ReLondon

London's food footprint

An analysis of material flows, consumption-based emissions, and levers for climate action

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In collaboration with **CIRCLE ECONOMY**

London's food footprint:

An analysis of material flows, consumption-based emissions and levers for climate action

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Glossary of terms

Carbon emissions

Carbon emissions relate to the greenhouse gases that are emitted and are expressed in terms of their equivalent warming potential to carbon dioxide (carbon dioxide equivalents (CO_2eq)).

Consumption-based emissions

Consumption-based emissions are those allocated to the final consumers or users of goods or services, rather than the producers of those emissions. They incorporate greenhouse gas emissions that occur over the lifecycle of products and services, as well as the emissions associated with waste management activities. These emissions may occur both within and outside a given territory, and are allocated to the final consumers or users, rather than the producers of those emissions.

Food loss and waste

Food loss and waste covers food that is lost and/or wasted at every step of the supply chain. 'Food loss' is when food is thrown away because of decisions and actions by stakeholders in the part of the supply chain between harvest and food services and retail. 'Food waste' typically refers to food that is thrown away because of decisions and actions at the end of the supply chain by distributors, retailers, food service providers and households.

Food and beverage supply

Food and beverage supply refers to the total quantity of food and beverages that are produced to fulfil the demand of a consumer group. Total food and beverage supply includes not only the food and beverages obtained through imported and primary production but also the food loss associated with imports and primary production.

Greenhouse gas emissions

Greenhouse gases are gases that are capable of absorbing infrared radiation and re-radiating infrared radiation within the Earth's atmosphere. Common greenhouse gases include carbon dioxide, methane and nitrous oxide.

Leverage point

A leverage point is a place to intervene in a complex system that can bring about significant changes to that system.

Net food consumption

Net food consumption refers to the quantity of food and beverages that are purchased. This figure does not necessarily indicate the total quantity of food eaten or beverages consumed, because some food and beverages are wasted before they are consumed.

Territorial emissions

Territorial emissions are the greenhouse gas emissions directly generated within a city's boundary.

Sankey diagram

A Sankey diagram is a flow diagram used to visualise systems. The width of the flow lines in the diagram is proportional to the flow quantity. In this report, the flow lines indicate material and greenhouse gas emission flows.

Lifecycle emissions

Lifecycle emissions are the greenhouse gas emissions that occur throughout the lifecycle of a product.

Waste hierarchy

The waste hierarchy is a ranking of waste management options according to what is best for the environment. It ranks prevention as the most desirable option, then re-use, recycling and other recovery (including incineration) as the next best options, and finally disposal as the least favourable option.

Contents

Executive summary

The Mayor of London has set ambitious targets for the city to become a leading net zero-carbon city by 2030 and zero-waste city by 2050, as well as supporting the city's green economy through the Green New Deal.

Cities play an influential role in achieving a sustainable future, with London's consumption-based emissions, embedded within the products consumed in the city, being 3.5 times bigger than the territorial emissions, occurring within the city boundaries[1]. When exploring these impacts, it is therefore critical that we understand not just the emissions we are directly responsible for producing within the city's boundaries (i.e., from the generation of electricity consumed in London), but also those associated with things we consume – in this case food – that are imported from elsewhere (i.e., from emissions right across the supply chain including energy required to operate machinery, land and fertiliser use, transport among others).

In this report we explore material flows through the entire food and beverage supply chain within Greater London: from imports, to consumption, to how waste is managed. From this we have linked data on greenhouse gas emissions to all the food and beverages that we grow, import, package, cook, eat and throw away in the city. Due to data availability, this research has a specific focus on the food consumed by Londoners, and so it does not include food consumption by visitors (including commuters and tourists).

The report details both the methodology and findings of the research, which has generated a robust evidence base that demonstrates the link between food flows and greenhouse gas emissions. We hope that the evidence and insights presented will inform the development of targets and actions to support a future where global temperature rises are kept within 1.5°C of pre-industrial levels.

Mapping the material flows and consumption-based emissions of London's food system – key findings

Approximately **6,347,000 tonnes of food** is produced to **supply** London's food system each year. Of this, 99% of London's food and beverages are imported from outside the city, with local production and farming accounting for less than 1% of the capital's food supply.

Before it reaches London, **836,000 tonnes of imported food is lost**, representing the second largest volume of food that is either lost or wasted across the supply chain, after household waste (931,000 tonnes).

From a demand perspective, **Londoners consume[2] an estimated 4,794,000 tonnes of food each year, either through food service (665,000 tonnes) or through consumption at home (4,129,000 tonnes)**. Most of the food consumed in London is eaten at home (86%), which is equal to about 460 kg per person per year. Food eaten out in places like cafés and restaurants makes up the remaining amount (14%).

London's **consumption-based emissions** arising from Londoners' food consumption is **equal to 15,483 kt CO2eq each year**. This takes into account all lifecycle greenhouse gas emissions from food and beverages consumed by London residents. That is, emissions associated with all activities, from the cultivation and processing of food outside London that enter London through imports, to manufacturing, wholesale and retail, as well as waste management. From this analysis, it shows that the majority of consumption-based emissions associated with London's food supply chain (approximately 78%) occur outside the city itself and are 'embodied' within the food and beverages we import.

Consumption-based emissions associated with London's food supply chain

- Imports
- Primary production in London
- Processing and manufacturing
- Wholesale and retail
- Waste management
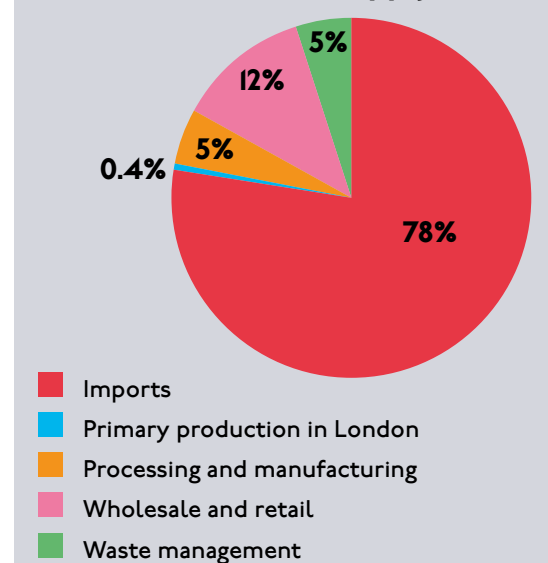
Please note these figures have been rounded so may not add up to 100%

This highlights the important role food supply has in mitigating global greenhouse gas emissions, which is shaped and driven by consumption behaviours within a city. The types of food consumed are also important as different food products are associated with different levels of emissions. Meat is particularly carbon intensive – it makes up approximately 5% of the food consumed by London households by mass, yet it is responsible for 27% of London households' consumption-based emissions. On the other hand, vegetables and fruit represent 21% of the food consumed by London households (by mass), yet they are responsible for 4% of those households' consumption-based emissions. This highlights the potential for dietary changes to reduce the city's consumption-based greenhouse gas emissions.

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A more detailed breakdown of the emissions associated with each food product consumed within London's households is presented in section 3.3. Interestingly, the majority (around three-quarters) of emissions within London's food imports occur before the food leaves the farm, while transportation and packaging are responsible for approximately less than 10% each.[3]

Approximately 41% (931,000 tonnes) of the total food loss and waste[4] generated across the supply chain (including imports) comes from households.
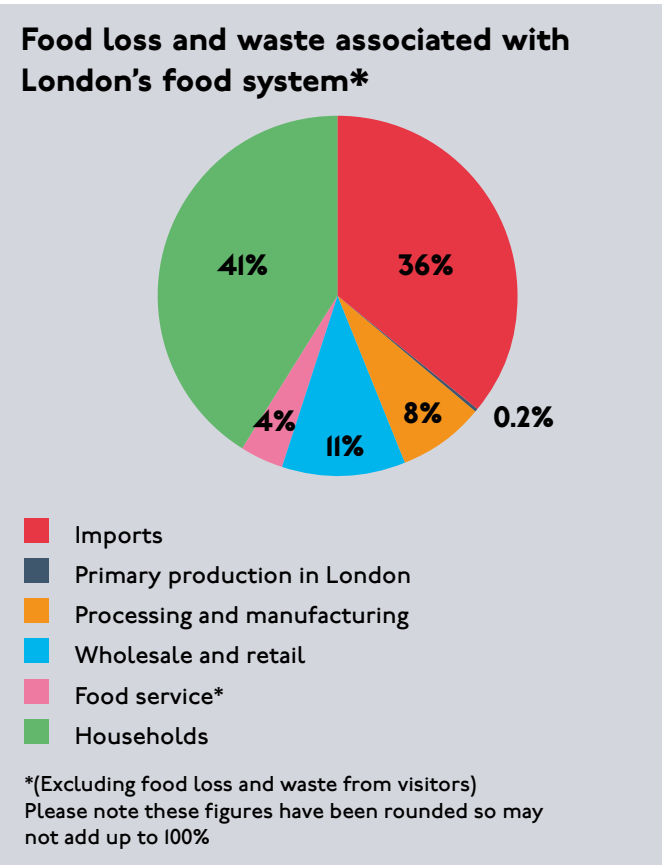
The majority of London's food loss and waste is incinerated (57%), while approximately 24% of food loss and waste is managed through anaerobic digestion and composting. Approximately 8% of food loss and waste is landfilled, which generates a sizable share (65%) of total greenhouse gases generated by London's food waste management system.

The report also looks at edible and avoidable waste at each stage of the supply chain. For example, it is estimated that all food loss occurring at the food wholesale and retail stage of the supply chain is considered 'edible', and thus potentially avoidable. About 75% of total food waste in food service, 60% of waste in households, and half of food loss in manufacturing is considered 'edible' and thus avoidable. More details can be found in section 3.2.

Food loss and waste associated with London's food system*

- Imports — 36%
- Primary production in London — 0.2%
- Processing and manufacturing — 8%
- Wholesale and retail — 11%
- Food service* — 4%
- Households — 41%

*(Excluding food loss and waste from visitors)
Please note these figures have been rounded so may not add up to 100%

Edible vs non-edible food waste and loss in London

- Total edible food waste and losses — 67%
- Total non-edible food waste and losses — 33%

Summary of the proportion of food loss and waste and consumption-based emissions associated with London's food supply chain (please note these figures have been rounded so may not add up to 100%)
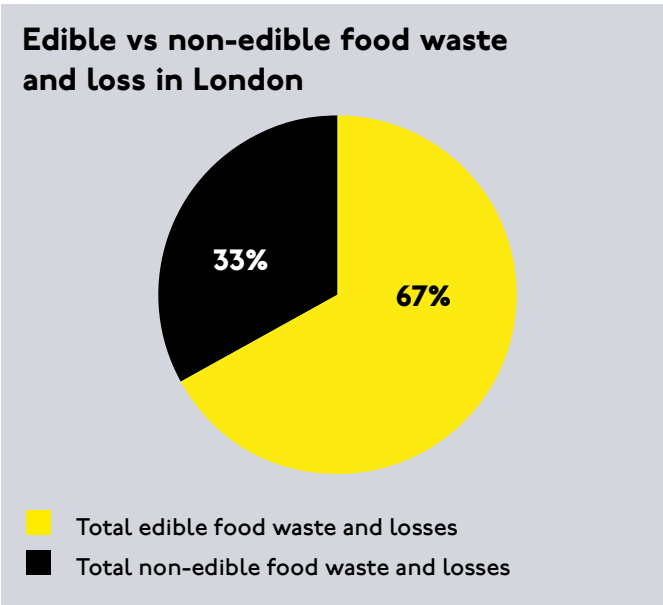
Stage along London's food supply chain	Food loss and waste		Consumption-based emissions
	Food loss and waste occurring within London (excluding import-related loss and waste)	Food loss and waste associated with London's food system (including import-related loss and waste)	
Imports	Not applicable 836,000 tonnes	36% 836,000 tonnes	78%
Primary production in London	0.3% 4,000 tonnes	0.2% 4,000 tonnes	0.4%
Processing and manufacturing	13% 182,000 tonnes	8% 182,000 tonnes	5%
Wholesale and retail	17% 246,000 tonnes	11% 246,000 tonnes	12%
Food service (excluding waste from visitors)	5% 93,000 tonnes	4% 93,000 tonnes	Not applicable
Households	65% 931,000 tonnes	41% 931,000 tonnes	Not applicable
Waste management	Not applicable	Not applicable	5%

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Leverage points to support a circular and low-carbon food system

Through the mapping of materials and emissions associated with London's food system, three key leverage points were identified that have the ability to support the transition towards a circular and low-carbon food system.

1   Shifting towards more healthy and sustainable diets.

2   Reducing food loss and waste.

3   Making better use of waste in combination with waste reduction.

Scenarios have been developed to highlight where the greatest reductions in consumption-based emissions could be made at different points across the food and beverage supply chain. Although local food production and the consumption of organic food provide the opportunity to reduce carbon emissions and other environmental impacts, this leverage point was not quantitatively modelled, since its ultimate carbon impact is heavily dependent on a diversity of context-specific factors, such as land availability and production efficiency.

The scenarios set out are for illustrative purposes and the percentages have been set in line with a variety of targets, including the Mayor of London's targets for food waste, the C40 and EAT-Lancet optimal health and planetary goals for diets, among others. In an ambitious scenario, reducing per capita meat consumption by 70% was estimated to yield a **20.1% reduction** in the consumption-based emissions associated with London's food system each year. Reducing food loss and waste in London by 50% could achieve an estimated **10.5% reduction** in emissions, and

if we combine this reduction with the circular management of waste then collectively this could reduce emissions by **10.9%**[5]. In a moderate scenario, reducing per capita meat consumption by 30% was estimated to yield a 8.6% reduction in the consumption-based emissions associated with London's food system each year. Reducing food loss and waste in London by 20% could achieve an estimated 4.2% reduction in emissions, and together with the circular management of waste, this could see a 5.6% reduction in emissions.

Overall, our research has made it very clear that Londoners' food consumption choices impact emissions, not only in London but beyond the boundaries of the city itself – so it is essential that we take these choices and their carbon impacts throughout the capital's food supply chain into account when acting to tackle the climate crisis.

This piece of research is a key milestone in achieving zero-carbon ambitions across cities globally, as it has been designed to be replicable to other sectors and other cities, beyond London's food sector. This approach could be used by decision-makers in cities across the world to identify interventions throughout their urban system that can help to reduce the generation of greenhouse gas emissions globally. For London, this research will be used to inform programmes such as the Food Flagship Initiative[6], a three-year partnership between ReLondon, the Greater London Authority and the Ellen MacArthur Foundation to design high impact data-driven policy interventions to reduce food-related consumption-based emissions. It will also inform London Councils' One World Living programme, led by the London Borough of Harrow, which is developing an action plan for boroughs to reduce consumption-based emissions.

Introduction

01

1. Introduction

Cities are at the centre of the global economy, both engines of innovation and hot spots of consumption. The greenhouse gas emissions that are generated in cities have received a great deal of attention in recent years.

However, the way cities consume goods, and the consumption-based greenhouse gas emissions that are generated by cities, is often overlooked. Developing our understanding of over-consumption is crucial for the transition towards a sustainable future within the ecological boundaries of our planet[7] and can provide new insights that can help to prioritise action to reduce greenhouse gas emissions and achieve other sustainability goals.

Conventionally, cities' efforts to achieve net zero greenhouse gas emissions are focused on reducing the emissions occurring within the city boundaries[8], such as low-carbon forms of transportation, improving energy efficiencies of housing and improving waste reduction and management measures. However, the broader climate impacts associated with urban consumption and consumption-based emissions can be overlooked. Taking a consumption-based emissions perspective can increase the carbon footprint of cities by 60% – that is, the emissions that are 'embodied' within the materials and products that are consumed within the city's boundaries.[9]

Recognising the influential role that cities can play in achieving a sustainable future, the Mayor of London has set ambitious targets for London

to become a leading net zero-carbon city by 2030 and zero-waste city by 2050[10]. Alongside this, three-quarters of London's boroughs have set targets to reach net zero by 2030[11]. For both London as a whole, and at a borough level, the city has calculated its consumption-based emissions and started work on reducing these emissions. Such commitments demonstrate London's ambitions to continue to be a frontrunner in the transition towards a more sustainable future, with the city's zero-carbon ambition exceeding the UK's national targets.

At the start of 2021, ReLondon commissioned Circle Economy to develop an analytical framework that would support policy making and inform actions to reduce consumption-based emissions at a city-wide and borough level. The aim of this first-of-its-kind research was to develop a robust evidence base that estimated the mass of materials flowing through London and their associated consumption-based emissions. The new evidence base and insights developed in this research project will help to inform the development of ambitions and actions to support a future where global temperature rises are kept within 1.5°C of pre-industrial levels.

1.1 Context

A circular economy presents an alternative to the current 'linear' way we produce and consume products and resources, characterised as 'take-make-waste'. In a circular economy, products and materials are designed to be kept at their highest value for as long as possible, in order to eliminate waste and pollution and regenerate natural systems[12]. Pursuing a more circular economy not only presents opportunities to reduce ecological degradation, but also provides opportunities to generate new economic value and jobs[13].

To support London's transition to become a circular city, the Mayor of London's 2018 London Environment Strategy set the city's targets in relation to waste and resources[14]. Notably, the Mayor of London is striving to send no biodegradable or recyclable waste to

landfill by 2026, aims for a 65% municipal waste recycling rate by 2030, to reduce food waste by 50% per person by 2030 in line with emerging Sustainable Development Goal 12.3 reduction targets and has signed up as '12.3 Champion'.[15,16] Alongside this, three-quarters of London's boroughs have set targets to reach net zero emissions by 2030 and London Councils' One World Living programme, has been set up to develop an action plan for boroughs to reduce consumption-based emissions by two-thirds by 2030, including a focus group on food.

Supporting a circular transition, London's Circular Economy Route Map[17] identified five priority sectors that should form the core focus of London's circular transition: food, textiles, plastics, electricals and the built environment. This report provides insights that support the practical implementation of both its zero-waste and zero-carbon goals.

1.2 The circular economy and carbon emissions

Over the past few years, there has been increased recognition and evidence that a circular economy can reduce greenhouse gas emissions and so help to keep global warming below 1.5°C.[18][19] In particular, recent research has underscored the importance of a circular economy in bridging the emissions gap between the current Nationally Determined Contributions that primarily focus on the transition towards renewable energies and a 1.5°C future[20].

Cities are a global driver of greenhouse gas emissions.[21] For many cities (especially those in the global north), the majority of these emissions occur outside of the city's boundaries and are embodied within the materials and products imported.[22] These embodied emissions relate to the greenhouse gases that are emitted and associated with, the generation and consumption of energy required for the extraction, manufacture and transportation of materials, products and services that are then consumed by residents.

Through the demand for and consumption of products that are produced around the world (such as food, clothing, cars and phones), residents, businesses and organisations within a city affect the amount of greenhouse gas emissions that are generated globally. In other words, cities (and the people in them) have the power to make great global change happen. Research commissioned by the Greater London Authority and conducted by the University of Leeds has analysed the size and profile of London's consumption-based emissions, highlighting that London households were

responsible for 78% of the city's consumption-based emissions in 2016.[23] London Councils and ReLondon also commissioned the University of Leeds to break this information down by borough to allow for a more granular picture. The report highlighted that food and beverages made up 10.9% of an average household's consumption-based emissions in London in 2018.[24]

To build on prior research conducted for London in relation to the city's consumption-based emissions, such as the University of Leeds study, a new approach was needed to support the identification of key leverage points for reducing those emissions and to provide decision-makers with an evidence base to focus their efforts on the most impactful actions. Therefore, this research takes that next step, linking the flow of materials within a city to their associated consumption-based emissions across the food and beverage supply chain.

Some cities are actively acknowledging and beginning to tackle their consumption. For example, in Amsterdam's latest circular economy strategy, the city has set targets to reduce the city's raw material consumption by half of current levels by 2030,[25] while the city of Portland, Oregon has developed a consumption-based emissions inventory for the city.[26] London is a leader in the development of a local circular economy,[27] and is now taking pioneering steps to generate the evidence base to link the city's circular economy to climate change mitigation. This approach can support the identification of leverage points to reduce London's consumption-based emissions through the circular economy and can be replicated to other cities to help them deliver their emissions targets.

1.3 A focus on food

Few things have as much influence on our lives as food. From a social perspective, food is deeply rooted in culture, tradition and identity, and food has a profound impact on people's health and wellbeing at every stage of their lives, as well as on the local and national economies and the environment. From an ecological perspective, the food system is responsible for an estimated one-third of global greenhouse gas emissions resulting from human activity,[28] while approximately one-third of the food that is produced globally is wasted.[29] In London, research commissioned by the Greater London Authority and conducted by the University of Leeds suggests that food is responsible for approximately 10% of the city's consumption-based emissions.[30]

London recognises the importance of food in reducing its carbon footprint and has emphasised food as a priority sector to focus actions and reduce the city's environmental impact, setting ambitious targets as stated previously in the report. London's boroughs are also leading the way in the UK government's commitment, supported by the Mayor of London

and ReLondon, a partnership between the Mayor of London and the London boroughs, to roll out separate household food waste collections by 2023 across the country, with 24 out of 33 London boroughs already having a food waste collection service in place. Moreover, London is one of the Ellen MacArthur Foundation's three Strategic Partner Cities (together with New York City and São Paulo) working to accelerate the transition to a circular economy, including a more circular urban food system.

Building on the work previously conducted by the Mayor of London, London's boroughs and ReLondon, the Food Flagship Initiative[31] is a three-year partnership between ReLondon, the Greater London Authority and the Ellen MacArthur Foundation to demonstrate how a circular economy for food can be achieved in London. The initiative will design and deliver interventions and evidence-based policies to reduce consumption-based emissions from food and bring together a consortium of public and private stakeholders across London's food supply chain, from peri-urban farmers' associations and innovators to food brands, retailers, hospitality and public sector institutions.

To demonstrate how a circular economy for food can be achieved in London, the initiative has committed to three pillars of action:

1. Increase the sourcing and production of food grown using agro-ecological practices and grown locally where possible.

2. Increase the prevalence of healthy and sustainable food items and menus.

3. Eliminate avoidable food waste wherever possible and recycle unavoidable food waste back into productive uses.[32]

The initiative will help tackle the climate crisis, generate new green economy jobs, build supply chain resilience and improve human health and community wellbeing, all in line with priorities of the Mayor of London and London Councils' Green New Deal mission as part of the London Recovery Board.

COVID-19 has also shone a spotlight on the fragility of urban food systems and their vulnerability to unexpected shocks and disruptions. London itself observed an increasing number of residents experiencing food insecurity and diet-related ill health during the pandemic, exacerbating existing socio-economic and health problems.[33] [34] With London's population projected to reach 10.8 million by 2041,[35] a change in the way food is produced (including outside London), consumed and disposed of in the city is vital.

Recognising the importance of food for London, this report focuses on the flow of food products and their associated consumption-based emissions to support policy making and the implementation of actions at a city-wide and London borough level. The insights from this report can help city stakeholders understand where greenhouse gas emission hot spots are across the food supply chain and where actions should be focused to reduce consumption-based emissions stemming from London's food system.

1.4 Aims and objectives of this project

London and its boroughs have very ambitious objectives to reduce greenhouse gas emissions. However, the evidence base, methodologies and decision-making tools currently do not exist to support this transition. In particular, evidence is needed to increase the understanding of the relationship between material flows, and their impact on consumption-based emissions.

ReLondon commissioned Circle Economy to develop an analytical framework that could be used to allow ReLondon and key stakeholders in London to deliver action to transition London to a circular economy. Circle Economy has developed a framework that shows the mass of food moving across the supply chain and its associated consumption-based emissions.

The approach is piloted for London's food system but has been developed with a view to be replicable to other priority sectors and other cities within the UK and across the world.

24 out of 33
London boroughs already have a food waste collection service in place.

Approach

02

2. Approach

In this section, we describe the approach and analytical framework that has been developed to explore the material flows and consumption-based emissions of London's food system. This framework forms the focus of this report.

2.1 Mapping material flows and consumption-based emissions – an overview of the approach

A food-system flow analysis methodology was used to develop the analytical framework, which provides a holistic view of how food flows through a system, in this case London. This analysis examines how resources are produced, processed, consumed and disposed of within the system, and it can generate greater insights into the current level of greenhouse gas emissions across the food and beverage chain. The approach provides estimates of the quantities of materials that flow through, and the waste and loss that is generated at key points across London's food system, from production to consumption and end-of-life management.

To complement the understanding of the flows of food throughout London's food system, a carbon footprint assessment was also carried out to examine the consumption-based emissions of Londoners. The analysis connects the flows of food products with their associated emissions at each stage of the supply chain – both the emissions that occur outside London (embodied in the products imported to the city) and the emissions occurring within the city's boundaries – for manufacturing, wholesale, retail and waste management of the food products that flow through and are consumed within the city itself.

Separately, the analysis also highlights the emissions resulting from the production of food within London for export. These emissions are not considered as part of London's total consumption-based emissions, as these emissions are embodied within the food that is exported out of London and not driven by Londoners' consumption of food.

The objective of this task is to provide a baseline level of the material flow of London's food system and identify leverage points to support a transition towards a circular and low-carbon food system. This is achieved by collecting and harmonising the best available data and representing it visually in a Sankey diagram.[36] The analysis offers a static 'snapshot' of food flows and their associated emissions within London for a given year, in this case 2019. The accuracy with which a food-system flow analysis can depict local realities is highly dependent on the quality, format, age and availability of data. However, to support London's ambitions to reduce consumption-based emissions and so reduce the impact on climate change, this analysis provides the city with a valuable starting point for the development of circular strategies in the food system.

2.2 Data availability and limitations

To provide the most comprehensive picture of material flows and consumption-based emissions throughout London's food and beverage supply chain, the analysis builds on various available data sources.

The data used within the food-system flow analysis is collected from a variety of sources, including from both government and other sources. Where possible, reliable London-specific data for the year 2019 was prioritised. Data was mainly sourced from the London Data Store,[37] as well as a complementary analysis conducted by ReLondon. However, data availability and quality vary across the food supply chain, with some stages boasting highly reliable and detailed data (such as household consumption and imports), and others (such as wholesale and retail) lacking detailed London-specific data.

In some cases where London-specific data is not available, national data has been downscaled to London using proxy data, such as employment (this assumes that the production efficiencies and characteristics for London are comparable to the UK average). In other cases, older data has been extrapolated to the focus year 2019. Such transformations of data introduce assumptions and uncertainties, and, as such, reduce its overall accuracy. However, this data is required to depict a system-level overview of London's food system.

To analyse the consumption-based emissions of food and beverages within London, the report uses detailed emissions factors (CO_2equ/T) that indicate the quantity of emissions generated for a given food product at various stages of its lifecycle, from production to consumption.

These factors are applied to the food products that flow through and are consumed within London.

It is important to note that these emission factors are not London-specific, but EU averages, and their use therefore assumes that these emissions factors are comparable to London. However, these emission factors are the most suitable data source for this analysis, and the resulting insights provide a valuable system-wide understanding of emission 'hot spots'.

While the results in this report are prepared using the best data available, the food-system flow and carbon footprint assessment should not be viewed as complete and comprehensive representations of the material and greenhouse gas emissions within London's food system. Nevertheless, the analysis provides an important start in understanding London's food system from both a mass and consumption-based emissions perspective.

The past two years have seen two events impacting both London and the UK economy: the COVID-19 pandemic and Brexit. At present, the greatest quantity of high quality and reliable data is available for 2019, so this year was selected as the target year. Therefore, the results present a 'snapshot' of London's food system as it was pre-Brexit and pre-pandemic. However, this does not negate its value for forward-looking strategic and policy planning, since the data from 2019 provides useful insights into some of the prevailing trends that are likely to persist post-COVID-19 and post-Brexit (for example, diets, food waste generation and food production).

Finally, this research has developed a framework and methodology that can be easily used in future years with more updated data. The framework can be used to monitor the impact of the latest disruptive events and allows for the reassessment of the hot spots previously identified in the material flow analysis.

2.3 Scope of the analysis

The scope of the analysis focuses on the flows of food that are consumed by Londoners. The analysis explores the direct inputs in London's food system and the food loss and waste that is generated at each stage along the food and beverage supply chain within the city. The key flows that are mapped throughout the system are:

Food products (tonnes)	The volume of fruit, vegetables and animal products originating from agriculture and forestry, as well as prepared meals and food products. Food products are disaggregated further into five categories:[38] 1 Vegetables & fruit 2 Meat & fish 3 Dairy 4 Beverages 5 Other (including cereals and grains, sugars, oils and other processed foods)
Food loss and waste (tonnes)	The amount of food loss arising across the supply chain (pre-consumer waste) and food waste arising at the point of consumption (post-consumer waste)
Greenhouse gas emissions (kt CO2eq)	Consumption-based emissions plus territorial emissions associated with exports[39]

The key steps along London's food and beverage supply chain are:

- **Imports**: imports of food products to London from outside the city boundaries, including from the rest of the UK, the EU and the rest of the world.

- **Primary production**: activities related to the cultivation of food-related plants and animals in London.

- **Processing and manufacturing**: activities related to the processing and manufacturing of food and beverages.

- **Wholesale and retail**: activities related to the sale and distribution of food and beverages, including wholesale trade and transport, supermarkets, markets and last-mile logistics.

- **Food service**: activities related to the service of Londoners consuming food and beverages outside of the household, including restaurants, cafés, catering services and canteens.

- **Households**: the consumption of food and beverages within London households.

- **Food redistribution**: activities related to the collection and redistribution of food and beverages that are suitable for human consumption.

- **Exports**: exports of food and beverages from London to outside the city boundaries, including to the rest of the UK, the EU and the rest of the world.

- **Waste collection**: activities related to the separation and collection of food waste in London.

- **Waste management**: activities related to the processing of London's food loss and waste. Many of these waste management activities occur outside of the city itself, although waste is generated within London. According to a study conducted by the London Assembly Environment Committee,[40] less than half of London's food waste is processed in London. Due to the requirements of space, the majority of London's waste authorities send their separated green waste – garden and food – to composting and anaerobic digestion facilities outside London, including in Kent, Surrey, Cambridgeshire, Warwickshire and Northamptonshire. Although this is the case, the greenhouse gas emissions associated with waste management activities (both within and outside of the boundaries of London itself) are considered when calculating London's consumption-based emissions as it relates to waste produced by Londoners. The following treatment processes are included in the analysis:

- **Anaerobic digestion**: residual organic matter is broken down by this process to produce biogas and biofertiliser.

- **Composting**: residual organic matter is decomposed to produce biofertiliser.

- **Incineration**: resources are burned to generate heat or other energy. Whereas a small fraction of the product's value is captured, most value is lost.

- **Landfill**: resources are diverted to a landfill site. Not only is all value lost, but landfilling waste causes additional environmental pressure and competes with other land uses.

- **Other recycling**: this includes a variety of applications such as land spreading and use as animal feed, as well as small and specific recycling activities.

The material flows and consumption-based emissions of London's food sector

03

3. The material flows and consumption-based emissions of London's food sector

This chapter presents the findings from the estimation and mapping of food flows throughout London, along with their associated consumption-based emissions. The analysis also showcases the food waste flows across the supply chain and its treatment methods, which are grouped into anaerobic digestion, composting, incineration, landfill and other recycling.

Firstly, subsection 3.1 presents a summarised view of London's food system, looking at a number of key material and emission indicators to highlight characteristics of London's food system. Subsection 3.2 then provides a more detailed description of each stage of London's food system, based on a Sankey diagram. All data points shown in the Sankey diagram have been rounded to the nearest one thousand. Finally, subsection 3.3 shows a breakdown of the types of foods that are consumed within London households.

3.1 London's food system at a glance

From this research, it is evident that London's food system has influence over vast quantities of food and beverages. This section introduces key concepts and figures that provide an overview of the scale of the system, prior to delving into detail in the following subsections.

London's food supply: 6,347,000 tonnes

Food supply refers to the total quantity of food that is produced to fulfil the demand of London's food system. For London, this includes not only the food imported from the rest of the UK, the EU and outside the EU, and primary production within London, but also the food loss associated with imports (generated outside of London itself) and primary production. This figure provides a lower estimation when compared to those presented in other studies, which is due to the assumptions and methods associated with the downscaling of data.[41]

London's net food consumption: 4,794,000 tonnes

London's net food consumption refers to the quantity of food and beverages that are purchased by Londoners through food service and for consumption in the home as well as the loss and waste generated at both stages of the supply chain. This figure does not necessarily indicate the total quantity of food eaten by Londoners themselves, as a certain proportion of the food that is purchased is wasted before it is eaten.

London's food system consumption-based emissions: 15,483 kt CO2eq

Consumption-based emissions refer to the lifecycle greenhouse gas emissions associated with food and beverages consumed by Londoners. These emissions occur both within and outside of London, and they are allocated to the final consumers rather than the original producers of those emissions. The estimated 15,483 kt CO2eq of consumption-based emissions generated by London's food supply chain are in line with other estimations, such as those conducted by the University of Leeds on behalf of the Greater London Authority.[42]

London's food loss and waste: 1,456,000 tonnes

Food loss and waste encompass food that is lost and/or wasted at each stage of the supply chain within London itself by London businesses and households (not including waste related to imports and not including waste generated by commuters and tourists). 'Food loss' refers to the discarding of food due to decisions and actions by stakeholders in the supply chain from post-harvest up to, but not including, food service and retail. 'Food waste' typically refers to food that is discarded due to decisions and actions by distributors, retailers, food service providers and households. The 1,456,000 tonnes of food loss and waste specifically refers to the waste generated by Londoners.

3.2 Food-system flow and consumption-based emissions overview

The following Sankey diagram illustrates the journey of food throughout London. The diagram flows from left to right, and it indicates the key stages of London's food system and how food flows through and is managed within the city; from imports, primary production, London's food industry, to the point of final consumption. The Sankey diagram indicates both the quantity of different types of food and the consumption-based emissions associated with each stage of the supply chain.

IMPORTS FROM THE REST OF THE UK AND EU
3,530,000 t

IMPORTS FROM THE REST OF THE WORLD
1,935,000 t

12,285 KtCO₂eq (including losses)

12,095 KtCO₂eq

IMPORTS
5,465,000 t

A 446,000
B 1,418,000
C 307,000
D 1,492,000
E 1,802,000

60 KtCO₂eq

A Meat & Fish
B Vegetables & Fruit
C Dairy products
D Beverages
E Other

LOSSES FROM IMPORTS
836,000 t

EXPORTS
285,000 t

1,281 KtCO₂eq

738 KtCO₂eq

738 KtCO₂eq

1,909 KtCO₂eq

60 KtCO₂eq

PRIMARY PRODUCTION
42,800 t

A 1,100
B 7,500
E 34,200

A
B
C
D
E

PROCESSING & MANUFACTURING
4,033,000 t

WHOLESALE & RETAIL
5,325,000 t

285,000

LOSSES FROM PRIMARY PRODUCTION

4,000
<10
1,800

182,000

246,000

4,600

665,000

FOOD SERVICE
665,000 t

93,000

900

4,129,000

HOUSEHOLDS
4,129,000 t

931,000

Biomass
unit = tonnes

Waste or loss
unit = tonnes

Food Rescue and Redistribution
unit = tonnes

Emissions
unit = KtCO₂eq

EXPORTS
285,000 t

261
CO₂eq

285,000

WHOLESALE &
RETAIL
5,325,000 t

1,909
KtCO₂eq

246,000

4,600

665,000

FOOD
SERVICE
665,000 t

93,000

900

4,129,000

HOUSEHOLDS
4,129,000 t

931,000

Flow coming from
Processing & Manufacturing

Flow coming from
Processing & Manufacturing

Flow coming from
Primary Production

Flow coming from
Primary Production

93,000

931,000

246,000

182,000

4,000

WASTE
COLLECTION
1,456,000 t

95
KtCO₂eq

900

4,600

1,800

<10

REDISTRIBUTION
7,310 t

OTHER
RECYCLING
150,000 t

6
KtCO₂eq

COMPOSTING
98,000 t

5
KtCO₂eq

ANAEROBIC
DIGESTION
248,000 t

22
KtCO₂eq

INCINERATION
821,000 t

107
KtCO₂eq

LANDFILL
122,000 t

256
KtCO₂eq

Consumption-
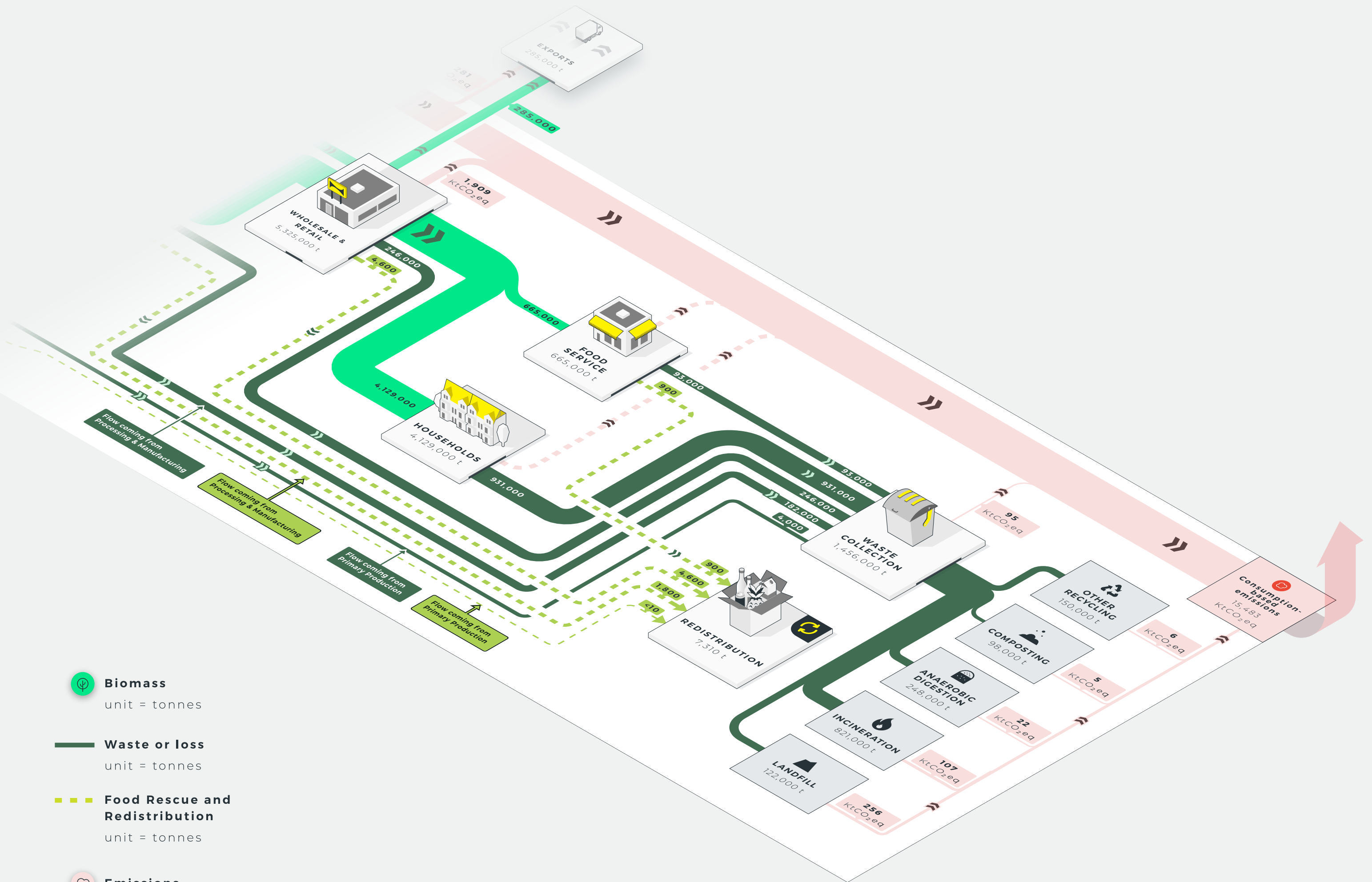based
emissions
13,483
KtCO₂eq

Biomass
unit = tonnes

Waste or loss
unit = tonnes

Food Rescue and
Redistribution
unit = tonnes

Emissions
unit = KtCO₂eq

Food supply for London

Approximately **6,347,800 tonnes** of food are produced to supply London's food system per year. This comes from two key sources: imports from outside the city, and production and cultivation within the boundaries of London. Interestingly, for every 1,000 kg of food supplied to London through imports, approximately 150 kg never enters London itself, which relates to the food loss generated outside London in its food and beverage supply chain.

Imports

- **Imports** are responsible for the vast majority of food that enters London (99%). Of this food imported to London (not including loss), approximately two-thirds (3,530,000 tonnes) come from the rest of the UK and other European countries, while the remaining one-third (1,935,000 tonnes) is imported from the rest of the world.

   Grains, cereals, sugars and other processed foods ('others') represent the largest food group imported to London (approximately 1,802,000 tonnes). **Beverages** (1,492,000 tonnes) and **vegetables and fruit** (1,418,000 tonnes) constitute the second and third largest imported product groups into London's food system respectively.

- From an **emissions** perspective, imports represent **approximately 78%** (12,095 kt CO2eq) of the total consumption-based emissions associated with London's food system. In particular, 48% (7,386 kt CO2eq) of London's total consumption-based emissions are associated with food imported from the UK (outside London) and the EU. Taken together, this implies that, on average, for each kilogram of food supplied from the UK and EU, 1.8 kg of CO2eq are generated. On the other hand, 30% (4,709 kt CO2eq) of total food-related, consumption-based emissions come from imports from the rest of the world, which implies that for each kilogram of food supplied from the rest of the world, 2.1 kg of CO2eq are generated.

Associated emissions are highly dependent on the type of food consumed. They are lower for plant-based products and higher for meat and dairy products, with red meat emitting the highest share of overall emissions. A more detailed breakdown of the emissions associated with each food product consumed within London's households is presented in section 3.3. Interestingly, the majority (around three-quarters) of emissions within London's food imports occur before the food leaves the farm, while transportation and packaging are responsible for approximately less than 10% each.[43]

While this magnitude of imports may not be surprising, what is crucial to underscore is that the vast majority of emissions related to London's food system are generated outside the city. This means that the emissions created through London's demand for food are not accounted for within London, making them difficult for the city to monitor, or indeed influence.

- The **production** and imports of food to London from the rest of the UK and the rest of the world are also responsible for the second highest food loss and waste generation after households (36% of total food loss and waste generated by London's food system). Importantly, this loss of food does not occur within, or enter, the geographic borders of London. This food loss and waste occurs at various points along the global supply chain, from primary production to distribution and manufacturing activities in other countries and regions to supply food to London. This serves to further highlight the influence of London's demand beyond its geographical borders.

Primary production

- Food produced from **agriculture and farming activities** within London account for a small proportion of the food supply of London (47,000 tonnes, less than 1%). Grains, cereals, sugars and other processed foods represent the largest food group produced in London (34,200 tonnes, close to 80% of total primary production). Vegetables and fruit are the second largest product group produced in London (7,500 tonnes, almost 18% of total primary production). Dairy and eggs have been excluded from this research due to limited data. The surrounding green belt of London is quite intensively farmed, yet producing crops not directly linked to London's food supply.[44]

   Due to the lack of available data, this research does not include food produced through hobby-farmers and allotments. However, this share is likely to be smaller than the share produced by professional agricultural activities in the city, given the availability of land and production capacity. Nevertheless, London has ambitions to increase the share of farmed land and land allocated to agriculture within the city. In the last decade, more than 2,700 new food growing spaces have been set up as part of Capital Growth.[45]

- Corresponding to the small share of primary production in London, **emissions** at this stage are responsible for 0.4% of London's food-related consumption-based emissions (60 kt CO2eq). This implies that for each kilogram of food produced, 1.4 kg of CO2eq are generated. Emissions for agricultural production can vary highly depending on a range of factors, such as energy demand and efficiency, as well as land and fertiliser use.

- **Food loss** also arises at this point in the supply chain. Primary production within London generates approximately 4,000 tonnes of food loss and waste, which represents 8% of the total food produced in primary production. The main reasons for this include the discarding of produce that doesn't meet aesthetic standards and over-planting as insurance against poor weather conditions.

   Only a small quantity of food loss is **redistributed** as food surplus. While there is no data in regard to the causes of food loss in London, there is likely to be potential to increase the proportion of food that is redistributed compared to food loss generated that cannot be avoided.[46]

Throughput of food in London

- London possesses a range of food-related **industrial activities**, from processing and manufacturing to wholesale, retail and distribution. There is great diversity and complexity in the flows of food between and within each of these activities. The Sankey diagram presents a simplified depiction of London's food system.

- The availability of reliable and accurate **data** in this section of London's food system is particularly limited. The results presented should therefore be viewed with a high degree of uncertainty (see Appendix). Additional data gathering activities focused on these food-system nodes could support the development of detailed recommendations for interventions to support improvements in the system.

Manufacturing and processing of food and beverages

- Approximately **4,033,000 tonnes** of food enters London's food **processing and manufacturing** industries and represents 64% of total food supply. The majority of food and beverages undergo processing and transformation into new and similar products, for example making lemonade (beverage) from lemons (vegetables and fruit).[47]

- The **emissions** produced at this stage relate to the energy that is required to operate the machinery associated with manufacturing food and beverages and corresponds to almost 5% (738 kt CO2eq) of the consumption-based emissions of London's food system. The more processing steps that are required to make a given food product, the higher the additional emissions embodied within it.

- **Food loss** generated at this stage represents a small proportion of total food input to the sector (4.5%), indicating good industrial efficiencies.[48] Taken as a whole, manufacturing and processing are responsible for 13% of total food loss and waste generated in London (excluding loss arising through imports), and 8% of the total food loss and waste of London's food system (including loss generated outside of London through imported food). Moreover, it is estimated that half of the loss at this stage is considered 'edible' and therefore avoidable.[49] The main causes of food loss in manufacturing and processing in the UK include process inefficiencies, rejection due to quality or safety standards, low forecasting accuracy and variations in temperature. However, the causes of food loss in processing and manufacturing vary considerably by food group.[50] [51]

Food wholesale and retail

- **Wholesale and retail** represent a range of activities, from supermarkets and wholesale markets to distribution activities. Approximately 5,325,000 tonnes of food flow into wholesale and retail, of which 1,470,000 tonnes (28%) come directly from imports and the remaining 3,856,000 tonnes (72%) from processing and manufacturing and from primary production.[52]

- **Emissions** at this point in the supply chain relate to the energy required for cold storage and transportation within the sale and storage of food and beverage products. This is responsible for 12% (1,909 kt CO2eq) of London's consumption-based emissions, which implies that for each kilogram of food distributed, 0.43 kg of CO2eq are generated.

- Approximately 246,000 tonnes of **food loss and waste** is generated by wholesale and retail activities in London, corresponding to 5% of the total food throughput of the wholesale and retail sector. Wholesale and retail are responsible for approximately 17% of the food loss and waste generated within London's food system (excluding loss associated with imports), and 11% of total food loss and waste throughout London's supply chain (including loss and waste generated outside the city boundaries via imported food).

  It is estimated that all of the food loss occurring during this stage is considered 'edible' and thus potentially avoidable. The causes of food loss in the retail stage include inaccurate forecasting resulting in overstocking, poor stock rotation on shelves and expiry of 'best before' dates,[53] [54] each of which has the potential to be reduced.

While an estimated 4,600 tonnes of potential food loss are donated for food redistribution at this point of London's food system, there is potential to increase this figure. Currently, there are insufficient incentives for grocery retailers to donate food. Although the 'zero VAT' policy exists in the UK for some food products, retailers donating surplus food cannot deduct the value of food donations from corporation tax, thus limiting its effectiveness.[55]

Exports

- Approximately 285,000 tonnes of food products are **exported** from London to other destinations outside the city. These exported food products will originate from a range of locations. In the Sankey diagram, exports are visualised to flow from wholesale and retail for simplicity. However, in reality, exports will also flow directly from primary production and from processing and manufacturing activities.

- From an **emissions** perspective, approximately 1,281 kt CO2eq are exported from the city. These 'exported emissions' relate to emissions that are generated by activities within the boundaries of London itself but are embodied within the products that are destined for another location outside of London. Importantly, these exported emissions are not considered within London's consumption-based emissions total, as they are not driven by the demand for food from Londoners.

Food consumption by Londoners

- Londoners consume an estimated total **4,794,200 tonnes** of food each year, which includes food that is eaten and not eaten (in other words wasted) after being purchased. This is consumed either in the household, or outside the household via food services such as cafes and restaurants.

- The results of the research showcase Londoners' food consumption and are based on household expenditure. Therefore, it is important to note that the consumption of food may not necessarily occur within London itself. For example, a Londoner may purchase a sandwich while travelling to another city. Nevertheless, this provides a valuable indication of the ability and influence Londoners have to reduce the overall impact of their food consumption choices. This distinction is particularly relevant for the food service sector, which serves many visitors (including tourists and commuters) each year. While not presented on the Sankey diagram, estimates of food waste generated by visitors[56] to London in the food service sector are provided below.

Food service

- London is home to a vibrant and diverse food service industry. As of March 2020, there were approximately 8,500 licensed restaurants, 6,300 unlicensed restaurants and cafés, and 5,700 takeaways and food stands in London. The number of food service businesses has been consistently increasing in recent years.[57] Correspondingly, 14% of the food consumed by Londoners occurs within **food service** settings, such as restaurants, cafés and canteens, accounting for about 665,000 tonnes of food per year (around 75 kg per person per year). Interestingly, this share is higher than the UK average, as Londoners eat out more (3.9 times per month) on average than the rest of the UK (3 times per month).[58]

- **Emissions** associated with food service activities relate to energy consumption in food preparation, storage and lighting. It has been suggested that carbon emissions related to food service activities are higher than for home cooking, given the amount of gas and electricity needed to prepare and store food and to light and heat the environment.[59] However, due to the limited availability of data, no emissions are directly attributed to food service activities within the scope of this research.

- Food consumed by Londoners within the food service sector is responsible for the generation of approximately 93,000 tonnes of **food waste**, which is about 6% of the total food loss and waste generated in London (excluding imports). When factoring in purchases by visitors, an additional estimated 192,600 tonnes of food waste are generated, bringing the total food waste generated by the sector to 285,600 tonnes. However, waste generated by visitors is not presented in the Sankey diagram for consistency.

Nevertheless, when looking at the shares of waste generated in relation to the inputs for each sector, the results present food service as a relatively wasteful sector, as approximately 14% of the food that flows into the sector is wasted.[60] About 75% of total food waste in food service is considered 'edible' and thus avoidable.[61] The key causes of this result from food preparation (45%), customer plates (34%) and spoilage (21%).[62]

Households

- The remaining 86% of food consumed by Londoners, approximately 4,129,000 tonnes, occurs within **households**, equating to about 460 kg per person per year. A range of socio-economic factors (such as household size, age, income and ethnicity) influence the type and quantity of food consumed.[63]

- Similar to the food service sector, **emissions** at this point of London's food system relate to energy consumption in food preparation and storage, such as the use of gas cookers and refrigerators. However, due to lack of data availability, no emissions are directly attributed to household food consumption within the scope of this research. Section 3.3 presents a breakdown of consumption-based emissions of Londoners.

- Approximately 64% (931,000 tonnes) of **total food loss and waste** generated in London (excluding loss arising from imports) comes from households, the highest volume of waste generated across the supply chain. According to the London Environment Strategy, food waste accounts for around 26% of total household waste.[64] As such, London households produce almost 104 kg of food waste per person each year.

There are a variety of factors that influence food wastage in households, most of which is considered edible and thus avoidable (around 60%).[65] Of this avoidable food waste, 48% is due to not being used before it spoils, 31% due to large servings/leftovers, 14% due to personal dislikes for certain foods and 4% due to accidents, such as freezer failure.[66] Wasted food is estimated to cost households £50 to £60 per month.[67] [68]

Redistribution

- According to the available data on food **redistribution** in London, only about 7,310 tonnes of food per year are kept in the loop through redistribution. These account for just 0.5% of total food waste and loss in London (excluding loss arising from imports).

Most food redistribution occurs within wholesale and retail (approximately 63% of the total food provided for redistribution). Processing and manufacturing, and food services and households – which together account for more than 80% of total food loss and waste in London – only support 37% of total food redistribution in London (25% and 12% respectively). Given that approximately 60% of household food waste is considered 'edible',[69] there is an opportunity to increase the proportion of food that is redistributed within London.

64%
of total food loss and waste generated in London comes from households.

Waste collection

- Taken together, food loss and waste generated in London total approximately 1,456,000 tonnes, excluding food waste generated by visitors. This food loss and waste is collected by both private and public entities. For example, waste from London's food industry (including processing and manufacturing as well as wholesale and retail) tends to be collected by private waste management companies, while waste generated at the point of consumption (including households and food services) tends to be collected through public waste management infrastructure.

  London consists of 33 waste collection authorities (32 boroughs and the City of London), 12 authorities that are 'unitary' waste authorities (combined collection and disposal), four statutory waste disposal authorities and one voluntary waste partnership. Every borough has a waste collection authority. Waste collection authorities are responsible for arranging household waste collections. Despite many (though not all) boroughs providing separate food waste collections, the amount of food waste recycled is low, with food waste still making up around 25% of non-recycled household waste.[70]

Anaerobic digestion

- Anaerobic digestion is responsible for the management of 248,000 tonnes of food loss and waste generated within London (representing 17% of the total).

  While the process generates approximately 22 kt CO_2eq greenhouse gas emissions (5.6% of total emissions generated by London's food waste management), the process of anaerobic digestion also produces bio-based fuels, which can be used as a low-carbon alternative to fossil fuels. Due to the space requirements of such facilities, much of London's food waste is treated by plants outside of the city boundaries.

Composting

- Approximately 98,000 tonnes of food loss and waste generated in London are composted (representing almost 7% of the total waste generated in London). Composting generates valuable biomaterials that can be used as bio-based fertilisers within agriculture. Approximately 5 kt CO_2eq is generated via composting activities (representing 1.2% of total emissions generated by London's food waste management).

Incineration

- The largest share of food waste in London is sent to incineration (57%, equal to 821,000 tonnes), most of which originates from households. Energy is commonly generated from the incineration of this waste. However, this process is responsible for the generation of 107 kt CO_2eq (27% of total emissions generated by London's food waste management), with an emission intensity of 0.13 kt CO_2eq per tonne of waste. Such incineration is commonly paired with energy capture techniques to generate a (semi) renewable source of energy. The Mayor of London supports the improvement of existing incinerators, to reduce their impact on air quality and to improve their efficiency by capturing heat for heat networks.

Landfill

- Approximately 122,000 tonnes of London's food loss and waste are sent to landfill (representing 8% of the total waste generated in London), which represents the least desirable option in the waste hierarchy. Sending waste to landfill not only eliminates the potential capture of value from these resources, but also generates a significant quantity of greenhouse gas emissions through decomposition. This is responsible for 65% (256 kt CO_2eq) of the emissions of London's food waste management, with an emission intensity of 2.11 kt CO_2eq per tonne of waste.

Other recycling

- Approximately 150,000 tonnes of food loss and waste (representing 10% of the total waste generated in London) are managed through a range of other recycling activities. 'Other recycling' refers to a range of processes that enable the cycling of food waste, including use as animal feed (5.1%), land spreading (4.5%) and other specialised recycling (0.8%). Such kinds of recycling are commonly carried out for food loss and waste from industry due to the higher homogeneity of food loss and waste.

3.3 Focus on household food consumption

Due to our globalised food and beverage supply chains, the types of food demanded by Londoners through their dietary choices influences the types of food that are produced around the world to fulfil this demand.

As illustrated in section 3.2, the supply of food and beverages generates a variety of greenhouse gas emissions at various points along the global food supply chain, from agricultural production to manufacturing and retail. The total sum of the greenhouse gases that are driven by the consumption of food, in this case by Londoners, are referred to as consumption-based emissions. Taken together, the total food-related consumption-based emissions of Londoners is approximately 15,483 kt CO_2eq.

Different types of food and beverages generate different magnitudes of greenhouse gas emissions. As such, different food and beverages have disproportionate contributions to the consumption-based emissions of Londoners.

The zoom-in visual on the next page shows a breakdown of the types of foods that are consumed (including food that is eaten and not eaten) within London households. The green bars indicate the share of different food products consumed in tonnes. The pink bars show the share of overall consumption-based emissions attributed to different food products consumed by Londoners in kt CO_2eq (that is, the emissions that are embodied throughout the supply chain to the point of consumption).
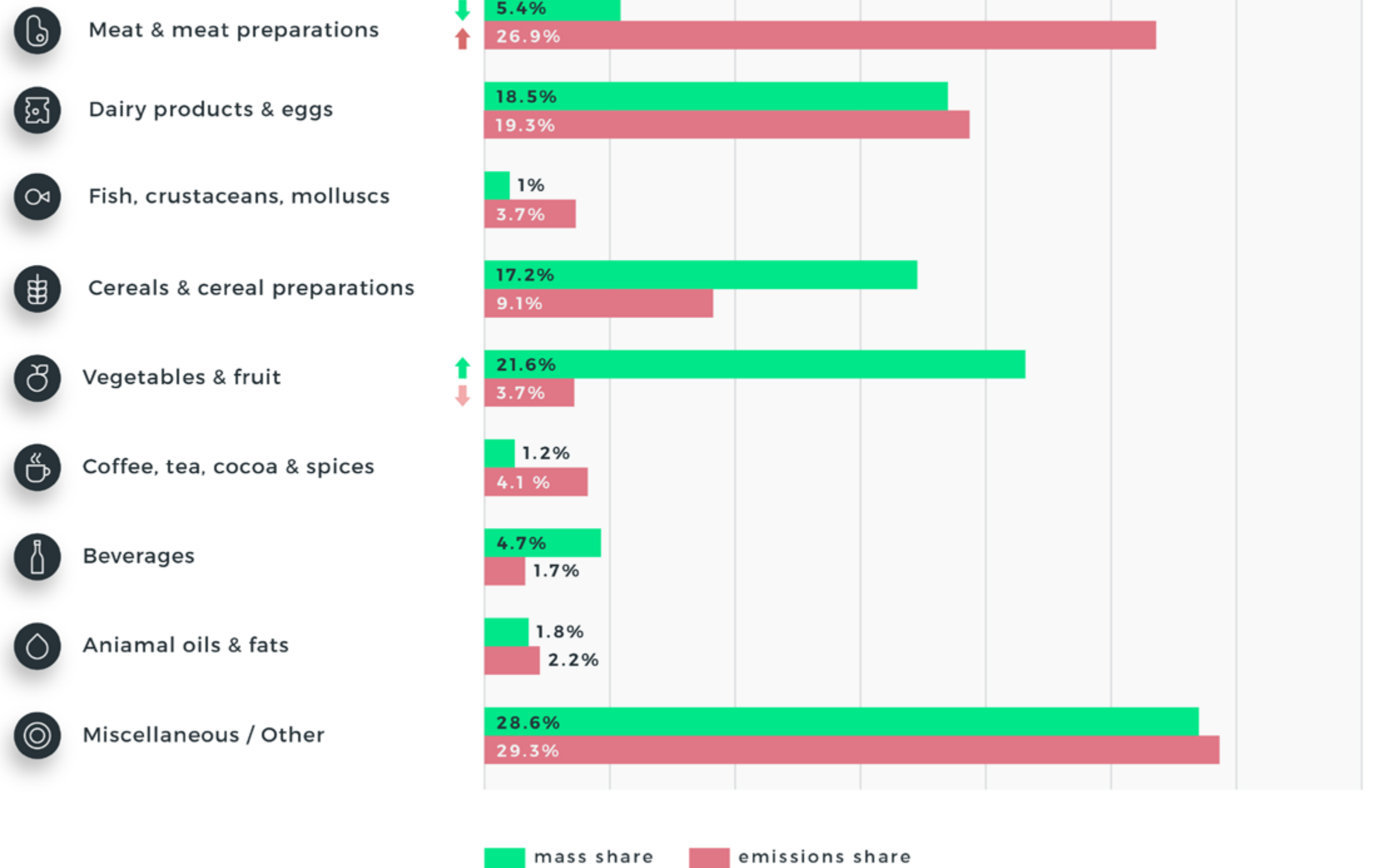
ZOOM IN
FOOD CONSUMPTION BY LONDON HOUSEHOLDS

Consumption-based emissions

15,483 ktCO$_2$eq

HOUSEHOLDS
4,129,000 t

129.000

931.000

Category	mass share	emissions share
Meat & meat preparations	5.4% ↓	26.9% ↑
Dairy products & eggs	18.5%	19.3%
Fish, crustaceans, molluscs	1%	3.7%
Cereals & cereal preparations	17.2%	9.1%
Vegetables & fruit	21.6% ↑	3.7% ↓
Coffee, tea, cocoa & spices	1.2%	4.1%
Beverages	4.7%	1.7%
Aniamal oils & fats	1.8%	2.2%
Miscellaneous / Other	28.6%	29.3%

mass share   emissions share

As can be seen in the chart on the previous page, different food products possess different consumption-based emission intensities. Notably:

- Despite only representing just over 5% of the food consumed by Londoners (in tonnes), **meat** is responsible for almost 27% of households' consumption-based emissions.

- **Dairy** represents a large proportion of food consumed in tonnes (over 18%) while also presenting a comparably high share of total consumption-based emissions (over 19%).

- **Cereals** make up an appreciable share of the food that is consumed in London households in tonnes (over 17%) and are responsible for just over 9% of the total consumption-based emissions. While the chart implies that cereals have a high share of consumption-based emissions, this is due to the volume (in tonnes) of cereals consumed by Londoners. In reality, cereals possess relatively low emission intensities per tonne of food produced.

- While **vegetables and fruit** make up a relatively large proportion (almost 22%) of the food that is consumed by London households (in tonnes), they have low consumption-based emissions (around 4%), highlighting their low emission intensity.

- The three food groups **fish, crustaceans and molluscs**, **coffees, teas and spices**, **and oils and fats** each make up relatively low proportions of both tonnes of food consumed and consumption-based emissions – all of which are below 5%. What is interesting is that each food group is responsible for a greater share of total consumption-based emissions than the share of food consumed (tonnes), implying that the production of these food groups is relatively carbon intensive.

- **Beverages** represent almost 5% of the total quantity of food and beverages consumed by households (in tonnes) and are responsible for around 2% of consumption-based emissions.

- The **miscellaneous / other** category includes a variety of often processed food products (such as sugars, snacks and pre-prepared meals), makes up a high proportion of food consumed and is relatively carbon intensive. When compared to less processed alternatives such as vegetables and fruit, this food group generates higher emissions per tonne.

Leverage points in London's food system

04

4. Leverage points in London's food system

The analysis of London's food system provides a system-level overview of the volumes of food, loss and waste flowing through the city and quantities of greenhouse gases emitted at each point along the supply chain.

This system-level overview provides an important evidence base to support the identification of leverage points in London's food system that can bring about significant reductions in emissions and support the achievement of London's zero-waste and zero-carbon ambitions.[71] These leverage points were discussed with the project advisory group, made up of experts in circular economy and urban food systems. Three key leverage points were selected to explore further:

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1 Shift towards more healthy and sustainable diets.

2 Reduce food loss and waste.

3 Make better use of waste in combination with waste reduction.

</div>

For each of the leverage points identified for London's food systems, future circular scenarios were developed based on a change in key variables of the system. These scenarios provide a quantified estimation of the potential for each leverage point to reduce London's food-related consumption-based emissions. Two scenarios have been developed for each leverage point:

- **Moderate scenario**: represents a scenario whereby concerted progress has been made to act upon each of the leverage points.

- **Ambitious scenario**: represents a scenario whereby actions have been pursued to a more ambitious extent to realise each of the leverage points.

The scenario inputs and results for both the 'moderate' and 'ambitious' scenarios are based on the baseline consumption-based emissions of the London area (2019 values), as estimated in section 3 of this report.

It is important to note that the scenarios developed in this research are indicative and provide a quantified example based on changing a variety of variables within the system flow and emissions model. Complex socio-economic, environmental and political factors, such as Brexit, COVID-19 and increasingly extreme weather, are out of the scope of this research but will all undoubtedly have notable impacts on London's (as well as the global) food system. The probably significant impact of these factors should be taken into account when interpreting the results presented here and should be considered within future research.

The visual presented in this section of the report provides a summary of the estimated impact each leverage point might have on the consumption-based emissions associated with London's food system across the scenarios when compared to the 2019 baseline. Further detail on each of the leverage points and their potential to reduce consumption-based emissions is provided in the subsequent sections of this report.

Although local food production and the consumption of organic food provide the opportunity to reduce carbon emissions and other environmental impacts, this leverage point was not quantitatively modelled, since its ultimate carbon impact is heavily dependent on a diversity of context-specific factors, such as land availability and production efficiency.

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Prioritising local and agro-ecological food

London is highly dependent on imports, with almost all of London's food supply (99%) being imported. Interestingly, the surrounding greenbelt is intensively farmed but much of this food does not find its way into London's food supply.[72] From a broad circular economy and ecological perspective, there are a number of benefits associated with prioritising locally produced food through agro-ecological means, for example boosting biodiversity, sequestrating carbon and improving local soil and water quality.[73] Supporting and prioritising food that is cultivated locally through sustainable practices forms part of the Mayor's London Food Strategy[74] and the Food Flagship Initiative.[75]
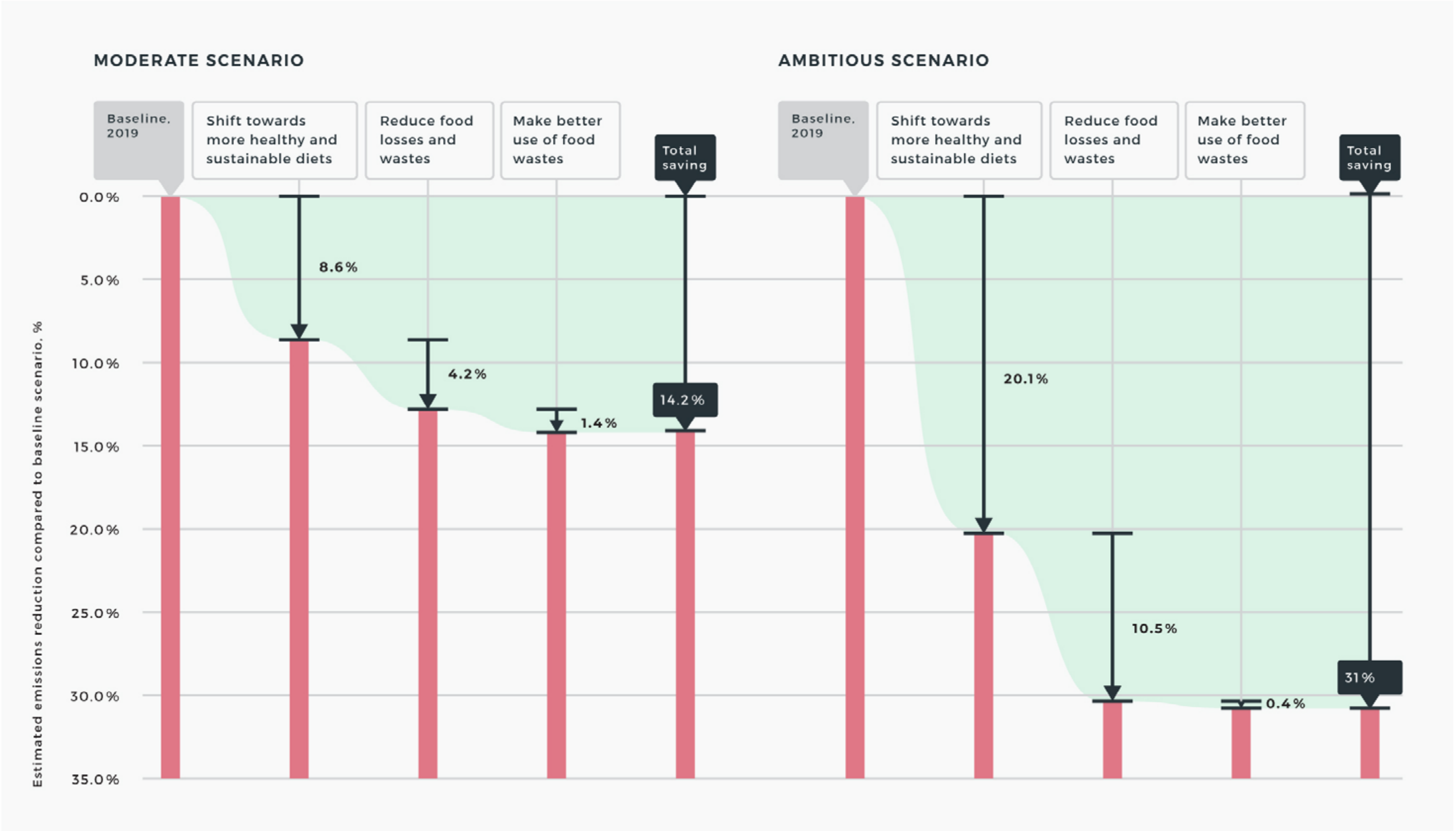
However, consuming food produced locally and/or through agro-ecological means may not necessarily lead to a reduction of greenhouse gas emissions.[76] The greenhouse gas emission impact of food production is heavily dependent on a diversity of context-specific factors[77] such as yields and production methods. It was, therefore, decided not to include it within this research.

This leverage point can also provide an opportunity to reduce greenhouse gas emissions indirectly, for example through an increased awareness of healthy and sustainable food choices. Such practices could also generate a diversity of broader ecological and socio-economic factors – from boosting biodiversity to providing education opportunities – and should be encouraged and explored further.

</div>

FOOD SYSTEM EMISSIONS REDUCTION

SUMMARY OF THE ESTIMATED EMISSIONS REDUCTION OF
CIRCULAR LEVERAGE POINTS ACROSS SCENARIOS

MODERATE SCENARIO

Baseline, 2019 | Shift towards more healthy and sustainable diets | Reduce food losses and wastes | Make better use of food wastes | Total saving

8.6 %
4.2 %
1.4 %
14.2 %

AMBITIOUS SCENARIO

Baseline, 2019 | Shift towards more healthy and sustainable diets | Reduce food losses and wastes | Make better use of food wastes | Total saving

20.1 %
10.5 %
0.4 %
31 %

Estimated emissions reduction compared to baseline scenario, %

0.0 %
5.0 %
10.0 %
15.0 %
20.0 %
25.0 %
30.0 %
35.0 %

What if London… shifted towards more healthy and sustainable diets?

Scenario	Scenario input	Change in Londoners' food-related consumption-based emissions
Moderate scenario	Reduce meat consumption by 30% per Londoner.	↓ **8.6%** reduction
Ambitious scenario	Reduce meat consumption by 70% per Londoner to reach an approximate total of 16 kg per person per year, as outlined by C40 and EAT-Lancet as optimal for health and planetary goals.[82]	↓ **20.1%** reduction

Key assumptions:

- Meat is substituted by a vegetable and fruit diet (of equal calorific value).
- Increase is applied to the entire vegetable and fruit group.
- Increase in tonnage is split according to the share between imports and primary production.

4.1 Shift towards more healthy and sustainable diets

The way Londoners eat and source their food and beverages is a significant driver of greenhouse gas emissions. As this research has highlighted, the majority (78%) of the consumption-based emissions associated with London's food and beverage system is embodied within the products before they reach the city; driven by the type of food and beverages that Londoners demand. Crucially, as has been highlighted in section 3.3, different food and beverage products have different carbon intensities, so some diets will be more carbon intensive than others. **Meat,** for example, represents the single largest contributor of consumption-based greenhouse gases stemming from food (almost 27%), while constituting only 5% of the volume of food consumed by Londoners.

The Mayor's London Food Strategy highlights the Mayor's aim to work in partnership with others to promote healthier and more sustainable food choices and eating behaviours.[78] There is a significant opportunity to reduce the consumption-based emissions of London's food system through a reduction in the consumption of meat. Research indicates that a diet consisting of 16 kg of meat protein per capita per year constitutes healthy levels of meat consumption.[79] [80] For Londoners, this would mean that the average person could reduce their meat intake by 70% when compared to 2019 levels which would cut London's consumption-based emissions by 20%. If the amount of meat eaten by every Londoner was reduced by up to 30%[81] this would still significantly reduce London's consumption-based emissions.

Key London actions

In October 2019, C40 published its Good Food Cities Declaration[83] which the Mayor of London signed. The declaration asks cities to align food procurement policies to the Planetary Health Diet ideally sourced from organic agriculture and support an overall increase in healthy plant-based food consumption in our cities, by shifting away from unsustainable, unhealthy diets.

In particular, the London Borough of Camden have committed to 'Introducing meat-free days across Council catering contracts from 2020, including schools' in their Climate Action Plan.[84]

Other international inspirations

New York (USA) – Reducing beef purchases by half

New York is committed to achieving carbon neutrality by 2050. As part of the measures to achieve this ambition, the city's Mayor has established New York City's Green New Deal, which among other things focuses on reducing meat consumption to tackle greenhouse gas emissions. Within the plan, the city intends to phase out all processed meat and cut the purchase of beef by 50% in city-managed facilities, including schools, prisons and hospitals. To support this, the city has launched 'Meatless Mondays' throughout public schools.[85]

Turku (Finland) – Public procurement of plant-based meals

To support an increase in the proportion of vegetarian meals, the city of Turku, Finland has implemented measures that reduce the proportion of meat that is offered on menus in publicly managed institutions. From 2020, the meals offered within education settings will increase vegetarian meals from six to eight, per six-week period. A further reduction of beef in meals in favour of plant-based alternatives is also included in the measures, as well as the integration of sustainability criteria within food service contracts to reduce the impact of the food supply on carbon emissions. The potential greenhouse gas emission reduction potential is promising. Between 2019 and 2020, greenhouse gas emissions produced by food services have already decreased by 4% per meal.[86]

4.2 Reduce food loss and waste

Approximately 1,456,000 tonnes of food are lost and wasted each year within London's food and beverage supply chain (not including loss associated with imports). Every time food and beverages are wasted, economic and material value is lost, while the emissions produced to make this product are also wasted. As such, reducing food loss and waste is key to both a low-carbon and circular economy.

However, it should be noted that not all food loss and waste can be prevented. A certain fraction of food loss and waste is considered 'non-edible', such as eggshells, bones and fruit peel, and so is unavoidable; unlike food and beverages that have been wasted for avoidable reasons, such as not being used in time or preparing too much.[87]

The share of edible versus non-edible food loss and waste varies across the supply chain: for example 75% of food waste from the food service sector is considered edible (such as extra food that is left on dinner plates), while around 50% of food loss and waste from manufacturing and processing is considered edible (such as food unnecessarily spoiling due to supply forecasting inaccuracies).[88] Although not all food loss and waste can be prevented, the edible proportion should be targeted. Reducing edible food waste can be prevented in a number of ways, from reducing the amount of food bought, to redirecting excess food to those in need through redistribution channels, to using it ultimately as animal feed.

In his London Environment Strategy and his London Food Strategy, the Mayor of London outlines ambitions to work in partnership to reduce food loss and waste throughout London's food and beverage supply chain to help meet its target of becoming a zero-waste city. By 2030, London has set a target to reduce food waste by 50% per person.[89] The ambitious scenario reflects these intentions to halve food waste generated in London, while the moderate scenario reflects a 20% reduction.

What if London… reduced food loss and waste?

Scenario	Scenario input	Change in Londoners' food-related consumption-based emissions
Moderate scenario	Reduce food loss and waste generation in London by 20%.	↓ **4.2%** reduction
Ambitious scenario	Reduce food loss and waste generation in London by 50%.	↓ **10.5%** reduction

Key assumptions:

- Reductions in food loss and waste in London are achieved through a 30% and 75% reduction in 'edible' / avoidable food loss and waste, for the moderate and ambitious scenarios respectively.

- Proportion of 'edible' / avoidable food waste for each supply chain node is comparable to UK averages. These are: primary production (90%),[90] manufacture and production (51.2%),[91] wholesale and retail (100%),[92] food service (75%),[93] households (60%).[94]

- Takes into account reducing waste originating within London only (i.e. not including loss from food imported to London).

- Avoided waste is achieved via prevention (45%), redistribution (35%) and incorporation into animal feed (20%).

- Food waste prevented at the point of consumption leads to a decrease in food input.[95] By reducing the amount of edible food that is wasted, this reduces the demand for more food. For example, leaving a carton of milk to spoil in the fridge often leads to purchasing another carton of milk to replace the wasted product. These scenarios take this into consideration and include both the greenhouse gas emissions from reduced waste management activities, as well as a reduction of the greenhouse gas emissions associated with a reduction in food consumption.

Key London actions

Through the London Environment Strategy[96], the Mayor of London is committed to reducing food waste by 50% per person by 2030 in the city and has deployed a wide range of leading programmes aiming at supporting citizens and businesses to reduce their food waste, including the TRiFOCAL[97] communications-based project, delivered by ReLondon in partnership with WRAP and Groundwork London, between 2017 and 2020. Working across 15 London boroughs and with 11 partner EU cities, the project sought to change food behaviours with businesses, schools, community groups and citizens across the city. The 'Small Change, Big Difference' householder campaign developed as part of the project used combined messaging around: healthy and sustainable eating, food waste prevention and food waste recycling. Among other results, the project measured a 9% reduction in avoidable food waste generated per household per week. The success of this programme has led to London's involvement in another ongoing EU education and awareness campaign on food and climate, targeted at younger citizens (15-35), called Food Wave[98].

Other international inspirations

Porto (Portugal) – Collaborating with municipalities to make the most of food

Porto is committed to combating food waste. Throughout the city and metropolitan area, there are a range of ongoing initiatives striving to reduce food waste, including Refood, which diverts edible food waste from landfill by redistributing it, and Fruta Feia (Ugly Fruit) Cooperative, which markets food products with visual imperfections that producers find hard to sell. By avoiding 50% of edible food waste going to landfill or incineration, this could:

- Avoid 92,600 tonnes of CO2eq in the Porto metropolitan area, due to reduced emissions from the production of food and treatment of food waste.

- Save US$92 million for the Porto metropolitan area (representing the value of food that is no longer wasted).[99]

Cincinnati (USA) – Reducing food waste by 20% by 2025

Under the 2018 Green Cincinnati Plan, the city has committed to reducing food waste with consumer campaigns and targeted food recovery networks, which collect food that would otherwise be wasted and redistribute it to residents facing food insecurity. The city estimates that composting food waste already reduces carbon emissions by 18,500 tonnes per year, saving US$185,000 in 2012.

4.3 Make better use of waste in combination with waste reduction

Of the 1,456,000 tonnes of food generated within London's food system each year (not including loss associated with imports), some of this waste is considered non-edible or largely unavoidable, such as eggshells and banana skins. The way in which this waste is managed is an important factor when analysing the greenhouse gas emissions of London's food system. For example, sending food waste to landfill generates the largest share of carbon emissions (65%) of all of London's food waste management options, despite only 8.4% of waste being managed in this way.

Other waste management options, such as anaerobic digestion, generate alternative fuels that reduce the use of fossil fuels and their associated greenhouse gas emissions. Effective management of food waste can therefore reduce London's overall greenhouse gas emissions and contribute to a circular economy. London's Environment Strategy sets out ambitions to achieve zero biodegradable or recyclable waste sent to landfill by 2026, and to recycle 65% of London's municipal waste by 2030.[100] In alignment with these ambitions, food waste management is modelled in the scenarios under the following shares:

- Anaerobic digestion: 60%
- Composting: 20% [101]
- Incineration: 10%
- Landfill: 0%
- Other recycling: 10%

Reflecting the integrated nature of London's food waste management system, this estimation builds on the reductions of food loss and waste achieved in the ambitious scenario of leverage point 2: Reduce food loss and waste.

What if London… made better use of its food loss and waste at the same time as reducing waste?

Scenario	Scenario input	Change in Londoners' food-related consumption-based emissions
Moderate scenario	Reduce food loss and waste generated in London by 20% and improve waste treatment.	↓ 1.4% reduction
Ambitious scenario	Reduce food loss and waste generated in London by 50% and improve waste treatment.	↓ 0.4% reduction

It is important to note that a lower total quantity of food waste is generated, and therefore enters the city's waste management system, in the ambitious scenario when compared to the moderate scenario. This lower total quantity of waste explains the lower contribution of the ambitious scenario (0.4%) to the reductions in the consumption-based emissions when compared to the moderate scenario (1.4%). In other words, as less food waste is generated, the optimisation of waste management practices of the remaining food waste makes a smaller difference to the overall consumption-based emissions of London's food system.

Key assumptions:

- Energy generated through anaerobic digestion and incineration leads to a reduction in fossil fuel-derived energy.
- Incineration includes energy capture.
- Anaerobic digestion is prioritised as this is, on average, the least carbon intensive waste management option.[102]
- Emissions savings include those from all waste management options.

Key London actions

The London Environment Strategy required London boroughs to develop reduction and recycling plans by 2020, which should include local reduction and recycling targets that contribute to the Mayor's London-wide targets. The objectives of Reduction and Recycling Plans (RRP) include driving resource efficiency to significantly reduce waste focusing specifically on food waste, reduce the environmental impact of waste activities (greenhouse gas emissions and air pollutants); maximise recycling rates, maximise local waste sites and ensure London has enough infrastructure to manage all the waste it produces.

London's boroughs are also leading the way in the UK government's commitment to roll out separate household food waste collections by 2023 across the country, with 24 out of 33 London Boroughs already having a food waste collection service in place.[103]

Other international inspirations

Milan (Italy) – Regenerating peri-urban and local soils, and utilising biogas

To increase the amount of food waste diverted from landfill to anaerobic digestion and composting facilities, the city of Milan used communication channels such as leafleting, radio and television, to give guidance and encourage the city's inhabitants to separate different organic and non-organic materials. As a result, by 2018, Milan achieved a source separation rate of nearly 56%. In total for that year alone, approximately 130,000 tonnes of organic resources were processed in this way, avoiding 8,760 tonnes of CO2e greenhouse gas emissions In addition, more than 20,000 tonnes of compost and more than 7M m^3 of biomethane were produced by the city.[104][105]

Bogor (Indonesia) – Using black soldier flies to create value from food waste

To address food waste, Bogor City's Environment Agency worked with a local community group to pilot a new approach to reduce organic waste that makes use of black soldier flies. These flies are particularly good at breaking down organic waste, and their larvae have a high protein and oil content that makes them a valuable source of animal feed and oils for lubrication, biodiesel and other uses. The remaining organic waste can be used as an organic fertiliser. The first facility opened in the Paledang area in mid-2020 and is estimated to reduce the city's organic waste by around 2 tonnes per day. In the process, the sale of beneficial by-products creates an alternative source of income for the local community. Following the pilot's success, the agency has replicated the initiative in other locations together with the local community.[106]

Amsterdam (Netherlands) – Community-based composting of food waste with 'worm hotels'

The city of Amsterdam has an ambition to transition to a fully circular city by 2050. To support this while addressing the large quantities of food waste generated each day, 'worm hotels' have been set up in parks and public spaces around the city. For residents who may not have gardens, these worm bins provide a place to dispose of food waste, which is broken down into compost by worms instead of going to landfill. Currently, there are an estimated 200 worm hotels throughout Amsterdam, and demand for memberships exceeds supply. The worm hotels collect food waste from about 1,500 Amsterdam households, and they offer additional benefits for community building, soil health and biodiversity support.[107]

Conclusions

05

5. Conclusions

Building on London's ambitions to become a low-carbon and circular city, this pioneering research uses data to provide deeper insight into the flows of food and waste travelling through London's food system, and links them to their associated consumption-based emissions.

From this research, it is clear that London's food system has a notable impact outside the city itself, influencing the food that is produced, the food loss and waste that is generated and the greenhouse gases that are emitted (with 78% of the consumption-based emissions associated with London's food system occurring outside London).

Furthermore, the research highlights the large quantities of food waste that are generated by London households (931,000 tonnes) each year. This food waste created by Londoners should also be viewed as contributing to an increase in the consumption-based emissions emitted when producing this food, which is then discarded. From the food loss and waste that is generated within London, 8% still ends up in landfill, which itself generates 256 kt CO2eq each year.

This research provides an important first step in the creation of an evidence base needed to support the transition towards a low-carbon food system and demonstrates the impact that circular interventions on food flows across the supply chain can have on reducing greenhouse gas emissions.

The key leverage points identified through this research highlight how a few bold and strategic steps to transition towards a more circular economy can help to reduce greenhouse gas emissions. Interventions associated with an 'ambitious' scenario hold the potential to reduce the consumption-based emissions of London's food system by an estimated 31%. These interventions also demonstrate the importance of an integrated approach and the impact potential of influencing the types of food consumed (shift towards healthy and sustainable diets) and influencing food loss and waste – both in terms of its generation (reduce food loss and waste) and management (make better use of waste).

The Mayor of London and the London boroughs, supported by ReLondon, are already taking actions across all these leverage points. This report will help further develop these actions and target efforts towards areas with the most impact. Among others, this will inform London programmes such as the Food Flagship Initiative, and the One World Living programme. This research is a key milestone in achieving zero-carbon ambitions across cities globally, as it has been designed to be replicable to other sectors and other cities, beyond London's food sector. This approach could be used by decision-makers in cities across the world to identify interventions throughout their urban food system that would help to reduce the generation of greenhouse gas emissions globally.

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Appendix

The table below qualitatively highlights the degree of uncertainty related to the data within each supply chain node to support the interpretation of the results and values presented in the report.

Supply chain node	Data uncertainty indication
Imports	Very good
Primary production	Moderate
Processing and manufacturing	Low
Wholesale and retail	Low
Exports	Good
Food service industry	Moderate
Households	Very good
Food redistribution	Moderate
Waste collection	Good
Waste management	Good

Endnotes

1   Owen, A. & Barrett, J. (2020). *Consumption-based Greenhouse Gas Emissions for London (2001–2016)*. University of Leeds. Sourced from: Greater London Authority website.

2   Consumption here refers to food that is purchased by Londoners, including food that is both eaten and thrown away (in other words, including waste).

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

4   'Food loss' refers to the discarding of food that results from decisions and actions by stakeholders in the supply chain from post-harvest up to (but not including) food services and retail. 'Food waste' typically refers to food that is discarded resulting from decisions and actions by distributors, retailers, food service providers and households.

5   In this scenario a lower total quantity of food waste is generated and therefore enters the city's waste management system. As such, with less food waste being generated, the optimisation of waste management practices of the remaining food waste makes a smaller difference to the overall consumption-based emissions of London's food system.

6   ReLondon, Greater London Authority & Ellen MacArthur Foundation (n.d.). *Food Flagship Initiative*. Sourced from: ReLondon website.

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8   Often referred to as territorial emissions.

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16   Sustainable Development Goal 12 (SDG 12) seeks to "ensure sustainable consumption and production patterns." The third target under this goal (Target 12.3) calls for cutting in half per capita global food waste at the retail and consumer level and reducing food loss along production and supply chains (including post-harvest loss) by 2030. More information is available at champions12.3.org

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21   UNEP (n.d.). *Cities and Climate Change*. Sourced from: UNEP website.

22   See Glossary of Terms.

23   Owen, A. & Barrett, J. (2020) *Consumption-based Greenhouse Gas Emissions for London (2001–2016)*. University of Leeds. Sourced from: Greater London Authority website.

24   University of Leeds (2021). *Consumption-based Greenhouse Gas Household Emissions Profiles for London Boroughs*. Sourced from: London Councils website.

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