the main contributor of GHGs from farming	10
3.2.2 Livestock emissions vary according to species	12
3.2.3 Livestock systems can also generate benefits to the environment and people	13
3.2.4 Grazing livestock and soil carbon sequestration: a contested issue	14
3.2.5 Emissions from cropping and horticultural production are on average lower than those from livestock	16
3.2.6 Produce grown in heated greenhouse systems can have high emissions (UK example)	17
<b>3.3 How important is transport?</b>	<b>18</b>
3.3.1 GHG contributions from transport depend on the mode of transport	18
3.3.2 Air freighting food generates high GHG impacts	19
3.3.3 We cannot consider "food miles" in isolation of other life cycle impacts	19
3.3.4 Seasonal food choices can make a difference	20
3.3.5 Positive developmental effects of export horticulture	21
3.3.6 Transport impacts in the USA	21
3.3.7 Transport impacts in India	22
<b>3.4 How important is storage and packaging?</b>	<b>23</b>
3.4.1 Fresh vs. frozen	23
3.4.2 Packaged and canned food	24
<b>3.5 Which food products have the highest overall impacts?</b>	<b>25</b>
3.5.1 Relative GHGs of different food products	25
3.5.2 Animal products dominate contributions from western diets – the UK as an example	26
3.5.3 GHG hotspots in production and supply chain vary by food type	27
<b>3.6 Conclusions</b>	<b>27</b>
<b>References</b>	<b>28</b>
<b>Credits</b>	<b>32</b>



# Why should you read this chapter?

Emissions resulting from the many activities involved in food systems, account for a substantial portion of all human-caused greenhouse gas (GHG) emissions and, as such, contribute to climate change. A major challenge for the sustainability of food systems is, therefore, to figure out how its contribution to GHG emissions can be reduced.

If we are to be able to address and the mitigate food system's contributions to climate change, it is important to understand where and how the greenhouse gas emissions arise across the whole food system. Also important, is to understand how different ways of organising parts of the food system, can result in differing levels of greenhouse gas emissions.

This chapter addresses the following:

- How significant are the global food system's greenhouse gas emissions as compared with other human-caused emissions?
- Where in the food system do greenhouse gas emissions arise? And how do different parts of the food system, differ in their contribution to overall emissions?
- What foods and types of food production contribute the most to emissions from agriculture?
- How are emissions from foods affected by the location and seasonality of production, its transport, storage and packaging?
- How do food systems contribute to emissions from land use change, such as deforestation?

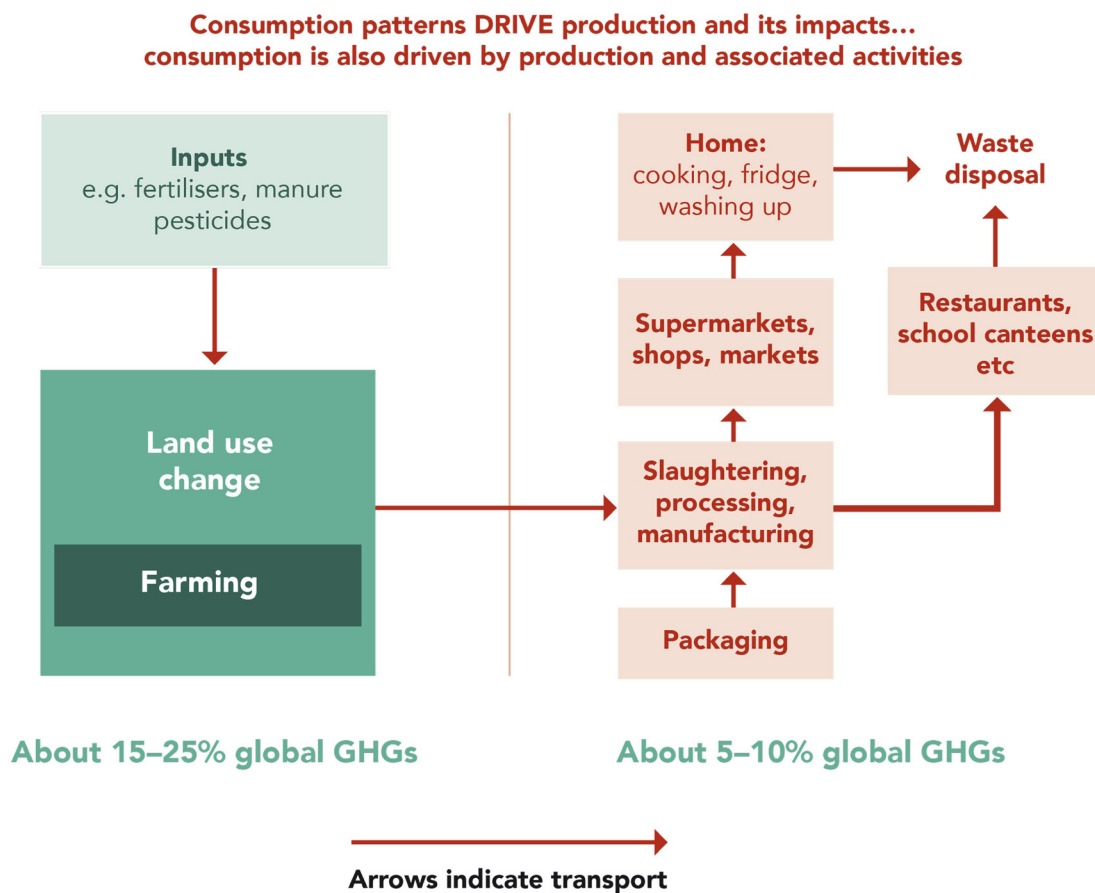
## Key points

- The sum of all activities that make up the global food system are estimated to contribute to some 20-30% of all human-associated greenhouse gas (GHG) emissions, but the exact numbers are highly uncertain.
- In general, most emissions from the food systems occur at the agricultural production stage (24% of human-caused emissions); emissions from all processes after food is produced add a further 5-10%.
- There are three main GHGs associated with food, each with different warming effects: carbon dioxide (CO<sub>2</sub>: weak), methane (CH<sub>4</sub>: strong), nitrous oxide (N<sub>2</sub>O: very strong). The very large amounts of CO<sub>2</sub> released, mean that its overall impact is large, despite being a less potent greenhouse gas.
- On-farm sources of emissions are responsible for roughly half of agricultural production's overall emissions, while the other half are caused indirectly, mostly through the release of carbon dioxide resulting from the conversion of ecosystems such as forests and wetlands, into new farmland.
- Livestock are by far the biggest contributor to food-related GHG emissions (alone, contributing 14.5% of human-caused emissions), but the exact magnitude and nature of these contributions varies substantially by animal species and location.
- In general, the foods with the highest overall GHG impacts are ruminant meat, followed by other meat (including seafood) and animal products (eggs, milk), with plant-based foods having the lowest impacts.
- While farming plant-based foods generally causes fewer GHG emissions, these can be substantially increased by the use of fossil fuel intensive processes such as long-haul flights, or being grown in heated and lit greenhouses.
- Minimising transport distance (i.e. lower food miles) does not necessarily minimise a food's lifecycle emissions (see [Chapter 2](#)), because these reductions may be outweighed by other interrelated sources of emissions, such as the need to heat greenhouses in winter.
- Dietary patterns and people's consumption practices – particularly the amount of animal products eaten – have a tangible impact on overall GHG emissions from the food system, by driving demand for certain foods and so methods of food production.

## 3.1 What is the food system's contribution to the global GHG emissions total?

### 3.1.1 The food system contributes 20-30% of global GHG emissions

#### Global perspective - food systems contribute 20-30% of GHGs



#### GHGs

GHGs is an abbreviation for greenhouse gases. These include gases such as carbon dioxide, methane, and nitrous oxide, which are released as a result of human activity, and which trap heat within the earth's atmosphere, leading to global warming.

**Figure 1: The food system's contribution to global greenhouse gas emissions - stages before and after farm gate.**

Source: Based on Vermeulen S.J. *et al.* (2012).

The food system is estimated to contribute approximately 20–30% of global human-made GHGs, although there is huge inherent uncertainty in these estimates.

The major impacts come from farming/agriculture and land-use change (see Figure 1 above), with fertilisers, pesticides, manure, farming and land-use change (LUC) together contributing as much as around 24% of global GHG emissions. Livestock alone contribute 14.5% of human-made GHG emissions.

Stages later in the food system such as packaging, retail, transport, processing, food preparation and waste disposal combined, contribute around 5-10% of global GHG emissions, although their importance and likely impacts are set to grow.

These stages are discussed in more detail later in this chapter (Sections 3.3 and 3.4). Within food systems, consumption patterns and production are interrelated, both impacting on one another.

### 3.1.2 GHG contributions from agricultural production are particularly significant

**Agriculture contributes to GHG emissions both directly (emissions from agricultural production) and indirectly (land-use change for agricultural purposes)**

**Main agricultural GHG emissions:**

**Carbon dioxide**

- Fossil fuels – and more importantly, land use change.
- Less potent – but lots of it.

**Methane**

- Burping cows (enteric fermentation), dung, rice paddies, waste.
- Less of it, very potent.

**Nitrous oxide**

- Fertilisers, soils, dung, urine.
- Less of it, extremely potent.

**Farm animals are the main source of agricultural emissions**

**Indirect emissions**

50% carbon dioxide – land use change

**Direct emissions**

Methane, nitrous oxide and (less significantly) CO<sub>2</sub> from burning of fossil fuels

For the three major greenhouse gases, direct emissions include:

- CO<sub>2</sub> from fossil fuel use (e.g. agricultural machinery, fertiliser production, pesticide production, production of farm structures (e.g. polytunnels).
- Methane from enteric fermentation from ruminant livestock, such as cows and sheep, as well as from manure, from rice paddies and from decomposing organic matter (e.g. waste in landfill).
- Nitrous oxide from soil bacteria, from legume production, from livestock manure and urine and from nitrogen fertilisers.

Indirect emissions are primarily CO<sub>2</sub> emissions from land-use change (such as deforestation and conversion of peatlands to create agricultural land).

**Enteric fermentation**

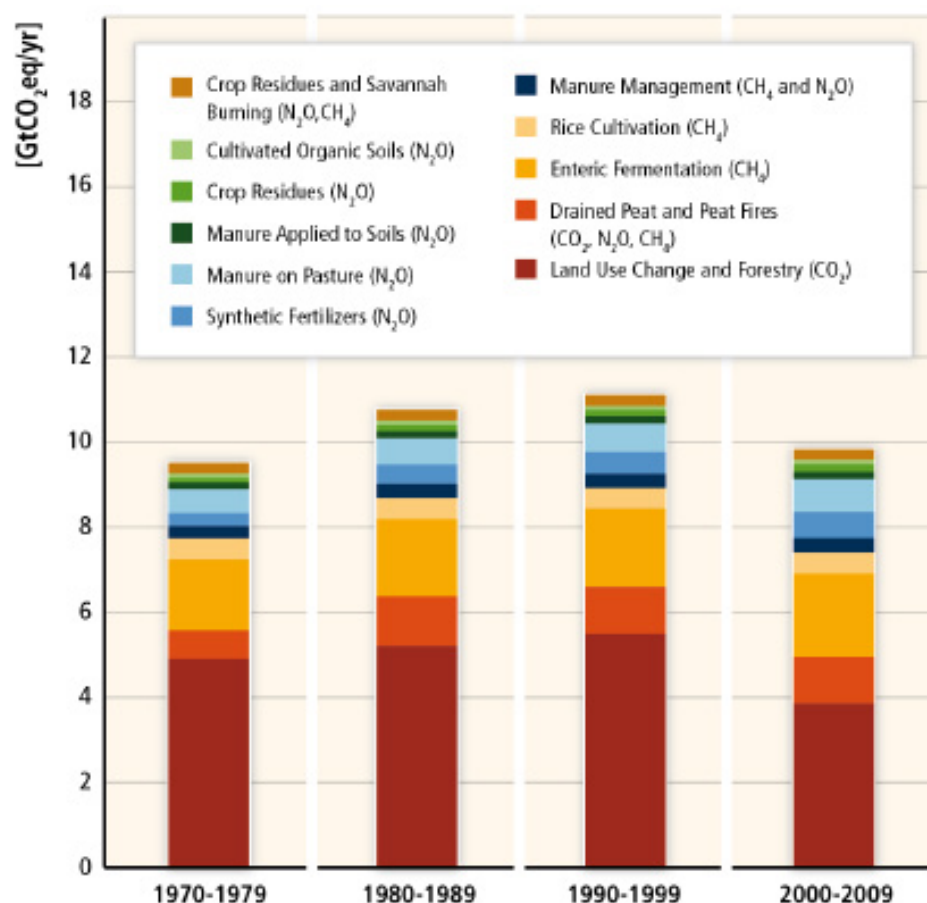
Enteric fermentation is a natural part of the digestive process of ruminant animals (e.g. cattle and sheep) where microbes decompose and ferment the food present in large rumen portion of the stomach. As a byproduct of this fermentation process, some bacteria species in the stomach produce methane.

**Ruminants**

Ruminant animals are distinguished by their specialised digestive system and include species such as cattle, sheep, goats, deer, and camels. In particular, their large rumen stomach allows plant matter to be regurgitated, chewed again, and for microbes to ferment it. This breaks down plant matter into digestible molecules that can be absorbed by the animal and allows ruminants to be fed on coarse plant matter such as grass, whereas other species such as pigs and chickens cannot.

Animal farming is a major cause both of direct and indirect agricultural emissions (see this chapter Section 3.3 and Chapter 8).

## Global perspective – focus on agricultural GHG emissions



**Figure 2: Greenhouse gas emissions from agriculture, forestry, and land use change.**

Source: Smith P., et al. (2014).

- Agriculture and land-use change account for 24% of total human-caused GHG emissions.
- While agricultural non-CO<sub>2</sub> GHG emissions increased, net CO<sub>2</sub> emissions fell from 1980 onwards, mainly due to decreasing deforestation, and increased afforestation rates.
- Emissions from food transport, storage, processing and waste are additional and not shown here.

The GHGs emitted from agriculture and associated land-use change shown here (around 10 gigatonnes of GHGs) account for 24% of human-made GHG emissions.

As shown in the graph, direct methane and nitrous oxide emissions constitute around half of this, and these emissions have increased in recent years.

Emissions from land-use change and forestry (mainly CO<sub>2</sub>) approximately make up the other half. Most, although not all, land use change and deforestation is driven by

agricultural expansion. Agriculture is estimated to be responsible for 80% of worldwide deforestation. Forest degradation (deteriorating forests and other lands, rather than actual clearing of forests) is driven more by timber extraction and logging, rather than agriculture.

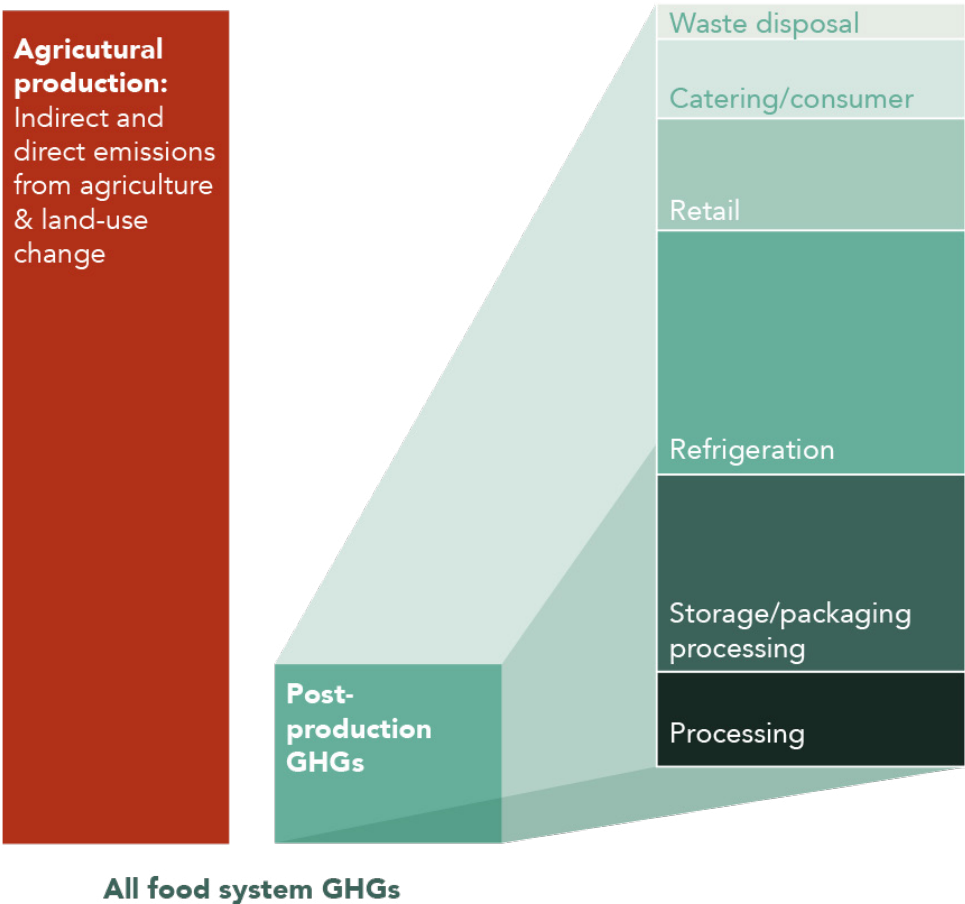
The land-use change referred to here relates to actual change of use, such as deforestation for crop production or livestock grazing, rather than land and forest degradation. Although degradation is also an important source of CO<sub>2</sub> emissions, it is not included here as an impact driven by food systems.

Some of the carbon losses from deforestation have in recent years been offset by afforestation (re-foresting land), but the net contribution from agricultural land-use change is still highly significant. There are large regional differences, with afforestation more prevalent in northern regions, and deforestation more so in southern regions of Asia and South America.

Within food systems, additional contributions come from transport, storage, and food preparation/processing (See Section 3.3).

### 3.1.3 Post-production GHG emissions are on average lower

#### Global estimates: production & post-production GHGs



**Figure 3: A comparison of emissions from agricultural production to post-production emissions.**

Source: Based on Vermeulen S.J., *et al.* (2012).

Agricultural production (including direct emissions from agriculture, and fertilizer production, pesticide production and energy use for animal feed) contribute the great majority of food system GHG emissions.

Post-agricultural production stages (processing, refrigeration, storage, packaging, processing, retail, catering and consumers, and waste disposal) contribute much less, but can be significant for some food types.

On a global scale, there is a great deal of uncertainty in measurements.

### 3.1.4 The UK as an example of food-related GHG emissions in developed countries

Many countries have sought to quantify the contribution that food consumption has on overall emissions. We use the UK as an example here.

In total, the food system in the UK contributes around 19% to UK human-made GHG emissions, excluding emissions from land-use change (LUC) for imported goods.

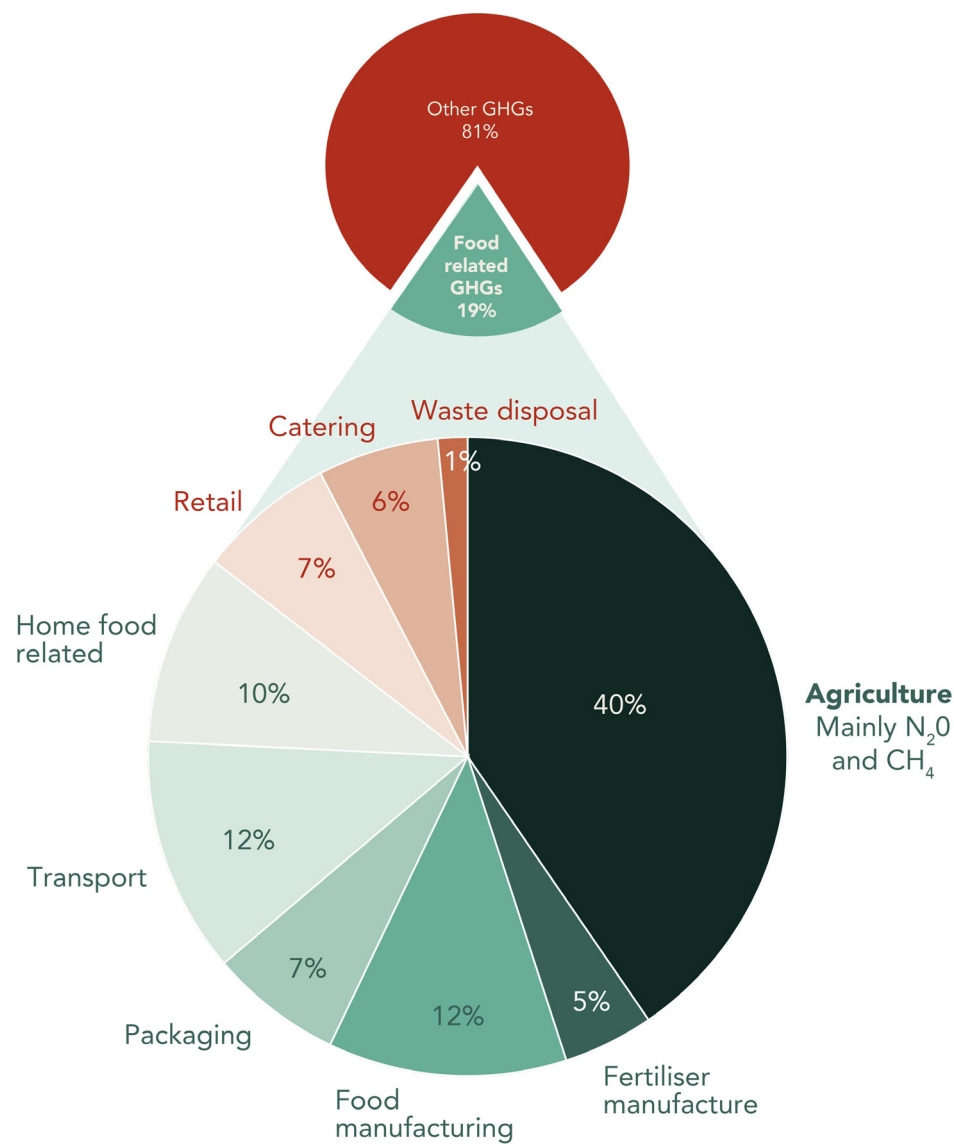
If global LUC-related emissions were included (i.e. the LUC-related emissions embedded in foods imported for UK consumption), then reported food-related emissions would increase further, although estimates of by how much vary.

The second graph shows that of the 19% contribution from the UK food system, agriculture contributes around 40% of the total, again excluding land-use change. The agricultural stage is the most significant largely because of livestock, which contribute methane and nitrous oxide.

Other contributions are much lower, but also of importance, such as transport, food manufacture, packaging, and storage and cooking, both at home and in business (retail and catering). Developed countries tend to have higher relative impacts from later stages than less developed countries, due to more energy use in processing and storage (e.g. refrigeration).



National level studies of different stages of the food system (the UK as an example)



Global land use change attributable to UK consumption increases UK's further although estimates vary.

Figure 4: The contribution of the food system to UK emissions – excluding land use change.

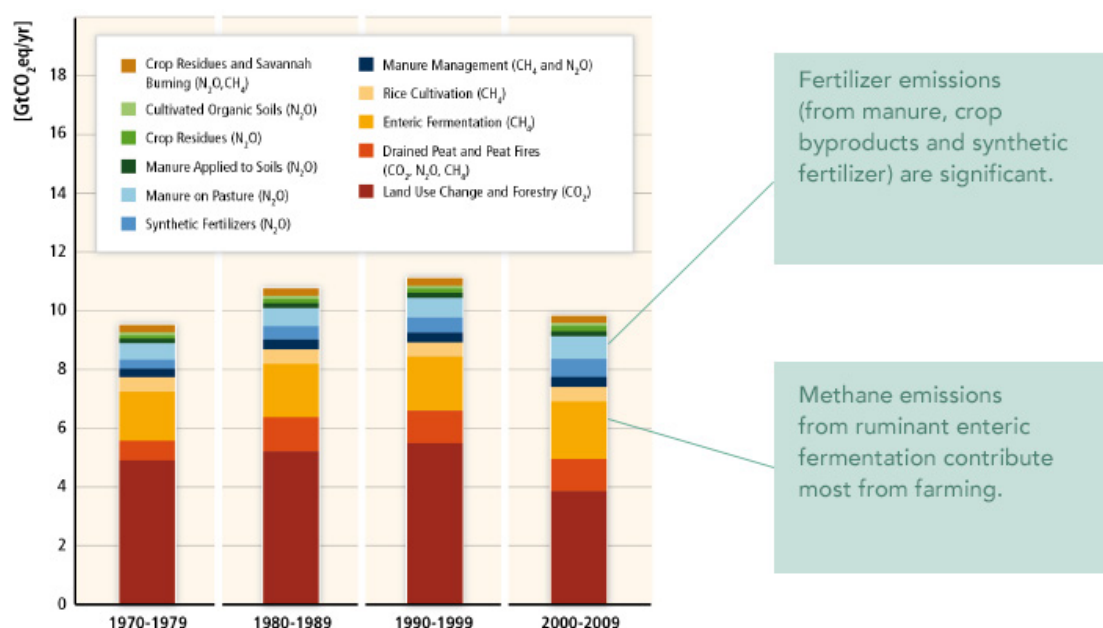
Source: Adapted from: Garnett T. (2008).

Global land use change attributable to UK consumption increases the UK's footprint further although estimates vary.

## 3.2 What are the main GHG contributions to agricultural emissions?

### 3.2.1 Livestock is by far the main contributor of GHGs from farming

The largest source of direct GHGs are enteric fermentation emissions from ruminants



**Figure 5: The contribution of livestock to agricultural greenhouse gas emissions.**

Source: Smith P., et al. (2014).

Global direct emissions from agriculture are mainly in the form of methane and nitrous oxide arising from ruminant enteric fermentation.

Synthetic and organic fertiliser applications (e.g. manure) are also significant contributors.

### Greenhouse gas contributions from livestock

Within the livestock sector, almost all GHG emission contributions come from enteric fermentation (methane emissions), manure (both methane and nitrous oxide), animal feed production (carbon dioxide and some methane), and from land-use change (carbon dioxide emissions from land clearing).

The percentage contribution from post-production emissions is very small for livestock – the CO<sub>2</sub> that is emitted results from the processing, transport of livestock products between the production and retail point, as well as from cold storage.

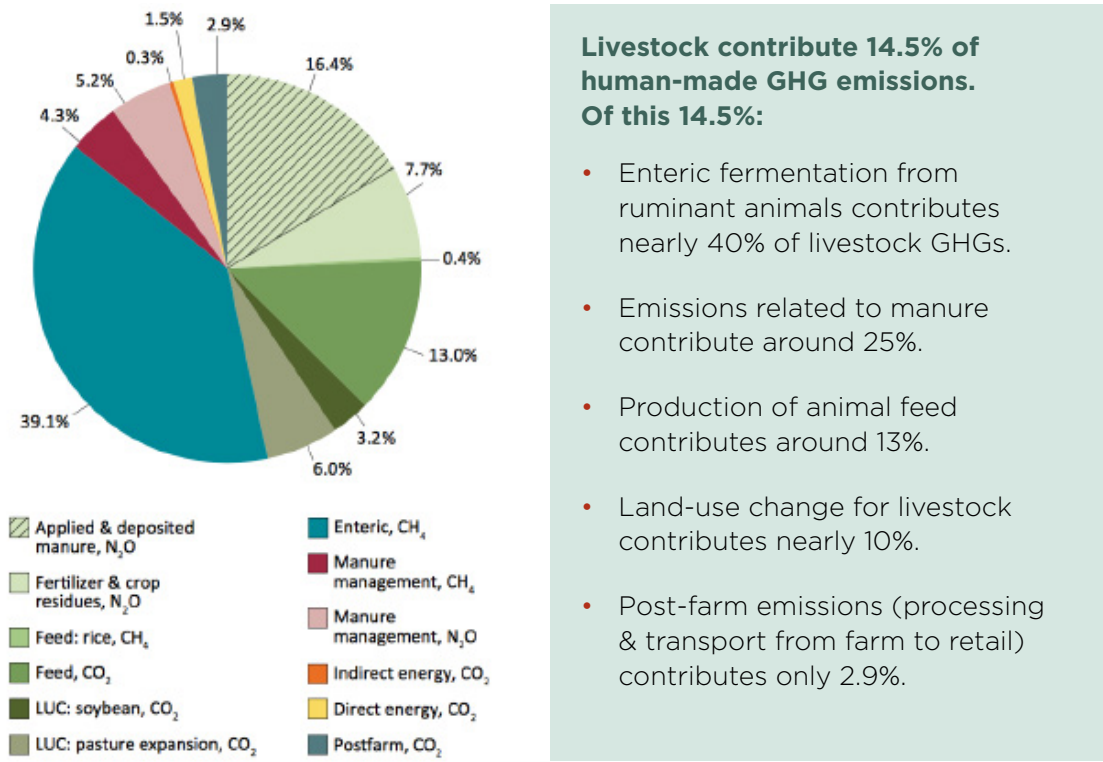


Figure 6: Total livestock-related emissions from direct and indirect sources.

Source: Gerber, et al. (2013).

Livestock contribute significantly to GHG emissions, but impacts of livestock are not limited only to GHG emissions.

Livestock and animal products: a convergence of issues

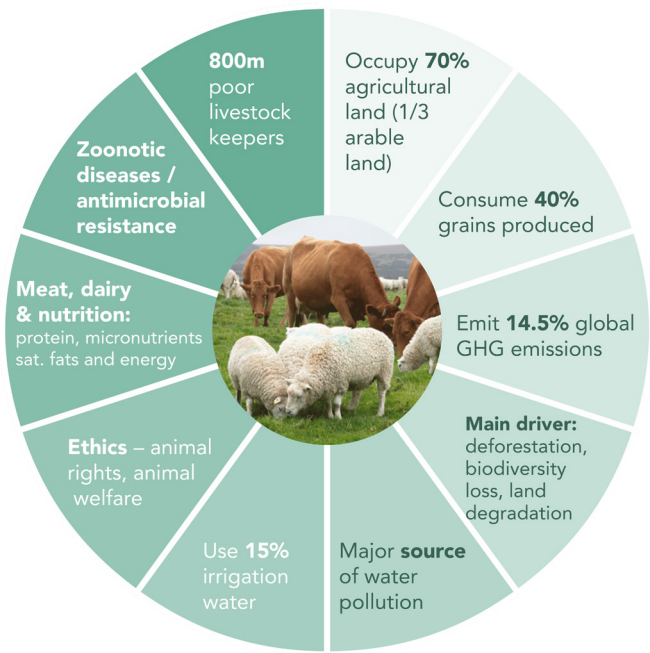


Figure 7: Livestock and animal products – a convergence of issues.

Source: FCRN. (2016).

Livestock are an important driver of deforestation, and as such are implicated in biodiversity loss.

Much of the world’s grain production is used to feed animals, with up to 1/3 of arable land dedicated to producing feed for animals. Since food energy is lost during the metabolic process, the use of cereals to feed animals is argued by some to be inefficient. Critics say that the land used to produce livestock feed could be better used for other purposes – such as to produce crops to be eaten by humans, or allowed to return to non-agricultural land use.

Livestock rearing also requires large volumes of water for feed production and to a lesser extent for consumption directly by animals, washing and so forth – although most of this is ‘green water’ – water that falls on grazing land or on unirrigated crops. Livestock manure is a major cause of water pollution, largely through poor manure management, which pollutes water systems.

Many human diseases are zoonotic in nature, meaning they are transmitted from animals to humans.

At the same time, animal products can be important sources of nutrition, and livestock keeping is central to the livelihoods of some of the world’s poorest people.

3.2.2 Livestock emissions vary according to species

Focus on livestock – global emissions by species

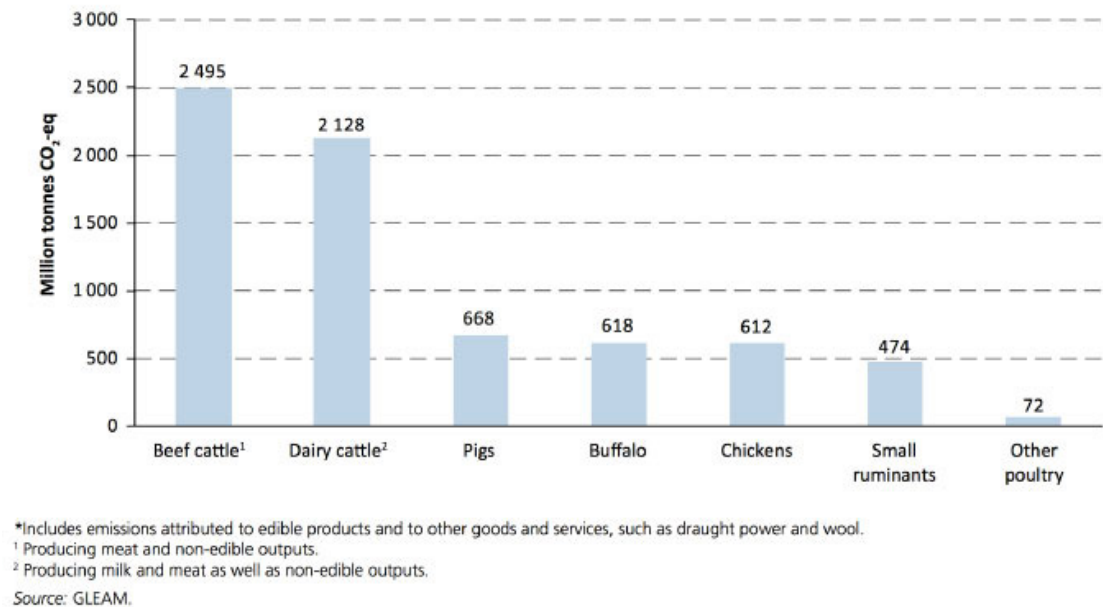


Figure 8: Total greenhouse gas emissions by livestock species.

Source: Gerber, et al. (2013)

Globally, beef and dairy cattle contribute most to total GHG emissions from livestock, since they are ruminants and farmed in high numbers. Other ruminants (for example buffalo, sheep and goats) contribute less overall because fewer of them are reared.

Arable Land

Arable land is by definition land used to grow arable crops, in contrast to land used for fruit and vegetable crops and for pasture used to feed grazing animals.

Zoonotic diseases

Zoonotic diseases are pathogens (e.g. viruses, bacteria, fungi, parasites) which can – to varying degrees – be transmitted between animals and human. Examples include bird and swine flu, lyme disease, bovine tuberculosis, rabies, and zika.

Ruminants

Ruminant animals are distinguished by their specialised digestive system and include species such as cattle, sheep, goats, deer, and camels. In particular, their large rumen stomach allows plant matter to be regurgitated, chewed again, and for microbes to ferment it. This breaks down plant matter into digestible molecules that can be absorbed by the animal and allows ruminants to be fed on coarse plant matter such as grass, whereas other species such as pigs and chickens cannot.



Non-ruminants such as pigs and chickens contribute less than cattle mainly because they do not emit as much methane from enteric fermentation, and their feed conversion efficiency is higher. As such, GHG emissions from pork and poultry production are lower, despite their being farmed in larger numbers.

### 3.2.3 Livestock systems can also generate benefits to the environment and people

	Benefits	Disbenefits	Comment
Nutrition	Excellent for protein, calcium, iron, vit. B12.	Excessive fat; protein can be more than needed.	Animal foods not essential; plants can substitute.
Non food benefits	Leather, wool, manure, rendered products.	Manure can be a pollutant.	Quantities needed? Plant alternatives?
Substitution cost	Eating will always produce impacts.	Generally plant foods have lower GHG profile.	
Carbon storage	Pasture land stores carbon – can sequester in right conditions if moving from bad to good grazing.	Excessive grazing & land use change releases carbon and reduces soil quality.	Land use change from pasture to crops will generate CO <sub>2</sub> . Huge uncertainties around the sequestration potential of grazing systems – more work needed.
Resource efficiency	Livestock can consume grass & by-products (some limited by legislation).	Supplemented with grains & cereals in intensive systems.	Byproducts can be used directly as energy source in anaerobic digestion systems.
Geography	Some land not suitable for cropping.	Arable land used for livestock when it could for example be allowed to re-wild.	Intensified systems are arable hungry.

Livestock can make positive contributions to sustainable food systems.

Animal products can supply many important nutritional benefits (see [Chapter 8](#)); livestock farming can also generate byproducts such as leather and wool; under the right conditions grazed pastures can store increased levels of carbon. Some research suggests that under the right conditions good grazing management can even lead to soil carbon sequestration, although the evidence base is uncertain and this is still

#### Enteric fermentation

Enteric fermentation is a natural part of the digestive process of ruminant animals (e.g. cattle and sheep) where microbes decompose and ferment the food present in large rumen portion of the stomach. As a byproduct of this fermentation process, some bacteria species in the stomach produce methane.

#### Anaerobic

Anaerobic processes occur in the absence of oxygen. For example, anaerobic respiration occurs when oxygen is not present.

a contested and under-researched issue. Animals can eat grass and byproducts not suitable for humans, and they can be produced on land not suited to crop production. Well managed livestock can also contribute to biodiversity and the aesthetic value of landscapes.

However, if livestock production continues to expand, or if livestock are poorly managed, the negatives can outweigh the positives.

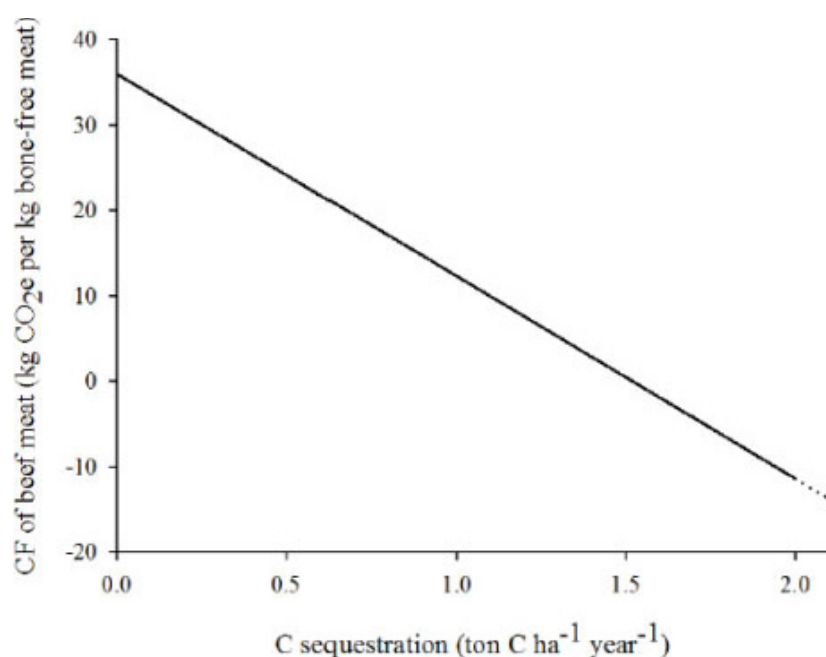
High levels of meat consumption may generate health problems (see [Chapter 8](#)); mismanaged byproducts (such as manure) can be polluting; excessive or poorly managed grazing can cause land degradation and associated soil carbon loss; while forest clearance to make way for grazing animals or feed crops causes the release of carbon dioxide and biodiversity loss. While livestock can consume byproducts, livestock in many systems (and increasingly so) are not fed solely on grass or byproducts but on dedicated feedcrops; 40% of arable-quality land is used for livestock.

### 3.2.4 Grazing livestock and soil carbon sequestration: a contested issue

#### Grazing livestock and soil carbon sequestration: a contested issue

- Advocates of grass-fed beef systems argue that well managed grazing livestock can help sequester carbon in soils.
- It is claimed that this sequestration can partly or entirely outweigh the methane and nitrous oxide the animals emit; potentially grazing livestock systems can even be 'emission negative'.

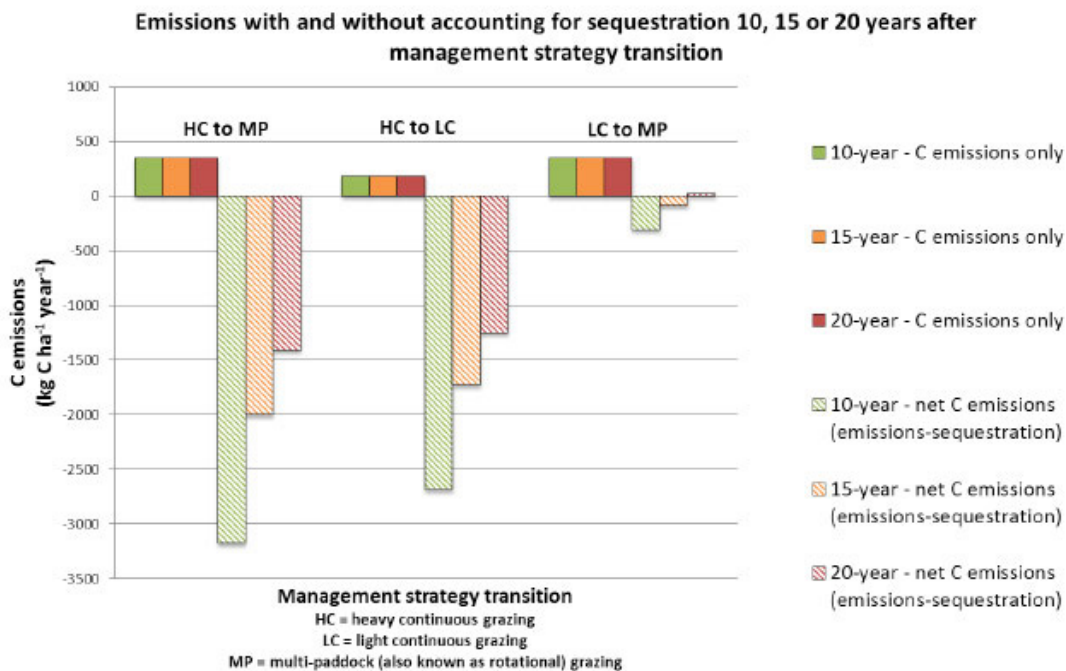
**If sequestration is assumed the carbon footprint of beef can shift from very high to very low**



**Figure 9: Relation between carbon footprint of beef and carbon sequestration.**

Source: Rööß E. and Nylander J. (2013).

## Changes in management strategy have been argued to lead to sequestration



**Figure 10: Carbon emissions after a change in grazing management strategy - with and without accounting for sequestration.**

Source: Graph produced from data presented in: Wang, *et al* (2015).

### But caution is needed...

- This is still an under researched area and the evidence base is still uncertain.
- Important to note that the benefits of avoided methane and nitrous oxide emissions are permanent, while carbon sinks are temporary.
- The extent to which sequestration occurs depends on: the status of the soil carbon levels before any management change, the baseline soil type and conditions, specific management techniques, climate, rainfall etc. – and many of these factors can change.
- Also need to consider: reversibility (grassland can be ploughed up) and saturation (after some decades soils approach carbon equilibrium; methane and nitrous oxide emissions will then always outweigh the sequestration); impacts on biodiversity can be mixed and may be negative.
- What is clear is that grasslands are major carbon stores – so it is important not to plough them up.
- Some grasslands are home to unique flora and fauna and grazing livestock may have historically contributed to this. But other grazing lands contain very little biodiversity.
- Poor grazing management can contribute to soil carbon losses while grazing livestock have historically (although less so now) been an important driver of deforestation.

## 3.2.5 Emissions from cropping and horticultural production are on average lower than those from livestock

### Fruit & vegetables

Higher GHGs



Lower GHGs



Air freighted  
Grown with additional heating or protection  
Pre-prepared, trimmed or chopped  
Fragile or highly perishable  
Unseasonal products (where airfreighted or grown with heated/protected environment)  
Seasonal field grown, robust produce  
  
Grown without additional heating or protection  
Overseas produce field grown, robust produce grown without additional heating or protection & transported short distances by sea or road  
Domestic is not always better

**Figure 11: Hierarchy of greenhouse gas emissions from fruit and vegetables.**

Source: FCRN. (2016).

Lower GHGs, but this depends on energy use and later stage inputs.

Fruit and vegetables contribute fewer GHGs than livestock on average, measured in terms of kg CO<sub>2</sub> eq./kg product – although other functional units may include emissions per unit of calories or protein, and the differences between products may narrow or widen.

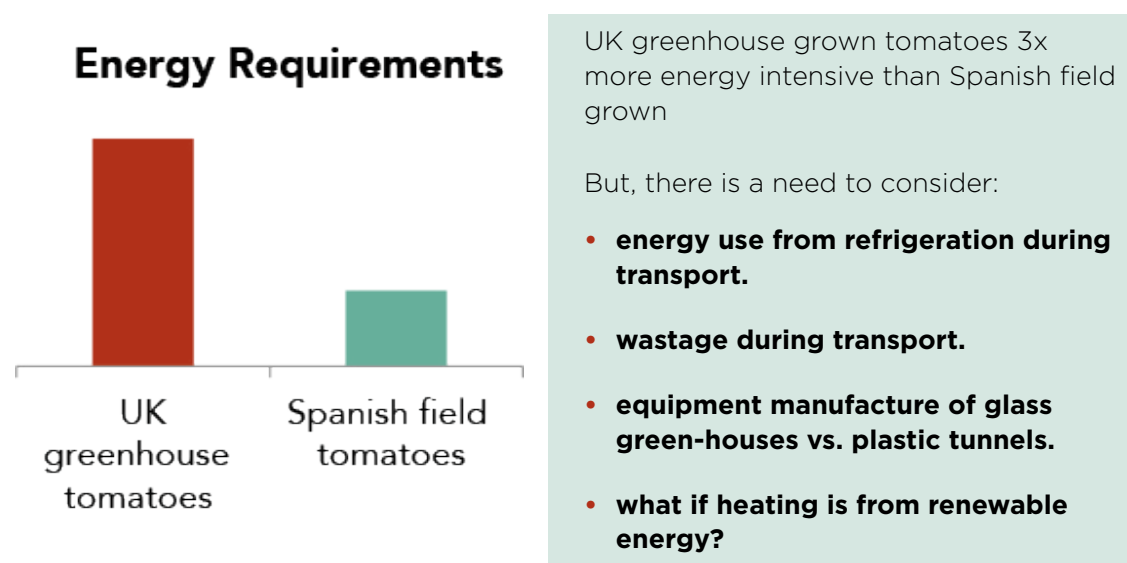
Lower impact produce are those that are field grown (for example not grown in greenhouses), transported shorter distances by road or ship (not air) and those that are more robust – i.e. less requiring of rapid transport modes such as air and less perishable – thus less prone to being spoiled or wasted.

More emissions-intensive fruit and vegetables are typically those grown in heated greenhouses, where much higher energy inputs are required. Airfreighting is extremely GHG intensive and so any produce transported in this way has a very high carbon footprint. Highly fragile produce may be more easily spoiled and wasted, meaning a waste of embedded emissions.



## 3.2.6 Produce grown in heated greenhouse systems can have high emissions (UK example)

### UK example – heated greenhouse impacts



**Figure 12: Comparison of energy use to produce tomatoes – UK greenhouse vs. Spanish field grown.**

Source: FCRN. (2016).

A study by the UK Department for Environment, Food and Rural Affairs (Defra) measured the GHG emissions from heated tomato production in the UK, compared to imported field grown (non-heated) tomatoes from Spain. The UK tomatoes were found to be three times more energy intensive than Spanish, due to the fossil-fuel energy requirements of heated food production in the UK. The warmer climate in Spain meant that additional heating was not required. See [Section 3.3](#) for more on this.

However, this was not a full study of all the impacts, including water use, while important factors such as energy use in refrigeration during transport were not included. Additionally, it is important to make sure that like-for-like product comparisons are made – for example cherry tomatoes have different production and storage requirements to standard tomatoes.

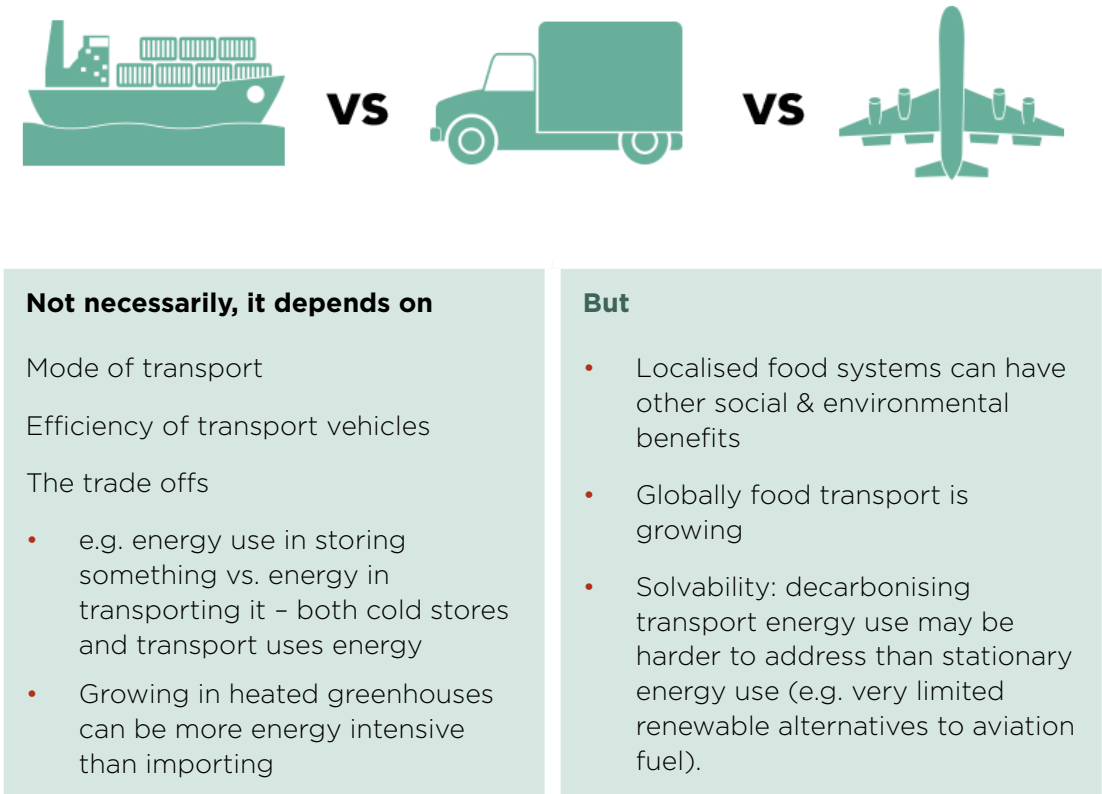
A further study (Antón et al. 2005) compared the impacts of permanent glass greenhouses in the UK with plastic (short-lived) tunnels in Spain, finding that the energy used to produce the plastic tunnels was a significant contribution to the overall impact.

The point is that heated production uses energy and has GHG emissions associated with it, but impacts from transport, material production, and storage as well as environmental issues other than GHGs need to be considered.

## 3.3 How important is transport?

### 3.3.1 GHG contributions from transport depend on the mode of transport

#### Food Miles: Is nearer better?



**Figure 13: Food miles – is nearer better?**

Source: FCRN. (2016).

GHG impacts arising food transport are not particularly significant, although they have increased in recent years.

The mode of transport is important, with air-freight having a much higher impact (see below).

This impact cannot, however, be assessed in isolation from impacts at other stages.

There are trade-offs to consider regarding energy use for both storage and transport, because both emit GHGs. This underlines the point that the whole system needs to be considered.

There may be other social, economic and environmental benefits arising from more localised food systems.

### 3.3.2 Air freighting food generates high GHG impacts

#### Air freighting food generates high GHG impacts

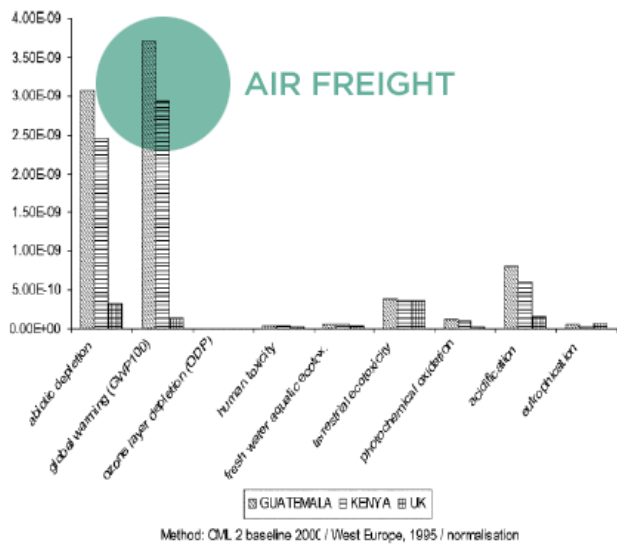


Figure 14: Comparison of impacts of air freighted vs. locally produced food.

Source: Sim. (2007).

Airfreighting is the most GHG-intensive mode of transport. This study shows how the impact from long-distance transport via air as compared with other modes (in this case road), can be very high. However a full life cycle approach needs to be taken. A comparison between roses grown in heated conditions in the Netherlands and then transported the short journey to the UK versus those grown in Kenya and airfreighted to to the UK found that the airfreighted roses had lower overall emissions.

This is because the heating and lighting requirements to grow roses are extremely high, and therefore highly energy intensive.

### 3.3.3 We cannot consider “food miles” in isolation of other life cycle impacts

#### Further isn’t always worse

Green = Lower in comparison Red = Higher in comparison	GWP t CO <sub>2</sub> eq. t <sup>-1</sup>	
	UK	Overseas
Tomatoes, UK vs Spain	2.2	0.7
Strawberries, UK vs Spain	1.0	0.9
Potatoes, UK vs Israel	0.3	0.5
Poultry, UK vs Brazil	2.8	2.6
Beef, UK vs Brazil	24.0	32.2
Apples, UK vs New Zealand	0.3	0.9
Lamb, UK vs New Zealand	14.1	11.6

Figure 15: Comparison between life cycle greenhouse gas emissions of foods – air freighted vs. UK produced.

Source: Webb, et al. (2013).

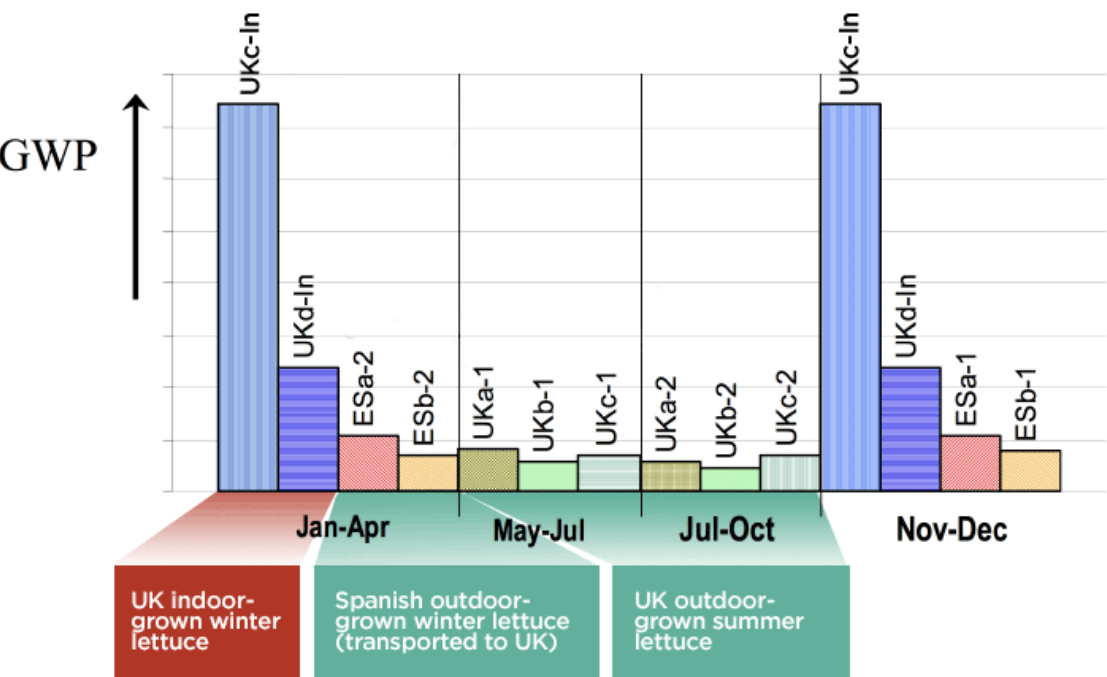
The above table illustrates that different products have different GHGs when imported to the UK vs. produced in the UK. “Food miles” cannot reliably indicate the total GHG emissions arising from a particular food product.

Different regions and countries have better growing conditions for certain foods; this may mean that, even after transport, the total GHG emissions of imported food can be lower than home-grown food.

However assessing the sustainability of products requires a wider consideration of other environmental, social, ethical and economic factors. In short, “food miles” are not a good indicator of sustainability.

### 3.3.4 Seasonal food choices can make a difference

#### Relative importance of transport can depend on seasons



**Figure 16: The effect of season and location on greenhouse gas emissions from lettuce production.**

Source: Edwards-Jones, G., et al. (2008).

This study illustrates the difference in GHGs for lettuce consumed in the UK for different seasons.

In winter, lettuce grown in the UK (grown indoors with fossil-fuel based heating and lighting) has a higher GHG footprint than field-grown Spanish imported lettuce, despite the shorter transport distances for UK lettuce.

In the summer, more UK lettuce can be grown outdoors, resulting in lower comparative GHGs for UK lettuce produce.



In other words, in winter the lowest GHG option is Spanish lettuce; in summer UK field-grown lettuce has (generally) lower GHGs. There are other important issues to consider however, such as water scarcity and pesticide use.

### 3.3.5 Positive developmental effects of export horticulture

**Export horticulture in low income countries can contribute positively to development**

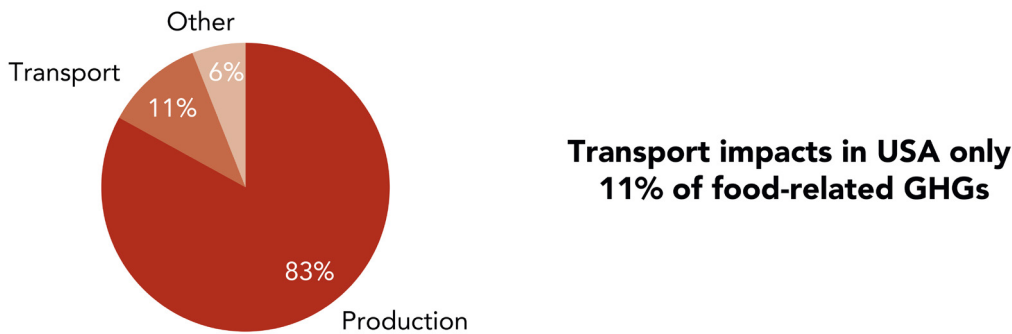
- High-value products with modern supply chains can contribute positively to incomes and jobs in poorer countries.
- Employment and supplier rights are important conditions of these successes and need to be present.
- Ethical trading initiatives can contribute to positive outcomes.

Products that are air-freighted may have high relative GHGs, but they also contribute positively to economic development in less developed countries. Well-managed production with modern supply chains and strong supplier/employee rights and gender equality has been shown to positively influence welfare in these situations. Standards can be strengthened following involvement in ethical trading initiatives.

The developmental benefits of export horticulture are good example of the kind of trade-offs first mentioned in **Chapter 1**, where some GHG mitigation initiatives (a switch away from air transport) may potentially have negative socio-economic consequences (the loss of employment and livelihoods in less developed countries). Note that perishable products, such as green beans, that are commonly grown in Sub Saharan Africa for export are too perishable to be transported the longer journey by sea.

### 3.3.6 Transport impacts in the USA

**Transport impacts in different regions – USA as an example**



**Figure 17: Relative contribution of transport to food related greenhouse gas emissions in the United States of America.**

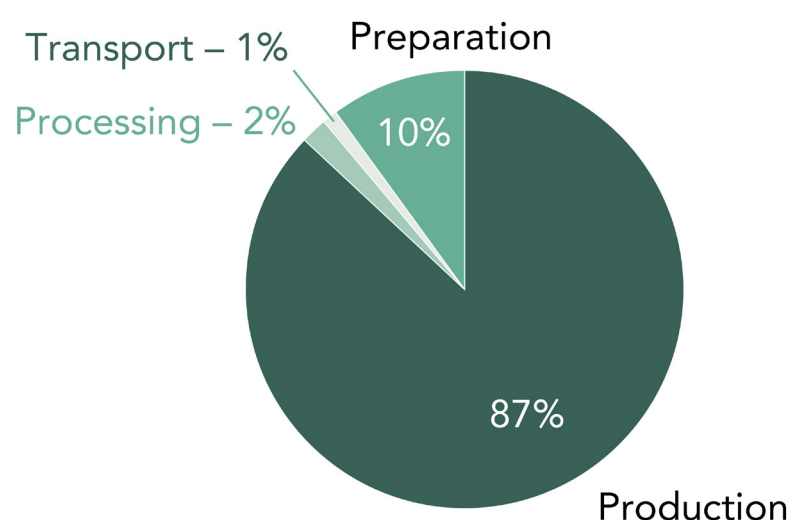
Source: Weber and Matthews. (2008).

This USA study found transport to contribute 11% of food related GHGs. The production stage contributed 83%, although their definition includes food processing, manufacture and preparation, not just agricultural production.

Note that the 11% is similar to the figure for food transport in the UK (12%) – see earlier in this chapter.

### 3.3.7 Transport impacts in India

#### Transport impacts in different regions – India as an example



**Figure 18: Relative contribution of transport to food related greenhouse gas emissions in India.**

*Source: Pathak, et al. (2010).*

This study in India found that agricultural production accounted for 87% of food system GHGs, while transport and other stages such as processing have a very small relative impact. This reflects the fact that food systems in India tend to be more localised and less mechanised than in countries such as the US or UK. More locally produced food is consumed, so transport impacts are very low.

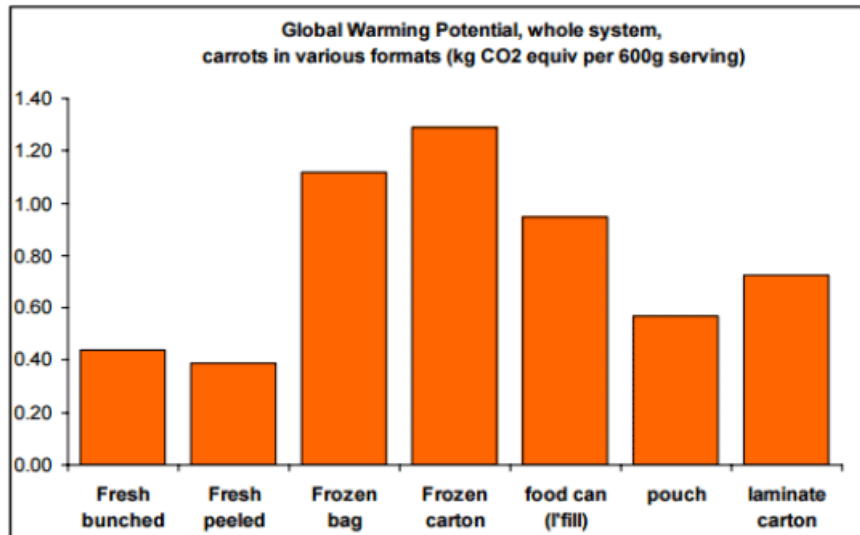
In general, there is a lack of research in Asia, and it is unclear how this might change over time.

It is unclear how the relative impact of non-agricultural stages might change over time, as diets and production systems shift as a result of industrialisation and economic development.

See [Chapter 4](#) and [Chapter 7](#) for more on dietary changes in different regions.

## 3.4 How important is storage and packaging?

### 3.4.1 Fresh vs. frozen



**Figure 19: Greenhouse gas emissions for carrots according to type of preservation and packaging used.**

Source: Lighthart, Ansems and Jetten. (2005).

This study finds that frozen carrots have higher impacts than fresh, due to energy use for freezing and cold storage. Similar results are found for broccoli.

But there are questions to consider:

- To what extent does fresh produce generate greater waste than frozen?
- If year-round fresh broccoli or carrots is obtained through imports that have energy costs, might frozen produce be better outside of the growing season?

#### **Carrots :**

Freezing food requires energy and packaging. This research showed higher GHGs for frozen, canned and packaged (laminate carton) carrots than fresh.

#### **Broccoli:**

Frozen broccoli has been shown to have higher GHGs than fresh broccoli, but the difference in GHGs depends on other factors such as food waste and transport.

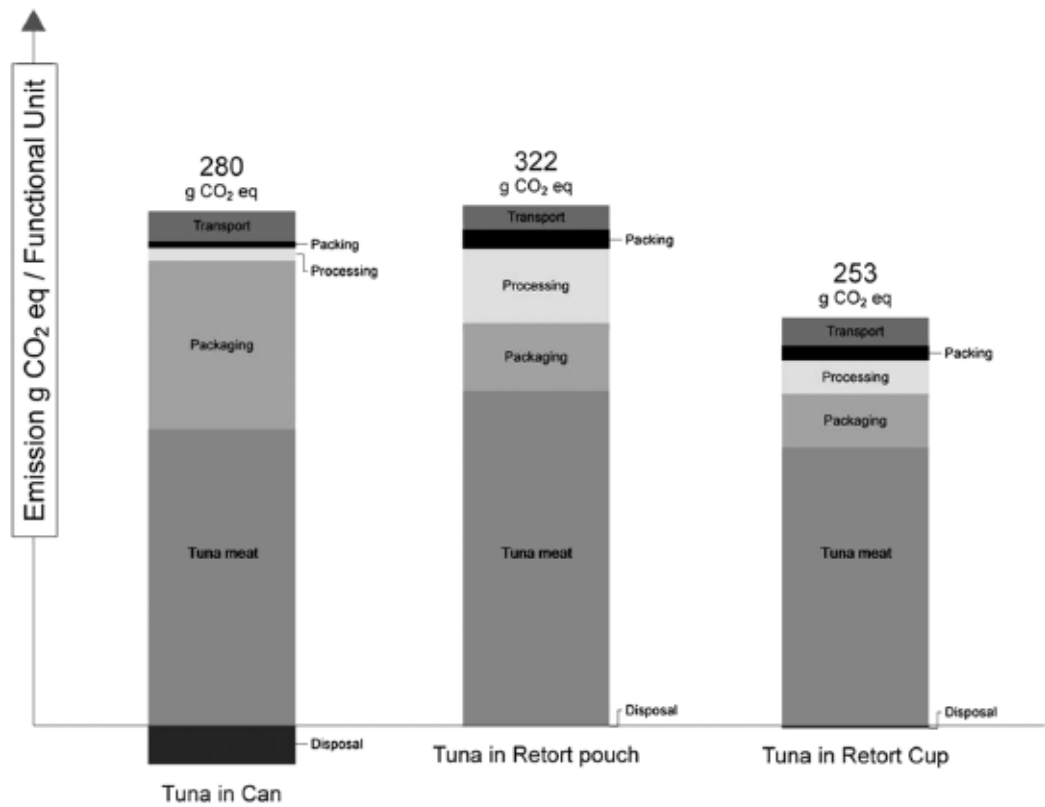
If less food is wasted from frozen produce, then the difference between fresh and frozen in GHGs per consumed food may be less significant.

With regard to seasonality, eating frozen produce “out of season” that has been produced locally could offset the transport GHGs of eating fresh produce that has been transported long distances.

As always, the full life cycle of the product needs to be considered.

### 3.4.2 Packaged and canned food

Canning and packaging increase GHGs due to material extraction, production and energy use. Here, all forms of packaging increased the GHG emissions associated with tuna.



**Figure 20: Life cycle greenhouse gas emissions related to different tuna products.**

Source: Poovarodom, Ponnak and Manatphrom. (2012).

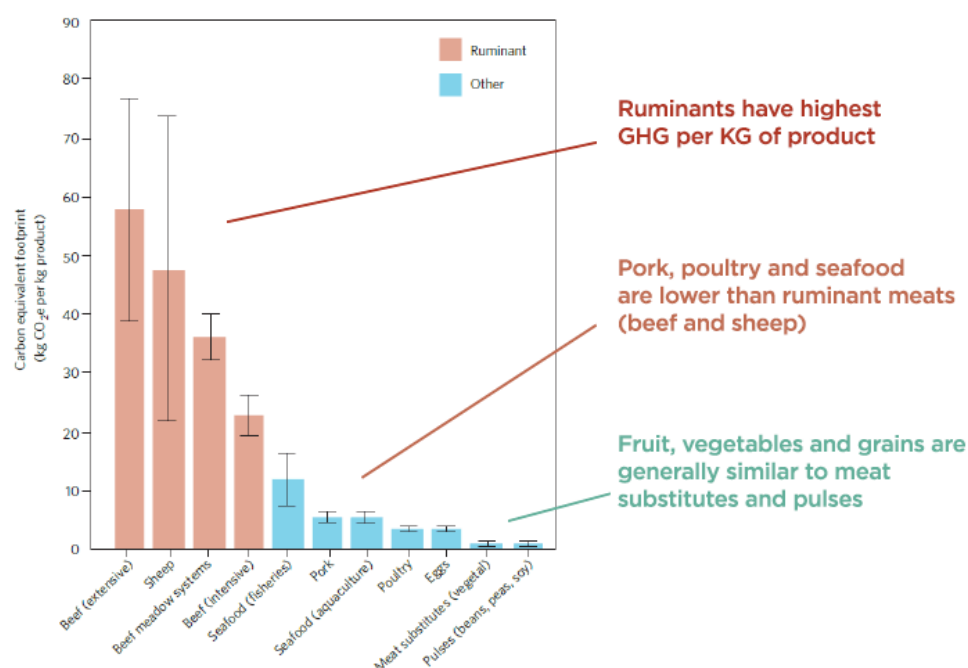
However, these additional emissions also need to be compared to emissions from cold storage (freezing or refrigeration) of tuna meat, and potential product wastage of fresh tuna.



## 3.5 Which food products have the highest overall impacts?

### 3.5.1 Relative GHGs of different food products

#### Relative GHGs of different food products



**Figure 21: Average greenhouse gas emissions from different protein-rich foods per kg of product.**

Source: Ripple *et al.* (2014).

This study shows the difference in GHG per kg of produce from different food types.

Per kg of product, all ruminants (cattle and sheep mainly, but also goats) have higher GHG emissions than other foods, primarily due to methane production. These data do not take into account any assumptions about the potential for grazing livestock to contribute to soil carbon sequestration (see [earlier in this chapter](#) for more on this).

Monogastric (single stomach) livestock such as pigs and poultry have lower GHG emissions due in the main to the lack of methane produced by enteric fermentation and other efficiencies such as higher feed conversion rates.

While GHG contributions from livestock vary by type, there are very important non-GHG issues to consider when making comparisons.

Seafood GHGs can vary, but are still lower than ruminants.

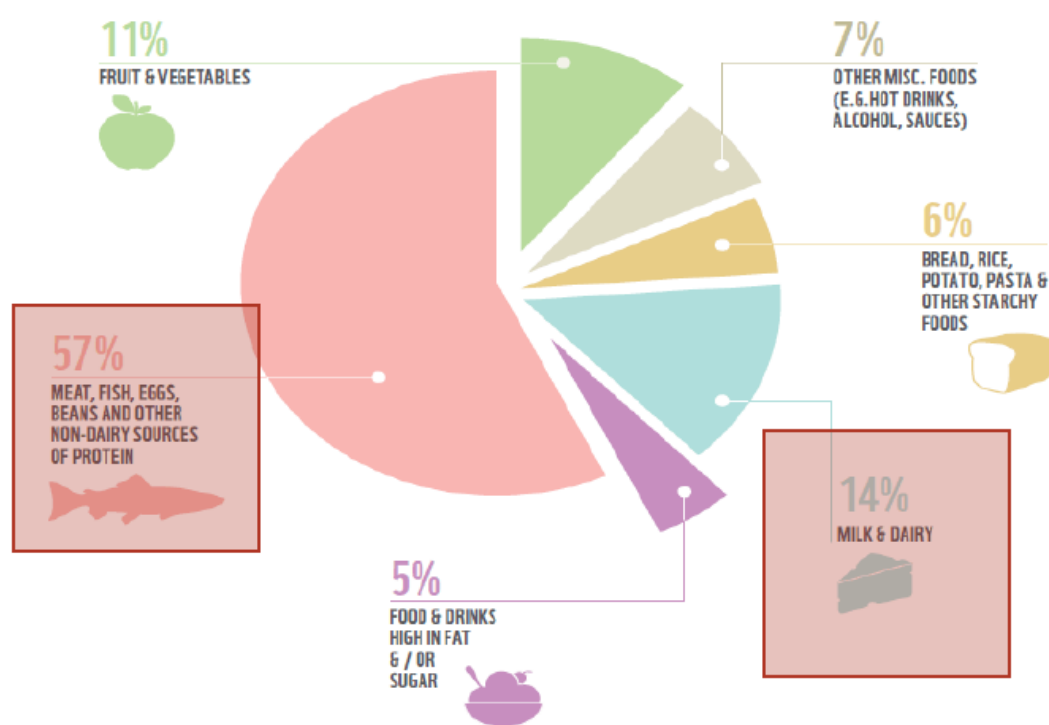
Fruits, vegetables and grains have the lowest GHG emissions. This study focuses on protein-rich foods, but many fruits, vegetables and grains have similar GHG emissions to pulses shown here (unless airfreighted, grown in greenhouses etc., in which case the GHG per kg of product may be increased considerably as discussed [earlier in this Chapter](#)).

One consideration to bear in mind is how different functional units can influence relative GHG emissions (see [Chapter 2](#) for more on functional units). For example, if we measure GHG emissions per 100g of protein, rather than per kg of product, then the relative difference between meats and vegetables can decrease. This is important when seeking to define what healthy and sustainable eating patterns look like (see [Chapter 7](#) and [Chapter 9](#) for more on this).

### 3.5.2 Animal products dominate contributions from western diets – the UK as an example

WWF UK's Livewell report in 2011 showed the relative GHGs from food, based on an average diet.

#### Meat and dairy contribute the most GHGs in typical western diet



**Figure 22: Relative contribution of different food groups to diet related GHG emissions.**

Source: WWF-UK (2011). Livewell Report, UK.

It shows that, from a dietary perspective, meats, fish, eggs and non-dairy protein sources contributed over half of the GHGs arising from a typical British diet.

Dairy contributed the next highest (14%), and a third was GHGs from fruit and vegetables. Fruit and vegetables in general have a lower per kg GHG than animal products, but can have higher GHGs than sugary processed foods. If people consumed more fruits and vegetables, in line with health recommendations, clearly the impacts of this category would increase and other categories could decline.

### 3.5.3 GHG hotspots in production and supply chain vary by food type

Emissions from agriculture dominate the carbon footprint of most foods – CH<sub>4</sub> emissions from ruminants; nitrous oxide from soils; CH<sub>4</sub> and N<sub>2</sub>O from manure; and CO<sub>2</sub> from energy use on the farm (tractor fuel and fuel for heating) and for the production of mineral fertilisers.

This is always the case for animal products, but for plant-based foods there are some exceptions:

- Transport will dominate if produce is air-freighted or when fruits and roots are transported very long distances.
- Packaging: contributes significantly to GHG emissions of bottled drinks.
- Preparation/cooking: this can be significant for lower impact foods, e.g. a baked potato.
- Storage – frozen peas, or see frozen carrots example [here](#).

These are just examples, and many of the topic areas have been discussed in more detail already. A great deal depends on the energy source that is used: for example if peas are frozen using renewable energy then the relative impact of the freezing and storage process will be lower than if fossil-fuel based energy is used. The same would apply for preparation and storage.

All the post harvest impacts very much depend on the energy source used. Using packaging as an example, the contribution of this step to a product's carbon footprint is influenced by the recycling rate of packaging materials (for example glass bottle, jars and metal tins). Higher recycling rates would in theory reduce the relative GHG emissions for producing 1 bottle of beer for example, because the bottle would not need to be made from scratch every time, although breakage rates and the distance to the recycling plant will influence the conclusion.

## 3.6 Conclusions

Food systems contribute up to 30% of global GHG emissions.

Agriculture contributes the largest share of this.

Within agriculture, GHG emissions from livestock are highest; protected horticulture can also have high impacts. Some methods of transport, packaging, preparation and storage also result in foods with high GHG emissions.

Our dietary patterns have a strong bearing on overall GHG emissions since our demand for certain types of food drives food production and associated emissions.

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See also the FCRN blog-post: [Grazing livestock in a world of climate change: do they have a role?](#) by Elin Rööb

For a more detailed discussion presenting two existing perspectives on the benefits and disbenefits, see for example [these blog post discussions](#) between FCRN's Tara Garnett and Sustainable Food Trust's Richard Young on the topic of red meat

For an example of some of the claims made about the potential of grazing livestock to sequester carbon see: Savory Institute (2013). [Restoring the climate through capture and storage of soil carbon through holistic planned grazing](#), Savory Institute

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