DISCUSSION PAPER

TOWARD FOSSIL FUEL-FREE FOOD

Why Collaboration Between Food & Energy Systems Players Is Key

GLOBAL ALLIANCE FOR THE FUTURE OF FOOD

GLOBAL ALLIANCE FOR THE FUTURE OF FOOD | 2023

Dalberg

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FOREWORD

Unprecedented numbers of wildfires across Canada and along the shores of Hawaii, soaring ocean temperatures from Florida to the Antarctic, extreme heat and devastating floods in China, catastrophic drought in the Horn of Africa… The effects of the climate crisis are as visceral as ever. Meanwhile, action to limit global warming continues to be stalled – due to indecision rather than outright denial.

As a global alliance of philanthropic foundations focused on food systems transformation, we know that the food sector is on the frontlines, simultaneously dealing with the devastating impacts of extreme weather events while being a key driver of the crisis. And we are alarmed by the lack of collective action on climate change. One-third of all greenhouse gas (GHG) emissions is linked to food.

We also know that the only way to meet the 1.5°C (2.7°F) goals of the Paris Agreement will be to ensure that all sectors of our society phase out dependence on fossil fuels – food systems are no exception. **Indeed, experts warn that even if we were to get everything else right concerning emissions reductions but failed to reign in food systems–related emissions, we would soar past the Paris goals.**

For more than a decade, the Global Alliance has brought together philanthropic foundations and other partners around the world to forge insights, convene actors, and incite action. Through this report, we hope to help spur further movement on food systems transformation and climate action by shining a light on opportunities at the nexus of food and energy. However, it is imperative that a focus on food does not distract from the decarbonization of other sectors.

We believe that in order to meet our climate goals – with equity and justice at the centre – we need to move beyond siloed approaches and identify ways to work and partner together on research, advocacy, policy solutions, investment, and implementation. In connecting across sectors and engaging those communities most impacted by the climate crisis, we will minimize unintended consequences and unleash numerous benefits for climate, health, and livelihoods.

It is our hope that the analysis presented here will uncover other untapped opportunities and highlight how those working to change food and energy systems can collaborate to achieve the profound, and swift, transformation our world so desperately needs.

There's no time for dithering. Let's take action – together.

ANNA LAPPÉ
Executive Director
Global Alliance for the Future of Food

PATTY FONG
Program Director,
Climate, Health & Well-Being
Global Alliance for the Future of Food

PREFACE

Welcome to our discussion paper, which accompanies the recently published report titled "**Power Shift: Why We Need to Wean Industrial Food Systems Off Fossil Fuels**."

The objective of this discussion paper is to provide a better understanding of the interconnectedness between food and energy systems, with a specific emphasis on the role of fossil fuels. We aim to unveil the trade-offs, synergies, gaps, and opportunities that arise within this nexus so that we can identify and recommend near-term opportunities for enhanced coordination and collaboration among food and energy systems policymakers, funders, and advocates. Our focus is on finding ways to reduce the dependency on fossil fuels in our food systems.

The primary audience for this discussion paper includes donors, funders, and philanthropic organizations who work in climate, energy, and food systems. A secondary audience includes the environmental non-governmental organizations, campaigning groups, and implementing organizations that work on these issues.

This paper does not seek to provide all of the answers. Instead, it is intended to be a catalyst for action, igniting conversations, encouraging collaboration, and fostering shared objectives within the food–energy nexus.

To clarify the scope of this paper: We did not undertake new modelling or in-depth analyses; rather, we relied on data gathered from existing resources and efforts. We do not delve deeply into specific topics within the food–energy nexus but instead provide a broad overview of the subject matter. Additionally, this paper does not target any specific community or work.

We hope this paper will stimulate meaningful discussions 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 in order to advance the recommendations made here and to collaborate with shared focus on the no-regret opportunities highlighted.

EXECUTIVE SUMMARY

Food and energy systems are fundamentally intertwined – with interactions across the food value chain, and broad social, economic, and environmental implications. Food systems contribute to more than a third of total GHG emissions.[1] In addition, our new calculations suggest that food systems currently account for at least 15 percent of global fossil fuel use annually.*

Food and energy intersect through energy consumption in food production (e.g., fertilizer and pesticide manufacturing, plastic packaging manufacturing, food processing, and transport), and energy production through food and agriculture (e.g., biofuels, bioenergy from livestock and food waste, and on-farm solar and hydropower).

Energy intensity in food systems is also growing due to increased mechanization, growing use of fossil-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 that require 1.5 to 6 times more energy than some meats and whole foods.[2, 3] Business-as-usual food production and processing means that fossil fuel use will also increase unless we drastically transform food systems to break the link between industrial food production and consumption and fossil fuels.[4]

As demand for fossil fuels for transport, power, and heating declines due to electrification and demand-reduction measures, the fossil fuel industry is investing significantly in petrochemicals to produce plastics and agrochemicals and lock in the dependence.[5] In the United States alone, the industry will spend over USD 164 billion on new petrochemical facilities or expansion projects between 2016 and 2023.[6] In the United Arab Emirates (UAE), major producers have announced USD 150 billion investments over the next 5 years to accelerate oil and gas production.[7]

In spite of their interdependence, not to mention the risks implied by current trends, interactions between the food and energy sectors do not receive the attention they deserve.

Collaboration is happening, but it is insufficient and nascent. Greater synergies at all levels are urgently needed to decarbonize food systems and address the negative consequences of food–energy intersections. Some cross-sectoral partnerships exist at the multilateral level, such as the United Nations Food and Agriculture Organization's (FAO) multi-partner energy-smart agriculture program with the International Renewable Energy Agency (IRENA) and United Nations Industrial Development Organization (UNIDO). Comparatively fewer partnerships or organizations focus explicitly on the nexus. Food and energy have largely remained in different domains, markets, and mindsets. This has led to limited understanding and action on implications such as food price volatility and insecurity, the health impacts of cooking without clean stoves or fuels, or the loss of environmental assets (such as biodiversity and soil health) from emissions.

* Based on data from USA (13.6 percent), Brazil (14 percent), and EU (~5 percent). USDA, The Role of Fossil Fuels in the U.S. Food System and the American Diet, 2017; Christophe 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.

> Greater collaboration on the food–energy nexus could create truly resilient, equitable, sustainable, and healthy food systems. Food and energy underpin our everyday livelihoods, and their interactions have far-reaching co-benefits. Collaboration has the potential to alleviate poverty through better energy and food access, enhance sustainability, protect biodiversity, reduce emissions, create sustainable livelihoods, and strengthen resilience to global and climate shocks. Food and energy interactions can benefit equity, rights, gender, behaviour, culture, and health.

For example, clean cooking can reduce respiratory issues from open fires and inefficient stoves, and close gender gaps in education and employment – women can spend less time collecting wood for fuel, and cooking, freeing up time to attend school and generate income.[8]

Lessons from the energy transition can be applied to food systems. For example, the declining cost of renewables can be partially attributed to well-timed climate targets, government policy, and investment levers.[9]

Greater collaboration on the food–energy nexus has been hampered by several challenges, including a lack of a clear definition, vision, and awareness of the nexus, as well as an imbalance of priorities. Awareness of interactions and implications across the systems is limited, partly due to siloed ways of thinking and working, and partly due to the energy sector often being prioritized at the expense of agriculture.[10] Sustainable food investment lags far behind energy because investors have a more limited understanding of the complexities of sustainable investing in food systems.

A number of conflicts and tensions arising from differing ideologies and priorities between key stakeholders have also obstructed effective collaboration. Acknowledging and navigating the following tensions will be crucial to minimize the trade-offs and maximize the co-benefits and synergies:

1. Some actors see renewable resources as the solution to reducing energy-related emissions in agriculture, while others believe its impacts on other planetary boundaries[11] (e.g., biogeochemical cycles, land systems, biodiversity) cancel out progress on emissions.
2. Some believe carbon markets weaken the push for more aggressive collective action, whereas others advocate that putting a price on pollution facilitates the energy transition.
3. There are unresolved tensions regarding competing uses of the same resources (crops, land, water, etc.) between the food and energy sectors.
4. There are many potential futures of food, each with diverging relationships to energy, labour, and the economy that are viewed differently across actors and geographies.
5. There are tensions related to fiscal policy decisions on how to remove subsidies for fossil fuels without affecting the livelihoods of smallholder farmers.
6. While industrializing food systems might seem to reduce costs for producers or consumers, they contribute to myriad hidden costs to society and to concentrations of power and influence by those who profit from perpetuating fossil fuel, chemical-dependent, and extractive food systems at the expense of farmers, local communities, consumers, and planetary boundaries.

We must acknowledge that there are different perspectives on fundamental priorities, which may limit collaboration on these contentious topics. Nonetheless, discussing these tensions will form the basic building blocks for navigating complexities of the nexus, particularly within broader environmental and climate conversations, and identifying opportunities for action, together.

Failure to enhance collaboration on the food–energy nexus could lead to compounded and potentially irreversible adverse consequences, especially for traditionally marginalized communities. To date, a limited understanding of the complex interdependence of the food and energy sectors has led to asset loss and pollution, social inequalities and injustice, unsustainable growth, commodification, and food price volatility. The dominance of industrial-scale food producers has perpetuated inequality and marginalization, stripped farmers and Indigenous communities of their economic livelihoods, and disrupted local food security. Fossil fuel–based intensive agriculture has hastened the decline of biodiversity and caused widespread pollution,[12] and induced adverse health impacts (such as acute pesticide poisonings in 44 percent of farmers, farmworkers, and pesticide applicators annually).[13]

Urgent decarbonization of our food systems is essential to prevent catastrophic climate change and to realize a host of other social, environmental, economic, and health benefits. We must swiftly shift away from fossil fuels and reduce the energy intensity of our food systems. Continuing "business as usual" with incremental shifts is insufficient to achieve the energy transition required. We need to end fossil fuel reliance and decarbonize by reducing fossil-based inputs and energy, and shift to low-carbon practices such as agroecology, sustainable diets, and localized value chains. We are at a crucial point in development, where planetary boundaries are reaching their tipping points.[15] It is imperative for actors in the food and energy sectors to engage in more systematic collaboration, working together to address challenges and reduce adverse consequences.

> We must swiftly shift away from fossil fuels and reduce the energy intensity of our food systems. Continuing "business as usual" with incremental shifts is likely insufficient to achieve the energy transition. We need to end fossil fuel reliance and decarbonize by reducing fossil-based inputs and energy, and shift to low-carbon practices such as agroecology, sustainable diets, and localized value chains.

High-impact "no regret" opportunities for greater collaboration include: 1) phasing out reliance on fossil fuel–based agrochemicals and transitioning to regenerative and agroecological approaches; 2) reviewing fiscal policies to counter negative externalities of energy production; 3) shifting to renewable energy for cooling, heating, drying, processing, and transport; 4) ensuring healthy, sustainable, and just food environments that support plant-rich diets and minimally processed foods; and 5) tracking and addressing corporate consolidation in the agrochemical and food industry. These actions were deemed "no regret" due to their potential impact and the level of collaboration that already exists in these areas today.

To act on these no-regret opportunities, several next steps have been identified, including scenario planning of different futures of food as well as dialogues to help align priorities and action. With different potential pathways for transforming our food systems, modelling the impact of different scenarios in the context of climate change impacts, geopolitics, and consumption trends, for example, will be critical to building a common understanding of the potential implications, trade-offs, and opportunities among policymakers, producers, industry, and civil society. A series of convenings to build awareness, prioritize research topics, and discuss tensions could help kickstart collaboration, building momentum for change within the ecosystem. Collaboration across donors and funders, civil society, producers, policymakers, and industry can move the needle toward greater effectiveness in both energy and food systems transformation, while protecting against unintended consequences.

> At a time of surging fossil fuel and food prices, deepening geopolitical divisions, and an escalating climate crisis, the case for collaboration on the food–energy nexus has never been more urgent. We cannot transform food systems without addressing fossil fuel consumption, and we will not be able to phase out fossil fuel use and stop runaway climate change without changing food systems.

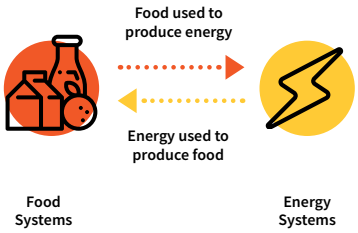
DEFINITIONS & ABBREVIATIONS

KEY DEFINITIONS

FIGURE 1. DEFINITION OF KEY TERMS USED THROUGHOUT THE REPORT

"INTERSECTIONS"

The **interactions** between food and energy systems, including **energy consumption** and **production**, anywhere along the food systems value chain.

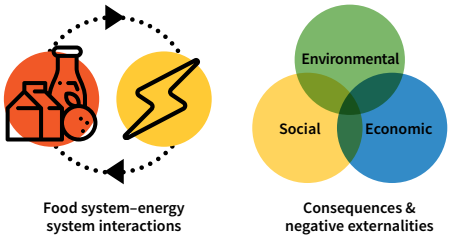


Examples

- **Energy consumption:** Energy used for transportation of food by air, rail, sea, road
- **Energy production:** Biofuel produced from foods such as corn, sunflower, rapeseed, etc

"IMPLICATIONS"

A consequence, issue, or negative externality that arises from the interactions between food and energy.

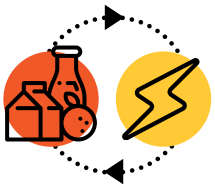


Examples

- **Health:** Using unclean energy and technologies to produce food, causing respiratory issues
- **Air and water pollution:** Incentivizing growth of the livestock industry for biogas production, creating GHG emissions and water pollution from manure

"TENSIONS"

An unresolved issue or differing views among food or energy stakeholders that may prevent or limit further collaboration on the food and energy nexus.



Examples

- **Renewables as a solution:** Clean energy may be fossil-free, but it creates other impacts, such as land resource competition between energy and agriculture (i.e., agriculture farms converted to solar farms); stakeholders can prioritize trade-offs differently, with conflicting opinions on use cases for renewables

ABBREVIATIONS

TABLE 1. LIST OF ABBREVIATIONS USED THROUGHOUT THE REPORT

ABBREVIATION	FULL TEXT
EJ	Exajoule, a unit of energy equal to 10^18 joules.
ESF	FAO Energy Smart Food for People and Climate Program
FAO	Food and Agriculture Organization
GHG	Greenhouse gas
IEA	International Energy Agency
IFAD	International Fund for Agricultural Development
IRENA	International Renewable Energy Agency
MJ	Megajoule, a unit of energy equal to 1 million joules
NGO	Non-governmental organization
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNIDO	United Nations Industrial Development Organization

THE FOOD–ENERGY NEXUS

As the "Power Shift" report shows, energy and food systems are co-dependent. Food systems account for at least 15% of global fossil fuel consumption each year. Energy is also produced by agriculture and land use in the form of biofuels, and land is an important carbon sink.

Taking action to transform food systems is essential to reduce global emissions but will also bring other benefits. Food systems transformation will not be possible without reducing fossil fuel dependence, and the urgent fossil fuel phase-out will not be possible without transforming food systems. However, food–energy synergies do not receive the attention they deserve, even though collaboration could yield positive social, economic, and environmental results, including on biodiversity, livelihoods, health and nutrition, and food and energy security.

Obstacles to collaboration exist, and issues need to be overcome and resolved. However, at a time of surging fossil fuel and food prices, deepening geopolitical divisions, and an escalating climate crisis, the case for coming together to address the challenges and realize the opportunities inherent in the food–energy nexus has never been more urgent. This paper seeks to help chart a course to that outcome.

This in-depth assessment consisted of desktop research and interviews with 28 stakeholders from diverse sectors and organizations, ensuring balanced geographic representation. The findings and key messages were further refined with input from 50+ stakeholders. For a detailed breakdown of stakeholder representation and overall methodology, please refer to the Appendix.

COLLABORATION IS NASCENT

At present, collaboration between actors on food and energy is at best nascent, and there is still a divide in approaches. Current work on the nexus is primarily focused on reducing fossil fuel energy dependence and GHG emissions from agriculture, with some organizations working on specific topics such as the phase out of agrochemicals, net-zero food processing, and clean cooking.

Organizations such as the FAO and IRENA mainly focus on energy-consumption interventions in the food sector, including shifting to low-carbon practices or renewable energy, decoupling food production from fossil fuels without diminishing food security, and reducing emissions. In 2011, the FAO launched the multi-partner Energy-Smart Food for People and Climate (ESF) program. This program has a clear overarching strategy anchored in more sustainable energy consumption along agri-food chains. It actively collaborates with relevant UN organizations (UNDP, UNEP, UNIDO), the International Fund for Agricultural Development (IFAD), the World Bank, and the IEA.[15] In 2021, IRENA and FAO signed a memorandum of understanding to improve the profitability and sustainability of food systems by accelerating the use of renewables and sustainable bioenergy.[16]

Most recently in 2022, the FAO and IRENA published an *Energising Agri-food Systems with Renewable Energy Compact*, which outlined actions to: 1) assess energy gaps and renewable energy opportunities within at least five agri-food systems, and 2) support pilot programs and strengthen the enabling environment for investments in renewable energy for agri-food systems. A total budget of USD 4.15 million is dedicated to these activities.[17] These high-level activities indicate that collaboration and work on the food–energy nexus is currently a growing priority for multilaterals and major global organizations.

Along the value chain, groups of alliances and organizations are also working on topics that relate to the nexus; for example: the phasing out of agrochemicals (e.g., Pesticide Action Network, Center for International Environmental Law), promotion of agroecology (e.g., Alliance for Food Sovereignty in Africa, Agroecology Coalition), transforming the supply chain (e.g., Clean Cooling Collaborative), and clean cooking (e.g., Clean Cooking Alliance, Global Cooksafe Coalition). Many of these groups were interviewed as part of this effort, and while they agreed some initiatives exist, they indicated opportunities remain.

Despite collaboration at the multilateral level, few organizations work on the nexus strategically. Most expenditure is driven by separate agriculture, energy, or climate programs rather than a consolidated focus on the food–energy nexus.

Several large organizations have relevant interventions across the value chain that are linked to their broader programs in agriculture or climate change. For example, the World Wide Fund for Nature (WWF) has food energy–related programs across the food system, including initiatives to reduce dangerous pesticides, promote agroecological practices in production, implement traceability solutions in the supply chain, and reduce consumer carbon footprints.

> The adoption of renewables (solar pumps, solar irrigation, and small-scale hydropower), electrification of machinery, and sustainable practices (conservation agriculture, drip irrigation) has improved significantly over the past 15 to 20 years.

Similarly, the World Resources Institute through the Food and Land Use Coalition has conducted work to 1) promote large-scale adoption of sustainable and regenerative agricultural practices; 2) create an evidence base for sustainable healthy diets; and 3) integrate food and land use into climate-neutrality strategies.[18]

Other organizations (such as private-sector companies) have adopted different strategies that relate to or work on the nexus, but they aren't cross-collaborating or coordinating with other players to achieve common goals. As part of their climate goals, many multinational food-processing and retail companies (such as Unilever and Nestlé) have announced their plans to achieve net-zero emissions. While these strategies relate to the food–energy nexus through a reduction of packaging and utilizing renewable energy in supply chains, for example, their primary focus is on emissions and thus excludes several other food–energy implications. On the other hand, organizations who are explicitly working on the nexus – via bioenergy production or clean cooking, for example – tend to focus on energy- or intervention-specific goals.

Adoption of sustainable technologies and practices in agriculture is steadily increasing (the fruits of previous work on the nexus), but more work is needed. According to Alessandro Flammini at the FAO, who has been working actively on the nexus for the past decade, ***"the adoption of renewables (solar pumps, solar irrigation, and small-scale hydropower), electrification of machinery, and sustainable practices (conservation agriculture, drip irrigation) has improved significantly over the past 15 to 20 years."***[19] This is further substantiated by global progress toward the clean energy transition and on related sustainable development goals (SDG 2 on zero hunger, and SDG 7 on affordable and clean energy). Nonetheless, significant work still needs to be done.

FIGURE 2. MAPPING OF ORGANIZATIONS WORKING ON THE NEXUS

NON-EXHAUSTIVE

AREA	EXISTING COLLABORATION	1 INPUT PRODUCTION	2 LAND USE & AGRICULTURAL PRODUCTION	3 PROCESSING & PACKAGING	4 RETAIL, CONSUMPTION, & WASTE
ENERGY CONSUMPTION	SHIFT TO LOWER-CARBON PRACTICES	*Phase out agrochemicals*: PAN, CIEL	*Promotion of agroecology*: AFSA, Agroecology Coalition; AGRO FOSSIL FREE		wrap, SUSTAINABLE PACKAGING COALITION
	REDUCE ENERGY INTENSITY	IRENA, FAO		GLOBAL COLD CHAIN ALLIANCE, Clean Cooling COLLABORATIVE, IIF/IIR	CLEAN COOKING ALLIANCE, GLOBAL COOKSAFE COALITION, Cleaner Cooking Coalition
	SHIFT TO RENEWABLE ENERGY	*Coordinated energy-smart agriculture program*	IFPRI	POWER FOR ALL, POWER SHIFT AFRICA	
	ACCESS TO SUSTAINABLE ENERGY	Farm to Fork, WWF, iPES FOOD, iea, WORLD RESOURCES INSTITUTE			
	CHANGE TO CONSUMPTION HABITS			ReFED	BEYOND PLASTICS
ENERGY PRODUCTION	BIOENERGY	*Organizations working on research & interventions across value chains & areas*	TAP, C2ES		FEEDBACK, divert
	ON-FARM ENERGY		American Farmland Trust, MILKEN INSTITUTE		

CASE STUDIES OF EFFECTIVE COLLABORATION

While both systemic collaboration and cooperation at the macro level and widespread recognition of the interdependence between food and energy systems are lacking, the following case studies illustrate what more effective collaboration looks like. In order to scale up deliberate collaboration and reform our food and energy systems, we need to learn from existing partnerships.

CASE STUDY

Plastic Pact Network: Global collaboration to reduce fossil-based plastics[20]

The Ellen MacArthur Foundation's Plastics Pact Network is a global initiative that addresses plastic waste and pollution by promoting collaboration and knowledge-sharing. Through national and regional initiatives, the network brings together stakeholders such as businesses, government institutions, NGOs, and citizens to drive change toward a circular economy for plastic. This global initiative has yielded significant impact and inspired action on a global scale – since the launch of the first plastics pact in 2018, numerous pacts and similar initiatives have emerged worldwide. These pacts, both within and outside the Foundation's network, are driven by the shared vision of eliminating unnecessary plastic packaging, transitioning to reusable models, and ensuring recyclability or composability of plastic packaging.

The Plastics Pact Network emphasizes the importance of collaborating and has thus played a critical role in facilitating the exchange of best practices and lessons learned across regions. By sharing insights and experiences, stakeholders have identified innovative solutions, effective policy frameworks, and successful business models to address the plastic waste crisis. This knowledge exchange has accelerated the transition to a circular economy for plastics, enabling stakeholders to collectively tackle this complex challenge. By aligning efforts, sharing expertise, and amplifying impact, the network demonstrates the power of collaboration in creating meaningful change, and the real feasibility of phasing out fossil-based materials through joint efforts.

CASE STUDY

Sustainable Land Use Futures: Collaboration to address competition for land[21]

A sustainable land use future program has been established in Australia to address climate change and sustainably transform the food and land use system. This initiative is led by Climateworks Centre, Deakin University, and the Commonwealth Scientific and Industrial Research Organization, a government agency responsible for scientific research. Recognizing that land is finite and subject to increasing competition between different uses, the program aims to transform Australia's food and land use systems. Through joint collaboration, the program will develop pathways to explore food and land use futures, identify strategies for transformation, support champions, and track progress and build momentum for sustainable land use.

Collaboration plays a pivotal role in this program by leveraging expertise from civil society, academic institutions, and government agencies, as well as stakeholders from the food, land, and oceans sectors to collectively support pathways toward a more sustainable future.

CASE STUDY

Private Equity Impact Strategy: Combining expertise for food transformation*

In May 2022, AXA, Unilever, and Tikehau Capital unveiled their shared commitment to address the urgent need for regenerative agriculture practices by establishing a private equity impact strategy dedicated to investing a total of USD 330 million in projects and companies that support the transition to regenerative agriculture. This tri-partite partnership recognizes the potential of regenerative agriculture to combat climate change, actively leveraging the individual expertise of each partner – AXA Climate on climate and agriculture risks management, Unilever on global food supply chains and local market experience, and Tikehau Capital in investments toward the energy transition and decarbonization.

The strategy, to be managed by Tikehau Capital, will focus on three core areas: protecting soil health, contributing to the future supply of regenerative ingredients, and unlocking technological solutions for agricultural transformation. The partners advocate for more systemic collaboration between stakeholders across the value chain, including farmers, producers, manufacturers, retailers, technology providers, and financial investors, which the fund seeks to bring to life.

The collaboration among AXA, Unilever, and Tikehau Capital showcases a pioneering effort to combine expertise and accelerate the adoption of regenerative agriculture practices.

* Information synthesized from AXA-Unilever-Tikehau Capital, Regenerative agriculture transition. Accessed May 2023.

CASE STUDY

Feedback Campaigns: Achieving impact through industry partnerships*

Feedback, a UK- and Netherlands-based environmental campaign group, has achieved progress in addressing critical issues in the global food system through research and partnerships with industry leads. Leveraging research, campaigns, and partnerships, Feedback has influenced industry practices, raised public awareness, and catalyzed action. Recently, Feedback has focused its effort on raising awareness on public subsidies of biogas energy production and the unintended consequences of incentivizing industrial livestock production. As part of their campaign to divest from "Big Livestock" (industrial livestock and dairy farms), Feedback has published impactful reports and exposed the funding sources supporting these industries. Through partnerships with investigative journalism organizations, Feedback has influenced public discourse and urged a halt to these harmful practices.

Feedback has also worked extensively on transforming supermarket practices on food waste. Through research, campaigns, and engagement with industry stakeholders, Feedback has raised public awareness and compelled UK businesses to take action. Their work played a crucial role in the former CEO of Tesco calling for mandatory food waste reporting to combat climate change.

* Information synthesized from Feedback, Our Campaigns. Accessed May 2023.

CASE STUDY

Coal Mine Repurposing Lab: Repurposing stranded assets for a just transition*

Change Pathways, a company specializing in sustainable solutions for climate change mitigation, energy, and evaluation, is addressing the challenge of transitioning away from coal mining in South Africa's Mpumalanga province. As part of their efforts, Change Pathways has established a coal mine repurposing lab, repurposing an underground coal mine site into a thriving hub of sustainable businesses, employment, and local livelihood support. They have selected Forzando South as the site for their first small-scale pilot project, and funding has been secured to establish a part of this underground coal mine as a hydroponics farm, benefiting the local community.

This initiative serves as a tangible example of how stranded assets from decarbonization, and the clean energy transition can be repurposed for other uses that promote economic diversification, sustainability, and inclusive growth. Change Pathways shows how stakeholder collaboration for a just transition can ensure legitimacy, support, and alignment with community needs. By focusing on three strategic areas – net-zero markets, sustainable food, and the bioeconomy – strong business opportunities are created that align with global warming targets and offer synergistic benefits.

* Information synthesized from Change Pathways, About. Accessed May 2023.

POTENTIAL CO-BENEFITS OF COLLABORATION

Food and energy systems underpin our everyday lives, and collaboration between each sector could have far-reaching co-benefits, including: 1) creating truly resilient, equitable, sustainable, and healthy food systems; 2) alleviating poverty through energy and food security; 3) reducing emissions; and 4) strengthening resilience to global and climate shocks.

Aline Mosnier, an economics expert from FABLE Consortium, observed: ***"Food and energy commodities are the basic purchases of households; any changes in these can create snowball effects on wider society."*** [22] Figure 3 illustrates how food and energy systems interact across the value chain.

Collaboration between food and energy sectors can have multiple crosscutting implications for equity, health, the environment, commodity markets, justice, and security, to name a few.

As Figure 4 shows, collaboration between the food and energy sectors has positive social implications, including within equity, rights, gender, behaviour, culture, and health spheres. For example, clean cooking of food can reduce respiratory issues (resulting from open fires and inefficient stoves) and close gender gaps in education and employment (women can spend less time collecting wood for fuel, and cooking, freeing up time to attend school and generate income).[23]

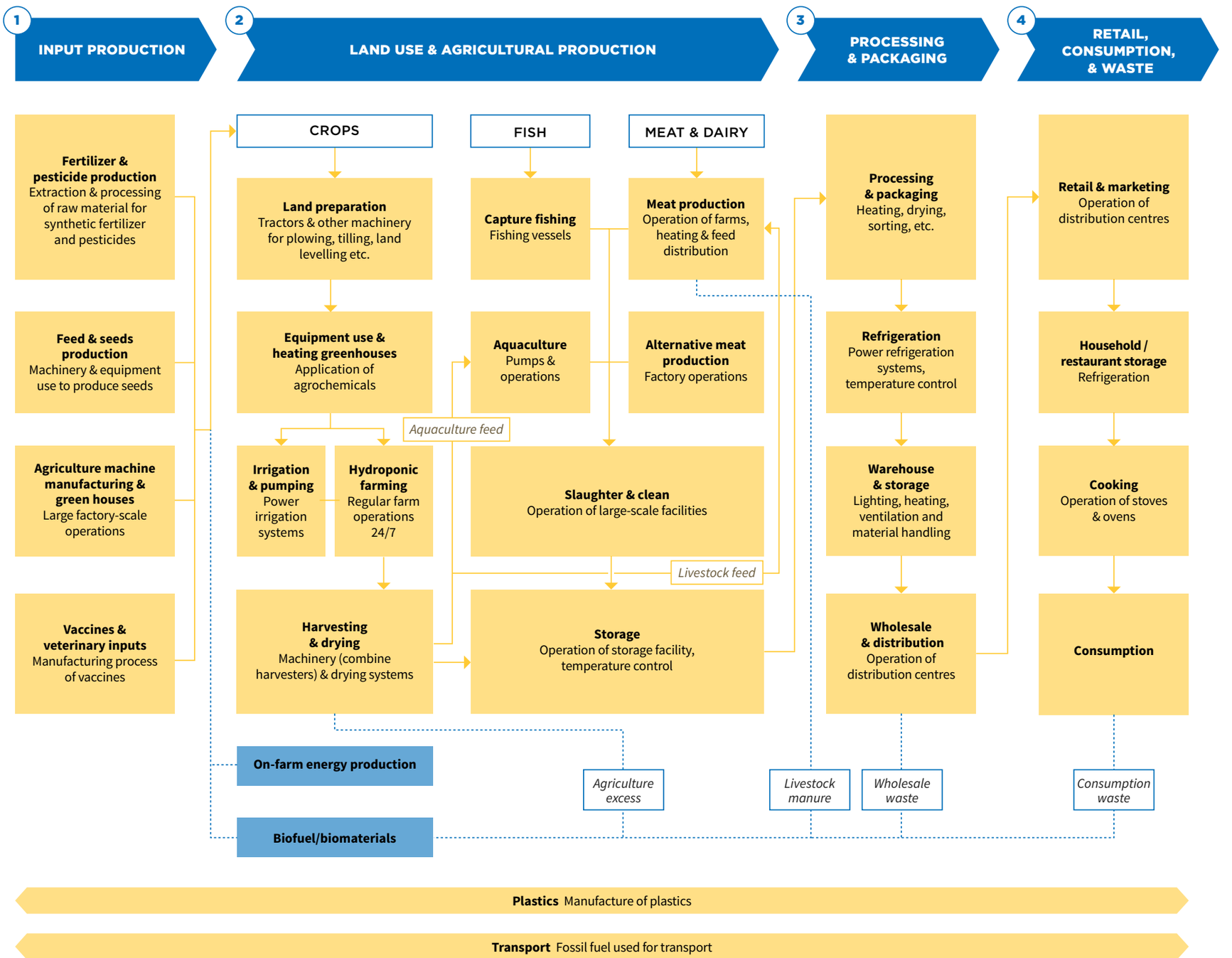
Potential economic benefits of food–energy interactions include stable food and energy markets, reduced competition for funding, and synergistic use of carbon sequestration and financing. The same funding resources, when utilized efficiently, can benefit both food and energy systems. For example, climate finance for energy and transport can also be used to catalyze regenerative forms of agriculture. Shifting to regenerative agriculture and agroecology has many advantages, such as improving ecosystem health, restoring degraded landscape, increasing nutrient density, and reducing GHG emissions.[24] One of the key benefits of regenerative agriculture and agroecology is the reduced dependency on agrochemicals as well as overall energy by leveraging ecosystem services and turning farmlands and pastures into carbon sinks, mitigating emissions.[25]

Environmental benefits include climate mitigation and adaptation, and protection of environmental assets such as biodiversity and soil health. For example, intercropping corn and soybeans* can promote higher plant resource efficiency (space, nutrients, water) and natural resistance to insects and pathogens (and therefore climate resiliency).**

* Energy crops are specifically grown for the purpose of producing biomass, biofuels, or renewable energy. These crops are chosen for their high energy content and suitability for conversion into various forms of energy. One example of an energy crop is switchgrass, a tall perennial grass that can be used as a feedstock for biofuel production due to its high cellulose content and ability to grow in diverse environments with low input requirements.

** Corn and soybeans are intercropped in some agricultural systems, although many large production systems continue to practice monoculture, including in the United States. Corn provides the main food crop, while soybeans serve as an energy crop due to their high protein content and their potential for oil extraction, which can be converted into biofuels.

FIGURE 3. ENERGY CONSUMPTION & PRODUCTION ACROSS THE FOOD VALUE CHAIN



LEGEND

Energy consumption | Energy production | *Text* Examples of fossil fuel / energy use | *Text* Biomaterial for energy production

Note: Meat production includes cow-calf operations, stockers, and backgrounding and feedlots.

Source: Food and Agriculture Organization, Energy-smart food for people and climate, 2011.

FIGURE 4. ENVIRONMENT, ECONOMIC, & SOCIAL IMPLICATIONS OF FOOD–ENERGY INTERACTIONS

EXAMPLE
Use of agricultural lands for energy production

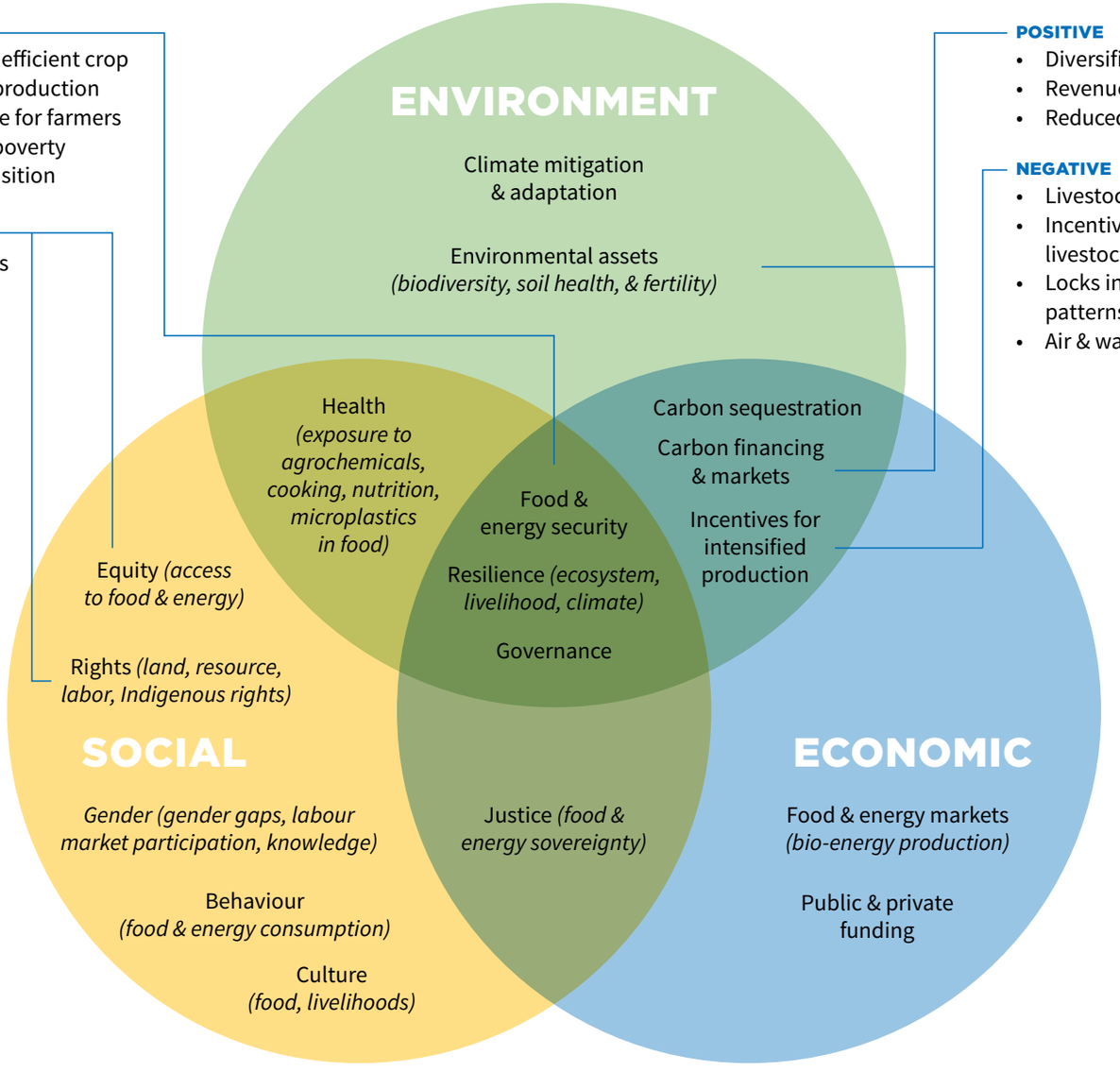
POSITIVE
- Use of residual/inefficient crop lands for energy production
- Diversified income for farmers
- Reduced energy poverty
- Clean energy transition

NEGATIVE
- Energy companies price out farmers
- Infringement on Indigenous rights
- Disrupt local food systems & food security

EXAMPLE
Biogas production from livestock manure

POSITIVE
- Diversified income for farmers
- Revenue stream for waste
- Reduced GHG from livestock manure

NEGATIVE
- Livestock waste systems
- Incentivizes growth of industrial livestock production
- Locks in current consumption patterns
- Air & water pollution



> Food and energy are intrinsically linked, yet conversations around funding and innovative solutions remain siloed. We need to bring food and energy into the same conversation to achieve the sustainable and resilient outcomes we're looking for.

On-farm renewables such as solar panels or wind turbines on farm can reduce energy poverty and increase energy sovereignty for both farmers and the surrounding community. Having access to a stable energy source can also expand food production, simultaneously improving local food security and sovereignty. These examples demonstrate how individual collaborations at the food–energy nexus can have ripple effects on individuals and communities. Figure 5 maps these positive implications across the food value chain. Food–energy interactions benefit all stages of the food value chain. Much of the narrative around food–energy benefits tends to focus on environmental aspects as well as on the land use and agriculture production stage (i.e., reduced emissions in food production or transportation).

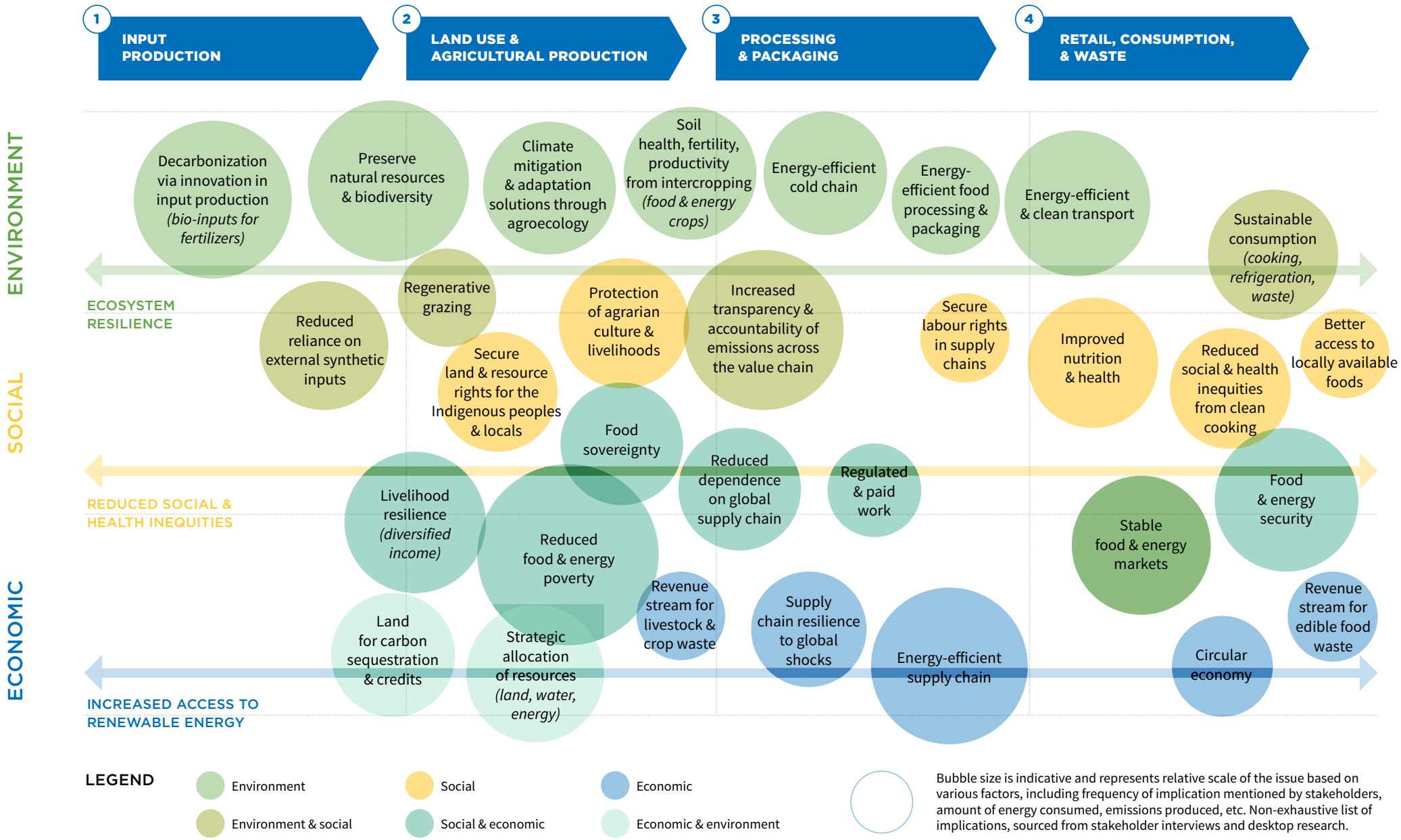
However, as shown in Figure 5, the benefits extend beyond the environment to various social and economic aspects across the value chain. Some of these positive implications include decarbonization and associated environmental impacts in the input production stage; increased transparency and accountability of emissions and supply chain resilience in the processing stage; better access to locally available foods; and revenue streams for food waste in the consumption stage.

Many successful initiatives from within the energy sector could be applied to food systems. For example, the cost of solar photovoltaics fell by 82 percent over a decade. The rapid progress is partially attributed to well-timed climate targets, government policy, and investment levers.[26] A similar combination of targets, incentives, and investment support could help accelerate the much-needed transformation of food systems.

With all these potential benefits in mind, many stakeholders have urgently called for greater collaboration. For example, Ilana Moreno from the Milken Institute stated, ***"Food and energy are intrinsically linked, yet conversations around funding and innovative solutions remain siloed. We need to bring food and energy into the same conversation to achieve the sustainable and resilient outcomes we're looking for."***[27]

Collaboration will increase the solutions space, especially since the energy sector is well versed in some areas (e.g., decarbonization, energy efficiency, rapid scaling of new technologies) and the food sector is well versed in others (e.g., land use planning, resource management).

FIGURE 5. POSITIVE IMPLICATIONS OF FOOD–ENERGY INTERACTIONS ACROSS THE VALUE CHAIN*



* Non-exhaustive with indicative bubble size. Based on desktop research and stakeholder interviews conducted April–May 2023.

OBSTACLES TO COLLABORATION

The stakeholders interviewed for this paper identified some common challenges that hamper greater collaboration at the food–energy nexus, including lack of a clear definition, vision, and awareness of the nexus, as well as organizational silos and an imbalance of priorities. Although most experts working on food and energy see energy consumption and production within food systems as the nexus, they each have different perspectives on the definition.

While food systems experts widely acknowledge that energy is a necessary component in all foods, energy sector experts, who primarily see interactions through a GHG emissions–reduction lens, tend to have a narrower view. These differing lenses have culminated in a lack of definition and awareness, as well as siloed organizational dynamics across government, academic, and civil society institutions.

Many of the stakeholders we spoke to noted that awareness of the interactions and implications across food–energy systems is limited, partly due to siloed ways of thinking and working (e.g., there are different ministries for energy and agriculture), and partly due to the energy sector often being prioritized at the expense of agriculture.[28] Conflicts also arise from differing ideologies and priorities between key stakeholders – and governance/decision-making structures that are influenced by those with the most access or power.[29]

Furthermore, those working on food systems have yet to align their visions for the future, whether it's agroecology, regenerative agriculture, or sustainable intensification (global or local). This is an obstacle to productive alignment and cooperation with those working on energy reform.

Fundamental barriers also discourage collaboration and reinforce lagging development, especially in terms of investments in food systems compared to energy systems (just 3 percent of public climate finance currently goes to food systems).[30] One investment expert said sustainable food investment is 10 to 15 years behind energy because investors have a preconceived notion that food systems are too complex. Financially, food systems are deemed high risk (e.g., weather dependent), with long time horizons (e.g., crop harvest cycles), small ticket sizes (e.g., several individual farmers involved), and low returns (e.g., long supply chains, resources used tracing these transactions).

Furthermore, there isn't a sizable track record of successful investments from which investors can draw inspiration and best practices. Many investors do not have technical knowledge in food systems and are averse to spending the money to solicit this expertise for a high-risk investment. This, coupled with the lack of unified vision of the future of food, causes an imbalance of priorities, where energy is often ranked ahead of food despite the importance of both sectors.

FIGURE 6. STAKEHOLDER INSIGHTS ON DRIVERS FOR LACK OF COLLABORATION*

LACK OF A CLEAR DEFINITION

"The food and energy nexus is ill defined; that's one of the core problems."

PETER ELWIN, Planet Tracker

LACK OF AWARENESS

"The food sector knows how the energy sector fits in, but I can't say the same for vice versa."

ILANA MORENA, Milken Institute

LACK OF A CLEAR VISION

"There is limited collaboration in the food–energy nexus because we have a vision for what a transformed world looks like for energy, but not for food."

TIM BENTON, Chatham House

ORGANIZATIONAL SET UP

"Most of the sector works in silos; the Ministry of Agriculture promotes various types of irrigation/schemes that use energy without working together with the Ministry of Energy."

SENA ALOUKA, Alliance for Food Sovereignty in Africa

IMBALANCE IN PRIORITY LEVELS

"I don't see collaboration; energy is prioritized at the expense of agriculture and food producers."

DEREK CABE, Coal-free Bataan

GOVERNANCE

"We need to strengthen institutional capacity and governance at a national level to ensure better collaboration."

ANONYMOUS

* Based on interviews with 28 stakeholders in the food and energy sectors. Interviews conducted April–May 2023.

In order for substantive and meaningful progress to be made, the following six key areas of tension and disagreement need to be resolved.

1. RENEWABLE ENERGY

Some key actors see renewable energy as the solution to reducing energy-related emissions in agriculture, while others have pointed to a lack of inclusion and engagement with local communities when it comes to the type of renewable energies to be used in food systems as well as how and where they are implemented, which leads to tensions.

Most renewable energy sources, such as wind and solar, are emissions-free; use of these sources can: 1) facilitate access to energy through decentralized production; 2) contribute to global climate targets; and 3) diversify income for farmers — although the production of renewable energy assets has a significant energy footprint (when manufactured with fossil fuels) and an environmental footprint (due to the need for minerals, such as rare earth). Many actors believe that renewables are a key tool in food systems but question whether specific sources (such as biofuels and biogas) can even be called renewable energies[31] as well as how and where renewable energy projects are implemented.

Contentious renewables include energy crop biofuels (e.g., corn, maize , soybean), biogas production (e.g., from livestock manure, food waste), hydrogen production, agrivoltaics, and carbon capture and storage. For example, the incentivization of biogas production can entrench food waste systems and support the growth of polluting sectors (e.g., industrial livestock production, fossil fuel industry through hydrogen production and ammonia).

> When local communities are not engaged, planetary impacts are often overlooked (e.g., the loss of local food security and agriculture livelihoods). When local communities are not included in decisions about which renewable energies will be used in their food systems, tensions result. Good, transparent, inclusive governance and decision-making — with all actors in the system — is critical.

2. CARBON MARKETS

Carbon markets can facilitate the global energy transition but have been criticized for weakening the push for more aggressive collective action. Carbon financing can help offset emissions and is a tool to achieve net-zero emissions, especially for industries that cannot undergo rapid decarbonization within the next few years. It also puts a price on pollution, potentially accelerating the clean energy transition.

Nonetheless, carbon financing requires a complex verification process, with limited regulation and transparency, and does not fundamentally change the modes of production or consumption, which generate emissions. It can also perpetuate inequality, as only those who can afford it can access carbon credits. The community is divided on its use, with food and energy stakeholders sitting on both sides.

3. RESOURCE ALLOCATION

The food and energy sectors directly compete for natural resources such as land and water, as well as indirectly for funding and policies. The same piece of land or volume of water can be allocated to the food sector for food security, sovereignty, or livelihood production or to the energy sector for energy security, access to energy, or decarbonization of the energy grid through renewables.

As Ann Tutwiler from Meridian Institute said, ***"There is a distinct policy link between the food and energy markets – particularly through subsidies that encourage farmers to grow crops for renewable fuels rather than for food, which drives up food prices without actually addressing climate change."*** [32]

As the global energy transition has come together in very cohesive and tangible ways, such as emissions accountability through nationally determined contributions (NDCs), energy has often been prioritized over food. Resources are finite, and it is important to balance the different trade-offs and benefits associated with each sector.

Resource competition typically materializes in three ways: water scarcity, land allocation, and national interest:

Water scarcity: Limited water resources present a significant challenge for both food and energy production. As competition for water intensifies, allocating sufficient water for irrigation or emphasizing the scaling up of farming practices that reduce the need for irrigation and improve on-farm water efficiency to ensure food security becomes more difficult. Conversely, water is crucial for energy production, particularly in hydropower generation and cooling processes for thermal power plants.

Land allocation: The increasing demand for land to accommodate renewable energy infrastructure, such as solar panels or wind turbines, can have adverse effects on local communities and agroecological systems. The conversion of typical rangelands and pastoral lands, previously used for grazing and supporting pastoralist livelihoods, disrupts traditional ways of life and negatively impacts local economies. Additionally, these land conversions can disrupt agroecological cycles and biodiversity, as grazing plays a vital role in maintaining ecosystem balance.

National interests: It can be hard to find the right balance between meeting national interests in energy generation and renewable energy targets and protecting the rights of local communities who have traditionally depended on the land in question. When governments prioritize land conversion for renewable energy projects without adequate consultation and consideration of community interests, it can lead to social, cultural, and economic disruptions.

4. THE FUTURE OF FOOD

There are many potential "futures of food," each with diverging relationships to energy, labour, and the economy that are optimized differently across actors. As such, different communities advocate for different sustainable food futures. Agroecology and regenerative agriculture sit at the opposite end of the spectrum from sustainable intensification.

> Agroecology and regenerative agriculture prioritize food sovereignty, biodiversity, and ecosystem services as well as livelihood resilience.

This implies lower energy use and higher human labour requirements, with a more localized or regionalized economy. On the other hand, advocates of sustainable intensification believe in limiting land use conversion through improving yields, which can have implications for higher energy use. A farm in each of these food futures would look very different, and each future has different benefits and trade-offs.

5. FISCAL POLICY

Existing agricultural subsidies are responsible for the loss of 2.2 million hectares (5.4 million acres) of forest per year (equivalent to 14 percent of global deforestation),[33] incentivize fossil fuel use, and lock in unsustainable methods of production. However, many smallholder farmers are reliant on fossil fuel subsidies or related subsidies (e.g., subsidized fertilizers in India). Cutting them would reduce fossil fuel use but would also have a disproportionately large impact on the livelihoods of farmers without fiscal support to transition to regenerative practices.

Current subsidies generally aim to support yields and/or farmer incomes at all costs, rather than planetary and human health and well-being. Few subsidies are designed to help farmers transition to more sustainable, regenerative, agroecological production systems, which could reduce overall reliance on input costs. A different starting point on the ultimate objectives of the food systems would bring a different understanding and approach to food security and subsidies.

Fiscal policies have also shaped and incentivized biofuel production, with some unintended consequences when biofuels are produced on a large scale. Tax credits, and over USD 160 billion in subsidies for corn and soy in the United States alone since 1995,[34] as well as 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.[35] Other potential drawbacks from the growth of the biofuel industry include changes to land use patterns that may increase GHG emissions, pressure on water resources, air and water pollution, and increased food costs.[36]

6. CORPORATE CONSOLIDATION AND POWER DYNAMICS

The commodification and globalization of inputs, crops, and food products can lead to market efficiency at the expense of climate, community, and supply chain resilience. While this may reduce direct costs for producers or consumers, it does not consider the costs to human and ecosystem health, nor other societal impacts such as human rights and Indigenous foodways. It also supports corporate consolidation and further exacerbates concentrations of power and influence by those who profit from perpetuating fossil fuel, chemical-dependent, and extractive food systems at the expense of farmers, local communities, consumers, and planetary boundaries.

Acknowledging and navigating these six key tensions will be crucial but difficult due to the political nature of food and energy, and stakeholders' differing priorities. Food and energy are fundamental national interests, and dialogue on these issues can be highly political. Key actors prioritize different benefits and trade-offs, and are often informed by their unique context.

Some countries may consider biofuels as the only way for them to meet the target in their NDCs, while for others, trade of food commodities in the globalized economy is crucial for GDP. There are technocratic, political, and ideological aspects to these tensions, and collaboration on these contentious topics may be fundamentally difficult, even with calls for greater collaboration.

It is also worth noting that poor governance and/or lack of inclusion are, to some extent, found across the six key tensions discussed. This is what drives the Global Alliance for the Future of Food's call to action on inclusive, participatory approaches to governance to address structural inequities and principles such as equity and inclusion.[37]

Building processes and policy platforms on principles of transparency, inclusive participation, and shared power can minimize some of the tensions through a shared understanding of the trade-offs and synergies, thereby ensuring policies and practices are driven not only by evidence but also by ethics and public interest. A principles-based approach to transformation, for both food and energy systems, emerges as a critical need to help address some of these tensions.

The future of the nexus between energy and food systems will have to navigate these tensions, finding a way forward with a mix of different solutions based on localized contexts. As Tara Garnet, from TABLE/University of Oxford reflected, ***"More mental flexibility will be required to resolve these tensions, with a way forward encompassing multiple solutions."***[38]

Tensions can be addressed by applying a principles-based approach to inform and guide decision-making. This will require deepening and diversifying the evidence base for needed transitions, and by equitably engaging all impacted actors to minimize unintended consequences, avoid siloed interventions, and identify place- and culture-specific solutions.

Additionally, coalitions can be built around specific issues, and relevant organizations can then choose to join based on their interests and expertise. As Aline Mosnier from FABLE Consortium observed, ***"Above ideological concerns, it is important to think through the structural changes required to make these sustainable food transitions – how can we have these types of transitions based on our current farm structure, supply chain, input, etc., across different local contexts?"*** [39]

NEGATIVE IMPLICATIONS OF LACK OF COLLABORATION

FIGURE 7. STAKEHOLDER INSIGHTS ON NEGATIVE IMPLICATIONS FROM LACK OF COLLABORATION *,**

"The most vulnerable are harmed by the lack of collaboration: Investments have shaped an energy future that, while striving for net-zero emissions, has the potential to reinforce wasteful systems, artificially drive up food prices, promote the unsustainable expansion of the industrial livestock industry, and ultimately cause widespread pollution and environmental degradation."

CARINA MILLSTONE Feedback Global

"Environmental impacts go beyond emissions: Energy production from biofuels also prop up vegetable oil markets such as oil palm and soy, both of which have been linked to extensive deforestation in Indonesia and Brazil – major global carbon sinks."

TIM BENTON, Chatham House

"Negative implications multiply for producers and consumers: In the Philippines and other parts of the world such as the U.S. and Europe, agricultural land is increasingly being converted for energy and industrial land use."

DEREK CABE, Coal-free Bataan

"Policy and financial incentives exacerbate inequality and marginalization: Even renewable energy such as solar or wind power have extensive footprints, often pricing out farmers for land and water – the energy sector pays on average USD 80 cents per cubic meter of water, while agriculture pays USD 10 cents."

PAULO D'ODORICO, University of California, Berkely

The stakeholders interviewed identified four primary negative implications from a lack of collaboration on the food–energy nexus as particularly harmful:

1. THE MOST VULNERABLE ARE HARMED BY THE LACK OF COLLABORATION

Without collaboration, interactions between food and energy systems can further perpetuate inequality and marginalization. For example, the dominance of fossil fuel–driven intensive agricultural production, driven by multinational firms, has perpetuated inequality and marginalization, stripped farmers and Indigenous communities of their economic livelihoods, disrupted local food security, and caused adverse health impacts

* Based on interviews with 28 stakeholders in the food and energy sectors. Interviews conducted April–May 2023.

** IEA, World Energy Investment, 2020. Considers biofuel, biogas, and biomethane investments from 2010–19.

for farm workers, with one study estimating that as many as 44 percent of farmers and farm workers are poisoned by pesticides globally every year.[40]

We are at a crucial point in development where planetary boundaries are reaching their tipping points.[41] It is imperative for food and energy actors to engage in more systematic collaboration, working together to address challenges and reduce adverse consequences.

2. NEGATIVE IMPLICATIONS MULTIPLY FOR ACTORS INVOLVED AT THE PRODUCTION AND CONSUMPTION STAGES

A limited understanding of the complex interdependence of the food and energy sectors has led to unintended negative consequences, such as loss of production assets (e.g., real estate, machinery) and pollution, social inequalities and injustice, unsustainable growth, commodification, and food price volatility.

When mapped across the value chain, many of these negative impacts cluster in the production and consumption stages. These stages involve multiple actors (e.g., small-scale producers, traders, and individual consumers) compared to the input, production, and processing stages that are mainly dominated by conglomerates (see Figure 8).

Access to clean cooking is especially an issue in developing countries: 60 percent of the global population without access to clean cooking facilities live in developing Asia.[42]

As such, it is usually communities and individuals who disproportionately bear the burden of negative implications at the food–energy nexus, further reinforcing existing inequities. Meanwhile, most of the profits in the value chain accrue to the input manufacturers, distributors, and large producers and traders.[43]

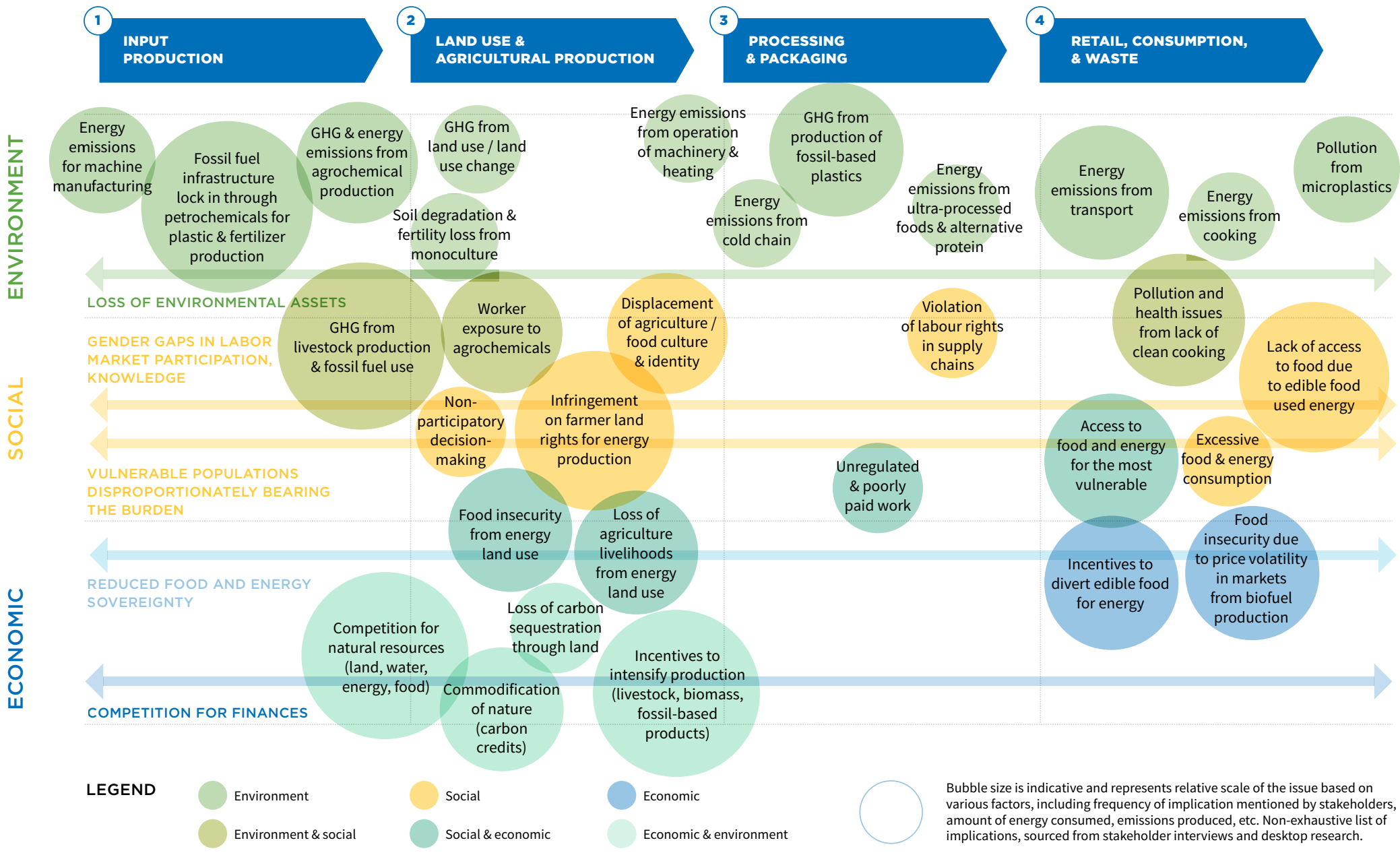
3. THE ENVIRONMENTAL IMPACTS GO BEYOND EMISSIONS

Understanding food–energy interactions through a narrow emissions lens often excludes other fundamental environmental impacts, such as biodiversity and pollution. For example, monoculture encouraged through production of corn and maize for biofuels can destabilize moisture and nutrients in the soil. In the EU, Renewable Energy Directive 10 has driven up demand for crop-based biodiesel leading to deforestation, habitat loss, and greater CO_2 emissions than the fossil diesel it replaces.[44]

Lisa Tostado from the Centre for Environmental Law further explains this dependence: ***"Continued reliance on fossil-based chemical inputs and plastics (microplastic coating of seeds, pesticides and fertilizers, packaging for food…) in agriculture and food systems locks in fossil fuel infrastructure, driving both increased emissions and pollution."*** [45]

A failure to collaborate exacerbates negative environmental impacts and results in unintended consequences.

FIGURE 8. NEGATIVE IMPLICATIONS OF FOOD–ENERGY INTERACTIONS ACROSS THE VALUE CHAIN*



* Non-exhaustive with indicative bubble size. Based on desktop research and stakeholder interviews conducted April–May 2023.

4. POLICY AND FINANCIAL INCENTIVES EXACERBATE INEQUALITY AND MARGINALIZATION

Incentives to produce biofuels can skew markets at the expense of smallholders. If energy replaces agriculture, small farmers often lose their economic livelihoods, and local food security is disrupted. This is particularly the case in the United States, which produced almost half of all biofuels globally in the past 10 years.[46]

In the United States, 45 percent of corn production goes toward ethanol production.[47] Due to government policies, the number of large corn farms has increased and the number of small corn farms has fallen, further exacerbating the decline and economic livelihoods of smallholder farms. Studies have also found that the renewable fuel standard raised crop prices, increased fertilizer use, and degraded water quality.[48]

Similarly, intensified growth of the unsustainable industrial livestock industry is an issue more specific to the United States, where biogas production on dairy farms has been incentivized by electricity policy changes and is estimated to contribute USD 131 million in additional revenue.[49]

Food–energy interactions can also incentivize unsustainable industrial production methods and lead to greater price volatility, increasing costs for everyday consumers. Carina Millstone from Feedback Global explains that biofuels and bioenergy production can have ***"positive implications"*** such as ***"reduced emissions, intercropping, and revenue streams for waste (livestock manure and crop waste), [but] it can also reinforce wasteful systems, artificially inflate food prices, and encourage the expansion of an unsustainable industrial livestock industry, causing widespread pollution."*** [50]

Those people most impacted by policies and investments of both energy and food systems do not experience energy and food as separate issues. This is why advocates, policymakers, and investors/funders need an integrated approach to the issue in which they ask those most impacted to identify the most appropriate solutions.

Collaboration that considers policy interactions across sectors as well as governance processes that include marginalized stakeholders is critical. This requires a consolidated and localized approach.

The differences between specific communities and geographies should also be taken into account. For example, An Mei and Min Hu from the Institute for Global Decarbonization Progress (iGDP) shared that ***"although resource competition for land is a growing concern in countries such as the U.S., Europe, Australia, etc., China's firm 'red line' on the total area of arable land (no less than 120 million hectares [296 million acres])***[51] ***is of high political priority, resulting in limited conflict between food security and renewable energy development."***[52]

CONCLUSION & RECOMMENDATIONS

Interviews with key stakeholders in the field have surfaced: 1) high-impact, no-regret opportunities for greater collaboration; 2) key next steps to foster greater collaboration, by stakeholder type; 3) a list of additional research topics within the nexus that can be explored; and 4) a number of key considerations that should be top of mind when focusing on the food–energy nexus.

HIGH-IMPACT, NO-REGRET OPPORTUNITIES

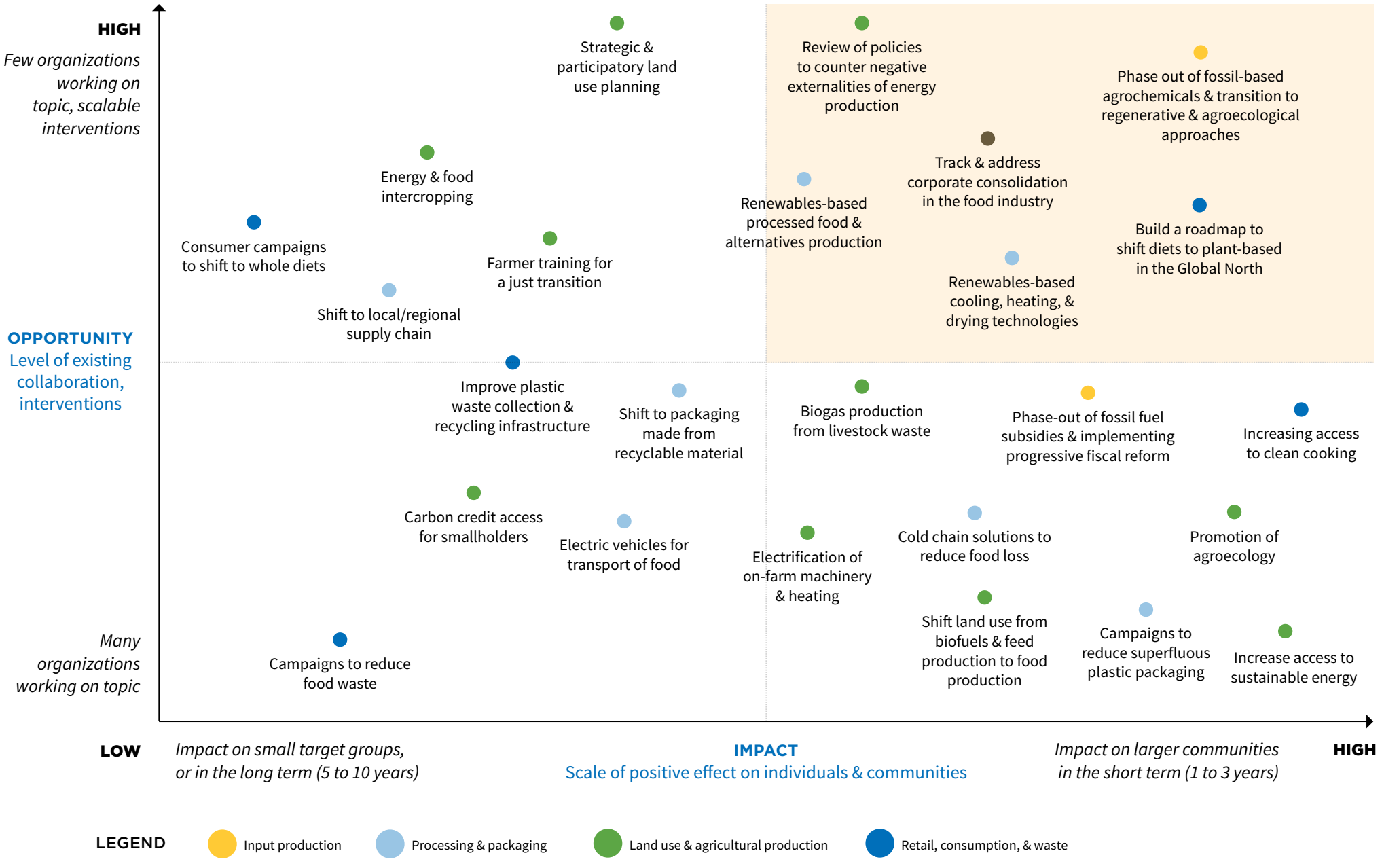
Our selection of high-impact opportunities considers existing collaboration and the time needed to materialize benefits. Some viable solutions already have multiple organizations working on them; others offer significant collaboration potential but require longer time frames or only benefit a small subset of the population. For instance, reduction of fossil-based plastics, innovation for alternatives, and improvements to waste collection and recycling are already prioritized on national agendas through initiatives like the global Plastics Pact Network and UN Environment Programme Plastics Pollution Treaty – although significant additional efforts are required.

Based on our assessment, the following interventions focusing on agrochemicals, cold chain, processed food and alternatives, and bioenergy production externalities present the high impact and immediate opportunities. See Figure 9 for the mapped opportunities.

- **Phase out fossil fuel–based agrochemicals and transition to regenerative and agroecological approaches:** There is widespread overuse of fossil fuel–based agrochemicals and limited focus on eliminating their use in food production. This calls for: 1) an urgent shift to agroecological production systems that are less reliant on external inputs; and 2) 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 energy production:** There is a need to review existing electricity subsidies for biogas production that 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.[53] A systemic review of policies such as government subsidies and mandates may fall under the purview of one ministry or department. However, engagement with other relevant ministries focused on agriculture and development is essential. This cross-ministerial cooperation can have far-reaching impacts on communities affected by competing food and energy interests, as well as broader implications on food and energy security.
- **Shift to cooling, heating, and drying technologies:** Renewables-based cooling and heating technologies for storage and drying agricultural products can potentially bring about multiple co-benefits with few resources in a short timeframe. A food systems expert explains this through an example: ***"Installing just one solar-powered refrigerator in rural communities can reduce food loss and increase farmer income by allowing farmers to keep excess produce for later resale, and produce ice for other food industries such as fisheries."***[54]

- **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. Some food conglomerates are relying on the decarbonization of the energy grid to facilitate their transition.[55]
- **Achieve healthy, sustainable, and just food environments that support plant-rich diets and minimally processed foods:** By shifting to more minimally processed plant-based diets, particularly where meat and saturated-fat consumption is high or growing at levels that risk human and/or planetary health, we have the potential to reduce the energy intensity of our food systems and diet-related GHG emissions by 49 percent while generating substantial health co-benefits.[56] Consumer groups, the public health community, NGOs, 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.[57, 58] 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. However, it is vitally important to consider context when implementing this opportunity, and to focus on reducing meat production and consumption where it is highest and elevating diverse diets around the world, including the Global South and its traditional whole foods diets.
- **Track and address corporate consolidation in the agrochemical and food industry 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 vested interests in promoting and perpetuating fossil fuel and chemical-dependent, extractive industrial food systems, and highly processed foods.

FIGURE 9. IMPACT & OPPORTUNITY OF INTERVENTIONS ACROSS THE FOOD VALUE CHAIN



NEXT STEPS TO FOSTER GREATER COLLABORATION

Policymakers, the private sector, donors and funders, civil society and producers, and academics will all need to play a role in fostering greater collaboration at the food–energy nexus. Each of these stakeholders sit at different levels of the ecosystem, with different capabilities. For example, policymakers are key decision makers, with tools such as platforms to elevate messages for public awareness, and the ability to implement economic incentives and regulations to ensure standards. Policymakers must focus on balancing competing priorities and trade-offs across sectors. On the other hand, civil society and producers, as predominantly self-organizing movements, can access on-the-ground communities and knowledge, and advocate for specific causes. Each stakeholder has a unique set of expertise and tools that can be leveraged for better collaboration at the food–energy nexus.

Priority recommendations for each stakeholder have been identified based on their skillsets and tools. These recommendations are broad and crosscut the different stages of the value chain; 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 to make better choices. Policymakers can also support policies that phase out the use of any unnecessary fossil fuel inputs in 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. When replacing inputs with more sustainable alternatives, policymakers must consider the ramifications, 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 to make 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 2). Such convenings can kickstart the momentum needed for change within the system and provide concrete grounds for collaboration that focus on the no-regret opportunities identified in this report.

TABLE 2. 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

Collaboration across donors and funders, civil society, producers, policymakers, and industry can move the needle with greater efficiency and fewer unintended consequences. For example, by allocating just 10 percent of existing climate finance, between 30 to 100 million farms could shift from fossil-based to renewable solar irrigation pumps, reducing emissions, providing farmers access to energy, and facilitating both the food and energy systems transformation.*

* Refer to the Appendix for calculation methodology and source.

RESEARCH OPPORTUNITIES

Beyond the no-regret opportunities highlighted in this paper, stakeholders have identified a longer list of research topics that could help foster greater collaboration on the food–energy nexus (see Table 3). A few are highlighted in the following table.

Developing datasets and building scenarios to inform decision-making

Key stakeholders interviewed highlighted the limited awareness of the complexities and implications of the nexus, and how awareness-raising through convenings, campaigns, trainings, and knowledge products would be helpful in establishing a baseline understanding for both sectors. In particular, many stakeholders have also demonstrated strong interest in the development of datasets for scenario planning and modelling to enable informed decision-making. Specifically, this includes future scenarios and inputs from the food and energy sectors required to support this, implications of decarbonization on agriculture (i.e., human labour, alternatives, economy), and sustainable food transition models at the country or sub-national levels. As Aline Mosnier from the FABLE Consortium stated, ***"To enable systemic food systems transformation, we need to be more precise about what inputs are required (i.e., energy, labour, water), and the different implications at the country scale, especially given varying food production and consumption behaviours across the world."***[59]

TABLE 3. RESEARCH OPPORTUNITIES IDENTIFIED BY STAKEHOLDERS

AREA	RESEARCH TOPICS
ENERGY CONSUMPTION	• Understand fossil fuel use, spatial distribution, and subsidy schemes. • Understand the potential of agroecology and regenerative agriculture to reduce reliance on fossil fuels. • Pilot new technology for reducing energy in nitrogen fertilizer synthesis. • Understand energy and emissions associated to fisheries. • Quantify F-gas emissions associated to cold chain and refrigeration. • Analyze the sustainability of alternative protein sources. • Analyze the potential for renewable energy integration in the food supply chain. • Understand energy use in animal feed activities, with special focus on concentrated animal-feeding operations. • Investigate the potential use of satellites to track emissions. • Quantify the environmental impact of different food production systems, including a lifecycle analysis of methane and pesticides.
ENERGY PRODUCTION	• Understand the lock-ins and externalities from energy production subsidy and tax regimes. • Model constituents, markets, and extent of biofuels in food systems and its implications on resources. • Evaluate the implications of food waste as an input for bio-fertilizers. • Investigate the role and assess the positive and negative implications and trade-offs of green hydrogen in sustainable food production. • Investigate how fossil fuel infrastructure can be repurposed (i.e., coal mines, export terminals, natural gas pipelines).

CONTINUED

TABLE 3. PRIORITY RECOMMENDATIONS BY TYPE OF STAKEHOLDER, CONTINUED

AREA	RESEARCH TOPICS
OTHERS	• Understand potential negative externalities. • Power mapping of stakeholders in the food–energy nexus to identify key stakeholder and nurture collaboration. • Explore food and energy links to nutrition for food security and a just transition. • Examine the role of consumer behaviour and dietary choices in the food–energy nexus. • Model future scenarios and state of the world (i.e., *climate change, geopolitics, attitudinal shifts, fossil fuel transition*) at the country or sub-national levels, detailing required inputs from the food and energy sectors. • Evaluate the social and economic impacts of transitioning to sustainable energy systems in food systems. • Study the lobbying, marketing, and public relations of the food industry, similar to the work done on the energy industry.

ADDITIONAL CONSIDERATIONS FOR GREATER COLLABORATION ON THE FOOD–ENERGY NEXUS

In order to simultaneously advance energy and food transformations, various stakeholders, specifically funders (including donors/funders, bi/multilateral institutions, and climate finance mechanisms) must play pivotal roles in driving sustainable change. Donors and funders can contribute by strategically directing their resources toward initiatives that support research, innovation, and capacity-building in the food–energy nexus. They can foster collaborations, facilitate knowledge-sharing, and promote inclusive solutions that address social and environmental dimensions. Bi/multilateral institutions, through their policy influence and financial mechanisms, can prioritize and incentivize sustainable agriculture practices, renewable energy deployment, and climate-smart investments. They can provide technical assistance, financial support, and policy frameworks that enable countries to integrate energy and food considerations into their development plans. Climate finance institutions can channel investments toward projects that promote renewable energy adoption in the agricultural sector, enhance energy efficiency along the food value chain, and facilitate climate-resilient farming practices.

Recognizing the diversity of regions across the Global North and Global South as well as different starting points and energy-consumption patterns, actors must tailor opportunities for greater collaboration on the food–energy nexus to regional and local needs. Tailoring solutions to the economic context of each region is imperative, given the broad differences in food consumption and production approaches. Consequently, a wide yet different array of stakeholders must work collaboratively to identify regional and local solutions.

To further elevate the relevance of the recommendations in this report, progress should be linked to each country's NDCs toward climate targets. Nationally determined contributions (NDCs) are country plans to reduce national emissions and adapt to the impacts of climate change.[60] Given strong political commitments and national interests in achieving NDCs, as well as inherent relationship between the food–energy nexus to emissions, many of these recommendations and interventions can be framed as necessary steps to achieving emissions reduction and climate change adaptation. For example, renewables-based cooling

technologies can link to emission NDCs through its role in reducing emissions from food loss, and the associated energy used to produce the food.

Many countries include a reference to agriculture in NDCs but few take on a food systems perspective, which ignore the food–energy nexus.[61] More can be done to ensure that food systems are a critical part of the climate agenda. Close to 89 percent (168/189 countries) have submitted NDCs that include agriculture in their climate change commitments. Though these are usually housed under overall economic or broad country targets, and mainly focus on food production stages, interventions on the nexus can draw links to these agriculture NDCs as well. Examples of the integration of food systems measures in NDCs include Costa Rica's 2020 updated NDCs with "Adapted Food Guides" promoting the consumption of Indigenous, traditional, and seasonal agricultural and food products, and their nutritional value and contribution to emissions reduction and food security. Similarly, the UAE plans to cut its food loss and waste by half in 2030, and in the country's 2020 and 2022 NDCs had encouraged hospitality, industry, and other sectors to adopt efficient food-management practices.[62] Nonetheless, it is also imperative to ensure that linking these interventions in NDCs does not further entrench a limited understanding of the food–energy nexus through a narrow GHG emissions lens. A holistic food systems approach to the NDCs can also help identify nexus issues and increase the solution space.

Further collaboration on the food–energy nexus must incorporate a robust justice lens, ensuring that any food systems transformation is just and equitable. Several opportunities along the entire value chain exist. It is imperative to address social equity and environmental justice through an inclusive decision-making process when implementing no-regret moves. Incorporating a justice lens can help ensure that the pursuit of sustainability within the food–energy nexus remains equitable, leaves no one behind, and fosters a just transition toward a resilient future. Food producers – and workers in the value chain – are at the heart of our food systems, and many of these producers are smallholders, and vulnerable populations that often disproportionately bear the costs of changing practices. Based on the Just Rural Transition, guiding principles for a just transition include supporting those in the transition through reskilling or new livelihood opportunities, ensuring consumers meet their nutritional needs and not experience hunger or hardship due to increased costs of food during the transition, and prioritizing financial or external support for regions who are most vulnerable.[63] From a consumption perspective, opportunities also exist to ensure affordable and accessible whole food and culturally appropriate diets. Figure 10 highlights many of the opportunities to ensure a just transition along the entire food systems value chain.

The financial implications of the opportunities and recommendations identified in this report have not been costed. A True Cost Accounting (TCA) approach will be critical. We have not conducted an in-depth analysis of the specific financial implications associated with these recommendations. It is, however, important to carefully consider the financial implications of such opportunities. In adopting a holistic approach to decision-making, stakeholders must weigh the potential costs and benefits – including non-financial benefits – through TCA approaches. (An example of a holistic approach to financial decisions is how socio-economic measures such as fiscal policies and tax reforms have proven instrumental in driving the transition away from fossil fuels.) By implementing incentives, subsidies, and taxation mechanisms, some governments and policymakers have successfully redirected investments and encouraged the adoption of cleaner and more sustainable energy alternatives.[64] These measures have facilitated the growth of renewable energy sectors, incentivized energy efficiency improvements, and promoted the decarbonization of various industries.

APPENDIX: METHODOLOGY

This in-depth assessment for a coordinated food–energy systems transformation, involving fossil fuel phase-out and clean energy transition strategies, was conducted over 3 months. The assessment used desktop research and interviews with 28 stakeholders from diverse sectors and organizations, ensuring balanced geographic representation.

The desktop research involved an extensive review of literature from leading organizations in sectors such as Food and Agriculture Organization (FAO) and International Renewable Energy Agency (IRENA), as well as academic papers. The findings and key messages were further refined with input from 50+ stakeholders.

Primary research was conducted through interviews with stakeholders working within food and energy systems to gather insights on current practices, challenges, and opportunities related to the food–energy nexus. Interviews were conducted with 28 stakeholders, and these interviewees were selected based on three key parameters: 1) equal representation of the Global North and Global South, with perspectives from each continent; 2) representation from a broad set of stakeholders, including public policy, government organizations, multilateral organizations, philanthropic funders, NGOs, and industry organizations; and 3) stakeholders currently focused on the food–energy nexus or likely to be interested in the topic. The following table includes a list of stakeholders interviewed.

TABLE 4. LIST OF STAKEHOLDERS INTERVIEWED

#	ORGANIZATION	STAKEHOLDER	TITLE	DATE OF INTERVIEW
1	Young Volunteers Association for the Environment (JVE) International	Sena Alouka	Founder	24 April 2023
2	Institute for Agriculture and Trade Policy (IATP)	Ben Liliston	Director of Climate Change and Rural Strategies (U.S.)	24 April 2023
3	Chatham House/ University of Leeds	Tim Benton	Research Director, Energy, Environment and Resources/ Professor	25 April 2023
4	UC Berkeley	Paolo D'Odorico	Professor	26 April 2023
5	Coal-free Bataan	Derek Cabe	Coordinator and community organizer	26 April 2023
6	Feedback Global	Carina Millstone	Executive Director	26 April 2023
7	The Institute for Sustainable Development and International Relations (IDDRI)	Pierre-Marie Aubert	Director, Agriculture and Food Policies	27 April 2023

CONTINUED

TABLE 4. LIST OF STAKEHOLDERS INTERVIEWED, CONTINUED

#	ORGANIZATION	STAKEHOLDER	TITLE	DATE OF INTERVIEW
8	UN Foundation/Clean Cooking Alliance	Lindsey Barone	Senior Director of Strategy	27 April 2023
9	Milken Institute – Feeding Change Program	Ilana Morena	Senior Associate	27 April 2023
10	International Panel of Experts on Sustainable Food Systems (IPES)	Molly Anderson	Expert/Director of Food Studies at Middlebury	28 April 2023
11	Planet Tracker	Peter Elwin	Head of Food & Land Use Programme	28 April 2023
12	E3G	Ronan Palmer; Pieter de Pous	Director, Clean Economy Program	2 May 2023
13	Feedback Global	Carina Millstone	Executive Director	27 April 2023
14	Centre for International Environmental Law	Lisa Tostado	Agrochemicals and Fossil Fuels Campaigner	3 May 2023
15	WRI/Food and Land-Use Coalition (FOLU)	Ed Davey	Policy and International Engagement Director	5 May 2023
16	ClimateWorks Centre Australia	Liam Walsh	System Lead – Food Land and Oceans	9 May 2023
17	UNSDSN/FABLE	Aline Mosnier	Scientific Director	9 May 2023
18	World Business Council for Sustainable Development (WBCSD)	Victoria Crawford	Senior Manager	10 May 2023
19	Tables Debates	Tara Garnett	Director	11 May 2023
20	Institute for Global Decarbonization Progress	Hu Min; Chen MeiAn	Principal & Senior Analyst	15 May 2023
21	International Maize and Wheat Improvement Center (CIMMYT)	Tek Sapkota	Agricultural Systems and Climate Change Scientist	15 May 2023
22	Changing Markets	Nusa Urbancic	Campaigns Director	15 May 2023
23	International Renewable Energy Agency (IRENA)	Wilson Matekenya; Divyam Nagpal	Country Engagement and Partnerships Division, Knowledge Policy and Finance Centre Division	16 May 2023
24	Change Pathways / How we Adapt	Lauren Hermanus; Anthony Dane	Co-founder	17 May 2023

CONTINUED

TABLE 4. LIST OF STAKEHOLDERS INTERVIEWED, CONTINUED

#	ORGANIZATION	STAKEHOLDER	TITLE	DATE OF INTERVIEW
25	Meridian Institute	Ann Tutwiller	Senior Fellow	18 May 2023
26	FAO Office of Biodiversity, Climate Change and Environment (OCB)	Francesco Tubiello; Alessandro Flammini	Senior Statistician and Team Leader, Environment	22 May 2023
27	WWF International	Martina Fleckenstein	Global Policy Manager, Food Practice	22 May 2023
28	WRAP	Richard Swannell	Director of Impact Growth	30 May 2023

TABLE 5. GEOGRAPHIC & SECTORAL REPRESENTATION OF INTERVIEWED STAKEHOLDERS

		GEOGRAPHY					
		AFRICA	ASIA	CHINA	EUROPE	GLOBAL	TOTAL
TYPE OF STAKEHOLDER	COMPANY	1					**1**
	CIVIL SOCIETY	1	1				**2**
	EDUCATION/ RESEARCH				1	2	**3**
	MULTILATERAL					2	**2**
	NETWORK	1				4	**5**
	NGO		1		2	3	**6**
	ORGANIZATION					1	**1**
	THINK TANK				1	2	**5**
	TOTAL	**3**	**2**	**1**	**5**	**17**	**28**

We also asked each stakeholder interviewed to share their perspective on which research papers, organizations, or other sources of information should be included as part of this research. This enabled us to broaden the search beyond existing networks and be as inclusive as possible.

Secondary research was conducted through extensive desk research, primarily relying on data sources that were widely used or cited, such as FAO's FAOSTAT. For data not available from major organizations like the FAO and IEA, we looked at peer-reviewed scientific papers and books that were cited more than 10 times. We have outlined our methodology for the main figures used in the report that follows. We reviewed all collected data to ensure its accuracy, relevance, and reliability, and examined data to identify patterns, trends, and insights.

SOURCES & CALCULATION METHODOLOGY FOR KEY NUMBERS

Energy-related food systems activities accounts for 14 percent of the world's emissions.

- **Source:** FAO, FAOSTAT. Accessed May 2023; Crippa et al., Food Systems Are Responsible for a Third of Global Anthropogenic GHG Emissions, 2021; IEA, *Global Energy Review*, 2020.
- **Methodology:** Using the range of existing data, two different but credible sources were used to determine the percentage of energy-related emissions in food systems.
- Calculation of Total Energy Emissions for 14 percent:
  1. Using the data from the IEA and FAOSTAT, we calculated the total energy emissions associated with pre- and post-farm production activities. The sum of these emissions was found to be 5.5 gigatons of carbon dioxide equivalent (Gt CO2eq).
  2. In order to focus specifically on energy-related emissions, we excluded two categories from the total energy emissions: 1) F-gas emissions, amounting to 0.45 Gt CO2eq, were removed, as they are not directly related to energy consumption within food systems; and 2) waste emissions, which accounted for 1.26 Gt CO2eq, were also excluded from the analysis, as they represent a separate category of emissions.
  3. To provide a comprehensive assessment of energy-related emissions in food systems, we included on-farm energy emissions in the calculation. These emissions were found to be 0.44 Gt CO2eq. By including on-farm energy emissions, we accounted for the energy consumption occurring directly on agricultural farms.

  By summing the total energy emissions from pre- and post-farm production activities (5.5 Gt CO2eq), excluding F-gas emissions (0.45 Gt CO2eq) and waste emissions (1.26 Gt CO2eq), and including on-farm energy emissions (0.44 Gt CO2eq), we arrived at a total of 4.23 Gt CO2eq. By dividing this value by the global total emissions reported by the IEA in the year 2020, i.e., 30.6 Gt, we obtained the derived 14 percent.

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

- **Source:** USDA. The Role of Fossil Fuels in the U.S. Food System and the American Diet, 2017; Reicosky, Don et al., Agricultural Contributions to Greenhouse Gas Emissions, 2000; Christophe 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
- **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. It is

important to 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, in 2000, estimated 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, it is important to 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 approximately 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.* It is important to 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.

70 percent of the energy consumed occurs after the farm, in transportation, processing, packaging, and shipping.

- **Source:** FAO, Energy. Accessed May 2023.

* Almost two-thirds of the marginal farmers who own agricultural pumps still rely on diesel/kerosene pumps (Wase Khalid, 2022).

One-third of the food we produce is lost or wasted, and with it around 38 percent of energy consumed in food systems.

- **Source:** FAO, Energy. Accessed May 2023.

Allocating ~10 percent of existing climate finance flows to activities that have co-benefits on both food and energy systems could help 30 to 100 million farms shift from fossil-based irrigation to solar-powered irrigation, for example.

- **Source:** IFC: World Bank, PULSE Report, 2019; Global Alliance for the Future of Food, Climate Financing for Food Systems Transformation, 2022.
- **Methodology:** To assess the potential impact of using existing climate financing to finance solar irrigation, we employed a market size approach.
  - Calculation of 10 percent of existing climate finance: To determine 10 percent of existing climate finance, we looked at the average value of climate finance for 2019 and 2020, which stood at USD 632; 10 percent of this is calculated at USD 63.2 billion.
  - Calculation of number of solar irrigation pumps that can be installed across farms: Next, using the PULSE report, we identified that each solar irrigation could cost USD 600 to 2000. We divided 63.2 billion by 2000, which equalled ~31 million; we also divided 63.2 billion by 600, which equalled ~105 million. We then rounded the number to 30 to 100 million.

ORGANIZATIONS WORKING ON THE FOOD–ENERGY NEXUS

The following is a non-exhaustive list of organizations that are currently working on the food–energy nexus. This list was sourced primarily via stakeholder interviews, with secondary research conducted to facilitate data-gathering. This list includes organizations that work explicitly on the nexus or on related smaller initiatives across the value chain. It is meant to be indicative and serve as a starting point for organizations looking to collaborate with other organizations that share similar interests.

TABLE 6. LIST OF SOME OF THE ORGANIZATIONS WORKING ON THE FOOD–ENERGY NEXUS

ORGANIZATION	DESCRIPTION
FOOD AND AGRICULTURE ORGANIZATION	The FAO has an Energy Smart Food program that aims to increase access to sustainable energy in food systems through innovative green energy solutions (i.e., energy efficiency, renewable energy, waste to energy).
INTERNATIONAL RENEWABLE ENERGY AGENCY (IRENA)	IRENA and the FAO jointly hosted an expert event on November 11, 2022, on the challenge of decoupling good production from fossil fuels without diminishing food security. IRENA also co-authored a report with FAO, released at COP26: "Renewable Energy for Agri-food Systems: Toward Sustainable Development Goals and the Paris Agreement."
CENTER FOR CLIMATE AND ENERGY SOLUTIONS	Environmental non-profit organization that has published strategies and interventions to reduce emissions in the agricultural sector in the United States.

CONTINUED

ORGANIZATION	DESCRIPTION
CENTRE FOR INTERNATIONAL ENVIRONMENTAL LAW (CIEL)	Serves a resource centre for environmental law and research in national, regional, and international contexts. Currently engaging in work on agrochemicals and fossil fuel campaigns.
WORLD WILDLIFE FUND	A multilateral organization focused on environmental protection, working on a net-zero food initiative to transform global food systems to be climate-friendly, equitable, and resilient.
INTERNATIONAL PANEL OF EXPERTS ON SUSTAINABLE FOOD SYSTEMS (IPES)	An independent expert panel focused on transitioning to sustainable food systems around the world. The expert panel includes individuals who have conducted research on the intersection of food and energy systems.
INTERNATIONAL ENERGY AGENCY	An agency that developed the Energy Technology Perspectives report series, which examines technologies, policies, and strategies that can help mitigate climate change.
WORLD RESOURCE INSTITUTE	An international think tank focused on sustainability and global development. WRI pioneered The Coolfood Pledge, which helps organizations commit to and achieve a science-based target to reduce the climate impact of the food you serve.
AGRO FOSSIL FREE	A platform working on strategies and technologies to de-fossilize EU agriculture by promoting adoption of available tools and practices by EU farmers.
FOSSIL FREE SWEDEN	A government initiative aimed at achieving a fossil-free economy in Sweden by 2045 – including in agriculture; have introduced roadmaps on fossil fuel–free agriculture.
INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE (IFPRI)	A research organization that partnered with the FAO and IRENA to host the expert event on decoupling agri-production with fossil fuels. It has also hosted workshops on the nexus of energy and food, such as a workshop on biofuels and food security interactions, and published relevant material on energy and agriculture.
POWER FOR ALL	A global network on 250 organizations that focus on deploying decentralized renewable energy to homes and businesses in Africa, Asia, and Latin America. With previous campaigns on decentralized renewables boosting agriculture and nutrition.
POWER SHIFT AFRICA	A non-profit organization that works to promote renewable energy, support climate justice and energy access initiatives, and build capacity for sustainable energy practices in Africa.
INSTITUTE FOR AGRICULTURE AND TRADE POLICY (IATP)	A think tank that conducts research and advocacy work on agriculture and trade policies, with a focus on creating sustainable food systems.

CONTINUED

ORGANIZATION	DESCRIPTION
AMERICAN FARMLAND TRUST	A trust focused on the agriculture conservation movement; provides resources for farmers to adopt regenerative agricultural practices through agri-voltaics across the United States.
THE GLOBAL COLD CHAIN ALLIANCE	A trade association working to improve the efficiency and sustainability of the cold chain, which includes transportation and storage of perishable foods.
THE INTERNATIONAL INSTITUTE OF REFRIGERATION	A non-profit organization focusing on promoting energy-efficient and environmentally friendly refrigeration technologies.
REFED	A multi-stakeholder non-profit aiming to reduce food waste by advancing innovation, policy, and business solutions.
WASTE AND RESOURCES ACTION PROGRAMMES	A non-profit organization working with businesses, governments, and communities to promote resource efficiency and reduce waste, including food waste.
SUSTAINABLE PACKAGING COALITION	A non-profit industry association working to improve the sustainability of packaging, including food packaging.
CLEAN COOKING ALLIANCE	A non-profit working to promote the use of clean and efficient cookstoves and fuels in developing countries, with a focus on improving health, gender equality, and climate resilience.
THE CLEANER COOKING COALITION	A multi-stakeholder partnership working to accelerate the transition to clean cooking solutions in low- and middle-income countries.
THE GLOBAL COOK SAFE COALITION	A multi-stakeholder initiative working to improve the safety and sustainability of cooking fuels and appliances in developing countries.

CONTINUED

ORGANIZATION	DESCRIPTION
BEYOND PLASTICS	A non-profit organization working to reduce plastic pollution and promote sustainable alternatives to plastic. It advocates for policies and practices that prioritize waste reduction.
FEEDBACK GLOBAL	An environmental campaign group investigating the negative externalities of biogas production from food and livestock waste.
DIVERT	A social enterprise working to reduce food waste and GHG emissions by removing carbon from the food value chain by converting wasted food into renewable energy.
GIZ (DEUTSCHE GESELLSCHAFT FÜR INTERNATIONALE ZUSAMMENARBEIT)	An agency supporting sustainable development initiatives worldwide, including projects focused on the food–energy nexus, by promoting renewable energy adoption and energy-efficient practices in the agricultural sector.
INTERNATIONAL WATER MANAGEMENT INSTITUTE	An institute conducting research and providing solutions for sustainable water management in agriculture, which is crucial for energy-efficient food production.
IFAT (INTERNATIONAL FEDERATION FOR ORGANIC AGRICULTURE MOVEMENTS)	A federation promoting organic agriculture, which contributes to the food–energy nexus by reducing energy-intensive inputs and promoting renewable energy use in farming.
SYSTEMIQ	A company working on system-level changes, including the food–energy nexus, by developing and implementing strategies to transform food and energy systems toward sustainability and resilience.
AGORA	AGORA is a global multilateral partnership for sharing knowledge and expertise on parliamentary development. It facilitates dialogue and knowledge exchange on sustainable development, including the food–energy nexus, by bringing together diverse stakeholders to collaborate on innovative solutions for a sustainable future.
IDDRI (INSTITUTE FOR SUSTAINABLE DEVELOPMENT AND INTERNATIONAL RELATIONS)	An institute conducting research and providing policy recommendations to foster sustainable development, including addressing the food–energy nexus by promoting renewable energy use in agriculture and food systems.
GAIN (GLOBAL ALLIANCE FOR IMPROVED NUTRITION)	A global alliance focusing on improving nutrition outcomes, including addressing the food–energy nexus by promoting sustainable agricultural practices and efficient energy use in food production.
STOCKHOLM RESILIENCE HUB	A hub conducting research on the resilience of food and energy systems, exploring ways to improve the efficiency, sustainability, and adaptive capacity of these interconnected systems.

CONTINUED

ORGANIZATION	DESCRIPTION
PESTICIDE ACTION NETWORK	A network raising awareness about the energy-related impacts of pesticide use in agriculture and advocating for sustainable farming practices that minimize energy consumption.
CLIMATE ACTION NETWORK	A network working toward a low-carbon and sustainable future, addressing the food–energy nexus by advocating for renewable energy adoption in the agricultural sector and promoting climate-friendly food systems.
CHATHAM HOUSE	A policy institute conducting research and policy analysis on the food–energy nexus, exploring the interactions between energy systems, agricultural production, and food security.
FRIENDS OF THE EARTH	An international network of grassroots environmental organizations advocating for sustainable agriculture practices, including reducing energy inputs, promoting renewable energy use, and addressing the energy-related impacts of industrial food production.
ENERGEA	An investment platform focusing on the food–energy–water nexus by providing innovative solutions to enhance energy efficiency and sustainable practices in the food industry.
SE4ALL (SUSTAINABLE ENERGY FOR ALL)	An organization promoting the integration of energy and food systems by working toward ensuring universal access to sustainable energy and promoting energy efficiency in the agricultural sector.
ENDEV	A global partnership promoting access to clean energy solutions in food systems, helping businesses and communities integrate renewable energy and improve energy efficiency throughout their value chains.
RENEWABLE ENERGY AND ENERGY EFFICIENCY PARTNERSHIP (REEEP)	A partnership supporting projects and initiatives that advance renewable energy and energy efficiency in food systems, aiming to reduce energy-related emissions and increase sustainability.
CIRCLE FOUNDATION	A foundation focusing on the food–energy nexus by developing and implementing sustainable farming practices and technologies that reduce energy consumption and promote renewable energy use in agriculture.
NOPLA INNOVATION	A sustainable packaging start-up working on innovative solutions for the food–energy nexus, addressing energy efficiency, renewable energy, and waste reduction to create sustainable and resilient food systems.
APEEL	A company that develops edible coatings for fruits and vegetables, extending their shelf life and reducing food waste, thereby contributing to energy savings and sustainability in the food supply chain.

CONTINUED

ORGANIZATION	DESCRIPTION
INSTITUTO DE ENERGIA E MEIO AMBIENTE	A research institute focusing on the food–energy nexus to promote sustainable energy practices in the food sector and mitigate environmental impacts.
CONSUMER GROUP FORUM	An advocacy organization working to ensure equitable access to affordable and sustainable food and energy options for consumers.
CENTRE FOR RESEARCH & DEVELOPMENT IN DRYLANDS	A centre dedicated to studying the interplay between food and energy in dryland regions, developing innovative solutions for sustainable agriculture and renewable energy production.
THE BREAKTHROUGH INSTITUTE	A think tank exploring the synergies between food and energy systems, seeking breakthrough solutions to address climate change, food security, and sustainable energy production.
FOOD AND WATER WATCH	A non-profit organization striving to protect food and water resources by advocating for sustainable energy practices in the food industry and promoting access to clean energy for agricultural purposes.
THE CLIMATE GROUP	An international organization engaging businesses, governments, and other stakeholders to accelerate the transition to a low-carbon economy, including initiatives that integrate food and energy systems for climate resilience.
OXFAM	A global humanitarian organization addressing the food–energy nexus by advocating for fairer distribution of resources, supporting sustainable agriculture, and promoting access to clean energy for communities in need.

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ABOUT THE GLOBAL ALLIANCE

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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