White paper

A Holistic Overview of the Food & Beverage Industry's Carbon Footprint

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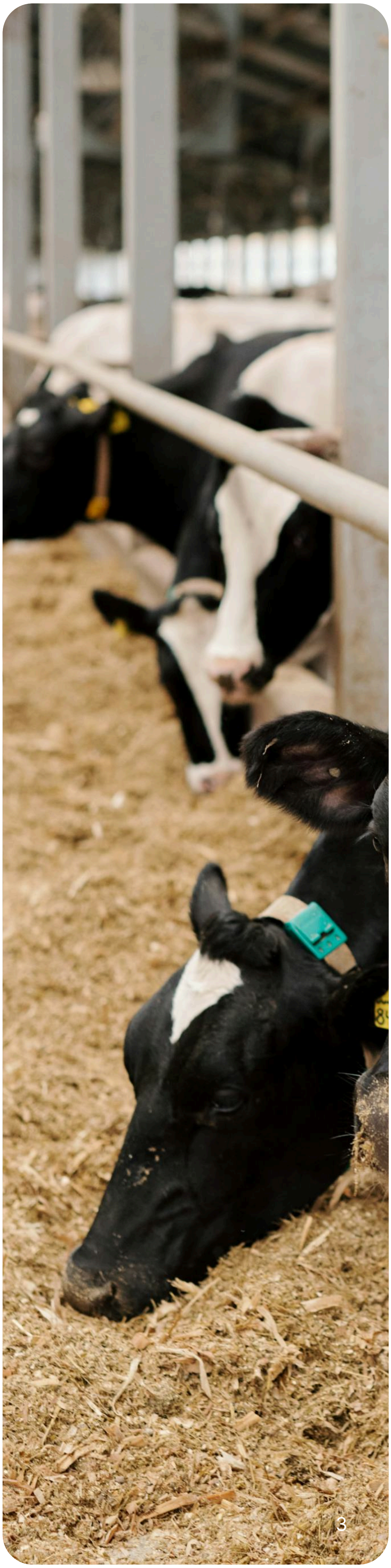
Introduction

Food, beverages and agrifood activities form the backbone of the global economy and human health. Ensuring healthy nutrition is not only about preserving today's food availability, but also about improving and expanding access to those still excluded, tackling the intertwined global challenges of malnutrition, undernutrition, and obesity, in line with the UN Sustainable Development Goals: SDG2 Zero Hunger, SDG3 Good health and wellbeing (SDGS, 2025). In 2024, the food and beverage market (including agriculture, food processing, distribution, and hospitality) was valued at approximately USD 8.2 trillion, representing around 8.7% of global GDP and directly employing over 300 million people worldwide, ranging from farmers and factory workers to chefs and marketers (WBC, 2024). Expanding the scope to agrifood systems (primary production through processing and retail) this figure rises to 1.23 billion direct jobs, or nearly one-third of the global workforce (Davis et al., 2023). Hence, the food sector is not only essential for human nourishment but also fundamental to economic stability, employment, and livelihoods on a global scale.

The food sector is a major driver of GHG global emissions. Today, food systems generate approximately one-quarter to one-third of global GHG emissions, with emissions stemming from land-use change, livestock production, processing, transport, packaging, food waste and end-of-life. In particular, agricultural land conversion (often for livestock feed or pasture) constitutes one of the most significant contributors and methane from ruminant livestock remains difficult to mitigate. Emissive food practices have climate effects that clash directly with the stability of the global food system. For instance, in Japan, rice prices rose 48 per cent in September 2024 after an unprecedented August heatwave across the region, fuelled by climate change, led to poor yields and consequently higher prices, a Barcelona Supercomputing Center study shows (Savage and Smith, 2025).



This white paper addresses a critical question: How can the food and beverage sector transform itself to be fully aligned with the goals of the Paris Agreement, namely to keep global warming well below 2°C above pre-industrial temperatures? In other words, how can we decarbonize a complex sector while preserving and improving its vital role for food security and livelihoods? Moreover, can this decarbonization strategy align with protecting the sector against the impacts of climate variability?

Key outputs

The Food & Beverage industry represents up to

a third of global GHG emissions.

Mitigation efforts

can have negative impacts on adaptation efforts and food security when badly thought through.

Agriculture and land use are the main hotspots across the value chain, highlighting the

prevalence of Scope 3 emissions

for food companies.

Mitigation efforts that do not hinder adaptation efforts and

food security

are numerous.

Mitigation efforts have a substantial potential in reducing global GHG emissions while providing companies with

clear economic opportunities.

Keywords: Agrifood systems, Food and Beverages industry, GHG emissions, Scope 3 emissions, Land-use change, Agricultural production, Food waste, Decarbonization strategies, Mitigation, Adaptation, Food security, Economic opportunities, Paris Agreement

Part 1 : The Food & Beverage Industry's Environmental Impact

Emissions of the sector

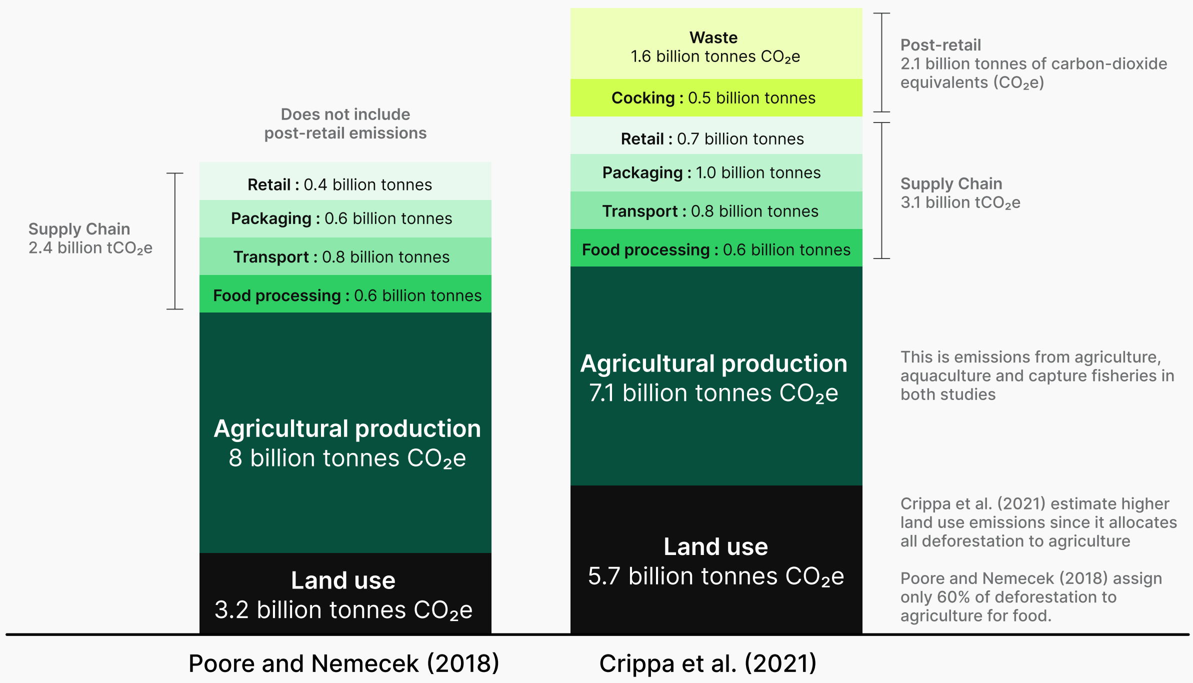
Global greenhouse gas emissions of the Food and Beverages sector

The global food system is a significant driver of climate change, accounting for 23-42% of global greenhouse gas (GHG) emissions, equivalent to approximately 17 Gt CO_2eq per year (IPCC et al., 2022). The gases involved in this greenhouse effect are nitrous oxide (N_2O, from soils, livestock manure, and fertilizer use), methane (CH_4, from ruminant digestion, rice cultivation, and anaerobic soils), carbon dioxide (CO_2, from fossil fuel combustion, fertilizer production, biomass burning, land-use change such as deforestation) and refrigerant gases (for food storage and transport). While these gases differ, they are all measured in CO_2 equivalents and contribute to the greenhouse effect in the atmosphere (Garnett, 2011).

Estimates of total emissions from food systems vary from one study to another. These discrepancies stem primarily from differences in the scope of processes included and in the attribution of land-use change. Figure 1 showcases a comparison of two major studies (Poore and Nemecek (2018) and Crippa et al. (2021)), from Our World in Data, that illustrates this variability.

How much of global greenhouse gas emissions come from the food system

Shown is the comparison of two leading estimates of global greenhouse gas emissions from the food system. Most studies estimate that food and agriculture is responsible for 25% to 35% of global greenhouse gas emissions.



Data source : Joseph Poore & Thomas Nemecek (2018). Reducing food's environmental impacts through producers and consumers. Science. Crippa, M., et al/ (2021) Food systems are responsible for a third of global anthropogenic GHG emissions. Nature Food.

Figure 1 - Emissions from the food system – a comparison of two key studies [Hannah Ritchie, Our World in Data]

When emissions are broken down into stages of the food chain, four main categories emerge:

Land use : deforestation, peatland degradation and fires, and emissions from cultivated soils.

Agricultural production : emissions from synthetic fertilizers (and the energy to produce them), manure, methane from livestock and rice cultivation, aquaculture, and fuel use on farms.

Supply chain : food processing, packaging, transport, and retail, with significant contributions from refrigeration.

Post-retail : consumer-level energy use for food preparation (e.g. refrigeration and cooking) and food waste at the household level.

Poore and Nemecek (left-side) estimated total food system emissions at 13.6 Gt CO_2eq, while Crippa et al. reported 17.9 Gt CO_2eq, a difference of around 4 Gt. This gap arises from three main factors:

1. **Consumer-level processes :** Poore and Nemecek exclude post-retail activities, such as household energy use and food waste, which account for around 2.1 Gt CO_2eq in Crippa et al.'s analysis.
2. **Land-use change :** Crippa et al. attribute all global deforestation to agriculture, whereas Poore and Nemecek assign only 60%. This difference results in an additional ~2.5 Gt CO_2eq in Crippa et al.'s estimate.
3. **Inclusion of non-food agricultural products :** Poore and Nemecek focus exclusively on food products, whereas Crippa et al. include some non-food agricultural commodities such as cotton, leather, and biofuels. (Hannah Ritchie, 2021)

Despite these methodological differences, both analyses converge on the conclusion that land-use change and agricultural production represent the most significant emission sources in the global food system. As such, they should be prioritized in strategies for sector-wide mitigation.

Emissions across the food value chain

Taking a closer look, Figure 2 from Our World in Data highlights what emits GHG at each stage of the food chain:

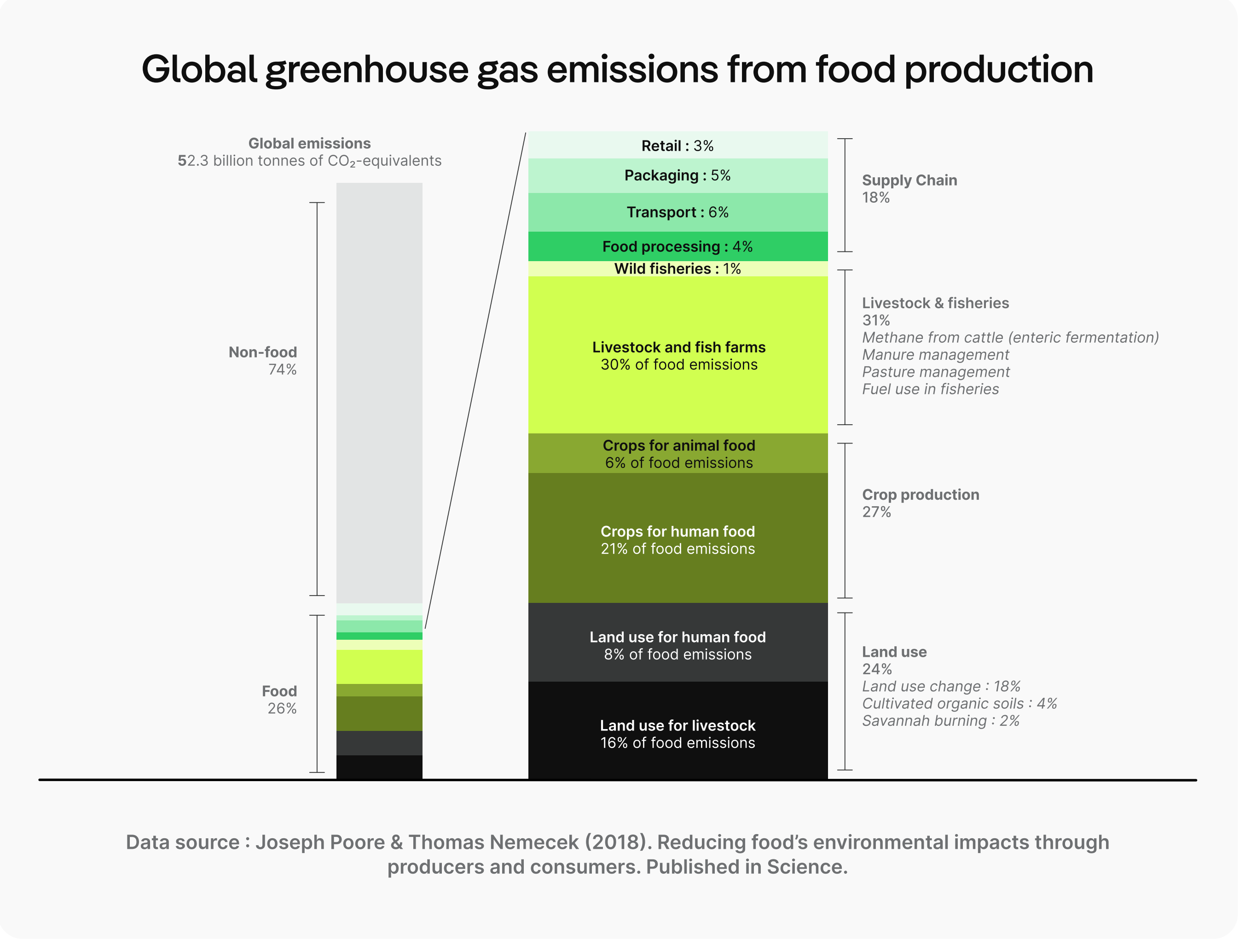


Figure 2 - Emissions from the food system – a comparison of two key studies [Hannah Ritchie, Our World in Data]

Livestock and fisheries : Animals raised for meat, dairy, eggs, and seafood account for nearly one-third of global food-related emissions (31%). The largest share comes from ruminant livestock which release significant amounts of methane through enteric fermentation. This category of emissions is all the more a hard-to-abate as this biological process cannot be altered. Additional sources include manure and pasture management, as well as fuel use by fishing vessels (Hannah Ritchie, 2019).

Crop production : Representing 27% of the industry, these emissions stem largely from nitrous oxide released by fertilizers and manure, methane from rice cultivation, and carbon dioxide from farm machinery and energy use (Hannah Ritchie, 2019).

Land use : Converting forests, grasslands, and peatlands into cropland or pasture remains one of the largest climate burdens. Together, land-use change, savanna burning, and organic soil cultivation release vast amounts of carbon dioxide (24% of the food chain), as carbon sinks are destroyed (Hannah Ritchie, 2019).

The proportion of emissions in the global Food & Beverages sector highlights the critical role of Scope 3 emissions for companies. The sustainability of their supply chains largely determines their overall GHG footprint.

Most emissive foods globally

More particularly, it is interesting to look at the most impactful products in terms of global impact on GHG emissions. Beef and rice are the largest contributors to climate change, with respectively 25% and 12% of total food emissions (Xu et al., 2021), while chocolate has the second highest relative impact (CO2eq/kg) after beef (Ritchie et al., 2022).

Enlightening though it could be, it is important to understand that simply avoiding these food items is not enough to achieve global net-zero emissions. Achieving this goal requires broader systemic changes across the entire food system, which will be discussed in more detail in the next section.

Beef

As shown in Figure 4, beef (from cattle herds and not dairy herds that produce dairy and beef) has the biggest emission factor among food products with 99kg CO_2eq/kg produced. In addition, beef held 19% of the world meat production in 2022 (Statistical Yearbook World FAO 2024). For this product, the farm stage accounts for the biggest part of these emissions with 56.23 kg CO_2eq / kg produced mainly because of enteric fermentation as shown in the graph below. As illustrated in figure 3, cattle generate methane as a byproduct of microbial fermentation during digestion, a process essential for their survival and for producing milk, meat, or leather. The fermentation residues are converted into methane by methanogenic microorganisms in their digestive tract. Contrary to popular belief, about 95% of this methane is released through burping (eructation), while only 5% comes from flatulence (Glasson et al., 2022).

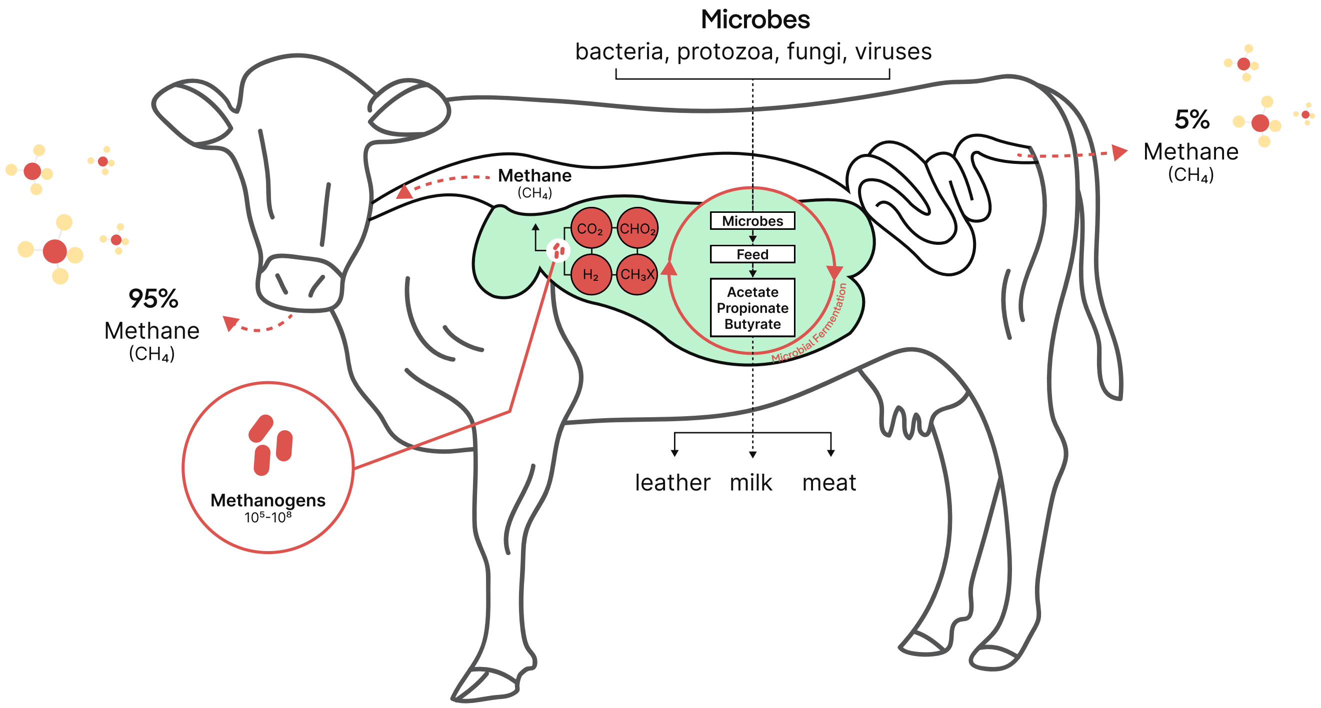


Figure 3 - Methane emissions from cattle due to enteric fermentation [Glasson et al., 2022]

In addition to enteric methane emissions, cattle ranching is by far the leading driver of tropical deforestation, responsible for 41% of forest loss, equivalent to 2.1 million hectares cleared each year, nearly half the size of the Netherlands. Brazil is at the center of this dynamic, with cattle ranching driving 72% of the country's overall deforestation. In contrast, crops such as palm oil and soy, often at the forefront of public debates, contribute 18% of deforestation when grouped with other oilseeds. Importantly, the majority of soy (57.2%) is used to feed poultry and pigs, with only 0.5% going to beef production. This highlights that it is not soy for cattle feed or other crop feed, but rather the direct expansion of pastureland, that constitutes the primary driver of land-use change and related emissions for beef (Hannah Ritchie, 2024).

Rice

In comparison, rice only emits 4kg CO_2eq / kg from field emissions due to microbial activity of methanogenic bacteria, fossil-based irrigation processes and agrochemical applications. Indeed, "flooded fields are a suitable habitat for methane-emitting bacteria. The anaerobic decomposition of the organic matter in the soil by the microbial activity of these methanogenic bacteria produces significant methane in rice fields" (Mahmood et al., 2023). However, it is important to consider the volumes. Rice represented 8% of the global production of primary crops in 2022 (800 million tons) (Statistical Yearbook World FAO 2024), which, when combined to its emission factor, makes it the second most emissive food globally. Further, it is enlightening to consider the absolute assessment of a product. An absolute environmental assessment is an environmental evaluation that measures impacts against fixed, science-based thresholds or limits, rather than just comparing one product, process, or scenario to another. The results of Mahmood et al.'s study for rice were well above the defined sustainable thresholds. Environmentally friendly irrigation methods, improved fertilizer efficiency, and high-yield, short-duration rice varieties were recommended for their potential to substantially reduce these impacts (Mahmood et al., 2023).

Chocolate

Looking at the relative greenhouse gas emissions measured in kilograms of carbon dioxide-equivalents (CO_2eq) per kilogram of food, dark chocolate has the second highest emission factor (47kg CO_2eq / kg produced) after beef according to Figure 4, a graph from Our World in Data. Other food items are also deeply emissive like lamb and mutton, coffee, shrimp, cheese, etc. (Ritchie et al., 2022).

Land-use change is the main source of emissions in this sector, as forests are often cleared to make way for cocoa cultivation. Between 2001 and 2015, cocoa farming replaced an estimated 2.3 million hectares of forest worldwide, roughly the size of Belgium (WRI, 2022). Cocoa cultivation, while smaller in scale compared to major drivers like palm oil, soy, cattle, and timber, has caused significant deforestation in biodiversity hotspots such as West Africa's Upper Guinea Rainforest, Southeast Asia, and parts of Latin America. Between 1988–2008, cocoa production led to an estimated 2 to 3 million hectares of forest loss, with Côte d'Ivoire, Ghana, Nigeria, Cameroon, and Indonesia being most affected. Key drivers include insecure land tenure, weak governance, declining soil fertility, and short-term economic incentives for expanding into forested land rather than replanting existing farms (Kroeger et al., 2017).

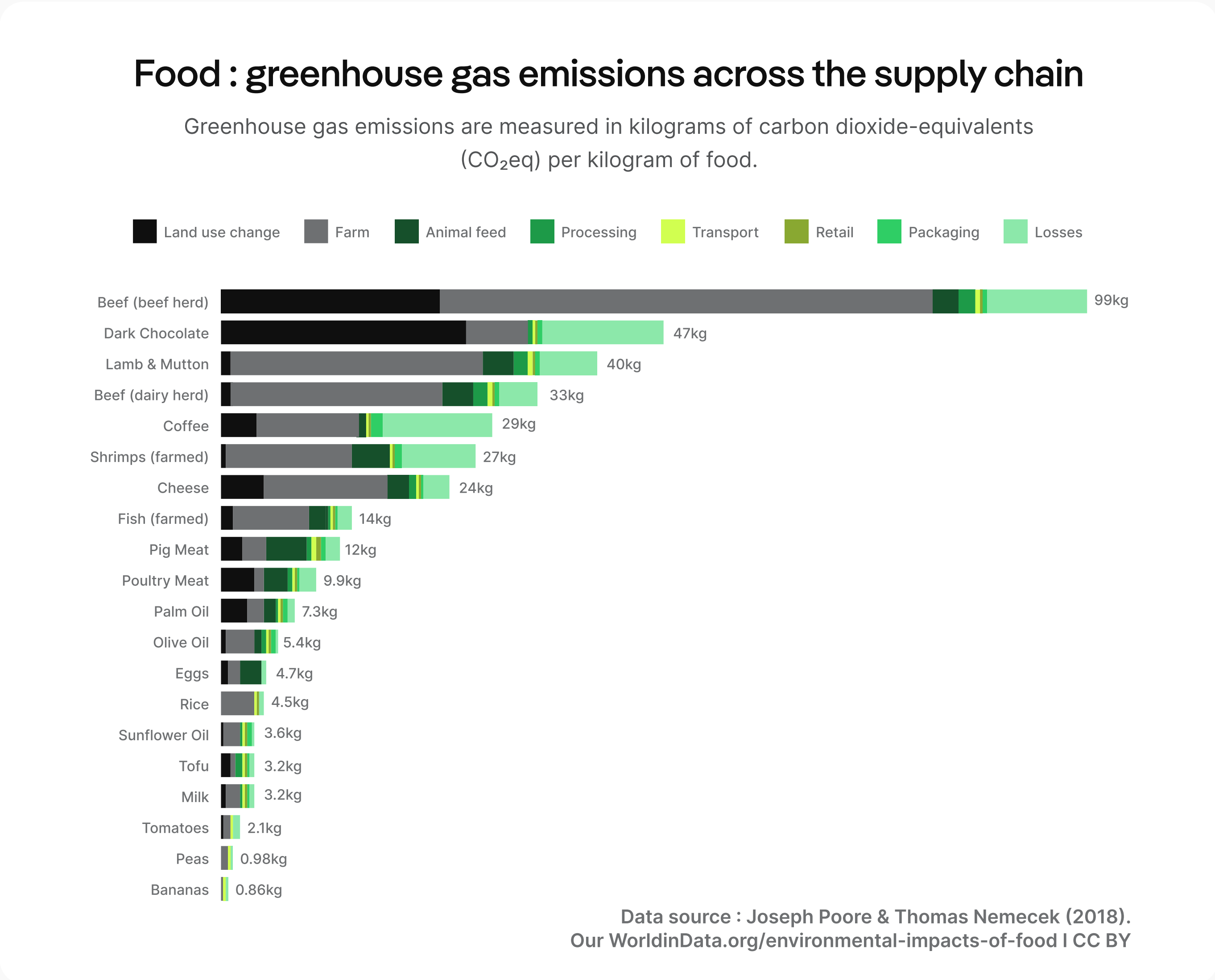


Figure 4 - Emissions per food item by stage of the supply chain [Our World in Data, 2023]

Global warming mitigation targets

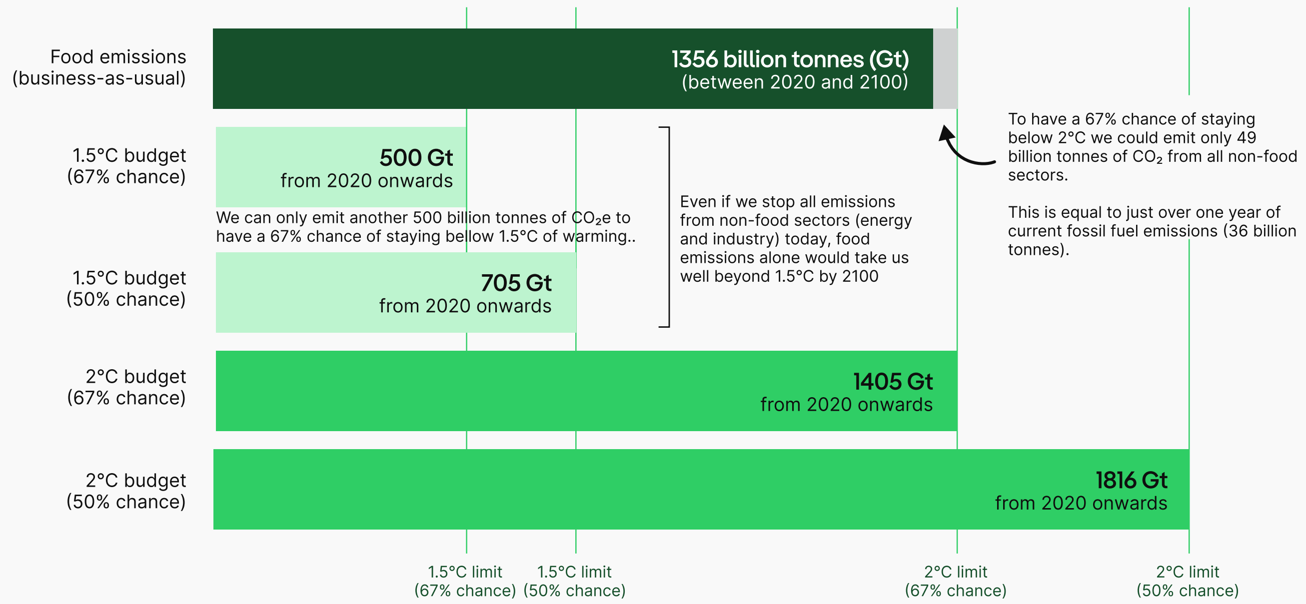
In an effort to combat climate change and its harmful impacts, world leaders gathered at the United Nations Climate Change Conference (COP21) in Paris and adopted the historic Paris Agreement. This landmark accord set out long-term objectives to guide all nations. Foremost among these is the commitment to significantly reduce global greenhouse gas emissions with the aim of limiting global warming to 2°C this century, while continuing efforts to further restrict the increase to 1.5°C (UN, 2025).

Although energy and industry remain the largest contributors to greenhouse gas emissions, addressing only these sectors will not be enough. As presented above, the significant share of GHG emissions from the Food & Beverages sector make it pivotal in our mitigation efforts. Research led by Michael Clark projects that, under a business-as-usual pathway, global food systems alone could emit around 1,356 billion tonnes of CO_2-equivalent by 2100. This trajectory would exceed the carbon budget for limiting warming to 1.5°C by a factor of two to three, and nearly exhaust the entire budget for keeping temperatures below 2°C, as Figure 5 depicts (Hannah Ritchie, 2021).

The message is clear: reducing food-related emissions cannot be sidelined if we hope to meet international climate goals. Even if fossil fuel combustion were to stop overnight, it would still not suffice: food system emissions alone would push us beyond safe climate limits. (Hannah Ritchie, 2021).

Food emissions could consume most of our 1.5°C or 2°C carbon budget

Shown are estimates of cumulative greenhouse gas emissions from food production from 2020 to 2100 based on population, dietary and agricultural trends in a business-as-usual scenario. This is shown relative to total cumulative emissions to keep global average temperature rise below 1.5°C or 2°C by 2100



Note : This is measure in global warming potential (GWP*) CO_2 warming-equivalents (CO_2-we).
Source : Michael Clark et al. (2020). Global food system emissions coulb preclude achieving the 1.5° and 2°C climate change targets. Science. OutWorldinData.org - Research and data to make progress against the world's largest problems

Figure 5 - Food system emissions relative to the global carbon budget under the Paris Agreement targets [Hannah Ritchie, Our World in Data]

Therefore, unlocking the full mitigation potential of the food system requires comprehensive transformations spanning the entire value chain: from production and distribution to consumption and waste management. According to the IPCC, integrated policy packages that blend market-based tools, regulatory measures, information campaigns, and behavioral incentives are far more effective than isolated actions. When carefully adapted to the needs of diverse stakeholders, such coordinated strategies can lower costs, deliver multiple sustainability benefits, and foster broader societal support (IPCC, 2022, AR6 WGIII).

Adaptation challenges of the food sector

Furthermore, the food industry is all the more affected by climate change. According to the IPCC, human-induced warming has slowed agricultural productivity and compromised crop yields through heat stress, ozone pollution, and methane-driven warming. Warming and drought have heightened tree mortality, reduced forest services, and lowered the stability of crops, grasslands, and livestock systems. Marine and freshwater food systems are also under stress because of ocean warming and acidification that have reduced wild fish stocks and impacted aquaculture species. Shifts in species distribution, altered timing of flowering and pollination, and increased pests and diseases further threaten food production. Climate extremes like droughts, floods, and marine heatwaves now more frequently trigger sudden food production losses, driving up prices and exacerbating malnutrition. And the coming decades will likely see these impacts grow more severe. (IPCC, 2022)

Farmers and fishers are already adopting autonomous measures, such as switching varieties, adjusting planting times, and modifying livestock management. Other options include agricultural diversification, climate services, improved cultivars (cultivated varieties), adaptive eco-management in fisheries, and ecosystem-based practices like agroforestry, agroecology, and land restoration. However, adaptation effectiveness is constrained by financial, institutional, and social barriers. We will discuss these strategies in the next section. (IPCC, 2022)

In addition, the food industry is increasingly shaped by shifting consumer demand. A growing global population, projected to reach 9.7 to 10.8 billion by 2050, will drive a 40-54% increase in food, feed, and biofuel production compared to 2012 levels. In the Global North, dietary patterns are gradually moving toward more plant-based choices, while in many developing countries, economic growth and urbanisation are fueling demand for more diverse and nutritious diets. By 2034, per capita consumption of animal-source foods is expected to rise about 6% globally, and by as much as 24% in lower-middle-income countries (UN, 2025).

Global hunger and nutrition issues

These risks are even more concerning in the context of global hunger and nutrition issues. Today, 815 million people remain chronically undernourished, lacking access to sufficient and nutritious food (FAO, UNICEF, WFP, and WHO, 2020). Simultaneously, low-quality diets and unbalanced nutrition contribute to rising rates of obesity and diet-related non-communicable diseases. Over 2 billion adults are overweight or obese, reflecting both unhealthy dietary patterns and the unequal distribution of food resources on a global scale (Duro et al., 2020; FAO, UNICEF, WFP, and WHO, 2020).

Other impacts of the food and beverages sector

It is important to note that the food sector's environmental impact extends well beyond greenhouse gas emissions. Other critical pressures, often less visible in public debate, include marine eutrophication, water resource depletion, terrestrial resource depletion, and acidification, among others.

For example, scarcity-weighted water use represents freshwater use weighted by local water scarcity. Nuts hold the biggest impact in this category with 230 thousand liters of scarcity-weighted water per kilogram of food compared to 662 liters for bananas (Poore and Nemecek, 2018). This impact is critical to consider, as in regions already facing water scarcity or severe drought, it can compete directly with local communities' access to drinking water. Figure 6 illustrates the relative contributions of different stages of food production to these diverse environmental impacts (Notarnicola et al., 2017).

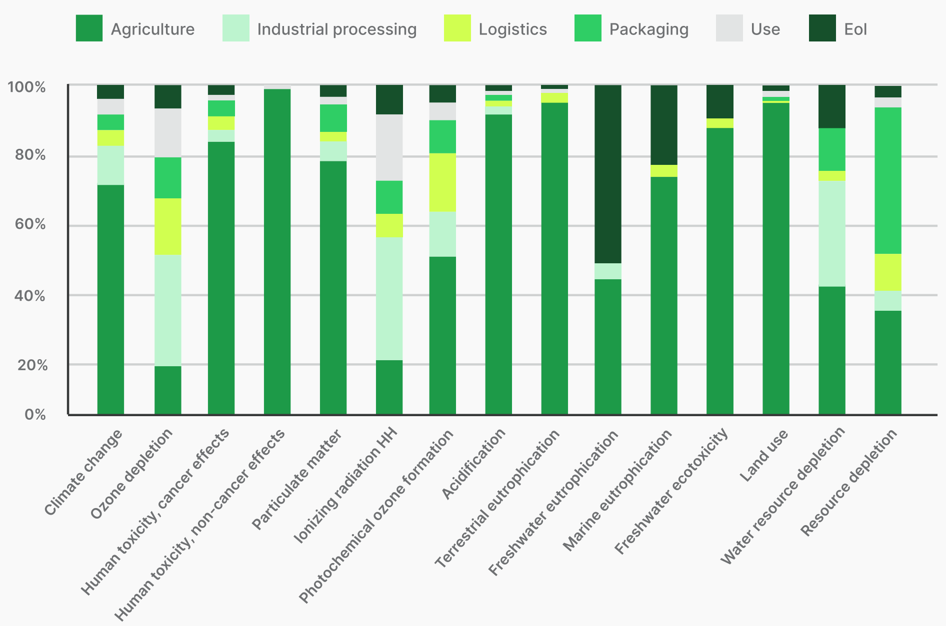


Figure 6 - Relative contribution of the six life cycle phases to the impact of the entire basket in each impact category [Notarnicola et al., 2017]

The graph highlights that the agricultural stage generally contributes the most across nearly all impact categories, especially in relation to terrestrial eutrophication, land use, human toxicity, and acidification. In contrast, end-of-life management (EoL) primarily influences freshwater and marine eutrophication (Notarnicola et al., 2017).

Another crucial dimension to consider is the social impact of the food sector. This goes from forced and child labor to discrimination, health impacts, to workers rights and corruption. For instance, in 2010, an estimated 60% of all child laborers aged 5-17, more than 98 million girls and boys worldwide, were employed in agriculture, including farming, fishing, aquaculture, forestry, and livestock (ILO, 2010). The categories of social impact are numerous, spanning issues such as child labor, forced labor, fair wages, working hours, discrimination, worker health and safety, access to social benefits, legal compliance, protection of workers' rights, fair competition, corruption, illiteracy, public health and safety, and respect for Indigenous rights (Mancini et al., 2023).

All of these environmental and social impacts need to be taken into account when assessing the broader impact of a food product in order for mitigation objectives to be set.

Part 2 : Decarbonization Efforts

State of the art of the sector's commitment

In the light of the impact and sensitivity of the food sector to climate change, numerous companies from the industry are taking voluntary action.

Company (Sector)	Net-Zero Target	SBTi-Aligned Target (validated)	Reporting/Framework Compliance
Walmart (Retail)	Zero emissions by 2040	No – originally set (50% by 2030) but SBTi "commitment removed" in 2024	Reports under GRI/SASB and TCFD frameworks (ESG reports)
Amazon (Retail/Distribution)	Net-zero by 2040	No – SBTi "commitment removed" (was pursuing 50% by 2030)	Aligns with SASB, TCFD, GRI frameworks
Nestlé (Food & Beverage)	Net-zero by 2050	Yes – SBTi-validated (near- and long-term, including net-zero by 2050)	Aligns with EU CSRD/ESRS and TCFD guidelines
Schwarz Group (Lidl/Kaufland, Retail)	Net-zero by 2050	Yes – SBTi-validated near-term targets (48% Scope 1&2 cut by 2030)	(Reports likely follow GRI/TCFD; formal disclosures under EU/IFRS)
Costco (Retail)	Net-zero by 2050	No – not pursuing SBTi alignment (shareholders pushed for SBTi targets)	Publishes SASB index and TCFD report
PepsiCo (Food & Beverage)	Net-zero by 2050	Yes – SBTi-validated (50% Scope 1&2 and sectoral Scope 3 cuts by 2030, net-zero by 2050)	Publishes SASB and TCFD indices
Tyson Foods (Meat/Poultry Processing)	Net-zero by 2050	Yes – SBTi-validated (e.g. 30% cut by 2030, 2.0°C pathway)	(Reports aligned to GRI/TCFD; publishes SDG-aligned goals)
JBS (Meat Processing)	Net-zero by 2040	No – SBTi net-zero commitment not validated (JBS's "gold standard" pledge halted)	(Has published sustainability goals; limited TCFD disclosures)
ADM – Archer Daniels Midland (Agribusiness)	Net-zero by 2040	Yes – SBTi-validated (50% Scope 1&2 cut by 2030; full value-chain cuts by 2040)	(Engaged with SBTi's Net-Zero standard; likely reports under GRI/TCFD)
Unilever (Food/Consumer Goods)	Net-zero by 2039	Yes – SBTi-aligned (1.5°C-aligned near-term targets)	Publishes TCFD disclosures; aligning with GRI/SASB (ESG/Impact reports)

Figure 7 - Sustainability Commitments of Top 10 Global Food & Beverage Companies

Figure 7 shows that 10 top companies of the industry have announced Net-Zero ambition for 2040 or 2050. Only some of them, like Nestlé or PepsiCo have validated SBTi targets. However, a major concern is that while many companies have set net-zero targets, they may not be aligning with the scientific targets needed to limit global warming to 1.5°C as set by the Paris Agreement

The Science Based Targets Initiative (SBTi) is a leading organization that helps companies align their emissions targets with climate science. At least 613 food companies have committed to developing targets to reduce emissions, according to an online database from the SBTi. As of January 2024, the tool shows 7,481 companies are taking action and 4,470 have established science-based targets. Within the food production - agricultural production sector, 83 companies have or are working on targets. 255 companies in the food and beverage processing sector committed to developing emissions targets, while another 275 have targets set (Cover Crop Strategies, 2024).

For example, while Walmart has announced a Net-Zero target for 2040, Figure 8 shows that it has withdrawn its commitment to the SBTi (SBTi target dashboard, August 2025). This raises concerns about the credibility and transparency of its climate strategy, suggesting that its goals may lack the concrete actions needed for effective implementation (Zero emissions White Paper, Walmart Sustainability).

Company	Near-term status	Net-zero status
Walmart Inc. United States of America, Northern America	Target Set	Commitment Removed

Figure 8 - Walmart’s SBTi status [SBTi target dashboard]

Mitigation efforts

Companies must therefore reduce the sector's emissions to align with the Paris Agreement and their net-zero commitments. Yet this raises a critical question: can such mitigation efforts be achieved without compromising global food availability? In other words, does reducing emissions imply less food availability?

Evidence suggests this is not the case. The global food system currently delivers around 4 billion tonnes of food annually (FAOSTAT, 2022): a quantity sufficient to feed both today's population and the nearly 10 billion people projected by 2050 (FAO, UNICEF, WFP, and WHO, 2020). These figures indicate a state of overproduction relative to nutritional requirements. Yet, despite this surplus and as mentioned earlier, 815 million people remain chronically undernourished and over 2 billion adults are overweight or obese. This sheds light on a profoundly inequitable distribution of food resources worldwide (Duro et al., 2020; FAO, UNICEF, WFP, and WHO, 2020).

Key decarbonization trends can be grouped into three main areas: Agricultural-Stage Mitigation, Post-Farm Gate Innovations, Consumption Patterns and Emerging Technologies (IPCC, 2022). We provide here a list of actions and strategies that must be tailored to the socio-economic, cultural, and geographical context to avoid unintended negative consequences.

Agricultural-Stage Mitigation

At the production level, technological and managerial approaches are being implemented to lower greenhouse gas (GHG) emissions. According to the IPCC, five broad categories of measures are particularly relevant (IPCC, 2022):

- **Enhancing carbon sequestration:** through land restoration, afforestation, conservation tillage, and incorporation of organic matter.
- **Optimising nutrient use:** via precision application of organic and inorganic fertilizers and crop rotations with nitrogen-fixing legumes.
- **Improving productivity:** by increasing yields per unit of emissions through breeding, feed optimisation, dietary additives, and pest/disease management.
- **Sustainable use of outputs:** including composting, manure management, and anaerobic digestion.
- **Low-carbon energy adoption:** using biomass, biogas, wind, or solar energy, alongside energy efficiency measures.

Closer look at 4p1000 Initiative

The “4 pour 1000” initiative, launched at COP21 in 2015, aims to increase global soil organic carbon stocks by 0.4% annually in the top 30-40 cm of soil. This modest yearly gain could significantly offset global CO_2 emissions, in particular in the food and beverages sector. Indeed, soils store 2 to 3 times more carbon than the atmosphere, making them crucial climate regulators (CIRAD, 2015). By adopting sustainable practices, such as no-till farming, crop rotation, agroforestry, compost application, and improved grazing, farmers can not only sequester carbon but also boost soil fertility, water retention, and food security, especially in climate-vulnerable regions (Shumba et al., 2023). Key practices include:

- Avoiding bare soil to reduce carbon loss.
- Restoring degraded cropland, pastures, and forests.
- Planting trees and legumes (which fix nitrogen).
- Adding compost and manure to enrich soils.
- Collecting and managing water efficiently at the base of plants.

In July 2024, the initiative had brought together over 830 stakeholders (among which 365 members), ranging from governments and research institutions to NGOs and farmers, to promote agroecological practices, share knowledge, and implement region-specific solutions (4p1000, 2024).

Although soil carbon sequestration cannot replace emission reductions, it acts as a powerful complementary strategy with multiple co-benefits for climate resilience, biodiversity, and rural livelihoods. The challenge remains ensuring permanence, proper monitoring, and integration with broader climate policies, but the approach represents a promising and inclusive pathway toward a more sustainable and secure food system (CIRAD, 2015).

Post-Farm Gate Innovations

Beyond the farm, food processing, packaging, distribution, and retail are also targeted for improvements (IPCC, 2022):

Energy efficiency : optimising equipment use, reducing unnecessary energy demand, and selecting the cleanest transport options.

Cleaner energy sources : transitioning to renewable electricity and combined heat and power systems.

Resource efficiency : minimizing waste through recycling, reuse, and better product management (sustainable packaging and sustainable sourcing).

Closer look at waste management

The sector is subject to significant inefficiencies: approximately one-third of all food produced for human consumption is lost or wasted, amounting to about 1.3 billion tonnes each year (FAO, 2021). On a per capita basis, this translates to an average of 79 kg of food wasted per person per year, equating to over one billion meals wasted daily (Gérard, 2024).

This not only undermines food security but also generates unnecessary emissions, with food loss and waste estimated to account for 8-10% of global GHG emissions, a share that could largely be avoided (UNEP, 2021) (Chiriacò et al., 2022).

Yet, strategies and initiatives to curb food waste are numerous:

International Frameworks

- SDG Target 12.3 aims to halve per capita global food waste by 2030 at retail and consumer levels and reduce supply chain losses (UN, 2025).
- The UNEP Food Waste Index Report monitors global progress and emphasizes public–private partnerships, improved data collection, and policy integration as critical tools (UNEP Food Waste Index Report, 2024).

Business-Led Initiatives

- The 10×20×30 Initiative (under Champions 12.3) brings together 10+ of the world's largest food retailers and providers (Tesco, Sodexo, Ikea, Carrefour, etc.), each engaging at least 20 suppliers to halve food loss and waste by 2030. For instance, IKEA cut waste by 54% in its restaurants, saving USD 37 million and avoiding 36,000 tons CO_2e annually (Goodwin and Lipinski, WRI, 2024).
- Businesses can also join the other 175,000 working with Too Good To Go, a mobile app that allows consumers to collect unsold surplus food. As of 2024, it saved over 450 million meals worldwide, which is equivalent to 1.2 million metric tons of CO_2e (Too Good To Go, Impact Report 2024).

Food Redistribution Networks

- As of 2023, The Farmlink Project in the U.S. had rescued over 200 million pounds of surplus produce and avoided 280,000 metric tons of CO2e (Farmlink, Annual Report 2023).
- Since 2020, the Food Recovery Network has mobilized students across 200 campuses, recovering 20 million meals and avoiding 8,000 metric tons of CO_2e (Food Recovery Network, Annual Report 2024).

Awareness & Policy Measures

- France's Anti-Waste Law bans the destruction of unsold goods, mandates donation and recycling, and promotes circular consumption (Ministère de l'aménagement du territoire et de la décentralisation, Ministère de la transition écologique, de la biodiversité, de la forêt, de la mer et de la pêche, 2024).
- WFP programs enhance post-harvest handling, storage, and market access to reduce waste among smallholder farmers (WFP, 2025).

Closer look at packaging

Reducing packaging plays a crucial role in lowering emissions, both by avoiding those generated during its production and by minimizing the environmental impact linked to its end-of-life. Plastic packaging, in particular, raises significant concerns due to its contribution to greenhouse gas emissions, its harmful effects on biodiversity, and its potential risks to human health. At the same time, packaging also serves an important function in reducing food waste, creating a complex balance between benefits and drawbacks. To explore this issue in depth, Greenly's White Paper on Plastic Decarbonization examines the current state of the plastic market, its future trends, and addresses the central question: can the use of plastics be compatible with Net Zero emissions and broader sustainability goals?

Consumption Patterns

Another way to limit the emissions of the sector is implementing changes in dietary patterns worldwide. Further, a growing body of evidence shows that changes in dietary choices are essential to achieve deep emissions reductions. Diets rich in plant-based proteins and low in meat and dairy are associated with significantly lower GHG emissions (high confidence, IPCC). These mitigation efforts necessarily involve corporate engagement as companies are crucial in promoting dietary changes through awareness campaigns or carbon labelling and through the diversification of their offer towards more plant-based products.

As mentioned earlier, livestock production is highly land-intensive. Producing a kilocalorie or gram of protein from beef or lamb requires 50 to 100 times more land than plant-based sources like tofu or peas. While two thirds of this land is pasture unsuitable for crops (pasture grasslands, steep hills, etc.), repurposing it for natural ecosystems could benefit biodiversity and carbon capture (Hannah Ritchie, 2021).

Studies even indicate that feeding the global population using existing cropland is possible, but only with a major shift toward plant-based diets. Further, in a scenario where the entire global population adopted a vegan diet, researchers estimate that agricultural land use could drop by 75% from 4.1 billion to just 1 billion hectares (less than the current cropland use, sum of human food and animal feed croplands). That's a land area equivalent to the combined size of North America and Brazil. That is because the crops actually used to feed livestock could be transferred to human food crops. Indeed, when producing beef, only 1.9% of energy intake from feed is effectively available in the end product, which makes the process highly inefficient. It is thus far more efficient in terms of land-use to consume cereals directly rather than through animal products (Hannah Ritchie, 2021).

Figure 9 sheds light on the double impact dietary changes have on global GHG emissions. First, the emissions linked to the production of animal-based products are left behind but most importantly carbon could additionally be sequestered in restored vegetation and soils (Hannah Ritchie, 2021).

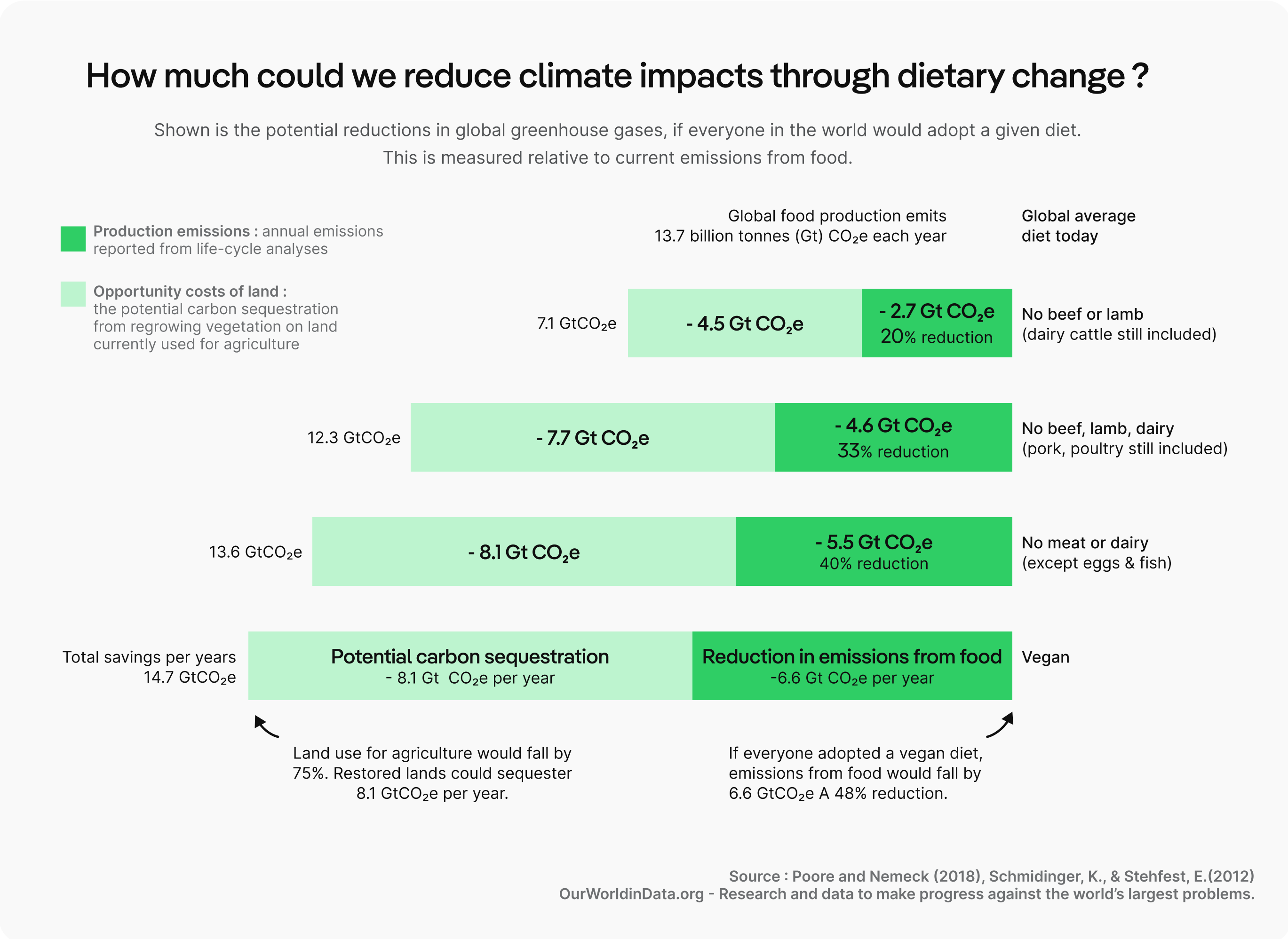


Figure 9 - Global emissions reduction opportunities across dietary shifts

All in all, companies have an important role to play in this transition, both by raising consumer awareness, for example through environmental labeling, public awareness campaigns and by expanding their plant-based product offerings to promote dietary shifts. Further, an interactive tool developed by ADEME can help companies and their consumers visualize the environmental impact of different food choices.

Emerging technologies

In parallel, emerging food technologies are reshaping the sector. Cellular fermentation, cultured meat, plant-based alternatives, and controlled-environment agriculture show strong potential for lowering land, water, and nutrient footprints while improving animal welfare. However, their mitigation potential is closely tied to the use of low-carbon energy, given the relatively high energy intensity of some of these technologies. Similarly, cold-chain and packaging innovations can reduce food waste but must be balanced against their increased energy demand (IPCC, 2022).

Close-up on food innovation: cellular fermentation

For instance, cellular fermentation is a biotechnology process that uses microorganisms (such as yeast, fungi, or bacteria) to produce specific ingredients, like proteins, fats, or enzymes, without the need to raise and slaughter animals (FAO, 2024). Cellular fermentation involves three key steps to produce specific animal-free proteins or fats. First, microorganisms are selected or genetically engineered to carry the DNA blueprint for a target compound, such as casein (found in milk) or myoglobin (found in meat). Next, these modified microbes are cultivated in bioreactors (much like in traditional brewing) where they are fed sugars and nutrients to stimulate production. Finally, once the microbes have generated the desired proteins or fats, these are harvested, purified, and incorporated into food products (FAO, 2023).

Cellular fermentation is being applied to create dairy alternatives, meat substitutes, egg replacements, and functional ingredients such as enzymes, vitamins, and fats for a variety of food uses. Its benefits include a much lower environmental footprint, requiring less land, water, and feed than conventional livestock production. It also enables customizable nutrition, with proteins and fats tailored to specific health or performance needs. Nonetheless, cellular fermentation still faces major challenges, including high energy requirements, production costs that remain above those of traditional methods, regulatory approval processes, and the need to gain wider consumer acceptance (FAO, 2023).

Costs and opportunities

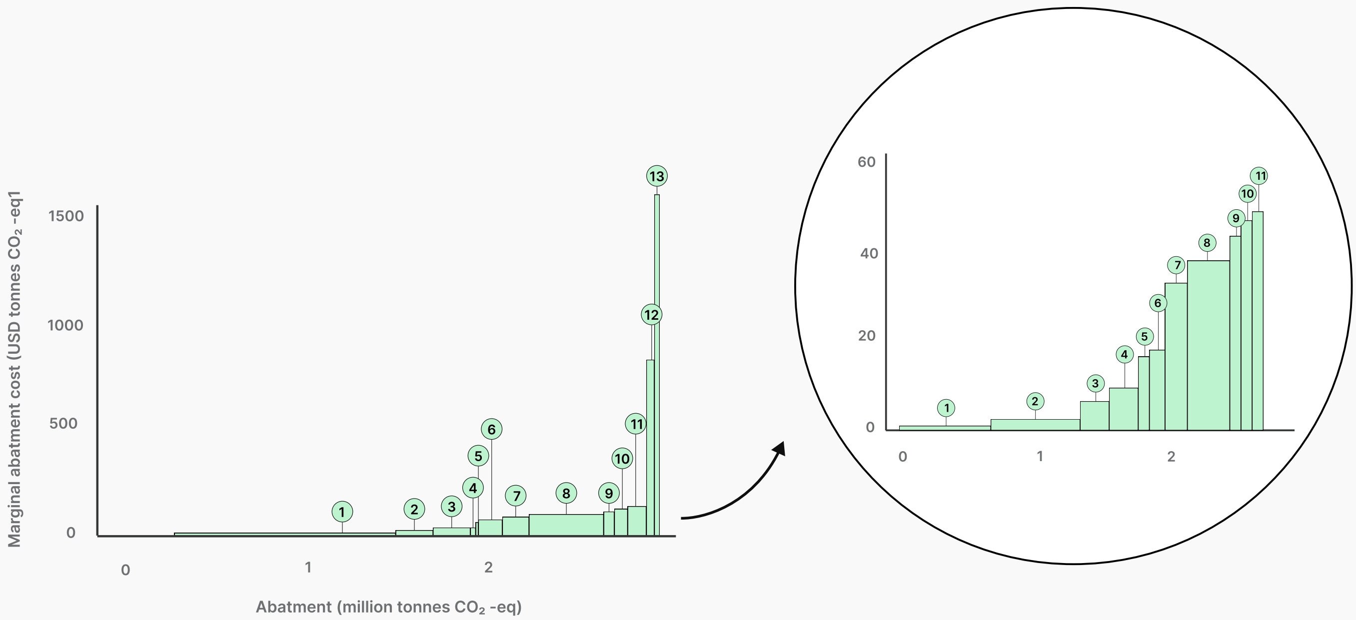
While developing toward sustainability has a cost, transforming global food systems through dietary shifts, greener agricultural practices, and reduced waste, could generate up to USD 10 trillion annually in benefits in terms of better public health, reduced environmental degradation and more equitable access to food (Watts, 2024).

Cost

MACCs (Marginal Abatement Cost Curves) evaluate the cost of reducing one additional unit of greenhouse gas, helping identify the most cost-effective mitigation strategies. The FAO's 2024 working paper refines bottom-up MACCs by linking real investment data to mitigation outcomes with tools like EX-ACT, which informs climate-investment decisions in agriculture. FAO's MACC (Figure 10) shows approximately 3 million tCO_2eq could be captured globally at a total value of nearly 2 million USD, averaging USD 215/tCO_2e (Ilicic et al., 2024).

USD 215/tCO2e

Average abatment cost for GAFSP portfolio



1. Forest management reducing degradation
2. Afforestation
3. Land use change to grassland and management
4. Land use change to agroforestry and management practices
5. Improvements in agroforestry systems
6. Annual cropland manure application
7. Flooded rice improved practices
8. Land use change to cropland and management practices
9. Annual cropland improved soil management
10. Water management
11. Grassland improved degradation state
12. Land use change to flooded rice and improved practices
13. Livestock improved practices

Figure 10 - Marginal abatement cost curves for the Global Agriculture and Food Security Program (GAFSP) portfolio. [Ilicic et al., 2024]

USD 205 billion/year
Such investment could deliver 9 Gt CO_2e/year mitigation by 2030.

USD 38 trillion/year
in climate damages by 2049.

USD 1 trillion per year
the estimated global cost of food loss and waste.

8.23%
CAGR of the global alternative protein market between 2025 and 2034

Return on investment for sustainability across the food system : Achieving these gains will require substantial investment: reports indicate that allocating up to USD 205 billion per year between 2025 and 2030 could deliver as much as 9 gigatons of CO_2-equivalent mitigation annually by 2030. While this represents less than 2% of projected food sector revenues, it could yield additional returns of up to USD 190 billion annually and savings of around USD 30 billion per year through on-farm solutions. However, the financial burden is unevenly distributed, falling most heavily on farmers, those least able to absorb these costs, highlighting the need for companies to work with policymakers and financial institutions to share risks and support value chain partners (Nilsson, Food and Land Use Coalition, 2024). Failure to act decisively on emissions now risks leaving today's younger generations with a staggering bill of up to USD 535 trillion, the estimated cost of deploying large-scale "negative emissions" technologies needed to remove CO_2 from the atmosphere and avert dangerous climate change (Dyke, 2017).

Prevent economic losses caused by climate change : From another point of view, mitigation is essential to avoiding the immense future costs that climate change is projected to impose. A comprehensive Nature study estimates that climate-related damages could reach USD 38 trillion annually by 2049, an amount exceeding the GDP of major economic blocs such as the European Union (Hart, Forbes, 2024). Looking at the Food & Beverages sector in the EU, it already suffers €28.3 billion in annual losses from climate-driven extreme weather, representing roughly 6% of total agricultural output. Droughts account for more than half of these losses, and without effective adaptation measures, crop damages could rise by 66% by 2050 (Abnett, Reuters, 2025).

Reducing food waste : According to the UNFCCC, global food loss and waste amount to an estimated USD 1 trillion in annual costs. Reducing food waste plays a crucial role not only in lowering the sector's environmental footprint but also in generating significant economic savings (UNFCCC).

The alternative proteins market : The global alternative protein market (plant-based proteins, insect protein, cultivated (lab-grown) meats and precision fermentation) was valued at USD 16.65 billion in 2024 and is projected to reach USD 36.37 billion by 2034, growing at a compound annual growth rate (CAGR) of 8.23% between 2025 and 2034 (Precedence Research, 2025). This expanding sector thus represents a significant source of future job creation. North America currently leads the market, while Asia-Pacific is the fastest-growing region (Grand View Research).

Leveraging renewable energy

Agri-food systems account for nearly 30% of global energy use, contributing around a third of their total GHG emissions (FAO, 2025), making energy decarbonization a critical element of sectorial transformation (IRENA, FAO, 2021). Initiatives led by IRENA and FAO are promoting the adoption of renewable energy technologies, such as solar-powered irrigation, to improve energy access, reduce losses, increase productivity, and support climate adaptation and mitigation across food systems (IRENA, FAO, 2021). Agrivoltaic systems, which integrate crop cultivation with solar photovoltaic panels, have demonstrated the potential to increase farm value by 30% (Dinesh and Pearce, 2016), while reducing greenhouse gas emissions by 69.3% and fossil energy consumption by 82.9% compared to conventional, separate systems (Pascaris et al., 2021).

30%

of global energy use come from agri-food systems

USD 3.2 million

investment in Brazil, supporting urban and peri-urban agriculture.

True Cost Accounting

Beyond direct abatement costs and the listed economic opportunities, True Cost Accounting (TCA) captures hidden externalities such as environmental degradation, health impacts, and social consequences of food production (FAO, 2023). A notable example is the TEEBAgriFood framework, jointly developed by UNEP and FAO, which provides a structured approach to valuing these impacts and supporting more holistic decision-making in agrifood systems. By economically recognizing nature's contributions, often overlooked in market prices, this framework has begun to transform agricultural and food policies. Implemented in 14 countries, TEEBAgriFood has already had tangible impacts: in Indonesia, it informed the inclusion of agroforestry in the national development plan; in India, it was integrated into the undergraduate Natural Farming syllabus across 51 state universities; and in Brazil, its advocacy for urban and peri-urban agriculture contributed to a presidential decree and a $3.2 million investment. By giving nature a seat at the table, TEEBAgriFood supports biodiversity policy mainstreaming aligned with the Convention on Biological Diversity (CBD) and the Post-2020 Global Biodiversity Framework, highlighting how valuing nature's hidden contributions can reshape food systems and advance both national priorities and global commitments (UNEP). Similarly, FAO's State of Food and Agriculture 2023 report calls on governments and the private sector to integrate true cost accounting into regular assessments of agrifood systems, in order to address the interlinked challenges of climate change, poverty, inequality, and food insecurity. Scaling up TCA, however, will require innovations in research and data, as well as sustained investments in data collection and capacity building, to ensure decision-making is both transparent and consistent (FAO, 2023).

Ultimately, although investments in sustainability involve upfront costs, TCA highlights their economic potential when the value of ecosystem services is considered.

Common barriers faced

Despite these opportunities, the agrifood industry still faces significant barriers to implementing sustainability actions.

First, there are the complex and opaque supply chains that build the industry. These extensive networks, spanning numerous countries and suppliers, make it difficult for companies to measure, monitor and control Scope 3 emissions. For instance, following the horsemeat scandal in Europe, one buyer for a major retailer reported having over 1,000 suppliers for a single lasagna line (Webb, 2018).

In addition, a substantial portion of these emissions originates directly from agricultural activities necessitating a fundamental and challenging shift in farming practices. For instance, methane emissions from livestock are particularly hard-to-abate. Currently, there is no scalable technology today that provides robust and consistent reductions in enteric methane emissions from the wide array of farm systems that exist in the world. We cannot ask farmers to lower methane emissions without providing them effective, safe, and profitable solutions. Studies of feed additive supplementation in cattle that span months, even years, are needed to confirm the persistence of methane reduction and animal safety. Diet, environment, management, animal genetics, and their microbiome are expected to uniquely influence the degree of methane reduction for feed additives. However, we have a limited understanding of how these factors impact the short and long-term efficacy of feed additives to inhibit methane production by cows (McFadden, 2023).

This complexity is compounded by a fragmented and divergent regulatory landscape; operating globally means companies must navigate a contradictory patchwork of national and regional rules on everything from pesticides to deforestation, increasing administrative burdens and discouraging unified sustainability strategies.

Finally, prohibitive costs present a major hurdle, as transitioning to sustainable methods requires significant upfront capital investment, approximated to $300-350 billion of investment per year until 2030, a tough proposition in a low-margin industry (WEF, 2023). The challenge is exacerbated by an economic model that fails to account for negative environmental externalities, keeping unsustainable products artificially cheap while sustainable alternatives carry a "green premium". A report by Kearney highlights this challenge, indicating that the average price of “green” fresh and processed foods can be 30 to 140% higher than regular products (Kearney.com, 2020). In one recent survey 65% said they want to buy purpose-driven brands that advocate sustainability, yet only about 26% actually do so, a phenomenon known as the "intention-action gap." (Harvard Business Review, 2019).

Danone: a leader of the sector with an ambitious decarbonization plan

Danone, a French multinational in the food industry producing dairy products, bottled water, and infant and medical nutrition, is pursuing an ambitious climate strategy aimed at achieving net-zero GHG emissions by 2050. Its objectives, set out in the company's Climate Transition Plan (Danone, 2023), have been validated by the Science Based Targets Initiative (SBTi Target Dashboard, August 2025). In 2024, Danone reported a 16.1% decrease in GHG emissions compared to 2020 and increased the share of renewable electricity used in its factories from 70.1% to 85.7% (Danone, 2024 Universal Registration Document).

The Climate Transition Plan outlines a number of strategic programs, notably regenerative agriculture, packaging transformation, and supplier engagement (Danone, 2023). A key commitment is a 30% reduction in methane emissions from fresh milk by 2030, aligning with the Global Methane Pledge (Le Monde/AFP, 2023). In 2024, Danone reported that 39% of its key ingredients were sourced from farms transitioning to regenerative agriculture (Danone, 2024 Committee Report). On packaging, the company has achieved an 8% reduction in virgin fossil-based plastics since 2020 (Danone, 2024 Annual Integrated Report). Meanwhile, through its "Battle Against Waste" program, Danone claims an 18.1% reduction in food waste per metric ton of product sold since 2020, working in partnership with suppliers, customers, and external stakeholders (Danone, 2024 Annual Integrated Report).

These achievements reflect Danone's proactive stance, but they also highlight the challenges of corporate sustainability reporting. Many figures remain company self-disclosures, which raises concerns about transparency, the scope of measurement, and the effectiveness of certain policies, such as Danone's Forest Policy and the implementation of its 4R approach (reduce, reuse, recycle, reclaim). This underlines the importance of grounding sustainability strategies in clear definitions, measurable outcomes, and recognized external standards and labels, to avoid the risk of vague or overstated claims.

Danone's experience also sheds light on the complex balance between sustainability and financial performance. The ousting of former CEO Emmanuel Faber in March 2021 sparked debate on whether a multinational can pursue an ambitious ESG agenda without alienating shareholders. According to Professor Christophe Thibierge, the decision was not driven by ESG concerns but by Danone's comparatively weak financial results. Using a risk-return-sustainability framework, he shows that while Danone enjoyed an AAA ESG rating, its profitability lagged behind peers such as Nestlé and Unilever. The case suggests that ESG and profitability are not incompatible, but that investors expect companies to deliver on both dimensions simultaneously (Thibierge, 2021).

How do decarbonization options favor or hinder climate change adaptation?

Many mitigation pathways can deliver "win-wins" for adaptation if designed with local ecosystems and communities in mind. Conversely, land-hungry carbon strategies (indiscriminate BECCS expansion, river-fragmenting dams, uniform tree plantations) risk trading short-term carbon gains for long-term vulnerability. The IPCC emphasizes integrated planning that weighs land, water, biodiversity, and social outcomes to avoid maladaptation while delivering durable emissions cuts (IPCC, 2022).

When Decarbonization Boosts Adaptation

Protecting, restoring, and managing ecosystems (such as forests with afforestation and reforestation) not only absorbs CO_2 from the atmosphere but also strengthen resilience to climate extremes. Vegetation cover further reduces soil erosion compared with bare land, preserving agricultural productivity and preventing desertification (Nunes et al., 2023). In addition, tree shade and evapotranspiration can lower local temperatures, creating microclimates that offer relief during extreme heat events (Mutani and Todeschi, 2020). Finally, restored forests also provide habitat corridors that support biodiversity and species migration, enhancing overall ecosystem resilience (Wang et al. 2021).

Similarly, renewable energy and decentralized grids can provide adaptation benefits while reducing emissions. Microgrids powered by renewables (solar PV, wind) can operate independently when centralized grids fail (He et al. 2025). Moreover, integrating rooftop solar panels with green roofs can lower surface temperatures, reducing building cooling needs and mitigating urban heat island effects (Simon, 2023). By diversifying energy sources, decentralized systems also reduce vulnerability to single-point failures common in centralized grids (Sustainability Directory, 2025).

Sustainable agriculture practices such as conservation tillage, agroforestry, and improved soil management offer the dual benefit of sequestering carbon while strengthening the resilience of farming systems. Conservation tillage helps preserve soil structure, enhance organic matter, and improve water retention, thereby increasing drought resilience (Srivastava, 2025). Agroforestry contributes by improving soil structure, preventing erosion, and boosting organic content, which in turn enhances agricultural productivity (Nandi et al., 2025). More broadly, conservation agriculture has been shown to deliver an average 21% improvement in soil health while maintaining comparable crop yields even under warming conditions (Teng et al., 2024). Together, these approaches enhance both environmental and economic resilience, positioning sustainable agriculture as a key lever for climate adaptation and mitigation.

+21% soil health

via conservation agriculture.

When Decarbonization Creates New Risks

However, not all decarbonization pathways are automatically compatible with adaptation goals. In some cases, strategies may create trade-offs or even undermine resilience, a challenge known as maladaptation.

One example is large-scale bioenergy with carbon capture and storage (BECCS). While BECCS aims to remove CO_2 from the atmosphere by burning biomass and capturing the emissions, large-scale deployment would displace cropland and threaten food security. In addition, expanding bioenergy crops often drives conversion of natural ecosystems, causing biodiversity loss and potentially releasing stored carbon (Braun et al., 2025).

Large hydropower projects present another case where mitigation may come at an adaptation cost. While they generate low-carbon electricity, dams disrupt sediment flows and damage riverine ecosystems and fisheries, with collapses in migratory fish populations documented in the Mekong and Amazon basins (Winemiller et al., 2016). By the end of the 20th century, between 40 and 80 million people were physically displaced due to the construction of large dams (WCD, 2000). Furthermore, intensifying rainfall events under climate change increase the risk of dam failure, raising serious safety concerns (Hwang and Lall, 2024).

Finally, afforestation with monocultures (planting vast areas with a single tree species) can sequester carbon efficiently in the short term but undermines resilience in the long term. Such forests are highly susceptible to pests, diseases, droughts, and fires (Messier et al., 2022).

40–80 million

people displaced by large dam construction, highlighting the adaptation trade-offs of hydropower.

All in all, while decarbonization is essential to limit the extent of future climate change, the way we decarbonize matters. Integrating adaptation considerations into decarbonization planning is crucial to avoid unintended negative consequences and to create a more resilient and sustainable future. This means prioritizing solutions that offer both mitigation and adaptation benefits, while carefully managing the trade-offs of other options.

Impact of decarbonization options on wider issues such as malnutrition and hunger

At first sight, one might agree that decarbonization efforts seem to have positive impacts on global nutrition issues. Indeed, limiting climate change protects yields & food security. The IPCC finds that cutting emissions reduces climate risks that already threaten food security (heat, drought, extremes) (IPCC, 2022). Likewise, in agriculture, rice methane mitigation (AWD) cuts GHGs with little/no yield penalty (Loaiza et al., 2024). Clean, reliable energy improves cold chains: FAO/UNEP estimate that strengthening sustainable food cold chains in developing countries could save up to 144 million tonnes of food annually. Cleaner cooling plus efficiency thus fights both waste and emissions.

However, when badly thought through, decarbonization efforts can threaten food security.

Large-scale land-based carbon removals (BECCS/afforestation) and first generation biofuels can compete with cropland. IPCC highlights risks to food prices and access if carbon projects occupy fertile land; safeguards and prioritising degraded lands are essential.

Agricultural climate policies can affect food prices in uneven ways. Research from the Potsdam Institute for Climate Impact Research (PIK) shows that in high-income countries, most of the retail food price comes from processing, retail, marketing, and transport. This structure shields consumers from fluctuations in farm-gate prices resulting from climate measures, such as pollution taxes or limits on land expansion. By 2050, consumer food prices in these countries are projected to be only 1.25 times higher under climate policies, even if producer prices increase by a factor of 2.73. In contrast, in low-income countries, where farming costs represent a larger share of final food prices, ambitious climate policies could lead to a 2.45-fold increase in consumer prices and a 3.3-fold increase in producer prices by 2050. This underscores the need for climate policy design that incorporates mechanisms to support both producers and consumers in the transition, including fair carbon pricing, targeted financial assistance for vulnerable regions and groups, and investments in sustainable agricultural practices. (Chen et al. 2025).

Well-designed carbon pricing can help achieve sustainability goals without raising food costs. Revenue recycling, subsidies and rebates, community-based initiatives, environmental justice assessments are some ideas of strategies that ensure equity. However, if poorly designed, it can disproportionately burden low-income and vulnerable populations, as higher prices for carbon-intensive goods and services, such as energy and transport, consume a larger share of their income. This regressive effect risks deepening existing inequalities, making equitable policy design essential (Habib et al., 2024).

Part 3 : Regulatory Trends

The sector is governed by a range of regulations and frameworks which, depending on their scope and level of maturity, hold significant potential to drive emissions mitigation.

Carbon Labeling

In Europe, consumer appetite for transparency is rising sharply: 58% consider climate impact an important factor, 76% support carbon footprint labels on food and beverages, and 80% say they would pay roughly 9.7% more for sustainable products. In response, brands are already taking action, Oatly (Sweden) lists climate-impact data on UK packaging, Just Salad (U.S.) adds carbon footprints to menu items and AEON supermarket (Japan) trials carbon footprint labeling. However, the absence of a unified method for calculating emissions means labels vary widely undermining comparability and credibility. This gap is likely to narrow as interest grow and regulations are put in place. EU initiatives, such as the European Commission's Sustainable Food Systems framework, the Corporate Sustainability Reporting Directive (CSRD), the Deforestation-Free Products Regulation (EUDR), and the Green Claims Directive and the EU Ecolabel, push companies toward standardized carbon labeling and robust supply-chain traceability (Farrelly Mitchell, 2024). The EU, through the Directive on Empowering Consumers for the Green Transition (ECGT), is also cracking down on misleading claims like “eco” or “climate neutral,” making them valid only with verified evidence. However, there is still no international consensus on the matter.

Extended Producer Responsibility (EPR) for Packaging

Extended Producer Responsibility (EPR) is an environmental policy approach that makes producers financially and/or operationally responsible for the end-of-life management of the products and packaging they place on the market. In Europe, the Packaging and Packaging Waste Regulation (PPWR 2025/40) aims to prevent and reduce packaging waste, require all new packaging to be recyclable by 2030, and mandate minimum recycled content. In the United Kingdom, a new EPR scheme shifts the responsibility and costs of managing packaging waste from local councils to producers, with fees determined by packaging weight and recyclability; the scheme administrator, PackUK, began operations in January 2025. In the United States, there is no federal EPR mandate for packaging, but several states, including California, Maine, Oregon, and Colorado, have enacted packaging EPR laws. South Africa has made EPR mandatory since 2021 under the National Environmental Management Waste Act (NEMWA). Other countries have similar EPR regulations but no international agreement has yet been established.

Food Waste Reduction Mandates

France's Anti-Waste and Circular Economy Law (AGEC), enacted in February 2020, targets waste reduction through measures such as banning the incineration of unsold food, requiring its donation or repurposing, encouraging reuse, and prohibiting single-use plastics in food services for on-site consumption, with the broader goal of phasing out single-use plastic packaging entirely by 2040. In the United States, the Environmental Protection Agency's Wasted Food Scale guides efforts to prevent and divert food waste from disposal, prioritizing actions that maximize environmental, social, and economic benefits.

Environmental Product Declaration (EPD)

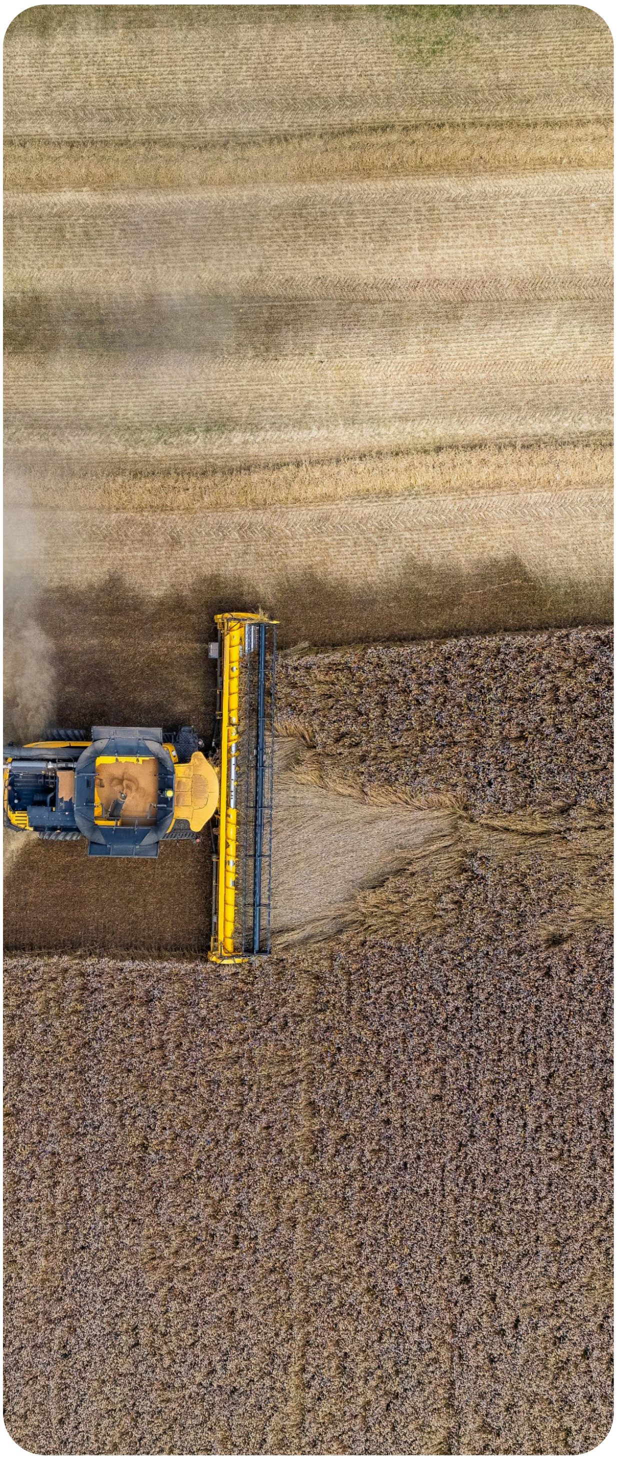
An EPD is a standardized, third-party-verified document that communicates the quantified environmental impacts of a product over its life cycle. It's essentially a "nutrition label" for sustainability, based on Life Cycle Assessment (LCA) data and prepared according to international standards. To date, manufacturers are not obliged (mandatory by law) to provide EPDs. But, the market increasingly regulates the use of EPDs in various applications itself.

Conclusion : The Imperative of Sustainability in Food & Beverage

The imperative for decarbonization within the food and beverage industry is multifaceted and urgent. Beyond the immediate environmental necessity of mitigating climate change, it is increasingly becoming a strategic business imperative. A proactive approach to reducing emissions not only contributes to global climate goals but also safeguards long-term operational viability by building resilience against climate impacts and resource scarcity.

The food and beverage sector is a significant contributor to global greenhouse gas (GHG) emissions, accounting for approximately one-quarter to one-third of total global emissions.
These emissions stem from various stages of the food system, mainly land-use change, agricultural production. The prevalence of Scope 3 emissions is a major concern for food companies, as a substantial portion of their carbon footprint originates upstream in their supply chains. Key decarbonization trends are emerging across agricultural-stage mitigation, post-farm gate innovations, consumption patterns, and emerging technologies. Strategies such as enhancing carbon sequestration in soils, optimizing nutrient use, improving productivity, sustainable use of agricultural outputs, and adopting low-carbon energy sources are crucial at the farm level. Beyond the farm, efforts include energy efficiency in processing and distribution, adoption of cleaner energy sources, and resource efficiency through waste minimization and sustainable packaging. Furthermore, shifting consumption patterns towards plant-based diets offers substantial potential for emission reductions.

In an era where environmental responsibility is no longer optional but expected, decarbonization is critical for the food and beverage industry's future success, ensuring its pivotal role in feeding a growing global population while safeguarding the planet.



Bibliography

- Abnett, Kate. "Extreme Weather Costs EU Farmers 28 Billion Euros a Year, EU Says." Reuters, May 20, 2025, sec. COP29.
- "Alternative Protein Market Size & Outlook, 2030." Accessed August 13, 2025.
- "Alternative Protein Market Size to Attain USD 36.37 Bn by 2034," July 16, 2025.
- Braun, Johanna, Constanze Werner, Dieter Gerten, Fabian Stenzel, Sibyll Schaphoff, and Wolfgang Lucht. "Multiple Planetary Boundaries Preclude Biomass Crops for Carbon Capture and Storage Outside of Agricultural Areas." Communications Earth & Environment 6, no. 1 (February 12, 2025): 102.
- Cardinael, Rémi, Armwell Shumba, and Vira Leng. "Piéger Le Carbone Dans Le Sol : Ce Que Peut l'agriculture," November 2, 2023.
- "Cell-Based Food and Precision Fermentation – Products, Safety and the Future Role." FAO, April 16, 2024.
- Chen, David Meng-Chuen, Benjamin Bodirsky, Xiaoxi Wang, Jiaqi Xuan, Jan Philipp Dietrich, Alexander Popp, and Hermann Lotze-Campen. "Future Food Prices Will Become Less Sensitive to Agricultural Market Prices and Mitigation Costs." Nature Food 6, no. 1 (January 3, 2025): 85–96.
- Chiriacò, Maria Vincenza, Simona Castaldi, and Riccardo Valentini. "Determining Organic versus Conventional Food Emissions to Foster the Transition to Sustainable Food Systems and Diets: Insights from a Systematic Review." Journal of Cleaner Production 380 (2022): 134937.
- CIRAD. "4 Pour 1000 | Les Sols Pour La Sécurité Alimentaire et Le Climat." Youtube, 2015.
- Clark, Michael, Marco Springmann, Mike Rayner, Peter Scarborough, Jason Hill, David Tilman, Jennie I. Macdiarmid, Jessica Fanzo, Lauren Bandy, and Richard A. Harrington. "Estimating the Environmental Impacts of 57,000 Food Products." Proceedings of the National Academy of Sciences 119, no. 33 (August 16, 2022): e2120584119.
- Crippa, M., E. Solazzo, D. Guizzardi, F. Monforti-Ferrario, F. N. Tubiello, and A. Leip. "Food Systems Are Responsible for a Third of Global Anthropogenic GHG Emissions." Nature Food 2, no. 3 (March 8, 2021): 198–209.
- Danone, "2024 Integrated Annual Report"
- Danone, "2024 Danone Missions Committee Report"
- Danone, "Danone Climate Transition Plan 2023"
- Danone, "2024 Universal registration document"
- Davis, B., Mane, E., Gurbuzer, L.Y., Caivano, G., Piedrahita, N., Schneider, K., Azhar, N., et al. Estimating Global and Country-Level Employment in Agrifood Systems. Vol. 23–34. FAO Statistics Working Paper. Rome: FAO, 2023.
- "Deforestation Linked to Agriculture | Global Forest Review." Accessed August 13, 2025.
- Dinesh, Harshavardhan, and Joshua M. Pearce. "The Potential of Agrivoltaic Systems." Renewable and Sustainable Energy Reviews 54 (2016): 299–308.
- Dyke, James. "Inaction on Climate Change Risks Leaving Future Generations $530 Trillion in Debt." The Conversation, July 18, 2017.
- Energy. "Facts and Figures | Energy | Food and Agriculture Organization of the United Nations." Accessed August 25, 2025.
- FAO. "Hidden Costs of Global Agrifood Systems Worth at Least $10 Trillion," November 6, 2023.
- "Food and Beverage – World Business Center." Accessed August 13, 2025

- “Food, Nature and Health Transitions – Repeatable Country Models.” WEF, BCG, 2023.
- Food Recovery Network. “Annual Report FY24.” Accessed August 13, 2025.
- Garnett, Tara. “Where Are the Best Opportunities for Reducing Greenhouse Gas Emissions in the Food System (Including the Food Chain)?” Food Policy 36 (2011): S23–32.
- Gérard, Mathilde. “One Billion Meals Thrown out Every Day: ‘Food Waste Exacerbates the Climate Crisis,’” March 30, 2024.
- Glasson, Christopher R.K., Robert D. Kinley, Rocky De Nys, Nick King, Serean L. Adams, Michael A. Packer, Johan Svenson, Charles T. Eason, and Marie Magnusson. “Benefits and Risks of Including the Bromoform Containing Seaweed Asparagopsis in Feed for the Reduction of Methane Production from Ruminants.” Algal Research 64 (2022): 102673.
- “Global Demand for Meat and Dairy Set to Rise, but Climate and Nutrition Gaps Remain | The United Nations Office at Geneva,” July 15, 2025.
- Goodwin, Liz, and Brian Lipinski. “How Much Food Does the World Really Waste? What We Know — and What We Don’t,” November 25, 2024.
- Goss, Megan A., and James Sherwood. “An Absolute Environmental Sustainability Assessment of Food.” Food Frontiers 5, no. 3 (2024): 855–66.
- Habib, Mehvish, Sakshi Singh, Yograj Bist, Yogesh Kumar, Kulsum Jan, Khalid Bashir, Shumaila Jan, and D.C. Saxena. “Carbon Pricing and the Food System: Implications for Sustainability and Equity.” Trends in Food Science & Technology 150 (2024): 104577.
- Hart, Robert. “Climate Change Will Cost Global Economy $38 Trillion Every Year Within 25 Years, Scientists Warn.” Forbes, April 17, 2024.
- Harvard Business Review. “The Elusive Green Consumer.” July 1, 2019.
- He, Jian-Hua, and Jhih-Hao Lin. “Review of Microgrids to Enhance Power System Resilience.” In 2024 IEEE 6th Eurasia Conference on IoT, Communication and Engineering, 82. MDPI, 2025. .
- “Https://Cdn.Prod.Website-Files.Com/5ffe29e15f6569d732bec2b3/67094a352c37ec199fe,” n.d.
- “Https://Cdn.Sanity.Io/Files/Nqimd3nr/Production/29eae5a1b44b8bd12471757a9d81ed7,” n.d.
- “Https://Www.Ilo.Org/International-Programme-Elimination-Child-Labour-Ipec/Secto,” n.d.
- Hwang, Jeongwoo, and Upmanu Lall. “Increasing Dam Failure Risk in the USA Due to Compound Rainfall Clusters as Climate Changes.” Npj Natural Hazards 1, no. 1 (October 10, 2024): 27.
- Ilicic, Joanna, Lorenzo Maestripieri, Greta Dobrovich, Adriana M. Ignaciuk, and Alma Rottem. Making Public Investments Paris Agreement-Aligned in a Cost-Effective Way: Calculating Marginal Abatement Cost Curves for Agricultural Investments. FAO Agricultural Development Economics Working Paper 24, 02. Rome: Food and Agriculture Organization of the United Nations, 2024.
- INRA. “Stocker Du Carbone Dans Les Sols Français.” INRA, November 2019.
- Pascaris, Alexis S., Rob Handler, Chelsea Schelly, and Joshua M. Pearce. “Life Cycle Assessment of Pasture-Based Agrivoltaic Systems: Emissions and Energy Use of Integrated Rabbit Production.” Cleaner and Responsible Consumption 3 (2021): 100030.
- Paukner, Michaela. “Here Are 613 Food Companies Committed to Emissions Goals.” Cover Crop Strategies, January 30, 2024
- Poore, J., and T. Nemecek. “Reducing Food’s Environmental Impacts through Producers and Consumers.” Science 360, no. 6392 (2018): 987–92.
- Renewable Energy and Agri-Food Systems: Advancing Energy and Food Security towards Sustainable Development Goals. IRENA and FAO, 2021.
- Ritchie, Hannah. “Drivers of Deforestation.” Our World in Data, February 4, 2021.
- Ritchie, Hannah. “Food Production Is Responsible for One-Quarter of the World’s Greenhouse Gas Emissions.” Our World in Data, November 6, 2019.
- Ritchie, Hannah. “If the World Adopted a Plant-Based Diet, We Would Reduce Global Agricultural Land Use from 4 to 1 Billion Hectares.” Our World in Data, March 4, 2021.
- ———. “How Much of Global Greenhouse Gas Emissions Come from Food?” Our World in Data, March 18, 2021.

- ———. “What Are the Carbon Opportunity Costs of Our Food?” Our World in Data, March 19, 2021.
- Ritchie, Hannah, Pablo Rosado, and Max Roser. “Environmental Impacts of Food Production.” Our World in Data, December 2, 2022.
- Savage, Susannah, and Alan Smith. “Extreme Weather Drives Food Price Surges across the Globe.” Financial Times, July 20, 2025.
- Science Based Targets Initiative. “Target Dashboard - Science Based Targets.” Accessed August 25, 2025.
- SHIFT project. “Pour Une Agriculture Bas Carbone, Résiliente et Prospère,” November 2024.
- Shumba, Armwell, Rémi Cardinael, and Vira Leng. “Piéger Le Carbone Dans Le Sol : Ce Que Peut l’agriculture.” The Conversation, November 2, 2023.
- Simon, Matt. “The Ultra-Efficient Farm of the Future Is in the Sky.” Wired. Accessed August 26, 2025.
- Srivastava, Rajiv Kumar. “Conservation Tillage Practices on GHG Emissions, Soil Health and Overall Agricultural Sustainability.” Soil Use and Management 41, no. 2 (2025): e70096. https://doi.org/10.1111/sum.70096.
- “STATISTICAL YEARBOOK WORLD FOOD AND AGRICULTURE 2024.” Accessed August 5, 2025.
- Sustainability Directory. “How Does Decentralized Energy Reduce Vulnerability? → Question.” Energy → Sustainability Directory (blog), March 17, 2025.
- Teng, Jialing, Ruixing Hou, Jennifer A. J. Dungait, Guiyao Zhou, Yakov Kuzyakov, Jingbo Zhang, Jing Tian, Zhenling Cui, Fusuo Zhang, and Manuel Delgado-Baquerizo. “Conservation Agriculture Improves Soil Health and Sustains Crop Yields after Long-Term Warming.” Nature Communications 15, no. 1 (October 10, 2024): 8785.
- “THE 17 GOALS | Sustainable Development.” Accessed August 13, 2025.
- Thibierge, Christophe. “‘The Case of Danone Does Not Show That ESG and Profitability Concerns Are Incompatible.’” The Choice by ESCP (blog), October 12, 2021.
- The State of Food and Agriculture 2023. FAO, 2023.
- Walmart Sustainability, “Zero emissions White Paper” Accessed August 5, 2025.
- Wang, Lin, Guopeng Ren, Fangyuan Hua, Stephen S. Young, Wei Wang, Chunyan Yang, and Jianguo Zhu. “Integrating Habitat Availability into Restoration Efforts for Biodiversity Conservation: Evaluating Effectiveness and Setting Priorities.” Biological Conservation 257 (2021): 109127.
- Watts, Jonathan, and Jonathan Watts Global environment editor. “Move to Sustainable Food Systems Could Bring $10tn Benefits a Year, Study Finds.” The Guardian, January 29, 2024, sec. Environment.
- Webb, Jonathan. “How Many Suppliers Do Businesses Have? How Many Should They Have?” Forbes. Accessed August 26, 2025.
- Winemiller, K. O., P. B. McIntyre, L. Castello, E. Fluet-Chouinard, T. Giarrizzo, S. Nam, I. G. Baird, et al. “Balancing Hydropower and Biodiversity in the Amazon, Congo, and Mekong.” Science 351, no. 6269 (January 8, 2016): 128–29.
- WFP, “Strategic Plan”
- Xu, Xiaoming, Prateek Sharma, Shijie Shu, Tzu-Shun Lin, Philippe Ciais, Francesco N. Tubiello, Pete Smith, Nelson Campbell, and Atul K. Jain. “Global Greenhouse Gas Emissions from Animal-Based Foods Are Twice Those of Plant-Based Foods.” Nature Food 2, no. 9 (September 13, 2021): 724–32.
- Youtube. “Cell-Based Food Production and Food Safety - Food and Agriculture Organization of the United Nations,” March 15, 2023.

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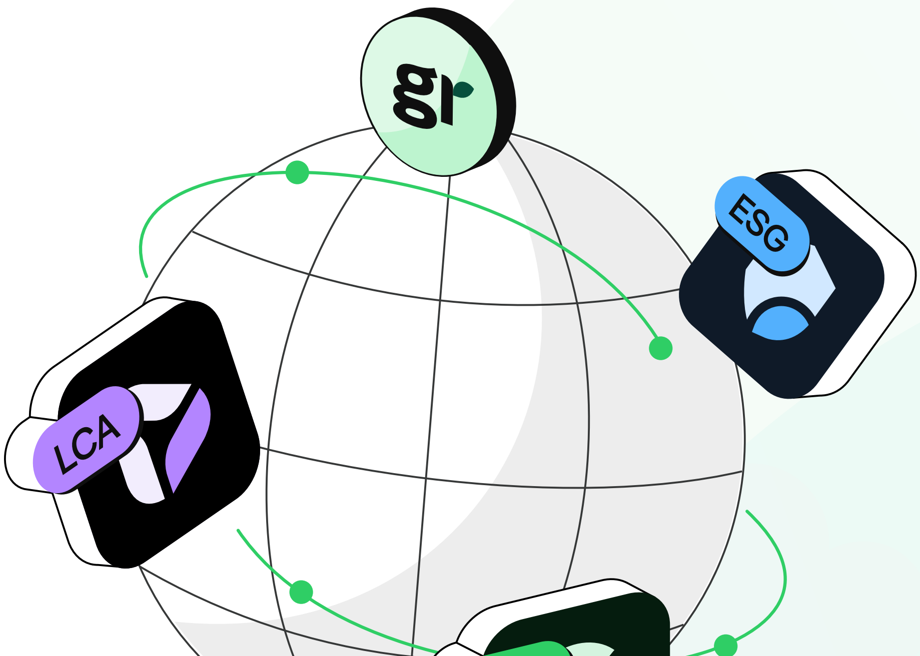
About Greenly

Greenly was founded with a simple mission: to make carbon accounting simple, precise, and intuitive for every company. Today, Greenly is a top-rated, industry-leading solution for carbon accounting and sustainability management, trusted by over 3,500 companies worldwide. Our platform is the highest-rated in its category, with a 4.8/5 satisfaction score on G2, Trustpilot, and Capterra.

We combine a powerful, AI-driven technology platform with the deep knowledge of over 60+ in-house climate experts to deliver an unparalleled service. Our comprehensive suite provides 360-degree coverage for every climate need, including GHG & Decarbonization Management, Life Cycle Assessment (LCA), and ESG Reporting.

At Greenly, we are not just building a compliance tool; we are building a new category of Carbon Intelligence to turn historical data into a management system for the future. We are dedicated to democratizing climate intelligence and making sustainability accessible, so every organization can take part in building the Net Zero economy.

Get Started



Just like 3500 companies, they have entrusted Greenly with their Carbon Footprint

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Website: www.greenly.earth
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EcoPilot: The New Era of Impact

Transforming Sustainability Strategy
with Greenly EcoPilot

The old world

- Data Chaos
- Scope 3 Blind Spots
- Compliance Pressure
- Static Reports
- Analysis Paralysis

The New World: Greenly's Vision for Carbon Intelligence

Carbon Intelligence turns historical data into a dynamic management system for the future, enabling ambitious teams to move from reporting to action at unprecedented speed. Imagine working on sustainability in a platform that feels less like a software and more like a conversation with a climate expert who learns from your company, your industry, and your goals. EcoPilot is the technological engine that makes Greenly the industry's smartest sustainability strategist: it combines the precision of experts with the speed of AI, delivering more results and greater value for your company, within the same budget.

Greenly EcoPilot

Core Capabilities: From Tedious Tasks to Strategic Impact

Sustainability as a Conversation, Not a Chore

The old world of sustainability software is defined by rigid menus, complex formulas, and endless clicking. EcoPilot introduces a new, conversational paradigm. [Visual: A conversational chat interface within the Greenly platform.]

Automated Data Processing with Dynamic Guidance

Data collection is the most time-consuming part of cqarbon accounting. Previously, users had to spend hours forcing messy company files into rigid templates.

Scaled Supplier Engagement for Clearer Scope 3

Addressing Scope 3 emissions requires engaging hundreds or thousands of suppliers, a task that has historically been manual and plagued by low response rates.

Instant Decarbonization Roadmaps

A carbon footprint is a diagnosis, not a cure. The real value lies in creating a clear, actionable plan to reduce emissions.

Accelerated Life Cycle Assessments (LCA)

For companies with hundreds or thousands of products, conducting LCAs has been a prohibitively slow and expensive process, taking months of manual work.

Fluid, Interoperable Reporting

Sustainability teams waste countless hours repurposing the same data for different reporting frameworks and stakeholders.

Audit-to-Action Insights

Static dashboards are useful for monitoring but often fail to answer specific strategic questions.

To learn more, read our EcoPilot Guide
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