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LOCAL, SEASONAL FOOD AND SHORT SUPPLY CHAINS

A review of the environmental impacts associated with food distribution

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Executive Summary

This report synthesises evidence surrounding the environmental impacts of 'local' and 'seasonal' food, comparing three related categories: local (supply chain distance and transport), short food supply chains (SFSC) (small number of intermediaries) and seasonal (produced in the natural growing season of a food). A Quick Scoping Review (QSR) was undertaken to identify evidence in the academic and grey literature, with a focus on quantified life-cycle assessments (LCAs). For each of the three categories, the literature was examined to understand *definitions* applied and evidence of environmental impacts, looking at both *greenhouses gases* as a priority and *other environmental impacts*. It does not examine the evidence for economic, social or other benefits, though acknowledges that these are motivating factors for many stakeholders.

From the trends research, ten key conclusions were identified. They may not apply to all food products in all scenarios, but are rather general trends:

1) 'Food miles' is not a suitable metric to analyse food sustainability, and being geographically 'local' does not guarantee reduced environmental impact;
2) Efficiency of transport is important: suppliers in 'local' and 'short' supply chains must take care to ensure that less-efficient logistics do not cancel out potential GHG savings from shorter distances travelled or alternate production practices. But inefficiencies can be mitigated, and SFSCs *can* be more efficient;
3) Consumer transport is as important as supply chain transport. Some alternative distribution networks encourage additional consumer car journeys to transport small volumes of food. This can be avoided through specific distribution methods and encouraging low-carbon journeys;
4) Where food is produced matters, as some regions are more productive than others. Importing from such regions can have lower environmental impacts than domestic production, though this must be balanced against economic and food security objectives;
5) There may be trade-offs between different environmental metrics – notably land use and water use – with one origin country or production method being favourable for some criteria but unfavourable in others;
6) Producing food out-of-season can substantially increase the GHG footprint, and importing from countries where it is in season ('global seasonal' food) is often preferable. 'Seasonal' is therefore a more important criteria than 'local' for environmental impact;
7) Air freighting food adds considerably to its carbon footprint and should be avoided;
8) Emerging technology and renewable energy may alter the conclusions relating to glasshouses and indoor production, with uses of renewables or CHP in some cases

having comparable, or only marginally higher GHG emissions than production without external energy inputs. The findings should be periodically reviewed as energy grid emission intensity decreases;

9) It is important to maintain a sense of scale. Most impacts identified in the literature were evaluated for crops such as fruits and vegetables, which generally have a low emission footprint per kg of produce. What may appear large relative differences – such as that between heated and unheated glasshouses – may be, in absolute terms, small. This is important for weighing up trade-offs, particularly around food security and domestic produce;

10) More sustainable on-farm practices may correlate with 'local' or SFSC producers, but it is not guaranteed. If production practices are the motivation for supporting a particular supplier, they should be discussed as such.

These conclusions are formed primarily based on where evidence has been quantified, i.e. via LCA. This may miss the less quantifiable 'cultural' benefits associated with food purchasing decisions and how they interact with consumer preferences and behaviours in other areas of life, such as if engaging with 'local' food encourages people to make further changes to their diet, transport and other behaviours. More research is needed to identify the role, if any, of such cultural knock-on effects.

Based on these findings, some general guidelines for environmental purchasing decisions – such as within institutional procurement – can be suggested:

a) Favour the procurement of local/domestic food that is produced seasonally, where it is socially, economically and environmentally plausible to do so. Recognise that the food procured does not necessarily have a lower environmental footprint just because it was procured 'locally';

b) Import seasonally-produced food from productive areas for products which cannot be grown in the UK without unreasonable environmental and economic impacts, or where domestic production is insufficient to meet demand, prioritising most efficient transport modes and avoiding air freight;

c) For products that cannot be procured in compliance with the above constraints, explore options for alternative food products that *can* be produced efficiently and seasonally, without compromising on nutrition;

d) Work with producers and suppliers to adopt efficient production practices that reduce environmental impacts, both domestically and internationally, such as by prioritising producers who are able to demonstrate such production practices when awarding contracts;

e) Work with all suppliers to improve logistics and reduce transport impacts, particularly looking to support the coordination of smaller or local suppliers. Additionally, encourage lower-carbon consumer journeys.

Contents

Local, seasonal and short food supply chains

1.0 Background

1.1 Purpose and research questions

The purpose of this research was to explore and synthesise the evidence surrounding the environmental impacts of localised food systems and the role of seasonality in both public procurement and food systems more broadly.

The research requirement was, in part, identified following Defra's release of the 'Government Food Strategy' in June 2022, along with the launch of consultation on the reform of the Government Buying Standards for Food and Catering Services (GBSF). This work was completed in the context of the 'Sustainable food procurement' research undertaken by WRAP and City University for Defra in 2021-22, building upon the work to form a more in-depth investigation of the questions of locality, seasonality and supply chain structure. This research aims to bring Defra's research on local food up to date, which could support future public procurement policy.

The report focuses on three core research questions:

1. What evidence is there for a link between local food production and environmental benefits?
2. What evidence is there for a link between short- and long-food supply chains and environmental benefits?
3. What evidence is there for a link between seasonality of food and environmental benefits?

Within each of these, sub-questions were considered relating to definitions and interactions between these three aspects of food provision.

1.2 Method

The method to address these research questions was a quick-scoping review (QSR), based on the guidance provided by Collins et al.[1] This involved conducting searches of academic and grey literature based on key words related to the three research questions, and screening out results in multiple stages, based on the title, abstract and then full reading of the text.

This led to a dataset of 102 publications, of which 85 were published in the academic literature and 17 in grey literature.

[1] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/560521/Production_of_quick_scoping_reviews_and_rapid_evidence_assessments.pdf

The papers were read and analysed for information to answer the research questions. The evidence was split into local, short food supply chain (SFSC) and seasonal components, though in many cases there was a cross over, with the same evidence informing more than one research question. The evidence of environmental benefits or impacts was split into two categories: climate change impact, measured in greenhouse gas (GHG) emissions, and 'other environmental' evidence. 'Other environmental' evidence captured all other possibly relevant factors discussed, such as biodiversity impact, water consumption, land use and eutrophication. The GHG impact is considered as the primary focus, as it is addressed the most frequently in the literature. Other impact categories that are addressed in the literature vary from paper to paper, the 'other environmental' evidence presented reflects impacts and issues that come up most regularly.

Due to the wide range of insights coming from this wealth of literature, the report is focused on the conclusions drawn from their analysis, with signposts and references to particularly relevant papers or examples throughout.

For further details on the methodology, including search terminology and screening process please refer to Appendix 1:.

2.0 Key findings

This report considered three related, but distinct aspects of food distribution: local food, food produced and distributed via short food supply chains and seasonal food. Each has different implications which are presented separately, before being considered together as a bigger picture.

Before presenting the findings, it should be noted that the literature identified through the QSR heavily focuses on crops: 65% (n=66) of the papers identified look at specific food products, of which 77% (n=51) discuss fruit and vegetables (i.e. 50% of the papers identified in QSR discuss produce). By contrast, just 26% (n=17) of the papers discussing specific products cover meat and dairy (17% of total QSR dataset). This disproportionate focus on crops may be due to biases in the literature or the search terminology used, as discussions around domestic and imported livestock products may focus on farming and production practices rather than 'food miles' or transport and logistics.

2.1 Local food

2.1.1 Definitions

'Local' is the least clearly defined, but most discussed, of the aspects considered in this project. It is defined in both exclusively geographic terms (i.e., measuring the 'food miles') and in terms which go beyond just geography, though there often remains a geographic component. More than one definition can be applied in any given example. A summary of the main definitions identified in the QSR, split into 'exclusively-geographic' and 'more-than-geographic' definitions, is provided in Table 1.

The relevance of specific geographic definitions may vary depending on *where* it is being applied. For a country the size of the US or Brazil, for example, 'local' at the scale of the subnational state may be comparable in distance terms to 'local' at the scale of the whole country in the UK. Similarly, for smaller countries like Belgium, it may be meaningful to consider food from neighbouring countries in Western Europe as being 'local'. This context-dependent definition is well summarised by Stein and Santini (2022): "the local is always experienced and understood in relation to larger geographical scales, such as the regional, national or global", with the boundary being "subjective, depending on context".

This subjectivity is equally demonstrated in the use of non-geographic definitions which may or may not overlap with geographic ones. As Goodwin-Hawkins (2020) claims, local is often more an "intuitive idea than a set of fixed criteria" which is defined in opposition to what it is *not*. This more political definition puts local food as "an alternative system of food production that addresses the perceived ills of the modern food system" (Peters et al. 2009). The alternate supply chains implied by such 'holistic' local definitions (Vargas et al. 2021) conflates geography and supply chain structure.

It should be noted that as well as different definitions being applied by different authors and specific contexts, they may be applied differently between food groups. Definitions primarily focus on where primary production takes place, indeed most of the research focuses on raw produce such as fruits and vegetables, or lightly processed foods like cheese or sausages (Willis 2019). Processed products may challenge the strictness of definitions: some traditional cheeses such as those with Protected Designation of Origin (PDO) may contain internationally-sourced inputs, like rennet, for example (Schmitt et al. 2016). Similarly, pastries baked to a local tradition by a local baker may use non-local inputs – consider the dried fruits, spices and rum in a Banbury cake, for example. For foods which cannot be grown in a certain region, such as cocoa or coffee in the UK, the distance from the processor to consumption may be considered more relevant than country of origin (Enthoven and Van den Broeck 2021). For Goodwin-Hawkins (2020), local processors and distributors are the 'missing middle', often not being considered part of 'local food' despite contributing to the local economy.

Table 1: Definitions of local food

Definition	Example	Notes
Exclusively-geographic definitions		
Within a geographic radius	Produced <100km from a city	Most relevant when evaluating 'food miles' travelled
Within a defined boundary	Produced in the same county, region or state	Particularly relevant in legal definitions, or for institutional procurement policies
Within the country	'British food'	Domestic vs. imported food is often compared in LCA studies, and relates to seasonality (section 2.3)
Within a multi-national region	Produced in Europe	More relevant to smaller countries and regions
More-than-geographic definitions		
Local traditions	Heirloom produce varieties, artisanal modes of production, local recipes (such as PDO foods)	Many traditional recipes or protected origin foods can only be 'local' to one defined place. Consumption not necessarily 'local' to where it was produced.
Close relations in supply chains	Community Supported Agriculture (CSA); Food hubs; Farmers' markets	'Local' is often conflated with 'Short Food Supply Chains', looking at intermediaries in supply chain and how food is distributed. Discussed further in section 2.2.
Mode of sale	Vegetable box schemes; farm shops etc.	
Values and ethics	Community Supported Agriculture (CSA); 'Family farms'	Difficult to define, and typically defined in relation to what it is *not* (conventional, 'mass-market' food). Implies purposeful, political decision to be involved. Is often associated with producers delivering environmental benefits.

In summary, 'local food' lacks clear definition and may be applied differently depending on the specific circumstance of location and product being considered. It has become a catch-all term with geographic, economic and political connotations which is defined *in opposition to the perceived 'status quo'*: food from 'near' rather than from 'far away', businesses which are smaller or 'visible' rather than transnational and 'invisible'. This broad approach presents analytical challenges when considering the impacts of 'local food' because researchers use the term to refer to very different things. Notably, amongst the identified LCA-based studies looking at 'local' food (n=54), a substantial majority (c.80%) used geographic definitions based on region, country or total distance travelled, with few (<10%) discussing supply chain structure definitions. As a result, for the purposes of this report, 'local' is evaluated in reference to *geographic proximity* and by association *transport-related emissions*. Supply chain structure and other non-geographic considerations fall more under 'short food supply chain' (discussed in section 2.2]).

For further reading on definitions of local, particularly useful references identified in the QSR include: (Stein and Santini 2022; Enthoven and Van den Broeck 2021; Schmitt, Dominique, and Six 2018; Chiffoleau and Dourian 2020; Peters et al. 2009; Vargas et al. 2021; Goodwin-Hawkins 2020; Smith et al. 2005; Martinez et al. 2010)

2.1.2 GHG Impact

The QSR identified a large number of papers exploring GHG impact and local food, although findings were largely inconclusive, with no clear trend as to whether 'local' food (however it was defined in a particular paper) was preferable or not: in some cases, it was, in other cases it was not, and often depended on particular circumstances. What was clear from the research, and confirms the findings of many other studies and reviews into this topic, was that 'food miles' is *not* a suitable proxy for environmental impact, and that food cannot be assumed to have a lower GHG footprint because it was produced locally. Context of *what* is being produced, *where* it is produced, *when* in the year (seasonality) and *how* it is produced, transported and procured all matter in determining whether 'local' food, however defined, is more beneficial than the alternative in any given comparison. Some key factors which were more important than geographic distance when comparing local food to the alternative, were identified:

Production-level factors: Including but not limited to:

- The local growing conditions: more productive areas with different climates and different growing seasons may influence how efficiently food can be grown at different points in the year, with the results depending in part on the season in question;
- Primary production practices including fertiliser use, following specific growing principles, such as organic farming, or the use of external energy inputs to provide food out-of-season, including heated glasshouse or long-term storage;

- Closely related to these factors was yield, to which LCA based studies were often sensitive.

Box 1

Comparisons of UK produce with imports from productive agricultural exporters such as New Zealand (see, for example, Saunders and Barber (2008); Saunders, Barber, and Taylor (2008); Edwards-Jones (2010)) and Spain (see Milà i Canals et al. (2008); Hospido et al. (2009); Foster et al. (2014); Angeles-Martinez et al. (2017)) were common, and did not find 'local' (British food) to be consistently preferable.

The papers often included analysis of heated glasshouses and long term storage, due to the substantial overlap between the 'local' and 'seasonal' questions (see 2.3). In some cases, field-grown produce is comparable across origin countries (e.g. lettuce and salad crops considered in Hospido et al. (2009) and Milà i Canals et al. (2008) and raspberries in Foster et al. (2014)), but heated-glasshouse produce are substantially more impactful than importing unheated produce (e.g. tomatoes in Pérez Neira et al. (2018), salad crops in Milà i Canals et al. (2008). As a result, whether local is preferable depends not just on *'where'* but *'when'* and *'how'*. Comparing two seasonal field-grown scenarios had some, often small, differences based on local growing conditions and farm practices, with more substantial differences observed with non-seasonal production, long term storage, or specific high-impact transport modes.

It is noteworthy that "the variation in some key variables between farms in the same country is at least as large as that between farms in the different countries", with "ample potential for improvement" Hospido et al. (2009), so the importance of context goes beyond just national boundaries and to specific producers.

Mode of transport: Rather than focusing exclusively on distance travelled, we must consider the impact of *how* food has travelled (Heller 2017):

- Sea freight is often very efficient per tonne-km, due to the large volumes; food can travel very long distances with relatively small contributions to footprint.
- Rail freight is generally more efficient than vehicle transport.
- For road transport, the vehicle size and load size is important in determining the efficiency, with smaller trucks being much less efficient per tonne-km than large, well packed ones. Ensuring return journeys are not empty is also important in this regard.
- Air-freighting is unambiguously a very high impact way of transporting food, and in many cases increases the GHG impact of transport by an order of magnitude.

Within each mode of transport, there are nuances: specific fuel types, the efficiency of the load and whether or not it is refrigerated, for example. Many journeys will require more than one mode of transport: the efficiency of importing products by cargo ship may be lost if they are then driven hundreds of kilometres inland inefficiently, for example. Nonetheless, a very clear conclusion was observed in the literature that 'distance' or 'food miles' alone is effectively meaningless without considering *how* those miles were travelled.

Box 2

The interaction between primary production factors and transport was helpfully expressed in some papers which considered an 'equivalent transport distance' to alternate production modes. This can otherwise be expressed as: if food is produced in a more efficient way, how much further can it travel before the benefits of production are cancelled out? By way of example: Keyes, Tyedmers, and Beazley (2015) considered wholewheat flour produced in organic and non-organic production: the lower GHG impact of organic production was equivalent to around 420km of transport of that flour, so organic flour could be sourced up to 420km further afield than 'local' non-organic flour and have a smaller impact. A similar approach was taken for chocolate in Pérez-Neira et al. (2020), with lower impact of organic production being cancelled out by 800km-equivlanet of emissions (considered relatively small, given the long-distance cacao may travel). Where this point of equivalence lies will depend on the product in question, production context, and mode of transport.

Consumer behaviour: this was less discussed, as many LCA-based studies looked only upstream and assumed that 'local' and 'non-local' food would be distributed through the same retail channels. Resultantly, system boundaries are often set from cradle-to-retail or cradle-to-retail distribution centre. In such cases, including consumer journeys could lead to a substantial increase in transport-related emissions.

As is discussed further in 2.2, where 'local food' implies alternate distribution associated with SFSCs, this may encourage additional, inefficient consumer journeys to farm shops or specialist retailers. If done by car, these can have an outsized impact which may outweigh benefits from the production process (Low et al. 2015; Heller 2017; Brodt, Feenstra, and Tomich 2008).

By contrast, distribution methods which avoid the need for consumer transport, such as direct-to-consumer delivery, could lead to reductions in transport-related emissions. This is highly dependent on the specific transport mode used and the efficiency of route planning or journeys, and is discussed further in 2.2.

Box 3

A study in Sardinia, Italy, considered several scenarios for canned tomatoes, the authors found that a 6km consumer shopping journey contributed 20-53% of the overall transport impact (Marletto and Sillig 2014). This will vary depending on which mode of transport the consumer uses, the efficiency of their load and the distance travelled. In one perhaps extreme example, a consumer round car trip of 5km to purchase a single bottle of wine, had a higher GHG footprint than the vineyard and winery activity combined for that same bottle (Point, Tyedmers, and Naugler 2012).

Variance by product: because transport of food generally has a low GHG impact (air-freight notwithstanding), its relative importance will also depend on the product in question. Products with smaller overall impact per kg of product – such as vegetables – will have a higher *share* of emissions attributed to transport, even if the *absolute impact* of the transport is the same.

Research conducted by Martin Heller for the State of Oregon Department of Environmental Quality (Heller 2017), which involved a meta-analysis of over 300 scenario datapoints from 116 food LCA studies including product distribution. The data were not adjusted for either different scopes of studies or transport modes considered (beyond at a basic level), so only approximate results can be derived, but they are still illustrative:

*Table 2: Average GHG impact of transport and share of total impact from distribution, by product category. Adapted from Heller (2017). *denotes particularly high variability of contribution shares.*

Product group	Median absolute GHG impact of distribution (kg CO_2e/kg)	Median % contribution of distribution to product chain GHG
Beverages	<0.25 kgCO_2e	<10%*
Cereals and grains	<0.25 kgCO_2e	<5%
Dairy	<0.50 kgCO_2e	<5%
Fish and seafood	c.0.50 kgCO_2e	>15%*
Fruit	<0.25 kgCO_2e	c.5%*
Legumes and nuts	c.0.25 kgCO_2e	<10%
Meat	c.0.50 kgCO_2e	<5%

Sweeteners	<0.25 $kgCO_2e$	<5%
Vegetables	<0.25 $kgCO_2e$	>20%*

The inclusion of some air-freighted food scenarios skews the mean emissions and shares – notably for seafood – so the median footprint and share, as presented in Table 2, is more appropriate to consider. What these results highlight is that in absolute terms, GHG emissions associated with distribution are generally small, on average not going above 500 grams CO_2e/kg product, regardless of product type. As a *share* of the emissions of that foodstuff, however, it is more variable. This is a reflection at least in part of very different emission factors associated with different product groups.

These conclusions, which focus on the importance of **production practices** and **mode of transport** are neither new nor controversial, and have been discussed widely in literature reviews around the topics of 'local' food and 'food miles' (Stein and Santini 2022; Enthoven and Van den Broeck 2021; Edwards-Jones 2010; Martinez et al. 2010; Rogissart, Foucherot, and Bellassen 2019; Heller 2017; Low et al. 2015). **Consumer transport** is less regularly discussed and may be more relevant when considering SFSCs and other alternative food provision, but is similarly widely reported to be impactful where analysed (Stein and Santini 2022; Enthoven and Van den Broeck 2021; Heller 2017) (see also discussion in section 2.2.2).

Some authors compare the impact of 'buying local' with other actions, such as dietary change, to illustrate the relatively small impact of transport (Stein and Santini 2022; Enthoven and Van den Broeck 2021; Rogissart, Foucherot, and Bellassen 2019). This is magnified by transport being *relatively* more important for vegetables, which already have low footprints per kilogramme in comparison to products such as meat and dairy: focusing on vegetable transport distance may miss the bigger picture when put in context, as there is still a limit to the *absolute* savings which are possible (see Box 5

).

For these reasons, the term 'local trap' is sometimes used to illustrate that believing 'local' food is inherently 'better' is misguided: "a local product can be grown with exploitation of families, workers or the environment" (Vargas et al. 2021; Goodwin-Hawkins 2020).

Given the variable definitions of local food (see 2.1.1), these findings arguably only address the 'geographic' definition by focusing on the impacts of transport. An alternative food system which is more localised may not be the same as buying food produced more locally in the conventional system, with little research quantifying this more abstract, system-level idea (Peters et al. 2009).

2.1.3 Other environmental impacts

For non-GHG environmental impacts related to 'local' food, the results depend on the impact category. Land use and water use in particular are more dependent on the specific location of production than the distance travelled, with some countries, regions or production methods having lower (or higher) associated footprints than others. Whether or not the 'local' option is associated with a lower impact will depend on where is 'local' to the person asking the question.

Notably, for water use (or scarcity, or consumption, depending on the paper's measurement methods), papers specifically examining the UK found that it generally came out favourably, even in situations where imported foods had a lower GHG footprint (see Table 3). In situations where two different locations are preferable on different metrics, decisions on supply may require a trade-off between the different environmental priorities.

Table 3: Comparison of UK and imported water use, consumption or scarcity, compared with GHG impact in identified papers

Paper reference	Product and origin(s)	Scenario with lowest water use/consumption/scarcity	Scenario with lowest GHG emissions
(Casey et al. 2022)	Lettuce (UK, ES, US, indoor)	UK field-grown	UK field-grown
(Webb et al. 2013)	Tomatoes (UK and Spain)	UK	Spain
	Strawberries (UK and Spain)	UK (large difference)	Spain (marginally)
	Early potatoes (UK and Israel)	Same	UK
	Lamb (UK and New Zealand)	UK (large difference)	New Zealand
	Beef (UK and Brazil)	Same	UK
(Foster et al. 2014)	Raspberries (UK fresh and frozen, Spain)	UK (large difference)	Very comparable (UK frozen slightly higher)
(Hospido et al. 2009)	Lettuce (UK indoor and outdoor, Spain)	UK generally (as much variation between farms and seasons as countries)	Field production: comparable and varies between farms. UK indoors higher
(Milà i Canals et al. 2008)	Broccoli (UK fresh and frozen, Spain)	UK	Comparable; as much variation between farms as countries
	Lettuce (UK fresh and indoors, Spain, Uganda)	Uganda (UK lower than Spain, although there is substantial variation within UK)	Field grown: UK (marginally lower than Spain). Indoors UK or air-freighted: Ugandan significantly higher.
	Beans (UK fresh and frozen, Kenya, Uganda)	Uganda (UK lower than Kenya, although there is substantial variation within UK)	UK (significantly lower due to air freight from Kenya and Uganda)

For land use, some possible trade-offs emerge; heated glasshouses are often quite compact and therefore do not occupy substantial areas of land, yet they are associated with much higher GHG footprints (Hospido et al. 2009). One comparison of lettuce is illustrative here:

whilst UK indoor growing had emissions between approximately 2-5 times higher than Spanish field grown, the land use was nearly halved (Milà i Canals et al. 2008, fig. 3-1 and 3-2).

Other impacts: The most regularly referenced are measures of eutrophication, acidification and toxicity (both human and environmental), which broadly correlated with GHG footprints, but may also vary substantially between specific farms and management practices. The 'where' and 'how' is of particular importance. The impacts of supply chains and transport on these measures also broadly correlate with GHG figures, with similar caveats as discussed regarding GHGs of 'local' supply chains possibly being less efficient or leading to additional consumer journeys. This is discussed further, with important evidence from Majewski et al. (2020), in section 2.2.

As may be intuitive, other environmental impacts which are strongly connected to vehicle use, i.e., congestion, air pollution, noise etc., are closely associated with transport (Smith et al. 2005), and so reduced transport would likely lead to a reduction in those impacts (López-Avilés et al. 2019). However, as with GHG footprints, some nuances may apply here with *consumer* transport or delivery-to-consumer potentially playing a disproportionate role, being more important in some cases than supply chain distance (Marletto and Sillig 2014). Local supply chains do not necessarily reduce consumer transport distances, and so other avenues around transport and urban planning could possibly tackle these issues more productively.

Biodiversity impacts were not systematically measured in the studies identified in this review. This is not unexpected, due to known challenges with biodiversity measurement. Where it was discussed, it was primarily in the context of more-than-geographic 'local' definitions, such as traditional varieties or alternative growing networks. Such claims include that 'Community Supported Agriculture' involves growing a biodiverse range of crops (Christensen, Galt, and Kendall 2018), and that applying a similar model to fisheries ('Community Supported Fisheries') can involve productively using underutilised species, or what would otherwise be considered bycatch (McClenachan et al. 2014). The overlap between 'local food' movements and organic or otherwise alternative production is in some cases used to argue the case for supporting biodiversity (Shindelar 2015). However the relationship between 'local' and 'organic' is not guaranteed (Schoolman 2019) and the driver of any such benefit is not the 'being local' aspect *per se*, as imported organic food could have similar benefits. Without better measurement of the impacts it is hard to evaluate robustly the impact on biodiversity, but it is clear that for those involved, they perceive benefits (Hay 2010; Preiss, Charão-Marques, and Wiskerke 2017). Arguably, however, if certain producer practices are believed to support biodiversity, those practices should be highlighted as the driver for supporting that producer (e.g. a biodynamic or agroecological farm), rather than their locality or supply chain structure which may or may not correlate with better production practices.

2.2 Short food supply chains

2.2.1 Definitions

'Short food supply chains' were observed in the literature to have substantial overlap with 'local' food, both its geographic and non-geographic definitions. Many definitions referred to the number of intermediaries being 'small', or indeed one or fewer, or there being a close link between stages of the supply chain including trust and transparency. However, a large share (50%) of all papers discussing short supply chains (n=26) also discussed geographic proximity. As was discussed in relation to 'local' food, the two aspects have substantial overlap.

These definitions are best summarised by the definition used in EU rural development policy: "a supply chain involving a limited number of economic operators, committed to cooperation, local economic development, and close geographical and social relations between producers, processors and consumers" (Stein and Santini 2022).[2] In these approaches, 'short' is "from both a physical and social perspective" (Strength2Food 2016).

Closely related to these physical and social proximities is the type of sale. One paper (Strength2Food 2016) considers three categories of SFSC, based on the type of sale and number of intermediaries:

a) Face-to-face, with producers and consumers having direct interaction (such as on-farm sales, or through Community-Supported Agriculture),

b) Proximate systems, delivered through a single intermediary (such as vegetable box schemes, or farm-to-institution procurement), and

c) Local systems, with more than one intermediary involved (such as processed products sold in a local shop).

Much like local food (see 2.1.1), the SFSC definition is in part defined by what it is *not*: long supply chains with multiple intermediaries, supplying conventional distribution channels. Whilst (geographically) 'local' food could in theory be sold in a large chain supermarket, a food would likely not be considered to be from an SFSC if bought there. A single 'local' brand, however, could sell through both SFSC and conventional channels: traditional 'farmhouse' cheeses, for example, may have both direct-to-consumer sales channels and operate in long-chain international export markets. This fluidity leads Schmitt et al. (Schmitt et al. 2016) to consider a 'local to global continuum' which firms operate within, rather than a binary opposition between 'local'; and 'global' supplier.

[2] Regulation (EU) No 1305/2013 of the European Parliament and of the Council of 17 December 2013 on support for rural development by the European Agricultural Fund for Rural Development (EAFRD) and repealing Council Regulation (EC) No 1698/2005 http://data.europa.eu/eli/reg/2013/1305/oj

'Long supply chains' were not regularly clearly defined or used as an analytical concept in the papers analysed. This may be because 'long food supply chains' are assumed to be the 'conventional' chain which SFSCs are defined in opposition to, they are therefore inferred as being whatever does not fit the SFSC definition. Arguably, this binary lacks some nuance for identifying something in the 'middle'. One paper (Loiseau et al. 2020) did present a supply chain classification for apples in France which included 'medium supply chains' as those which involve multiple intermediaries but operate on the local-regional scale, such as outdoor markets which source from wholesalers, whilst acknowledging that some supermarkets may offer some products sourced directly from a producer (see fig. 1 and fig. 2 in (Loiseau et al. 2020)). Such an approach may better acknowledge the fluidity and diversity of suppliers and retailers operating within multiple supply chains at once.

Despite some nuances between specific distribution systems, geographic proximities or number of intermediaries, papers discussing SFSC were largely consistent in using these same criteria, with the EU definition providing a clear summary of the key components: few intermediaries, geographic proximity and some degree of co-operation, transparency or closeness in the supply chain.

For further reading on SFSC definitions, see (Loiseau et al. 2020; Doernberg et al. 2022; Preiss, Charão-Marques, and Wiskerke 2017; Strength2Food 2016).

2.2.2 GHG impact

Conclusions on the GHG impact of SFSCs are closely related to those found for 'local' food (see 2.1.2), highlighting the importance of **transport efficiency**. Transport efficiency considerations apply to two primary areas:

- **Supply chain logistics**; where SFSCs and smaller producers are often associated with less efficient logistics than large-scale supply chains.

Box 4

Where **supply chain logistics** in SFSCs rely on smaller, less well-loaded vehicles, this may cancel out the benefits associated with having fewer intermediaries, or different production practices. As an example: one comparison of tinned tomatoes in the US found very comparable emissions associated with 'conventional' supply chains with multiple additional processing stages (bulk packaging, interstate transport, remanufacturing, consumer packaging, final transport) and an organic supply chain with fewer stages (consumer packaging, interstate transport), as the 'conventional' supply chain used rail rather than truck for most of the interstate transport (Brodt et al. 2013).

- **Consumer transport**, where SFSCs may encourage additional consumer trips to purchase small volumes of food.

SFSCs often imply alternate modes of provision, such as using smaller retailers or farm shops. If these incentivise **additional consumer transport**, particularly car trips, to purchase small quantities, this may substantially increase the transport footprint. Whilst transport often accounts for around 20% of a vegetable GHG footprint (see Table 2), car trips to a farm shop were associated with as much as 90% of the emissions of organic spring onions in one example (Theurl et al. 2017).

The most comprehensive analysis of consumer transport dynamics comes from a piece of research conducted within the Strength2Food project, which carried out an eco-efficiency LCA on over 400 supply chains involving 191 food producers (Majewski et al. 2020). These were classified into short supply chains and long supply chains, and the LCA results include impacts associated with production and use of machinery, buildings, energy and waste management rather than just the transport impact. The transport impacts sum both supply chain and consumer transport into a single 'food miles' figure.

Table 4: Food miles and GHG impact associated with different supply chains. Adapted from Majewski et al. (2020)

Supply chain classification	Average food miles (km/kg product)	GHG impact ($kgCO_2e$ / kg product)
Short supply chains		
Pick-your-own	6.04	1.54
On-farm sales to consumers	3.75	0.97
Internet sales – courier deliveries	0.15	0.07
Direct deliveries to consumer	1.65	0.64
Sales on farmers' markets	1.36	0.49
Direct deliveries to retail	0.49	0.33
Long supply chains		
On-farm sales to intermediaries	0.26	0.24
Sales on wholesale market	0.62	0.40
Sales to hypermarket chains	0.67	0.33

What these results show is that short supply chains generally perform unfavourably compared to long supply chains, regarding both total greenhouse gas emissions and food miles per kg of product. In the 'pick your own' and 'on-farm sales to consumers', this is driven "mainly by consumers' travel". There were some scenarios whereby SFSC were comparable or even performed better than some long supply chains: direct deliveries to retail were comparable to hypermarket chains, partly through the beneficial location of smaller retailers in towns, allowing purchases to be done during travels for other purposes, or without a car. Due to the assumed "optimized distribution by courier companies", internet courier sales come out as being the most beneficial option (though consumer control over delivery dates and times may undermine this efficiency). Therefore, whilst long- and short-supply chains are associated with *average* differences in efficiencies, variation *within* short supply chains is substantial and even more important. **SFSCs are not on average more environmentally efficient, though it is possible for them to be with improved logistics**.

This point is well illustrated in the case of a regional tomato producer in Sardinia, Italy. In this case, the regional brand deals in sufficient quantities to have "fully loaded HGVs for both outward and (most) return trips". In other words, if producing locally or with fewer intermediaries, but with the haulage efficiency of conventional supply chains, then "centralization of loads is not always the most efficient solution" (Marletto and Sillig 2014). For smaller producers who cannot deal in these volumes alone, other solutions such as co-operative logistics may allow for improved efficiency.

These examples focus on the emissions associated with transport, rather than the whole product. SFSCs can be associated with lower levels of processing, packaging or alternate production practices which may have lower emissions associated (e.g. (Tasca, Nessi, and Rigamonti (2017)). In these cases, relative transport inefficiencies could counteract and balance out the savings associated with having fewer stages or inputs (e.g. Brodt et al. (2013)). Repurposing the 'equivalent-tonne KM' concept introduced Box 2

can help illustrate this: comparing the average farmers' market and hypermarket sales in Table 4, a farmers' market product needs to have emissions lower by at least 0.17 $kgCO_2e/kg$ associated with its production, processing and packaging than an equivalent product sold in a hypermarket. A farm-shop sale would need at least 0.65 $kgCO_2e/kg$ – a taller order, depending on the product. In cases where SFSC production has lower impact, it is imperative to ensure that this benefit is not undone by inefficient supply chains.

2.2.3 Other environmental impacts

Due to the substantial overlap between SFSCs and 'local' food, the findings relating to other environmental impacts were very similar to those identified in the 'local' section 2.1.3. In papers which considered SFSCs, few directly quantified other environmental impacts. The very notable exception to this is Majewski et al. (2020), which conducted an eco-efficiency LCA grouped by different supply chain types, based on hundreds of supply chains across multiple countries. This found that the results broadly correlated with GHG impacts across multiple impact categories: **acidification**, **eutrophication**, **ozone depletion** potential, **photochemical oxidant creation** potential, non-hazardous **waste** disposed. As the GHG impacts show (detailed in Table 4), the efficiency of 'long chains' or conventional markets, such as direct deliveries to retail or hypermarket chains, actually had relatively low impacts when compared with alternative distribution modes often associated with SFSCs, such as farm shops or farmers' markets (Majewski et al. 2020, fig. 3).

As was the case for GHG impacts, the role of consumer can be particularly important in determining SFSC efficiency. This is well illustrated in a paper studying apple supply chains in France (Loiseau et al. 2020) which included evaluation of **ecosystem impacts**: two key factors of *quantities purchased,* and *distance travelled by consumer car journey* interact to determine whether long or short supply chains (in this case, on-farm purchase) is preferable. It is only at shorter distances or larger quantities that consumer trips to the farm is preferable. At lower quantities purchased – or indeed lower shares of goods purchased (i.e. specialist trips for few items) – long supply chains have a lower impact in more cases (Loiseau et al. 2020, fig. 7).

As with more holistic definitions of 'local' food, there is often correlation between SFSCs and alternate production practices, such as organic, which is cited as a driver of lower impact (Stein and Santini 2022; Preiss, Charão-Marques, and Wiskerke 2017; Enthoven and Van den Broeck 2021; Willis 2019). Where quantified, local, SFSC and organic supply chains may have lower impact across multiple environmental criteria (Tasca, Nessi, and Rigamonti 2017) though in these cases the driving factor is *production practices* rather than *supply chain distance or structure*.

For both 'local' and 'SFSC' environmental impacts, there is an argument to be made that this may correlate with alternate farming practices, including protected biodiversity or reduced inputs, including organic farming. However, in these cases the drivers of the impact are production practices rather than supply chain structure. Therefore, how the food is produced – not how it is *assumed* to be produced because of other factors, such as where it is sold – should be where the focus is applied. At the same time, the way it is sold – and the implications for introducing additional, inefficient vehicle journeys – should be considered to avoid SFSC production leading to *increased* impacts.

2.3 Seasonal food

2.3.1 Definitions

'Seasonality' was quite clearly defined across the papers, with all definitions grouping around a common understanding based on the 'natural growing season' of produce. This relates to the time in which food can be produced without climate control practices such as using artificial energy inputs, i.e., heated glasshouses, or long-term cold storage or freezing. Food which has gone other forms of preservation processing, such as tinning or drying, are also outside the defined scope of seasonal food. In other words, being grown at the time when the climate is suitable to do so in a field or utilising simple, low-tech farm infrastructure (such as unheated glasshouses or polytunnels). The focus is therefore on *production* and on *plants* such as fruits and vegetables rather than meat or fish.[3]

Further clarification may be necessary to define the relationship between production and consumption, and place of origin. Whilst 'seasonality' is defined primarily by the time and method of production, 'seasonal food' is more centred around *consumption*, with the implication that it applies only to fresh food consumed close to the point of its production or harvest. Whilst apples may have been grown 'in season'; if they are subsequently cold-stored for months, they are no longer being consumed 'seasonally'. Similarly, apricots grown and picked in summer but then dried would not be considered 'seasonal', even though they were not grown out-of-season.

Some authors make a distinction between 'local' and 'global' seasonal:

- 'Local seasonality' being food produced without external energy inputs or long-term storage, consumed in geographic proximity or the same climactic zone to its production;
- 'Global seasonality' being produced in the natural growing season of the geography in which it was produced, but not necessarily consumed there.

Many of the most insightful papers which consider the environmental impact of both 'local' and 'seasonal' food take as a starting point the desire to eat produce out of its local growing season, then comparing the options of eating locally-grown with additional energy inputs (heating or storage) or importing from somewhere with a different growing season (for example, (Röös and Karlsson 2013; Milà i Canals et al. 2007; Hoolohan, McLachlan, and Mander 2016)). This arguably misses the point for advocates of 'seasonal' consumption, who may take the 'local seasonal' availability as a starting point. On the other hand, it reflects the choices consumers may desire when year-round availability has become normalised. In some places with more limited growing seasons, there may be nutritional trade-offs with following

[3] Some argue that meat has seasons – see here, for example – but this was not discussed in the papers identified in the QSR, which focused on fruit and vegetable produce.

the 'local season' strictly (see the discussion on tomatoes in Sweden, (Röös and Karlsson 2013), summarised in 2.3.2). Eating a diverse 'local seasonal' diet may be more or less realistic depending on where you are and what can be grown locally.

For particularly useful papers discussing 'seasonal' definitions, see (Röös and Karlsson 2013; Vargas et al. 2021; Foster et al. 2014).

2.3.2 GHG Impact

Most of the evidence identified regarding 'seasonal' consumption supported the consumption of food grown in season, without external energy inputs. This takes a 'global seasonal' approach, whereby products imported from countries where they are grown without external energy inputs are considered 'in season'. However, the exact means of eating produce out of season may have different implications:

- Indoor production such as heated glasshouses or controlled-environment agriculture came out generally unfavourably in the papers identified: the emissions associated with heating them often substantially exceeded those associated with transporting a product from a location where it was grown without heating inputs (Edwards-Jones 2010; Webb et al. 2013). Air freight is an exception to this, with air-freighted produce generally being more impactful than heated produce (Hoolohan, McLachlan, and Mander 2016). The impacts are highly dependent on the emission intensity of energy used (Casey et al. 2022), so energy decarbonisation could reduce this impact. This is discussed further below..
- Long-term cold storage or freezing was in many cases comparable to imported fresh produce (Milà i Canals et al. 2007; Brodt et al. 2013; Edwards-Jones 2010), and what is preferable may be more context-dependent: what the product is, how efficiently it is grown and processed (Blanke and Burdick 2005), from where an alternative could be sourced, and how that is transported. Frozen fruits and vegetables often benefit from having reduced losses and waste, though whether they can be considered a direct substitute for fresh products may depend on the particular food and use (consumers may use frozen instead of fresh raspberries for a smoothie, but not all would use them garnish a dessert, for example)
- Other processing such as canning or drying, were not directly compared with fresh imported produce in the literature identified. They are arguably not functionally equivalent in most use cases.

Emerging technology and renewable energy

Emerging technology, such as advanced 'controlled environmental agriculture' (CEA), could alter some conclusions formed based on heated glasshouses. Limited evidence was identified which analysed CEA, though a few notable papers were identified:

- One comparison of tomato production in Australia, looking at field-grown compared with glasshouses of three technological levels, authors found field-grown to have the lowest cradle-to-farmgate footprint (0.3 $kgCO_2e/kg$) of options considered. Low-tech, seasonal glasshouses in the urban area had a smaller cradle-to-*market* footprint (0.44 $kgCO_2e/kg$) than field-grown (0.66 $kgCO_2e/kg$), due to the very limited transport – though they may not be able to provide sufficient quantity for an entire urban area. However year-round production, even in the 'high tech' controlled environment, had much higher footprints (1.86 $kgCO_2e/kg$, cradle-to-farmgate) (Page, Ridoutt, and Bellotti 2012, fig. 2). This suggests production which has limited or no energy inputs is preferable, but may also reflect the carbon intensity of Australian electricity generation.
- A comparison of CEA lettuce production systems illustrates that CEA production systems are highly sensitive to the energy mix in the producing region; observing a 37-fold variation *between* CEA systems, from wind power to coal power (see Figure 1). Whilst CEA can be comparable to imported field-grown from Spain, even some primarily renewable scenarios include higher emissions, and no scenario has emissions as low as seasonally field-grown in the UK (Casey et al. 2022, table 3). These findings suggest that efficient, renewable systems *can* offer improvements on other out-of-season production, but seasonal production still emerges as the overall preferable option for GHG impact.

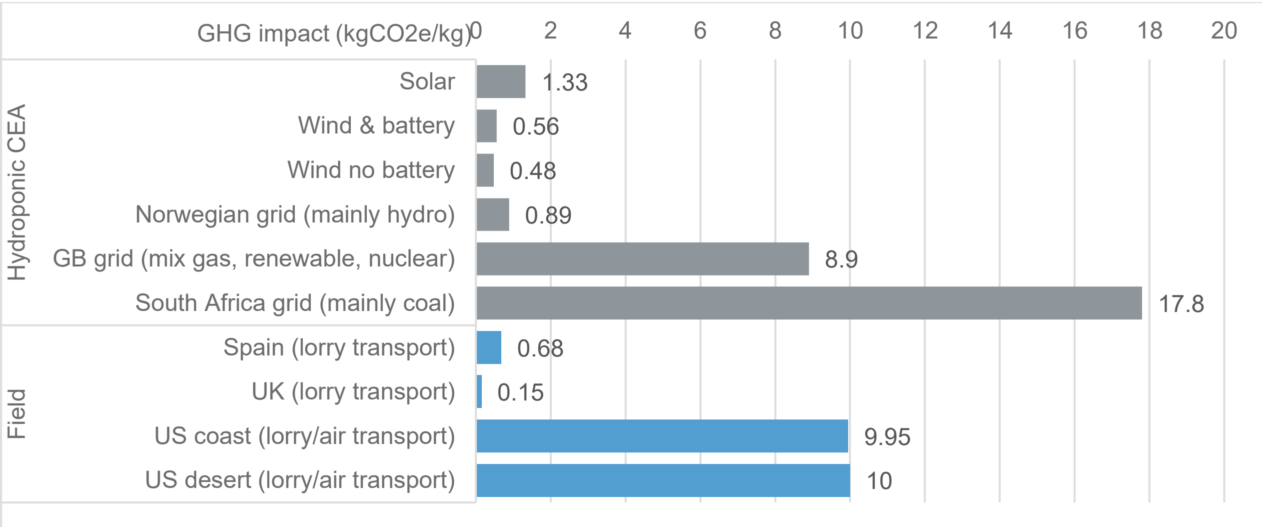


Figure 1: Comparison of hydroponic CEA and field production for lettuce. Data from Casey et al. (2022).
Note: CEA modelling does not include any transport impacts. Reference to countries is those countries' grid intensity, not imports from that country. Field production does include transport impacts to the UK.

- One modelling paper on tomato supply chains in the US contains a summary of cradle-to-farm gate life-cycle footprints of tomatoes grown by different means (E. Bell, Qin, and Horvath 2023). With the data from this paper it is possible to conduct original analysis, grouping the LCAs by field-grown, low-tech infrastructure like unheated glasshouses, polytunnels or plastic, and heated glasshouses (Figure 2). Comparing the range of results in these data reinforce the findings above: field and low-tech production are generally smaller impact than heated glasshouses, but heated glasshouses have a substantial range. The lowest-impact heated production was comparable to the upper end of field production. Notably, a subset of the heated glasshouse studies were specifically scenarios with used residual heat, combined heat and power (CHP) systems or renewables, and the mean emission factor from these (0.91 kgCO_2e/kg) was in the lower end of heated glasshouse impacts.

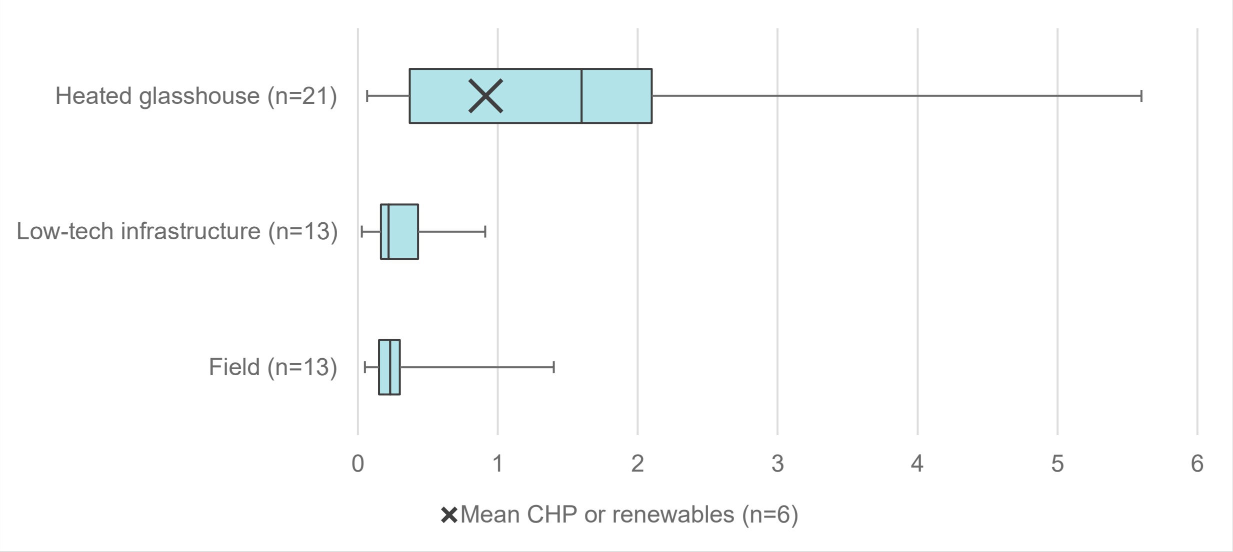


Figure 2: Comparison of cradle-to-farm gate impacts of tomato production from LCA data in Bell et al. (2023).

These results suggest that, as indoor production techniques continue to develop and renewable energy is increasingly deployed, they can become increasingly carbon-competitive with imports. It should be noted that in CHP situations, the glasshouses may be using heat which would otherwise be wasted, therefore 'sharing' the allocation of emissions which may have been happening anyway. However, growing without inputs, where possible, is generally associated with lower impacts.

Seasonal diets

Much of the literature identified takes the starting point of 'what is the most sustainable option to consume food out of season', it arguably misses the point that some advocates of seasonal consumption may be making, that *what* is consumed should change through the seasons. A more comprehensive comparison could therefore look comparing seasonal diets across a year, rather than a single product at a single point in time. Research of that precise nature was not identified in this review, though some notable analogues were identified:

- One paper looked specifically at school food procurement in Galicia, Spain, based on an LCA of food purchased over a year. Increasing seasonal (defined as those grown outdoors) vegetables and eggs from 30% to 70% of volumes procured would lead to a 6.5% reduction of total emissions. This was more significant than some other changes (a 40% increase in 'local' food from the region was associated with a 2.2%

reduction, for example) but less than others (65% of the food being organic and 30% of meat and fish being from plant sources were associated with 15.3% and 11.1% reductions, respectively) (Perez-Neira, Simón, and Copena 2021).

- One particularly useful study compared four definitions of 'seasonal' consumption in Sweden, applied to carrots and tomatoes. These four were based on whether using produce grown in Sweden only, or across Europe, and whether heated glasshouses were permitted or not, compared to a baseline of current consumption and import patterns (8.8 kgCO_2e/person/year associated with carrot and tomato consumption). The strictest 'seasonal' definition of Swedish produce without heating had the biggest savings, reducing emissions by more than 60% compared to the baseline, though Swedish produce *with* heated glasshouses also saw a roughly 50% reduction from the baseline, due to moving from Dutch gas-powered glasshouses to Swedish biofuel ones, reinforcing the importance of energy sources for heated glasshouses (Röös and Karlsson 2013).

However, as Röös and Karlsson note, such theoretical calculations may run into other challenges or trade-offs. In the Swedish case, the strictest definitions of seasonality change tomatoes from a year-round food to being eaten in higher quantities in smaller windows, and as a result are "nutritionally different" (other ways of consuming tomatoes, such as tinned, are not considered in the LCA and may alleviate this). Furthermore, the strictest definition with the biggest savings – Swedish produce without heating – is "not a realistic scenario" (at the time of publication), being unprofitable due to "low yields and short growing season" (Röös and Karlsson 2013). These are significant points to consider: 'local-seasonal' diets are constrained by what can be commercially produced, and the availability of diverse foodstuffs and nutrients throughout the year is an important health consideration which may take precedence over marginal GHG benefits for consumers, and indeed government and wider society.

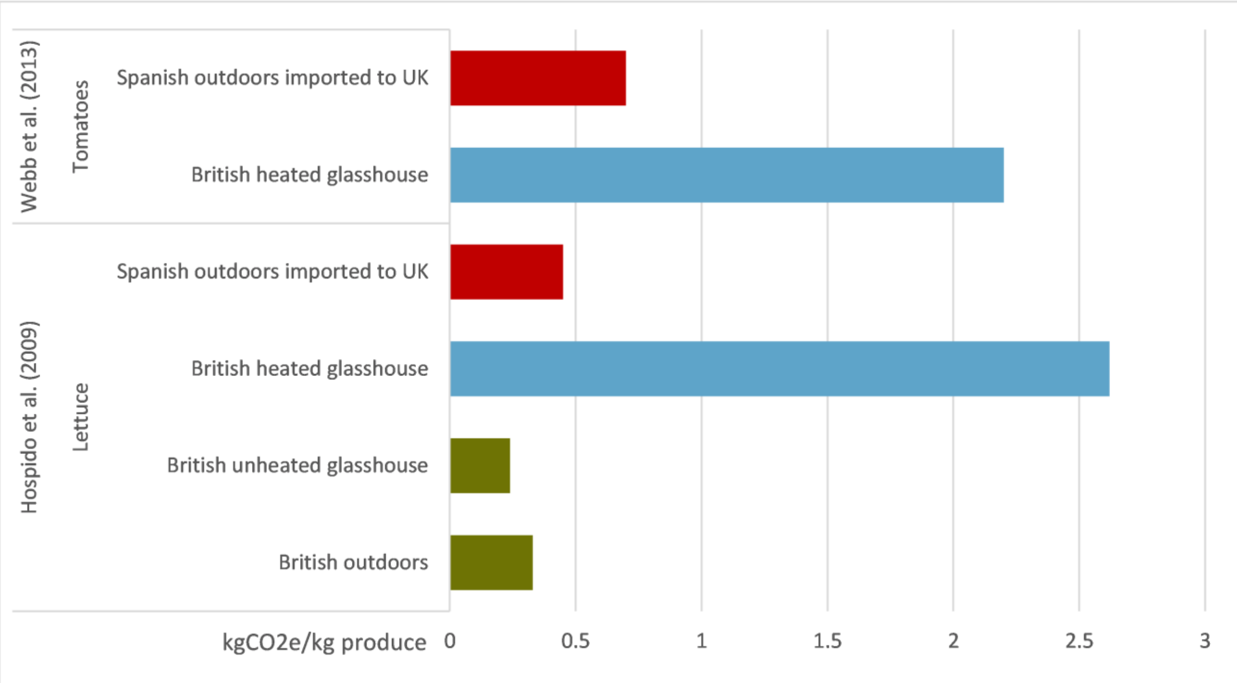
A more important point from the same paper, in light of this report's research focus, is that though the emission reduction potential from seasonal consumption is substantial *relative* to the emissions associated with those products, in *absolute* terms it is quite small. The 30-60% reduction in GHGs from Swedish carrot and tomato consumption "represents a reduction of 3–5 kg of CO_2e per capita per year". This, the authors state, corresponds to approximately the emissions from "the production of 0.5 kg of cheese" (Röös and Karlsson 2013). It is certainly arguable that encouraging 0.5 kg less cheese consumption – or indeed waste – per person per year would be a more efficient way to achieve the same GHG savings than drastically reforming tomato production and distribution. This is a crucial point, as it speaks to the limits of what can be achieved with seasonal production. This sense of scale is important for policymakers in weighing up environmental concerns with food security, political, economic or social concerns. An initial suggestion of the scale of possible impacts associated with out-of-season salad crops in the UK is calculated in Box 5

. Changes to reduce the impact of crops like fruits and vegetables are limited by the relatively small share of environmental impact which they account for.

Box 5

To explore the absolute scale of seasonal production, it is possible to approximate the calculations conducted by Röös and Karlsson (2013) using UK data. These calculations are **rough approximates only to get a sense of scale** and should not be treated as robust modelling of UK supply options.

Papers identified in the QSR (Webb et al., 2013 and Hospido et al., 2009) examined tomatoes and lettuce produced in heated glasshouses in the UK, compared with Spanish outdoor production then imported to the UK. Heated glasshouse tomatoes having 3x higher emissions and glasshouse lettuce nearly 8x. For a simplified calculation, these figures can be used as proxy for 'non-seasonal' and 'seasonal' consumption respectively.



Using data from the Family Food Survey, Britons on average purchase 4.6 kg/person/year fresh tomatoes and 2.4 kg/person/year leafy salad (for which lettuce is assumed to be representative).[4] Assuming that consumption is spread out evenly by months of the year, consumption by month can be assigned as 'seasonal' or not based on a British culinary calendar.[5] In this default baseline, the 4.6 kg tomatoes are associated with 7.21 kgCO_2e per hear, and the 2.4 kg lettuce are associated with 2.6 kgCO_2e, a total of 9.81 kgCO_2e per person per year.

Box 5 (continued)

If the same amount of lettuce and tomato was consumed, but all 'seasonally' (whether through eating in a shorter time window or importing from Spain), the associated emissions would reduce to 3.20 kgCO_2e for tomatoes and 0.79 kgCO_2e for lettuce, a combined reduction of nearly 60%. In relative terms, this is a big saving. When contextualised, however, the absolute savings appear less significant: a 5.82 kgCO_2e/person saving would total 390 ktCO_2e. For context, this is equivalent to about 1% of the emissions associated with UK agriculture, and just 0.3% of the entire UK food system.[6]

Given recent supply chain disruption experienced with imported salad crops, policymakers may judge that this environmental trade-off is worth the political and economic benefits to food security, particularly if efficient renewable energy use reduces the environmental impact of glasshouses.

2.3.3 Other environmental impacts

Only a small number of papers (n=10) included discussion of other environmental impacts, with fewer again providing quantification.

Water use was the most regularly quantified (n=6), with the majority (67%) suggesting the 'seasonal' production involved lower water consumption. As most LCA-related papers compared scenarios between two options, domestic (with heating or storage) and importing (from a different climate), it is difficult to disentangle effects associated with season of production and different growing practices and climates in different countries, and so these results may reflect variation between countries – and indeed between farms *within* countries – as much as the season of production. As an example: an analysis of water use in lettuce production across Spanish, Ugandan and UK farms (including both indoor and outdoor growing) saw more than three-fold variation within Spanish results based on farm and whether first or second crop, with UK lettuce varying a similar degree, though slightly lower in overall impacts (Milà i Canals et al. 2008, figs 3–2). The 'preferable' option in any case depends as much on which farm and crop, as it does between countries or seasons.

Land use was only quantified in few papers (n=3), but the evidence suggests there could be a trade-off with GHG emissions, heated glasshouses, whilst energy intensive, can involve reduced land use when compared with field grown.

[4] https://www.gov.uk/government/collections/family-food-statistics
[5] https://www.bbcgoodfood.com/seasonal-calendar
[6] https://wrap.org.uk/resources/report/tracking-uk-food-system-greenhouse-gas-emissions-2022-update

Other environmental impacts were not discussed regularly to draw strong conclusions, and some such as eutrophication or acidification are likely to vary based on agricultural practices and local conditions. Where out-of-season energy use is involved, whether for heating or for cooling, it is likely to depend on specific energy mixes in different countries, making general rules difficult to establish.

2.4 Interactions between categories

As should be clear from the preceding sections, fully disentangling the questions of 'local', 'short supply chain' and 'seasonal' is difficult: SFSCs are often defined as having a (geographically) 'local' element, and comparing 'local' and imported food is one of the main ways of evaluating the role of 'seasonal' food. As a result of these overlaps, many of the conclusions drawn above are found applicable to the broader picture. The interaction of 'local and SFSC' and 'local and seasonal' are considered below: 'SFSC and seasonal' is not considered because it is not an analytically meaningful category other than where it overlaps with 'local'. The conclusions derived from all three factors is considered in the following section (3.0).

2.4.1 Local and short food supply chains

Due to the overlapping definitions of SFSC and some definitions of 'local' food, most papers discussing SFSCs also discussed 'local' food, though the reverse was not true due to the 'local' papers which focused exclusively on transport distances.

Within these papers, two main conclusions came through, both relating to transport emissions:

Supply chain efficiencies: Transport *distance* can only be considered relevant when also considering transport *mode*. The use of different, often smaller, vehicles to serve local SFSCs, may undermine or even cancel out entirely GHG benefits associated with smaller transport distances, reduced processing, packaging or alternate production practices. It is therefore not guaranteed that local-SFSCs will have lower GHG emissions associated than conventional supply chains. Addressing this transport efficiency problem, such as through regional SFSCs dealing in larger volumes, or combined logistics amongst smaller producers, may make it more likely for an environmental benefit to be realised.

Consumer transport: If the mode of distribution of SFSCs encourages additional trips by car, this could substantially increase the GHG emissions per kg of food. This was particularly highlighted for farm shops, 'pick your own' or remote specialist retail which may require trips solely for the purpose of moving relatively small volumes. Distribution to in-town retail or farmers' markets appeared more favourable as consumers may travel by walking, cycling or public transport, or are more likely to combine shopping trips with other purposes. Removing the need for consumer transport with (efficiently organised) deliveries could similarly reduce this burden.

These dynamics are discussed further in section 2.1 and 2.2. It may appear paradoxical that these findings suggest the most carbon-efficient local SFSC is *not* the one with the fewest intermediaries: food retail or logistics can play an important part in consolidating orders, increasing the supply chain efficiency and reducing consumer transport needs. There are exceptions: retailers or farmers' markets may allow direct trade whilst 'meeting in the middle' and direct deliveries of sufficiently large volumes – such as those from a farm to an institution, like a school or hospital – may benefit from 'cutting out the middleman', for example. Increased adoption of lower-carbon vehicles including electric vehicles and cargo bikes could similarly alter this picture. Nonetheless, a clear conclusion is drawn: 'local SFSCs' are not guaranteed to reduce emissions when compared with conventional food supply chains due to relative transport efficiencies undermining possible gains elsewhere in the production process. These transport-related risks, however, can be mitigated, meaning GHG benefits *could* be achieved.

2.4.2 Local and seasonal

Within the evidence which considered both 'local' and 'seasonal' impacts (Figure 3), a very clear trend was identified: seasonal production *was often* associated with lower GHGs, whereas 'local' was *not consistently*, with it often being very context dependent on the product, mode of production and mode of transport.

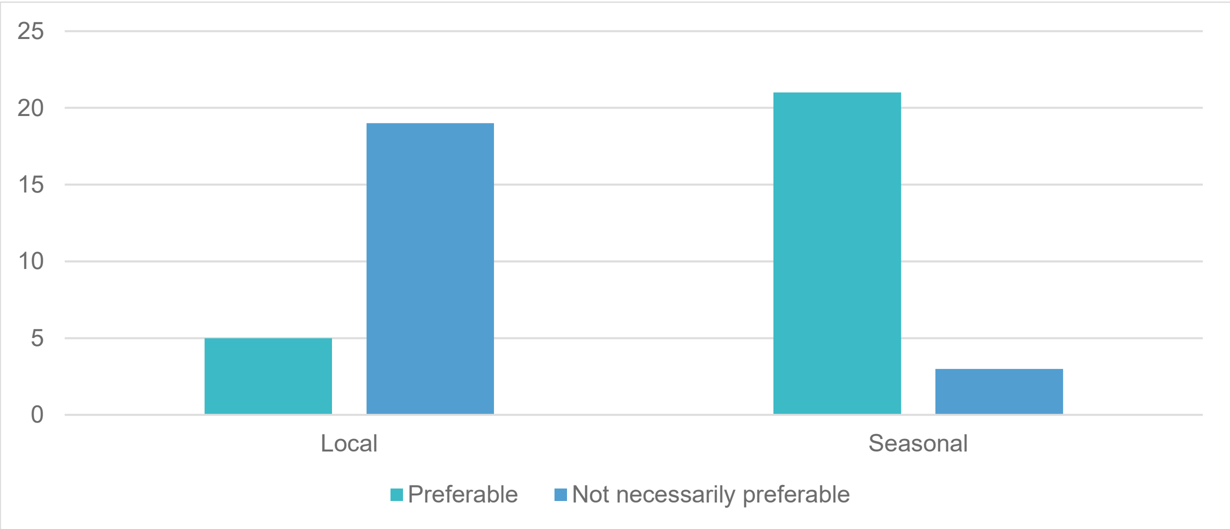


Figure 3: Number of papers looking at both local and seasonal aspects (n=24), by whether they indicate if 'local' or 'seasonal' production is environmentally preferable (local and seasonal considered separately).

It is intuitive that in these papers which look at both elements, they mirror each other: research examining both 'local' and 'seasonal' aspects often compared *globally seasonal* food (i.e. produced without external energy in a different country from which it is produced) with *local out-of-season* food (i.e. produced in the country of consumption, with external energy to grow or store it). Because of the high GHG impact of heated glasshouses in particular, and the relatively low impact of transport emissions in comparison, the message coming through is that it is often preferable to buy 'out of season' food from somewhere where it *is* in season than to artificially extend the growing season in the country of consumption.

Some caveats to consider:

- As detailed in 2.3.2, the evidence was clear that heated glasshouses have an outsized impact in comparison to transport, but for long-term cooling or freezing produce, it was less clear, and the balance in any particular circumstance may depend on the product, the efficiency of the process, the alternative transport option and the losses associated. Other processing such as drying or canning was not systematically considered. In short, using external energy to extend the *growing season* is less desirable than extending the *storage period.*
- This trend does not hold if the 'seasonal' food is transported by air freight, as this is associated with more additional GHGs than heated glasshouses or long-term storage is.
- Changes to the energy grid and emerging technologies such as indoor farms may complicate the picture and in some cases be preferable to 'global seasonal' imported produce. This requires more research to establish in which cases it may apply.

Due to the focus on crops, which generally have a low emission factor, the *relative* savings per kg of produce may appear substantial whilst the *absolute* savings of changing consumption practices may be limited (see Box 5

for discussion). As a result, other non-environmental political or economic factors may be judged 'worth' the environmental trade-off of local out-of-season food by policymakers.

One implication of these findings is that it suggests that priorities should be shifted between the 'local' and 'seasonal' categories. The typical phrasing is 'local, seasonal food', but this should arguably be reversed to 'seasonal, local food' to reflect that the seasonal element is more important, and prioritising the *local* to the expense of *seasonal* may in fact be counterproductive.

3.0 Overall conclusions

Drawing together the trends identified in the above findings, it becomes clear that in many cases, the existence of environmental benefits from local, SFSC or seasonal food will be context dependent and that there are few 'iron rules'. Nonetheless, some key trends regarding what shapes those context-dependent decisions can be identified. With these, it is possible to form some general principles which could help to evaluate options around supply chain structure without requiring full life cycle impact assessment studies.

An important caveat should be noted: the purpose of this report was only to consider *environmental* impacts, with a focus on GHG emissions. There are many other reasons – such as those regarding the local economy, national food security, health, or supporting 'food culture' – which may motivate local, seasonal or SFSC purchases. We do not suggest one or other of these objectives is more important, or propose a way to weigh up competing concerns. The hope is that the general principles around environmental impact below will help a government, organisation or individual to do so themselves in an informed manner.

1) 'Food miles' is not a suitable metric to analyse food sustainability, and being geographically 'local' does not guarantee reduced environmental impact.

Firstly, the impact of food transport is generally quite small, and is substantially outweighed by that of production. This has been well-documented elsewhere, with transportation estimated as contributing approximately 5% to total food-system GHG emissions.[7] A meta-analysis of LCA studies, discussed in detail above (2.1.2) suggested that regardless of food and drink product, the average emissions associated with transport are below 0.5 $kgCO_2e$ per kg, in many product categories the average emissions are below 0.25 $kgCO_2e/kg$ (see Table 2). In most cases, this represents a small share of the overall product footprint. Where it represents a larger share, such as for vegetables, this is likely more a reflection of the small GHG footprint of those products than the impact of transport.

Secondly, the *distance travelled* must be considered alongside the *mode of transport* to understand the impact of transport in any case, as shorter distances travelled by inefficient modes (such as smaller volumes in vans or trucks) can have higher emissions than much longer distances travelled by highly-efficient modes (such as intercontinental freight shipping).

2) Efficiency of transport is important: suppliers in 'local' and 'short' supply chains must take care to ensure that less-efficient logistics do not cancel out potential GHG savings from shorter distances travelled or alternate production practices. But inefficiencies can be mitigated, and SFSCs *can* be more efficient.

[7] https://www.nature.com/articles/s43016-021-00225-9

One of the drivers of the relatively low footprint of food transport is the large volumes in which conventional supply chains operate, allowing for the economies of scale provided by international shipping, fully loaded HGVs and advanced logistics. SFSCs often lack this scale or efficiency, delivering goods in smaller vehicles or loads. As a result, the benefits of lower transport *distances* may be cancelled out by reduced transport *efficiency*. Counterintuitively, shorter supply chains can involve more kilometres travelled per kg of food (see Table 4). Similarly, benefits from specific supplier production practices, processing level or packaging options when compared with conventional supply chains could be negated, or at least reduced, by relatively less-efficient transport.

These inefficiencies are not guaranteed and could be mitigated. Whilst SFSCs are not on average more environmentally efficient, they can be in scenarios with improved logistics (see Table 4). Scenarios such as high-volume local or regional supply chains, multiple smaller suppliers collaborating on logistics or using efficient courier services, for example, could facilitate more efficient transport and minimise excess road journeys.

3) Consumer transport is as important as supply chain transport. Some alternative distribution networks encourage additional consumer car journeys to transport small volumes of food. This can be avoided through specific distribution methods and encouraging low-carbon journeys.

Distribution of food through non-conventional modes such as farm shops or markets may require consumers to make additional journeys to pick up food. Longer distances and smaller volumes, especially when travelled by car, can quickly make consumer transport amongst the most impactful stage in a food's like cycle. As many LCAs of 'local' food quantified only up to the point of sale, assuming it to be the same, this has been less widely quantified than supply chain factors. Where it has, consumer car transport has been regularly identified as a driver of higher emissions (see Table 4).

These impacts can be avoided through different methods of distribution, with direct retail deliveries or farmers' markets being more comparable to long supply chains. Cutting out consumer journeys entirely, such as through (efficiently organised) deliveries, could similarly reduce this impact. Urban design and transport policies which enable greater use of public transport and active travel to shops could similarly reduce the consumer transport impact for SFSCs and conventional supply chains alike, so should take greater prominence in discussions around 'food miles'.

4) Where food is produced matters, as some regions are more productive than others. Importing from such regions may have lower environmental impact than domestic production, though this must be balanced against economic and food security objectives.

As highlighted in 1), production is more important than transportation for a food's overall environmental impact. Some climates or regions have favourable growing conditions which allow lower use of inputs or higher yields. As long as a relatively efficient transport mode is used, importing from such places could have environmental benefits. *From where* alternative food is sourced is a key consideration when determine if 'local' is better in any given case, and the answer may be different depending on the countries considered, specific farms and production practices within those countries, times of year and how it would be transported. In the case of fruits and vegetables, due to their lower than average GHG footprint, the benefits are often small. Because LCAs are generally snapshots of specific farms at a point in time, variability within producers may be just as significant as those between countries.

Nonetheless, pursuing marginal environmental gains from these imports when food can be produced domestically with comparable impacts may not be desirable due to trade-offs with food security and domestic production. How these two objectives are balanced are social and political decisions, which should retain a sense of scale (see 9)).

5) There may be trade-offs between different environmental metrics – notably land use and water use – with one origin country or production method being favourable for some criteria but unfavourable in others.

In some cases, GHG footprints will broadly correlate with other environmental impacts. For transport related impacts, that appears to be the case with many quantifiable metrics (see 2.2.2). However, in the case of land use and water use in particular, there may be trade-offs. As detailed in section 2.1.3, the UK was regularly identified as having a favourable water footprint, even in situations where imported produce had a lower GHG impact. Heated glasshouses, whilst having much higher GHG impacts than field-grown, tend to have lower land-use due to the compact nature of the structure and high productivity. In such cases, a trade-off may be required between different environmental issues.

6) Producing food out-of-season can substantially increase the GHG footprint, and importing from countries where it is in season ('global seasonal' food) is often preferable. 'Seasonal' is therefore a more important criteria than 'local' for environmental impact.

Using external energy inputs can substantially increase the GHG footprint of a product. This was particularly clear in the literature regarding heated glasshouses, which alter when food can be *produced*. Energy-using storage of seasonally-produced food, such as through cold stores or freezing, was more ambiguous and may depend on specific circumstances. As a result, buying food which is *produced* without external energy inputs, even if that involves importing (the 'global seasonal' definition of seasonality) is likely to be environmentally preferable to extending the growing season in the place of consumption through heated glasshouses. This is subject to caveats and may depend on the energy mix for glasshouse production, since the impacts can vary so substantially, or if the imported 'seasonal' option includes airfreighting.

Because producing food in season is more clearly associated with environmental benefits than shorter transport distances, we can infer that 'seasonal' is more important than 'local'.

Whilst the phrasing used is often 'local, seasonal' food, thinking in terms of 'seasonal, local' could reflect these relative priorities.

7) Air freighting food adds considerably to its carbon footprint and should be avoided.

One finding which was rather unambiguous was the substantial impact of air freighting. This drastically increases the impact of a food item, in some cases tenfold. Whilst, globally, food aviation is expected to contribute only a small amount of transport emissions[8], for any given product it involves an outsized impact. It should therefore be avoided wherever possible. Where it cannot practically be avoided – because in-season fresh produce can only be procured from a certain area – arguably, whether that food *needs* to be procured fresh at that time or not should be re-evaluated.

8) Emerging technology and renewable energy may alter the conclusions relating to glasshouses and indoor production, with uses of renewables or CHP in some cases having comparable, or only marginally higher GHG emissions than production without external energy inputs. The findings should be periodically reviewed as energy grid emission intensity decreases.

As renewable electricity and heat generation sources develop, the impact of out-of-season production or storage may reduce. Similarly, emerging technologies for 'controlled-environment agriculture' of crops such as vertical farms, may not be comparable to glasshouses, and could allow for drastic reductions in transport if situated in urban areas. Current evidence suggests substantial sensitivity to the carbon intensity of energy, with low-impact renewable systems or CHP being comparable with field production, or only involving a small increase in emissions (see 2.3.2). Grid decarbonisation and technology developments in future may alter these conclusions and so should be monitored, analysed and the compared with seasonal field-grown and imported produce periodically.

9) It is important to maintain a sense of scale. Most impacts identified in the literature were evaluated for crops such as fruits and vegetables, which generally have a low emission footprint per kg of produce. What may appear large *relative* differences – such as that between heated and unheated glasshouses – may be, in *absolute* terms, small. This is important for weighing up trade-offs, particularly around food security and domestic produce.

The difference in emission impacts associated with 'non-seasonal' production are large in *relative* terms, when considering the emission factor of a product grown in season. However, when contextualised with consumption patterns, the *absolute* opportunity may be limited in size. An initial calculation based on data identified in this QSR to get an approximate sense of scale for the UK suggests that the possible savings from moving all tomato and lettuce consumption to 'seasonal' and avoiding heated greenhouses would save emissions equivalent to about 1% of UK agriculture, and <0.5% of the total emissions associated with

[8] https://www.nature.com/articles/s43016-021-00225-9

the UK food system. Because crops like fruits and vegetables are generally low-impact per kg of produce, improvements to them – whether by seasonality, or indeed transport – are somewhat limited in absolute impact. Because the environmental outcomes highlighted in the preceding findings may imply a trade-off with food security, it is important for policymakers to have a sense of scale in informing how to address such trade-offs.

10) **Beneficial on-farm practices *might* correlate with 'local' or SFSC producers, but it is not guaranteed. If production practices are the motivation for supporting a particular supplier, they should be discussed as such.**

When it comes to other environmental benefits – such as biodiversity impacts – there is clearly a widespread perception of 'local' and SFSC food being beneficial, though there is lack of measured evidence to validate this. The claims tend to rely on factors perceived to *correlate* with local-SFSC food, such as crop diversity, reduced inputs or organic production. It may be that many local-SFSC producers do encourage these practices, but equally some may not: a producer using excessive chemical fertilisers and heated glasshouses can sell its produce via a farm shop or farmers' market and benefit from the way such food is perceived. Local-SFSC food advocates may suggest that the increased visibility of the supply chains encourages better practices, but research investigating this dynamic was not identified.

This problem stems partly from the competing definitions of 'local' food, which can mean different things to different stakeholders (see 2.1.1). Greater clarity and specificity about *what* 'sustainable' production practices are, or at least what they are perceived to be, would help in this regard. If the production practices of a supplier are perceived to be beneficial, they should be discussed as such, rather than being attributed to vague concepts based on how far the food has travelled or the way it is sold.

These are general trends only, and may not necessarily apply in every circumstance. One area that LCA-based research may struggle to inform is in some of the less quantifiable benefits associated with food purchasing decisions, such as how it may interact with your broader diet, engagement with environmental issues or behaviours in other areas of life. Some evidence from institutional procurement across multiple countries suggests that 'local food' policies are associated with lower GHG menus, not because the food was local but because the 'local food' menus typically had lower amounts of meat and hard cheese (Strength2Food 2019, 2). Such indirect environmental benefits could be associated with lifestyle changes driven by personal or institutional food procurement decisions, and this is worthy of additional research.

Whilst LCA-based comparative studies were crucial for informing the conclusions drawn above, it would not be feasible to conduct LCA to support decision making for every possible product, producer and transport arrangement. For situations in which purchasing decisions must be made – such as within public institutional procurement policies – some more general guidance may be more practical. Based on the findings above, such guidance could encourage:

a) Favour the procurement of local/domestic food that is produced seasonally, where it is socially, economically and environmentally plausible to do so. Recognise that the food procured does not necessarily have a lower environmental footprint just because it was procured 'locally';

b) Import seasonally produced food from productive areas for products which cannot be grown in the UK within reasonable environmental and economic impacts, or where domestic production is insufficient to meet demand, prioritising most efficient transport modes and avoiding air freight;

c) For products that cannot be procured in compliance with the above constraints, explore options for alternative food products that *can* be produced efficiently and seasonally, without compromising on nutrition

d) Work with producers and suppliers to adopt efficient production practices that reduce environmental impacts, both domestically and internationally, such as by prioritising producers who are able to demonstrate such production practices when awarding contracts

e) Work with all suppliers to improve logistics and reduce transport impacts, particularly looking to support the coordination of smaller or local suppliers. Additionally, encourage lower-carbon consumer journeys.

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Appendix 1: Methodology

Research questions

The report focuses on three core research questions, with associated sub-questions:

1) What evidence is there for a link between local food production and environmental benefits?
    a. How have localised food models used in public procurement strategies overseas been defined?
    b. What is the evidence for environmental benefits of local food production?
    c. Are there products which the UK has an environmental advantage (or disadvantage) in producing?
    d. Are there papers which discuss barriers or environmental trade-offs or opportunities or unintended consequences which may be associated with more localised production? Does this relate to definitions identified in 1a? do any papers environmental papers mention social or economic indicators in addition to environmental ones?
2) What evidence is there for a link between short- and long-food supply chains and environmental benefits?
    a. How have short food supply chains (SFSCs) and long food supply chains been defined in the literature?
    b. What is the evidence for environmental benefits from SFSCs? Do these findings relate to how SFSCs have been defined?
    c. What role can SFSCs and/or LFSCs play in localised food model with regards to environmental gains?
3) What evidence is there for a link between seasonality of food and environmental benefits?
    a. How has seasonality been defined?
    b. Have the impacts of seasonality been quantified in the UK and overseas?
    c. How does seasonality relate to the impact of specific production methods, such as infrastructure (both traditional [e.g. glasshouses] and modern [e.g. vertical farming]) or standards (e.g. organic)

Throughout, 'environmental benefit' was to be characterised in two ways: a) reduced greenhouse gas emissions, as the primary interest, and b) other measured reductions on environmental impact indicators such as land use, biodiversity loss, water use etc. which may be typically found in life cycle assessments.

Though the questions were framed around the 'benefits', environmental disadvantages or damages of any particular mode were also considered.

Methodological approach

The method to address these research questions was a quick-scoping review (QSR), based on the guidance provided by Collins et al.[9] This involved conducting searches of academic and grey literature based on key words related to the three research questions, and screening out results in multiple stages, based on the title, abstract and then full reading of the text.

Searches

Searches were split into those targeting academic literature and those targeting grey literature.

Academic searches were conducted in October 2022 using Web of Science. Fourteen searches were completed. These were combined with a small number (9) of academic papers of which the authors were already aware of through their day-to-day work.

Grey literature involved searches on multiple avenues, generally using broader criteria than the academic searches.

- Google.com searches were conducted using general terms, with search criteria to try and focus on published reports (pdf file types) whilst avoiding academic literature already captured in academic searches (including '-abstract' in the criteria.
- The System for Information on Grey Literature in Europe (SIGL)[10]
- Gov.uk, filtered for 'research and statistics' focusing
- The US National Technical Reports Library[11] was also searched, particularly to counteract location-based biases which might come out of using Google from the UK.

A total of 29 searches were completed. The search terms used are recorded in Table 5. The combined list of papers then had all duplicates removed before moving on to screening.

[9] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/560521/Production_of_quick_scoping_reviews_and_rapid_evidence_assessments.pdf
[10] https://opengrey.eu/
[11] https://ntrl.ntis.gov/NTRL/

Local, seasonal and short food supply chains

Table 5: List of searches conducted

Category	Search	RQ targeted	Avenue	Search terms
Academic	1	1	Web of Science	"local food" AND "environment* impact*"
	2	1	Web of Science	"local* food" OR "locavore" OR "food miles" AND "LCA" OR "Life cycle" OR "Life-cycle" AND "greenhouse gas*" OR "GHG" OR "GWP" OR "climate impact"
	3	1	Web of Science	"local* food" OR "locavore" OR "food miles" AND "LCA" OR "Life cycle" OR "Life-cycle" AND "Water us*" OR "Water stress" OR "Water scarcity"
	4	1	Web of Science	"local* food" OR "locavore" OR "food miles" AND "LCA" OR "Life cycle" OR "Life-cycle" AND "biodivers*" OR "eutrophication" OR "Air pollution" OR "land us*" OR "land footprint"
	5	2	Web of Science	"season*" or "in-season" AND "food" AND "LCA" OR "Life cycle" OR "Life-cycle" AND "Water us*" OR "Water stress" OR "Water scarcity"
	6	2	Web of Science	"season*" OR "in-season" AND "food" AND "LCA" OR "Life cycle" OR "Life-cycle" AND "biodivers*" OR "eutrophication" OR "Air pollution" OR "land us*" OR "land footprint"
	7	2	Web of Science	"season*" OR "in-season" AND "food" AND "LCA" OR "Life cycle" OR "Life-cycle" AND "greenhouse gas*" OR "GHG" OR "GWP" OR "climate impact"
	8	3	Web of Science	"SFSC*" OR "Short supply chain*" OR "short food supply chain*" AND "environment* impact*" AND "food"
	9	3	Web of Science	"SFSC*" OR "Short supply chain*" OR "short food supply chain*" AND "LCA" OR "Life cycle" OR "Life-cycle" AND "food"
	10	3	Web of Science	"SFSC*" OR "Short supply chain*" OR "short food supply chain*" AND "greenhouse gas*" OR "GHG" OR "GWP" OR "climate impact" AND "food"
	11	3	Web of Science	"SFSC*" OR "Short supply chain*" OR "short food supply chain*" AND "Water us*" OR "Water stress" OR "Water scarcity" AND "food"
	12	3	Web of Science	"LFSC" OR "Long supply chain" OR "long food supply chain" AND "Water us*" OR "Water stress" OR "Water scarcity" AND "food"
	13	3	Web of Science	"LFSC" OR "Long supply chain" OR "long food supply chain" AND "greenhouse gas*" OR "GHG" OR "GWP" OR "climate impact" AND "food"
	14	3	Web of Science	"LFSC" OR "Long supply chain" OR "long food supply chain" AND "environment* impact*" AND "food"
	n/a	n/a	*Already known academic*	

Grey	15	1	Google	"local food" "environment* impact*" -abstract type:pdf
	16	1	Google	"local food" "greenhouse gas*" -abstract type:pdf
	17	2	Google	"short supply chain" "food" "environment*" "impact*" -abstract type:pdf
	18	2	Google	"short supply chain" "food" "greenhouse gas*" -abstract type:pdf
	19	3	Google	"seasonal* food" "environment*" "impact*" -abstract type:pdf
	20	3	Google	"seasonal* food" "greenhouse gas*" -abstract type:pdf
	21	1	SIGL	"Local food"
	22	2	SIGL	"Seasonal food"
	23	2	SIGL	food in-season
	24	3	SIGL	SFSC
	25	3	SIGL	Food supply chain
	26	1	US National Technical Reports	Search "Local food" + Title: "food" from 2000-2022, only documents with full text
	27	1	gov.uk	Search "local food" filtered by 'Research and statistics'
	28	3	gov.uk	Search "seasonal food" filtered by 'Research and statistics'
	29	2	gov.uk	Search "short" "food supply chain" filtered by 'Research and statistics'
	n/a	n/a	*Already known grey literature*	

Screening

Following the QSR guidance by Collins et al., results from this search process were screened in two phases.

The first phase was based entirely on the title of the paper, with all other information hidden. Papers were allocated either 'clearly relevant', 'clearly not relevant' or 'unclear'. Those 'clearly not relevant' were screened out, with the rest going through to the second phase.

In the second phase, the paper abstract was considered, with papers either judged to be 'in scope' or 'not in scope'. A small number at this stage were still uncertain, so all three reviewers considered that list in more depth and discussed the results together before agreeing for each whether it was in or out of scope.

This exact process couldn't be followed for all grey literature due to the nature of the reports and how they were searched for. In some cases (such as SIGL or Gov.uk), very preliminary screening happened online, with only those appearing possibly relevant considered for downloading. Where papers lacked an abstract for the second screen, the contents were examined and the papers skimmed and searched to see if possibly relevant sections existed.

Those which passed the first two screens were read in full. A small number were then screened out upon reading the full text where it emerged that they did not fit the criteria.

The inclusion and exclusion criteria used to help shape the search terms and screening is displayed in Table 6.

Table 6: Inclusion and exclusion criteria

Inclusion and exclusion criteria for QSR	How implemented in the QSR
Exclusion criteria	
Research on consumer perceptions, willingness-to-pay etc. of local, seasonal etc. foods	Search criteria Manually during screening
Discursive commentary on local, seasonal etc. foods without (quantitative) evaluation of environmental impacts (or reference to such evaluation, such as a review paper)	Through searches criteria Manually during screening
About local/sustainable foods more generally, not including environmental impact	Search criteria Manually during screening
Inclusion criteria	
Research published between the year 2000 and 2023	Search criteria
In English	Search criteria
Studies with (preferably quantitative) assessment of environmental impact	Search criteria (focused on title/abstract/keywords) and manually during data selection

Studies with comparative or scenario analysis of supply chains/seasonality rather than presenting one mode in isolation*	Primarily through screening

*The implication of this specific criteria was that standalone life cycle assessments of products were generally not included if they did not have multiple scenarios or consideration of alternatives. Some of those papers may have had quantification of transport impacts which were relevant for the research questions if, say, comparing between two similar LCAs. However, comparison between independent LCAs was not the purpose of the project, rather comparison of the findings in existing literature.

Number of papers by stage

The total number of papers identified at each stage, by academic and grey literature, are summarised in Figure 4. A total of 102 publications were considered.

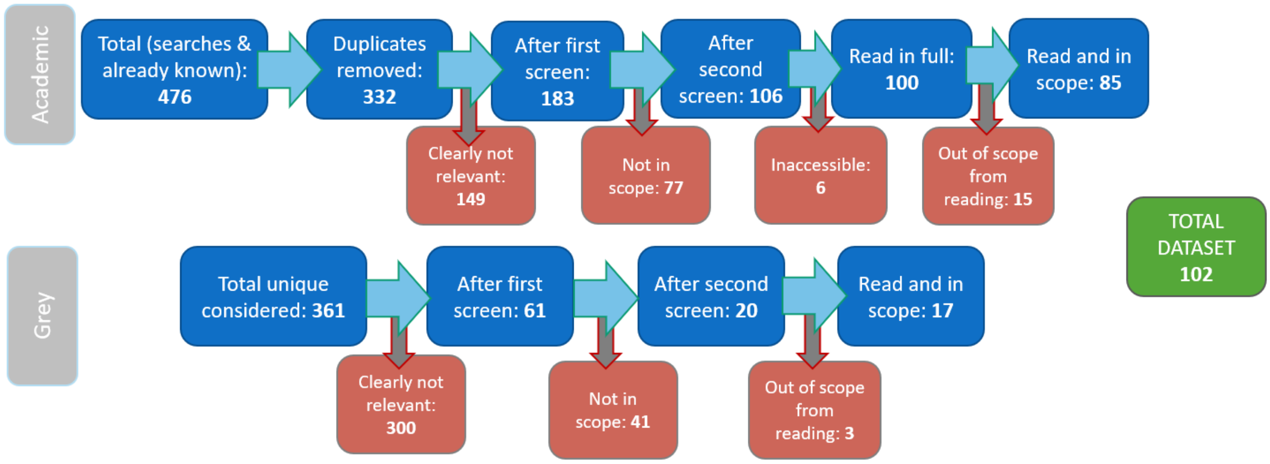

Figure 4: Number of papers at each stage of the searching and screening process.

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