Sustainable Research Project: Organic North

Tomato Supply Chain Analysis

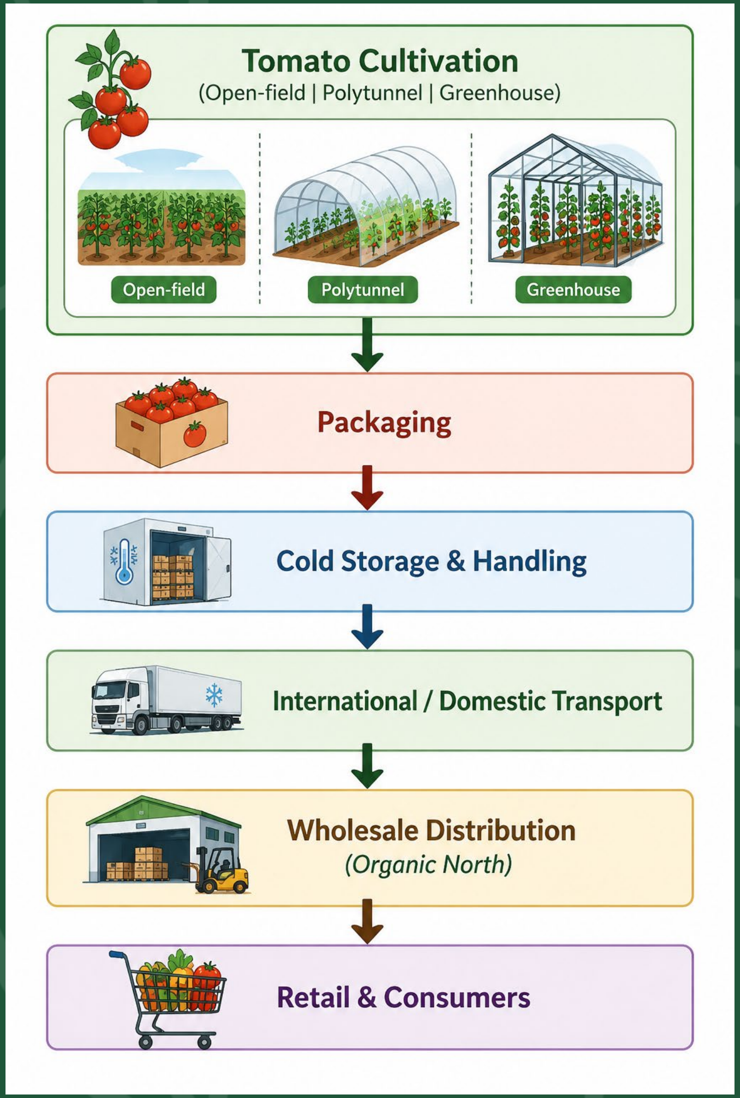
Agenda

- Research Aim & Background
- Methodologies and Scope
- Primary Data: Organic North
- Secondary Data: Comparative Analysis
- Packaging: Analysis
- Recommendations

Research Background:

Sustainability in the Global Tomato Industry

- Tomatoes are produced in open-field, protected and climate-controlled systems.
- Environmental performance varies with energy, water, fertiliser use and yield (Ntinas et al., 2017; Maureira et al., 2022).
- Impacts also arise from packaging, storage, transport and waste.
- Sustainability depends on trade-offs across the whole supply chain, not simply whether tomatoes are local or imported (Payen et al., 2015; Zhu & Miller, 2025).



Environmental Challenges Across the Tomato Supply Chain

- **Cultivation**
  - Heated greenhouses can have high energy demand.
- **Transport**
  - Imported supply can increase transport emissions.
- **Packaging & waste**
  - Packaging protects quality but adds material impacts (Mota et al., 2025).
- **Key message**
  - No production system is universally the most sustainable.

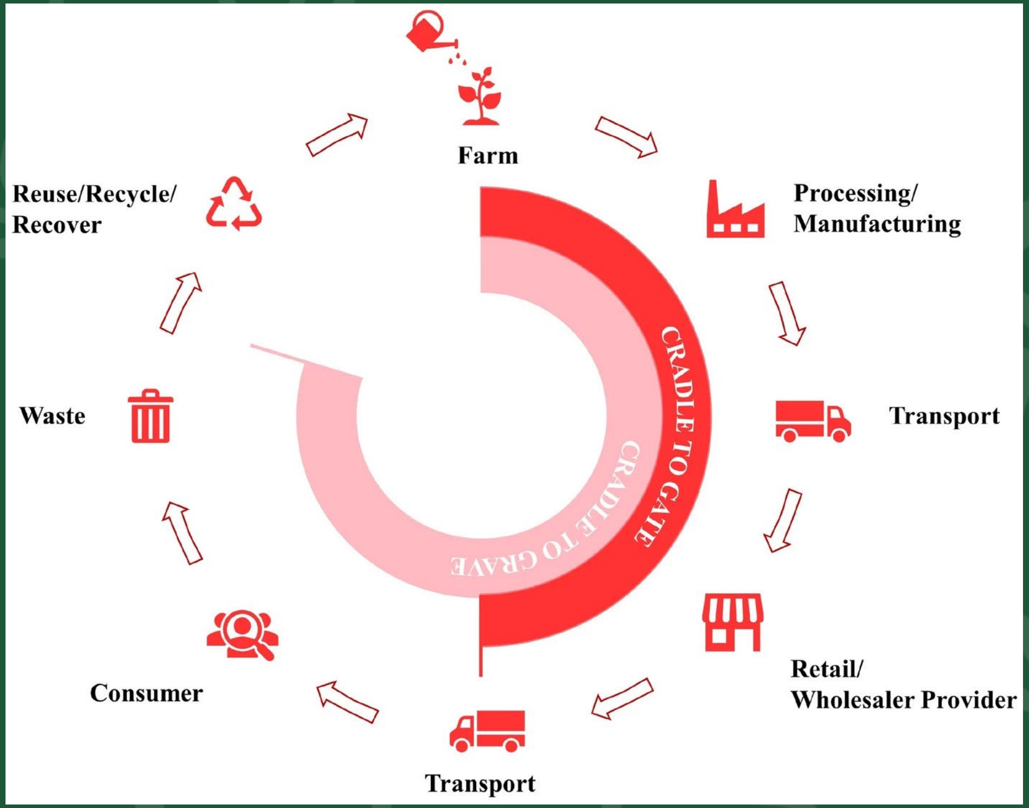
Supply Chain Stage	Major Environmental Impact
🌱 Cultivation	Energy use, fertilisers, irrigation, GHG emissions
📦 Packaging	Plastic use, material consumption, waste generation
❄️ Cold Storage	Electricity consumption and refrigeration emissions
🚛 Transportation	Fuel use, carbon emissions, logistics efficiency
🏪 Wholesale Distribution	Refrigeration, handling losses, operational energy

Organic North Company Profile and Project Context

- **Organic North**
  - Organic North is a United Kingdom-based wholesaler specializing in the sourcing and distribution of **organic and sustainably produced fruit and vegetables**. The company works closely with domestic and international growers, ensuring a continuous supply of fresh produce while maintaining product quality, traceability, and sustainability throughout its operations.
- **Business Context**
  - Operates within highly **time-sensitive and perishable** fresh produce supply chains.
  - Sources products from multiple geographical regions depending on seasonality and availability.
  - Balances commercial competitiveness with environmental responsibility and food quality.
  - Works collaboratively with growers and logistics partners to improve supply chain efficiency and sustainability.
- **Why Tomatoes?**
  - Are one of Organic North's important fresh produce categories.
  - Are sourced from different countries and cultivation systems.
  - Exhibit significant variation in energy use, transport requirements, packaging, and storage.
  - Provide an ideal case study for comparing the environmental performance of alternative supply chains.
- **Project Significance**
  - The study supports Organic North by:
  - Identifying environmental hotspots.
  - Comparing local and imported sourcing strategies.
  - Providing practical recommendations for reducing environmental impacts while maintaining supply chain performance.

Why Life Cycle Assessment (LCA)?

- Life Cycle Assessment (LCA) evaluates inputs, outputs and potential environmental impacts across a product system (ISO, 2006).
- **Why use LCA?**
  - Compares alternative supply chains on a consistent basis.
  - Identifies environmental hotspots.
  - Makes trade-offs visible across cultivation, packaging, storage and transport.
  - Supports evidence-based sourcing decisions



Source: (Kumar et al., 2024)

Methodological Challenges of Life Cycle Assessment

- **Variability in Agricultural Systems**
  - Tomato production varies across **open-field, protected cultivation, and climate-controlled greenhouse systems**.
  - Climate, irrigation, fertilization, greenhouse technology, crop management, and yield can substantially influence reported environmental performance (Perrin, Basset-Mens & Gabrielle, 2014).
- **Data Quality and Methodological Differences**
  - The reliability and comparability of published LCAs depend on the quality and consistency of their underlying Life Cycle Inventory (LCI) data.
  - Key challenges include:
    - Different functional units and system boundaries.
    - Inconsistent inventory data and reporting.
    - Different assumptions and emission-estimation methods.
    - Limited availability of primary environmental data.
    - Dependence on secondary databases (Perrin, Basset-Mens & Gabrielle, 2014; Torres Pineda *et al.*, 2021).
- **Role of Standardized Methodology**
  - **ISO 14040/14044** provides methodological principles and requirements that can improve consistency and transparency across LCA studies.
  - Published studies are therefore examined with attention to:
    - Functional units.
    - System boundaries.
    - Inventory data and assumptions.
    - Impact assessment methods.
    - Interpretation of environmental results.
- These methodological differences are considered when determining whether findings can be meaningfully compared.

Limitations Identified from Literature

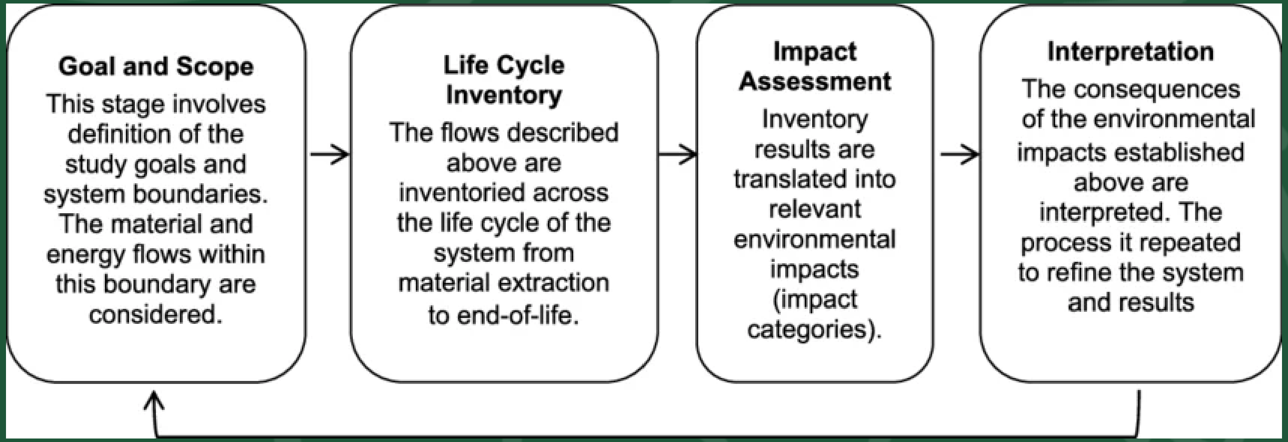
- Previous research has reported that vegetable LCAs often differ because of:
  - Different system boundaries.
  - Alternative allocation methods.
  - Variations in emission estimation models.
  - Inconsistent inventory datasets.
  - Limited transparency regarding modeling assumptions (Meier et al., 2015; Perrin, Basset-Mens & Gabrielle, 2014).

Research Aim, Objectives and Scope

- **Research Aim**
  - Compare the environmental performance of locally produced and imported tomatoes supplied through Organic North using supplier data and peer-reviewed LCA evidence.
- **Objectives**
  - Compare impacts across relevant supply-chain stages.
  - Identify major environmental hotspots and trade-offs.
  - Translate the evidence into practical sourcing recommendations.

Framework for Comparing Published LCA Evidence

- **Comparison framework**
  - 1. Select relevant peer-reviewed tomato LCA studies.
  - 2. Check functional units, system boundaries, locations and production systems.
  - 3. Compare reported environmental impacts.
  - 4. Identify hotspots and interpret trade-offs for Organic North.
- ISO 14040/14044 provides the methodological reference.



Source: (Whitehead et al., 2015)

Data Collection Methodology

Primary/company information

- Supplier interviews and Organic North operational information.
- Growing methods, packaging, storage, and transport context.

Secondary evidence

- Peer-reviewed tomato LCA studies.
- ISO 14040/14044 and relevant methodological guidance.

Use

- Published LCAs provide impact evidence; company data helps interpret it in Organic North's supply-chain context.

Functional Unit, System Boundary and Impact Categories

- **Functional unit**
  - 1 kg of fresh tomatoes.
- **Supply-chain stages**
  - Growing methods and inputs
  - Packaging
  - Storage
  - Transportation
  - Wholesale distribution
- **Impact categories**
  - Climate change
  - Water use
  - Soil-related impacts

Study Contribution

- The study will:
  - Compare local and imported tomato supply chains using peer-reviewed LCA evidence.
  - Identify where the largest environmental impacts occur.
  - Highlight trade-offs between cultivation, packaging, storage and transport.
  - Support practical sourcing and supplier decisions for Organic North.

Primary Operational Data Inventory

Operational Metric	Primary Baseline Value	Methodological Notes
Annual Tomato Throughput	120 tonnes / year	Primary functional product unit for mass allocation
Electricity Consumption (Grid)	91,781 kWh / year	Facility refrigeration & hub logistics baseload
Fleet Fuel Consumption (Diesel)	37,935 litres / year	10 LCV distribution vans (regional delivery)
Water Usage Measurement	Unmeasured	Municipal fixed-rate charge (negligible impact)
Packaging Input (Outbound)	~100 pallets / week	LLDPE stretch wrap (non-recyclable output)
Sourcing Mix	≥ 75% Import / ≤ 25% Domestic	Main sources: Spain, France, Poland, and UK

Estimated Carbon Footprint

~120.8

tCO_2e / year (Total Operational Baseline)

Scope 1 & Scope 2 Footprint Summary

Fleet Diesel (Scope 1): 37,935 L generates **~101.8 tCO_2e** based on DESNZ 2023 conversion factors.

Facility Grid Electricity (Scope 2): 91,781 kWh accounts for **~19.0 tCO_2e** location-based emissions.

**Note: This calculation represents a high-level operational gate-to-gate estimate rather than a full corporate GHG Protocol inventory.*

Multi-Product Allocation Dilemma

Shared Infrastructure

Organic North handles dozens of organic produce lines sharing facility refrigeration (91,781 kWh) and delivery routes (37,935 L diesel).

Overestimation Risk

Assigning total wholesale operational emissions directly to tomatoes would severely overestimate their individual environmental footprint.

Mass Allocation

Applying mass-based allocation across total annual throughput reduces tomato gate-to-gate carbon intensity per 1 kg functional unit to a secondary factor.

Upstream Hotspot Dominance

Agronomic & Freight Life Cycle Hotspots

Organic North's direct operational footprint (gate-to-gate) represents a **minor contribution** compared to total product embedded carbon.

Agricultural Cultivation: Heated greenhouse energy inputs dominate overall life cycle impacts during production.

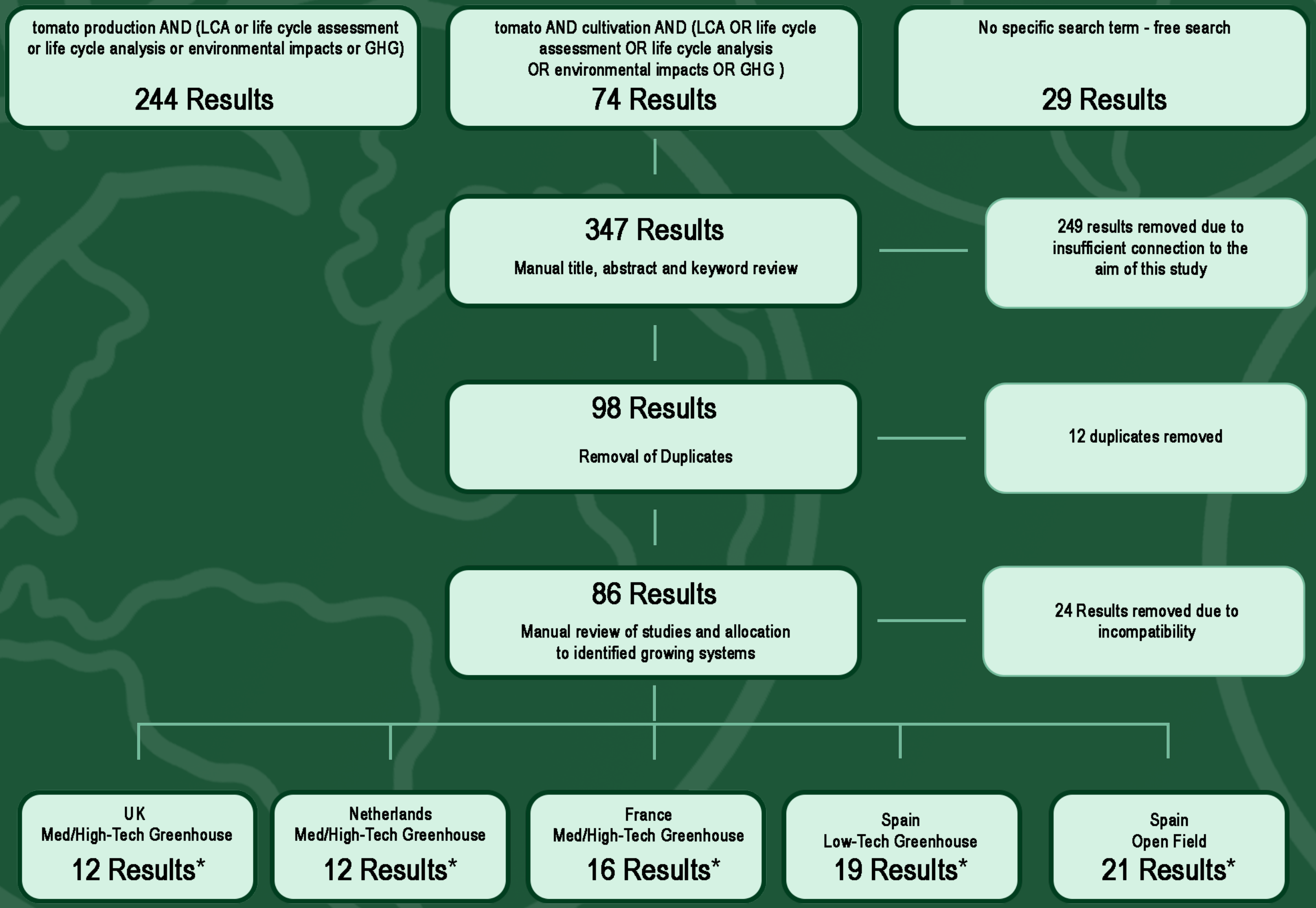
International Transit: Reliance on European imports (>75% from Spain, France, Poland) drives significant freight emissions.

Storage Optimization: Same-day dispatch sell-to-order model minimizes internal cold storage baseload.

Analytical Summary

Gate-to-gate logistics play a minor role compared to agricultural cultivation and international freight in tomato life cycle assessment.

Secondary Data



- Research in Scopus: Peer-reviewed sources for LCAs
- Selection for high impact journal articles
- 347 initial results
- Manual review for applicability
- 86 results after manual review and duplicate removal

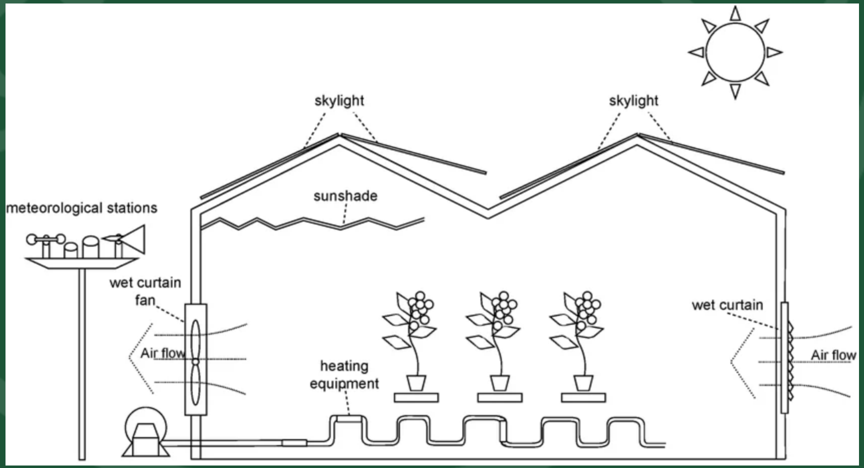
Cross-Study Comparability

- Peer reviewed LCAs often follow ISO 14040/14044 or EPD standards
- Growing systems are very diverse (inputs, climate, season, varieties...)
- Methodology leaves room for variances (boundaries, inventory data, impact categories...)

→ **Very limited comparability, high uncertainty and risk of errors**

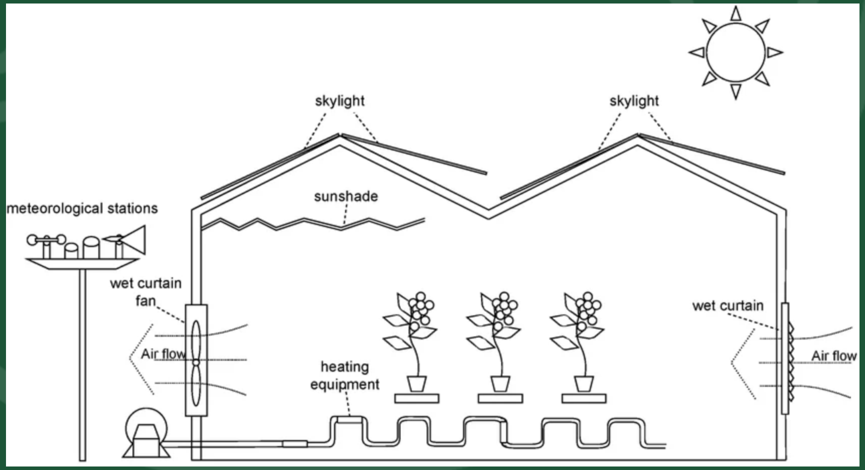
UK – High/Med-Tech Greenhouses

Growing System Description



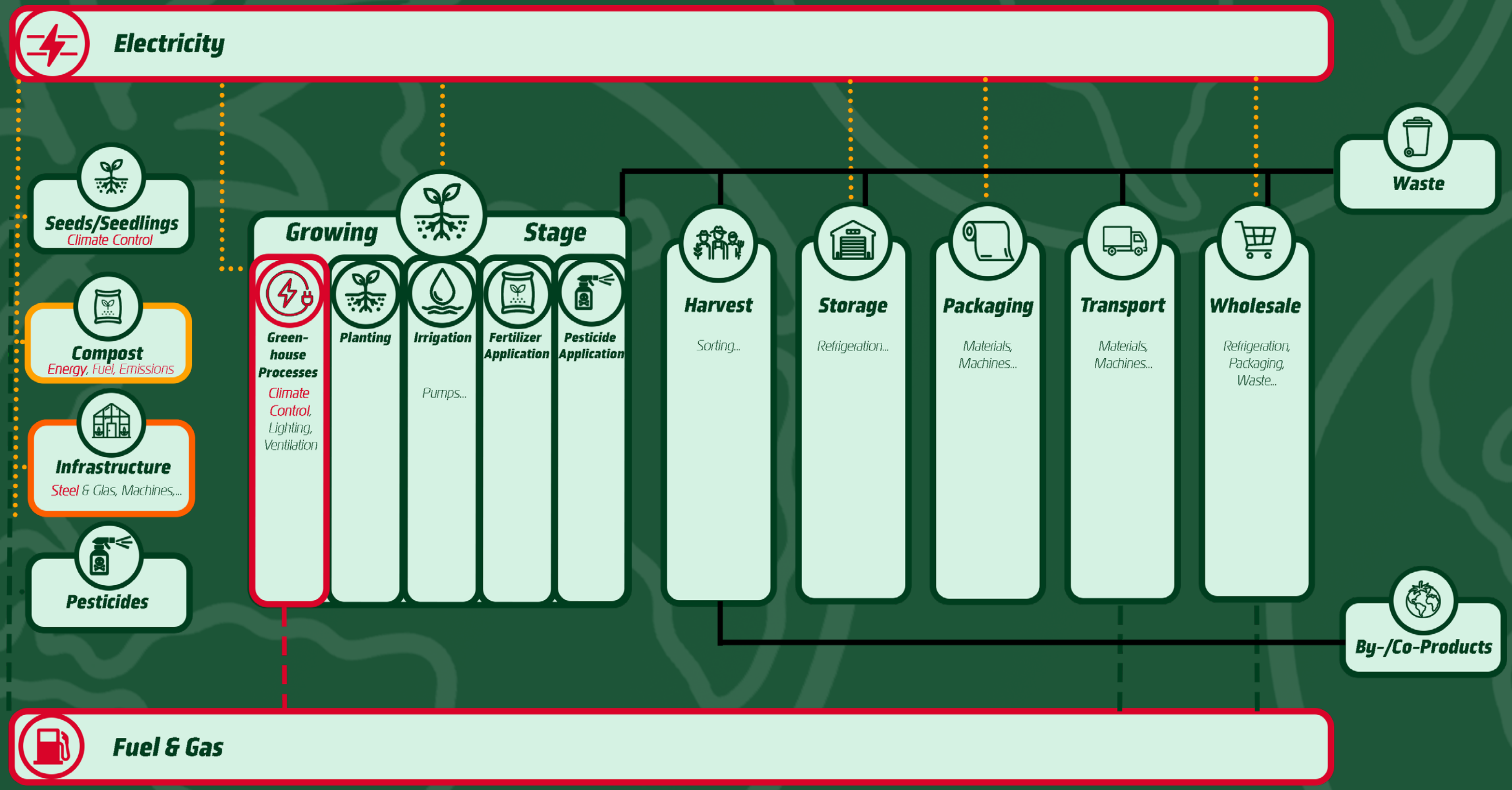
- Organic fertilisers
- Grown in soil or substrate
- Low organic pesticide usage
- Permanent greenhouse structures (Venlo type – glass or Permanent-Polytunnel)
- Passive/Active air circulation
- Supplemental heating
- Supplemental lighting

Central Europe – High/Med-Tech Greenhouses



- Organic fertilisers
- Grown in substrate, sometimes soil
- Low organic pesticide usage
- Venlo-Type Glass-Greenhouses
- Supplemental heating
- Active air circulation
- Supplemental lighting

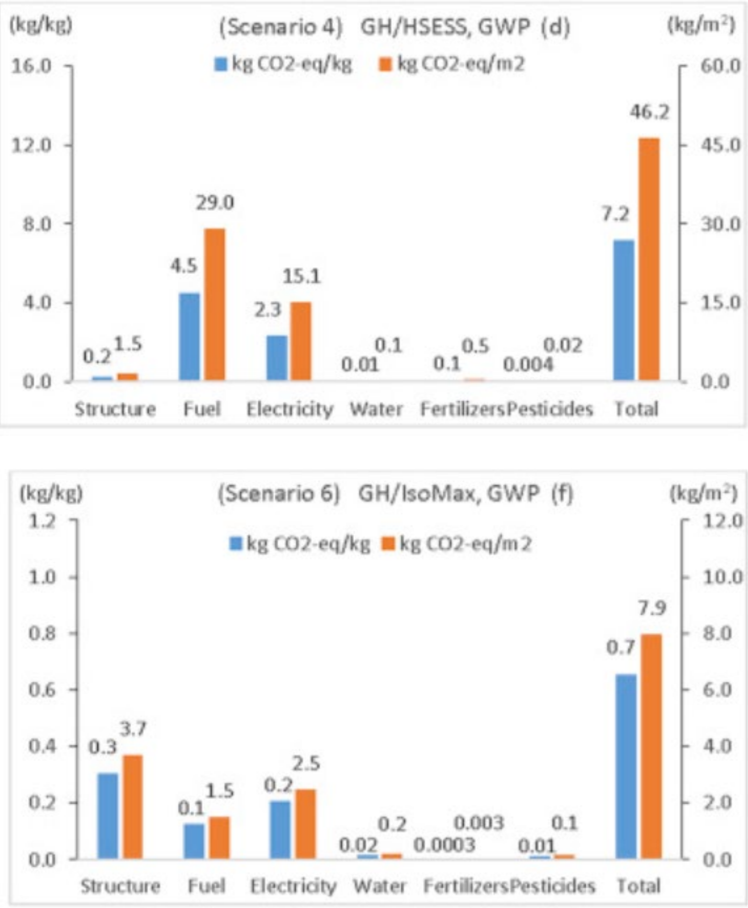
UK & CE – High/Med-Tech Greenhouses



Hotspot	Source
Climate Control (Heating)	Burg et al., (2025); Webb et al., (2013); Jensen et al., (2024); Bosona & Gebresenbet, (2018); Torres Pineda et al., (2021)
Infrastructure	Jensen et al., (2024); Ntinas et al., (2017)
Organic Fertiliser Production	Martínez-Blanco et al. (2009, 2011); Quiros et al. (2015); Maffia et al. (2023)
Organic Fertiliser Application	Fan et al., (2022); Zhou et al., (2021); Jensen et al., (2024)

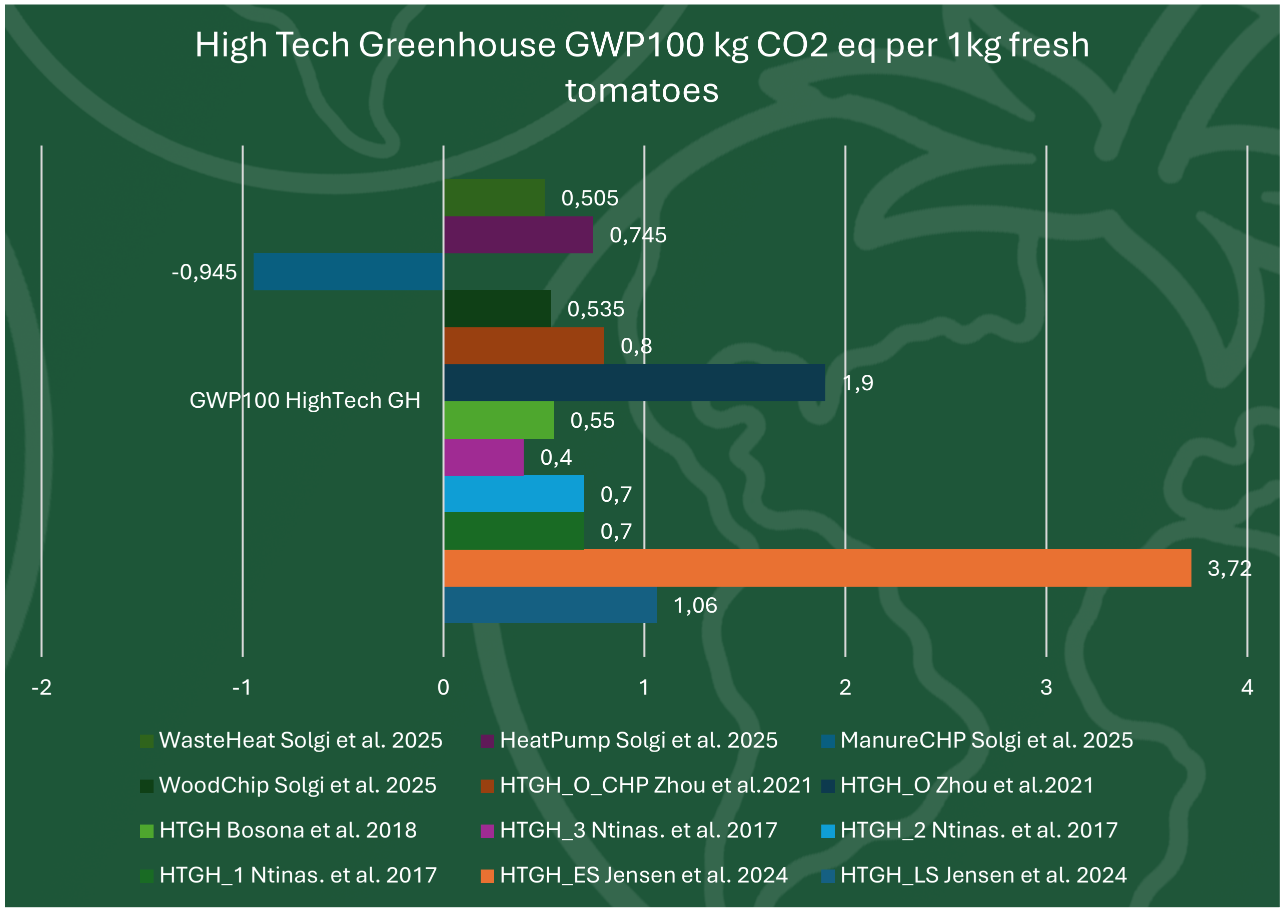
UK & CE – High/Med-Tech Greenhouses

Heated Greenhouse – Natural Gas



Heated Greenhouse – Wood Chips

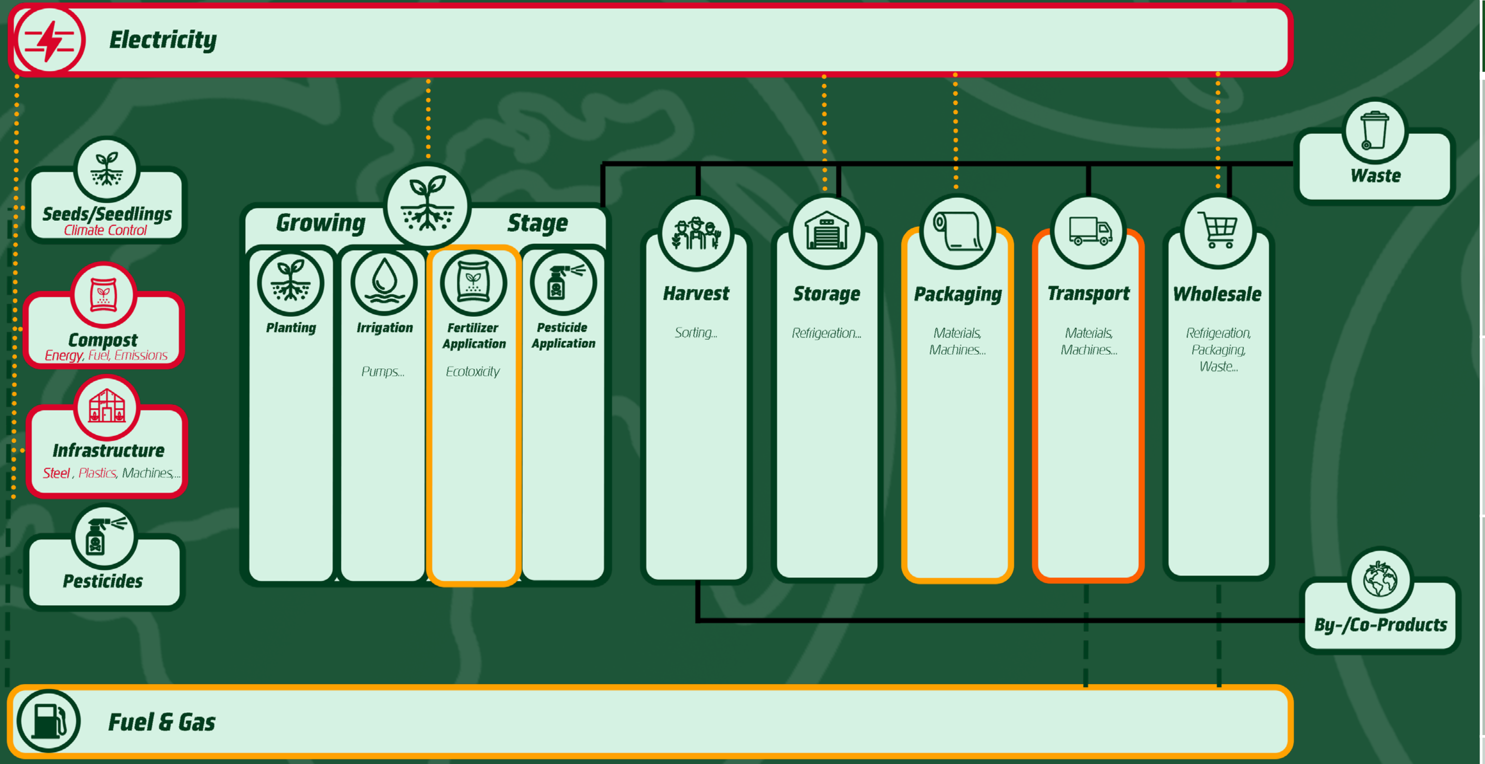
Source: Ntinas et al. (2017)



Mediterranean – Low-Tech Greenhouses

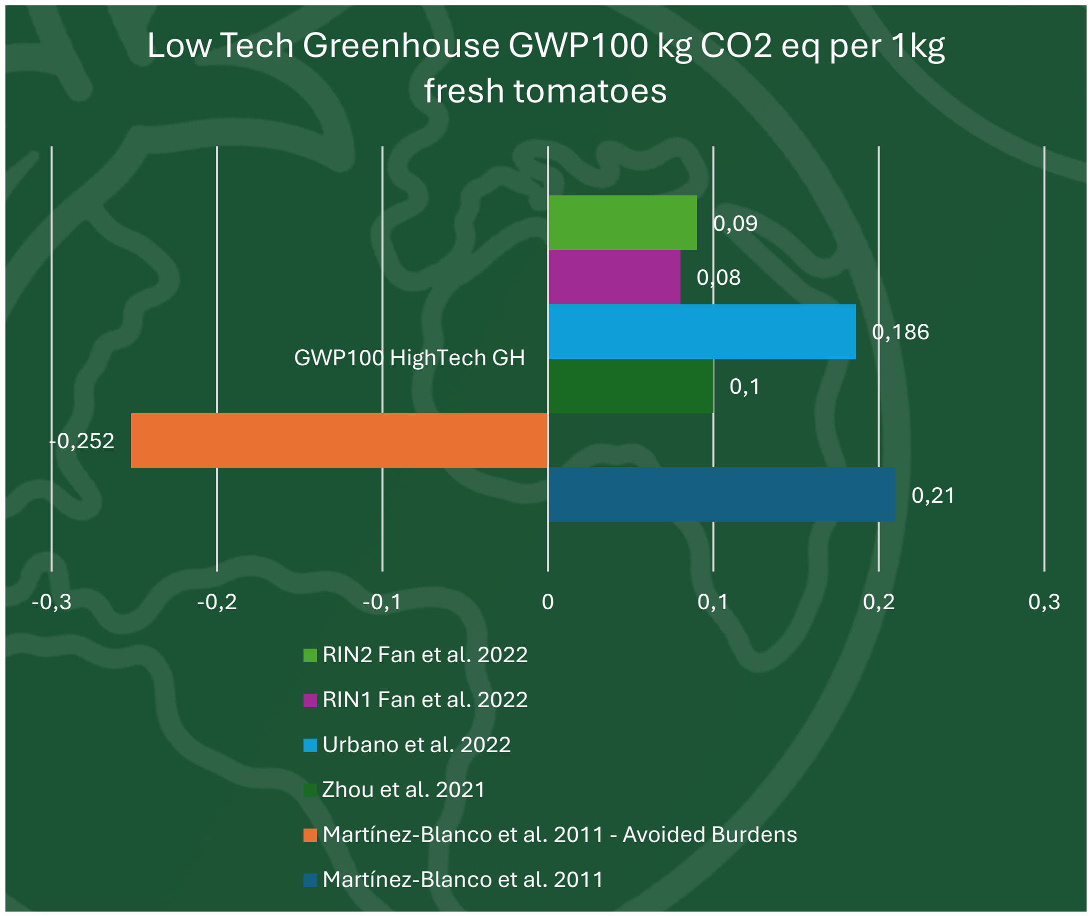
- Organic fertilizers
- Grown in soil
- Higher pesticide usage
- Greenhouse structures (steel/aluminum)
- No heating/AC
- Automatic irrigation
- High levels of water scarcity

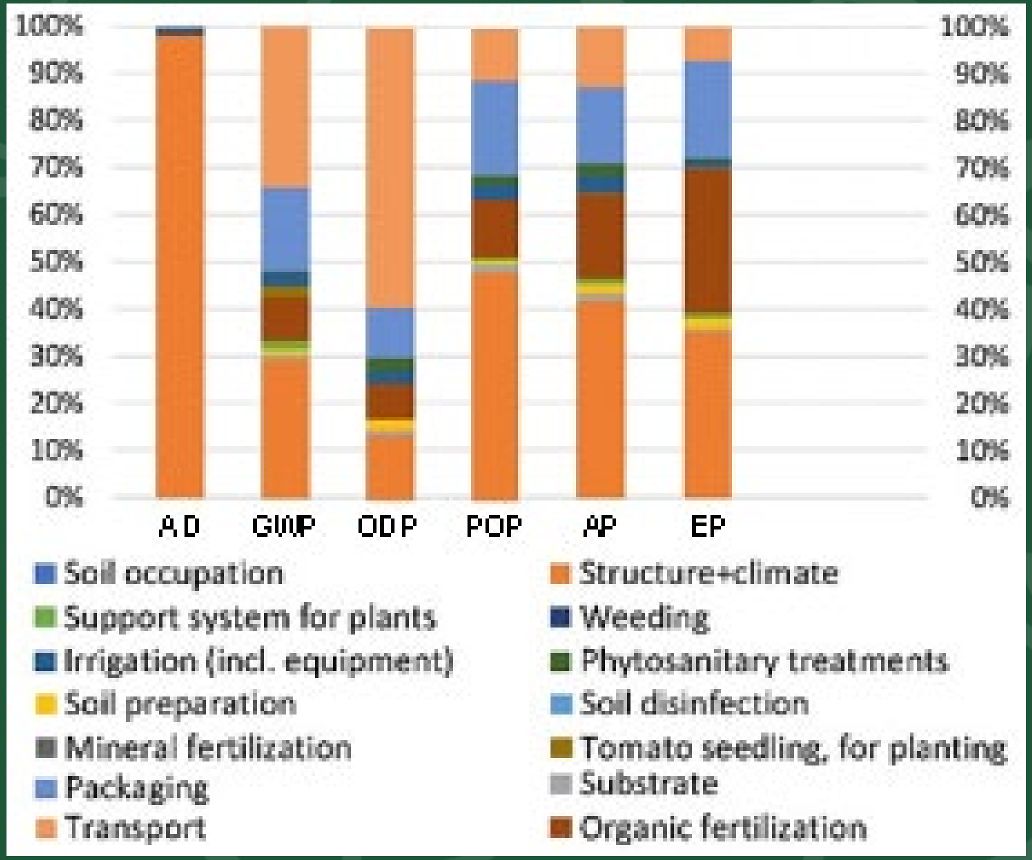
Mediterranean – Low-Tech Greenhouses



Hotspot	Source
Infrastructure	Jensen et al., (2024); Ntinas et al., (2017)
Organic Fertilizer Production	Martínez-Blanco et al. (2009, 2011); Quiros et al. (2015); Maffia et al. (2023)
Organic Fertilizer Application	Fan et al., (2022); Zhou et al., (2021); Jensen et al., (2024)
Transport	Pérez Neira et al., (2018); Urbano et al; (2022)

Mediterranean – Low-Tech Greenhouses





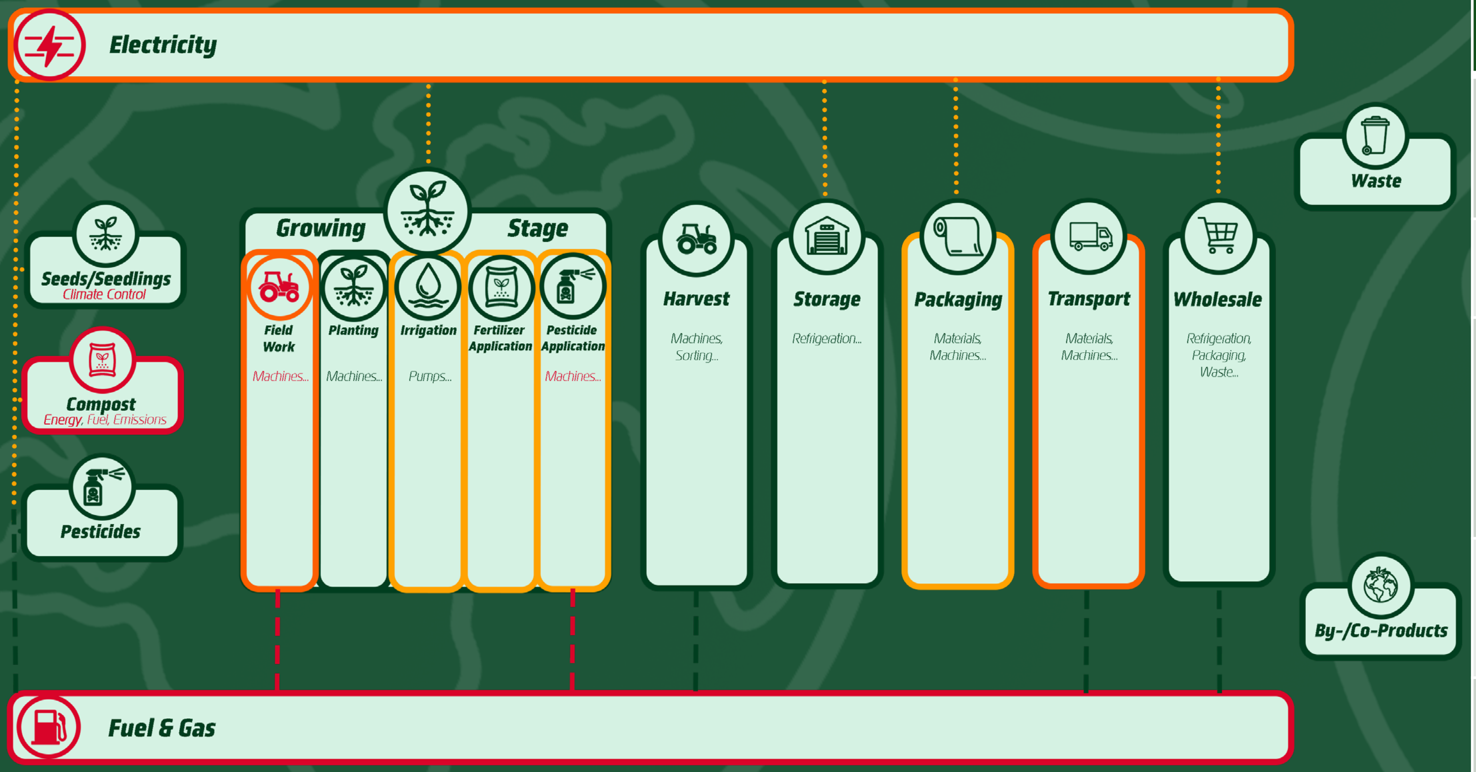
Source: Urbano et al. (2022)

Mediterranean – Open Field

- Organic fertilizers
- Highest pesticide usage
- Planted in soil
- No heating/AC
- Automatic irrigation
- High water scarcity
- **Lower yields** than GH systems

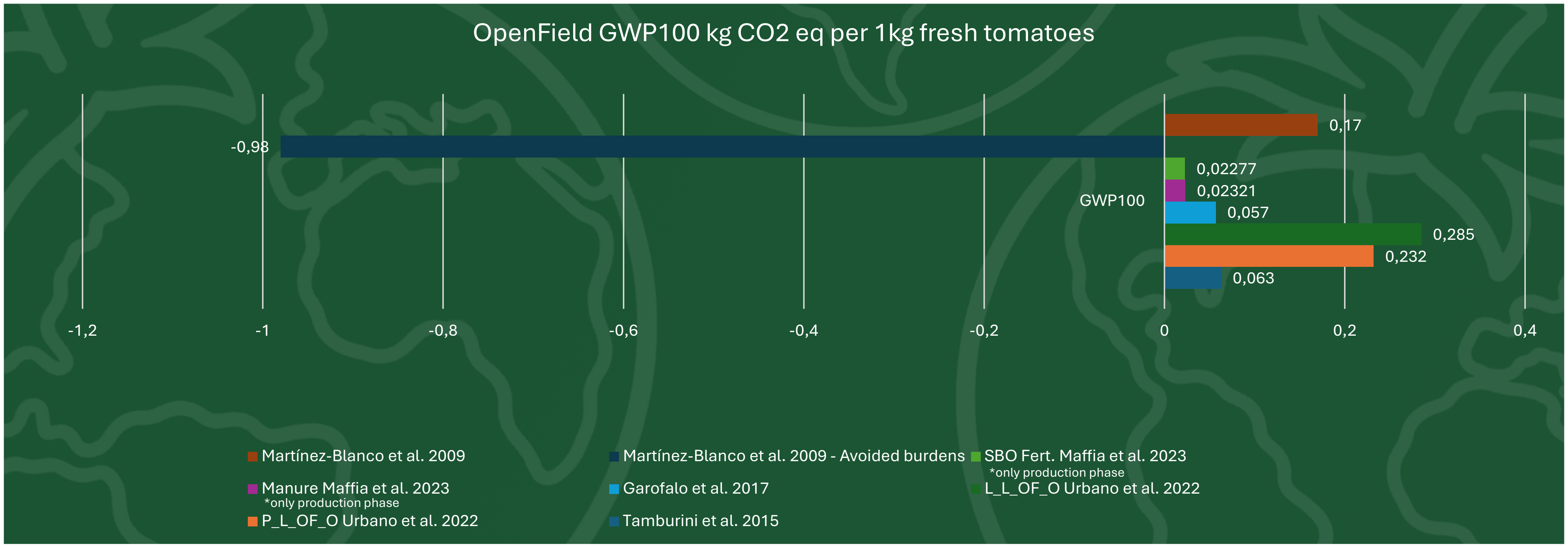
⇨ strongly influences environmental performance per kg

Mediterranean – Open Field

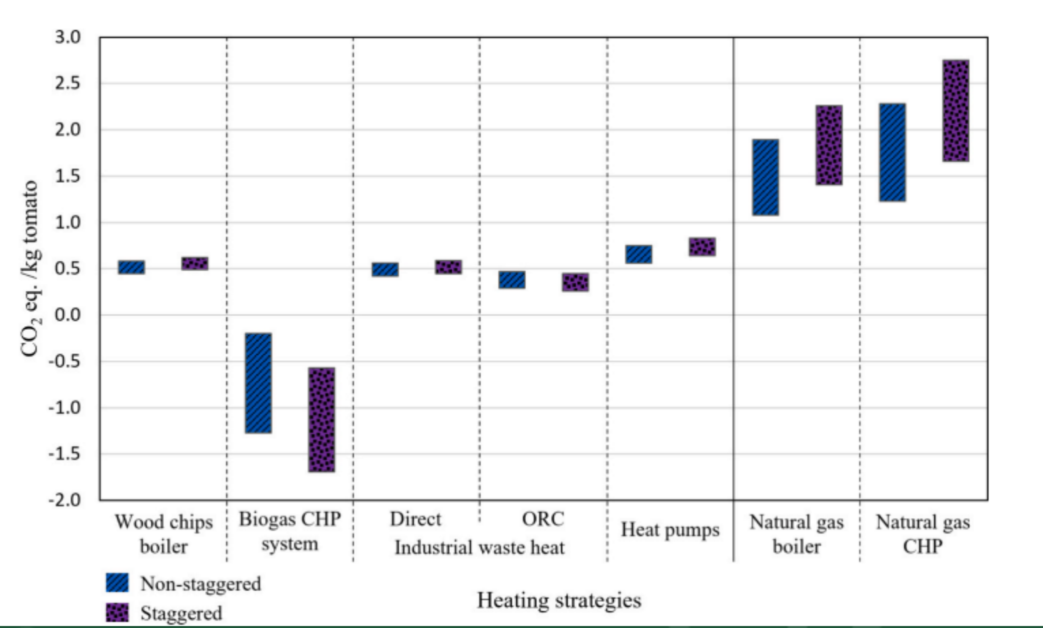


Hotspot	Source
Field Work	Ronga et al. (2019); Quiros et al. (2015); Urbano et al. (2022)
Irrigation Energy	Ntinas et al. (2017); Quiros et al. (2015)
Organic Fertilizer Production	Martínez-Blanco et al. (2009, 2011); Quiros et al. (2015); Maffia et al. (2023)
Organic Fertilizer Application	Fan et al., (2022); Zhou et al., (2021); Jensen et al., (2024)
Transport	Pérez Neira et al., (2018); Urbano et al; (2022)
Irrigation	Chapagain & Orr (2009)

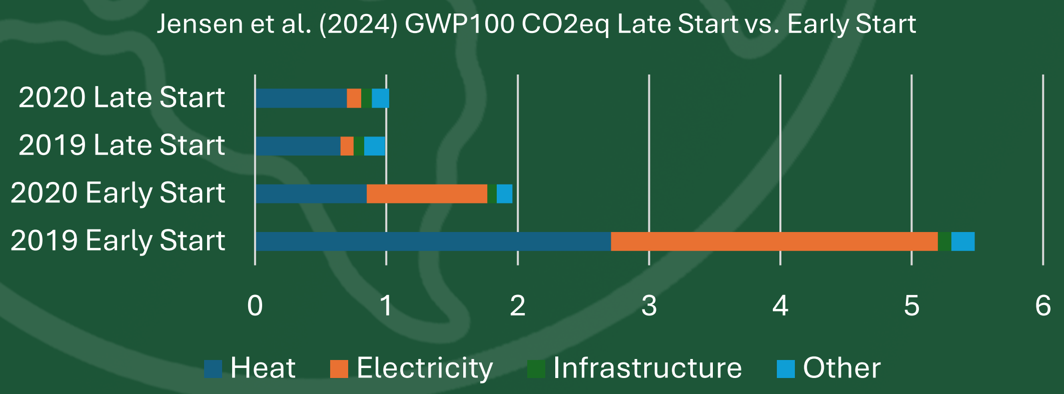
Mediterranean– Open Field



Hotspot: Greenhouse Heating



Source: Solghi et al. (2025)



- **Generally the biggest contributor in heated systems (GHG, EP, AP, OD)**
- **Heavily dependent on multiple factors:**
  - Cultivation Region
  - Greenhouse Insulation
  - Growing Season
  - Climate Conditions
  - Fuel Type
  - Impact Allocation

Hotspot: Infrastructure

Source	GH-Type	% Energy Demand	% GHG-Emissions	% Acidification Potential	% Eutrophication Potential
Pérez Neira et al., 2018	LTGH	43.3%	-	-	-
Torrellas et al., 2012	LTGH	~47%	~35%	~37%	~30%
Torrellas et al., 2012	HTGH Gas	~2,3%	~2,5%	~8,6%	~10,2%
Fan et al., 2022	LTGH	>79%	>85%	Main contributor	Main contributor
Urbano et al., 2022 (P_L_G_Lt-Scenario)	LTGH	~18%	~27%	~40%	~30%
Ntinas et al. (2017)	HTGH Wood Chip	42,8%	-	-	-

- Most significant for non-heated greenhouses or ones with low emission heating technologies
- Greenhouse steel and glass production are major contributors to infrastructure impacts (ED, GHG, EP, AP, OD)
- Major area for resource depletion

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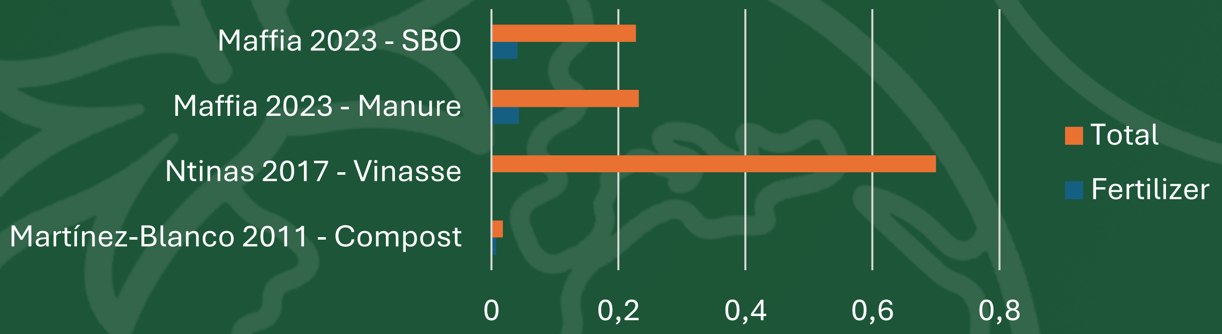
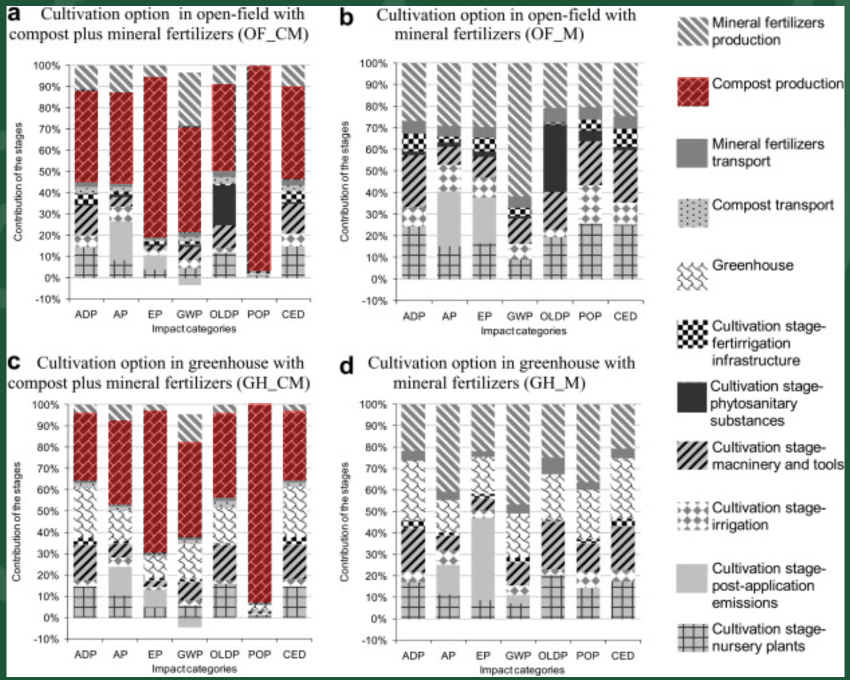
Hotspot: Fertiliser

GWP100 kg CO_2 eq per kg fresh tomatoes





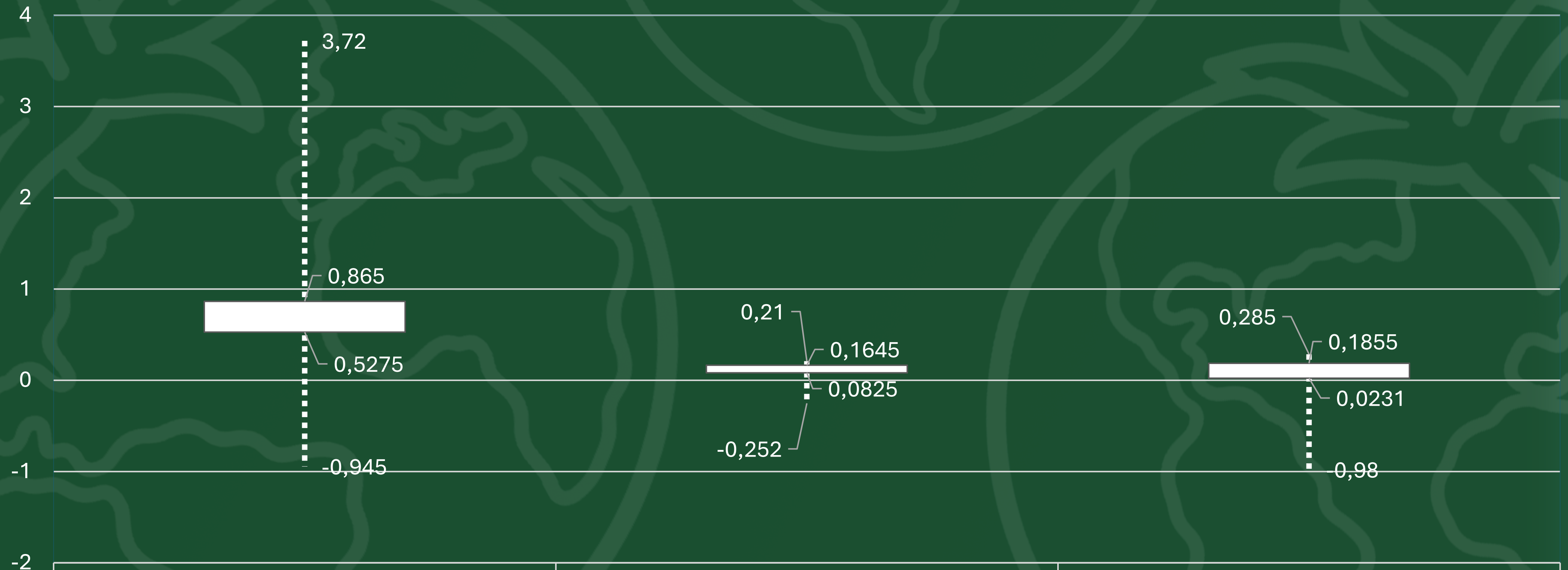
Source: Martínez Blanco et al. (2011)

- **High impacts during compost production:**
  - Municipal waste collection and composting processes are energy intensive and cause emissions (ED, GHG, EP, AP, OD)
  - Certain compost types are superior (*Martínez-Blanco, 2009; 2011*)
  - Avoided burdens lead to negative net-emissions
- **Processed organic fertilizers are often found to be low-impact**
  - *Ntinas et al. (2017)*: Vinasse
  - *Maffia et al. (2023)*: SBO
- **Manure only application can have soil impacts** (Eco-)Toxicity *(Zhou et al., 2025)*
  - Heavy metal contamination
  - Nitrogen leaching

➡ **Fertilisers are not always a hotspot**

Growing System Comparison

GHG Comparison: 1kg CO_2eq per 1kg fresh tomatoes



	HTGH	LTGH	OF
1Q	0,5275	0,0825	0,0231
Max.	3,72	0,21	0,285
Min.	-0,945	-0,252	-0,98
3Q	0,865	0,1645	0,1855

Manchester Metropolitan University

Growing System Comparison

	Climate Change	Acidification & Eutrophication	Soil & Ecotoxicity	Water Use Efficiency
HTGH	-	-	+/-	+
LTGH	+	-	+/-	+
OF	+	-	-	-

- High Tech Greenhouses: Very high energy/fuel impacts, high infrastructure impacts, potential for high water & fertilizer efficiency
- Low Tech Greenhouse: Low energy/fuel impacts, medium infrastructure impacts, potential for high/medium water efficiency
- Open Field: Low energy/fuel impacts, low infrastructure impacts, high ecotoxicity potential, low water use efficiency

The ideal system:

Low/Med-tech greenhouse without heating, closed loop irrigation, mix of processed organic fertilizers and compost & manual labour

Tomato Packaging at the Wholesale Level

The core finding, and the evidence behind it

No material wins categorically. Packaging weight and design predict impact far better than cardboard versus plastic.

1

Production is the hotspot

In the one ISO-compliant fresh-tomato LCA (Mota et al., 2025), making the primary packaging drives over half of impact in every category, ahead of transport and end-of-life once growing is excluded.

2

Weight beats material

The worst pack was a heavy paperboard tray, the best a coated paperboard cup. Two paper trays sat at opposite ends of the range on weight alone. A fibre tray needs more mass to match a thin plastic one.

3

End-of-life is secondary

Meeting 2030 EU recycling targets cut global warming impact by only about 6 to 8%. Recycling gains are modest next to getting material and carton weight right.

Source: Mota et al. (2025), Journal of Cleaner Production 519, 145951

Reusable crates versus single-use cartons

The Contested Question: Reusable crates versus single-use cartons
The answer is conditional, not a verdict. What flips the result is route geometry, not the material.

Reusable crates win when...

- high reuse-cycle counts per crate
- short transport distances
- efficient empty-return, not wasted backhaul
- washing on low-carbon electricity

Single-use corrugated wins when...

- long transport distances
- low crate reuse counts
- poor backhaul utilisation
- airfreight, which penalises the heavier crate

For Organic North: single-use cartons are the sensible default on long-haul imported supply; reusable systems could pay off only on short-haul domestic flows.

Sources: Gao et al. (2025); Fibre Box Association (2024, industry-funded).

Why **Wholesale Packaging** is a Small Burden

- **It is mass per package that matters, not the material**
  - *Read per package, not per kilogram. A wholesale carton uses a few grams of material; processed consumer packaging uses far more, which is where the large impact sits.*

Packaging element	Mass per unit	Relative impact
Corrugated board tray (secondary)	~9.6 g	Largest wholesale element, still small
LDPE pallet stretch film (per tray)	~0.3 g	Negligible; lower GWP than paper wrap
Wooden pallet (per tray)	reused	Excluded: long life, many reuses
Glass jar (processed) — contrast	~200+ g	Order of magnitude higher
Tinplate can (processed) — contrast	~25–40 g	Materially higher

- **What to act on :**
  1. **Cut carton grammage.** Lighter, well-designed cartons beat heavier ones regardless of fibre or plastic.
  2. **Confirm real recycling.** Model current practice, not theoretical recyclability.
  3. **Keep single-use on imports.** The route geometry favours it.

Recommendations

Three-Phase Action Plan

Phase 1: Quick Wins (0-6 Months)

Phase 2: Medium-Term Actions (6–18 Months)

Phase 3: Longer-Term Strategy (18+ Months)

Recommendations ordered by:

- Implementation feasibility.
- Expected environmental benefit.
- Organic North's practical ability to influence change within its supply chain.

Greatest opportunities for sustainability improvements

- Strengthening procurement decisions
- Supplier collaboration
- Long-term supply chain partnership

Recommendations – Phase 1

- Establish a baseline supplier data request form (Transport Mode and Fertiliser Type)

ON collects no environmental performance data from its 26 suppliers as of now

→

What the form should capture?

- Transport mode per supply route.
- Fertiliser type and organic input source.

➢ **What the findings show (Transport):**

25% less GHG
(Sea Freight over Road)
Payen, Basset-Mens and Perret (2015)

18% less GHG
(Fully Loaded Trucks)
Payen, Basset-Mens and Perret (2015)

ecoinvent
Ecoinvent (2023)

GREENHOUSE GAS PROTOCOL
Burkitbayeva et al. (2026)

SimaPro
Dudkowiak et al. (2025)

Recommendations – Phase 2

- **Differentiate organic fertiliser inputs and reduce manure dependency for suppliers**

Lower-Impact Alternatives

Sulfur-based Bentonite (GH Emissions)
0.0227 kg CO_2eq/kg
vs.0.0232 kg CO_2eq/kg for manure (Maffia et al., 2023)

Sulfur-based Bentonite (Water Consumption)
0.0796 m^3/kg
vs. 0.0827m^3/kg for manure (Maffia et al., 2023)

Azolla + Manure Mix
0.547 CO_2eq/kg
much lower than manure-only (Maham et al., 2020)

Vinasse (Fermentation by-product)
< 0.03%
contribution to climate change (Ntinas et al., 2017)

What can ON do?

Collaborate with suppliers to shift to higher-performing organic fertiliser inputs.

Develop a preferred fertiliser input list.

Share guidance on lower-impact fertiliser alternatives for suppliers using manure-heavy inputs.

Recommendations – Phase 2: Medium-Term Actions

- Optimise irrigation efficiency without compromising yield

Why this matters for ON?

Organic systems already face yield gaps relative to conventional production

— any further yield suppression amplifies per-unit impact.

Maham et al. (2020)

Mediterranean suppliers especially in Málaga and Almería operate in water-stressed regions where this pressure is most.

(Ntinas et al., 2017; Quirós, 2015)

Guide suppliers toward precision and closed-loop irrigation systems that maintain yield while reducing water footprint, combat water scarcity, and lower energy consumption.

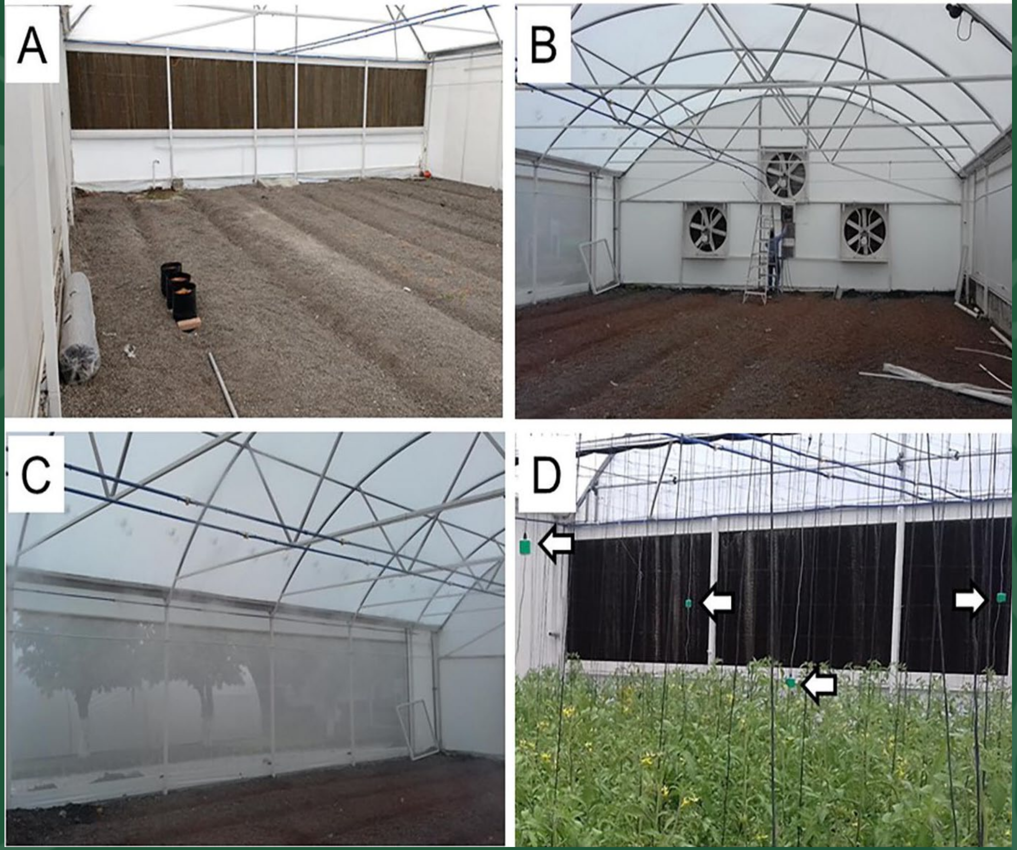
Recommendations – Phase 2

- **Support sensor-based optimisation for Mediterranean suppliers**

Treatment	Yield (ton/ha-year)
With biological treatment	254.4
Without biological treatment	183.6

Source: Serrano-Carreón et al. (2022)

38%
Increase in yield than average crop in GH tech



Source: Serrano-Carreón et al. (2022)

44-60%
Reduction in water consumption

28%
Reduction in tomato cost per unit

25%
Less chemical nitrogen fertiliser use

45%
Increase in grower profit

Source: Serrano-Carreón et al. (2022)

What ON can do?

- Identify willing Mediterranean suppliers to trial this approach.
- Partnership with an agricultural engineering or sustainability advisory specialist.
- Share the results across the supplier network as part of a sustainability guidance document

Recommendations – Phase 3

- **Facilitate Low-Carbon Heating among Local Greenhouse Suppliers**

Heating source	Impact	Source
Natural Gas	Highest Impact	*Torres Pineda et al. (2021)*
Wood Chips	Medium Impact	*Torres Pineda et al. (2021)*
Wood Pellets	Low Impact	*Torres Pineda et al. (2021)*
Biogas with Avoided Burdens	Net Negative	*Solgi et al. (2025)*

52-76%
Percentage of heating emissions of fossil fuel heated GHs
Solgi et al. (2025)

What Organic North can do?

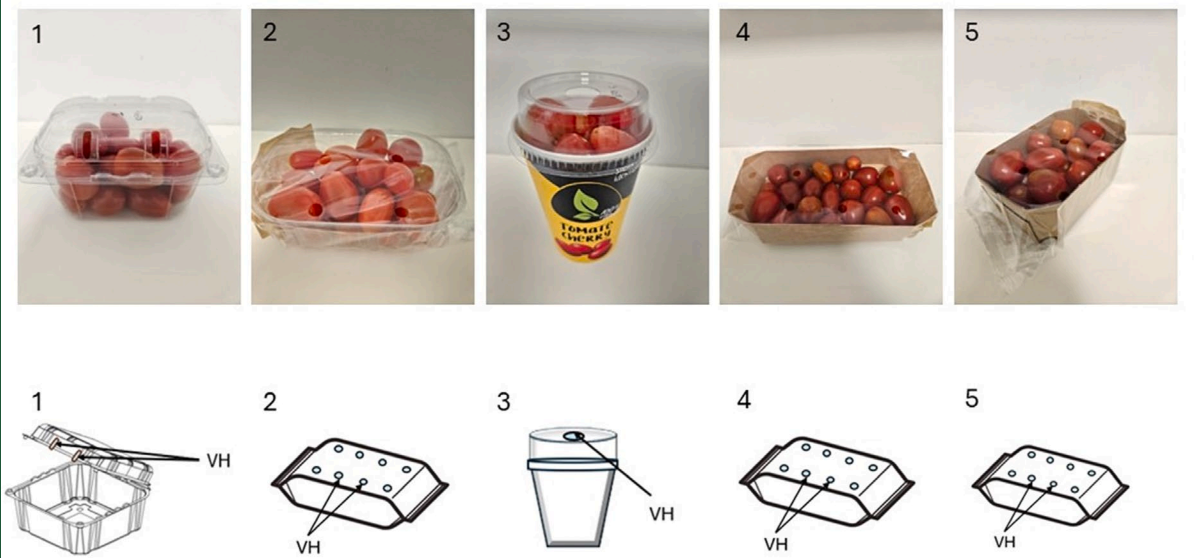
- Formally include heating source as a criterion in local supplier procurement decisions.
- Share findings as an attractive commercial proposition for transitioning to low-carbon heating.
- Engage a GH engineering or biomass energy advisor to support supplier transition planning.

Recommendations – Phase 3

- **Packaging Optimisation**

What Organic North can do?

- Require suppliers to demonstrate packaging efficiency through low material weight, effective product protection and whole-life environmental performance.
- Verify its own inbound cardboard waste stream is in fact being recycled and not just assuming theoretical recyclability.
- Single-use recycled corrugated board is the ideal option for long-distance imported routes.
- Reusable systems may be considered for shorter domestic flows from suppliers or customers if it is viable in the future.



Source: Mota et al. (2025)

Any Questions?

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