Food Footprint

part I

unite peas 22-23

The nexus

Food, energy and water: this is what the United Nations refers to as the ‘nexus’ of sustainable development.

As the world’s population has expanded and gotten richer, the demand for all three has seen a rapid increase.

Not only has demand for all three increased, but they are also strongly interlinked: food production requires water and energy; traditional energy production demands water resources; agriculture provides a potential energy source.

Today’s lecture

Today we shall focus on the environmental impact of food production and distribution.

Ensuring everyone in the world has access to a nutritious diet in a sustainable way is one of the greatest challenges we face.

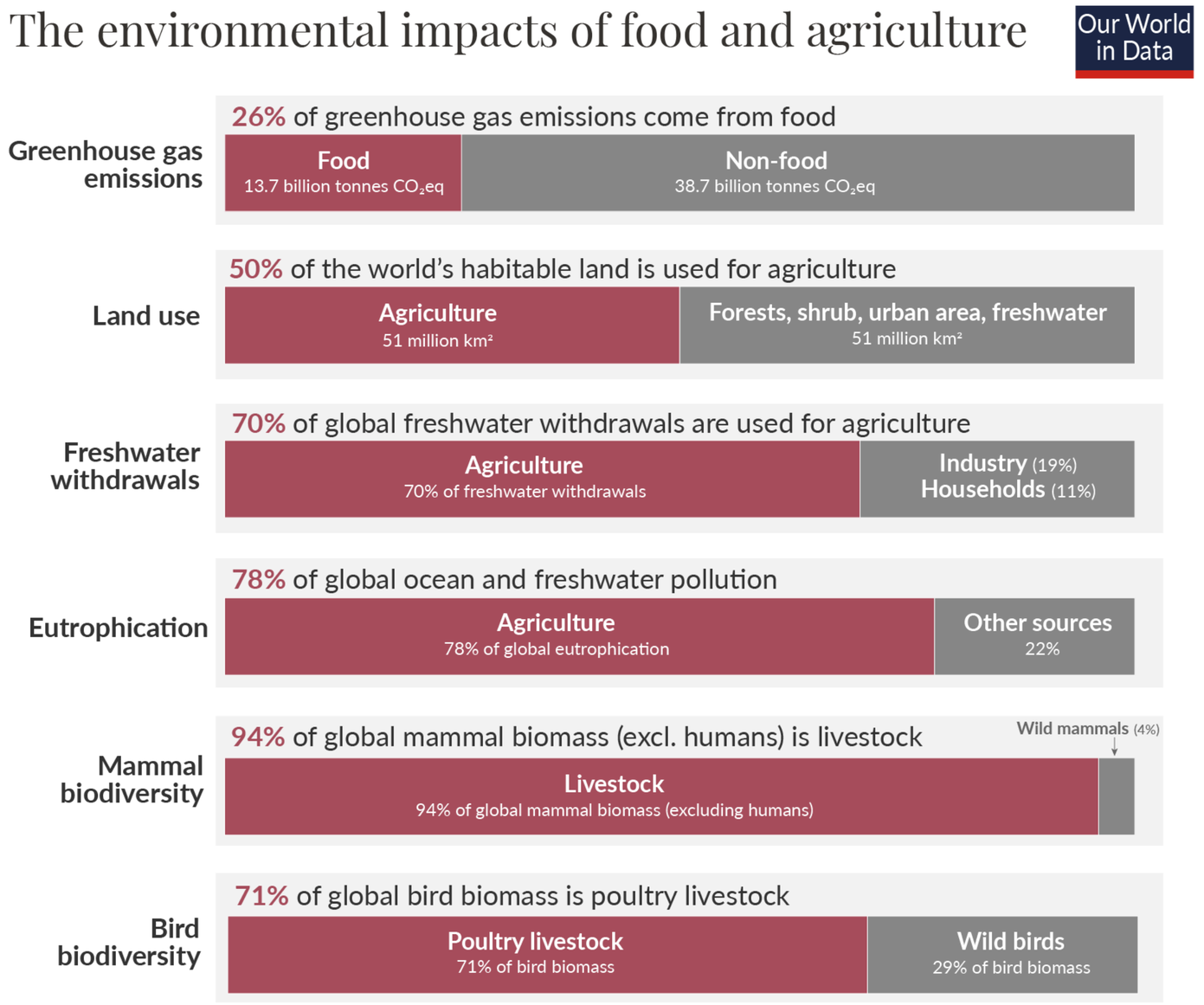
Environmental impacts of food and agriculture

Environmental impact of food and agricolture

A summary of some of the main global impacts:

- Food accounts for over a quarter (26%) of global greenhouse gas emissions;
- Half of the world's habitable (ice- and desert-free) land is used for agriculture;
- 70% of global freshwater withdrawals are used for agriculture;
- 78% of global ocean and freshwater eutrophication (the pollution of waterways with nutrient-rich pollutants) is caused by agriculture;
- 94% of mammal biomass (excluding humans) is livestock. This means livestock outweigh wild mammals by a factor of 15-to-1.

Food, therefore, lies at the heart of trying to tackle climate change, reducing water stress, pollution, restoring lands back to forests or grasslands, and protecting the world's wildlife.



Land Use

Land Use 1

For much of human history, most of the world's land was wilderness.

Over the last few centuries, this has changed dramatically: wild habitats have been squeezed out by turning it into agricultural land.

If we rewind 1000 years, it is estimated that only 4 million square kilometers – less than 4% of the world's ice-free and non-barren land area was used for farming.

10% of the world is covered by glaciers, and a further 19% is barren land. This leaves what we call 'habitable land'.

Half of all habitable land is used for agriculture.

Land Use 2

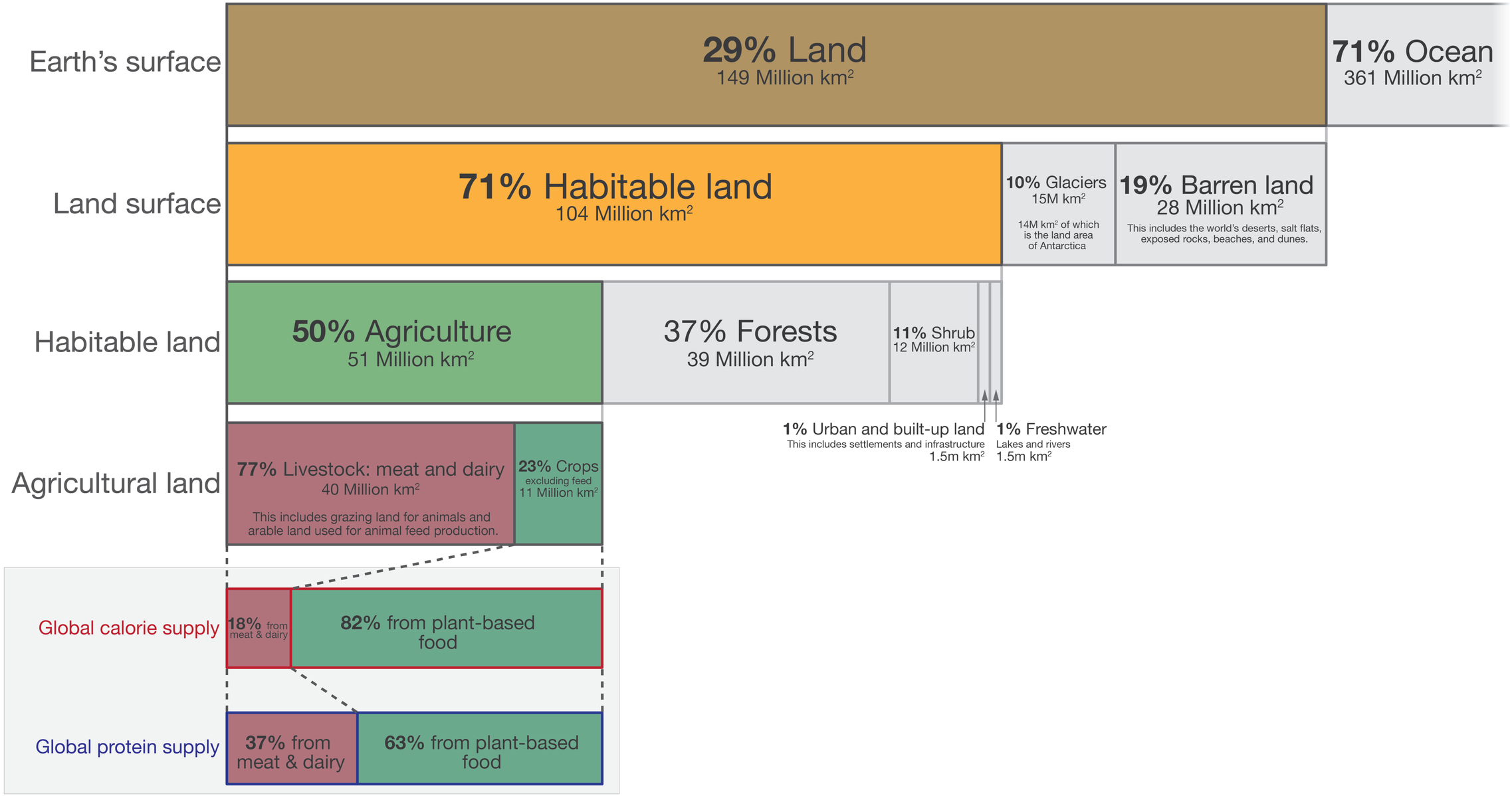
This leaves only 37% for forests; 11% as shrubs and grasslands; 1% as freshwater coverage and the remaining 1% is built-up urban area.

There is also a highly unequal distribution of land use between livestock and crops for human consumption. If we combine pastures used for grazing with land used to grow crops for animal feed, livestock accounts for 77% of global farming land. While livestock takes up most of the world's agricultural land it only produces 18% of the world's calories and 37% of total protein.

The expansion of agriculture has been one of humanity's largest impacts on the environment. It has transformed habitats and is one of the greatest pressures for biodiversity: of the 28,000 species evaluated to be threatened with extinction on agriculture is listed as a threat for 24,000 of them.

But we also know that we can reduce these impacts – both through dietary changes, by substituting some meat with plant-based alternatives and through technology advances. Crop yields have increased significantly in recent decades, meaning we have spared a lot of land from agricultural production: globally, to produce the same amount of crops as in 1961, we need only 30% of the farmland.

Global land use for food production



Data source: UN Food and Agriculture Organization (FAO)

Land use footprint of food

How do the land footprint of different food products compare? Which foods used the most and least land in their production?

We can look at these comparisons based on mass: the land used to produce one kilogram of food product.

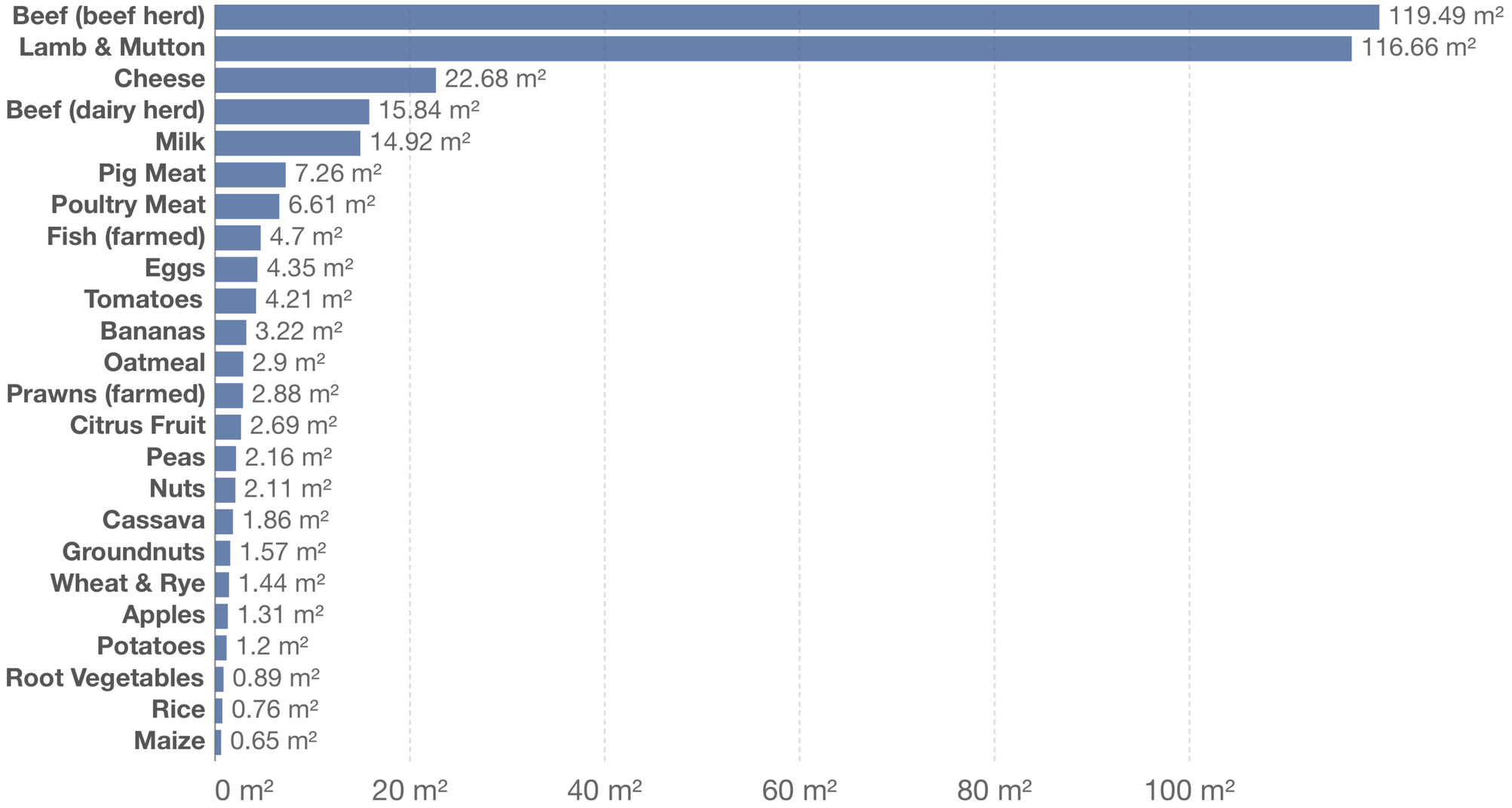
But it's also important to look at these comparisons in terms of nutritional units: this gives a measure of how low or high-impact different foods are in supplying protein or energy/calories.

Next slide: we show the land footprint of foods, measured in m2 per kilogram, 100 grams of protein, and per 1000 kilocalories.

Land use of foods per 1000 kilocalories

Land use is measured in meters squared (m²) required to produce 1000 kilocalories of a given food product.

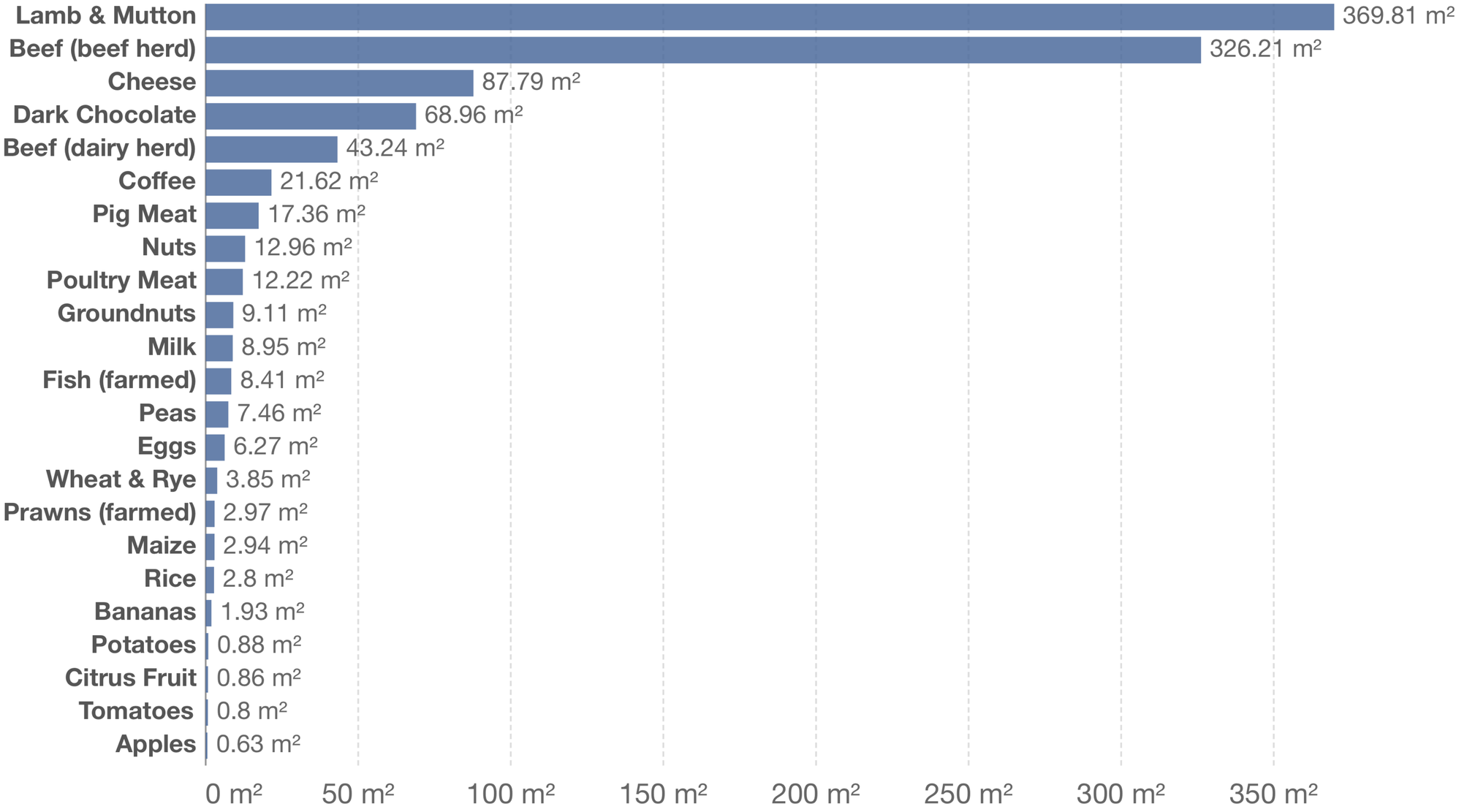
Our World in Data



Source: Poore, J., & Nemecek, T. (2018). Additional calculations by Our World in Data.
Note: The median year of the studies involved in this research was 2010.

Land use per kilogram of food product

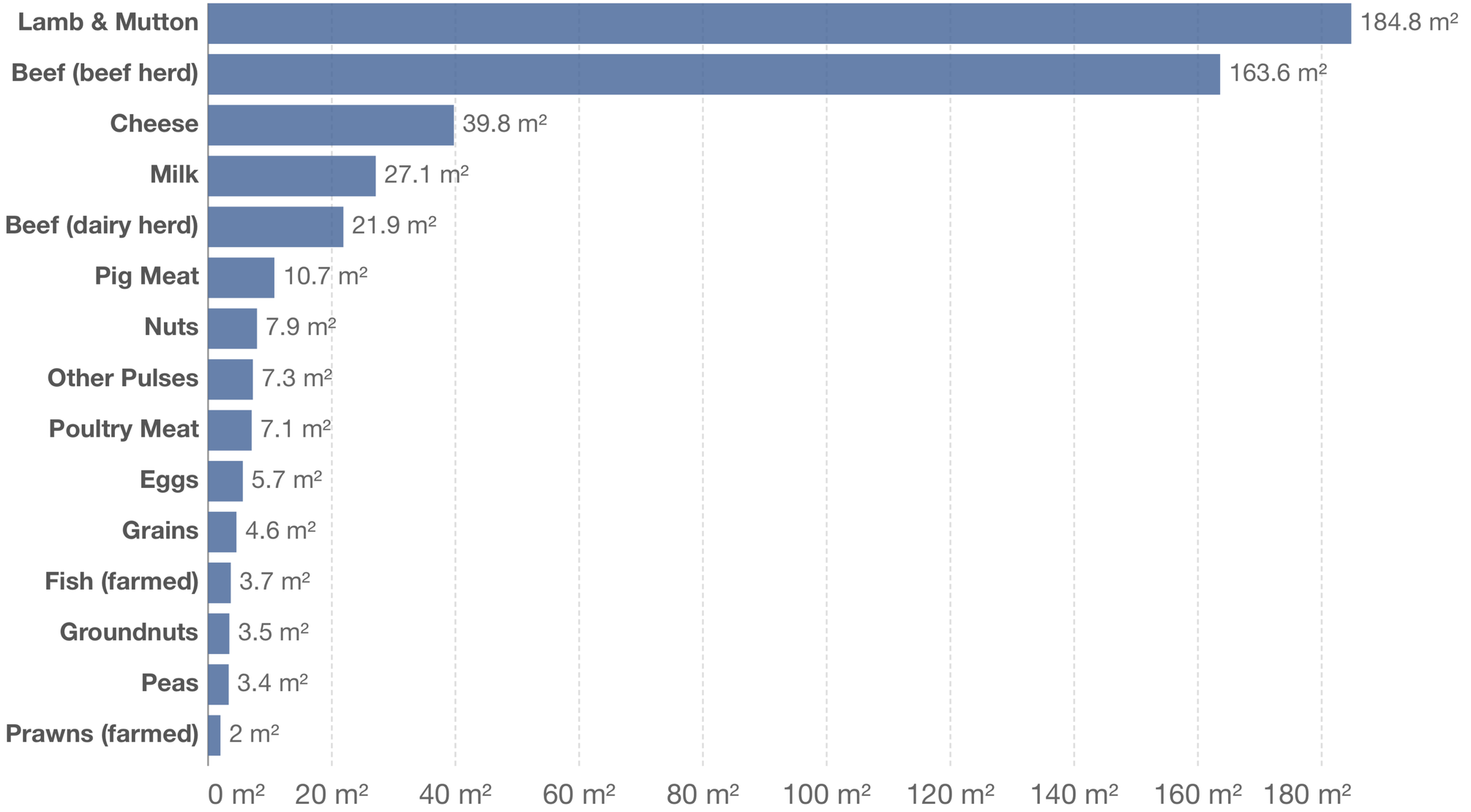
Land use is measured in meters squared (m²) per kilogram of a given food product.



Source: Poore, J., & Nemecek, T. (2018). Reducing food's environmental impacts through producers and consumers.
OurWorldInData.org/environmental-impacts-of-food • CC BY

Land use per 100 grams of protein

Land use is measured in meters squared (m²) per 100 grams of protein across various food products.



Source: Poore, J., & Nemecek, T. (2018). Additional calculations by Our World in Data.
OurWorldInData.org/environmental-impacts-of-food • CC BY

Poore and Nemeck results

Poore, J., & Nemecek, T. (2018). Reducing food's environmental impacts through producers and consumers. *Science*, 360(6392), 987-992.

Most charts which compare the land footprint of different food products look at the average value for each. This is a useful comparison, but could mask large differences in land footprints depending on where and how they are produced.

In this study, the authors looked at data across more than 38,000 commercial farms in 119 countries. Land use here is measured in meters squared (m2) of agricultural and – which includes pasture and land for crops or animal feed – per 100 grams of protein.

But since there are large differences between producers, this chart also shows the full spectrum of land use – from the lowest to highest producers. The height at each point in the curve represents the amount of global production with that specific footprint.

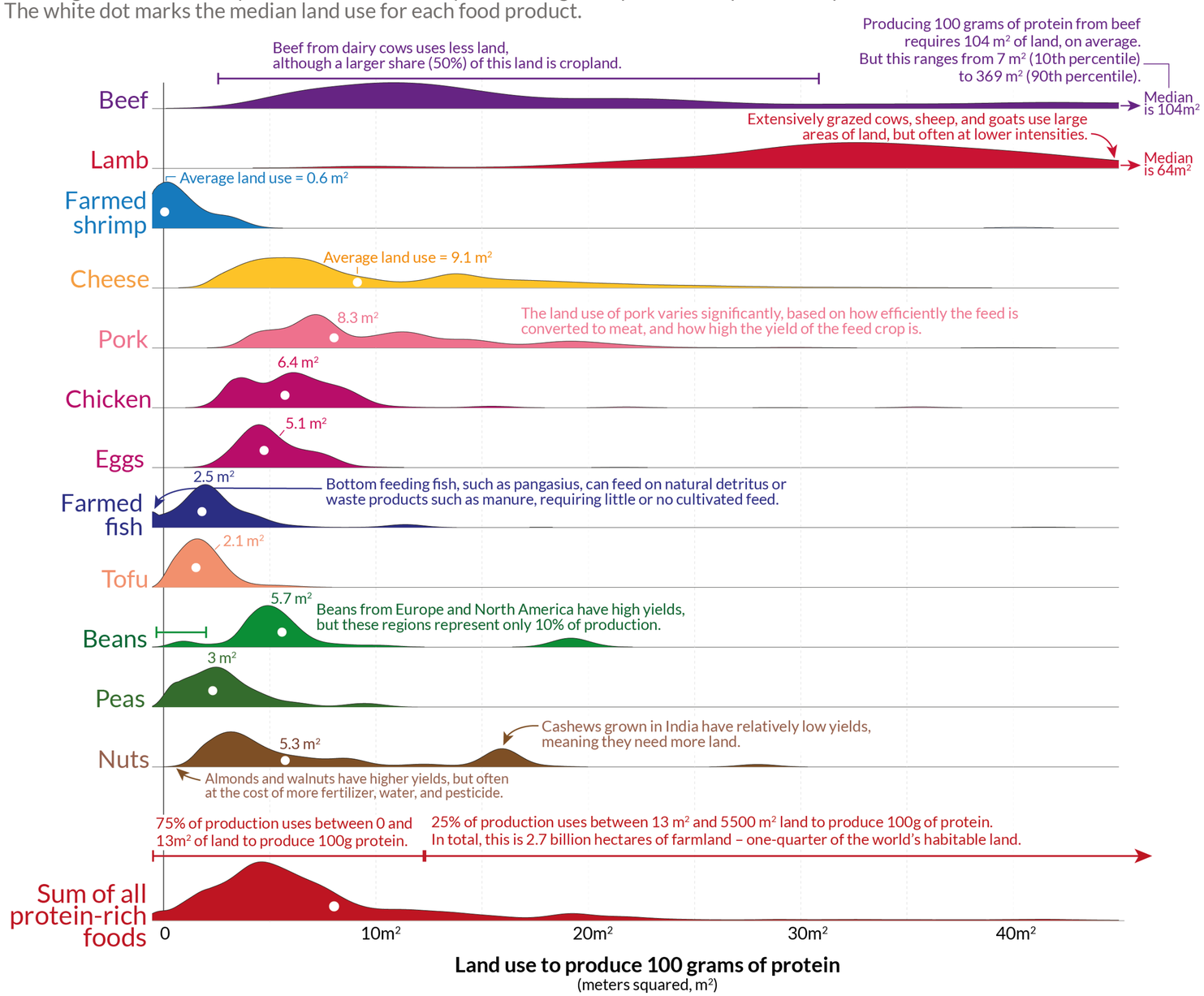
The median footprint for beef is 104 m2 per 100 grams of protein. But the range across producers is huge: spanning from 7 m2 to 369 m2.

The land use of foods are largely dependent on the intensity of farming. This is certainly true for crops: higher yields mean they need less land. But also for livestock: animals fed on crops with very high yields will need less land.

How much land do different food products use?

Land use from protein-rich foods are shown per 100 grams of protein across a global sample of 38,700 commercially viable farms in 119 countries.
The height of the curve represents the amount of production globally with that specific footprint.
The white dot marks the median land use for each food product.

Our World in Data



Data source: Poore & Nemecek (2018). Reducing food's environmental impacts through producers and consumers. *Science*.

CO2 and GHG emissions

Co2 and greenhouse gas emissions

When it comes to tackling climate change, the focus tends to be on ‘clean energy’ solutions. Indeed, energy accounts for the majority – 76% – of greenhouse gas (GHG) emissions.

But the global food system, which encompasses production, and post-farm process such as processing, and distribution is also a key contributor to emissions. And it’s a problem for which we don’t yet have viable technological solutions.

Next slide – based on Poore and Nemecek (2018) - summarizes food’s share of total emissions and breaks it down by source.

Food is responsible for approximately 26% of global GHG emissions.

There are four key elements to consider when trying to quantify food GHG emissions.

Livestock & fisheries account for 31% of food emissions

Livestock – animals raised for meat, dairy, eggs and seafood production – contribute to emissions in several ways.

Ruminant livestock – mainly cattle – for example, produce methane through their digestive processes (in a process known as ‘enteric fermentation’).

Manure management, pasture management, and fuel consumption from fishing vessels also fall into this category.

This 31% of emissions relates to on-farm ‘production’ emissions only: it does not include land use change or supply chain emissions from the production of crops for animal feed: these figures are included separately in the other categories.

Crop production accounts for 27% of food emissions

21% of food's emissions comes from crop production for direct human consumption, and 6% comes from the production of animal feed.

They are the direct emissions which result from agricultural production – this includes elements such as the release of nitrous oxide from the application of fertilizers and manure; methane emissions from rice production; and carbon dioxide from agricultural machinery.

Land use accounts for 24% of food emissions

Twice as many emissions result from land use for livestock (16%) as for crops for human consumption (8%).

Agricultural expansion results in the conversion of forests, grasslands and other carbon ‘sinks’ into cropland or pasture resulting in carbon dioxide emissions.

‘Land use’ here is the sum of land use change, savannah burning and organic soil cultivation (plowing and overturning of soils).

Supply chains account for 18% of food emissions

Food processing (converting produce from the farm into final products), transport, packaging and retail all require energy and resource inputs.

Many assume that eating local is key to a low-carbon diet, however, transport emissions are often a very small percentage of food's total emissions – only 6% globally.

Whilst supply chain emissions may seem high, at 18%, it's essential for reducing emissions by preventing food waste. Food waste emissions are large: one-quarter of emissions (3.3 billion tonnes of CO2eq) from food production ends up as wastage either from supply chain losses or consumers. Durable packaging, refrigeration and food processing can all help to prevent food waste. For example, wastage of processed fruit and vegetables is ~14% lower than fresh, and 8% lower for seafood.13

Hard stuff…

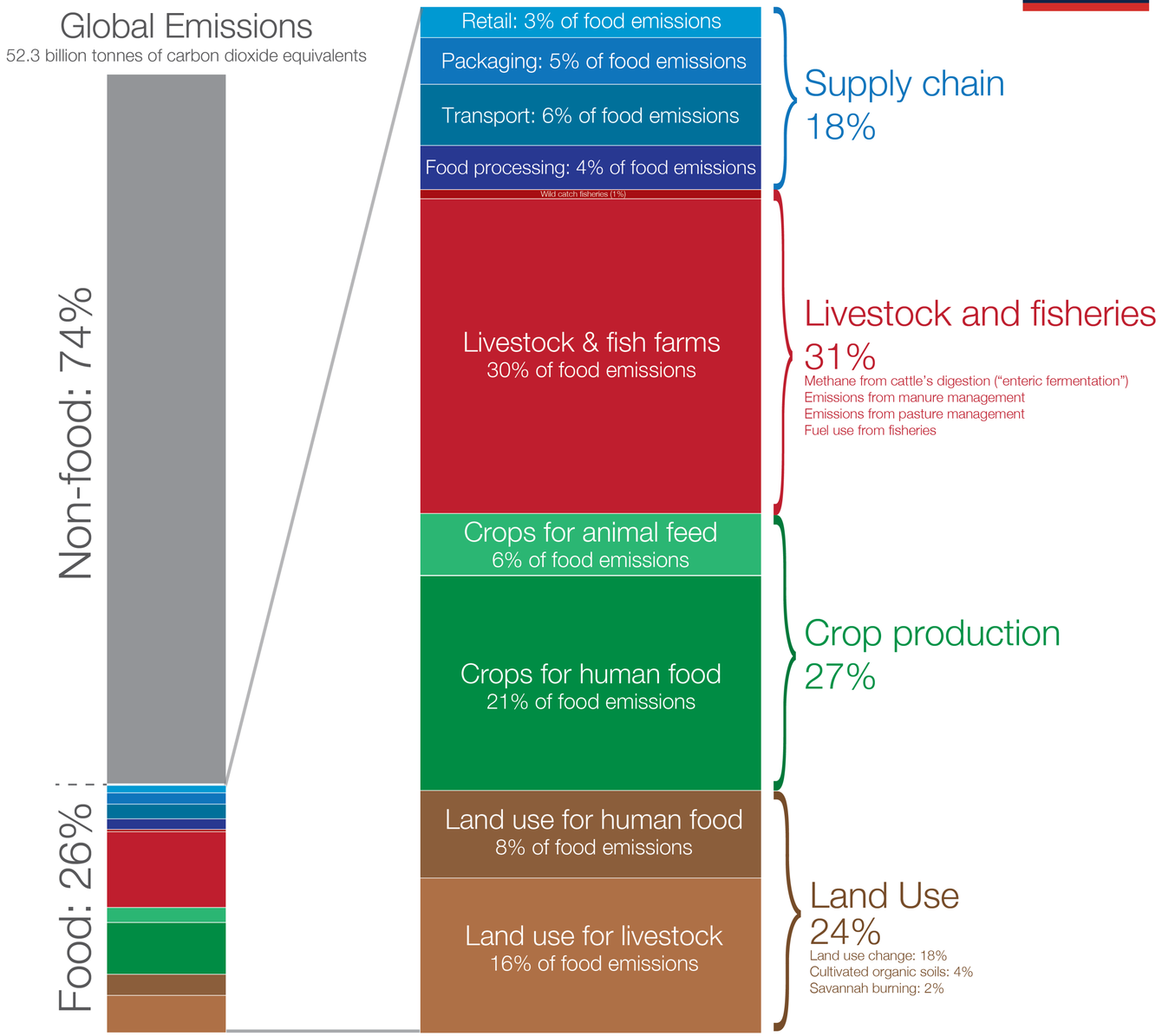
Reducing emissions from food production will be one of our greatest challenges in the coming decades.

Unlike many aspects of energy production where viable opportunities for upscaling low-carbon energy – renewable or nuclear energy – are available, the ways in which we can decarbonize agriculture are less clear.

We need inputs such as fertilizers to meet growing food demands, and we can't stop cattle from producing methane. We will need a menu of solutions: changes to diets; food waste reduction; improvements in agricultural efficiency; and technologies that make low-carbon food alternatives scalable and affordable. a

Global greenhouse gas emissions from food production

Our World in Data



Data source: Joseph Poore & Thomas Nemecek (2018). Reducing food's environmental impacts through producers and consumers. Published in *Science*.

Focus on what you eat , not on whether your food is local!

- People across the world are becoming increasingly concerned about climate change.
- Food production is responsible for one-quarter of the world's greenhouse gas emissions.
- There is rightly a growing awareness that our diet and food choices have a significant impact on our carbon 'footprint'. What can you do to really reduce the carbon footprint of your breakfast, lunches, and dinner?
- 'Eating local' is a recommendation you hear often: it is **one of the most misguided pieces of advice.**
- Eating locally would only have a significant impact if transport was responsible for a large share of food's final carbon footprint. For most foods, this is *not* the case.
- GHG emissions from transportation make up a very small amount of the emissions from food and what you eat is *far more* important than where your food traveled from.
- Let's have a look at data from Poore, J., & Nemecek, T. (2018).

Poore, J., & Nemecek, T. (2018).

GHG emissions from 29 different food products – from beef at the top to nuts at the bottom.

For each product, it is calculated from which stage in the supply chain its emissions originate.

This extends from land use changes to transport and packaging.

Poore, J., & Nemecek, T. (2018).

In this study, authors look at the total GHG emissions per kilogram of food product.

CO2 is the most important GHG, but not the only one – agriculture is a large source of the greenhouse gases methane and nitrous oxide.

To capture all GHG emissions from food production researchers therefore express them in kilograms of ‘carbon dioxide equivalents’. This metric takes account not just CO2 but all greenhouse gases (pause: explanation of this metric in the next slide!)

CO2 equivalent metric

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To capture all GHG emissions from food production researchers therefore express them in kilograms of ‘carbon dioxide equivalents’.

To express all greenhouse gases in carbon dioxide equivalents (CO2-eq), they are each weighted by their global warming potential (GWP) value.

GWP measures the relative warming impact one molecule or unit mass of a greenhouse gas relative to carbon dioxide over a given timescale – usually over 100 years.

GWP100 values are used to combine greenhouse gases into a single metric of emissions called carbon dioxide equivalents (CO2eq).

CO2eq is then derived by multiplying the mass of emissions of a specific greenhouse gas by its equivalent GWP100 factor. The sum of all gases in their CO2eq form provide a measure of total greenhouse gas emissions.

Poore, J., & Nemecek, T. (2018).

The most important insight from this study: there are massive differences in the GHG emissions of different foods: producing a kilogram of beef emits 60 kilograms of greenhouse gases (CO2-equivalents). While peas emits just 1 kilogram per kg.

Overall, animal-based foods tend to have a higher footprint than plant-based. Lamb and cheese both emit more than 20 kilograms CO2-equivalents per kilogram. Poultry and pork have lower footprints but are still higher than most plant-based foods, at 6 and 7 kg CO2-equivalents, respectively.

Poore, J., & Nemecek, T. (2018).

For most foods – and particularly the largest emitters – most GHG emissions result from land use change (shown in green), and from processes at the farm stage (brown).

Farm-stage emissions include processes such as the application of fertilizers – both organic and synthetic and enteric fermentation (the production of methane in the stomachs of cattle).

Combined, land use and farm-stage emissions account for more than 80% of the footprint for most foods.

Poore, J., & Nemecek, T. (2018).

Transport is a small contributor to emissions. For most food products, it accounts for less than 10%, and it’s much smaller for the largest GHG emitters. In beef from beef herds, it’s 0.5%.

Not just transport, but all processes in the supply chain after the food left the farm – processing, transport, retail and packaging – mostly account for a small share of emissions.