FUEL TO FORK

What will it take to get fossil fuels out of our food systems?

iPES FOOD
INTERNATIONAL PANEL OF EXPERTS ON SUSTAINABLE FOOD SYSTEMS

Acknowledgements

This report was made possible through the collective efforts of many individuals and organizations. We are deeply grateful to the members of our Working Group: Molly Anderson, Errol Schweizer, Raj Patel, Mamadou Goïta, Emile Frison, Jennifer Clapp, Georgina Catacora-Vargas, and Pat Mooney, for their critical guidance and thought leadership throughout the development of this work. Project management, development, and drafting was carried out by Nicole Pita, Nick Jacobs, and Anna Paskal, with essential research support from Pablo Thorne and Saskia Colombant. We owe particular thanks to our external reviewers Lili Fuhr, Taylor Hodge, Barnaby Pace, Matthew Kessler, and Anna Lappé, whose insightful feedback was invaluable. Design was led by Robbie Blake, with support from Chantal Wei-Ying Clément, and graphic design was skillfully executed by The Ethical Agency. We extend our appreciation to all the experts who generously shared their time and perspectives in interviews and on the Fuel to Fork podcast, and to our podcast partners at TABLE and the Global Alliance for the Future of Food for their collaboration and support.

Approved by the IPES-Food panel, June 2025.

Citation

IPES-Food. 2025. Fuel to Fork: What will it take to get fossil fuels out of our food systems?

Layout & graphic design

ethicalagency.co.za

With support from

ROSA
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FOUNDATION

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KEY MESSAGES

Fossil fuels are the lifeblood of the food industry. They are deeply embedded in every part of the food chain – accounting for at least 15% of total fossil fuel use globally – and their use in food systems is accelerating. As fossil fuel extraction continues to expand, and decarbonization strategies focus on energy and transport, the oil and gas industry is increasingly turning to petrochemicals – particularly agrochemicals and plastic food packaging – as its next growth frontier. Global governments agreed at COP28 to "transition away from fossil fuels," yet action on food systems is missing.

Fossil-based fertilizers and plastic food packaging have become critical lifelines for oil and gas companies, offering a new way to keep fossil fuels flowing even as other sectors begin to decarbonize. Ultra-processed foods are the ultimate expression of fossil-fueled food systems – born from commodity crops produced with fossil-based agrochemicals, harvested with fossil-fueled machinery, shaped by energy-intensive industrial processing, wrapped in layers of plastic packaging, and shipped around the world.

At the same time, major **agribusiness corporations are aggressively pushing solutions that only deepen dependency on fossil fuels and agrochemicals** while introducing new environmental and public health risks. Meanwhile major food corporations are actively working to block or weaken environmental and public health policies aimed at reducing plastic use and curbing ultra-processed foods.

We can't tackle climate change unless we get fossil fuels out of food systems, yet this remains a major blind spot in climate and food policy debates.

Key findings from the report include:

- **40% of all global petrochemicals are consumed by food systems**, mainly in the form of synthetic fertilizers and plastic packaging for food and beverages.
- One-third of all petrochemicals go toward producing synthetic nitrogen fertilizers, making them the single biggest fossil fuel consumer in agriculture.
- 99% of synthetic nitrogen fertilizers and pesticides are derived from fossil fuels.
- Fossil fuel-dependent food systems are dangerously vulnerable to price shocks, with spikes in the price of oil and gas triggering surges in fertilizer and food prices – putting millions at risk of hunger.
- At least 3.5% of global plastics are used in food production, and 10% in food and drink packaging.
- While food transportation relies on fossil fuels, its role is relatively small compared to the broader fossil fuel footprint of food systems, and it is rapidly electrifying.
- Industry-promoted 'blue' ammonia fertilizers, 'synthetic biology' approaches, and high-tech, digital farming tools are expensive, energy-intensive, and risk keeping food systems tethered to fossil fuels and farmers dependent on agrochemicals.
- These technologies are controlled by a handful of powerful corporations, locking farmers into industrial monoculture systems, and deepening existing power imbalances in food systems.

Food systems are a critical front in the fight against fossil fuels. To break industrial food's fossil fuel addiction, we must phase out agrochemicals, and scale up agroecological farming, local food supply chains, and healthy food environments. This transition is already underway, and if accelerated, it can deliver healthier, more just and climate-resilient food systems.

What it will take to get fossil fuels out of food systems:

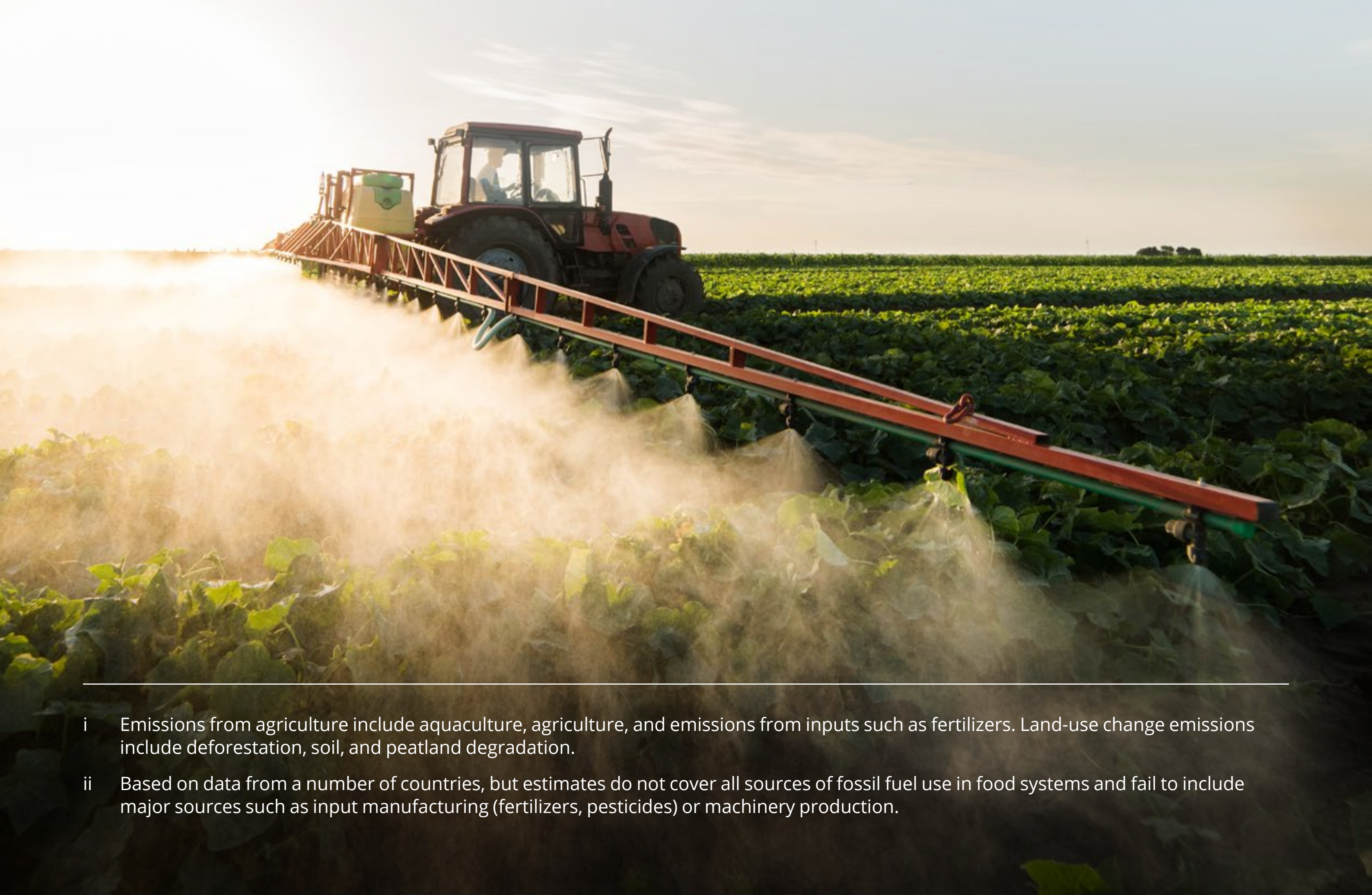
- Advance a just energy transition that expands and equitably distributes renewable energy;
- Phase out agrochemicals and promote agroecological farming;
- Rebuild local food supply chains;
- Reduce plastic by scaling up reuse systems and holding corporations accountable;
- Cut ultra-processed food consumption and expand healthy food access;
- Eliminate food waste and scale up clean and electric cooking;
- Rein in corporate power and democratize food systems governance.

INTRODUCTION: THE LIMITS OF THE SOLUTIONS ON THE TABLE

For years, the climate impact of our food systems has been widely recognized and is now impossible to ignore. It is now well established that food systems are responsible for roughly one-third of global greenhouse gas emissions (GHGs). Agriculture and associated land-use changes account for the lion's share of these emissions and a quarter of total global GHG emissions, mostly through land conversion to high chemical input and resource-intensive commodity crop production systems, as well as the destruction of forests for cattle pastures. [1,i] The production and use of synthetic nitrogen fertilizers alone is responsible for roughly 2% of global GHGs.[2]

While the emissions produced by food systems are now being recognized, far less attention is paid to the fossil fuels that go into food systems. In its 2023 *Power Shift* report, the Global Alliance for the Future of Food estimated that food systems account for at least 15% of total fossil fuel use.[3,ii] This figure already exceeds a number of industrial sectors, and is set to grow. For example, the steel industry consumes 8% of global energy (mainly coal),[4] while the paper and mining industries consume 6%[5] and 1.7%[6] of global energy, respectively.

Fossil fuels are, in fact, deeply embedded in every part of the food chain – from agrochemicals and plastic packaging to energy-intensive food processing and the fuel that powers our stoves. And current national and international policies and funding structures serve to lock in high fossil fuel use and chemical-intensive farming. Direct annual subsidies for coal, oil, and fossil ('natural') gas have surged to USD 2 trillion,[7] while over USD 540 billion are allocated each year to agricultural subsidies, primarily supporting chemical-intensive commodity crop production (see Box 1).[8]



i Emissions from agriculture include aquaculture, agriculture, and emissions from inputs such as fertilizers. Land-use change emissions include deforestation, soil, and peatland degradation.

ii Based on data from a number of countries, but estimates do not cover all sources of fossil fuel use in food systems and fail to include major sources such as input manufacturing (fertilizers, pesticides) or machinery production.

BOX 1

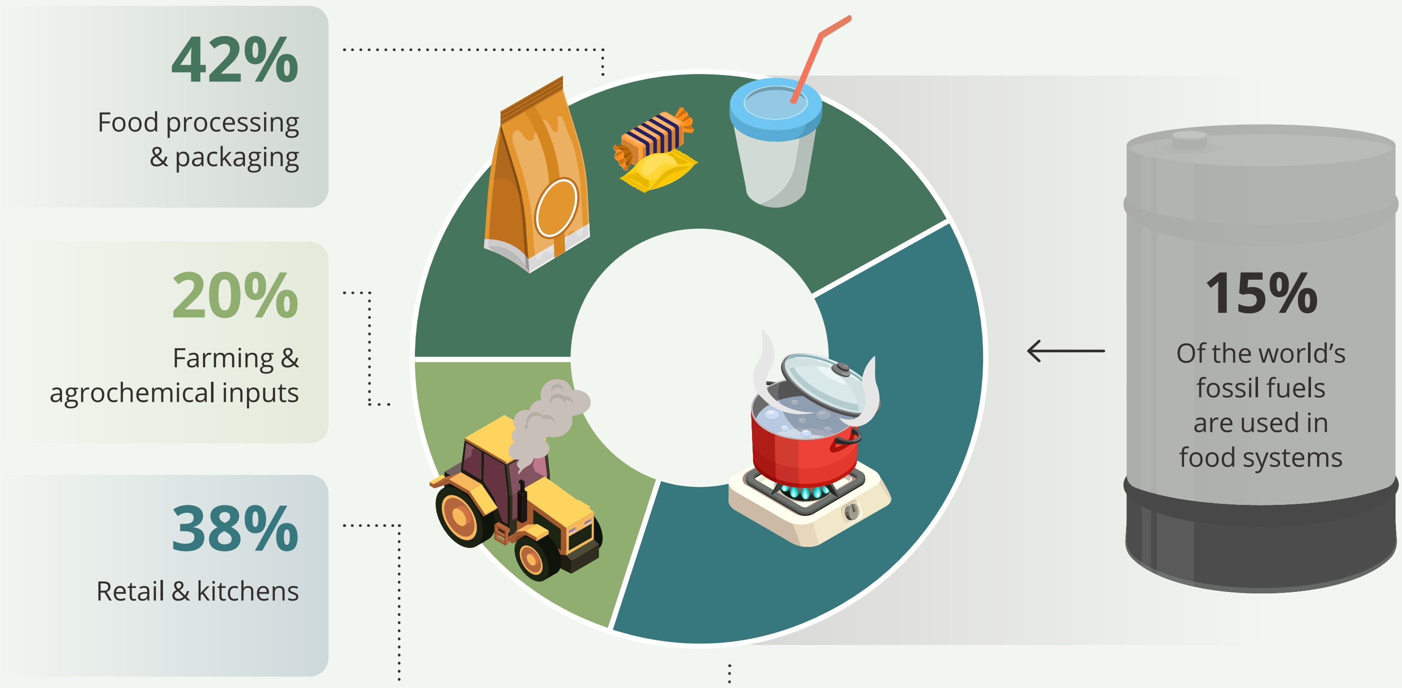
THE COST OF HARMFUL FOSSIL FUEL AND FARMING SUBSIDIES

Fossil fuel prices fail to reflect the enormous environmental and social costs they incur. Indeed, fossil fuels are often subsidized and incentivized by governments, rather than being taxed in line with the negative costs they generate. Annual subsidies, both direct and indirect, for coal, oil, and fossil gas keep increasing and have reached USD 7 trillion – 7.1% of global GDP.[9] This amount exceeds annual government spending on education and equals about two-thirds of healthcare expenditures. In 2024, USD 2 trillion were handed out as direct subsidies, and the remaining USD 5 trillion were calculated to be the costs to society, such as air pollution, oil spills, and environmental damages. This number would nearly double if climate change-related harms were valued at levels suggested in the most recent scientific research.[10] All of this persists despite the fact that 197 countries signed on to phase out "inefficient" fossil fuel subsidies at the 2021 Climate COP in Glasgow.[11]

Meanwhile, nearly 90% of the USD 540 billion spent annually on agricultural subsidies harms both people and the planet by supporting chemical-intensive commodity crop production.[12] Much of this funding comes in the form of price protections and payments tied to specific commodity crops or farming inputs, reinforcing unsustainable practices. Fertilizer subsidies, in particular, promote overuse and have contributed to up to 17% of all nitrogen pollution in water over the past 30 years.[13]

FIGURE 1

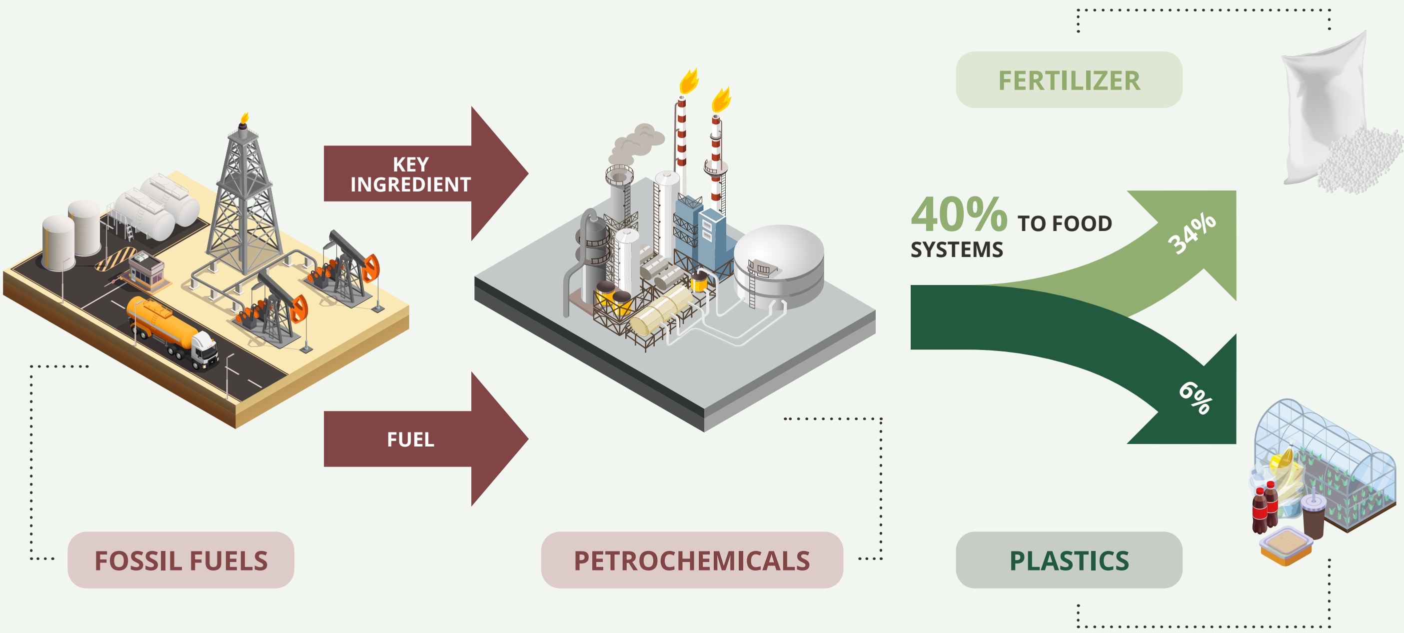
FOOD SYSTEMS CONSUME 15% OF GLOBAL FOSSIL FUELS



Source: Global Alliance for the Future of Food. (2023). Power shift: Why we need to wean industrial food systems off fossil fuel.

FIGURE 2

FOOD SYSTEMS EAT UP 40% OF GLOBAL PETROCHEMICALS



An estimated 40% of global petrochemicals are used in food systems – primarily as synthetic fertilizers on farms and as plastics in food and beverage packaging.*

Source: Levi, P. G., & Cullen, J. M. (2018). Mapping global flows of chemicals: from fossil fuel feedstocks to chemical products. Environmental Science & Technology, 52(4), 1725–1734.

FAO. (2021) Assessment of agricultural plastics and their sustainability – A call for action.

* Plastic use estimates are based on FAO calculations using limited global data and broad regional assumptions. The figures exclude plastics used in storage, processing, transport, and distribution, and likely underestimate total plastic use in food and drink packaging. As such, they should be considered a conservative estimate of the sector's plastic footprint.

> ***Fossil fuels are embedded in almost all of the inputs that are going into industrial food and farming today.***
>
> **Jennifer Clapp**
> Fuel to Fork podcast

Most worryingly, our food systems are becoming more deeply locked into fossil fuel dependence. The clean energy transition is slowing demand for dirty fuels globally, but oil and gas production continues to surge, leaving fossil fuel companies with a supply glut.[14,15] In response, they are turning to petrochemicals, particularly fertilizers and plastics, as a key outlet for excess supply.[16,17]

Fertilizers and plastics, which together account for 74% of petrochemical production, are fast becoming pillars of fossil fuel companies' growth strategies.[18,19] Oil is increasingly funneled into plastic production, while fossil gas is channeled into ammonia manufacturing for synthetic fertilizers. In food systems alone, the footprint is substantial: about 3.5% of plastics are used in food production and 10.4% are used in food and drink packaging, according to the FAO.[20]

Moreover, one-third of all petrochemicals (34%) are used for synthetic nitrogen fertilizer production.[21] Taken together, this means that roughly 40% of global petrochemicals are consumed by food systems (see Figure 2).

Yet despite their centrality to oil and gas markets, petrochemicals remain one of the major "blind spots" in global climate and energy debates, receiving far less scrutiny due to their complexity and diversity.[22] This lack of attention conceals the reality that petrochemicals are on track to become the single largest driver of oil demand growth, accounting for over a third of growth through 2030, and nearly half by 2050, surpassing the transport sector.[23] If left unchecked, petrochemical expansion – fueled by rising plastic and fertilizer production – will lock in decades of fossil fuel dependency, undermining efforts to decarbonize food systems and the broader economy.

Fossil fuel-dependent food systems are highly exposed to economic turbulence.

Fossil fuel price spikes can cause a cascade of cost increases from energy (on-farm and along the food chain), to fertilizer, to food (see Figure 3).

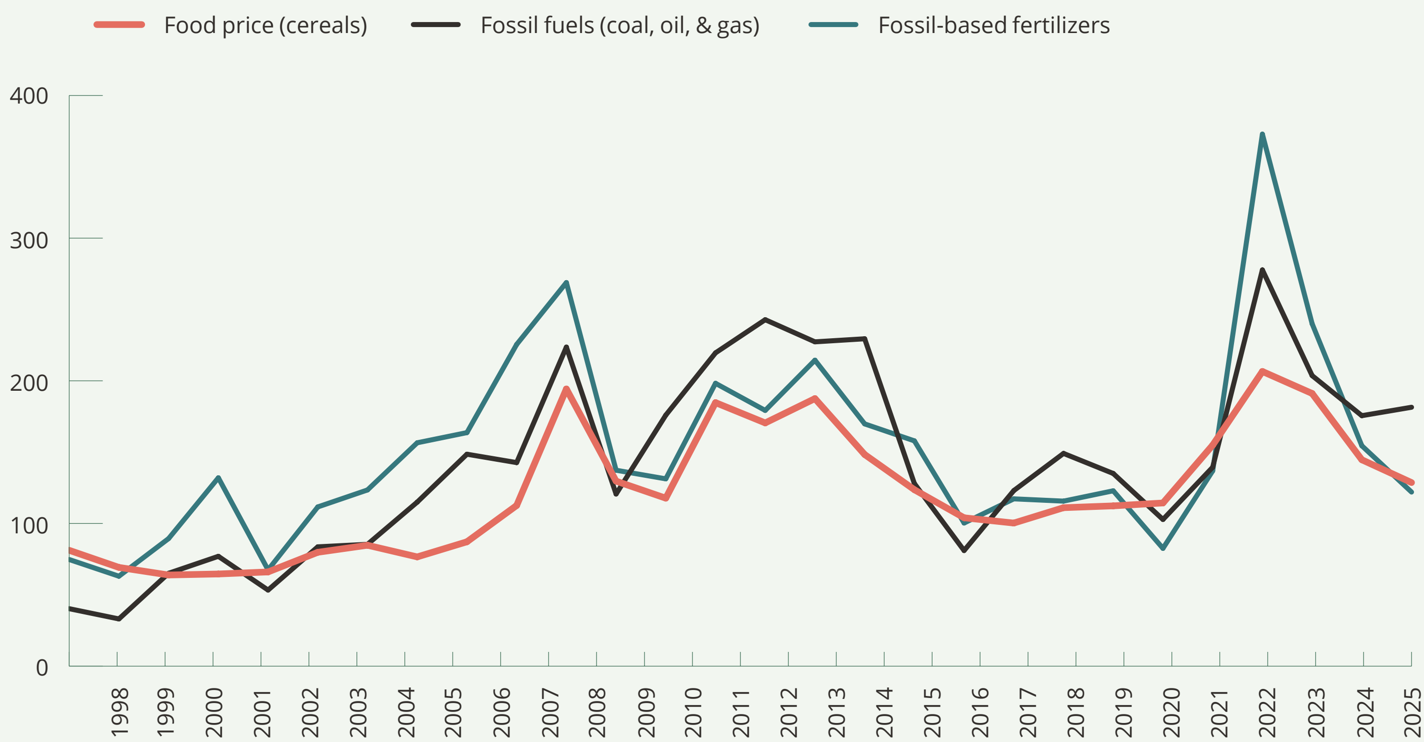
Acute spikes in fertilizer, food, and energy prices occurred in the wake of COVID-19 and the Russian invasion of Ukraine.

This price volatility has clearly been exacerbated by financial speculation and agribusiness profiteering – in a context of unprecedented corporate concentration across agri-food chains.[24,25,26]

> ***Agrochemicals are fossil fuels in another form. And that makes our food system vulnerable to fossil price shocks – and to authoritarian regimes that control supply.***
>
> **Lisa Tostado**
> Fuel to Fork podcast

FIGURE 3

FOOD, FERTILIZER, AND FOSSIL ENERGY PRICES ARE DEEPLY INTERLINKED



Source: Levi, IMF Primary Commodity Price Index.

> ***Plastics and fertilizers together account for three-quarters of all petrochemicals produced, and they're major drivers of fossil fuel growth. We cannot take our eye off this huge growth area that big oil has set its sights on.***
>
> **Anna Lappé**
> Fuel to Fork podcast

The food on our plates, therefore, has a major climate footprint and is linked to a broader set of environmental and social harms arising from the extraction and use of fossil fuels. At the 2023 climate summit in Dubai, COP28, governments unanimously agreed on *"transitioning away from fossil fuels in energy systems, in a just, orderly and equitable manner, accelerating action in this critical decade."* [27] Food systems were left out of this agreement, but are clearly a major part of the challenge.

Further, **fossil fuel dependencies are a component of a food system that is failing more broadly. It is increasingly recognized that today's industrial food systems are deeply unsustainable and inequitable**. A huge plethora of scientists, civil society groups, and international bodies are calling for a paradigm shift, and a 'food system transformation' – requiring comprehensive strategies to tackle the worsening challenges of climate change, biodiversity loss, hunger, and poverty together.[28,29]

Around the world, farmers, communities, food businesses, and governments (including local and regional authorities) are working to redesign and rethink food systems in fundamental ways. These include phasing out agrochemicals and transitioning to agroecological farming practices, re-localizing food supply chains, and deploying integrated policies to foster healthy, sustainable diets. Recent supply chain shocks and rampant food and fuel price inflation have galvanized this movement.

Considering the ubiquity of fossil fuels along the food chain brings into stark relief the systemic nature of the changes that are needed.
Arguably, **today's fossil-intensive industrial food systems cannot be tweaked or 'fixed': the challenges are so vast and the power imbalances so great, that only changes of a more fundamental nature – changes that remake food systems and redistribute power – will do**.

As these transformative approaches gather steam, incremental approaches are also advancing with a view to substituting out fossil fuels at select points in the chain (e.g., by electrifying kitchens and food transportation), bringing major opportunities, as well as challenges and trade-offs. Alongside these steps, a number of more 'disruptive' agribusiness-led, high-tech fixes are being developed, rolled out, and touted as solutions to enhance the sustainability of food systems – including new forms of synthetic nitrogen fertilizers (so-called 'blue' and 'green' ammonia fertilizers) and genetically engineered 'biologicals' and 'microbials'.

A number of these high-tech approaches are already being rapidly rolled out despite a number of risks and major question marks about whether they actually reduce or reinforce fossil fuel dependencies, and what they mean in terms of the broader challenge of building more sustainable and equitable food systems.

In 2024, IPES-Food joined forces with the Global Alliance for the Future of Food and TABLE to take forward the challenge of exposing the fossil fuels in our food through the *Fuel to Fork* podcast series. This report distills key insights from the podcast and takes them further. Moving through the food chain, we identify the various ways in which food system activities have become dependent on fossil fuels, and what can be done to reduce and ultimately remove fossil fuels from food systems.

In sections 1-3, we examine the full impacts and risks of many of today's most widely promoted food system fixes – incremental and 'disruptive'/high-tech – and whether they are truly capable of cutting fossil fuel dependencies across the food supply chain. This is not an exhaustive review; rather, looking along the food chain, we spotlight a handful of the most prominent solutions – i.e., those already gaining political traction and/or attracting substantial financial investments – in order to illustrate key trajectories.

Subsequently, in Section 4, we outline holistic approaches that would cut fossil fuel dependencies as part of a more fundamental redesign of food and farming systems. We consider what this food system transformation looks like in terms of fossil fuels and just energy transition, where change is already underway, and what barriers and remaining challenges stand in the way of the urgently needed transformation of food systems.

Through the *Fuel to Fork* podcast and this companion report, we aim to provide a key waypoint on the journey to end fossil fuel dependence, offering a snapshot of the opportunities and challenges at various points in the supply chain, and identifying the holistic measures that can and must be taken towards fossil fuel-free food systems.

ADDRESSING FOSSIL FUELS ON THE FARM

Incremental fixes or false solutions?

1

What is the problem?

Fossil fuels – in the form of fuel for farm machinery and as a key ingredient in synthetic fertilizers and pesticides – have transformed agriculture over the past century, underpinning the large-scale industrial monoculture production that now typifies so many agricultural landscapes.

Agriculture accounts for roughly 20% of total energy use in food systems. Energy inputs required for agriculture vary by region, crop, and farming system, but those that require high fertilizer use, tillage, intensive post-harvest processing, and cold storage are the most energy-intensive.[30] In European agriculture, agrochemicals and diesel fuel are the top two uses of fossil fuels, accounting for 50% and 31% of total energy inputs, respectively.[31] Agrochemical and diesel requirements vary by crop. For example, corn requires 180% more fertilizers and 7% more pesticides than soy, while soy requires 30% more diesel than corn.[32]

99% of all synthetic fertilizers and pesticides are derived from fossil fuels.[33,34] Pesticides, including herbicides, insecticides, and fungicides, are synthesized from petroleum and its by-products, which serve as both active and inert ingredients in formulations. While active ingredients are disclosed, inert components – such as surfactants and emulsifiers that enhance pesticide potency – are considered proprietary, hidden from public view, and do not require toxicity studies.[35,36] However, these inert ingredients can make up to 50% of pesticide products, and the vast majority that have been tested are actually more toxic than the declared active ingredients.[37] Many pesticides are also coated in petroleum-derived microplastics for controlled release.[38] Furthermore, though more nitrogen fertilizers are used in agriculture than pesticides, the production of pesticides is highly energy-intensive, requiring roughly ten times more energy per kilogram than nitrogen fertilizers.[39]

Pesticide use globally continues to rise, increasing by 13% in the last decade and doubling since 1990 – especially in China, the US, Brazil, Thailand, and Argentina.[40] China is by far the world's largest producer of pesticides, accounting for one-third of global production.[41]

And climate change is expected to intensify use, as rising temperatures and shifting pest patterns reduce pesticide efficacy, prompting higher usage and creating a vicious feedback loop between climate impacts and chemical dependency in agriculture.[42]

The growing use of fossil fuel-based pesticides has severe environmental and health consequences. Pesticide production, application, and their chemical interactions in the environment all contribute significantly to greenhouse gas emissions, though no studies calculate the GHG emissions of pesticide use over the full life cycle of the chemicals, making precise estimations difficult.[43]

Their ecological toll is profound – pesticides are now recognized among the top global drivers of biodiversity loss.[44] Human health impacts are equally dire: over 385 million unintentional pesticide poisonings occur annually, with 11,000 deaths, affecting nearly 44% of the global farming population.[45,iii] Chronic exposures are linked to cancer, reproductive harm, and neurological disorders.[46] These harms fall disproportionately on agricultural workers, rural communities, and fenceline communities where pesticides are produced, compounding existing vulnerabilities and injustices.[47]

> ***Punjab, once India's agricultural breadbasket, now faces depleted soils, poisoned water, and soaring cancer rates due to years of chemical fertilizer and pesticide use – so much so that the train that takes people to the nearest hospital is known as the 'cancer train.***
>
> **Navina Khanna**
> Fuel to Fork podcast

iii Boedeker et al.'s widely cited estimate of 385 million annual pesticide poisonings and 11,000 annual deaths was based on a systematic review of global data. The article was later retracted following sustained pesticide industry pressure that cast doubt on the science, despite the use of established methods and peer-reviewed sources.

Like pesticides, nitrogen fertilizers are derived from fossil fuels and are the single biggest consumer of fossil fuels in agriculture. Virtually all ammonia – the key ingredient for synthetic nitrogen fertilizer – is made of fossil fuels, mostly fossil gas and some coal.[48] Synthetic nitrogen fertilizer use has increased by 800% since 1961,[49] following the post-war 'Green Revolution' era where states and industry promoted chemical-intensive farming to increase yields.

The US, EU, and other high-income countries currently use up to 10 times more fertilizer per capita than low-income countries (see Box 2).[50] The FAO projects a 50% increase in global nitrogen fertilizer use by 2050,[51] with the industry focused in particular on ramping up sales in the Global South.[52]

Synthetic fertilizers are responsible for a number of environmental damages. Today, the nitrogen fertilizer supply chain is responsible for over 2% of global GHG emissions.[57] The production of synthetic fertilizers is responsible for approximately 40% of total fertilizer GHG emissions, while around 60% of fertilizer emissions stem from its on-field application,[58] mainly in the form of nitrous oxide – a greenhouse gas 300 times more potent than CO_2 (see Figure 4).[59] Nitrous oxide emissions are responsible for 10% of net global warming since the industrial revolution.[60]

In addition to GHGs, nitrogen pollution has many other damaging impacts. The planetary boundary for nitrogen was breached in 1970 due to synthetic nitrogen fertilizer use. Since then, total nitrogen use has doubled,[61] again driven primarily by synthetic fertilizer, with increasingly severe consequences.

Globally, more than half of the nitrogen fertilizers applied to crops are lost to the environment, polluting air, water, and soils (see Box 3).[62] Three billion people are at risk of water shortage from nitrogen pollution.[63] Nitrates in drinking water – originating from fertilizers and manure – can cause blue baby syndrome, a potentially fatal condition in infants that deprives the body of oxygen, and have also been linked to cancer.[64] Nitrogen dioxide emissions from fertilizer production and application, along with ammonia emissions from fertilizer application, also contribute to air pollution and a large number of respiratory illnesses and death.[65,66,67,68] Nitrogen pollution is also one of the biggest drivers of biodiversity loss.[69]

BOX 2

REGIONAL DISPARITIES IN NITROGEN FERTILIZER USE

It is important to note that nitrogen fertilizer use varies dramatically across the world. While the US and parts of the EU are stabilizing at high levels of fertilizer use, some countries like China, India, and Egypt already use high amounts of nitrogen fertilizers and continue to use more and more, with increasing deleterious effects on human and environmental health.[53] Meanwhile, in parts of sub-Saharan Africa – including countries like Nigeria and Benin – fertilizer use remains low, and yields are stagnant or erratic.[54] These outcomes are primarily driven by persistent droughts, infrastructure deficiencies, and deeper socio-political factors, such as land tenure insecurity, underinvestment in rural areas, weak extension services, and conflict.[55,56]

BOX 3

HOW SYNTHETIC NITROGEN FERTILIZERS POLLUTE OUR AIR AND WATER AND HARM HUMAN HEALTH

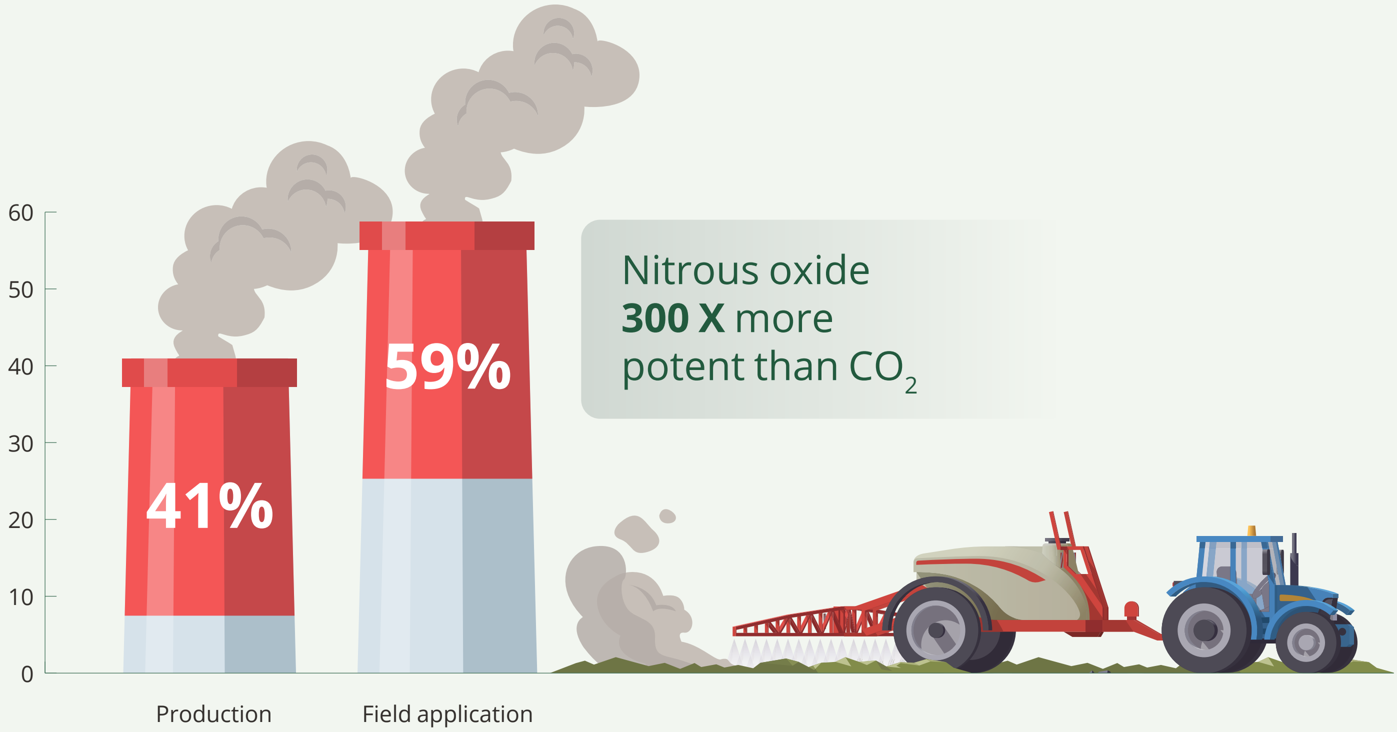
Synthetic fertilizers supply nitrogen in forms that plants can easily absorb, mainly as ammonium and sometimes nitrate. While crops do take up some of this nitrogen, a lot of it reacts with soil microbes and sets off a chain of chemical processes. Ammonium is often converted into nitrate, which plants can use – but when there is too much nitrogen in the soil, especially in wet conditions, some of it escapes into the air as gases like nitrous oxide, a powerful greenhouse gas, or dinitrogen. Meanwhile, both nitrate and ammonium can wash into rivers, lakes, and groundwater after rain, and excess ammonium can evaporate into the air as harmful gases like ammonia and nitrogen oxides.

These nitrogen cycles happen naturally, even with organic fertilizers like manure or compost. However, as a result of their overuse and readily available, reactive state, synthetic nitrogen fertilizers are prone to leaking into water and air. This leads to serious environmental damage, polluting waterways, worsening climate change, and harming human health.

> ***The toxic toll of fertilizers begins with communities living in the shadow of manufacturing plants, spreads through rural areas facing health crises from overuse, and flows into waterways, harming aquatic life and fisher livelihoods.***
>
> **Darrin Qualman**
> Fuel to Fork podcast

FIGURE 4

MOST GREENHOUSE GASES FROM FOSSIL-BASED FERTILIZERS ARE EMITTED ON THE FARM



While 41% of synthetic fertilizer emissions come from fossil-fuel-based production, cleaning up this process does nothing to mitigate the majority of emissions released after fertilizers are applied to fields. These field emissions are mainly in the form of nitrous oxide, a greenhouse gas 300x more potent than CO_2

Source: Menegat, S., Ledo, A., & Tirado, R. (2022). Greenhouse gas emissions from global production and use of nitrogen synthetic fertilisers in agriculture. Scientific Reports, 12(1), 14490.

Fossil fuels are also used abundantly to power tractors, harvesters, and other on-farm machinery and installations. Tilling and plowing have particularly high energy demands, accounting for almost half (47%) of the energy used in field operations in the EU.[70,71] However, no-till farming, often touted as a form of regenerative agriculture, is dependent on pesticides, particularly herbicides, to manage weeds and has been found to increase herbicide use on conventional farms.[72] On-farm vehicles tend to have a lifespan of roughly 20-30 years,[73] meaning that failure to shift rapidly to alternative ways of powering the farm could lock in significant fossil fuel usage and greenhouse gas emissions.

> ***Farm machinery lasts decades, so we've got to stop producing fossil-fueled equipment now – each new machine locks in emissions for up to 30 years.***
>
> **Darrin Qualman**
> Fuel to Fork podcast

Although not explored in depth in this report, several post-harvest on-farm processes are also significant sources of fossil fuel use. Grain drying, in particular, is highly energy-intensive and essential for preventing spoilage and maintaining safe storage conditions. In the US and other high-income countries, farms typically rely on fossil fuels, primarily propane, for drying. This process alone accounts for an estimated 12–25% of total energy consumption in grain production.[74]

Fossil fuels are also prevalent on the farm in the shape of plastics, present in almost all forms and scales of food production, with total usage rising. Agriculture, fisheries, and aquaculture utilize 3.5% of global plastics.[75] Crop and livestock production are the sectors with the highest plastic usage, accounting for 10 million tonnes per year combined (2.8% of global plastic production), followed by fisheries and aquaculture with 2.1 million tonnes.[76] Greenhouses, mulching, and silage films currently account for half of agricultural plastics by volume, and their production is forecast to increase by 50% from 6.1 million tonnes in 2018 to 9.5 million tonnes in 2030.[77,iv]

Additional plastic uses on farms include drip irrigation systems, plastic seedling trays and pots, and plastic-coated seeds and plastic-coated fertilizers, with the latter representing a direct introduction of microplastics into the environment. In Europe, these plastic-coated seeds and agrochemicals are responsible for 22,500 tonnes of microplastic pollution per year, or 62% of the region's intentionally-released microplastics.[78,v] Microplastics have been found in drinking water and across a wide range of foods, with growing evidence linking them to serious risks for both human and environmental health.[79,80]

The accumulation of micro- and nano-plastics in soils, and chemical leaching from plastic additives, drives wide-ranging impacts on soil, microbial, plant, and animal health, as well as on water infiltration and retention, and soil erosion and fertility.[81] Chemical additives identified in soils are known to generate a range of toxic effects, including endocrine disruption.[82] Alarming new research suggests that microplastics can disrupt photosynthesis, potentially hindering plant growth and productivity.[83] All told, studies suggest there are more microplastics contained in our agricultural soils than microplastic pollution in the ocean.[84,85]

Plastic pollution poses challenges throughout the entire food supply chain. Section 2 will explore these issues in greater depth, including emerging strategies to reduce or replace fossil-based plastics.

> ***Microplastics are found in seafood, in the soil we grow our food in, in the placenta, passed on to babies, in our bodies, in animals, even in the atmosphere.***
>
> **Emma Priestland**
> Fuel to Fork podcast

iv Plastic greenhouse covers and tunnel films create controlled environments to protect plants and extend growing seasons. Plastic films are used in mulching to retain soil moisture, suppress weeds, and regulate temperature. Plastics are used in silage wraps and bags to maintain airtight conditions for animal feed storage.

v Microplastics are extremely small pieces of plastic that are either deliberately added to products to perform a specific function (i.e., intentionally-released) or a byproduct of the breakdown of larger pieces of plastic.

'GREEN' AND 'BLUE' NITROGEN FERTILIZERS

What are 'green' and 'blue' nitrogen fertilizers?

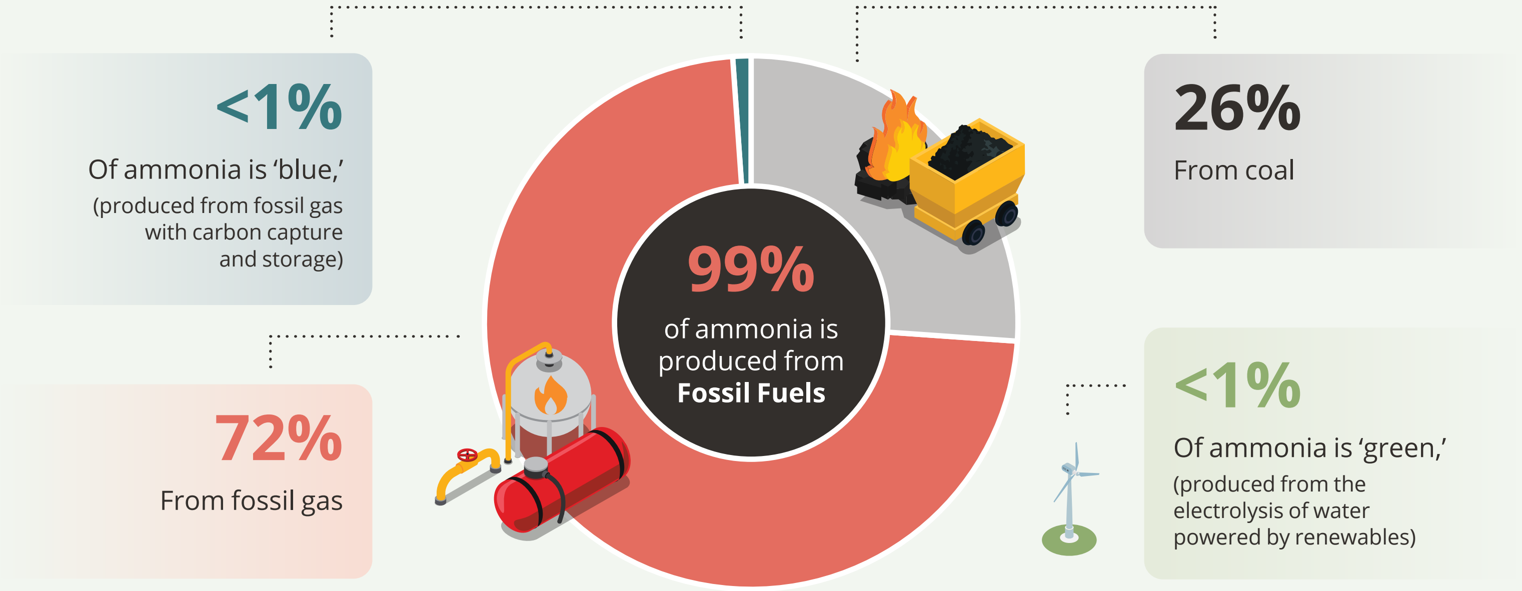
Although fertilizer is rarely central in public discussions about food systems, synthetic nitrogen fertilizer is the single biggest source of fossil fuels in food systems. It is therefore imperative to consider what can be done to address fertilizer – and to scrutinize the so-called solutions being proposed by agribusinesses in this regard.

'Green' and 'blue' ammonia fertilizers – dubbed 'low carbon fertilizers' by fertilizer companies – are being proposed by agribusinesses, and some governments and international agencies, as ways to clean up the nitrogen fertilizer production process.[vi]

Conventional nitrogen fertilizer is derived from ammonia that is synthesized by combining nitrogen gas from the air with hydrogen from fossil fuels, typically fossil gas and sometimes coal. The IEA estimates that 99% of global hydrogen production in 2023 was fossil fuel-based (see Figure 5).[86] 'Blue' nitrogen fertilizers are made like conventional synthetic fertilizers but aim to capture and store carbon dioxide from the production process ('carbon capture and storage' or 'CCS'). In contrast, 'green' nitrogen fertilizers are made by deriving hydrogen from water instead of fossil feedstocks,[vii] through an energy-intensive electrolysis process that can theoretically be powered by renewables (e.g., wind, solar).[viii]

FIGURE 5

FERTILIZER PRODUCTION RELIES OVERWHELMINGLY ON FOSSIL FUELS



Ammonia is the key ingredient in synthetic nitrogen fertilizers, and currently, 99% is produced from fossil fuels; less than 1% is considered 'green.'

Sources: Ammonia Energy Association. (February 2025). Low-Emission Ammonia Data (LEAD): Plants Executive Summary.
Agora Industry. (2024). Global Green Fertiliser Tracker.
International Energy Agency. (2021). Ammonia Technology Roadmap.

vi Countries with significant regulatory support for so-called low-carbon ammonia projects include the US, Australia, Brazil, Canada, Chile, and the EU. The UN Industrial Development Organisation launched the Global Programme for Hydrogen in Industry in 2021, supporting low-income countries in decarbonizing the chemical and fertilizer industries through 'green' ammonia.

vii Another potential source of hydrogen is geologic hydrogen, or natural hydrogen, this is hydrogen gas generated and stored naturally in the Earth's subsurface. Despite growing interest, the commercial viability of geologic hydrogen remains uncertain, with only one proven reserve and limited data and untested potential from other sites of geologic hydrogen. See Patonia, A., Lambert, M., Lin, N., & Shuster, M. (2024). Natural (geologic) hydrogen and its potential role in a net-zero carbon future: Is all that glitters gold? Oxford Institute for Energy Studies.

vii Interestingly, some of the first synthesis of nitrogen, in the late 19th and early 20th centuries, was performed using electricity from waterfalls. Listen to Episode 2 of the Fuel to Fork podcast for more historical background on nitrogen synthesis.

How viable are these solutions, and how transformative could they be?

There are significant emerging concerns about the inability of 'green' and 'blue' ammonia fertilizers to cut fossil fuel dependencies, reduce emissions, and address the broader issues with nitrogen fertilizer production and over-use. These approaches also entail serious additional environmental and social harms.

'Blue' nitrogen fertilizers, made with the same fossil fuel feedstock as synthetic fertilizers, clearly risk locking in the existing fossil economy and related extractive processes. Despite decades of research and subsidies, there is no evidence that commercial-scale CCS projects function anywhere near the industry claims of 90 to 95% carbon capture rates.[87] For example, Enid, a fertilizer plant running the second oldest CCS project in the world (since 1982), only captures 28% of CO_2.[88]

Companies' reported carbon capture rates often overlook the full life-cycle emissions of 'blue' hydrogen, including emissions from the energy-intensive capture process and leakage during transportation and attempted storage.[89] Some of the carbon captured by the fertilizer industry is reused as a feedstock for fertilizers, but 73% of captured carbon is used for enhanced oil recovery by the fossil fuel industry, a process that uses CO_2 to extract even more oil, thereby increasing fossil energy production and, ultimately, GHG emissions.[90]

'Green' ammonia fertilizers are still in their infancy, representing only a tiny fraction of current fertilizer sales worldwide. It is important to note that only four production sites globally currently perform electrolysis of water with renewable energy, accounting for just 0.3% of global ammonia used in nitrogen fertilizer.[91] And the future build-out of ammonia continues to rely on fossil fuels. For example, of all the planned ammonia projects in the US, 95% are based on fossil fuels, not electrolysis.[92] Further, this process entails very high costs at present, making it uncompetitive with fossil-based fertilizer. A fully *green* hydrogen/ammonia production process is therefore hard to imagine in the short-to-medium term, and would require a major diversion of renewable power capacity.

Scaling up the production of 'blue' and 'green' fertilizers also requires large amounts of land, water, and energy, exceeding the total footprint of business-as-usual fertilizer production. One study found that converting from conventional to 'blue' ammonia fertilizers would increase energy use by 58%, double land use, and triple water use, while converting to 'green' ammonia fertilizers would require 24 times more electricity (or 5% of global electricity), 30 times more land, and 50 times more water.[93]

Further, equity issues are arising as 'green' hydrogen production expands, with major projects being developed in water-scarce areas in the Global South,[ix] sometimes at the expense of traditional rangelands that are mislabelled as "wastelands."[94] Further, these projects are overwhelmingly for export, with the EU looking to double 'green' hydrogen imports by 2030 to support its green energy transition.[95]

It is also worth recalling that emissions resulting from the application of nitrogen fertilizers (mainly in the form of nitrous oxide) account for 60% of fertilizer-based emissions and contribute to climate change.[96] Even if fossil fuel usage can be reduced through 'green' fertilizer production processes, failure to meaningfully curb nitrogen fertilizer use will mean ongoing severe health and environmental impacts.

> ***Any food system rooted in extraction from nature rather than reciprocity with nature destroys the very home it depends on – nature is not a resource, it's a relationship.***
>
> **Molly Anderson**
> Fuel to Fork podcast

ix More than a third of the biggest green hydrogen projects are planned in countries facing high or extremely high water stress. See Corporate Europe Observatory. (2023, October 10). The dirty truth about the EU's hydrogen push.

GENETIC ENGINEERING AND SYNTHETIC BIOLOGY

What are next-generation genetic engineering and synthetic biology approaches in agriculture?

Again, largely under the radar, huge amounts of agricultural research dollars are being channeled into next-generation genetic engineering and synthetic biology approaches – with big claims about how these technologies can provide a 'climate-smart' pathway out of agrochemical and fossil fuel dependence and towards a sustainable bio-based food system and 'bioeconomy'.[97,x]

While often framed as a clean break from the past, it's worth noting that first-generation genetic engineering, such as herbicide-tolerant and insect-resistant crops, was also promoted as a solution to pesticide use. Yet, after nearly 30 years, the continued need to stack genes conferring resistance to multiple pesticides has only intensified the pesticide treadmill – ultimately to the benefit of the agrochemical industry.[98] Despite the relative lack of scrutiny, new genetic approaches carry their own major social and environmental risks.

Genetic engineering refers to artificially altering the genetic material of organisms (e.g., DNA, RNA). Today's frontier developments allow for targeted gene editing and insertion and are described as biological engineering or 'synthetic biology' to distinguish from older techniques that often relied on the random insertion of genes.

Key approaches, with products already on or close to market, include the following:

- **Genetic Pesticides (RNAi sprays and crops):** The technology is called RNA interference (RNAi). Instead of spraying petrochemical-derived pesticides, short strands of double-stranded synthetic RNA are deployed to genetically disrupt insects and kill them.[99] In some cases, crops are bioengineered to produce their own RNAi strands.[100]

- **Engineered 'biologicals' and 'microbials':** Agribusinesses are promoting the use of engineered biological molecules ('biologicals') and proteins (fermented in vats) as well as altered microbes ('microbials') as another way of replacing agrochemicals.[101] Examples include engineering plants to produce insect pheromones,[102] modifying insecticidal bacteria to increase their effectiveness, or adding engineered soil bacteria to improve crop nutrient uptake.[103]

- Other approaches include directly engineering insects to spread sterility or other traits, in some cases applied to a whole insect population – known as 'gene drives.'[104]

- **Engineered nitrogen fixation:** This approach artificially increases the amount of nitrogen fixed by plants through synthetic biology, thereby reducing fertilizer requirements. This is done either by engineering plants to take up and fix more nitrogen,[105] by introducing gene-edited microbes that attach to plant roots and fix nitrogen,[106] or potentially by introducing an engineered structure into crops that allows them to produce their own nitrogen.[107]

Instead of relying on conventional chemical action, synthetic biology transmits biological information that influences plant or insect development and gene expression. Moreover, microbes, gene drives, and genetically modified plants can self-replicate, meaning they have the ability to spread their biological 'messages' independently over time.

x The term 'bioeconomy' refers to economic activities based on biological and purportedly environmentally friendly solutions.

How viable are these solutions, and how transformative could they be?

In theory, genetic approaches provide an avenue towards reducing fossil fuel-intensive agrochemicals. Framed as 'nature-based' or 'nature-identical' solutions, genetically engineered microbes, biomolecules, and organisms are also promoted as safer alternatives that could mitigate some of the biodiversity and health risks associated with conventional agrochemicals. However, in practice, synthetic biology carries serious risks to health, ecosystems, and social equity – risks that call into question the viability of the approach altogether.

Firstly, much of the petrochemical use in pesticides is hidden, and complete phase-out is not guaranteed. Petrochemicals in pesticides are in hidden surfactants, emulsifiers, and additives, which are used to increase the potency and uptake of these external inputs.[108] These elements also feature in RNAi sprays.[109]

Secondly, the potential health effects of RNAi technology are unknown. Yet, farmers, farmworkers, and nearby communities may be exposed through airborne drift, while consumers could ingest synthetic RNAi residues in food. Preliminary research suggests that naturally occurring interfering RNAs in mammalian diets play a role in regulating metabolism, raising concerns that synthetic RNAi, whether inhaled or ingested, could unintentionally disrupt key physiological processes in mammals, including humans.[110]

Further, the field of synthetic biology remains controversial. Release to the wild of living engineered organisms risks extensive and irreversible disruption to food webs and ecosystems. Since genetic engineering and synthetic biology alter the basis of how living systems function, reproduce, and communicate, the long-term impacts on ecosystems are uncertain. For example, genetic pesticides such as RNAi may disrupt non-target beneficial insects and pollinators (e.g., honey bees). They also risk making unwanted and off-target genetic changes that are passed onto other species and future generations. RNAi is also expected to contribute to the familiar treadmill of escalating inputs, as weeds and insects develop resistance – potentially even requiring the genetic engineering of weeds to 'resensitize' them to herbicides.[111,112]

> ***Quite a lot of money is invested to tweak current ecologically damaging agricultural practices, but we never step back to ask whether we need these practices in the first place.***
>
> **Raj Patel**
> Fuel to Fork podcast

There are also power and equity issues, as these technologies are controlled by just a handful of large transnational corporations. Like many 'substitution' pathways, swapping out fossil-based agrochemicals for genetic pesticides and 'biologicals' sustains the logic of current systems – and the power imbalances that accompany them. Genetic and syn-bio approaches fit seamlessly into a paradigm of capital-intensive, input-intensive, large-scale monoculture production, i.e., approaches that oversimplify agroecosystems and drive farms towards overproduction, ultimately depleting nutrients and narrowing agricultural genetic diversity. By adapting weed species to proprietary (genetic) pesticides, some of the approaches described above could be used to lock in agricultural landscapes that benefit large and powerful corporate interests, further concentrating economic and decision-making power in food systems.

Indeed, a small handful of biotechnology firms (and increasingly, data firms) exercise control over the DNA sequences and intellectual property in question, granting those firms outsize power over the future of food and agriculture.[113] With 142 patent families acquired between 2013 and 2023, Bayer holds the most RNAi-based crop protection patents, followed by Corteva with 19.[114] These patents add to their existing dominance in agricultural inputs, where together they hold 40% of the seed market and more than 25% of the agrochemical market.[115]

The rapid development and release of genetically engineered organisms is outpacing regulatory oversight, unfolding at a time when public regulatory capacity is being actively dismantled. Corporations like Bayer and Corteva are aggressively patenting genetic traits – whether naturally occurring or engineered – while simultaneously lobbying to exempt these organisms from safety checks and labeling.[116] This raises serious concerns about transparency, biosafety, and corporate control. Moreover, these technologies carry potential for militarization, including use in bioweapons systems.[117]

> ***In the US, agribusiness spends more on lobbying than the oil and gas industry or the defense industry. Their hands are wrapped tightly around the neck of government.***
>
> **Raj Patel**
> Fuel to Fork podcast

DIGITAL FARMING PLATFORMS AND PRECISION AGRICULTURE

What are digital farming platforms and precision agriculture?

The push for digital agriculture is now everywhere in food system discussions, and is increasingly presented as a pathway towards more efficient and more sustainable food systems, and notably, reduced agrochemical usage – claims that merit serious scrutiny.

Through 'digital farming' platforms like Bayer's 'Climate Fieldview™' and John Deere's 'Operations Center™', agribusinesses are teaming up with tech firms to build digital decision-making tools into farm machinery and landscapes. This includes major agrochemical firms, which are integrating digital agriculture offerings into their business model. These platforms gather data (often without charging money) and analyze data sets (machine-readable forms of information) about the farm, including information about weather, soil fertility, weeds, insects, disease, nutrients, moisture, and yield.[xi] Artificial Intelligence (AI) tools, located in distant 'cloud' data centers, process these reams of farm-level data to create digital models of specific farms (called 'digital twins') and generate farm-specific prescriptions.

Through these approaches, proponents argue that fossil fuel use can be more efficient, and productivity and sustainability increased, in a number of ways:

- Shifting from the current over-application of agrochemicals to targeted (and supposedly more limited) 'precision' applications[118] guided by granular farm-specific data. This technology can further be augmented by using plastic-coated fertilizers and pesticides that slowly release chemicals or nutrients into soils, reducing losses to air or water.
- Replacing agrochemicals with mechanical and non-chemical forms of weed control, e.g., employing lasers, or fleets of small robots to zap and remove weeds.[119]
- Reducing fuel consumption of agricultural machinery in field work through the combination of 'autosteer' technologies (e.g., self-driving tractors) and more targeted application of inputs.[120]

How viable are these solutions, and how transformative could they be?

Cutting back on fossil fuel-intensive agricultural inputs is essential and is used as a key justification for bringing data-driven efficiencies to industrial farming. However, when examining real-world data rather than modeling scenarios, the results are far from clear.

For example, a USDA field study found that autosteered tractors, commonly used in precision agriculture, can actually increase fuel use.[121] However, this finding calls for nuance as precision farming may lead to higher fossil fuel consumption than conventional agriculture, while simultaneously reducing other environmental impacts.[122] In other cases, the data has not been made readily available.

For example, key data underpinning a 2021 study by the Association of Equipment Manufacturers and the pesticide lobby group Croplife, which advanced bold claims about the efficiencies and energy savings of digital/precision agriculture, is unavailable.[xii]

xi For an overview of digital farming and precision agriculture, see for example, U.S. Government Accountability Office. (2024). Precision Agriculture: benefits and challenges for technology adoption and use.

xii According to the study, precision agriculture had improved "fertilizer placement efficiency" by an estimated 7%, decreased herbicide use by 9% and decreased on-farm fossil fuel use for machinery by 6%. See Association of Equipment Manufacturers (AEM). (2021). The environmental benefits of precision agriculture in the United States.

Further, the algorithms that set precision fertilizer applications may be focused more on increasing production per hectare than on reducing total fertilizer use. As one industry source explains, *"[w]e reduce the total amount very little, but we have found by redistributing it within the field the value per unit of input goes up and the ROI (return on investment) on fertilizer dollars comes in."*[123]

Tractor electrification to phase out fossil fuels on farms faces many challenges, including limited range, high upfront costs, and inadequate charging infrastructure. Farmers also worry about battery performance and maintenance.[124] In low-income countries, steep purchase prices and low awareness of vehicle emissions limit interest and uptake.[125] Some manufacturers are developing tractors with improved battery technologies, but these remain in prototype stages and target large-scale, industrial farming operations.[126] While interest is growing, especially in high-income countries where some farmers are willing to pay more for cleaner machinery,[127] widespread adoption remains a long way off.

Plastic-coated fertilizers and pesticides, whose use is on the rise, not only reinforce agrochemical dependence but also represent an overlooked yet major source of microplastic pollution, with their plastic encapsulation potentially intensifying the already serious environmental and health risks of agrochemical use.[128]

Precision agriculture technologies are often out of reach for resource-poor farmers, who often lack access to digital services, digital literacy, or the financial means to adopt them.[129] But even wealthier farmers in high-income countries face significant hurdles – tools can be costly, difficult to operate, or incompatible with existing equipment and practices.[130]

> ***AI doesn't just advise farmers – it locks them into using specific seeds, fertilizers, and herbicides.***
>
> **Jennifer Clapp**
> Fuel to Fork podcast

In many cases, the promised benefits of precision farming remain limited by real-world challenges in both affordability and usability.

> ***Adopting the variable rate fertilizer technology sounds really nice, but we're in our third year of pulling our hair out at the functionality of the technology and getting it to work with our farming equipment. It doesn't work right.***
>
> **Joanna Larson**
> Fuel to Fork podcast

Most significantly, data processing and AI tools for digital platforms have major energy requirements of their own. Data consists of electronic signals, and the storage, processing, and transmission of these signals requires electrical energy, often generated by coal or fossil gas. Data processing, housed in large energy-intensive warehouses called 'hyperscale data centers', is expanding rapidly. These consume energy to run computation and storage, to cool down the servers (through air conditioning and refrigeration), and in the production of the hardware itself.[131]

The energy requirements of data processing have recently skyrocketed, particularly as a result of AI, which requires much heavier computation. Food and farming data is particularly 'big' as it entails prescriptions on a farm scale. Even before the recent boom in generative AI, global data center electricity consumption had been growing at 12% annually since 2017 – over four times faster than the growth rate of overall electricity consumption – reaching 1.5% of global electricity demand by 2024.[132] With the accelerating rise of AI, data center electricity use is projected to more than double by 2030.[133]

Renewable energy production is struggling to keep up with expanding data-center demand. In the US, fossil gas is projected to supply some 60% of new capacity,[134] while coal-fired power stations, which had been scheduled to retire, are being kept online to power data centers.[135] In early 2025, the incoming Trump administration declared an energy emergency in the US in order to generate more energy to power AI data centers.[136] In Ireland, some 80 data centers already consume a fifth of that country's electricity, expected to rise to a third within the next few years.[137] Huge additional volumes of fossil energy are required for data transmission, especially to rural and remote farm locations using wifi, 5G, and edge computing networks, with concurrent GHG emissions impacts (see Box 4).

> ***Data centers – the backbone of digital farming – are massive energy hogs, requiring constant water for cooling and power to operate.***
>
> **Pat Mooney**
> Fuel to Fork podcast

BOX 4

DATA CENTERS AND THE BALLOONING ENERGY AND CARBON FOOTPRINT OF BIG TECH

Amazon, Microsoft, and Google are the three industry leaders in AI adoption and data center expansion. Driven by the 'generative AI' boom, and despite their 'net-zero' initiatives, Amazon, Microsoft, and Google have seen their emissions soar.[138,139,140] For example, Microsoft's emissions increased by 29% since 2020, primarily from the construction of data centers.[141] Indeed, capital investment in 2023 by Amazon, Microsoft, and Google for AI adoption and data center expansion was greater than that of the US oil and gas sector.[142] By 2030, US data center emissions could nearly double as rising energy demands continue to rely on gas-fired power generation.[143] Securing enough clean energy will be challenging due to the rapid and significant growth in their power consumption.

Data centers also use tremendous quantities of water to cool down servers,[144] while semiconductor production requires significant amounts of energy, water, chemicals, and minerals – both contribute to substantial environmental and human rights impacts.[145,xiii] The production of components for on-farm digital equipment may also result in higher e-waste in rural settings.

Besides the material and energy costs of digital farming, food movements are raising serious social, economic, and justice concerns about these innovation pathways, as will be comprehensively explored in IPES-Food's next major report. Data-driven farm platforms and AI-driven automation risks further concentrating economic power in the hands of a small number of tech and agribusiness firms, moving decision-making away from smallholder farmers and farmworkers and undermining their agency, in ways that could ultimately threaten their livelihoods.[xiv]

Companies are also using digital agriculture agreements as a basis to restrict farmers' 'right to repair,' or to manage their own equipment.[146] At the same time, these companies gain a strategic advantage by collecting vast amounts of farm data – often for free – which they use to develop products, shape prices, and lock farmers into dependent relationships, further entrenching their market dominance and deepening inequalities in the food system.[147]

> ***Digital farming shifts power away from farmers and into the hands of agribusinesses and tech firms, which increasingly control the tools, inputs, and ownership of farm data.***
>
> **Pat Mooney**
> Fuel to Fork podcast

xiii Digital components are made out of different types of metals such as aluminum, copper, tin, tantalum, lithium, gallium, germanium, palladium, cobalt and tungsten. These are not inputs that were previously significant in farming systems. Hundreds of tonnes of ore typically need to be dug up and processed to get a single ton of relatively common metals such as copper or aluminum. See Mills, M.P. (2020). Mines, Minerals, and "Green" Energy: A Reality Check. Manhattan Institute.

xiv This concern is particularly acute where farmers are being placed in long-term contractual agreements with digital farming companies, requiring they follow AI-derived 'prescriptions' in return for carbon farming payments. Such agreements may lock farmers into contracts with agribusiness for up to a decade, while surrendering extensive farm data to corporate entities. See ETC Group. (2024). Trojan horses on the farm: Six critical questions – challenging the digitalization of the agrifood chain.

ADDRESSING FOSSIL FUELS IN THE MIDDLE OF THE CHAIN

Incremental fixes or false solutions?

2

What is the problem?

The biggest share of fossil fuel usage in food systems, 42%, occurs in the middle of the food chain, i.e., in the energy-intensive processes through which foods are transformed, manufactured, packaged, and shipped to retailers and end consumers.[148] To ensure the efficient and safe handling of food, processing and transportation rely on energy-intensive equipment, refrigeration, and vehicles that all still largely run on fossil fuels. Energy use in the middle of the chain is rising globally, due to the growing consumption of ultra-processed foods and longer supply chains, which increase processing and packaging as well as food miles.

Food processing often requires heat (e.g., for sterilization, pasteurization, baking, and drying), which is energy-intensive to generate and accounts for 60-70% of the total energy needs of food manufacturers.[149] Although electricity can equally be deployed to power these processes, fossil gas is traditionally used.[150] Food processing often involves breaking down whole foods, such as corn, wheat, and soy, through physical and/or chemical methods into components like sugars, oils, fats, proteins, starches, and fibre. Wet milling is commonly performed to grind down corn and is particularly energy intensive.[151]

Ultra-processed foods (UPFs) are industrially manufactured food products made up of formulations of ingredients that are in turn a result of a series of industrial processes.[152] UPFs are particularly energy-intensive, using 2 to 10 times more energy in their production than whole foods.[153] These products – heavily subsidised,[154] fiercely promoted,[155] highly profitable,[156] and designed to induce over-eating[157] – already make up a significant portion (up to 60%) of the total calories consumed in many wealthy countries.[158] Urbanization and rising incomes in low-income countries have led to increased food consumption and greater dietary diversity, including more dairy, fish, meat, legumes, fresh fruits and vegetables, as well as a rapidly growing intake of processed foods in a number of regions.[159]

> ***The food system isn't just a supply chain. It's a system that makes fossil-fueled farming, plastic packaging, and ultra-processing feel perfectly normal. Fossil fuels are there every step of the way, making normal some of the weirdest things about the way we eat.***
>
> **Raj Patel**
> Fuel to Fork podcast

High fructose corn syrup is a common ingredient in ultra-processed foods. While conventional corn production already uses ample fossil fuels (thanks to synthetic fertilizers and pesticides), the rest of the process is even more energy-intensive, with wet milling and refining – powered primarily by fossil fuels – accounting for some 80% of the total energy required to produce high fructose corn syrup.[160] Some newer forms of food processing are particularly energy-intensive. For example, cultivated meat (culturing animal cells in a factory using biotechnology) is more than twice as energy-intensive to produce as chicken.[161]

Beyond their fossil fuel footprint, UPFs are detrimental to human and environmental health. Evidence from numerous global studies consistently links ultra-processed food consumption to a wide array of adverse health outcomes, including premature death, cancer, and various cardiovascular, gastrointestinal, and metabolic diseases.[162,163] Further, the production of ultra-processed foods relies on large-scale monoculture farming, the use of significant energy during production, long-distance transportation, and excessive packaging. As such, ultra-processed foods can significantly contribute to land-use change, greenhouse gas emissions, high water use, as well as high energy use.[164]

> ***The real food desert is the one in our guts. Ultra-processed foods and the narrowness of the food system have wiped out the microbial diversity in our guts. The long-term nutritional and mental health impacts are only just being explored.***
>
> **Pat Mooney**
> Fuel to Fork podcast

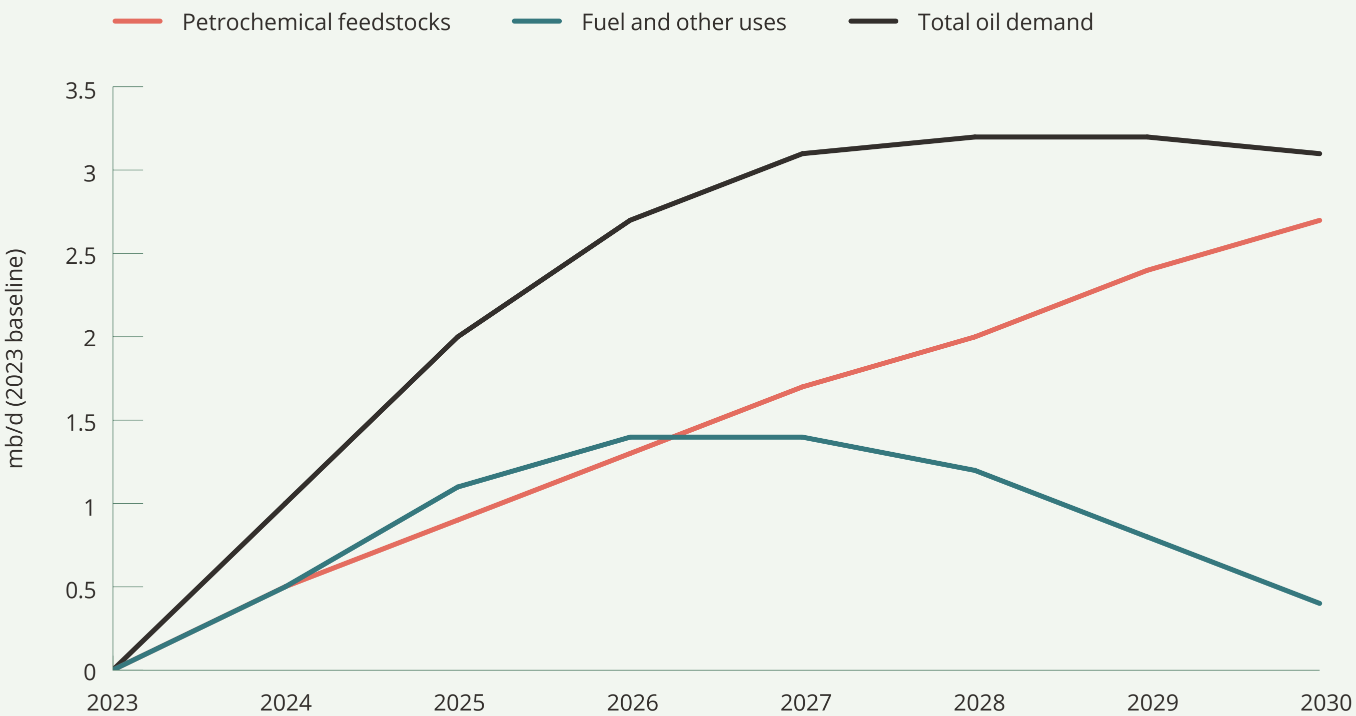
Plastic food packaging is a huge source of fossil fuel usage in the middle of the chain, with plastics widespread across the food system, including on the farm (see Section 1).[165] Globally, food and drink packaging accounts for at least 10% of all plastic production.[166] Ultra-processed foods, in particular, are heavily wrapped in plastic, compounding the problem.[167] Asia leads the plastic packaging market with over 43% of global revenue in 2023 and is projected to grow fastest through 2030, particularly in China, India, Vietnam, South Korea, and Thailand.[168] China dominates as the top producer and consumer of plastic packaging.[169]

Petrochemicals – especially plastics – account for around 14% of total oil demand, and plastic production is expected to more than double by 2050.[170,171] Petrochemicals are on track to become the single largest driver of oil demand growth, accounting for over a third of growth through 2030, and nearly half by 2050 (see Figure 6).[172]

FIGURE 6

PETROCHEMICALS SET TO DRIVE OIL DEMAND

Cumulative oil demand growth projections from 2024-2030 (million barrels per day)



While oil demand for energy is projected to decline with the clean energy transition, petrochemical production is set to rise. The fossil fuel industry is increasingly relying on plastics and other petrochemicals to absorb excess oil supply and drive future global demand.

Source: IEA (2024). Oil 2024

Recycling has been widely promoted by the plastics industry as the primary solution to plastic waste, but this narrative has diverted attention from upstream solutions such as reducing production and redesigning packaging.[173] In reality, plastics were never designed to be recovered,[174] less than 10% of plastics are recycled globally,[175] and food packaging is among the most difficult to recover due to contamination and complex material mixes.

Plastic's reputation as a recyclable material has been carefully cultivated by industry groups, misleading consumers and policymakers alike.[xv] This illusion has not only shifted the cost and responsibility of plastic waste management onto consumers, local governments, and informal waste workers, but has also allowed the plastics industry to continue expanding production and protecting its profit margins.

The rise in plastic usage – particularly single-use plastics, whose production surged amid public health concerns during the COVID-19 pandemic – has led to a sharp increase in plastic pollution.[176] Food and beverage companies play a disproportionately large role in driving this trend.[177] Coca-Cola, PepsiCo, and Nestlé have consistently been the top three plastic polluters since global brand auditing campaigns began in 2018.[178] In the most recent audit, 83% of all collected and counted plastic waste was food packaging, primarily bottles, food wrappers, and containers.

> ***Plastic production is plastic pollution – and the biggest drivers are food and beverage companies. They have enormous power to change the system, but they aren't making any substantial changes to their business models.***
>
> **Emma Priestland**
> Fuel to Fork podcast

> ***For every dollar spent on food in the US, more than two dollars go to cleaning up its consequences – from healthcare and worker exploitation to environmental destruction and climate change. These hidden costs are concealed deliberately and effectively by the food industry.***
>
> **Raj Patel**
> Fuel to Fork podcast

The impacts of plastic packaging reach far beyond fossil fuels, posing risks to both human and ecosystem health, particularly in terms of the harmful chemicals they are made of and the explosion in microplastic pollution. Microplastics have been found in human organs and tissue, including blood, lungs, brain, placenta, and breast milk, with research indicating they are toxic and linked to a range of serious health conditions.[179]

All plastics, including those used for food packaging, contain thousands of chemicals, at least 4,219 of which are known or suspected to pose risks to human health.[180] For example, humans are exposed to BPA (Bisphenol A) and phthalates in plastic food packaging, which are linked to serious health risks, including cancer, reproductive problems, and hormone disruption.[181] However, many plastic chemicals remain entirely untested, and those labeled as safe often lack evaluation against the most current, hazard-based safety standards.[182]

xv See, for example, The Recycling Partnership campaign funded by the PepsiCo Foundation which frames plastic waste reduction as the responsibility of municipalities and consumers.

Finally, in the middle of the chain, food transportation also has a fossil fuel footprint. While food transportation relies on fossil fuels, its role is relatively small compared to the broader fossil fuel footprint of food systems. Food miles often get more attention because they are more visible to consumers, who tend to think about fossil fuel use in their own travel.

The combustion of fossil fuels in trucks, trains, ships, and airplanes accounts for some 2 billion barrels of oil per year, and 4.8% of food-related GHG emissions.[183,xvi] Despite accounting for just 31% of global food miles, road freight emits 81% of food system transportation emissions.[184] Rail freight, a little more than half of which is electrified,[185] follows with 15% of emissions.[186]

In contrast, shipping accounts for nearly 60% of total food miles and yet is the most carbon-efficient mode per ton-mile, contributing only 3.6% of total transport emissions.[187,188] Aviation is the most carbon-intensive mode per ton-mile, but remains a niche contributor (less than 0.5%), used mainly for high-value, perishable items like fresh fruits and seafood, which require rapid delivery over long distances.[189] As urbanization intensifies, global trade flows – including food shipments – continue to rise, especially in rapidly developing regions of Asia, Latin America, and Africa.[190]

Once again, the impacts extend beyond climate change. Fossil fuel-powered transportation emits pollutants like particulate matter, nitrogen oxides, and sulfur oxides that harm human health and ecosystems. Every year, particulate pollution contributes to an estimated 2-6 million premature deaths worldwide.[191]

Major transport corridors – often in or near densely populated areas – bring elevated health risks, particularly for children, the elderly, and people with chronic cardiovascular or respiratory conditions. Heavy fuel oils used in shipping emit substantial sulfur oxides, fueling acid rain and ocean acidification.[192] Long-distance transportation must also contend with rising geopolitical instability and bottlenecks in highly concentrated global shipping routes, representing risks to food security.[xvii]

> ***Fossil fuels are – disturbingly – the lifeblood of the food industry. From how food is grown, processed, and packaged to how it's refrigerated and delivered, nearly every step is fossil fuel-based.***
>
> **Errol Schweizer**
> Fuel to Fork podcast

xvi Transportation accounts for 4.8% of food systems emission, or ~864Mt CO_2 eq, according to Crippa et al. This is comparable to the potential emissions of 2 billion barrels of oil, according to the EPA. Calculated using the EPA's greenhouse gas equivalencies calculator.

xvii Major 'chokepoints,' where a significant share of global trade passes, include the Panama Canal and the Strait of Malacca, which are significant for linking western and Asian markets, the Turkish Straits (particularly for wheat), and others in the US, Brazil, and the Black Sea. Chokepoint risks are rising due to three main hazards: weather and climate-related disruptions, security threats from conflict and crime, and institutional actions like export controls or closures by authorities. See Bailey, R., & Wellesley, L. (2023, May 18). Chokepoints and vulnerabilities in global food trade (Updated report). Chatham House.

MOVING TO 'CLEAN' FOOD PROCESSING

What does 'cleaner' food processing look like, and what steps are food companies taking?

Significant steps to improve energy efficiency and switch to renewable power in food processing appear to be financially viable and technically feasible, and shifts are already underway in the sector. Since most food processing requires heat at medium or low temperatures, and cooling and refrigeration are already provided by electricity, research has shown that renewable energy sources can readily replace fossil energy in this sector.[193,194]

Renewable energy is already being utilized by many manufacturers, with ongoing projects demonstrating the feasibility of solar thermal energy.[195] Solar thermal energy captures sunlight to generate heat, which can then be directly applied for heating water, air, or for industrial processes like drying, heating, and cooling.

A key challenge – and arguably one of the simplest – is to improve the efficiency and reduce the total energy requirements of existing food processing systems. This includes avoiding idle equipment, optimizing production scheduling, and improving equipment maintenance.

For example, an average industrial cookie-baking oven is only 35% energy efficient, meaning most energy is lost into the air.[196] Improving the insulation and heat recovery of ovens can dramatically reduce energy consumption.[197]

Switching all current electricity use to renewable sources is another crucial challenge in phasing fossil fuels out of food processing, including through on-site renewable generation, e.g., through geothermal or solar panel installations.

Decarbonization can also be achieved through the adoption of new, energy-efficient equipment. Heat pumps, which run on electricity, are an emerging technology that can readily replace fossil gas-burning equipment in the food and beverage industry. They provide both heating and cooling, are highly efficient, and help recover excess heat.[198] Investments in new equipment can be expensive, but through energy savings, they have been shown to pay for themselves fairly quickly.[199]

How viable are these solutions, and how transformative could they be?

A wholesale shift towards greener processing could be highly significant. Many manufacturers are now investing in energy optimisation strategies, and a number of the largest food and beverage manufacturers have already set and met goals to source electricity from renewables, usually by negotiating power purchase agreements.[200,201,202] If implemented across the sector, these steps could drive down the fossil fuel and climate footprint of food processing.

However, while generally feasible, some technical challenges remain in terms of scaling the best practices, as well as a lack of political will. Firstly, energy efficiency measures for the food and beverage industry are not well known, understood, or prioritized, and most companies, wary of risk, stick to the status quo to avoid jeopardizing food quality.[203]

Secondly, it remains challenging to electrify and improve equipment that runs on fossil gas, still the dominant fuel source in food processing, largely due to favourable policy incentives that keep fossil energy relatively cheap.[204]

Electrification – for example, to replace gas boilers with electric boilers or heat pumps – requires a large initial investment in infrastructure upgrades and can significantly raise operating costs, sometimes even doubling them.[205] Small and medium food and beverage manufacturers, in particular, cannot afford to invest in energy efficiency or renewable energy integration, and lack appropriate financing mechanisms.[206]

Thirdly, shifting food processing to clean electricity entails significant additional demand for renewable energy, and with it, difficult trade-offs associated with the energy transition (more on this in Section 4). Although some of these pressures could be alleviated by renewable power generation on-site, progress to date has been painfully slow, and policy incentives remain weak.

Some firms have made significant investments in renewable energy generation. For example, a PepsiCo facility in Ireland is generating over 20% of its electricity through rooftop solar.[207] However, these investments in renewable energy generation can be expensive – 2.4 million EUR in the case of PepsiCo – and often require new plants to be constructed in favorable areas. While notable, renewable energy investments alone by ultra-processed food manufacturers do nothing to address the broader health and environmental impacts of their business models.

Getting fossil fuels out of food and beverage manufacturing remains a distant prospect for many companies. The most significant levers of change remain untouched, and many companies are failing to meet or backtracking on their already modest sustainability targets.[208,209] Arguably, curbing the production of UPFs, particularly among the world's largest UPF producers, is the greatest opportunity in terms of reducing total energy requirements, reducing plastic packaging, and driving major health gains.

However, food companies are reluctant to address UPFs and, in some cases, are actively undermining political action (see Box 5).

> ***Bear in mind that the fossil fuel industry and the food industry to some extent work hand in glove.***
>
> **Raj Patel**
> Fuel to Fork podcast

BOX 5

HOW THE FOOD INDUSTRY UNDERMINES PUBLIC HEALTH POLICIES

Major food corporations frequently use aggressive tactics to weaken or block public health and environmental policies, mirroring the strategies long employed by fossil fuel companies to delay climate action.[210] As concerns over health and environmental harms have grown, many countries have introduced measures to reduce ultra-processed food consumption and ban single-use plastics. In response, leading food and beverage companies have worked to undermine these efforts – funding research to cast doubt on policy effectiveness, lobbying heavily against regulations, promoting voluntary self-regulation as a substitute, and even targeting advocacy groups through threats and surveillance.[211,212]

The world's largest food and beverage manufacturers, led by Nestlé, Coca-Cola, Unilever, PepsiCo, and Danone, have built an extensive global network of interest groups spanning multiple jurisdictions and governance arenas, creating a powerful system that makes it significantly harder for governments to implement strong public health and sustainability measures.[213]

REPLACING FOSSIL FUEL-BASED PLASTICS WITH BIOPLASTICS

What are bioplastics?

Plastics are rife along the food chain, especially in food packaging, and represent a huge source of revenue, present and future, for fossil fuel and petrochemical firms. While a number of approaches exist to reduce plastic packaging, bioplastics have been the main focus of attempts to replace conventional plastics in mainstream food retail supply chains.

Bioplastics is a broad term covering plastics that are bio-based, biodegradable, and/or compostable. Bio-based plastics incorporate some portion of organic materials into their feedstock, yet they are not necessarily biodegradable and often contain fossil-based additives.[214] Bio-based plastics are typically made from crops like sugarcane, corn, and potatoes. So-called 'next generation' bio-based plastics are made out of feedstocks such as food waste, algae, and mushrooms.

Biodegradable plastics can be bio-based or entirely made out of fossil fuels. Bio-based biodegradable plastics are widely used in takeout containers, cutlery, and bags, while fossil-fuel-based biodegradable plastics are used for mulch films in agriculture, compostable refuse bags, and cutlery.

Biodegradable plastics can break down into natural components – such as carbon dioxide, water, mineral salts, and new microbial biomass – but there is no commonly agreed standard for breakdown, with degradation periods ranging from weeks to centuries.[215]

In contrast, compostable plastics must meet more stringent standards to ensure full decomposition within a set period under specific conditions. For example, certain US standards require a complete breakdown within 12 weeks in commercial composting facilities,[216] while Europe's standard mandates total disintegration in three months and complete decomposition in six months.[217]

> ***Where are plastics in the food system? I think the more important question is, where aren't plastics in the food system?***
>
> **Emma Priestland**
> Fuel to Fork podcast

How viable are these solutions, and how transformative could they be?

Firstly, it is worth noting that bio-based plastics do not have identical properties to fossil-based plastic (e.g., in terms of durability and temperature resistance), and cannot readily replace plastic in its various applications in the food chain because of issues of food safety and shelf-life. Conventional plastics also tend to be much cheaper to produce and procure than the alternatives, although public policy incentives have an impact on the relative costs and remain skewed in favour of the fossil economy.

The economic viability of bio-based plastics depends largely on oil, energy, and feedstock prices, which shape the cost competitiveness of these materials. Limited consumer awareness further hinders their adoption.[218] These factors may explain why there has been so little movement towards bio-based plastics, with more than 99% of all plastic still made from fossil fuels.[219] Further, new evidence calls into question whether bioplastics are any safer for human health than conventional plastics. Even products made largely from biological sources can include fossil-based chemical additives.[220] Bioplastics have been found to contain thousands of chemicals, some toxic, making them similarly hazardous to conventional plastics.[221] These include per- and polyfluoroalkyl substances, known as PFAS, which have been used for decades to make food packaging resistant to grease and water. PFAS do not break down easily, which is why they are known as 'forever chemicals.' PFAS can migrate into food and build up in the human body, raising serious health concerns including cancer, immune system damage, and developmental problems.[222]

Further, the biodegradability of bioplastics – a key part of what makes them environmentally preferable to conventional plastics – is not always guaranteed. Biodegradation requires an aerobic environment – bioplastics will not biodegrade in anaerobic landfills – and industrial composting facilities require very high heat to compost bioplastics. Adequate composting infrastructures are often lacking, and the diversity of bioplastic materials presents significant barriers to effective recycling.[223] Even when composted, compost derived from biodegradable food packaging has been found to contain PFAS levels up to 20 times higher than compost made from manure or separated food waste.[224]

Beyond this, the scale-up of bio-based plastics raises challenges in terms of the diversion of land and resources away from food production, similar to the challenges facing biofuels. Replacing all plastic packaging with bio-based plastics would require over half of today's global maize production, a land area larger than France, and 60% more freshwater than the EU uses in a year.[225,226]

There are therefore major risks of pitting bioplastics production against food production, and – through the resulting competition for land – spreading agriculture into important natural areas and driving deforestation. Further, sugarcane, corn, and potato-based plastics typically rely on large-scale monocultures grown with agrochemicals, undermining the benefits of moving away from conventional plastics and adding to soil and water contamination from agricultural run-off.

'Next generation' bio-based plastics (made from food waste, algae, and mushrooms) are touted as a way around these issues. However, there are also trade-offs. For example, food waste diverted to bio-based plastics would no longer be available for on-farm uses such as feeding animals or providing nutrients to soils. Algae scale-up is also problematic. Micro algae require significant land and/or large amounts of water, energy, and continuous fertilizer input.[227] Macro algae are connected with widespread disruption of coastal ecosystems, and biomass processing that may entail significant CO_2 release.[228]

With all of these concerns, it is clear that oversight is needed. However, conflicts of interest are rife. Bioplastic certification programs are typically led by trade alliances and other representatives of bioplastics companies, often the same companies that produce conventional plastic. For instance, the board of the leading US compostable packaging certifier (BPI) includes executives from BASF,[229] one of four firms (along with Syngenta, Bayer, and Corteva) who control the majority of the seed and pesticide markets.[xviii] Meanwhile, the trade association European Bioplastics counts petrochemical corporations worth billions among its members.[xix]

xviii These companies are heavily invested in keeping fossil fuels flowing into petrochemicals. In 2022, BASF was ranked as the third most influential company blocking climate action globally by InfluenceMap, just behind Chevron and ExxonMobil. See InfluenceMap (2022). Corporate Climate Policy Footprint.

xix Members include BASF, TotalEnergies, Asahi Kasei Corporation, LG Chem, and Mitsubishi Chemical. See European Bioplastics. (n.d.). Members list. Accessed March 3, 2025.

DECARBONIZING TRANSPORT IN GLOBAL FOOD SUPPLY CHAINS

What does decarbonizing global food transport entail?

Decarbonizing transport is a major and urgent global challenge. Transportation accounts for one-fifth of global CO_2 emissions – a number that continues to rise. The primary focus of efforts to decarbonize transportation is on developing and rolling out low- or zero-emission vehicles, and in parallel, shifting to relatively lower-emission modes of transport wherever possible (e.g., substituting some air and road freight with rail or maritime shipping to achieve higher efficiency per ton-mile).

Given the prevalence of road freight in food transportation, and its high per-unit emissions, electrifying trucking is a central goal.[230,231] Governments have set ambitious targets under the Paris Agreement and beyond, aiming for significant electrification of new truck sales by 2030 and full electrification of heavy-duty fleets by 2040 in major economies.[232]

Electrifying rail freight and powering rail networks from renewable energy sources can also dramatically cut fossil fuel usage and GHG emissions in agri-food and other sectors. Biofuels offer another potential alternative to gasoline, but some could be even worse for the climate than gasoline (see below).[233]

Hydrogen- and ammonia-based fuels, including 'blue' ammonia, are also entering the mix, but they could be just as bad or worse than conventional shipping fuels.[234] While potentially relevant in hard-to-abate sectors where electricity cannot efficiently or affordably substitute fossil fuels,[235] these applications are still in early R&D phases,[236] and major question marks remain (see below).

How viable are these solutions, and how transformative could they be?

Sustainable transportation technologies are advancing rapidly. Declining battery costs, increasing battery energy density, and improved charging infrastructure and vehicle range are already making electric trucks more viable, especially for last-mile and short-haul delivery. Regulatory frameworks and incentives, e.g., EU policies mandating a 90% reduction in emissions by 2040, or California's zero-emission targets by 2035, could further accelerate this transition.[237]

In regions with robust rail infrastructure, a modal shift from road to rail could substantially reduce emissions. Further electrification of rail freight also appears to be a viable prospect. However, leveraging the potential of rail freight requires investments in rail infrastructure (particularly terminals to increase truck-rail transfers), as well as overhauling and aligning policy and regulations.[238,239] Examples of policies that encourage a combination of road and rail transport include tax exemptions for vehicles used in rail-road transport and lowering the minimum required distance for the rail portion of a journey.

> ***Fossil fuels are a one-time use. You take them out of the ground, you burn them, and you have to take more. With battery materials, you use them, and they can be recycled. So over time, we have to take less and less out of the ground.***
>
> **Rachel Muncrief**
> Fuel to Fork podcast

However, other aspects of change appear further off, with fossil fuel dependencies harder to cut. Heavy-duty electric trucks are more expensive, and trucking over long distances is more difficult to electrify due to the weight and energy density requirements of batteries.[240] While battery technologies have improved considerably, long-haul operations face range limitations and slower charging times.

Most importantly, the electrification of road and rail transport, and the powering of those grids with renewable energy, comes with important challenges and trade-offs. The production of batteries (e.g., for electric vehicles) requires lithium, cobalt, and other 'transition minerals,' also referred to as 'critical minerals.' Extraction of these minerals can entail mining in ecologically sensitive areas, contested land rights, and labor issues.[241,242] The broader challenges of ensuring a just energy transition will be explored in Section 4.

Aviation remains more challenging to decarbonize, still, but represents less than 0.5% of global food transport emissions.[243] Sustainable Aviation Fuels (SAFs), produced from natural feedstocks like used cooking oil and animal fats, currently represent the only viable low-carbon fuel option for aviation. Efforts to replace conventional aviation fuel with SAFs face significant challenges, including limited commercial viability, exaggerated claims, and the immense scale of global fuel demand.[244]

Sustainable Aviation Fuels account for only 0.3% of global jet fuel production, and despite billions invested, production remains largely unproven at scale.[245] Many SAFs are derived from controversial sources, including slaughterhouse byproducts and industrial monocultures of soy, corn, and palm oil, potentially entrenching harmful industrial production systems. Aircraft that run on hydrogen are still in development, and strict industry regulations will likely keep them in the demonstration phase for a long time before commercial adoption.[246]

A first portion of shipping emissions appears more straightforward to cut: a 10% reduction in operational speed can slash maritime emissions by around 20%, while also significantly curbing GHG emissions and harmful pollutants like nitrogen oxides and particulate matter.[247] Many studies show that the benefits of slowing down ships outweigh the costs, but measures may need to be taken to guarantee food quality over longer journeys.[248]

Cargill has trialled sail technologies on cargo ships, which reduce emissions and fuel consumption by an average of 14%.[249] These savings have the potential to increase with further development, but adoption rates across the shipping sector remain low.[250] With fluctuating fuel prices and freight rates incentivizing change, there has also been significant progress on ship fuel efficiency, outstripping the requirements of frameworks like the International Maritime Organization's Energy Efficiency Design Index.[251]

However, no straightforward alternative to heavy fuel oil is evident yet. Liquefied natural gas (LNG) is the most commonly proposed alternative, but the climate, human, and environmental health impacts associated with the extraction, transport, liquefaction, and regasification of LNG are the same as or worse than burning fossil gas itself (see Box 6).

There are also major limitations and harmful impacts to introducing ammonia-based shipping fuels. Using ammonia for shipping would demand equal or even double the amount of nitrogen currently used for agriculture,[252] and competition for the resource is significant.[253]

Ammonia is highly toxic to aquatic life and, if spilled, can trigger harmful algal blooms through eutrophication, depleting oxygen, and killing marine life.[254] When used as marine fuel, it also poses risks of air pollution by releasing nitrogen oxides, nitrous oxide, and unburned ammonia, with limited data and technologies available to control these emissions.[255] Further, its status as a 'clean fuel' remains largely aspirational. With 99% of ammonia production still fossil-based, ammonia-based shipping fuels could potentially lock in fossil fuel dependence (see also Section 1).

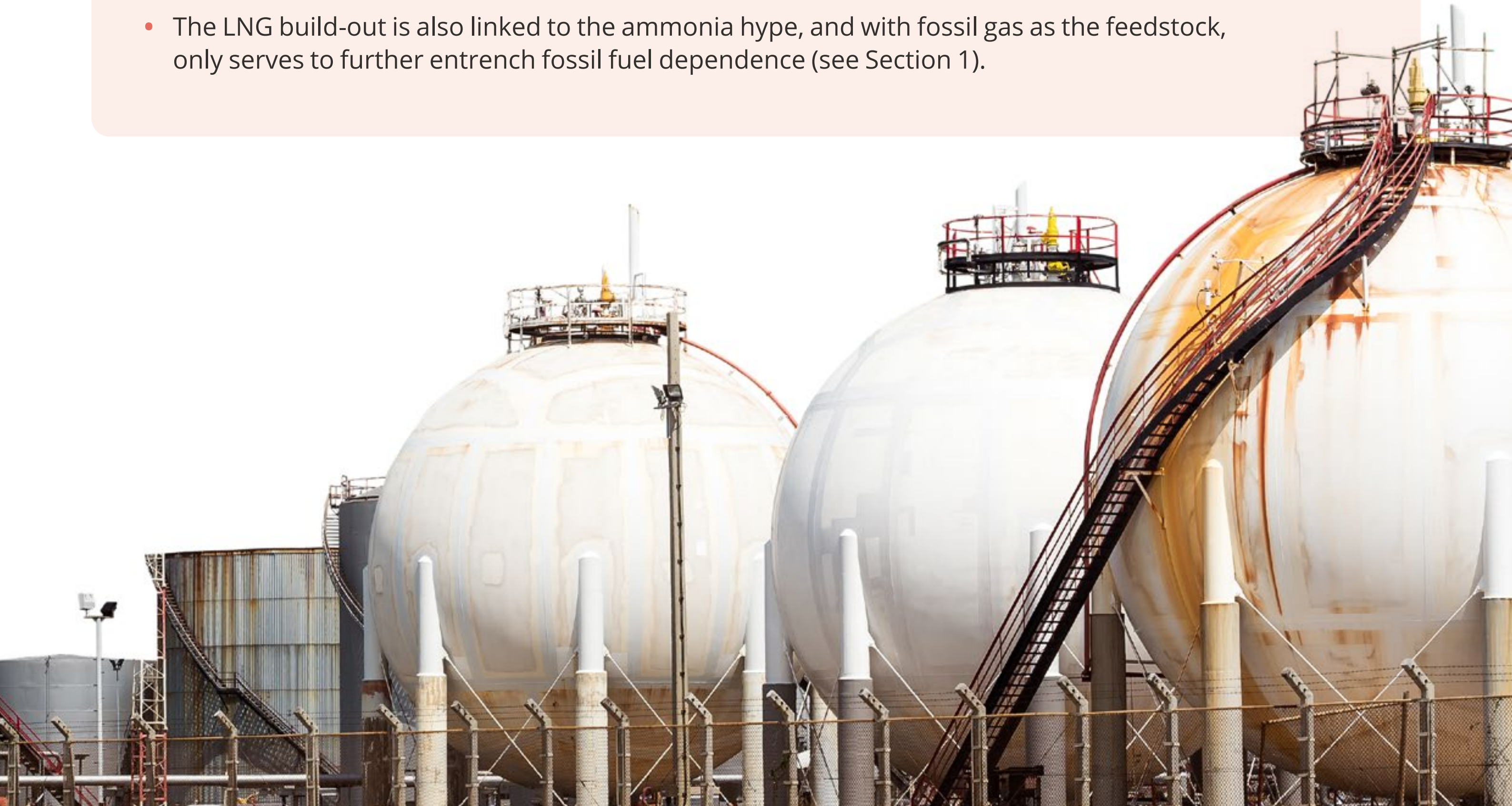
Finally, the potential of biofuels as a sustainable transport fuel, in food systems, or other sectors, remains extremely limited and subject to complex food-fuel trade-offs. A review of the Renewable Fuel Standard in the US (which accounts for nearly half of global biofuel production) found that the carbon intensity of corn ethanol production was likely 24% higher than gasoline and had driven a 3-8% increase in annual nationwide fertilizer use.[256]

While second-generation biofuels (e.g., made from agricultural and forestry waste) avoid land competition, they are not currently cost-efficient vis-à-vis conventional biofuels and fossil-based transportation fuels, requiring more costly and complex conversion processes into fuel. In 2021, only 1% of the total bioethanol production in the EU was second generation.[257]

BOX 6

LIQUEFIED NATURAL GAS (LNG), A 'SOLUTION' THAT COMPOUNDS MULTIPLE PROBLEMS

- The GHG emissions associated with the extraction, transport, liquefaction, and regasification of LNG can nearly match those generated by burning fossil gas itself, effectively doubling the climate impact of each unit of energy transported in the form of LNG.[258] And the GHG emissions of LNG are 33% worse than burning coal due to persistent methane leakage when burned on ships.[259]
- In comparison, the life cycle GHG emissions of solar power are less than 7% of those from LNG, while wind power generates less than 2% of LNG emissions.
- The estimated human and environmental cost of climate-related damage from US LNG exports was $8.1 billion in 2019. By 2030, when US LNG exports are expected to triple, these 'true costs' could rise to $30.5 billion.[260]
- LNG extraction and expansion have significant impacts on coastal communities and marine ecosystems. In the United States, communities of color disproportionately suffer from poor air quality near LNG facilities. Meanwhile, expanding LNG facilities in Mexico, the Philippines, Mozambique, and Brazil pose threats to local and global marine ecosystems, as well as to Indigenous and local communities.[261]
- The LNG build-out is also linked to the ammonia hype, and with fossil gas as the feedstock, only serves to further entrench fossil fuel dependence (see Section 1).



ADDRESSING FOSSIL FUELS IN KITCHENS AND COLD CHAINS

Incremental fixes or false solutions?

3

What is the problem?

Over a third of the world's population – ranging from 2.3 to 2.8 billion people in 2020 – relies on highly polluting solid fuels like wood, charcoal, and dung for cooking.[262,263] Reliance on these fuels is particularly acute in Sub-Saharan Africa, where more than 80% of the population still cooks with polluting fuels, a situation that will persist through 2030 without significant intervention.[264]

The burning and gathering of wood and charcoal for cooking and heating is responsible for around 2% of annual anthropogenic GHG emissions, primarily in the form of carbon dioxide and black carbon.[265,266] These fuels produce harmful pollutants such as particulate matter, carbon monoxide, and various volatile organic compounds. Chronic exposure to these pollutants is linked to severe respiratory and cardiovascular diseases, contributing to 3.2 million premature deaths each year.[267] Cooking that relies on biomass and fossil fuels is also a significant but under-recognised contributor to urban heat stress, particularly in low-income countries.[268]

Women and children bear the brunt of the impacts from harmful cooking fuels. High temperatures in cooking spaces raise the risk of heat-related illnesses, especially for women, who cook three times more than men.[269] 60% of global deaths attributable to indoor air pollution occur among women and children.[270] Further, the strenuous work of gathering charcoal, dung, and firewood is often performed by women and children. The World Bank estimates the negative toll of polluting cooking fuels on health, the environment, and gender equality at an astounding USD 2.4 trillion annually.[271]

> ***Food security is not only what goes into the pot but also what goes underneath that pot.***
>
> **Christa Roth**
> Fuel to Fork podcast

While shifting from solid fuels to fossil-based gaseous fuels, e.g., liquefied petroleum gas, represents an improvement in terms of moving to cleaner fuels, and liquefied petroleum gas can be scaled rapidly with minimal infrastructural investment, burning gas indoors still emits pollutants harmful to the climate and human health, including particulate matter and nitrogen oxides that can exacerbate respiratory illnesses, particularly in children.[272,273,274] In the US and Europe, where electric cooking (45%) is now more common than gas cooking (39%), some governments are enacting policies to phase out gas-based cooking.[275]

> ***Liquefied petroleum gas is a fossil fuel. Its whole supply chain has a huge climate footprint. While it may be cleaner to burn than solid fuels, you still have pollution.***
>
> **Christa Roth**
> Fuel to Fork podcast

Refrigeration is another aspect of the food chain with a substantial energy footprint. Although only 40% of foods require refrigeration, refrigerators and freezers consume roughly 15% of global electricity,[276] accounting for some 40% of energy consumption by the retail and supermarket sector.[277] Open refrigerated displays, common in retail stores, can consume up to five times more energy than closed units.[278]

Failure to ensure an effective cold chain has climate impacts of its own. Globally, 620 million metric tons of food are lost per year due to insufficient refrigeration,[279] meaning that all of the energy, inputs, and resources invested through the lifecycle of that food are wasted. This trend is particularly pronounced in low-income countries, where only about 20% of perishable food is refrigerated.[280] Furthermore, it has been estimated that inefficient cold chains around the world generate more than triple the annual GHG emissions of Canada;[281] and halving food loss and waste across the entire supply chain could mitigate up to 8% of annual GHG emissions.[282,xx]

Cold chain and food storage failures also have huge socio-economic impacts. In many low-income countries, inadequate refrigeration is a major cause of food loss – accounting for 37% in Sub-Saharan Africa, primarily within the critical 'first mile' between harvesting and processing.[283] As a result, farmers face significant spoilage and may be forced to sell quickly at unfavorable prices. Post-harvest losses have been estimated to cost smallholder farmers in the Global South as much as 15% of their income,[284] undermining local and national food security. In the Global North, a significant proportion of food waste – and associated climate costs – occurs downstream, driven by a combination of retailer practices and consumer behavior.

SHIFTING TO EFFICIENT COLD CHAINS, CLEANER COOKING FUELS, AND ELECTRIFIED KITCHENS

What are the main pathways to cleaner kitchens, cold chains, and refrigeration?

The definition of a more sustainable kitchen is dynamic and context-dependent. Where refrigeration is concerned, the focus of discussion is on closing the gap between low- and high-income countries, and upgrading cold chains to best-practice standards. In developed contexts, where refrigeration is already widespread, the focus is on converting electrical grids to renewable energy, improving efficiency, and curbing retail-level food waste. Efficiency gains can be made through energy-efficient practices and technologies.

The challenges are equally varied in terms of cooking. Gas-based cooking is cleaner than burning biomass and kerosene. In regions still largely reliant on solid fuels, shifting to fossil gas cooking can slash indoor air pollution, enable more efficient combustion, and lower GHG emissions, as well as curbing the environmental degradation and gender inequity associated with charcoal and firewood gathering.[285]

Elsewhere, the focus may be on moving from gas to electric cooking, particularly induction stoves, ultimately powered by renewable energy. Electric stoves would eliminate harmful air pollution associated with gas stoves.[286]

Induction stoves are three times more efficient than gas stoves and 10% more efficient than traditional electric ranges.[287] Indeed, approximately 40% of countries' climate plans include references to cooking.[288] Solar-powered cookers provide a key avenue to potentially accelerate the transition to clean cooking, especially in low-income countries.

> ***An induction stove is 90% efficient. As opposed to gas, where for every dollar you spend on energy, at best 35 cents is used.***
>
> **Chef Chris Galarza**
> Fuel to Fork podcast

xx The percentages listed are in relation to 2019 annual greenhouse gas emissions, which reached 57.4 gigatons of CO_2 equivalent emissions. This figure is based on the EDGAR data set, which is the most comprehensive data set on global greenhouse emissions up to 2019. See PBL Netherlands Environmental Assessment Agency. (2020). Trends in global CO_2 and total greenhouse gas emissions: 2020 Report.

How viable are these solutions, and how transformative could they be?

Improvements in the cold chain appear to be viable and to potentially have a high impact. Improving access to refrigeration in low-income countries could prevent up to 25% of food losses due to inadequate cold storage infrastructure.[289] Closing the gap between high-income and low-income countries could halve combined emissions from refrigeration and food loss (even accounting for the increased energy consumption of an expanded cold chain).[290] Further fossil fuel reductions would be unlocked as electrical grids transition to renewable energy.

There are also low-hanging fruits in the retail sector, though corporations are highly reluctant to shift existing business models. Simple measures – such as adding doors to refrigerated display cabinets, conducting better maintenance, and investing in high-efficiency refrigeration technologies – could halve grocery store energy use.[291] At the same time, food waste policies that encourage clearer date labeling and consumer education can potentially help to minimize waste and deliver significant environmental and economic benefits.

However, energy efficiency and the decarbonization of energy sources remain low priorities for most retailers, as energy accounts for only a small portion of overall production costs in the sector.[292]

As a result, companies often pursue only minimal improvements, with little incentive to fundamentally shift their business models. For instance, Kroger – one of the largest grocery retailers in the United States – has well-documented needs for increased staffing, infrastructure repairs, and store modernization. Yet rather than investing in these areas or in clean energy initiatives, the company chose to prioritize shareholder returns, executing a USD 7.5 billion stock buyback in 2024.[293]

> ***We need to look critically at refrigeration and scale back unnecessary uses. For example, we need to stop selling so many carbonated beverages in coolers.***
>
> **Errol Schweizer**
> Fuel to Fork podcast

Where cooking is concerned, solution pathways are more varied, more complex, and potentially even more transformative. A global shift from polluting fuels to cleaner alternatives such as liquefied petroleum gas (LPG) and electric cooking could cut cooking-related GHG emissions by up to 40% compared to 2018 levels – if universal adoption is achieved by 2040.[294] Encouragingly, the number of people using polluting fuels is projected to fall from 2.3 billion to 1.9 billion by 2030.[295] While LPG and electric cooking may initially offer similar emissions outcomes where grids rely on fossil fuels, the growing share of renewables means electric cooking could deliver deeper, long-term reductions and ultimately approach a near-zero carbon footprint.

In low-income settings, solar and solar-electric (hybrid) cookers offer opportunities to cut reliance on harmful solid fuels or other fossil-based cooking systems. About four million solar cookers had been distributed globally by 2021.[296] New hybrid solar-electric cookstoves are also nearing commercial viability. Solar-electric cookers have been successfully piloted by UNHCR in a range of locations, including displacement settings.[297] In 2023, India launched a new solar-electric cookstove technology, aiming to reach 30 million households within the first few years of the program.[298]

Although there are persistent barriers to the uptake of electric cooking in low-income settings (including high up-front costs), initial evidence suggests that hybrid solar-electric cookers could be well-adapted to these contexts, as well as helping to overcome some of the challenges associated with solar cookers, including slow cooking times and intermittency of power.[299]

Further, governments can set stricter air emissions standards, incentivize electrification, or mandate building codes that encourage all-electric appliances in new construction. For example, both Washington State and New York State require new buildings to meet high standards of energy use efficiency, with New York banning fossil gas for both heating and cooking, incentivizing enhanced market offerings of cleaner cooking solutions.[300,301,302]

However, such measures often face fierce resistance from the fossil fuel industry. In Berkeley, the first US city to ban gas hookups for new buildings, industry pushback led to the policy being overturned.[303] Across the US, gas industry front groups are infiltrating neighborhood organizations, deploying social media influencers, and bombarding communities with messaging to sow controversy over local bans on fossil gas.[304]

> ***The term 'natural gas' was a corporate construction. The industry created a norm around cooking in our homes with a toxic gas and marketed it as totally safe.***
>
> **Anna Lappé**
> Fuel to Fork podcast

Meanwhile, current levels of global financial and policy support for clean cooking are falling far short of what is needed to meet Sustainable Development Goal 7 – ensure access to affordable, reliable, sustainable, and modern energy for all. Advocates calculate that at least USD 5 billion in financing must be invested in the clean cooking sector by 2025, USD 10 billion by 2027, and USD 20 billion by 2030.[305] In 2020, improved cookstoves received USD 51 million in financing while electric cooking accounted for less than USD 5 million of tracked investments.[306] Without expanded and equitable financing, technology dissemination will remain slow and uneven, and the potential health, social, and environmental gains will remain unrealized.

CONCLUSION

What will it take to get fossil fuels out of food systems?

4

THE DANGERS OF 'TECHNO-FIXES' AND WHY ONLY TRANSFORMATIVE CHANGE WILL DO

Some of today's most widely-promoted 'fixes' risk locking-in fossil fuel dependence in food systems for decades to come – and these approaches are being rolled out at pace. In particular, the digitalization of agriculture is driving rapid expansion of energy-intensive data centers, while assuming perpetual usage of fossil-based chemical fertilizers and pesticides, albeit in more precise applications. Further, digital farming platforms are plugging data into new generations of fossil fuel-powered machinery, including tractors with a 20-30-year lifespan. Much of this so-called 'disruptive' innovation is being driven by chemical-intensive commodity crop systems that remain propped up by substantial government subsidies.[307]

Despite mounting concerns and underwhelming performance, government support for carbon capture and storage (CCS) tied to 'blue' hydrogen and ammonia production is growing. These facilities demand extensive new infrastructure, cementing long-term fossil fuel dependency.

Meanwhile, many of the substitution strategies being promoted – like 'green' ammonia or bioplastics – fail to address the root problems. Green ammonia does nothing to reduce the nitrogen pollution harming air, soil, and water. Bioplastics, often marketed as sustainable, may not biodegrade effectively and frequently contain thousands of synthetic chemicals that raise similar health and environmental concerns as conventional plastics. Both solutions also carry heavy land and natural resource footprints, worsening competition for land and undermining other sustainability goals.

The prevalence of these 'fixes' reflects a skewed and increasingly privatized innovation paradigm. With public investment in agricultural research and development (R&D) declining, the field is now largely driven by private sector interests, particularly agribusiness and tech companies. Their R&D priorities are guided by profitability, not the public good. As a result, innovation is focused on sustaining demand for proprietary inputs like agrochemicals and genetically engineered seeds, rather than shifting away from them.

This emphasis comes at the expense of approaches aimed at redesigning systems more fundamentally, through a mix of technological, social, and organizational innovation. Deregulation of both products and processes further removes public oversight from these technologies, leaving little space for democratic input or accountability. The public interest – equity, sustainability, and long-term resilience – is effectively absent from the dominant innovation agenda (as will be explored in IPES-Food's upcoming report on innovation pathways).

Dominant high-tech 'solutions' are also consolidating power in new and troubling ways. Digital agriculture platforms are giving unprecedented control to major tech firms and agribusinesses, while new genetic engineering and synthetic biology technologies pose similar risks. This concentration of power is not incidental – it is actively reinforced by the rising political influence of these industries. As food systems increasingly cater to corporate priorities, the convergence of agribusiness, big tech, and fossil fuel interests poses a serious threat to democratic governance and public accountability.

> ***The unequal power structures in food systems make it so that we're on this incredibly tilted plane where the multi-billion dollar players in the system keep urging us toward their high-cost pseudo-solutions.***
>
> **Darrin Qualman**
> Fuel to Fork podcast

Today, agribusiness spends more on lobbying the US Congress than the fossil fuel sector.[308] At global climate and plastics negotiations, corporate lobbyists routinely outnumber country delegations, using obstruction, misinformation, and intimidation to derail progress (see Box 7). They dominate decision-making spaces while sidelining frontline communities and public interest voices.

Major food corporations employ the same tactics as oil and gas companies to weaken or block regulations, from public health measures to environmental protections.[309] **Without reclaiming public control over food and energy policy, and reorienting innovation toward equity and sustainability, corporate-led 'fixes' will only entrench the very crises they claim to address**.

> ***Corporate capture of UN treaty negotiations is a severe problem. From plastics to climate, we're seeing the same playbook – industry lobbyists embedded in country delegations, shaping policies to serve corporate interests, not the public good.***
>
> **Emma Priestland**
> Fuel to Fork podcast

BOX 7

HOW INDUSTRY LOBBYISTS DERAIL GLOBAL CLIMATE AND PLASTICS AGREEMENTS

The Global Plastics Treaty is a UN-led initiative aiming to create a legally binding agreement to tackle plastic pollution across its entire life cycle – from production to disposal. But after two years of negotiations, talks collapsed in December 2024. A key sticking point was the refusal of oil-rich nations, led by Saudi Arabia, to accept any deal that placed limits on plastic production.[310] Industry influence was overwhelming: over 220 fossil fuel and chemical lobbyists attended the final round of negotiations, representing the largest single delegation.[311] Companies like Dow and ExxonMobil had some of the most lobbyists present.

Fossil fuel influence is also rampant at the annual climate negotiations, the **UN Climate COPs**. At COP29 in 2024, more than 1,700 fossil fuel lobbyists were granted access, outnumbering nearly every national delegation.[312] This follows a record-breaking 2,456 fossil fuel lobbyists attending COP28, which was hosted by the head of the UAE's national oil company.[313] Industry-affiliated lobbyists at COP28 were nearly four times the number present at COP27 in Sharm el-Sheikh.

Industrial agribusiness lobbyists are also increasingly active at climate negotiations. At COP29, 204 agribusiness lobbyists attended,[314] and 340 attended COP28.[315] Notably, nearly 40% of lobbyists at COP29 held country delegation badges, giving them privileged access to negotiations, up from just 5% at COP27.

While the COP28 agreement included a call for a "transition away from fossil fuels in energy systems," marking a shift from earlier texts that avoided naming specific sectors or actions, it still failed to address fossil fuel use in food systems.[316]

Therefore, a holistic transformation of food systems is essential – one that not only shifts practices but also challenges the entrenched power structures shaping them. Central to this is dismantling the agrochemical–petrochemical complex, which continues to drive ecological harm, fossil fuel dependence, and corporate consolidation. There are major opportunities to drastically cut fossil fuels, agrochemicals, and plastics in food systems, and move toward healthier, more sustainable alternatives. Before outlining this holistic vision, the next section examines a critical prerequisite for any meaningful shift away from fossil fuels: a just energy transition.

> ***The question I'm always keen on is not what can we substitute for fossil fuels, but what structural change would be required to make fossil fuels irrelevant?***
>
> **Raj Patel**
> Fuel to Fork podcast

A FOSSIL FUEL-FREE FOOD SYSTEM DEPENDS ON A JUST ENERGY TRANSITION

Plans to phase out fossil fuels in any sector of society rely on mass electrification and extensive production of renewable energy. Cleaner food processing, sustainable transportation, and other proposed solutions all require abundant, renewable-powered electricity. This approach underscores a central challenge: how to generate sufficient clean energy and ensure it is distributed equitably. In short, **achieving a fossil fuel-free food system hinges on a just energy transition**.

A successful clean energy transition will require renewables-based electricity to become the backbone of the energy system, supported by major improvements in energy efficiency and energy storage. Reducing overall energy demand through efficiency not only eases pressure on renewable infrastructure but also enhances resilience and accelerates the transition. Ensuring reliability from intermittent sources like wind and solar requires increased battery storage, demand response, and grid flexibility.[317] However, battery technology must rapidly advance and expand, including innovations in chemical makeup and improved recycling.[318] As highlighted by the recent blackouts in Spain and Portugal, it is also crucial to upgrade electricity grids to cater for increased renewable power, as current grids are insufficient.[319,320]

> ***The majority of coal and natural gas burning goes towards generating electricity. That is something that we can substitute. But how we mobilize the capital to ensure the transition happens in a swift and just way is political.***
>
> **Gabe Eckhouse**
> Fuel to Fork podcast

Renewable energy has become increasingly competitive. In 2023, 96% of new solar and onshore wind capacity cost less than new coal and fossil gas plants, and three-quarters of new solar and wind projects delivered cheaper electricity than existing fossil fuel facilities.[321] By 2024, clean power surpassed 40% of global electricity generation, driven by record growth in renewables, particularly solar.[322]

However, global energy demand continues to outpace the expansion of clean energy, climate change poses increased challenges, and emissions continue to rise.[323] Heatwaves in 2024 drove a surge in cooling demand, pushing electricity demand up by 4% – far above the 2.6% rise in 2023.[324] This led to an increase in fossil power generation and record power sector emissions. **Without major gains in energy efficiency, the clean energy transition will remain a race with an ever-distancing finish line**.

Further, **renewable energy production, storage, and transmission rely on 'transition minerals'** like lithium, cobalt, and rare earth elements, whose extraction poses environmental risks, human rights violations, threatens biodiversity, and can lead to conflicts over land and resource rights.[325,326] For example, the civil conflicts that have ravaged the Democratic Republic of the Congo are closely tied to the country's wealth of 'transition minerals.'

> ***Until we stop fossil fuel extraction, we are going to be stuck. Renewables are just augmenting fossil fuels for now, not replacing them significantly.***
>
> **Molly Anderson**
> Fuel to Fork podcast

Along with fossil fuel extraction, securing access to 'transition minerals' is now shaping global geopolitics and creating harmful new dependencies, as exemplified again in Ukraine.[xxi]

> ***Over half of the minerals needed for the energy transition are located on or near lands of Indigenous and peasant peoples. The green energy transition must be decolonized. We don't want to exchange one form of exploitation for another.***
>
> **Nnimmo Bassey**
> Fuel to Fork podcast

Moreover, the growing energy demand, driven by sectors such as data centers and artificial intelligence, raises significant questions about who benefits from this energy and how equity can be ensured in the global transition to renewable energy.

These challenges are further exacerbated by highly inequitable North-South relations. Under the Paris Agreement, high-income countries have pledged to lead the phase out of fossil fuels, yet they are granting record numbers of oil and gas licenses, and are consistently falling short on climate targets and finance for climate adaptation and energy transitions in low-income countries (see Box 8).[327] As a result, G20 nations account for nearly 90% of global renewable power capacity to date,[328] while low-income countries still face prohibitive costs. UNCTAD estimates that a clean energy transition for 48 developing economies would require USD 5.8 trillion annually, approximately 20% of their collective GDP.[329]

xxi At the time of writing, US security guarantees to Ukraine remain contingent on access to Ukrainian oil, gas, coal, and minerals (including rare earths), demonstrating the geopolitical importance attached to fossil fuels and critical minerals, and suggesting that the interests of major powers will override other concerns in terms of the future exploitation of these resources. See Democracy Now! (2025, May 1). Is Trump's "minerals deal" a fossil fuel shakedown? Antonia Juhasz on new U.S.-Ukraine agreement.

At the same time, the costs of critical mineral extraction are disproportionately borne by low-income countries, often by Indigenous Peoples who do not benefit from the renewable energy these minerals help produce. Over the coming decades, the risks of extractivism escalating at unprecedented scales – where raw materials flow from South to North and dirty technologies from North to South – are significant.

In food systems, like in many other sectors, it is therefore critical to ensure that efforts to phase out fossil fuels are part of a just energy transition. This requires careful strategies to phase out fossil fuel extraction and accelerate electrification, energy efficiency, and battery storage, while managing associated risks and ensuring an equitable energy transition with clearly differentiated responsibility among world regions (see Box 9).

> ***The future of the planet is inseparable from the future of the working class – and if we ignore that, we end up with climate solutions that just punish the working class.***
>
> **Raj Patel**
> Fuel to Fork podcast

BOX 8

HOW THE MOST POWERFUL COUNTRIES ARE FAILING ON FOSSIL FUEL PHASE-OUT

Diversified, wealthier economies, including **the UK, the US, Canada, Norway, and Australia**, are in the strongest position to transition away from fossil fuels. However, instead of leading the shift to renewable energy, they continue to expand fossil fuel extraction, issuing a record 825 new oil and gas licenses in 2023.[330] These five countries account for over two-thirds of all new global oil and gas licenses since 2020. The US alone is fast-tracking 688 new fossil fuel projects in 2025, including pipelines and power plants, and bypassing environmental reviews and public input.[331]

Meanwhile, emerging economies like **India and China** are rapidly expanding fossil fuel production. Across the G20, fossil fuel subsidies hit a record USD 1 trillion in 2022 – over four times the 2021 level – driven largely by consumer pressure to offset high fossil fuel prices.[332] India aims to scale up solar and wind capacity, but progress remains slow, and it has made no commitment to phase out coal. Coal production and imports hit a record high in early 2024, fueled by rising electricity demand during extreme heatwaves.[333] Coal remains central to India's energy mix, with ongoing subsidies, tax incentives, and plans to expand domestic mining. While renewables do receive support, subsidies for fossil fuels are eight times greater.[334] China, meanwhile, has surpassed its 2030 wind and solar deployment target six years early, yet coal remains China's dominant energy and emissions source.[335] Despite an 83% drop in new coal permits in early 2024, construction remains high due to many approvals from 2022–2023.[336]

While the Paris Agreement calls for an immediate halt to new fossil fuel developments and a sharp decline in production, governments have continued to accelerate fossil fuel expansion, undermining their climate commitments.[337,xxii] Governments collectively still plan to produce more than double the amount of fossil fuels in 2030 than would be compatible with limiting global warming to 1.5 °C.[338] Redirecting the annual USD 570 billion projected for new oil and gas projects by 2030 to wind and solar energy could fully bridge the investment gap needed to meet climate targets for these renewables.[339]

xxii The United States is the only country to have officially withdrawn from the Paris Climate Agreement. It officially withdrew in 2020 but rejoined in 2021, and recently announced its withdrawal in January 2025 which will take effect in January 2026.

BOX 9

GLOBAL FRAMEWORKS FOR A JUST ENERGY TRANSITION

The governments of Tuvalu and Vanuatu proposed a groundbreaking collective action framework at the 2022 COP27 climate summit: the **Fossil Fuel Non-Proliferation Treaty**. This proposed international agreement calls for a coordinated global effort to halt the expansion of fossil fuel production, equitably phase out existing extraction, and scale up investments in renewable energy and a just transition. The treaty directly confronts the political reality that no country wants to cut production alone while others profit. It has garnered growing support, including endorsements from 135 cities and subnational governments, over 3,390 organizations and institutions, and hundreds of elected officials.

Nearly 350 civil society groups have endorsed the 2024 Civil Society Equity Review report, **Fair Shares, Finance, Transformation**, which assesses national climate pledges for 2035 and sets fair share benchmarks for emissions cuts and fossil fuel phaseout. It proposes a just transition framework that protects workers, communities, and those most affected by climate impacts. The report argues that the financial resources for a fair global transition exist, outlines multiple avenues for raising climate finance, and details both short- and long-term reforms to end fossil fuel dependence and address deepening global inequality.

In 2024, to address the challenges around equity, transparency, investment, sustainability, and human rights concerning 'transition minerals,' the UN established a **Panel on Critical Energy Transition Minerals**. The panel's findings emphasized the need to promote a fair transition to renewable energy while leveraging 'transition minerals' for sustainable development. It called for ensuring that countries and communities rich in these minerals benefit economically, particularly through local value creation, while safeguarding environmental and social interests. Additionally, the panel recommended strengthening international collaboration by aligning and harmonizing existing norms, standards, and initiatives, and identifying areas for increased multilateral action.

HOLISTIC APPROACHES TO GET FOSSIL FUELS OUT OF OUR FOOD SYSTEMS

This section maps out the systemic shifts needed to move beyond fossil fuel-dependent food systems. It outlines a bold, holistic vision for transforming how food is produced, distributed, and consumed – one that significantly reduces fossil fuel use in the medium term, and ultimately aims to eliminate it altogether. These changes are by nature fundamental and systemic, requiring huge changes in practices, economic structures, and political incentives. We highlight the transformative approaches already gaining traction, examine the barriers to their broader adoption, and identify the levers needed to accelerate their implementation.

> ***To break with fossil fuels is to crack open our imagination radically.***
>
> **Raj Patel**
> Fuel to Fork podcast

Transforming agricultural practices to phase out fossil fuels

On the production side, holistic redesign approaches have considerable momentum and an increasing body of evidence behind them. It has been estimated that changes to production practices that prevent and reverse land-use change and land degradation could mitigate about 18% of annual GHG emissions, while building soil fertility, protecting ecosystems, and strengthening resilience to climate shocks.[340]

In particular, **agroecological approaches** that recycle organic materials as nutrient inputs can significantly reduce the reliance on agrochemicals – potentially enabling a complete phase-out when coupled with dietary shifts – without switching to 'blue' and 'green' nitrogen fertilizers (and the harms they entail), or to potentially risky forms of ecosystem engineering and genetic pesticides.[xxiii]

Studies show that nitrogen use could be drastically reduced today without affecting yields, as globally, more than half of the nitrogen fertilizers applied to crops are lost to the environment. **Immediate, steep cuts in nitrogen fertilizer use are possible by improving efficiency through minimizing waste, recycling nutrients, using cover crops and crop rotations, and cutting back application in high-use areas.**[341]

But efficiency gains are not enough. Using nitrogen fertilizers more efficiently does not address the underlying degradation of soils or break farmers' dependence on fossil-based inputs. Through diversified agroecological systems, agrochemicals can ultimately be phased out and fertility rebuilt through ecological processes.

Agroecological practices for improved fertility include cover cropping, enhanced crop rotations, the use of microbial inoculants,[xxiv] **growing nitrogen-fixing legumes, crop diversification, agroforestry, and integrating crops and livestock** (see Figure 7).

> ***Agroecology isn't just about switching to natural inputs. It's about reestablishing biological relationships and ecological functions, feeding the soil, and recycling nutrients.***
>
> **Georgina Catacora-Vargas**
> Fuel to Fork podcast

Studies analyzing extensive trial data from both low-input systems in Africa and high-input systems in Europe have confirmed a positive link between crop diversity and productivity.[342,343] The findings demonstrate that crop yields increase as crop diversity rises, and when legumes are included, they reduce the need for synthetic nitrogen fertilizers. This conclusion is further supported by a global meta-analysis of over 400 trials, which found that incorporating legumes into crop rotations, across various legume species and staple crops, boosts the yield of main crops.[344]

xxiii Agroecology is the application of the science of ecology to the study, design, and management of sustainable food systems, the integration of the diverse knowledge systems generated by food system practitioners, and the involvement of the social movements that are promoting the transition to fair, just, and sovereign food systems. In other words, agroecology is understood as a science, practice, and as a social movement. See High Level Panel of Experts on Food Security and Nutrition. (2019). Agroecological and other innovative approaches for sustainable agriculture and food systems that enhance food security and nutrition. FAO.

xxiv Biofertilizers, biostimulants, and biopesticides are terms used to describe biologically derived products (from bacteria, fungi, or plant extracts) intended to support plant health and reduce reliance on synthetic agrochemicals. However, formal definitions remain inconsistent, and there is growing concern over the rapid commercialization and corporate capture of these technologies. This trend risks reinforcing farmer dependence on costly external inputs, despite the fact that many farmers, especially in the Global South, already possess the knowledge and means to produce effective bio-based inputs locally. See AFSA, (2023, April 23). Are biofertilizers a part of the solution to Africa's concerns with soil health and the environment? and War on Want. (2021, February 12). Building alternatives to toxic pesticides: peasant agroecology in Kenya.

FIGURE 7

AGROECOLOGICAL PRACTICES THAT ENHANCE SOIL FERTILITY AND ELIMINATE THE NEED FOR SYNTHETIC FERTILIZERS AND PESTICIDES

01. REDUCED TILLAGE	02. COMPOST	03. NITROGEN-FIXING LEGUMES	04. BIOSTIMULANTS	05. MULCHING	06. MANURE	07. CROP ROTATIONS
08. DIVERSITY OF CROPS	09. LOCALLY-ADAPTED VARIETIES	10. INTER-CROPPING	11. AGROFORESTRY	12. CROP-LIVESTOCK INTEGRATION	13. DIVERSIFICATION	14. ECOLOGICAL PEST MANAGEMENT

Meanwhile, many agroecological practices can also help farmers eliminate chemical pesticides and improve yields.[345,346] **Integrated pest management (IPM)** – relying on natural pest control methods and using chemical pesticides only as a last resort – can also significantly cut pesticide use and, in some cases, boost yields by supporting pollinator populations.[347,348]

However, despite its original intent, IPM is often practiced with continued heavy pesticide use, partly due to unclear definitions and the agrochemical industry's influence.[349] In contrast, early studies of pesticide- and fertilizer-free systems like Community-Managed Natural Farming practices in Andhra Pradesh show that yields can match or even exceed those of conventional farming (see Box 10).[350]

> ***The work that sustains life – farming, care, cooking – is deeply undervalued. We need to redignify peasant agriculture and all forms of care work.***
>
> **Georgina Catacora-Vargas**
> Fuel to Fork podcast

Agroecological practices not only break the cycle of dependence on synthetic inputs, but also strengthen food security and nutrition across individual, household, and regional levels – particularly when multiple elements of agroecology are integrated.[351] A study conducted in Ecuador, for example, found that agroecological farmers spend less on food than their non-agroecological neighbours while maintaining more nutritious diets rooted in traditional foodways.[352]

These co-benefits extend beyond farming methods and are closely tied to the social networks and localized markets fostered by agroecology, which support solidarity-based economies and health-promoting environments. As low-input systems, agroecological models also increase farmers' autonomy over their means of production, enabling more dignified and resilient livelihoods.[353]

However, a complete, global phase out of agrochemicals cannot be accomplished without a shift in diets. Research shows it would be possible to feed 10 billion people without synthetic nitrogen fertilizer and without additional land use, if global diets shifted, specifically, a shift to more diverse, lower-meat diets in high-meat-consuming regions.[354]

Healthy diets tend to be low-emission diets,[355] and beyond emissions and public health benefits, shifting to diets rich in fruits and vegetables, whole grains, nuts, and legumes, and with dramatically lower meat consumption in high-income countries would also reduce biodiversity loss.[356]

When integrated into crop rotations, legumes can provide much of the nitrogen needed for plant growth, while also enhancing soil structure, suppressing pests and weeds, and contributing to healthy diets. Importantly, without such dietary changes, eliminating synthetic nitrogen fertilizers would almost certainly trigger food shortages or widespread deforestation.[357]

BOX 10

AGROECOLOGY IN ACTION ACROSS THE WORLD

In **Cuba**, the collapse of the Soviet Union and the US trade embargo set in motion the Campesino-to-Campesino Agroecology Movement (MACAC), described by some as an agroecology revolution.[358] Supported from the outset by the Cuban Association of Small Farmers (ANAP), farmers in MACAC exchanged knowledge through a farmer-to-farmer model that became the cornerstone of the transition.[359] On farms, synthetic inputs were replaced with biofertilizers and biopesticides, later evolving into holistic practices such as crop diversification and agroforestry.[360] The movement also gained backing from the government, NGOs, and scientists.[361,362] More than half of Cuban peasant farmers (200,000 families) now participate in MACAC, over 3,000 cooperatives are part of ANAP, and small-scale farmers' productivity has doubled over 20 years, while increasingly feeding local communities (up to 80% in some regions).[363,364,365]

In **India**, the Andhra Pradesh Community-Managed Natural Farming (APCNF) program, launched in 2016, is the world's largest agroecological initiative. It is piloted by Ryuthy Sadhikara Samstha (RySS), a non-profit organization established under the Andhra Pradesh Department of Agriculture. Aiming to transition 6 million farmers across 6 million hectares, APCNF is based on zero-budget natural farming, which rejects synthetic inputs.[366] Natural farming includes practices such as crop diversification, biological pest control, soil conservation, and the use of indigenous seeds and natural inputs.[367] Today, nearly 1 million farmers on over 1 million acres are enrolled in the program, resulting in economic and environmental co-benefits.[368] RySS also collaborates with governments, research institutes, and other organizations to scale up natural farming in India and beyond.[369]

The **Drôme valley** in southeastern France, home to 56,000 residents across 2,200 km^2, has become a leading site of agroecological transition. In the 1960s-70s, organic pioneers – local farmers and urban newcomers – sparked this transition through peer-to-peer knowledge exchange networks, supported by extension agents promoting organic inputs.[370] By the end of the 1990s, organic supply chains, long-term agroecological programs, and short distribution networks were established.[371] In 2009, local authorities gave new momentum to the movement with the Biovallée project, shaped by participatory governance from local actors. Its goals include reaching 50% organic farmland, cutting synthetic inputs in conventional farming by 50%, and sourcing 80% organic and/or local food in public catering by 2040.[372] The project also promotes energy transition, biodiversity, soil and water protection, and green employment. These efforts have resulted in organic farmland growing from 19% in 2008 to 38% in 2023 (over three times the national average).[373,374]

Whether digital precision technologies are needed to complement these agroecological approaches, and to what extent they are appropriate for small-scale farms, remains highly contested. Some hybrid approaches are emerging whereby technological tools are integrated into farmer-led processes. For example, through initiatives such as the 'Laboratorio de Tecnologías Abiertas' in Argentina, where small farmers are working together in cooperatives, alliances, and networks to bring together, store, control, and make collective use of their farm-level data.[375]

Crucially, agroecology is not only about sustainable farming practices – it is also about transforming power in food systems. That means shifting control over land, seeds, technology, and knowledge into the hands of small-scale farmers, and ensuring that food system decisions are made collectively, democratically, and in the public interest.[376]

Agroecological systems tend to be more labour- and knowledge-intensive, relying less on fossil-fuel-powered machinery such as tractors. While this raises questions about economic viability, it is important to note that farming, regardless of method, is often not economically viable in many parts of the world, in large part because it is heavily subsidized by governments, but at uneven rates. Vast subsidies in high-income countries make food production hard to compete with in low-income countries. However, subsidies tend to favour chemical-intensive, industrial agriculture, while agroecological approaches typically receive little or no comparable support.[377] This policy imbalance has contributed to underinvestment in more sustainable models.

Nevertheless, agroecological systems, while more labour-intensive, tend to be more profitable.[378] Given the potential of agroecology to generate more – and more meaningful – employment in rural areas,[379] many now argue that creating quality rural jobs should be a central aim of agricultural policy. **There is also considerable scope for farms to reduce their on-farm energy needs and even generate energy** through elements of system redesign.

Farms are integrating renewable energy generation into production systems in various forms and at a range of scales. It is worth noting that it is still much more common for large swathes of farmland to be converted from agriculture to solar energy production; 1,372 km^2 in 2018, or 27% of global photovoltaic installations, a shift entailing environmental and food security trade-offs.[380]

> ***Governments played a huge role in facilitating the development and spread of industrial agriculture, they can play a huge role in facilitating the development and spread of non-fossil fuel dependent agriculture.***
>
> **Jennifer Clapp**
> Fuel to Fork podcast

Amid these concerns, there is increasing experimentation with agrivoltaic systems, i.e., elevated solar panels that are combined with grazing animals or crop production. Similarly, wind turbines are often installed on cropland with minimal damage to crops, preserving farmland for agricultural use.[381] Nonetheless, renewable energy produced on the farm is not necessarily used on-farm, and these systems face challenges and sometimes prohibitive costs (see Box 11).

BOX 11

THE PROMISES AND CHALLENGES OF ON-FARM ENERGY GENERATION

On-farm energy generation can reduce operating costs and (if produced in surplus) can be sold to the energy grid, providing an additional income stream that isn't connected to fluctuating commodity markets. Renewable energy generation has been integrated onto farms across Asia, Europe, and North America, but farmers in low-income countries face significant financial and technical barriers to adoption.[382] Land competition between energy and food production is another significant challenge and necessitates strong political commitment and carefully planned incentive structures.

Agrivoltaic systems use elevated solar panels on farms, greenhouses, or on land, either above crops or integrated into livestock pasture. Elevated solar panels provide shade for grazing animals, reducing heat stress, as well as improving pasture quality.[383] Agrivoltaics are not compatible with all crops but many studies have shown that yields remain the same or improve as solar panels protect crops from frost (by acting as a thermal blanket and trapping heat at night) as well as high temperatures and water stress (by providing shade during the day and reducing water evaporation).[384,385,386] While some governments are now supporting these integrated food-energy approaches, such as development policies in China,[387] the US,[388] and Europe, including EUR 1.7 billion (USD 1.82 billion) of incentives in Italy, financial and policy supports remain low.[389]

Installing **wind turbines** on farms allows farmers to generate renewable energy with minimal crop damage.[390] However, larger agricultural farms benefit more than smaller enterprises.[391] And wind turbines come with challenges, including noise pollution and visual impact, which may require community consultations before installation. While the cost of wind turbines is gradually decreasing, the initial investment remains high and explains why installations exist mainly in higher-income countries.

Biogas, produced from agricultural waste or manure through anaerobic digestion, can generate heat or electricity, providing an alternative to fossil fuels for powering farm processes. It is often promoted as a solution to reduce GHG emissions and mitigate nutrient runoff from livestock waste. However, the benefits of anaerobic digestion are sometimes exaggerated. While it can offer some GHG emission reductions, these are limited in scope, and burning biogas produces the same air pollutants as burning fossil gas.[392] Additionally, substantial subsidies are required to make anaerobic digestion competitive with more cost-effective renewable options like solar and wind energy, and these subsidies often accrue to the largest farms.[393,394] Anaerobic digesters on industrial feedlots have been highly criticized for greenwashing the environmental harm caused by large-scale industrial farming practices and leaking methane, undermining purported GHG reductions.[395,396] However, smaller biogas digesters can be used sustainability on small and medium-sized farms, even in low-income settings, but scaling their use depends on improved access and farmer training.[397]

Actions in the middle of the chain to curb fossil fuel use

There is significant potential to slash fossil fuels in the middle of the food chain by **restructuring and relocalizing food supply chains**. This means shifting away from global, corporate-led commodity chains toward **territorial, agroecological food networks** that emphasize local and regional production, distribution, and consumption.

As highlighted in IPES-Food's 2024 report, *Food From Somewhere*, **local and territorial markets** offer critical outlets for diverse smallholder production, particularly for foods that are produced to high environmental standards, e.g., organic food produced without agrochemicals. These localized systems can enhance transparency, market stability, and resilience while reducing dependency on long, energy-intensive transport routes.

However, unlocking these benefits requires **investment in regional infrastructure**, including **processing, cold storage, logistics hubs, and wholesale facilities**. These are essential for supporting territorial markets, especially those focused on fresh foods, prepared foods, and minimally processed pantry staples.

The **decentralization of cold chains** is particularly critical: decentralized, renewable-powered (or even unpowered) storage solutions such as cool chambers, cheese caves, and natural drying methods are already in use and could be strengthened to prevent spoilage in areas with unreliable power grids, such as Sub-Saharan Africa (see Box 12).

BOX 12

DECENTRALIZED COMMUNAL COLD STORAGE FACILITIES AROUND THE WORLD

A range of companies in **Sub-Saharan Africa** provide solar-powered communal cold storage facilities. In Nigeria, ColdHubs operates 54 communal solar-powered cold storage rooms that have preserved more than 42,000 tons of food from spoilage for 5,250 farmers, retailers, and wholesalers in 2022. The company estimates it increased customers' incomes by an average of 50%.[398] In Kenya, Solar Freeze provides mobile cold storage units to over 3,000 smallholders, reducing losses by 50%.[399] In Ghana, AkoFresh aims to halve post-harvest crop losses across 10 smallholder communities.[400]

Natural insulation can also provide large-scale, effective cold storage. In the **US**, the USDA stores 1.5 billion pounds of cheese, 355 million pounds of butter, and 211 million pounds of pecans in underground caves near Springfield, Missouri, kept at about 15 °C year-round without external energy.[401] On a smaller scale, communities in **Ladakh, India**, use naturally insulated underground pits at 0–8 °C to keep produce like potatoes and carrots fresh for up to six months without electricity.[402]

Reducing postharvest losses is especially urgent in the Global South, where the majority of food waste occurs not at the consumer level, but during and after harvest. A growing body of evidence highlights a wide array of practices that can help reduce these losses, ranging from improved harvesting tools and ventilated or hermetic storage containers to timely harvesting, drying, and sorting to remove spoiled crops.[403] However, studies also reveal a critical gap: most interventions focus narrowly on technologies or handling practices, while far less attention is given to training, infrastructure, market access, finance, and policy support.

Modelling indicates that establishing more localized and less industrialized food supply chains may prevent larger amounts of food loss compared to optimizing cold chains.[404] This effect holds true across both industrialized and non-industrialized settings, though it is stronger in the latter. Local, short supply chains can also cut down on packaging and facilitate packaging recovery and reuse, reducing plastics in the supply chain.[405]

> ***Local, nimble, and short supply chains are more resilient. Rather than offering whatever you want whenever you want, the priority is making sure that everyone is well fed.***
>
> **Raj Patel**
> Fuel to Fork podcast

On the transportation side, **combining short-haul electric freight or non-motorized transportation with localized distribution systems** can be mutually reinforcing and drive social, economic, and environmental benefits.[406] Shifting short-distance freight from diesel to electric trucks is already technically viable.

Municipalities of all sizes are emerging as pioneers in building local, sustainable food systems and are well-placed to adopt radical strategies for reducing the fossil fuel footprint of their food supplies (see Box 13). Building on existing experimentation and visioning based around **'city-region food systems'** and 'local food sheds', there is high potential to develop integrated models whereby municipalities source food sustainability from their hinterlands using fleets of electric vehicles.[407]

On the consumer side, local and informal food markets – especially street vendors and city markets – are vital for advancing sustainable development and improving food access. But these spaces are also shaped by persistent economic and social inequalities that determine who can participate, who can buy, and who benefits.

While market upgrading can bring needed investment, it often risks exclusion, particularly when it involves relocation or the imposition of formal standards.[408] Informal vendors, who face precarious conditions and limited returns, are especially vulnerable to closures justified by health and safety regulations designed for corporate value chains.[409] These measures are sometimes applied selectively, driven more by real estate speculation than public health. Deliberate efforts grounded in equity and food justice are needed to ensure markets truly improve access to diverse, safe, fresh, and affordable foods for all communities.[xxv]

To scale such systems, **both demand-side and supply-side policy levers are essential**. On the demand side, governments can establish **minimum sustainability criteria for public procurement**, requiring schools, hospitals, and other institutions to source food from local, environmentally responsible producers. These criteria could begin with limits on chemical inputs and progressively incentivize a shift toward organic, agroecological, or regenerative farming practices that avoid chemical inputs altogether.

On the supply side, this transition will require **supporting Indigenous farmers and foodways, safeguarding farmland from development, offering technical and financial support to help farmers adopt sustainable methods, and providing market guarantees** to de-risk agroecological production and ensure stable, viable livelihoods.

xxi For detailed policy guidance and global examples of equitable transformations of urban food markets see ICLEI - Local Governments for Sustainability (2025). The CityFood Market Handbook for Healthy and Resilient Cities.

Transportation policy can further support this shift. For example, countries can adopt tax exemptions for rail-road freight vehicles and lower the minimum required rail distance to incentivize multimodal, low-emission logistics. These kinds of policies are vital to rethinking supply chains in a way that genuinely reduces fossil energy use across both storage and distribution.

BOX 13

HOW MUNICIPALITIES, BIG AND SMALL, ARE BUILDING SUSTAINABLE FOOD SYSTEMS THROUGH INTEGRATED FOOD POLICIES

São Paulo, Brazil's *Connect the Dots* programme, protects forests, reservoirs, and farmland in the city's rural outskirts from urban sprawl. It supports farmers with technical assistance to improve yields, transition to sustainable practices, and access urban markets for organic produce. The city also runs one of the world's largest school meal programmes, serving over 2 million healthy meals daily, with a purchasing programme that focuses on sourcing from local, sustainable, family farms. Furthermore, LUPPA, the Urban Laboratory on Public Food Policies, assists and connects Brazilian cities doing work on sustainable urban food policies to help scale out and replicate successful strategies. Urban food policies in Brazil are further supported by the newly established National Strategy for Food and Nutritional Security in Cities, which aims to increase the production, availability, access to, and consumption of healthy food, with a strong focus on supporting vulnerable and marginalized communities.

In **Mouans-Sartoux, France**, the municipality protected 112 hectares of farmland from urban development and invested in organic agriculture to support its goal of serving 100% organic and local food in school canteens. To overcome urbanization pressures, the city enacted policies linking farmland protection with public procurement. It established a publicly owned organic farm to supply schools, supported by collaboration between local government, farmers, schools, and parents. Children are engaged through farm visits and food waste initiatives. A survey later showed that 87% of families improved their eating habits toward organic and local food as a result.

Quezon City in the Philippines is advancing a holistic approach to sustainable urban food systems through integrated policies that span production, supply chains, and consumption. Flagship urban farming initiatives have converted a total of 381,650 m^2 of idle land for urban agriculture and established over 160 urban farms. These are reinforced by the Healthy Public Food Procurement Policy, which sets nutrition standards and promotes sourcing from local farms. Complementary policies, such as the ban on single-use plastics and the City's participation in the Sustainable Diner Project, support waste reduction and environmentally responsible consumption. Together, these efforts tackle hunger, improve nutrition, reduce food waste and plastic pollution, and build a resilient, community-rooted food system.

While processing and packaging needs could potentially be slashed in a food system re-centered on agroecology, territorial markets, and sustainable diets, there has been relatively little attention to or investment in **alternatives to plastic food packaging**. Although plastic packaging can sometimes extend shelf life, many practices – especially in industrialized, long food supply chains – prioritize branding, cosmetic standards, and economic efficiency over food preservation, often exacerbating both food and packaging waste.[410]

At the household level, plastic-wrapped products do not significantly reduce food waste.[411] Instead, **consumer knowledge and thoughtful purchasing habits** are more effective. Similarly, in food service, particularly fast food and delivery, high levels of packaging waste accompany food waste. However, **short food supply chains and reusable packaging** offer more viable and sustainable alternatives.

Many experts argue that **eliminating unnecessary packaging** (e.g., on fresh produce) and shifting to sustainable materials like paper or cardboard should be prioritized.[412] Practices like multipacks, single-use wrappers, and standardized packaging can drive waste at every stage of the chain, from producers to retailers. Recognizing the problem, dozens of countries have already established **single-use plastic bans**. In 2018, Vanuatu became one of the first countries to ban single-use plastics, with impressive results. Banned items used to make up 35% of their waste and now make up only 2%.[413]

However, plastic bans alone are not enough to stem the tide of plastic waste. Without additional measures or a broader phase-out strategy, simply banning certain items has minimal impact on the throwaway culture that underpins overproduction, overconsumption, and waste.[414]

There have also been calls to **adopt 'essential use' criteria**, to guide decisions on plastic packaging, helping to distinguish between truly necessary uses (e.g., for health or safety) and those that can be eliminated or substituted.[415] Further, many advocates recommend **'extended producer responsibility'** regulations, whereby companies are responsible for plastic packaging through the life cycle.[416] These could be paired with enhanced local infrastructure for the **recovery and reuse of packaging** and accompanying policy frameworks.

Reusable packaging has declined to historic lows, even in the drink sector where it once thrived. Yet studies show reuse systems can cut environmental impact and save costs.[417] While reuse and refill models are starting to grow again in retail, they remain hindered by a lack of incentives, legal frameworks, and clear standards.

Finally, some are calling for more **research and experimentation to find plastic packaging alternatives**. This includes packaging based on locally available materials or using green chemistry approaches outside of patented proprietary systems to develop bio-based materials that minimize or eliminate the use and generation of hazardous substances.[418]

> ***We have a finite climate budget – we can only burn so many fossil fuels. So, we need to ask: what's the smartest use of plastic? Maybe it makes more sense in healthcare instead of wrapping junk food.***
>
> **Emma Priestland**
> Fuel to Fork podcast

Demand-side changes to slash fossil fuel use

Relocalizing food supply chains and accelerating the shift to agroecology depend on **changing diets and creating healthier food environments**. These demand-side changes must be **supported by efforts to reduce food waste**, particularly in the Global North, where the majority of waste occurs at the retail and consumer levels, and by placing **greater responsibility on retailers and manufacturers to improve energy efficiency and supply chain practices**.

Transitioning to sustainable, healthy diets – particularly by reducing meat consumption in high-intake regions – alongside major reductions in food waste, are essential pillars of any comprehensive food system transformation.

One European study found that adopting these strategies alongside improved farm management could reduce nitrogen fertilizer use by 40% and nitrogen losses by 50%, while also delivering substantial environmental and public health benefits.[419]

The climate benefits of reducing consumption of factory-farmed meat and dairy are now well-established: studies have shown that transitioning to sustainable, healthy diets and halving global industrial meat production and consumption could mitigate up to 8% of annual global GHG emissions, while improving health and reducing pressures on land and ecosystems.[420,421]

While reducing overall meat and dairy consumption is key, it's important to recognize some nuances. Factory-farmed beef may emit less methane than pasture-fed beef per kilogram of meat (primarily due to faster growth rates and shorter lifespans), but factory farms typically rely on chemical-intensive feedstocks that are associated with higher emissions of CO_2 and nitrous oxide, as well as having high fossil energy requirements.[422,423,424] In contrast, agroecological or pasture-raised systems, though higher in methane emissions, are associated with lower CO_2 and nitrous oxide emissions, can reduce fossil fuel use, and support broader environmental and animal welfare goals.

Dietary shifts can help drive broader transformations in food production and supply chains by reducing fossil fuel dependence and delivering co-benefits for health and the environment. **Cutting back on ultra-processed foods (UPFs)** can significantly reduce fossil fuel usage, GHG emissions, and plastic packaging.

The most harmful UPFs, such as sugar-sweetened beverages, industrially processed meats, sugary cereals, snack foods, and candy, offer little or no nutritional value and rely heavily on monocultures and intensive livestock systems. Moving toward diets based on local, seasonal, minimally processed foods not only aligns with healthy eating guidelines but also supports diversified agroecological farming and regionalized food markets.

With 42% of the global population unable to afford a healthy diet,[425] shorter food supply chains, leveraging public procurement, taxing UPFs, and reforming agricultural subsidies could drive down the relative cost of healthy food.

Cooking at home is associated with lower consumption of UPFs and higher consumption of unprocessed or minimally processed foods, but time is often cited as a barrier to cooking and eating healthy.[426] Cooking at home is also highly gendered nearly everywhere in the world, with women cooking at home three times more than men.[427] Local food supply chains can play a vital role by preparing ingredients for healthy meals, helping to reduce the domestic labour (typically shouldered by women) that may increase with reduced reliance on ultra-processed foods.

> ***Home cooking remains deeply gendered labour, and we can't ignore that processed foods have, in many cases, lightened that burden – mostly for women. So, while there's plenty to critique, we also need to recognize that there are some nuances here that don't fit neatly into a 'good' versus 'bad' dualism.***
>
> **Errol Schweizer**
> Fuel to Fork podcast

Holistic visions for changing the incentives and behaviours around diets are often articulated within strategies for **building healthier 'food environments'** – now a focal point of major policy frameworks, including the EU *Farm to Fork* strategy.[xxvi]

Chile provides a compelling case. The introduction of policies in 2016 – including restrictions on advertising unhealthy foods, mandatory front-of-package warnings, and a ban on junk food in schools – led to a nearly 25% reduction in sugar-sweetened beverage consumption within 18 months (see Box 14).[428] Adopting similar labeling policies in other countries, particularly where UPFs have not yet saturated the market, could significantly shape food environments. In the US, studies of hundreds of thousands of packaged food items available in major grocery stores find that 70% of items sold are ultra-processed foods and would require a warning label under Chilean standards.[429,430]

xxvi Unfortunately, progress has stalled on many of the initiatives set out in the Farm to Fork Strategy. Nevertheless, many European countries are advancing integrated food policies to build healthy food environments, see for example case studies from the report by Agora Agriculture and IDDRI (2025). Towards national food policies that support healthy and sustainable consumption. Country case studies and the role of EU food policy.

A landmark lawsuit in the US could mark a pivotal shift in holding the ultra-processed food industry accountable for its role in public health harms. Brought by an 18-year-old plaintiff against 11 major corporations – including Coca-Cola, Nestlé, PepsiCo, and General Mills – the case alleges these companies intentionally engineered addictive products and targeted children, supported by internal documents and extensive research.[431] This unprecedented legal action not only opens the debate on the industry's civil liability but also exposes major regulatory failures, potentially paving the way for broader reforms and a wave of future lawsuits.

BOX 14

LATIN AMERICA LEADS THE WAY IN REGULATING UPFS

Latin America is pioneering the regulation of ultra-processed foods (UPFs) through labeling, taxation, and marketing restrictions. Chile, Peru, Uruguay, Mexico, Argentina, Colombia, and Venezuela currently require front-of-package **warning labels** on foods and beverages high in sugar, salt, fats, and/or calories.[432] Ecuador, Bolivia, and Brazil also mandate labeling for unhealthy foods.[433] Furthermore, Brazil, Chile, Ecuador, Mexico, Peru, and Uruguay promote minimally processed foods and avoidance of ultra-processed products in their **dietary guidelines**.[434,435,436]

Several countries have introduced **taxes** as well. Ecuador, Chile, and Peru apply ad valorem taxes on soft drinks (10%, 18%, and 25% respectively), and Colombia taxes both UPFs and soft drinks at 25%.[437,438] Mexico imposes a one peso per liter tax on sugar-sweetened beverages and an 8% tax on nonessential, high-calorie packaged foods.[439]

Further, Mexico **bans UPF advertisements** on television during children's hours, while Chile goes further, banning all UPF marketing to children across all media, and restricting UPF ads on television and in cinemas from 6 a.m. to 10 p.m.[440] Both countries also ban child-appealing images for UPFs' marketing.[441,442] Additionally, Mexico, Chile, Uruguay, and Argentina **prohibit the sales of products with warning labels in schools**.[443,444,445]

Early evidence suggests these policies are effective. In Chile, studies estimate that labeling and advertising regulations have reduced consumers' purchasing by 37% in sugar, 22% in sodium, 16% in saturated fats, and 23% in calories.[446] In Mexico, research indicates that about 40% of adults and youth reported buying fewer UPFs after warning labels were introduced.[447]

Lastly, across food, plastics, and climate policy, corporate interests wield outsized influence, shaping decisions that prioritize profit over people and planet. Robust safeguards are urgently needed to eliminate corporate capture, while inclusive, participatory governance must be institutionalized to realign decision-making with the public good. Without this step, progress on food systems transformation as outlined in this section will be severely undermined. Further analysis and recommendations can be found in our report, *Who's Tipping the Scales*.

> ***The first thing we need to do is break up the big food processors and retailers. None of the changes we're discussing will matter unless we do that – they absorb all the oxygen, all the energy, all the capital.***
>
> **Errol Schweizer**
> Fuel to Fork podcast

RECOMMENDATIONS

5

Food systems are deeply entangled with fossil fuels, but as this report has shown, transforming them to break that dependence is both necessary and achievable. As the climate crisis accelerates, causing mounting harm to people, ecosystems, and economies, and jeopardizing food access, addressing this dependence is more urgent than ever. Yet this critical link remains largely absent from mainstream climate discussions.

But to truly reduce dependence, the path forward requires confronting false solutions. Technologies like 'blue' and 'green' ammonia, digital agriculture, and synthetic biology are often presented as climate solutions but instead entrench dependence on fossil fuels, agrochemicals, and industrial models of production. Backed by powerful coalitions of fossil fuel, agribusiness, and tech firms, these approaches represent a new form of delay and denialism that obstructs real change and undermines public control.

Meanwhile, global climate agreements face growing political resistance, particularly from far-right movements, while fossil fuel extraction continues largely unchecked. At the same time, food and fuel price inflation and public concern over plastic pollution, supply chain fragility, and unhealthy diets have pushed food system transformation into the spotlight.

It is precisely amid these geopolitical and socio-economic pressures that efforts to reduce fossil fuel dependence and rebuild resilient, sustainable food systems are more urgent and more unifying than ever. But this transformation is not just about food and farming – it is about reclaiming democracy. Fossil fuel dependency reflects deeper failures of accountability and equity. Where democratic control and collective action thrive, fossil fuels lose their grip.

Immediate and medium-term actions – such as phasing out agrochemicals, leveraging public procurement, and reducing ultra-processed foods – can significantly curb fossil fuel use. In the long term, deeper shifts will be needed to dismantle fossil-fueled industrial food systems: confronting corporate power, redistributing control, and building democratic food governance.

This transformation must also move in step with a just energy transition. Reducing energy demand is essential, but achieving sustainable food systems will also depend on expanding electrification and ensuring equitable access to renewable energy. As detailed in Sections 2 and 3, intersections between these transitions – such as electrifying transport, processing, and farm operations, and investing in energy efficiency and on-site renewables – can support a resilient, fossil fuel-free future.

Below, we outline eight key recommendations to put us on this path. These actions are interconnected and, when pursued together, can deliver real and lasting change. While the recommendations are primarily directed at governments, we also highlight the critical role of collective, community-led action in driving change from the ground up. The path ahead is ambitious, but these recommendations chart a pathway toward food systems that are more resilient, more equitable, and free from the instability and destruction wrought by fossil fuel dependence.

Recommendation 1: Advance a just energy transition

- **Halt fossil fuel subsidies, stop all new fossil fuel development, and phase out existing infrastructure**, recognizing that cheap fossil fuels are the foundation of the industrial food system and the leading driver of climate change.
- **Redirect public finance toward a just energy transition**, one that ensures renewable energy is not only expanded but equitably distributed, affordable, and efficiently used, prioritizing access for communities and sectors most in need, especially in the Global South. This entails protecting workers, communities, and those most affected by climate impacts.
- **Invest in battery technology and improved recycling and upgrade electricity grids** to cater for increased renewable power.
- **Establish clear, binding energy efficiency targets** for all sectors, with a focus on reducing consumption and optimizing use. This would also entail scaling up public and low-cost financing mechanisms to enable small and medium-sized enterprises to adopt energy-efficient technologies and invest in self-generating a portion of their energy through renewables.
- **Advance maritime transport energy efficiency** by reducing operational speeds and investing in the development of sustainable technologies such as sail-powered cargo ships.
- **Implement polluter-pays policies**, such as carbon taxes, to generate further revenue for a just energy transition.
- **Support transnational alliances**, among local movements and across the Global South, that are advocating for just energy transformations.
- **Curb corporate influence** over climate policy to break industry co-optation of governance spaces and ensure democratic, people-centered governance (see Recommendation 8).

Recommendation 2: Phase out agrochemicals

- **Eliminate subsidies** for synthetic fertilizers and pesticides, which have driven overuse and entrenched dependency, while supporting farmers and farm workers in a just transition away from agrochemical reliance.
- **Reform and reallocate agricultural subsidies** to support agroecological practices (see Recommendation 3).
- **Institute ambitious national agrochemical phase-out plans** that include clear reduction targets, ambitious timelines, and specific measures. Managed phase-out plans would include measures to reduce industrial meat production and consumption in high-intake regions.
- **Eliminate public funding** for techno-fixes, such as 'blue' and 'green' ammonia, precision agriculture, and synthetic biology, that entrench extractive, industrial systems and lead to harmful environmental and social impacts.
- **Implement polluter-pays policies**, such as a pesticide tax, to generate further revenue for an agrochemical phase out.
- **Curb corporate influence** over agricultural policy to break industry co-optation of governance spaces and ensure democratic, people-centered governance (see Recommendation 8).

Recommendation 3: Promote agroecological farming

- **Reform agricultural subsidies** to support agroecological practices such as crop diversification, cover cropping, ecological pest management, microbial biostimulants, agroforestry, nitrogen-fixing legumes, and integrated crop-livestock systems.
- **Redirect research and development** to scale agroecological innovation, including repurposing existing research institutions and public advisory services toward ecological and farmer-led approaches.
- **Support knowledge sharing and co-creation** through the ongoing documentation and best practice sharing among farmers, social movements, and researchers.
- **Align agricultural and food policy priorities** through coordinated, integrated food policies that strengthen local supply chains (see Recommendation 4), support healthy diets (see Recommendation 6), reduce food loss and waste (see Recommendation 7), and build democratic food governance (see Recommendation 8).

Recommendation 4: Rebuild and strengthen local food supply chains

- **Fund scale-appropriate infrastructure** across rural, urban, and peri-urban areas, including decentralized storage, processing facilities, cold-chain systems, clean water access, sanitation, and renewable energy.
- **Develop and upgrade local market infrastructure**, such as wholesale and wet markets, retail outlets, warehouses, transport and logistics networks, regional food hubs, and institutional kitchens.
- **Align public procurement policies** with sustainability and proximity goals by sourcing from local and agroecological producers (see also Recommendation 6).
- **Establish publicly owned and managed supply chains** to guarantee markets for sustainable producers and to make healthy, local food the most accessible and affordable choice.
- **Reduce fossil fuel use in food transport by shifting short-haul freight to electric trucks** or non-motorized transport and expanding rail-road intermodal transport with supportive taxes and policies.
- **Leverage shorter supply chains** to reduce food waste, eliminate unnecessary plastic packaging, and expand reuse and recycling systems (see also Recommendation 5).
- **Guarantee equitable access to clean energy and food system infrastructure**, especially in underserved regions, as a central pillar of a just energy transition.

Recommendation 5: Significantly reduce plastic production and accelerate investment in alternatives and reuse systems

- **Eliminate unnecessary packaging** by applying 'essential use' frameworks to phase out non-critical plastic (e.g., on fresh produce), and ban wasteful forms like single-use wrappers, multipacks, and standardized marketing-driven designs.
- **Set mandatory plastic production reduction targets**, including through international agreements like the UN Global Plastics Treaty.
- **Rebuild and strengthen short supply chains and territorial markets** that lessen the need for preservation and packaging, and support reuse-oriented, low-waste solutions (see Recommendation 4).
- **Enact extended producer responsibility laws** that hold companies accountable for plastic waste across its entire life cycle, backed by strong enforcement and well-funded local systems for collection, reuse, and recycling.
- **Establish waste prevention and reuse targets** and rebuild infrastructure and incentives for reusable packaging across retail, delivery, and beverage sectors.
- **Invest in public-interest research and innovation to develop alternatives to plastic** in food packaging and agriculture, prioritizing locally available, sustainable, and open-source materials developed independently of petrochemical interests.

Recommendation 6: Cut ultra-processed food consumption and build healthy food environments

- **Launch widespread public education campaigns** to promote sustainable, nutritious diets, paired with subsidies and targeted support for low-income communities.
- **Curb the availability and appeal of ultra-processed foods** by introducing front-of-package warning labels, restricting advertising (especially to children), taxing UPFs, and banning them in schools and public canteens.
- **Redirect agricultural subsidies** to support the production and accessibility of fresh, local foods (see Recommendation 3).
- **Leverage public procurement to expand access** to local, nutritious foods in public institutions, supported by integrated food policies that set minimum sustainability standards, provide farmer training and financial support, and protect farmland to ensure long-term viability (see Recommendation 4).
- **Curb the outsized market and political power of major food and beverage corporations**, whose lobbying efforts continue to block essential public health policies (see Recommendation 8).

Recommendation 7: Eliminate food waste and scale up clean cookstoves

- **Dramatically reduce postharvest food losses**, particularly in the Global South, by investing in local, short supply chains (see Recommendation 4). This includes upgrading infrastructure and providing training and finance to improve crop harvesting, processing, and storage.
- **Support consumer and retail campaigns**, particularly in the Global North, to cut food waste. This includes introducing food waste bans and fines to hold businesses accountable and scaling up food rescue and redistribution programs. Consumer-facing campaigns should equip people with knowledge and tools to reduce food waste through better purchasing, storage, and preparation habits.
- **Guarantee equitable access to clean energy and accelerate the transition to electric stoves**, particularly induction stoves in high-income countries, through updated building codes and incentive programs. And finance the electric and hybrid solar-electric cookstove transition in low-and middle-income countries.

Recommendation 8: Rein in corporate power and democratize food systems governance

- **Establish clear and enforceable rules on conflicts of interest, lobbying, and 'revolving doors'** in governance and scientific research bodies, particularly excluding fossil fuel, petrochemical, and agribusiness lobbyists from global climate and plastics negotiations.
- **Strengthen antitrust laws** and implement policies to reduce excessive corporate market power across the food and energy sectors.
- **Close tax loopholes** and enact fair, progressive tax policies to curb corporate tax avoidance and ensure adequate public financing for just food and energy transitions.
- **Institutionalize inclusive, participatory governance** by prioritizing the meaningful involvement of social movements, people's organizations, and civil society in decision-making at all levels.

> ***The post-fossil fuel economy isn't one of privation – it's an economy of abundance, built on care for each other and the planet.***
>
> **Raj Patel**
> Fuel to Fork podcast

FIGURE 8

WHAT WILL IT TAKE TO GET FOSSIL FUELS OUT OF FOOD SYSTEMS?

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The International Panel of Experts on Sustainable Food Systems (IPES-Food) is a global think tank and expert group guiding action for sustainable food systems around the world. Bringing together 25 groundbreaking thinkers and practitioners from diverse fields and world regions, we conduct research, provide policy recommendations, and advocate for sustainable, equitable, and healthy food systems worldwide. Rooted in science, and grounded in the realities of those on the front lines of hunger and climate crises, IPES-Food has since 2015 been a leading voice advancing policy solutions and bringing together alliances to address the most pressing questions for food and farming. The panel is co-chaired by Olivier De Schutter, UN Special Rapporteur on extreme poverty and human rights, and Lim Li Ching, Senior Researcher at Third World Network.

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This publication was supported by the Rosa-Luxemburg-Stiftung. Its content is the sole responsibility of IPES-Food. The positions expressed herein do not necessarily reflect the views of the Rosa-Luxemburg-Stiftung.

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