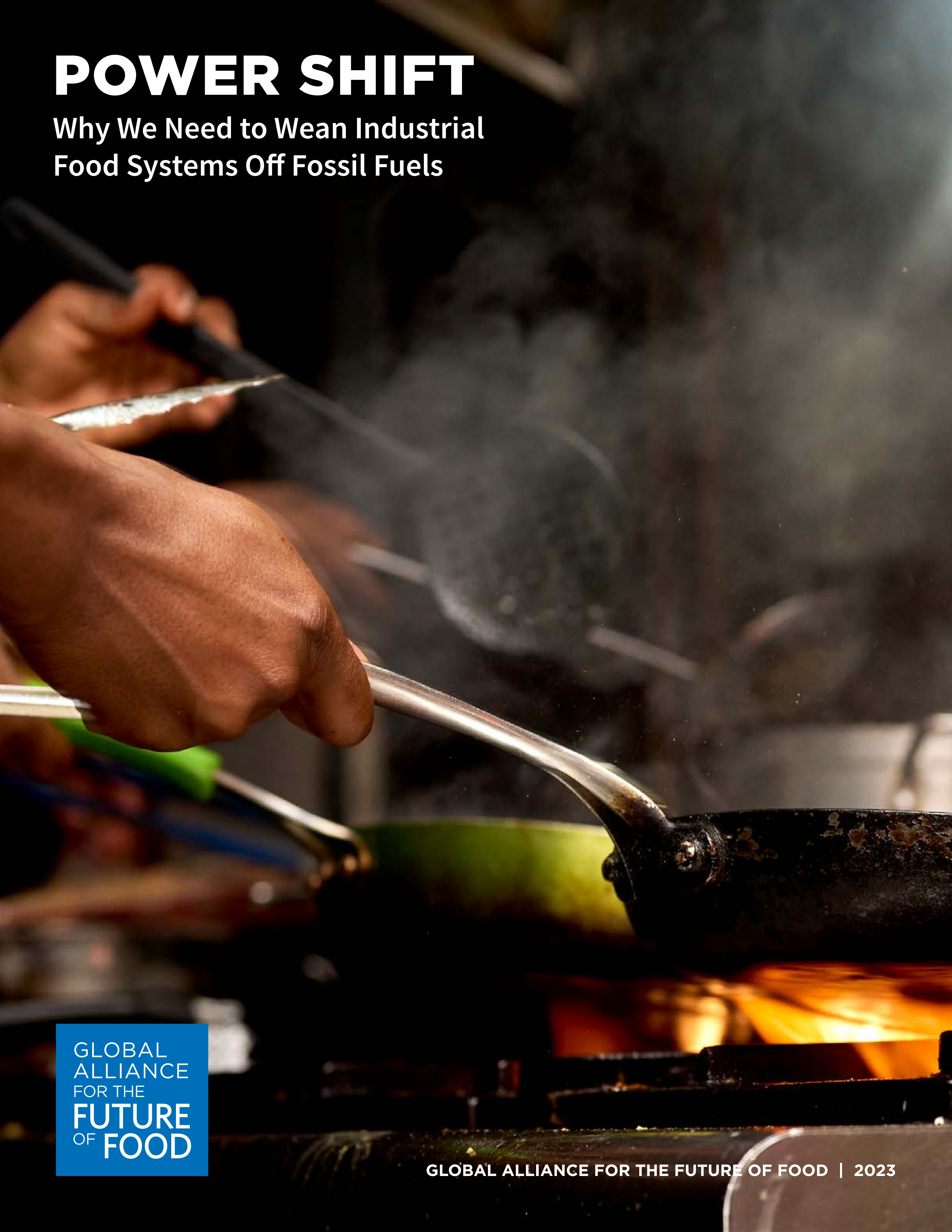
POWER SHIFT

Why We Need to Wean Industrial Food Systems Off Fossil Fuels



GLOBAL ALLIANCE FOR THE FUTURE OF FOOD

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CONTENTS

PREFACE

This report serves as a call to action for all stakeholders in the food and energy sectors — as well as advocates, funders, and policymakers — to work together in the transition away from fossil fuels and toward a sustainable future, in which global warming is limited to 1.5°C (2.7°F). It also serves to underscore the importance of collaboration as we work together to phase out fossil fuels, aligning our efforts with the objectives of the Paris Agreement.

This report is a companion piece for the Discussion Paper "**Toward Fossil Fuel–free Food: Why Collaboration between Food and Energy Systems Players Is Key**." The objective of the Discussion Paper is to provide a better understanding of the interconnectedness between food and energy systems, taking into account the role of fossil fuels. In the Discussion Paper, we delve into the trade-offs, synergies, gaps, and opportunities that arise within this nexus, as well as develop recommendations and identify near-term opportunities for enhanced coordination and collaboration among policymakers, funders, and advocates working across the food–energy nexus. The emphasis is on identifying measures to reduce fossil fuel usage in food systems.

We hope this report and the companion Discussion Paper will stimulate meaningful conversations and drive positive change in our food system's reliance on fossil fuels. In partnership with others, we plan to hold a series of convenings to advance the paper's recommendations and align on concrete activities for collaboration between the food and energy sectors, with a focus on the no-regret opportunities discussed.

KEY MESSAGES

1. Fossil fuel use is by far the biggest driver of climate change. We need to radically reduce it now and phase it out almost completely by 2050 in order to reach net-zero emissions. Our new calculations suggest that food systems currently account for at least 15 percent* of global fossil fuels use annually, driving as many emissions as all EU countries and Russia combined.[1]

2. Food and energy systems are fundamentally intertwined — with interactions across the food value chain, and broad social, economic, and environmental implications. Therefore, collaboration between actors within these two systems is crucial.

3. Food systems contribute to and are significantly affected by climate change. Food systems account for more than one-third of total greenhouse gas (GHG) emission.[2] Food systems transformation is thus a crucial part of the solution to keeping global warming below 1.5°C (2.7°F).

4. Industrial food systems are highly energy intensive and dependent on fossil fuels across the four stages of the value chain: the majority of fossil fuel consumption is in the processing and packaging stage (42 percent), and in retail consumption and waste (38 percent). The stages of input and agriculture production together account for 20 percent of energy use in food systems,** with fossil fuel use to produce fertilizers expected to increase substantially through 2050.[3, 4]

5. The dependence of food systems on fossil fuels requires a collaborative and deliberate approach by both the energy and food sectors. We cannot transform food systems without addressing fossil fuel consumption, and we will not be able to phase out fossil fuel use and stop catastrophic climate change without changing food systems.

6. Energy intensity in food systems is growing due to increased mechanization; growing use of fertilizers and other fossil fuel–based inputs; globalized supply chains; growing demand for meat, dairy, and ultra-processed foods; and, to some extent, new food trends such as alternative proteins.

7. The fossil fuel industry is investing heavily in petrochemicals to lock in the dependence of food systems, with investments of over USD 164 billion planned between 2016–2023 in the United States alone. Food-related plastics and fertilizers together represent approximately 40 percent of petrochemical products.

* Based on data from USA (13.6 percent), Brazil (14 percent), and EU (~13 percent). USDA, The Role of Fossil Fuels in the U.S. Food System and the American Diet, 2017; de Gouvello et al., Brazil Low Carbon Case Study Technical Synthesis Report, 2010 (does not include transport in food production system); European Environment Agency, Final Energy Consumption by Sector and Fuel, 2013.

** FAO, Recommendations Paper: Achieving a 1.5°C Future Requires a Food Systems Approach, 2021. Though the land use and agricultural production stage only accounts for ~15 percent of energy use within the value chain, it contributes to 55 to 65 percent of total emissions from food systems from land use emissions (28 percent) (e.g., land use change, cultivated organic soils, savannah burning), and livestock and fisheries emissions (36 percent) (e.g., methane from cattle digestion, manure and pasture management, and fuel use from fisheries).

8. The agri-food and energy sectors are dominated by a small number of large, vertically integrated, multinational firms with a vested interest in maintaining the current fossil fuel and chemical-dependent industrial food system. Recognizing and addressing the concentration of corporate power and taking measures to improve participation and agency of smallholder farmers and small-scale fishers, small and medium enterprises, local communities, and other actors will be key to real food systems transformation.

9. Food systems don't just consume energy, they also produce it in the form of biofuels, biomaterials, and on-farm energy, which is often incentivized via public subsidies. This energy production can have negative side effects, including displacing food production or local communities, or pushing up food prices.

10. With business-as-usual food production and processing driving the demand for energy-intensive and ultra-processed foods, immediate action to decouple food production from fossil fuel use is required. We have identified the following high-impact, no-regret opportunities for greater collaboration on the food-energy nexus:

    - Phase out fossil fuel–based agrochemicals and transition to regenerative and agroecological approaches;
    - Review fiscal policies to counter the negative externalities of bioenergy production;
    - Shift to renewables-based cooling, heating, and drying technologies;
    - Shift to renewable energy for food processing and transport;
    - Ensure healthy, sustainable, and just food environments that support plant-rich diets and minimally processed foods; and
    - Track and address corporate consolidation in the agrochemical and food industries while actively supporting a just transition through more inclusive and equitable governance and decision-making.

    These changes would not only substantially reduce fossil fuel dependency but also realize a raft of benefits for people's health, livelihoods, and the environment.

FOSSIL FUEL PHASE-OUT REQUIRES FOOD SYSTEMS TRANSFORMATION

In 2015, signatories to the Paris Agreement agreed to pursue efforts to limit global average temperature increases to 1.5°C (2.7°F) above pre-industrial levels.[5] This is a critical target. Extreme weather is already causing havoc around the world, while average temperatures are already up by at least 1.1°C (nearly 2°F) compared to pre-industrial levels.[6, 7, 9] According to the Intergovernmental Panel on Climate Change, all climate impacts will intensify if the 1.5°C (2.7°F) threshold is breached — from flooding to drought to heatwaves, crop failure and food scarcity, species loss and sea level rise — with dramatic effects on human health and well-being.[9]

Every fraction of a degree counts, yet current food and energy policies put us on track for around 2.7°C (4.7°F) by the end of the century.[10] Fossil fuel use is by far the biggest driver of climate change.[11] We need to radically reduce it now and phase it out almost completely by 2050 in order to reach net-zero emissions and prevent catastrophic climate change.[12]

The science and economics are clear, but the political will is still lacking. Our modern economies and societies still run largely on fossil fuels, and there is a strong, powerful, and effective industry lobby working to delay action to end this. Countries whose economies gain significant revenue from fossil fuel production are often more reluctant than others to implement the policies needed.[13, 14]

LINK BETWEEN FOOD SYSTEMS, ENERGY, & CLIMATE

The Global Alliance for the Future of Food has previously documented the link between food systems and climate change. Our 2022 report analyzing countries' climate pledges demonstrated how food systems not only contribute to and are significantly affected by climate change, but are also a crucial part of the solutions urgently needed to keep global warming below 1.5°C (2.7°F).[15]

> We highlighted then that changing the way we produce and consume food could reduce global greenhouse gas (GHG) emissions by at least 10.3 gigatons a year, which is equivalent to 20 percent of the cut needed by 2050 to stay below 1.5°C (2.7°F).[16]

This report follows on from that analysis and shows how the dependence of food systems on fossil fuels requires a collaborative and deliberate approach by both the energy and food sectors. We cannot transform food systems without addressing fossil fuel consumption, and we will not be able to phase out fossil fuel use and stop catastrophic climate change without changing food systems.

Any high level political commitment and action on sustainable agriculture and food must be explicitly linked to and include efforts to phase out fossil fuel production. With the latest UN numbers showing that approximately 735 million people globally still face hunger and 3.1 billion cannot afford and/or do not have access to healthy diets, the need to reform food systems to enhance food security, improve nutrition, preserve nature, and help stop climate change has never been clearer.[17]

THE INTERDEPENDENCE OF FOOD & ENERGY SYSTEMS

Industrial food systems are intertwined with the fossil fuel industry; they are highly energy intensive and dependent on fossil fuels across the value chain. Our new calculations suggest that food production currently accounts for an estimated 15 percent of global fossil fuels use annually* (4.6 gigatons CO_2-equivalent), driving as many emissions as all EU countries and Russia combined). In a business-as-usual scenario, global food demand is expected to increase between 35 and 56 percent by 2050,[18] meaning that fossil fuel use will also go up unless we drastically transform food systems to break the link between food production and consumption and fossil fuels.[19]

The dangers of this dependence have been highlighted throughout 2022–2023, with the war in Ukraine having both a direct and indirect effect on food supplies and prices. Direct, because Ukraine and Russia have been exporting less grain, cooking oil, and fertilizer,[20] and indirect as a result of higher oil prices affecting transport and fertilizer costs in particular. Reducing this dependence on centralized exports of energy- and fossil fuel–intensive commodities would thus enhance global food security.

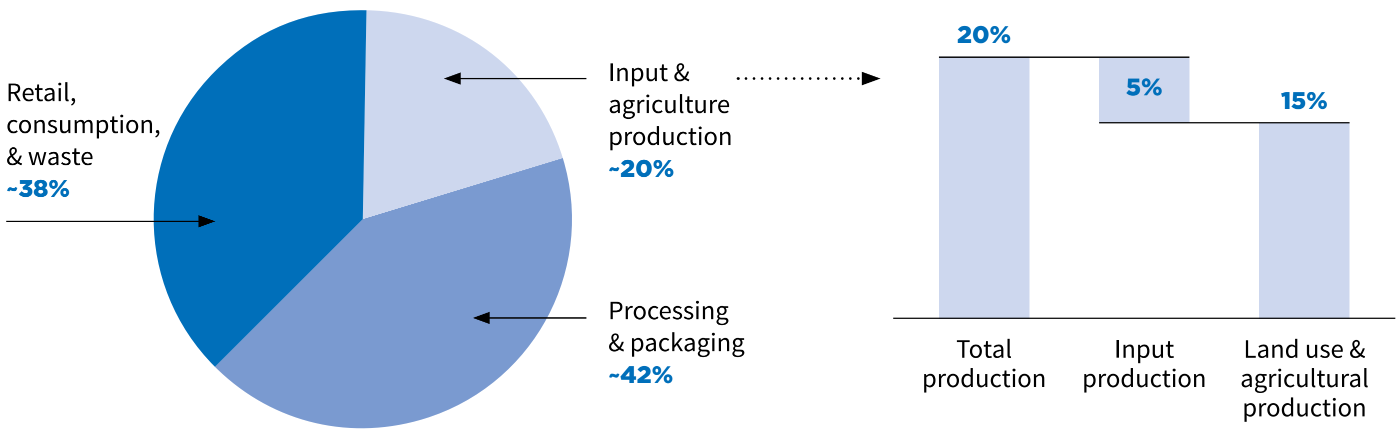
Fossil fuels play a crucial role in the production of food throughout the four stages of the value chain: input production; land use and agricultural production; processing and packaging; and retail, consumption, and waste. Energy is used to produce and package food, power machinery and equipment, fuel transportation systems, and for storage and cooking.

Energy intensity in food systems is also growing due to increased mechanization; growing use of fossil fuel–based inputs; globalized supply chains; growing demand for meat, dairy, and ultra-processed foods; and, to some extent, new food trends such as ultra-processed foods and alternative meats.[21, 22] We need to decouple food production from fossil fuel use if we are to stop catastrophic climate change.

* Based on data from USA (13.6 percent), Brazil (14 percent), and EU (~13 percent). USDA, The Role of Fossil Fuels in the U.S. Food System and the American Diet, 2017; de Gouvello et al., Brazil Low Carbon Case Study Technical Synthesis Report, 2010 (does not include transport in food production system) European Environment Agency, Final Energy Consumption by Sector and Fuel, 2013. Refer to the Appendix for details on the calculation approach.

ENERGY IS USED THROUGHOUT FOOD SYSTEMS

FIGURE 1. INDICATIVE GLOBAL ENERGY CONSUMPTION ACROSS THE FOOD VALUE CHAIN *



Direct (planting, harvesting, etc.) & indirect energy (transport, fertilizer production, etc.) inputs in each stage globally.
Unit of measurement: % share of EJ/YR, 2011

Direct & indirect energy inputs in production stage globally.
Unit of measurement: % share of EJ/YR, 2011

The vast majority of the fossil fuel consumption is in the processing and packaging stage, and in retail, consumption, and waste.

Processing and packaging accounts for an estimated 42 percent of energy use globally. Food processing, refrigeration, warehousing, storage, and transportation consume a lot of energy because they rely on energy-intensive equipment, refrigeration systems, and transport to ensure the efficient handling and preservation of food from farm to table. The energy intensity of this stage is increasing as supply chains get longer, requiring increased use of packaging and stricter processing requirements.

Retail, consumption, and waste is the next most energy-intensive part of the supply chain, accounting for around 38 percent of energy use. This is driven by food transportation, embedded plastics, cooking, and food waste. An estimated one-third of globally produced food is lost or wasted. In high-income countries, retail is particularly energy intensive due to higher consumption of processed foods and associated refrigeration

* Based on 2011 FAO data, which provides the latest available data on energy inputs across the value chain. FAO, "Energy-smart" food for people and climate, 2011. FAO data for cropping, livestock, and fisheries production accounts for ~20 percent of global energy inputs. Allocated ~5 percent to input production and ~15 percent to land use and agriculture production based on data from the International Fertilizer Society, fertilizer production consumes 1.2 percent of the global energy. Percentage of energy consumed by fertilizer production in the food and agriculture value chain is (% of energy consumed by fertilizer production / % of food systems share of total energy) = ~ 4 percent. An extra 1 percent is accounted to produce other agricultural inputs and chemicals. The data presented is from 2011. Although it may not reflect the most current figures, it remains a valuable resource for gaining an indicative understanding of the energy share across the value chain. This is further supported by more recent reports that have consistently reported similar figures.

** EJ stands for exajoule, which is a unit of energy equal to 10^18 joules. EJ/YR is exajoule energy spent in one calendar year.

requirements.* The distance that our food travels has increased by a quarter over the last two decades, increasing emissions. However, as electrification increases emissions could fall, particularly in developed countries.

The stages of input and agriculture production together account for 20 percent of energy use in food systems, with land use and agricultural production accounting for about 15 percent and input production (excluding transportation) accounting for about 5 percent. Energy-consuming activities for crop production include pumping water, operating machinery, fertilizer distribution systems, greenhouse heating, and drying harvest. Livestock and fisheries production consume energy** through feed production, animal housing and ventilation, boat fuel engines, and other activities.[23]

Input production includes the production of fertilizer, pesticides, animal feed, vaccines, farm machinery, plastics, and equipment. The manufacturing of fertilizers is the most energy-intensive and fossil fuel–dependent stage. The most common fertilizer, synthetic nitrogen,*** requires an extremely energy-intensive process that involves high temperatures and pressures.[24] For example, according to CIEL, producing the ammonia (NH_3) on which nitrogen fertilizers are based releases an estimated 450 million tons of carbon dioxide (CO_2) per year—equivalent to the total energy system emissions of South Africa.[25] The FAO projects that nitrogen fertilizer use could increase by another 50 percent by 2050.[26] Furthermore, the International Energy Agency (IEA) projects ammonia production to grow by nearly 40 percent by 2050 based on current economic trends, with over half of fossil gas consumption to go toward producing hydrogen, the key ingredient in ammonia.[27]

* Crippa et al., Food Systems Are Responsible for a Third of Global Anthropogenic GHG Emissions, 2021. Refer to Figure 3 in the paper: Emissions from energy use retail, industrialized (3 percent); emissions from energy use retail, developing (<1 percent).

** Though the land use and agricultural production stage only accounts for ~15 percent of energy use within the value chain, it contributes to 55 to 65 percent of total emissions from food systems from land use emissions (28 percent) (e.g., land use change, cultivated organic soils, savannah burning), and livestock and fisheries emissions (36 percent) (e.g., methane from cattle digestion, manure and pasture management, and fuel use from fisheries).

*** The Haber-Bosch process industrially produces ammonia by combining nitrogen and hydrogen at high pressure (200 atmospheres) and temperature (400 to 500°C/752 to 932°F) using an iron catalyst. This process is energy-intensive due to the need for maintaining high pressure and temperature conditions, which require a significant amount of energy to sustain the reaction. This energy-intensive process enables large-scale production of ammonia from atmospheric nitrogen. Ammonia serves as a crucial component for creating nitrogen-based fertilizers such as urea, ammonium nitrate, and ammonium phosphate.

FOOD TRENDS ARE DRIVING INCREASED ENERGY USE

Ultra-processed products* such as snacks, drinks, and ready-made meals are dominant in high-income countries, and their consumption is now rapidly increasing in low- and middle-income countries as well.[28] Currently, a high proportion of the energy requirement for these processed foods is from fossil fuels — although in the future, this energy could be produced from renewable sources as renewable energy increasingly becomes more cost effective. Production of ultra-processed food is 2 to 10 times more energy intensive than whole foods,** and the uptick in their consumption implies increased fossil fuel use over time (see Figure 2).[29]

Similarly, while proponents of alternative meats and proteins argue these products reduce land and water footprints relative to industrial-scale meat production, some of these alternatives are still very energy intensive. Some studies have shown that lab-grown meat requires up to six times more energy compared to chicken and other less-processed alternative options.[30] However, the evidence on the carbon footprint and lifecycle impact of lab-grown meat compared to animal meat remains disputed.[31]

In general, alternative proteins may improve individual sustainability indicators when compared with industrially produced equivalents, but the evidence is limited and speculative for lab-grown meat.[32] There are also open questions on the potential impact of the alternative protein industry on further concentration of power in food systems, given the large research and development budgets required to produce these proteins. The industrialization that comes with alternative protein could undermine resilience, jeopardizing the livelihoods of millions of food producers.[33]

Furthermore, each kilogram of lab-grown meat has a lower protein content (10 to 25 percent) compared to chicken (31 percent; see Figure 3).*** This implies that, from a nutritional perspective, more lab-grown meat would need to be produced and consumed to obtain the same amount of protein, resulting in higher energy intensiveness. A holistic understanding of the implications and trade-offs of alternative meats and protein is important to mitigate unintended consequences.

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* FAO definition: NOVA classifies all foods into four groups. One of these, termed ultra-processed foods, is made up of snacks, drinks, ready meals, and many other product types formulated mostly or entirely from substances extracted from foods or derived from food constituents.

** Note that the comparative energy intensity of another set of comparable foods could be significantly greater since; for instance, fresh milk itself is energy intensive to produce.

*** Smetana et al., Meat Alternatives: Life Cycle Assessment of Most Known Meat Substitutes, 2015. While this paper was published in 2015, it is widely cited in recent studies on the environmental impact of alternative meats and proteins, and is aligned with recent papers substantiating the significant energy demand to maintain controlled manufacturing environments for alternative meats and protein, such as the report by Lynch and Pierrehumbert, Climate Impacts of Cultured Meat and Beef Cattle, 2019.

FIGURE 2: EXAMPLE: ULTRA-PROCESSED DAIRY IS 10 TIMES MORE ENERGY INTENSIVE THAN FRESH MILK*

Energy used (in MJ) to produce 1 kilogram
Unit of measurement: MJ/kg

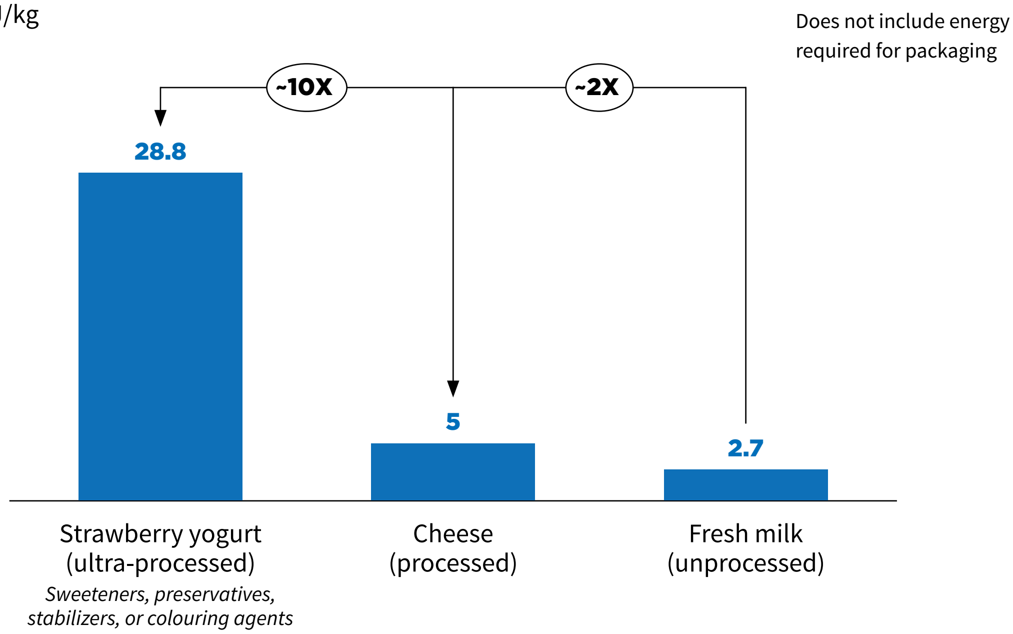
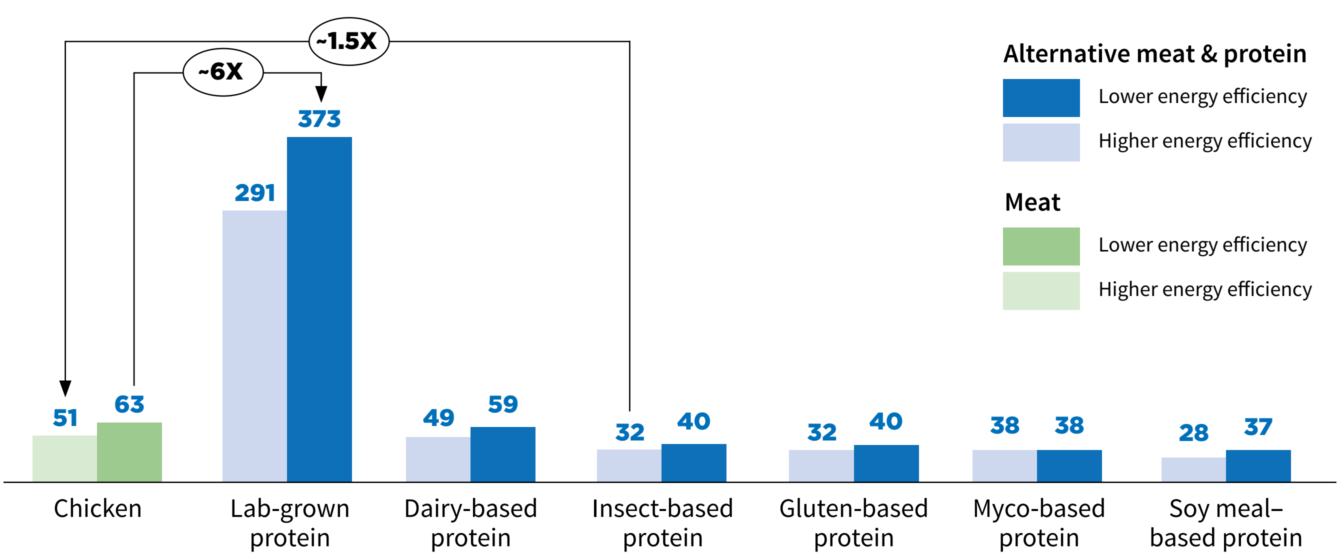


FIGURE 3: LAB-GROWN PROTEIN IS THE MOST ENERGY-INTENSIVE FORM OF ALTERNATIVE MEATS & PROTEINS**

Energy used (in MJ) to produce 1 kilogram
Unit of measurement: MJ/kg



* Bakalis et al., Mapping Energy Consumption in Food Manufacturing, 2019. The end-use energy does not include energy used for packaging the food. Sorgüven et al., Energy Utilization, Carbon Dioxide Emission, and Exergy Loss in Flavored Yogurt Production Process, 2012. For flavoured yogurt, the end-use energy before packaging has been presented to ensure parity.

** Smetana et al., Meat Alternatives: Life Cycle Assessment of Most Known Meat Substitutes, 2015.

VESTED INTERESTS ARE BARRIERS TO FOSSIL FUEL PHASE-OUT IN FOOD SYSTEMS

As demand for fossil fuels for transport, power, and heating declines due to electrification and demand-reduction measures, companies are investing significantly in petrochemicals to produce plastics and agrochemicals.[34] Agrochemicals, including fertilizers and pesticides, and plastics, including for packaging, are key to sustaining some industrial food systems activities, and the fossil fuel industry is banking on their growth to sustain profits.[35]

The growing petrochemicals market accounted for 14 percent of oil production in 2018, and 8 percent of gas production.[36] Food-related plastics and fertilizers together represent approximately 40 percent of petro-chemical products.[37] The IEA estimates that plastics will drive nearly half of oil demand growth by midcentury, outstripping sectors like aviation and shipping.[38]

Recognizing — and striving to realize — this potential, the fossil fuel industry in the United States alone was projected to spend over USD 164 billion from 2016 to 2023 on constructing new facilities and expanding existing projects within the petrochemical industry.[39] Similarly in the UAE, major producers have announced USD 150 billion in investments over the next 5 years to accelerate oil and gas production — some of which is likely aimed at meeting growing demand for plastics.[40]

It is worth noting that the top petrochemical, plastics, and agrochemical companies are often part of the same corporate structures, for example, China Petroleum & Chemical Corp, TotalEnergies, Exxon Mobil.[41] Many agri-food sectors are dominated by four to six firms with vested interests in maintaining the status quo of agriculture inputs and markets.[42] These companies possess a vested interest in promoting and perpetuating fossil fuel– and chemical-dependent, extractive industrial food systems and make significant political contributions to ensure their influence. U.S. agribusiness, which includes meat and dairy companies as well as other agricultural companies, spent USD 750 million on national political candidates from 2000 to 2020, and USD 2.5 billion on lobbying from 2000 and 2019. By comparison, the U.S. energy sector spent USD 1 billion on political candidates and USD 6.2 billion on lobbying.[43]

FOOD SYSTEMS ARE MAKERS OF ENERGY, NOT JUST TAKERS

As well as consuming energy, food systems produce energy in the form of biofuels (e.g., corn, maize), biomaterials (e.g., livestock manure, edible food waste), and on-farm energy production (e.g., agrivoltaics, small scale hydropower).

However, this energy production is not always without undesirable side effects. Some renewable energy projects can have a negative impact on the environment and local communities, and production of biofuels can take land away from food production. Some studies have found that corn-based ethanol is worse for the climate than gasoline.[44]

Fiscal policies have also shaped and incentivized biofuel production, with some unintended consequences when biofuels are produced on a large scale. Tax credits, subsidies, and loans have increased the production of biofuel feedstocks such as soy and corn. Subsidies for biogas production also incentivize the growth of the industrial livestock industry, with the development of manure-to-energy projects.[45] One study estimated that the European Union's palm biodiesel policies caused the loss of a tropical forest area the size of the Netherlands between 2009 and 2019.[46]

Other potential drawbacks from the growth of the biofuel industry include changes to land use patterns that increase GHG emissions, pressure on water resources, air and water pollution, and increased food costs.[47]

Fundamentally, food and energy both rely on natural resources of land and water — requiring vast tracts of land for cultivation or infrastructure, and using water for irrigation, extraction in fracking, and energy generation.

Crops also remove carbon dioxide from the atmosphere and sequester this carbon into soil, although the potential varies by crop and needs to be further studied.[48] Agricultural lands are thus major carbon sinks that can be used to offset emissions from the energy sector. As governments push toward net-zero, agricultural lands will be key. According to the OECD, net soil carbon sequestration on agricultural lands could offset 4 percent of annual global human-induced GHG emissions over the rest of the century and make an important contribution to meeting the targets of the Paris Agreement.[49] This does not mean that agriculture can become an offset for fossil fuel producers. Agriculture is part of the solution but not a replacement for the need for fossil fuel phase-out.

This interconnectedness gives rise to complex interactions, both trade-offs and synergies. For example, allocating finite resources such as land and water to one sector can limit their availability for another.But synergies and optimal solutions with multiple benefits can be found by engaging equitably with all actors, especially those most impacted by the resource allocation and policy decisions. This will be key to charting our way to a sustainable, equitable, and low-carbon future.

UNLOCKING TRANSFORMATION

Urgent decarbonization of our food systems is essential, via a rapid shift away from fossil fuels. The interactions and co-dependencies of the food and energy systems do not receive the attention they deserve; nor is there enough focus on the potential dividends of collaboration, including for climate change, biodiversity, land and water pollution, livelihoods, food and energy security, and nutrition.

To seize multiple opportunities and avert a deeper crisis than the world faces already, we need to identify and prioritize actions that will help transform both the energy and food sectors, increase resilience, reduce price volatility, enhance food security and nutrition, contribute to a cleaner and healthier environment, and improve livelihoods while also reducing emissions and enabling the low-carbon transition.

> Agriculture and food systems don't just need to reduce fossil fuel consumption, they need to become less energy intensive overall.

This same shift needs to happen across all sectors in order to achieve net-zero targets. We cannot simply replace one form of energy with another; we must reduce energy use overall.

Just as we need to fundamentally transform industrial food systems, energy systems based on renewable energy rather than fossil fuels also require fundamental changes to grid and storage infrastructure that can integrate the diverse characteristics associated with different sources of renewable energy (e.g., solar availability, wind speeds, hydro availability). Decarbonized energy systems require us to reduce demand for energy as well as shift when and how we use it.

Meanwhile, so-called "green" alternatives or techno-fixes, such as green hydrogen or genetically modified crops, are contentious; they can "lock in" negative practices such as synthetic fertilizer use and dependencies on pesticides as well as adversely impact biodiversity and further exacerbate concentration of power and profit among a limited number of global companies.

Green hydrogen specifically may have a modest but valuable role to play in hard-to-abate sectors such as steel and chemicals, but those applications are limited and often overstated.[50] Moreover, many energy companies are looking to green hydrogen to decarbonize their oil and gas operations to boost their longevity.[51]

CONCLUSION & RECOMMENDATIONS

By interviewing key stakeholders, we have identified the following high-impact, no-regret opportunities for greater collaboration on the food–energy nexus. (See the companion Discussion Paper for more detail on the insights leading to the prioritization of these opportunities.)

- **Phase out fossil fuel–based agrochemicals and transition to regenerative and agroecological approaches:** Widespread overuse of fossil fuel-based agrochemicals and limited focus on eliminating their use in food production calls for an urgent shift to agroecological production systems that are less reliant on external inputs and replacing residual need with environmentally friendly inputs such as bio-fertilizers and through on-farm practices for pest management. Shifting to low-carbon practices such as agroecology and regenerative approaches will enable the decoupling of food production from GHG emissions.
- **Review fiscal policies to counter negative externalities of bioenergy production:** There is a need to review existing electricity subsidies for biogas production that unintentionally incentivize the growth of the industrial livestock industry, as well as tax credits, subsidies, and loans to increase production of biofuel feedstocks such as soy and corn.[52]
- **Shift to renewables-based cooling, heating, and drying technologies:** Renewables-based technologies for cooling, heating, and drying agricultural products can potentially bring about multiple co-benefits with few resources in a short timeframe.
- **Shift to renewable energy for food processing and transport:** Work with food-processing companies to assess and minimize energy use, as well as shift to less-processed foods to reduce emissions, associated environmental implications, and improve health outcomes. Currently, some food conglomerates are relying on the decarbonization of the energy grid to facilitate their transition.[53]
- **Ensure healthy, sustainable, and just food environments that support plant-rich diets and minimally processed foods:** By shifting to more minimally processed plant-rich diets, particularly where meat and saturated-fat consumption is high or growing at levels that risk human and/or planetary health, there is potential to reduce the energy intensity of our food systems and diet-related GHG emissions by 49 percent while generating substantial health co-benefits.[54] Consumer groups, the public health community, and even countries have called for action. For example, Mexico and Denmark have promoted new dietary guidelines that emphasize the need to reduce beef and dairy consumption.[55, 56] A comprehensive roadmap to creating systemic change across different geographies reflecting diverse cultural food preferences and issues of over-consumption and food security is required. Nonetheless, it is important to consider the context in the implementation of this opportunity, as meat consumption is highest in developed countries, and some traditional diets in the Global South are traditionally plant-based.
- **Track and address corporate consolidation in the agrochemical and food industries while actively supporting a just transition through more inclusive and equitable governance and decision-making:** With a trend of consolidation in the processing industry through food conglomerates, as well as between the top petrochemical, plastics, and agrochemical companies, governments must address the impacts of this consolidation. They must also enable new forms of participatory and equitable governance to counter the vested interests in promoting and perpetuating fossil fuel and chemical-dependent, extractive industrial food systems, and highly processed foods.

Policymakers, private sector actors, investors, donors, funders, civil society, and academics all need to play a role in fostering greater collaboration at the food–energy nexus. For example:

- Philanthropies and donors can initiate a series of dialogues around food and energy, and fund action opportunities emerging from these, including awareness-raising initiatives and campaigns and ensuring affected communities are being heard in these discussions.
- Policymakers can actively support and promote healthy, sustainable, and just food environments that incentivize consumers in making better choices. They can also support policies that phase out the use of any unnecessary fossil fuel inputs into food systems, such as single-use plastic and fertilizers, while ensuring that these phase-outs are part of a just transition that does not disproportionately affect lower-income producers and consumers. The replacement of inputs with more sustainable alternatives must consider any challenges regarding risks, such as increasing food loss and waste.
- Policymakers and public sector investors can act on negative externalities of energy production through a review of existing policies, legislation, and regulations. They can also fund research and social innovation.
- Civil society and producers can focus on raising awareness through research, communications, and advocacy.
- Private sector companies and investors can finance and scale innovations that reduce energy intensity in food systems and transport.
- Private sector organizations can also actively support and promote healthy, sustainable, and just food environments that incentivize consumers in making better choices.
- Academics can conduct additional research needed at the nexus.

A series of convenings are needed to build awareness, prioritize research topics, and discuss tensions in order to advance these and many other recommendations (see Table 1).

TABLE 1. PRIORITY RECOMMENDATIONS BY TYPE OF STAKEHOLDER

	POLICY MAKERS & THE PUBLIC SECTOR Key decision makers, investors, implementers	**PRIVATE SECTOR** Investors, innovators, and implementers	**PHILANTHROPIES & DONORS** Funders and conveners	**CIVIL SOCIETY & PRODUCERS** Educators and leaders	**ACADEMICS** Frontiers of knowledge
EXPERTISE	Balancing the priorities and trade-offs of differing stakeholder views	Understanding market and user requirements for widely adopted solutions	Bringing together different actors, financing new initiatives	Identifying and elevating issues through research and advocacy	Conducting research on new topics and approaches
TOOLS	• Platforms to elevate messages for public awareness • Tax and subsidy schemes to create incentives • Regulations and legislations to ensure standards • Policies and programs to support implementation	• Capacity to promote and support innovation • Widespread reach (i.e., large customer base, users) to test and encourage adoption	• Finances to support events, research, pilot initiatives • Strong connections across sectors and stakeholders • De-risk transition process, support early action	• Self organization and development • Access to and understanding of people on the ground, in marginalized communities, etc.	• Primary and secondary data • Interdisciplinary approaches and collaborations • Platforms to communicate research
PRIORITY RECOMMENDATIONS	• Act on existing negative externalities • Encourage energy and food ministry collaboration • Fund research and social innovation	• Invest in the sustainable transition of food • Drive implementation and scaling of solutions	• Convene stakeholders • Fund awareness-raising and advocacy • Fund transformative energy and food systems solutions	• Raise awareness • Sensitize stakeholders • Build alliances and gather input from a wide variety of stakeholders	• Conduct additional research • Pilot new interventions

The bottom line is that continuing business-as-usual with incremental shifts will not be enough to achieve the radical energy and food systems transitions needed to prevent catastrophic climate change and solve health and nutrition crises. Even if all governments delivered on their 2030 climate pledges (or Nationally Determined Contributions), fossil fuel use in our food system would still blow the 1.5°C (2.7°F) carbon budget by 2037.

We need to dramatically change the way food is produced and consumed, and get off the unsustainable path of fossil fuel dependency once and for all. Shifting to low-carbon practices such as agroecology, regenerative approaches, sustainable diets, and localized value chains will enable the decoupling of food production from GHG emissions and realize a whole raft of other benefits for people's health, livelihoods, and the environment. This will require collaboration and a willingness on the part of stakeholders across sectors to compromise and cooperate (see the companion Discussion Paper for more on this).

At a time of surging fossil fuel and food prices, deepening geopolitical divisions, and an escalating climate crisis, the case for action has never been clearer.

APPENDIX: METHODOLOGY

NOTE: A detailed overview of the sources and methodology for the key figures used in this paper is available in the Appendix of the accompanying Discussion Paper.

Food systems currently account for at least 15 percent of global fossil fuel consumption

- Source: USDA, The Role of Fossil Fuels in the U.S. Food System and the American Diet, 2017; Reicosky et al., Agricultural Contributions to Greenhouse Gas Emissions, 2000; de Gouvello et al, Brazil Low Carbon Case Study Technical Synthesis Report, 2010; European Commission, Energy Use in the EU Food Sector: State of Play and Opportunities for Improvement, 2015. European Environment Agency, Final Energy Consumption by Sector and Fuel, 2013. Press Information Bureau – Government of India, All India Study Report to PPAC on sale of Diesel and Petrol, 2014. United Nations, Causes and Effects of Climate Change, accessed September 2023. Resource Watch, Which Countries Use the Most Fossil Fuels, 2019.
- Methodology: Given the limited availability of global data on fossil fuel usage in food production, we adopted a country-wide approach to gather relevant information. We collected data from different sources to capture the perspectives of various countries in terms of their fossil fuel consumption for food production. These estimates do not cover all sources of emissions in food systems and do not capture major sources, such as input manufacturing (fertilizers, pesticides) or machinery production.
    - United States: We referred to a study called "The Role of Fossil Fuels in the U.S. Food System and the American Diet" conducted in 2017. This study reported that approximately 13.6 percent of fossil fuels used in the United States are utilized in food production within the country. Note that the paper does not mention whether it considers input production in its calculation of fossil fuel in the food systems. This is in line with an older study that estimated in 2000 that fossil fuel requirements by the food system as a whole account for 10 to 20 percent of the total fossil fuel consumption in the United States.
    - Brazil: For data on fossil fuel usage in food production in Brazil, we relied on a technical synthesis report titled "Brazil Low Carbon Case Study" published in 2010. According to this report, approximately 14 percent of fossil fuels that are consumed in Brazil are utilized in the food production processes of Brazil. However, note that this report does not include transport within the food production system. The paper also does not specify whether it considers fossil fuel use in input production in the food production system.
    - European Union: Two estimates exist from the European Commission and the European Environment Agency: Estimate 1: According to the European Commission, the food sector is a major consumer of energy: the amount of energy necessary to cultivate, process, pack, and bring the food to European citizens' tables accounts for 17 percent of the EU's gross energy consumption in 2013. Additionally, fossil fuels account for almost 79 percent of the energy consumed by the food sector. 79 percent of 17 percent is 13 to 14 percent. Estimate 2: The data regarding fossil fuel usage in the food production system of the European Union was obtained from the European Environment Agency. Their report on final energy consumption by sector and fuel, released in 2013, provided insights into the energy consumption patterns in various sectors, including food production. Although the exact percentage was not specified, the data indicated that the EU's share of its fossil fuel usage in food production is estimated to be around 5 percent. This estimate is lower than the European Commission, as it excludes transport, consumption, industrial food processing, and inputs.

  - India: The data regarding fossil fuel use in agriculture was obtained from a press release by the Ministry of Petroleum in India, which states that the agriculture sector is a major consumer of diesel, with about 13 percent of the total consumption accounted for by it. While this only takes diesel into account, it gives us a fair estimate of fossil fuel consumption, as most of India's farmers still rely on diesel as their primary source of fuel.[57] Note that this percentage likely does not take into account fuel consumed at the input production stage.

- To estimate the potential percentage share of global fossil fuels used in the food system, we combined the data points from the United States (13.6 percent), Brazil (14 percent), the European Union (~5 to 15 percent), and India (13 percent). By considering these individual percentages, we determined that the collective usage of fossil fuels in food production could potentially reach at least 15 percent of all global fossil fuel consumption.
- To estimate the comparison with emissions from EU countries and Russia: We obtained the share of CO_2-equivalent emissions from fossil fuel usage from UN Climate Action (75 percent). We multiplied this by 15 percent, the share of food systems in fossil fuel consumption. This yields 11.3 percent as the share of CO_2-equivalent emissions from fossil fuels in agriculture. We leverage Resource Watch data on fossil fuel use by country from 2019, and calculated the share of fossil fuels used by Europe and Russia in total CO_2-equivalent emissions, which amounted to 11.4 percent.
- To estimate the GHG emissions from fossil fuel used in food systems, we multiplied the 11.3 percent (the share of CO_2-equivalent emissions from fossil fuels in agriculture) by the total amount of CO_2-equivalent emissions in 2021 (40.8 Gt according to the IEA), which equates to 4.6 gigatons of CO_2-equivalent emissions.

Figure 1: Indicative global energy consumption across the food value chain

- Data sourced from the FAO report "Energy-smart" food for people and climate."
- The report provided energy-intensity data across the food value chain using a five-part framework: cropping production, livestock production, fisheries production, processing and distribution, and retail, preparation, and cooking. However, for consistency throughout our report, we used a four-part value chain framework: input production, land use and agriculture, processing and packaging, and retail, consumption, and waste.
- To depict the share of energy consumption for each stage of the four parts used framework, we first divided the estimate for cropping, livestock, and input production from FAO's framework between our input production and land use and agriculture stages. To calculate the energy consumption for input production, we used data from the International Fertilizer Society, which stated that fertilizer production consumes 1.2 percent of global energy. According to the FAO, the food and agriculture value chain combined accounts for 30 percent of total energy consumed. We estimated the percentage of energy consumed by fertilizer production in the food and agriculture value chain as (1.2 percent / 30 percent) x 100 percent = 4 percent. To account for the remaining agricultural inputs, we added an additional 1 percent.
- For land use and agriculture, we accounted for livestock and fisheries production in this stage completely and assumed the remaining cropping production was in this stage. The division of energy use remained the same for the last two parts of each framework, namely processing and packaging and retail, consumption, and waste.

Figure 2: Example: Ultra-processed dairy is 10 times more energy intensive than milk

- Data for fresh milk and cheese was directly sourced from a report by Alia Ladha-Sabur titled "Mapping Energy Consumption in Food Manufacturing," published in 2019. The study is a literature survey that was carried out to collect energy consumption data for the food manufacturing sector between 1980 and 2015.
- Data for strawberry yogurt was sourced from a report by Sorgüven and Özilgen titled "Energy Utilization, Carbon Dioxide Emission, and Energy Loss in Flavored Yogurt Production Process," published in 2012.

  To calculate the end-use energy of yogurt production (MJ/kg), data from Table 10, "Energy Utilization for Unpacked Flavored Yogurt (28,820.7 MJ/metric ton)" was divided by 1000 to derive the energy use per kg of product (MJ/kg).
- While the 2 to 10 times higher energy intensity is derived from the specific example of milk-based products, it can be reasonably extrapolated to most UPFs. This is because the process of converting whole foods to UPFs often involves similar activities, such as milling, heating, and refining, which significantly increase their energy intensity.

Figure 3: Non-renewable energy required to produce alternative meats

- Data source from a study by Sergiy Smetana et al. titled "Meat Alternatives: Life Cycle Assessment of Most Known Meat Substitutes," published in 2015. The report is a literature review of multiple papers and accumulates data from all sources while also conducting their own calculations.
- The report directly presents data on non-renewable energy use in MJ/KG for each of the alternative meats. The data represented only accounts for non-renewable energy use across the life cycle of the meat substitutes. However, it can be considered an accurate source to understand the magnitude of energy use across all types of meat substitutes, as globally only 13 percent of renewable energy is used in the agricultural food chain on average. Even if renewable energy were included, the magnitude of the results would remain similar.
- Definitions:
  - Lab-grown meat: Cultured animal cells produced in a lab, often using bioreactors and scaffolds.
  - Dairy-based meat: Meat analogs made from dairy proteins, such as casein or whey.
  - Insect-based meat: Meat derived from edible insects, such as crickets or mealworms, which are high in protein.
  - Mycoprotein-based meat: Meat alternatives made from fermented fungi, such as Quorn, which are high in protein and low in fat.
  - Soy meal–based meat: Meat analogs made from soy flour, which is high in protein and versatile in texture.
  - Meat substitutes made from wheat gluten, which is the protein found in wheat that gives it its elasticity and chewy texture.

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The Global Alliance for the Future of Food is a strategic alliance of philanthropic foundations working together and with others to transform global food systems now and for future generations. We believe in the urgency of transforming global food systems, and in the power of working together and with others to effect positive change. Food systems reform requires that we craft new and better solutions at all scales through a systems level approach and deep collaboration among philanthropy, researchers, grassroots movements, the private sector, farmers and food systems workers, Indigenous Peoples, government, and policymakers.

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