Food is Solvable

How entrepreneurs & early stage investors can solve structural problems in the global food system.

GULLSPÅNG
re:food

Executive summary

A global food system transformation is critical in order to feed a growing population while operating within the means of our planet. This report aims to assert that this future scenario is not only possible but also an excellent investment opportunity for investors and entrepreneurs. Rising levels of food innovation, consumer demand, and sustainability-driven public policy have developed the right market conditions for a new frontier of food companies to prosper.

We've developed the Re:food circle as a tool to guide sustainable investments. This model defines a sustainable and resilient food system in terms of its planetary and ethical boundaries. Truly sustainable companies must operate within these boundaries and adhere to eight sustainability principles.

Four paradigm shifts must occur to ensure a prosperous food system, all of which can yield exponential financial, social, and environmental returns. As such, we've made these four shifts our investment themes, referred to as the protein shift, the regenerative farming revolution, the circular supply chain reformation, and the healthy diet transformation.

These shifts are critical to reverse the damages caused by root cause problems, such as animal factory farming, overfishing, wasteful and linear supply chains, myopic crop yield techniques, and the resulting lack of access to nutritious diets for everyone. These problems are driving direct and indirect harm across the food system and beyond. It's essential to understand these root causes to determine which leverage points have the potential to yield transformational change across the entire system.

This report lists promising innovations to drive structural impact. Instead of depleting natural resources to increase the food supply, these innovations, applied at the right leverage points, introduce a regenerative and/or restorative function to the food system. The result is transformational impact as opposed to incremental improvements. When deployed at an industrialized scale, these innovations can secure a healthy food supply for all people for generations to come.

Contents

Standing on the shoulders of giants

This report builds on the work of many others. We've used the Framework for Strategic Sustainable Development (FSSD) and especially its *ABCD* approach as a foundation while adding complementary models in systems thinking and sustainable economics. Our approach has been to:

A) Describe a future vision for the global food system

A global food system that meets the needs of all people while operating within the means of our planet for generations to come.

Regenerative and restorative practices are systematically built in to ensure productive yet sustainable use of natural resources.

Companies are incentivized to maximize the health and resilience of natural resources and the consumers they feed by optimizing for nutritional density and minimal waste.

There's a strong connection between producers and consumers, allowing for pull-based supply chains with minimum waste.

Widespread understanding of how diets impact our short-term and long-term health.

Sufficient nutrition to feed everyone; the nutritional density of basic food is high and free from toxins and antibiotics causing harm to our gut health.

Biodiversity is promoted as a means to build resilience and strong planetary and public health.

Animals are treated as sentient beings as opposed to commoditized products.

Profits and power are balanced along the supply chain in relation to value creation.

B) Analyze current problems preventing us from realizing the future vision

We've developed the Re:food circle to illustrate how today's food system violates planetary and ethical boundaries. This model takes inspiration from Stockholm Resilience Center's *Nine Planetary Boundaries*, tailored to the food system by applying the EAT-Lancet's planetary boundaries and adding ocean use. Our ethical foundation is primarily based on sub-goals of the UN's Sustainable Development Goals and Five Animal Freedoms.

In addition, we've applied systems thinking, inspired by Donella Meadows' work, to better understand the dynamics of the food system and how it's interconnected with other complex systems. This includes analyzing its overarching goal, root causes, leverage points, and feedback loops.

C) Identify alternative solutions to realize the future vision

Building upon the root causes identified in step B, we've identified four related paradigm shifts that provide the greatest opportunities for entrepreneurs and investors to make a transformative impact. These shifts have been inspired by the EAT-Lancet Commission's Food in the Anthropocene, and the Food and Land Use Coalition's report Growing Better. For each theme, we've identified leverage points as well as promising innovations with the potential of creating transformational financial, social, and environmental returns.

We've described market signals indicating that the market conditions are favorable for alternative solutions to prosper driven by consumer demand and public policy.

D) Find ways to prioritize solutions (e.g. by using screening tools) to ensure strategic sustainability transformation

We use eight sustainability principles designed to prevent alternative solutions from adding additional stress on our planetary and ethical boundaries, developed by Göran Broman and Karl-Henrik Robèrt at Blekinge Institute of Technology.

The Three Horizons framework is used to help assess promising innovation in the short, medium, and long-term, developed by Bill Sharp. The framework also describes transformative versus incremental innovation.

Introduction - the food system Re:formation

The global food system is the largest system ever created by humankind. It's defined as all elements and activities related to the production, processing, distribution, preparation, and consumption of food. In its current form, it causes severe health and environmental problems. Diet-related diseases are the largest driver of premature deaths, and industrialized food production has left us at the brink of an environmental collapse.

Over two billion people are overweight, three billion are undernourished, while the system continuously consumes planetary resources and jeopardizes public health to boost short-term food production. Agricultural advancements that initially were able to end hunger for millions have paradoxically turned into our largest threat to food security when deployed at scale. And as the global population continues to grow, so does the food system's stress on our planet. Unless we do something about it. Fortunately, it *is* possible to feed a growing population within the means of our planet. It will, however, require a reformation of the entire food system.

Gullspång Re:food invests in entrepreneurs reforming the global food system to meet the needs of all people while operating within the boundaries of our planet.

It's our belief that the food system reformation will be driven by entrepreneurship and innovation; backed by risk-tolerant investments, consumer demand and public policy. These combined market forces will make it increasingly difficult for companies causing harm to environmental or public health to remain profitable. Instead, food companies with sustainable agendas will prosper while yielding impressive social and financial returns.

We hope this report will inspire entrepreneurs and investors to develop and support solutions to the food system's structural challenges given its massive potential for financial, social, and environmental returns. We also hope that the Re:food circle and its planetary and ethical boundaries can help others evaluate promising innovation. Although this transformation has already been set in motion, it remains in its infancy. To successfully reverse the current trajectory of the food system, we urgently need more innovation, talent, and visionary ideas to secure sufficient nutrition for future generations.

Lastly, we hope this report will spark a discussion with changemakers around the world. Whether you're offering a new perspective, critique, or have any questions, we're always here to listen, learn and expand our perspective.

We're just one email away at **info@refood.vc** if you want to get in touch!

Therése Dalebrant, Author
May 11th, 2021

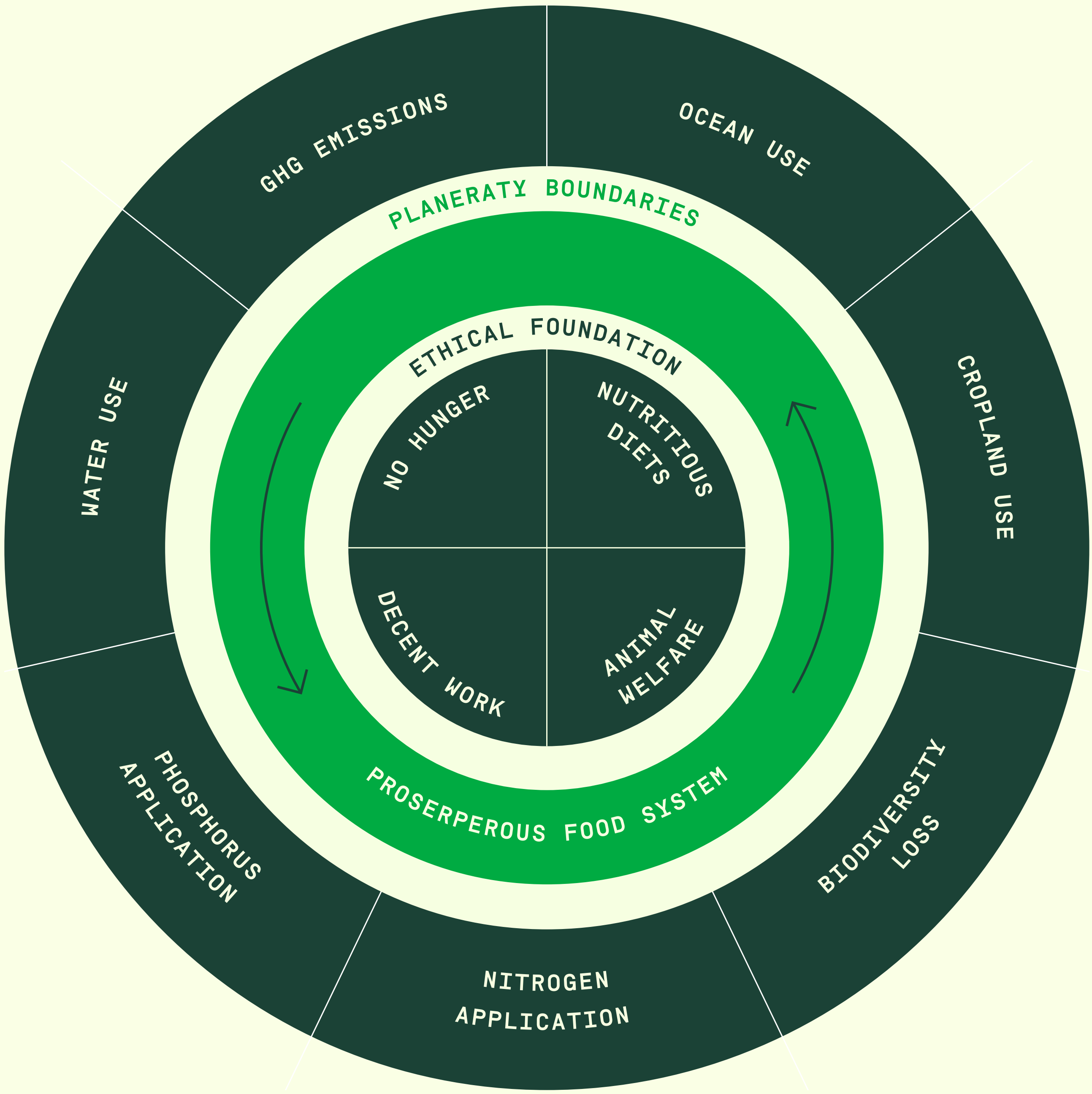
GULLSPÅNG re:food

About

We're a for-profit, family-owned investment firm driven by the mission to solve food system challenges for future generations. Our goal is to serve as one of the many instigators needed to drive the food system reformation forward. As one of the early investors in Oatly, we're convinced that that sustainable investments are incredibly good business.

Gustaf Brandberg, Partner
Gullspång Re:food, Stockholm

The Re:food Circle



We developed **The Re:food Circle*** as a framework defining the boundaries and ethical foundations of a sustainable food system to help guide transformative investments. The food system is sustainable when it operates within the Re:food circle's ethical and planetary boundaries. It's resilient when its design allows it to do so despite severe stress from external events such as harsh weather, droughts, pandemics, or financial crises.

A truly sustainable solution must also comply with the sustainability principles defined in the Framework for Strategic Sustainable Development (FSSD). The Three Horizons model can help us identify a long-term path of change towards such solutions. (Read more under "Innovation Screening".)

The Re:food cirle components

Ethical foundation

Animal welfare: Based on the internationally recognized Five Freedoms by the Farm Animal Welfare Council, stating that farm animals should be free from hunger and thirst; discomfort; pain, injury, or disease; fear and distress; and freedom to express normal behavior.

Nutriets diets: Reduce malnutrition (SDG 2.2) and premature deaths from diet-related diseases (cardiovascular disease, cancer, diabetes, obesity) (SDG 3.4). Increased access to affordable nutrient-rich food worldwide. Improved nutritional density of basic food, and reduced risk of diet-related zoonotic diseases and antibiotic resistance.

No Hunger: Ensure future food security for a growing population by implementing "resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding, and other disasters, and that progressively improve land and soil quality" (SDG 2.4). Reduce food waste and loss by 50% and improve the distribution of existing food supply to people lacking food security (SDG 12.2 and 12.5).

Decent work: Ensure "full and productive employment and decent work for all women and men, including for young people and persons with disabilities, and equal pay for work of equal value" (SDG 8.5). No forced labor or modern slavery (SDG 8.7) and ensure safe and secure working environments for all workers (SDG 8.8). Ensure that jobs are meaningful and bring value to society and our planet. Equal access to knowledge and innovation for everyone, as well as balanced proficts and power along the value chain.

Planetary boundaries *(uncertainty range)*

GHG emissions 5Gt Co_2 eq/year *(4.7-5.4)*	**Cropland use** 13 M km^2 *(11-15)*	**Water use** 2,500 km^3/year *(1000-4000)*	**Nitrogen application** 90 Tg N/year *(65-90)* (90-130 Tg N)***
Phosphorus application 80 Tg P/year *(6-12)* (8-16)***	**Extinction rate** 10 E/MSY *(1-80)*	**Ocean use** Not calculated	

* Lower boundary range if improved production practices and redistribution are not adopted.
** Upper boundary range if improved production practices and redistribution are adopted and 50% of applied phosphorus is recycled.

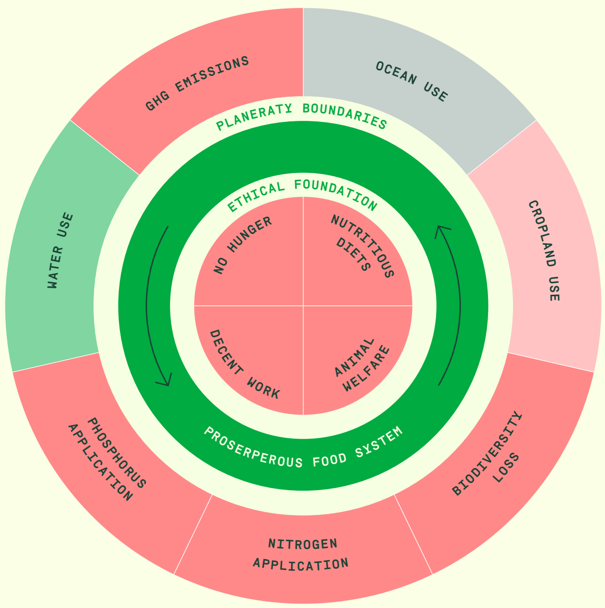
Source: EAT-Lancet

The Re:food circle takes inspiration and builds upon the work of Stockholm Resilience Center's *Nine Planetary Boundaries*. We've tailored the boundaries of our model to match the ones used by the EAT-Lancet Commission to best reflect the specific impact of the global food system. We've added an ethical foundation inspired by Kate Raworth's *Doughnut Economics* work*. Our ethical foundation consists of sub-goals of the UN's SDGs, and the Five Freedoms by the Farm Animal Welfare Council.

*The Re:food circle is a separate model not related to the "Doughnut Economics" model other than its shape. Thus, the Re:food circle should not be treated as a downscaled version of the "Doughnut".

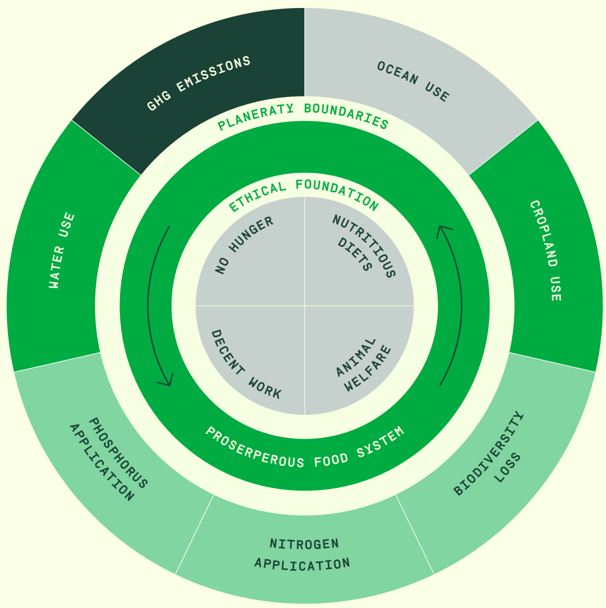
The trajectory of today's food system must be reversed

Today (2019)



BOUNDARY VIOLATED
BOUNDARY MET
WITHIN BOUNDARY

Future vision & potential (2050)



BELOW LOWER RANGE
BELOW/EQUAL TO LOWER RANGE
BELOW UPPER RANGE
IMPACT NOT CALCULATED

Source: EAT-Lancet

Today's food system violates several ethical and planetary boundaries. We urgently need new ways of producing, distributing, and consuming food to reverse this destructive trajectory. Luckily, it's not too late to reform the food system into a sustainable and resilient state. Four major shifts are required for the food system transformation to take place: the protein shift, the regenerative farming revolution, the circular supply chain reformation, and the healthy diet transformation. Given the urgency and critical importance for these shifts to succeed, we've made them our investment themes to ensure we devote our full attention and resources to supporting the entrepreneurial instigators at the forefront of these rising paradigm shifts.

Our investment themes are the protein shift, the regenerative farming revolution, the circular supply chain reformation, and the healthy diet transformation.

These shifts seek to reverse the damages caused by animal factory farming, overfishing, wasteful and linear supply chains, myopic crop yield techniques, and the global rise of malnutrition. **Successfully reversing the damage caused by their root causes can yield transformational returns to the food system, society, and biosphere for generations to come.** Thankfully, these four shifts are already in motion, enabled by innovations with transformative potential. To ensure the future food system is truly sustainable we must understand the dynamic complexities of the global food system and carefully monitor the impact when scaling new solutions.

Four shifts driving the food system transformation

I. The protein shift

A shift from nutrition from the top of the food chain to alternative proteins and fats.

For thousands of years, domesticated animals and wild fish have been good sources of high-quality and nutritious food to maintain a balanced diet. Domesticated livestock is also significantly easier to attain compared to hunting wild animals. During the last century, however, farms and fishing fleets have been industrialized, turning these two industries into two of the worst violators of planetary and ethical boundaries.

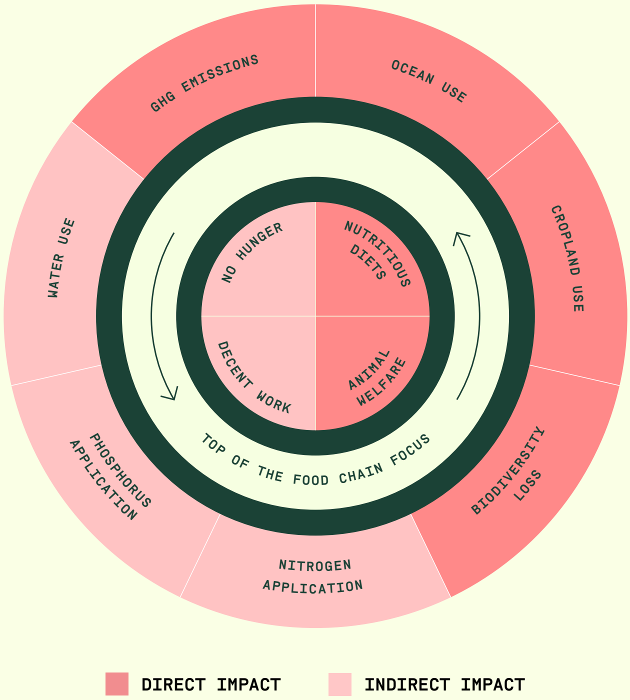
Until recently, there have not been comparable substitutes to meat and wild fish in terms of taste, texture, nutrition, product assortment, and price. Most western countries have also been educated to consume animal-based food as their primary source of protein. Today, we're seeing novel techniques of producing tasty and nutritious food using inputs further down the food chain powering a shift in how we produce and consume protein and fat.

Root cause: Animal Factory Farming

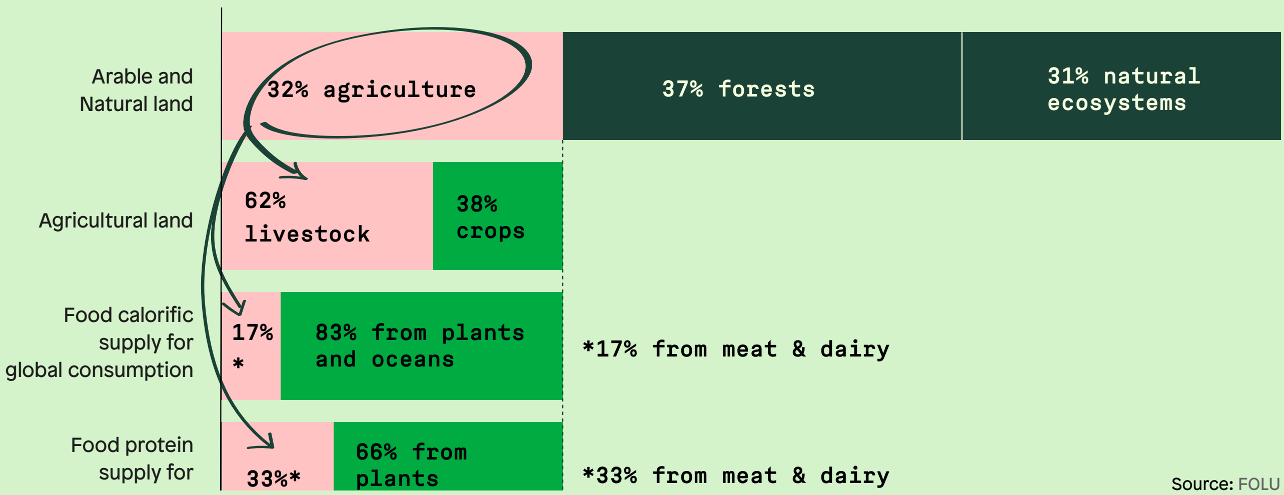
Producing food at the top of the food is an inefficient way from a calorie viewpoint: for every calorie you get from a chicken, pig, or cow, 7 to 30 calories of feed are used as input (Shike; Hall; GRDC). Even reaching these inefficient conversion rates have required industrialized streamlining of production at the expense of animal welfare and large quantities of antibiotics to speed up growth. The two most damaging practices are **animal factory farming** and **overfishing.**

Animal factory farming has a direct planetary impact in terms of greenhouse gas emissions, cropland use, and animal welfare. Indirect impacts include consumptive water use, biodiversity loss, and phosphorus and nitrogen application. These problems introduce new ones, such as ocean acidification and global warming. In other words: a negative spiral of compounding environmental harm. Overfishing leads to a myriad of additional problems, including biodiversity loss and health risks related to antibiotic resistance.

Consuming animal-based protein is not an environmental problem per se; today's environmental problems associated with animal factory farming and the seafood industry are a result of industrialized processes. At larger scales, the efficiency of consuming animal-based protein is significantly reduced in terms of caloric output for production land and feed used. This inefficiency is driven by two factors: nutrition loss along the food chain, and the vast amounts of land required for animal feed and grazing.



Breakdown of global land area dedicated to food supply



Source: FOLU

Planetary & ethical impact of animal factory farming

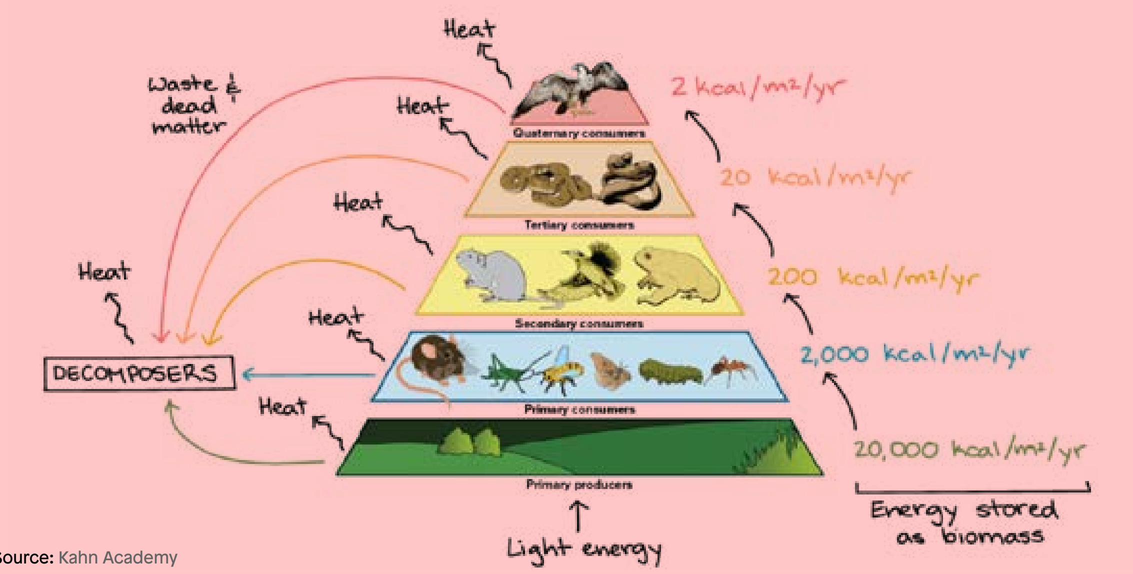
Highly inefficient land use
Agriculture represents 32% of the world's habitable land, out of which 62% is used for livestock, meat, and dairy production. Surprisingly, the food supply generated by livestock equals merely 17% of the world's total calories. In contrast, crops represent 83% of total calories, but only 38% of the agricultural land (FOLU).

Rapid depletion of fish populations
As of 2018, over 90% of wild fisheries were overfished or at maximal capacity with fish populations in coastal areas near depletion. This has pushed fishing practices further out at sea with lacking law enforcement, resulting in severe human rights violations such as slavery, occupational hazards, along with chemical and pathogenic contamination for consumers. Today, over 30% of all seafood is caught illegally.

Exponential energy loss
The excessive land and ocean use required to farm animal- based meat and dairy is explained by the concept of energy transfer along the food chain. We lose 90% of stored energy in terms of biomass for each level we move up the food chain (a process known as "the 10% rule"). Thus, by growing feed to sustain animal factory farming and consuming animals as opposed to crops, we waste nutritional energy at exponential rates (National Geographic).

Major driver of biodiversity loss
Animal factory farming has resulted in massive deforestation to leave room for the massive surface areas needed to feed primarily livestock. The seafood industry has harmed biodiversity both above and below land with over 40% of what's caught at sea are known as "bycatch", referring to the accidental catch of other animals or non-target species (GFI). Bottom trawling is another culprit and refers to a common fishing technique of dragging heavy nets and metals along the ocean floor, destroying massive areas of natural habitats and coral reefs (USGS).

Generates 50% of food production's total greenhouse gases.
Livestock and aquaculture represent 30% of total greenhouse gas emissions from food production. The land used for livestock represents another 16%, and land use to grow crops for animal feed 6%. Livestock also produces the greenhouse gas methane through enteric fermentation. Combining all these factors, animal factory farming drive over 50% of the total greenhouse gas emissions from food production (Our World in Data).



Source: Kahn Academy

Increased risk for zoonotic and non-communicable diseases and exposure to toxins. Consuming animal-based protein provides an increased risk for zoonotic diseases caused by viruses, bacteria, parasites, and fungi spread from animals to people (CDC). Red meat consumption has also been associated with an increased risk for non-communicable diseases, including certain types of cancer (National Cancer Institute), cardiovascular diseases, and type 2 diabetes (National Library of Medicine). Moreover, lack of regulatory oversight and illegal fishing has exposed consumers to toxic levels of mercury, microplastics, and pathogens. In the U.S. alone, 300,000 babies are born every year exposed to potentially toxic levels of mercury in the womb, and 90% of all mercury found in our bodies can be traced back to seafood consumption (GFI).

Massive rise of antimicrobial resistance (AMR) and related deaths. AMR results in over 700,000 human deaths every year, for which heavy use of antibiotics in animal factory farming and aquaculture plays a major role. Antibiotics is used to treat diseases and infections in farm animals resulting from dense and unsanitary living conditions. If these practices continue in their current form, the number of AMR-related deaths is expected to reach 10 million by 2050. The livestock sector alone uses over 240,000 tons of antibiotics every year; the same number as the global healthcare industry, and a number expected to rise by 67% between 2010-2030. (SeaBOS).

50 billion animals suffering each year (not accounting for fish and marine species) Animal factory farming is the world's largest source of animal cruelty through intensive confinement and caging of animals, deprived of natural behavior and daylight. 50 billion animals are raised in factory farming settings each year, where they are treated as commoditized products as opposed to sentient beings (CIWF). This is excluding fish and marine species, which typically aren't covered by animal welfare legislation. As a result, it's common to skin, gut and cook living fish while they remain alive and conscious (GFI).

Opportunities arising from the protein shift

The protein shift provides immense opportunities for completely new markets of novel protein production methods. Many new alternatives will serve as substitutes without requiring significant behavioral change for the consumer and therefore minimal friction for widespread adoption. From a consumer's perspective, purchasing a burger that's been grown in a bioreactor, or choosing a dairy product made from crops instead of cows makes little difference if the price and taste are comparable.

It won't be possible for merely a handful of companies or one novel production process to succeed in the alternative protein space; a steady inflow of new players and production techniques is needed to meet the rising protein demand worldwide. This includes plant-based options, fermentation, cellular agriculture, and a shift towards the bottom of the food chain. The reason is simple: given the massive global demand for animal-based foods, we'll need multiple new sources to sustainably feed a growing population.

A large-scale shift of sourcing protein and fat further down the food chain could by itself generate an exponential rise in caloric efficiency and minimal energy waste. Primary producers (e.g. plants, algae, and some bacteria) are by far the most resource-efficient food categories for humans to consume, as they rely on light as opposed to food to grow, followed by primary consumers such as insects (National Geographic).

Market size & maturity

The protein shift has already begun and is currently the most mature food system transformation. The alternative meat market is expected to grow at a CAGR of 14.8% between 2020-2025 (Statista), compared to near-zero growth rates for the traditional meat industry. **The global meat industry is worth over $1 trillion; should the alternative meat market reach a 10% market share, it will be worth over $100 billion** (Statista). Given that that plant-based milk already represents 15% of total milk dollar sales in the U.S., this number is a conservative estimate (GFI).

The U.S. demand for plant-based food grew 29% between 2017 and 2019, outpacing traditional food growth 5x in terms of dollar sales with plant-based milk representing almost 40% of total plant-based sales. In contrast, the plant-based meat market is still in a relatively early stage, representing 1.4% of the total meat market. If everyone who consumed plant-based milk were to convert to plant-based meat, the market in the U.S. alone would be 12 billion USD.

Plant-based eggs, condiments, and dressing are growing rapidly while representing a much smaller market share. U.S. sales of plant-based eggs grew 168% in 2020, compared to traditional egg sales that declined by 10% the previous year. By 2026, this market is estimated to reach 1.5 BUSD (GFI).

Cellular agriculture is not yet commercially available, but the past few years have shown great strides towards a market launch. The novel industry is forecasted to reach 140 BUSD in global market value over the next decade (Reuters). However, this number is difficult to predict as the product has not yet been commercialized.

Examples of innovations

Plant-based alternatives

Vegan substitutes for meat, dairy products, and eggs

A technique of producing food typically made of animal inputs using plant-based ingredients high in protein and fat. Emerging protein sources include sunflower, mung bean, potato, rice, duckweed, chickpea, navy bean, oat, and fungi (GFI). Plant-based alternatives often use microbial fermentation, a process using biomass fermentation enabling microorganisms to produce large quantities of protein.

Cellular agriculture

Premium meat substitute

Also known as cultivated or cell-based meat. It's the practice of growing animal protein or fat in bioreactors. Cells are harvested from live animals to be grown in bioreactors by feeding the cells nutrients, mimicking how the cells would grow inside of an animal. This process holds the potential of producing real meat with a significantly lower environmental impact while eliminating animal harm and the use of antibiotics (GFI).

Insect farming

Using insects as affordable ingredient substitute and upcycling food waste to animal feed

Entomophagy (human consumption of insects). Over 1,900 insects are consumed by over 2 billion people and are expected to play an even larger role in protein consumption with a lower environmental impact than animals. Insects also play an important ecological role in several aspects, such as soil improvement, plant reproduction, and pollination (FAO).

Insect bioconversion. Insects also hold great potential for large scale bioconversion upcycling of food waste into animal feed due to their ability to break down food waste into high quality protein sources. The EU estimates that one third of their total food waste (90 million tons) could be upcycled via insects (EU).

Algae farming

Affordable ingredient substitutes high in protein and fat

Growing algae to be used as ingredients in areas of land otherwise unable to grow crops in. Algae convert sunlight and carbon dioxide to nutrients rich in protein through photosynthesis. This has the potential of becoming a great protein source with minimal environmental impact and is currently used on a small scale in food supplements (Scientific Reports).

Note: Both insect farming and large-scale algae farming must be carefully planned to ensure sustainable impact at an industrialized scale.

II. The regenerative farming revolution

Farming techniques improving the productivity of the soil instead of degrading it.

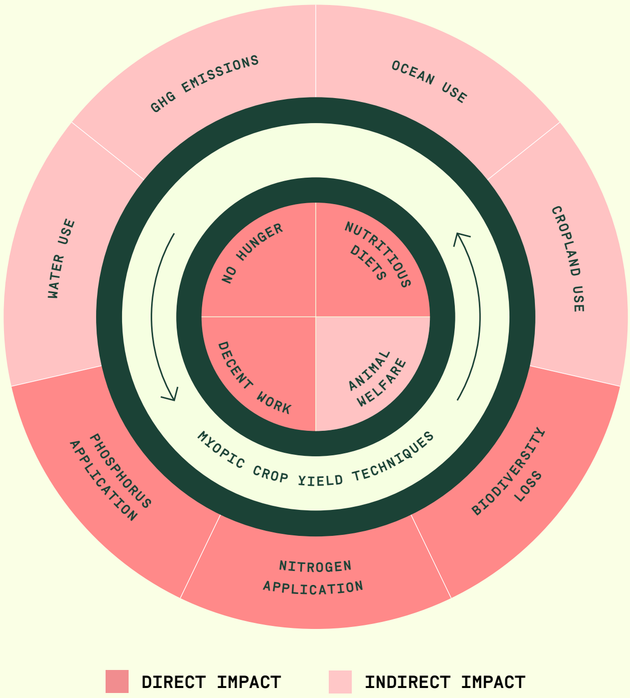
The first agricultural revolution was characterized by the shift from hunting and gathering to growing crops. The second involved mechanization of farming. The third was driven by innovations in synthetic nutrients, pesticides, and GMOs (genetically modified organisms), all of which making huge contributions to increasing food supply, predictability, and reduction of hunger.

On an industrialized scale, however, the long-term consequences of increased pesticides and synthetic fertilizers have negatively impacted soil health to the point where it's threatening our future food security. We're currently on the brink of a fourth agricultural revolution centered around introducing regenerative practices with the ability to restore soil health and our natural ecosystems.

Root cause: Myopic Crop Yield Techniques

Industrialized agriculture of plowing and tilling the soil to grow crops has damaged our natural soil and its fertility. Over the past 150 years, half of the world's fertile topsoil has been damaged through agricultural practices. This is alarming since the restoration of crop soil takes time; 3 cm takes 1,000 years to form. Monocropping and the systematic replacement of perennials with annual crops have also left our ecosystem significantly more exposed to environmental catastrophes and longer recovery periods for crops. If current agricultural practices continue without new innovation, we'll only have 60 harvests left (Scientific American).

Part of the solution to this problem has been to apply fertilizers, such as nitrogen and phosphorus, to increase crop yields as they are essential to plant growth. However, their natural availability in most agricultural settings is limited, calling for additional application to produce sufficient yields. Paradoxically, an oversupply of nitrogen and phosphorus can lead to soil erosion and ultimately desertification (UN).



Planetary & ethical impact of myopic crop yield techniques

Leading driver of biodiversity loss
Industrialized agriculture is a leading driver of biodiversity loss by land expansion converting natural ecosystems into cropland, excessive use of fertilizers and pesticides, and monocropping (European Commission).

Nitrogen and phosphorus can end up in our freshwater systems through rainfall, causing nutrient loading and increased growth of algae. When algae die, they extract oxygen from the water through eutrophication causing aquatic dead zones. The largest dead zone is located in the Gulf of Mexico and is the size of New Jersey (National Geographic).

Another harmful side effect is agrobiodiversity, which has declined by 75% during the past century. This includes microorganisms of the soil which are essential to feed crops their nutrients and overall soil health (FAO).

Monocropping has resulted in a lack of diversity of crops. It's a technique used where farmers grow only one type of crop that yields the highest profit (often corn, soybeans, and wheat). Despite monocropping making the soil and crops less resilient against disease as biodiversity serves as nature's natural disease protection (Debating Science).

Rapid depletion of phosphorus deposits
Nitrogen can be produced synthetically, although the process of doing so emits high levels of greenhouse gases. Phosphorus, on the other hand, is a non-renewable source with deposits expected to run out within 50-100 years if current application rates are maintained (FOLU).

Highly unoptimized application of nitrogen and phosphorus globally
Current application levels of nitrogen and phosphorus are oversupplied in high-income countries and under-supplied in low-income countries. Many of which would benefit from increased application levels to boost crop yields while remaining below the threshold of harming the surrounding ecosystems. Rebalancing nitrogen and phosphorus application worldwide, combined with improved recycling and wastewater practices would allow increased application and production levels globally, without adding additional stress to our planet (Lancet).

Water pollution and depletion harming natural ecosystems
Agriculture irrigation drives 70% of total water use worldwide and is both a driver of water constraints, as well as a victim of it. Lack of efficient water management and recycling in agriculture leads to water constraints and water pollution. Run-off agriculture water containing fertilizers and pesticides contaminate our water, while groundwater pumping for irrigation can lead to ground-water depletion, drying up of wells, and lower water levels in streams and lakes (OECD).

Current agricultural practices could lead to 90% soil erosion by 2050
Industrialized agriculture and tilling practices have to lead to alarmingly high rates of soil erosion. This results in decreased soil nutrition for crops, leading to smaller crop yields and less nutritious food. Tilling, monocropping, excessive use of pesticides, and replacement of perennials for annual crops are major drivers of soil erosion. With today's current trajectory and agricultural practices, up to 90% of the world's soil could be degraded by 2050 posing a major threat to food security (FAO).

Opportunities arising from the regenerative farming revolution

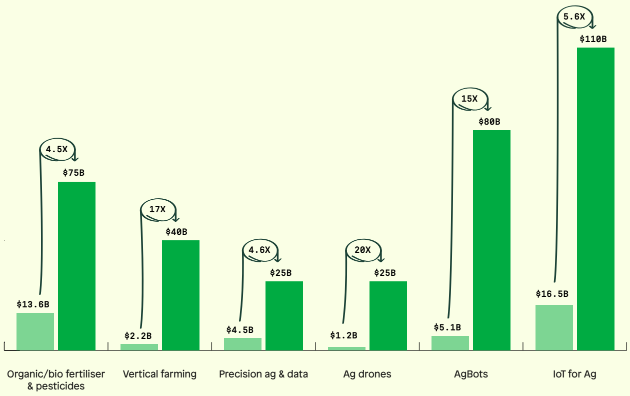
New agricultural practices will be supported by technological advancements and substitutes for pesticides and fertilizers, while others will require behavioral change for farmers. Agricultural robots and drones for example will require less time spent out on the field, while improving soil health likely will require a shift away from monocroppoing to growing a wider variety of crops. Some of these changes will require public policy support and increased education and financial incentive structures for farmers to join the regenerative revolution.

Market size & maturity

The innovation of the regenerative revolution pertains to a wide spectrum of business models at various stages of maturity. The AgTech market consisting of drones, precision ag, agBots, and IoT builds upon technical advances across other industries and is as such relatively advanced compared to other sub-segments. In turn, crops produced by vertical farming technology are already commercially available in select retailers around the world.

Solutions designed to restore soil health will be fundamentally critical for the food system transformation, and much more innovation is needed in this space. Securing soil health might in fact be the single most crucial problem to reverse, as it serves as the foundation for all nutrients and food supply. Without healthy soils rich in microbes, our plants will not receive the nutrients needed to grow. As a result, micronutrient deficiencies across the human population will rise even more rapidly, harming our gut health and immune system.

One leading project aimed to better understand how our food and agricultural practices impact our gut health and the immune system is currently being conducted by the Meridian Institute funded by Rockefeller Foundation. This project is called the Periodic Table of Food Initiative and is mapping the genomes of the 1,000 most common food products consumed and their health impact. Similarly, we need to improve both farmer's and society's understanding of the complex systems that enable us to grow food at all, and how everything is connected.



Source: The Food and Land Coalition and additional Re:food analysis.
A detailed explanation of the calculations can be found in the Technical Annex Table 3.

Examples of innovations

Carbon farming

Practices to regenerate rather than deplete soil health

A set of agricultural practices designed to store carbon in the soil utilizing photosynthesis. In contrast, traditional agriculture releases carbon from the soil (4p1000).

Agroforestry is a collective term to describe regenerative techniques where woody perennials, such as trees and bamboos, are grown together with agricultural crops (agrisilvicultural systems), or together with grazing or domesticated animals (silvopastoral systems) (FAO).

Vertical farming

A complement to traditional agriculture allowing cropland to rest and restore systematically, while making crop yields independent from weather for improved food system resilience

Climate-controlled indoor farms to grow crops without soil utilizing techniques such as hydroponics or aero- ponics, LED lighting, automated nutrient dosing, pH controls, and CO_2 enrichment (Nature).

Precision agriculture

Minimizes need for inputs such as synthetic fertilizers and pesticides

A range of technologies utilizing satellite data and advances in computing for more precise information across the crop cycle. With help from the reflection of light in different wavelengths, new technology help farmers depict valuable information such as biomass and chlorophyll content to optimize crop yields (Planet). Examples include:

RNAi for disease control is a method of utilizing biologicals that naturally occur in the immune systems for animals and plants as a way to treat disease and pests (Future Science).

Bioherbicides and nanotechnology, the development of biological herbicides derived from microorganisms to fight weeds as opposed to using pesticides (Science Direct).

Multispectral camera drones to collect information from the electromagnetic spectrum invisible to the human eye in to detect diseases (i.e. fungal disease) before it grows into a problem (Nature).

Regenerative seafood production

Techniques to eliminate overfishing and restore ocean health

Wild capture. The practice of capturing overfished stocks, from fisheries (EU).

Mesopelagic fish. Fish that feed on zooplankton. Currently not exploited but has the potential of being harvested for food if more resources and technical expertise is developed in the area (EU).

Mariculture. Farming of primary producers (i.e. seaweed and mollusks). These do not require feed as large fish do as they extract nutrients directly from the ocean while sequestering carbon in the ocean, and thus reducing ocean acidification (EU).

III. The circular supply chain reformation

From linear wasteful supply chains to a circular resource-efficient supply chain minimizing lost nutrients, materials, and energy.

The food system's supply chain comes full circle whether we pay attention to it or not. The packaging we use to protect our food re-enters the system after throwing out the trash at night, and the food we consume gets reintroduced to natural ecosystems after passing through our digestive tracks. Similarly, fertilizers applied to cropland can end up in our water supply through rainfall, causing severe harm such as tainted drinking water and aquatic dead zones.

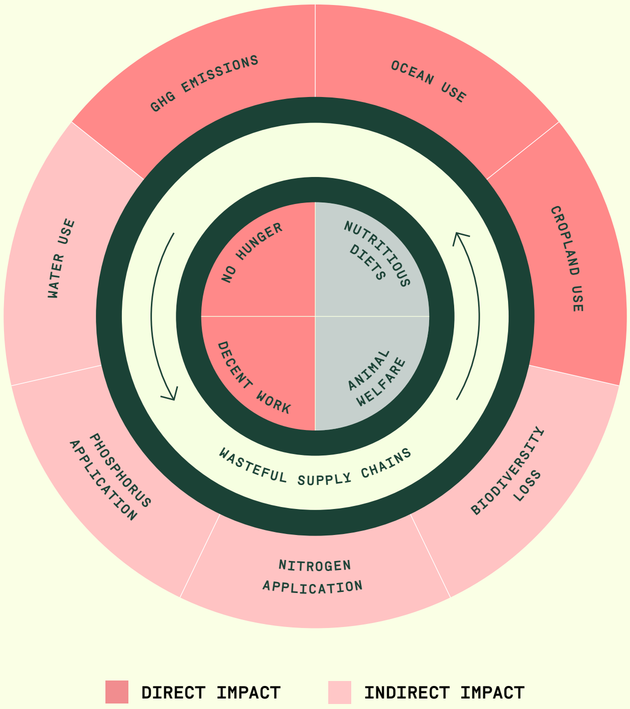
A more direct impact of linear supply chains is food waste and food loss that occurs along the entire supply chain, from production to distribution and consumption of food. Many argue that global hunger isn't primarily a result of insufficient food production; it results from inefficient supply chains and distribution. Improved transparency, added feedback loops, and communication between all food system players is key to building resource-efficient supply chains.

Root cause: Linear Wasteful Supply Chains

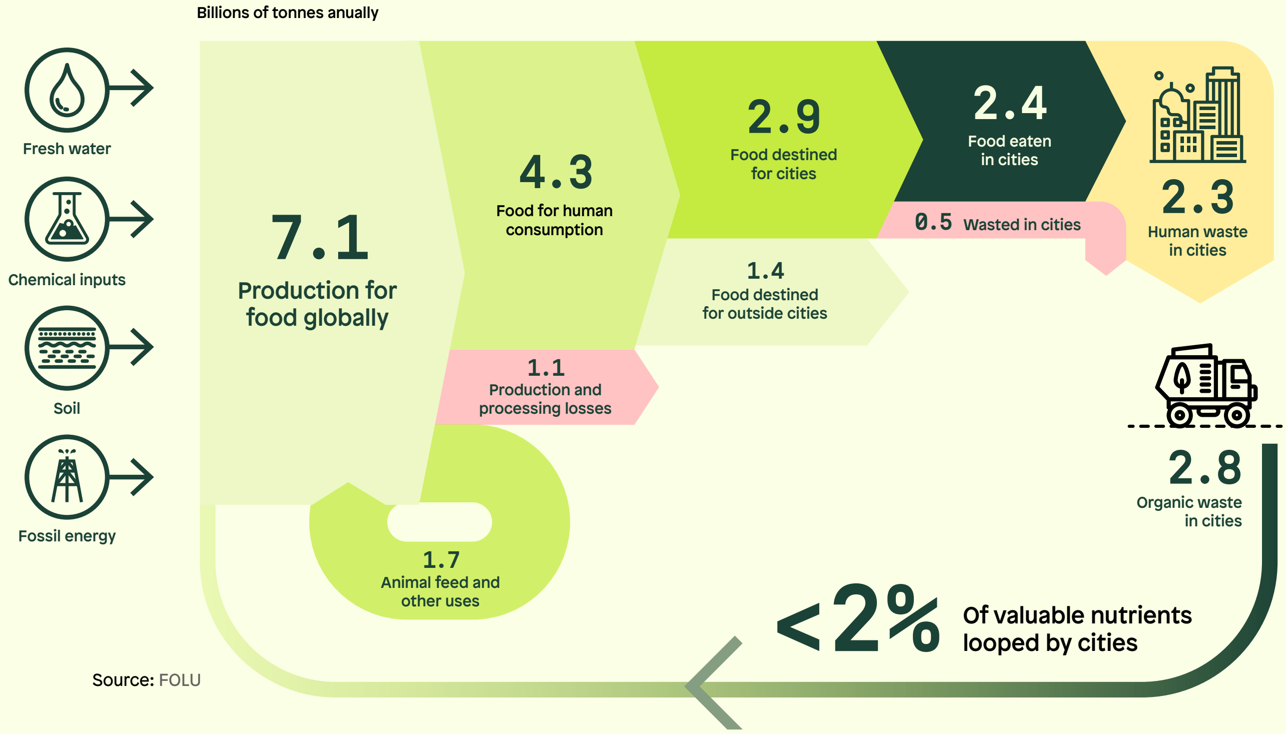
Over one-third of all food produced ends up as food loss or waste. The land required to produce this food is equivalent to the size of China. Optimizing supply chains is therefore crucial to combat world hunger.

Estimated costs related to food loss and waste reach 1.25 trillion USD each year, excluding indirect costs such as greenhouse gas emissions. These costs however are hidden to most producers and consumers making it a tricky problem to solve. Food is also cheap and abundant in rich countries, allowing for unoptimized consumption habits, as the lost food doesn't hurt the consumers' wallets enough to change their behavior. Food safety regulations also limit the timing retailers can sell food, where best before dates overrule actual food spoilage (FOLU).

The problems associated with linear supply chains extend beyond the inefficiencies of food loss and waste. Packaging, sewage, animal manure, fertilizers, and pesticides all re-enter the system. In linear supply chains, we lack control of how this reintroduction occurs, which can have devastating consequences to the ecosystem. Lack of transparency along the supply chain also makes it very challenging to trace problems back to their roots, making the problems difficult to prevent.



Efficiency losses in food and land use systems



Source: FOLU

Planetary & ethical impact of liner and wasteful supply chains

3.3 billion tons CO2 equivalents in annual emissions
Supply chain inefficiencies represent 18% of total greenhouse gas food emissions or 3.3 billion tonnes of CO2eq annually. These emissions are relatively evenly spread across the various stages of production, transportation, packaging, and retail (Our World in Data).

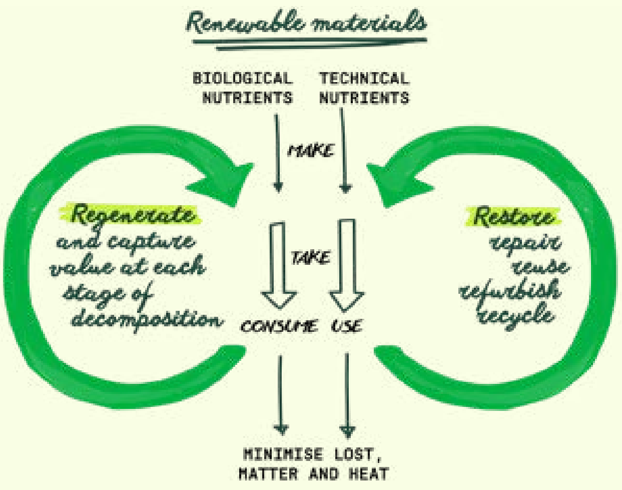
Profits heavily skewed along the supply chain giving rise to inequality
Profits are heavily skewed towards the end of the supply chain (e.g. food brands and retailers), pressuring farmers to maximize yields at any cost to maintain profitability; even when there's not enough demand for the food produced. This profit distribution also penalizes farmers wanting to invest in more sustainable methods, as their margins would vanish with increased capital investments (FOLU).

Major driver of marine plastic pollution
Non-biodegradable food packaging drives pollution of our oceans harming both aquatic life and human well-being. Microplastic debris has entered our drinking water and seafood consumed, containing toxics for human consumption (Science Direct).

Air pollution and water contamination
Sewage and manure release toxins such as ammonia, nitrous oxide, and hydrogen sulfide. If left uncontrolled, these toxins can pollute our air and water supply, This increases the risk for respiratory diseases, waterborne pathogens, and the growth of algae blooms (The Guardian). Excess fertilizers reaching our waters can also cause algae blooms. This can ultimately lead to aquatic dead zones through eutrophication.

Opportunities arising from the circular supply-chain reformation

A 15% reduction of food waste in the U.S. alone could feed 25 million people annually. Most food waste and loss come from the production stage as a result of unoptimized production practices and overproduction. The second-largest source of food waste is lack of efficient distribution, followed by a lack of upcycling of food waste (Harvard).



Source: TED Ideas

By improving communication between producers and consumers, supply chains could move towards a pull-based model in order to reduce overproduction of food and related waste. The current supply chain operates on a push-based model, where producers are driven to maximize production volumes, regardless of actual demand. Instead, the goal of the system should be to optimize production to meet the exact demand at any given point in time (or vice versa, i.e. nudge the demand to match what's available).

Market size & maturity

The size of the food waste industry holds tremendous potential to transform the economic loss of $1.15 trillion each year into new revenue streams. Food worth $400 billion is lost every year even before reaching the retail shelves, with an even larger portion ending up as waste at the consumer level. The upcycled food industry aims at reducing food waste before reaching the retailers and was valued at $46.7 billion in 2019 with an estimated CAGR of 5% for the coming decade.

The circular supply chain reformation will require behavioral change across the food system, ranging from production, distribution, and consumption. This will require new feedback loops at every level providing direct environmental, social, and financial information related to food loss and waste. A producer or consumer is much more likely to change their behavior after seeing the financial and/or environmental price tag associated with their everyday food loss or waste.

Business models aimed at solving food waste at the retail stores have already been proven successful through new services purchasing "ugly produce" from retailers and selling it directly to consumers. Produce deemed unsellable by retailers due to aesthetic reasons make up 40% of total food waste, creating a significant market to capture (Forbes). Moreover, perishable food that does make it to the shelves is also expected to see reduced food waste thanks to smart labeling designed to maximize shelf life. In 2017, the smart labeling market was valued at $5 billion and is expected to reach $13.6 billion by 2023 (Allied Market Research).

Other segments of the circular supply chain reformation, such as biodegradable plastics and smart kitchens, will require further innovation prior to being commercially viable.

Examples of innovations

Upcycling
Reducing food loss in the production process while adding new revenue streams for producers

Transforming food about to get wasted into ingredients used in other products (FoodTank).

Redistribution platforms
Minimizing waste of finished food

Platforms to redistribute surplus food for retailers, restaurants, and consumers (UN). P2P platforms allow consumers to exchange purchased food in local neighborhoods (Science Direct). Other platforms provide new revenue streams to producers or retailers by facilitating sales of food that otherwise would have been wasted due to imperfect packaging, short best before dates, or aesthetics.

Smart labeling & packaging
Reducing plastic pollution and food waste driven by incorrect best before dates

Smart labeling could replace best before dates by placing sensors on food packaging to analyze actual spoilage rates (Science).

Edible wax coating. Coating produced using wasted agricultural products to extend the shelf life of fruits and vegetables (New York Times).

Biodegradable plastic. Polylactic plastic (PLA) derived from renewable sources (e.g. sugar canes or corn starch). This technique holds the potential of replacing existing plastic packaging with biodegradable options. More developments are needed before success at a large scale (Nature).

IV. The healthy diet transformation

Improved diets with the goal of maximizing nutrients to prevent disease and optimize health, as opposed to diets accelerating premature deaths.

The human brain has evolved to crave food high in salt, sugar, and fat, although excessive consumption of these nutrients leads to an increased risk of diet-related obesity, diabetes, coronary heart disease, and stroke (Lancet). The delayed feedback between the food we consume on a daily basis and its impact on our long-term health is very slow, making it difficult to see the connection. This area is becoming better understood, although much more innovation is required to reduce premature deaths related to diets.

On the flip side, the food we consume can also play a major role in preventing future health problems on a global scale. This section primarily addresses junk food and unhealthy diets in developed countries since malnutrition in developing countries will likely be more dependent on public policy as opposed to entrepreneurship. The innovation discussed in the circular supply chain and regenerative revolution section, however, will likely play a large role in ensuring future food security worldwide.

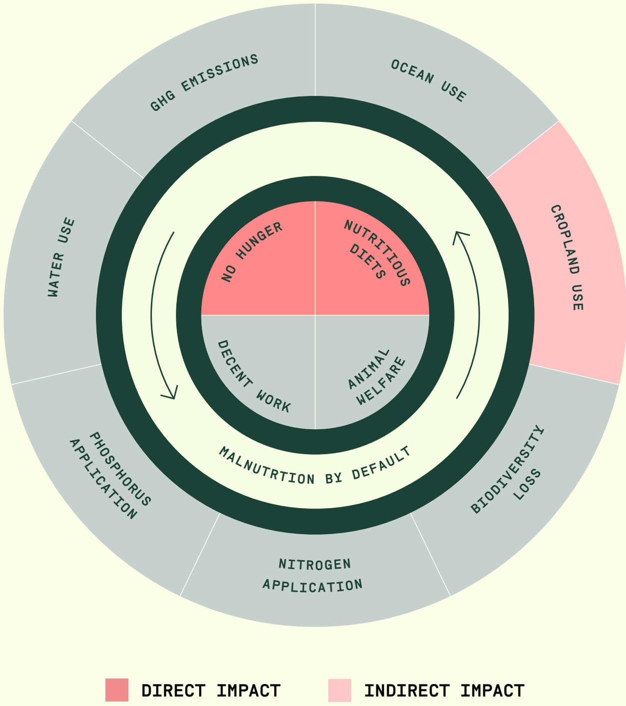
Root cause: malnutrition from myopic crop yield techniques & wasteful supply chains

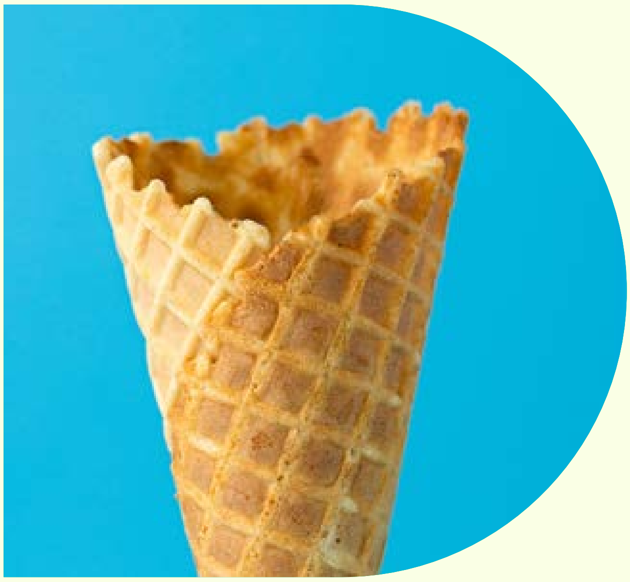
Malnutrition pertains to deficiencies, excesses, or imbalances in a person's diet. This includes both undernutrition, i.e. lack of sufficient food or micro-nutrient deficiencies in food consumed, as well as overnutrition, which can lead to obesity and other diet-related diseases (WHO).

Paradoxically, developed countries struggle with both overnutrition and undernutrition simultaneously. This is a result of excessive junk food and day-to-day diets lacking essential nutrients. Developing countries, on the other hand, primarily struggle with undernutrition due to a lack of food security.

The malnutrition challenges of developing and developed countries require vastly different solutions. This section primarily addresses junk food and unhealthy diets in developing countries. Undernutrition in developing countries will likely be more dependent on public policy as opposed to entrepreneurship. The innovation discussed in the circular supply chain and regenerative revolution section, however, will likely play a large role in ensuring future food security.

The human brain has evolved to crave food high in salt, sugar, and fat, although excessive consumption of these nutrients leads to an increased risk of diet-related obesity, diabetes, coronary heart disease, and stroke (Lancet). The rise in diet-related diseases can also be attributed to the delayed feedback making it difficult to see the connection between diets and related health problems.





Planetary & ethical impact of unhealthy diets

21 million premature deaths related to unhealthy diets
In 2017, the number one leading risk factor attributed to premature deaths was high blood pressure, which is associated with high intakes of sodium. The third leading risk factor was high blood sugar and the fifth obesity.

Unhealthy diets are a major driver of cancer
Almost one-fifth of all cancer cases in the U.S. are related to overweight, poor nutrition, alcohol consumption, and/or physical inactivity. Many of these cancer cases could be prevented through healthy diets (American Cancer Society).

One third of the global population is malnourished
A number expected to reach 50% should the healthy diet transformation not take place. In total, 1.5 billion people have a deficiency in micronutrients (WHO). The costs related to diet-related diseases are estimated at $2.7 trillion annually (WHO) and these costs will only increase unless we improve our baseline nutrition worldwide.

Opportunities arising from the healthy diet transformation

The healthy diet transformation must improve the nutritional quality of both baseline food and indulgence to significantly improve public health. Lancet has developed a reference diet with the potential to avert between 10,8 - 11,6 million deaths every year (EAT) that involves a significant shift towards a more plant-centered diet.

Given how difficult resisting temptation and changing behavior is, we need to make indulgent food healthier for us. This includes removing the unhealthy ingredients such as salt, sugar, and saturated fats from comfort food such as ice cream, candies, and snacks while keeping the same sweet, salty, and rich taste profile.

We also need a better understanding of how our diets are connected to our gut health, genetics, and related diseases (Johns Hopkins Medicine). Food as medicine holds tremendous potential for preventative health and massive drops in global healthcare spending.

The healthy diet transformation will require both substitutes to improve existing dietary habits with minimal friction for consumers to adopt, while functional food to some extent will require the introduction of new feedback loops and an increased understanding of food's impact on our long-term health to impact consumer behavior.

What innovation holds the potential for solving hunger in developing countries?

This is an area where we've yet to identify innovation and profitable business models to incentivize entrepreneurs to enter the space. We're actively looking for innovation that could resolve this critical problem without relying on public policy or non-profits. We'd love to hear from you if you've got the answer!

Market size & maturity

The natural and wellness food channel is growing at 8% in the U.S., compared to conventional food growing at 2% (SPINS). The organic food market in the U.S. is estimated to reach $730 billion by 2030 with a CAGR of 14.56%. The fortified food market of enhancing food with micronutrients is expected to reach $600 billion by 2030 with a CAGR of 10.5% (FOLU). These numbers may indicate that the healthy diet transformation is well underway, but we believe it's only the beginning.

Diet and nutrition have historically been overlooked by science and technology relative to therapeutics, despite their enormous effects on health. Although healthy categories such as organic and functional food have grown rapidly over the past decade, there are tremendous discoveries to be made within healthy foods which is the least developed shift of this report despite holding the largest potential.

Technological advancements that have powered the personalization of medicine are now being applied to understand the full biochemical spectrum of the food we consume and how it affects our gut health and immune system. This could open up a whole new market for individualized food designed for disease prevention. New business models are starting to take shape around the microbial mapping of food. Microbial and nutrition density trackers are likely to play a key function in the next generation of smartphones and wearables introducing direct feedback loops of the food we consume and long-term disease impact (Food Periodic Table).

That said, it's still too early to accurately predict new innovation and related financial opportunities that will arise from demystifying the remaining 99% of the nutrition and its impact on our health. What we do know is that our view of healthy diets will be altered over the next decade and that personalized nutrition will likely play a critical role in future disease prevention and health care practices.

Examples of innovations

Nutrient optimization

Enhancing baseline nutrition to reduce malnutrition

Nano-encapsulation. A technology used to encapsulate bioactive compounds with positive health effects in food, such as omega-3 (CORDIS).

Nutrient density trackers. Technology designed to measure the nutrient density and microbial composition of food. This technology is currently being developed and could be embedded in smartphones and wearables allowing consumers to scan food in retail stores for optimal and personalized nutrients composition (World Economic Forum).

Gene editing to enhance nutrition in baseline food. Humans have selectively bred plants for optimal traits for thousands of years. Gene-editing techniques such as CRISPR promise substantially more precise modification of crop traits. These techniques turn on and off traits that are already present in a given crop, rather than adding traits transgenically (i.e. GMO). Gene editing could dramatically reduce the time it takes to create crops that withstand harsh weather conditions, provide enhanced nutrition, or improved shelf life to reduce waste without altering our natural ecosystems (National Geographic).

Food as medicine

Tailored diets to prevent disease and health issues

Nutrigenetics. Diets tailored to your genome or gut bacteria with the purpose optimize food intake based on individual traits (Nature).

Synbiotics is the combination of probiotics and prebiotics in food that promotes gut health and related microbiota. Improving gut bacteria has been proven to prevent many diseases, as gut health controls much of overall human health and disease (Science Direct).

Improving/removing temptation

Improving existing dietary habits

Ingredient innovation. New ways to produce food with the same sweet, salty, or rich taste profile, but without salt, sugar, or fats (Fooddive).

Neurogastronomy. Techniques to manipulate the brain's perception of taste by activating additional senses or blocking certain flavors (APA).

E-commerce solutions. By removing the physical visit in a store and the related exposure to impulse purchase there is potential for consumers to make healthier choices, including e-commerce grocery alternatives or meal kit services (Cambridge).

V. [Insert next transformation here]

We're humble to the notion that the problems and possibilities listed in this report are not a complete representation of the global food system. Thus, we welcome collaboration with innovative minds worldwide.

Are you working on solving a problem not listed here? Have you discovered an innovative way that accelerates any of the investment themes already mentioned? Get in touch!

Systems thinking to reform the food system

In order to fully transform the global food system, we need to understand which *paradigm* the current food system builds on, its *overarching goal*, the *root causes* driving structural harm, and identify its *leverage points* able to generate *transformational change*. We also need to understand the *complexity* of the food system's underlying structure and how it *interacts* with other complex systems.

Paradigms, goals, root causes and leverage points

Paradigms are the mindset out of which systems and their goals, structure, rules, information flows and parameters arise. The current and longest-lasting paradigm of the food system is to keep increasing production volumes to feed more people. There's nothing wrong with this paradigm per se; the problem occurs when production techniques are rewarded despite driving significant harm to society.

All systems have an explicit or implicit overarching goal based on a paradigm, acting as the underlying force of where the system is headed. Each actor within the system develops individual sub-goals related tied to this overarching goal, driving behavior in a given system. **Changing the goal of a system is one of the most powerful ways to drive structural change.**

Food for thought: changing the goal

What do you think would happen to the food system if the global market, instead of rewarding increasing production volumes at low cost, created financial incentives to ...

1. *Maximize the nutritional density of products (as opposed to production volumes)*
2. *Maximize nutrition for as many people as possible (as opposed to overall sales)*
3. *Maximize lifetime agricultural yields (as opposed to short-term productivity improvements)*

What business models, technology, or innovations would be needed to meet these altered goals?

Feedback loops are information regarding how one person's behavior in a system impacts the system as a whole. Feedback loops can be efficient ways to drive behavioral change with very little effort. To illustrate this, consider if your behavior would change in either of the following scenarios:

Food for thought: introducing feedback loops'

Would your food consumption habits change if your trash bin had a sensor simply providing information on how many hungry people the food waste in your bin could feed? And what if it also included drop-off information to the nearest foodbank?

Would your dietary habits change if you had a smartwatch with sensors tailored to your unique genetic disposition providing instant feedback on how each meal impacts your daily and-long term predisposed health traits? What if your watch sent dietary recommendations to help optimize your daily well-being (based on real-time energy and hormonal levels) and long-term health?

Root causes are the core issues that set in motion a chain reaction across the global food system. Notably, many of these root causes doesn't pose environmental or ethical threats on a small scale. In contrast, these practices often provide benefits to society at first, while causing massive harm at an industrialized scale.

Food for thought: identifying root causes

We've identified and described four root causes driving harm to the food system: factory animal farming, myopic crop yield techniques, linear and wasteful supply chains, all resulting in widespread malnutrition. Can you think of any others?

Leverage points are places within a complex system where a small shift in one thing can produce big changes in everything with the potential of reversing underlying root cause problems. These can bring both positive and negative effects with varying degrees of impact. Examples of leverage points are new feedback loops, changed goals or rules, full-cost pricing, or new incentives to transform behavior. The most powerful leverage point is at the paradigm level (Donella Medows).

Food for thought: the power of leverage points

Nutritional density trackers is an example of an innovation that could drive behavioral change across the food system by targeting a leverage point: the incentive for farmers to grow crops in a certain way. This emerging technology measures the nutritional density of food items (e.g. through a smartphone), allowing consumers to directly compare the nutritional value of different products, and retailers can use it to guide (and justify) pricing decisions.

This could incentivize farmers to grow crops in a more sustainable way to preserve soil health and microbes and reverse the current paradigm of maximizing short-term yields and profits (at the expense of future ones). Instead, farmers would be incentivized to maximize soil health to drive increase nutritional density and profits.

The complexity of systems: food, climate & our bodies

The global food system is not only the largest and most important system created by humankind, but it's also directly connected with the most complex systems on earth: the climate system, the economic system, the political system, and the human body's various systems. For the purposes of this report, we'll primarily focus on the systems where entrepreneurship and investments have the largest potential impact, namely the climate system and the human body. That said, the political and economic systems are incredibly important for the food system transformation and must change in tandem to facilitate the introduction and scaling of sustainable innovation.

Our first step in understanding how to transform the food system is to understand what other systems it's interconnected with and how. To start, the food system is deeply intertwined with the climate system, which in turn is made up of five dynamic components: the atmosphere, oceans, land surface, the cryosphere, and the biosphere. In turn, the food we consume directly impacts our body's various systems, such as the immune system, nervous system and endocrine system in ways scientists have yet to uncover.

We actually know less than 1% of food's impacts on our health; the remaining 99% is known as *the dark matter of nutrition* (PMC). To date, we've mapped out 150 major macro- and micronutrients (e.g. proteins, fats, vitamins, and minerals) and have a pretty good understanding of how these impact our health. However, our food consists of at least 26,000 smaller biochemicals, for which health correlation remains widely unknown. New discoveries indicate that these biochemicals may heavily impact disease by affecting our cellular signaling through genetic expression (Nature). Read more under *The Healthy Diet Transformation.*

Lastly, the food we consume ultimately re-enters the climate system after passing through our digestive systems. This goes for our domesticated animals as well, both of which impact the soil and the water we use for new food production.

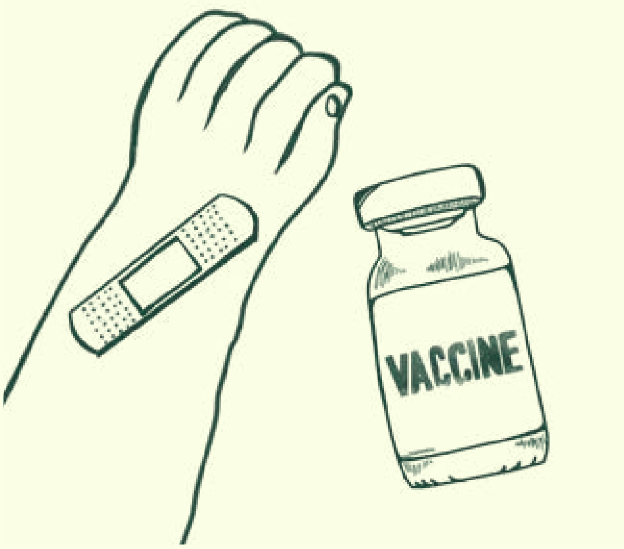
Root causes versus symptoms

To successfully transform the food system we need to develop solutions to solve its root causes as opposed to symptoms arising from these problems. An analogy is the eradication of a disease as opposed to treatment; once a disease has been eradicated, it's been removed from the host population, and treatments are no longer needed. In contrast, treatment might help to alleviate the symptoms of the disease while the underlying source of the disease (i.e. the pathogen) still exists in the population. Even if the treatment is highly efficient, there's still a risk for new infection surges as the root cause problem still exists.

Examples include cancer and diabetes caused by unhealthy diets, marine plastic pollution due to linear supply chains, and aquatic dead zones as a result of excess nitrogen and phosphorus ending up in our waters. It's tempting to get lost in solving these side effects as opposed to reversing their root cause. Doing so, however, only generates incremental improvements as opposed to structural change.

How do we know which food system solutions are comparable to eradicating a disease as opposed to treating symptoms? That's the million-dollar question, and the unsatisfactory answer is that no one really knows due to the complexity of the global food system. Rather, we must continuously model, test, analyze and reiterate potential solutions to transform the global food system. And since most solutions require constant improvements, it's difficult to know upfront which solutions have the potential to become "disease eradicators" as opposed to "treatments". This report introduces various frameworks and ways of assessing promising innovation with the ultimate goal of eradicating root cause problems and redirecting the food system's trajectory towards a sustainable and resilient state.

Most of the food system's unwanted side effects are in fact symptoms, and solutions to these are merely treatments akin to symptom alleviation as opposed to a solution eradicating the underlying source of the problem giving rise to the symptoms.



Screening tools for long-term sustainability & resilience

To avoid scaling solutions with adverse planetary or ethical impact, we've gathered leading resources designed to screen the sustainable impact of new innovation. These help guide food system investments by assessing if an innovation merely introduces incremental improvements to an existing problem (or even worse, introduces a new big problem), or if it in fact could eradicate the problem itself. That said, there are many other factors beyond frameworks to consider when assessing if an innovation has the potential to drive transformational change. Especially when we're talking about the largest and most critical industry ever created.

At the end of the day, the engine of any industrial revolution are the entrepreneurs willing to devote their careers to building transformational solutions. Thus, the most important part of our screening process is getting to know the entrepreneur and the team behind the innovation. We want to understand their underlying purpose and long-term vision for the food system and their ability to build a company able to realize that vision.

I. Framework for Strategic Sustainable Development (FSSD) sustainability principles

A methodology supporting a process of continual learning and action that incorporates other methods, tools, and concepts into a shared, structured overview used for modeling future scenarios. The FSSD consists of a set of sustainability principles for ecological and social sustainability aimed to define the boundary inside of which the system can function and evolve long-term, outside of which it cannot. To reach a truly sustainable state, all industries must meet these principles while following a strategic implementation process to reach the future state. The underlying goal of the FSSD is to help decision-makers "design the problem out of the system" by addressing the root cause of the problem, as opposed to symptom alleviation (BTH).

The FSSD sustainability principles:
In a sustainable society, nature is not subject to systematically increasing:

1 ...concentrations of substances extracted from the Earth's crust, e.g., fossil carbon and metals;

2 ...concentrations of substances produced by society, e.g., NOx and CFCs;

3 ...degradation by physical means, e.g., over-harvesting of forests and overfishing;

...and people are not subject to structural obstacles to:

4 ...health, e.g., by dangerous working conditions or insufficient rest from work;

5 ...influence, e.g., by suppression of free speech or neglect of opinions;

6 ...competence, e.g., by obstacles to education or insufficient possibilities for personal development;

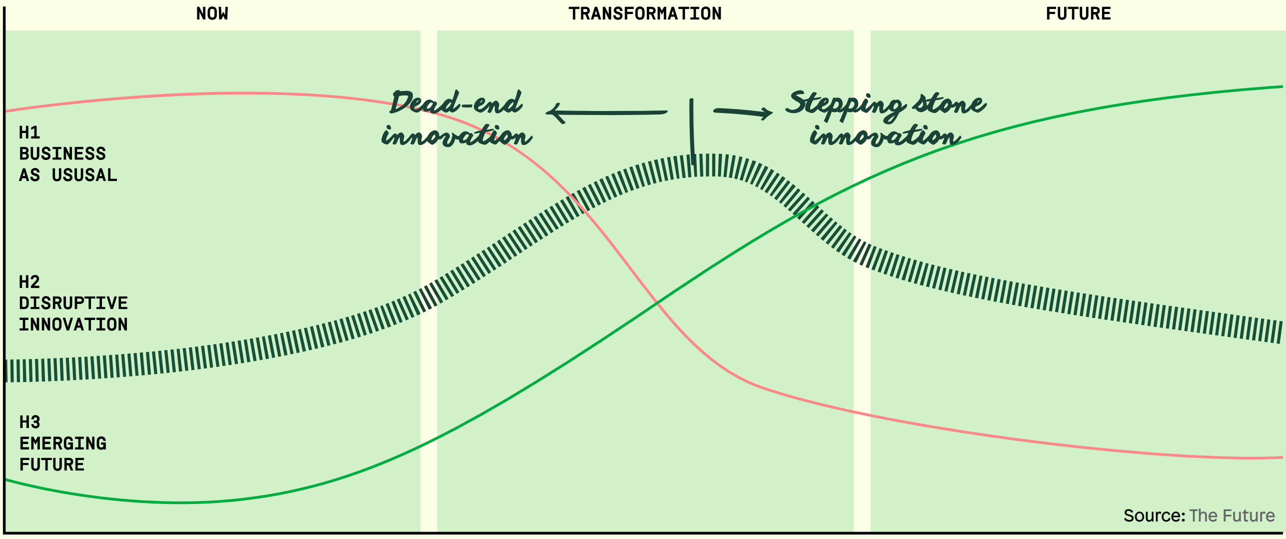
7 ...impartiality, e.g., by discrimination or unfair selection to job positions;

8 ...meaning-making, e.g., by suppression of cultural expression or obstacles to co-creation of purposeful conditions.

Broman, G.I., Robèrt K.-H., 2017. A framework for strategic sustainable development. Journal of Cleaner Production 140: 1.

II. Three Horizons to ensure long-term sustainability

Reforming a major system requires mapping out short, medium, and long-term waves of change and an understanding of how these interact with each other. Bill Sharp has developed an excellent framework for this purpose known as "The Three Horizons". The horizons describe waves of change where a dominant way of doing business ultimately gets replaced by another better way of working. We've described each horizon below in the context of the global food system*.



Horizon 1: Today's food system & current ways of working

Horizon 1 describes how the global food system operates today, despite showing signs of being unsustainable in the long run (i.e. failing to provide an ethical foundation for everyone while violating planetary boundaries). Common practices are often "locked-in" due to regulations, policies, and vast amounts of capital tied up in machinery and industrialized production practices. Even though we've understood that today's way of working is bad and follows a harmful trajectory, it's difficult to change its overall direction due to this inertia.

Horizon 2: Disruption & transition path

Many innovations merely extend the life of harmful practices by introducing incremental improvements without addressing their root cause problems. We call these dead-end innovations, as they move us back to where we started as opposed to carving out a brand new path toward the future. Innovations propelling us onto a new path are referred to as stepping stones.

It's not always obvious if an innovation will serve as a stepping stone towards the future, or dead-end extending practices of the past since new solutions evolve and improve over time. That said, it's important to consider the three horizons and critically examine new innovation to ensure it has the potential to become a stepping stone to the future as opposed to a dead-end prolonging current problems. To avoid this scenario, it's helpful to define a list of criteria alternative solutions must adhere to. The FSSD framework refers to these as "sustainability principles".

* McKinsey has developed a version of this framework called "The Three Horizons of Growth" used as a tool for companies to sustain long-term growth by moving along the three horizons. For the purposes of this report, we refer to the original model developed by Bill Sharp.

Horizon 3: The emerging future of a prosperous food system

Horizon 3 maps out a potential future state, which we define as a prosperous food system operating within the boundaries of the Re:food circle. We can experience some glimpses of this future through current innovation and behavioral change, such as the massive plant-based movement we're currently experiencing. These are referred to as "pockets of the future in the present".

Today's food system is somewhere between horizon 1 and 2 with new innovation providing glimpses of the future in the present

Our current food system has widespread harmful practices that we know must change, and we've made fantastic strides in developing sustainable alternatives to producing food. Yet, there's much more work to be done to redirect the food system towards horizon 3. To succeed with this, entrepreneurs, investors, and policymakers must separate incremental innovation extending harmful practices (dead-ends), from transformative innovations (stepping-stones) redirecting us toward a new path headed toward a better future.

III. Incremental versus transformative innovations

The act of separating a dead-end innovation from a stepping-stone solution is not an easy task, if it was we'd already been well on our way towards a prosperous future state. In fact, many of the harmful food practices we have in place today were initially viewed as technological breakthroughs improving the lives of millions of people. However, on an industrialized scale, they generate massive harm to our planet.

Dead-end innovations

Dead-end innovations are ones that provide incremental improvement to existing production practices. This is not a negative thing by definition, however, if we focus all our energy and resources on these innovations we'd simply be extending the lifeline of our current food system (i.e. horizon 1) and therefore delaying the transformation we need. Thus. incremental improvements don't do much for the planet as a whole.

Examples of a dead-end innovation would be producing only organic meat and dairy; it improves some aspects of the meat and dairy industry, but it doesn't remove the problem itself (i.e. consuming animal-based food high up the food chain as a primary source of protein). Even if organic products are better for the environment, human- and animal health, the protein yield per unit of agricultural land is still highly inefficient and detrimental to our planet at scale. With a population trending towards 10 billion people there's simply not enough land to continue practices that require large-scale breeding and feeding of animals for human food production.

Stepping stone innovations

Stepping stone innovations are those that yield transformational impact by introducing a new way of doing things that removes the root cause driving harm in the first place. These innovations create a new path toward a future state (i.e. horizon 2).

A potential stepping stone innovation that could yield transformative impact is replacing animal-based products with plant-based options, which require significantly less

land and resources for each unit of protein produced. Plant-based solutions remove the need for animal factory farming by introducing a completely new way of producing alternative meat and dairy.

Innovations too early to categorize

Since most new solutions and technology undergo several iterations during their lifecycle, it can be difficult to see if an innovation will end up as a dead-end or a stepping stone. The important factor to look for in these cases is if the ultimate vision of the solution, in theory, could remove the root cause driving harm without introducing new adverse effects elsewhere in society. For this to happen, several technological breakthroughs may be required that aren't available today but could become available in the future.

Cellular agriculture (i.e. growing animal cells in bioreactors to produce meat) is an innovation too early to categorize before it's reached large-scale production. Until then, we won't be able to accurately benchmark the energy and resources required to build and operate bioreactors against animal factory farming. That said, advances within cellular agriculture combined with the rise of renewable energy indicate that there's great potential for cellular agriculture to become a stepping stone towards our target future state, as it could replace the need for large-scale animal farming to produce animal-based protein.

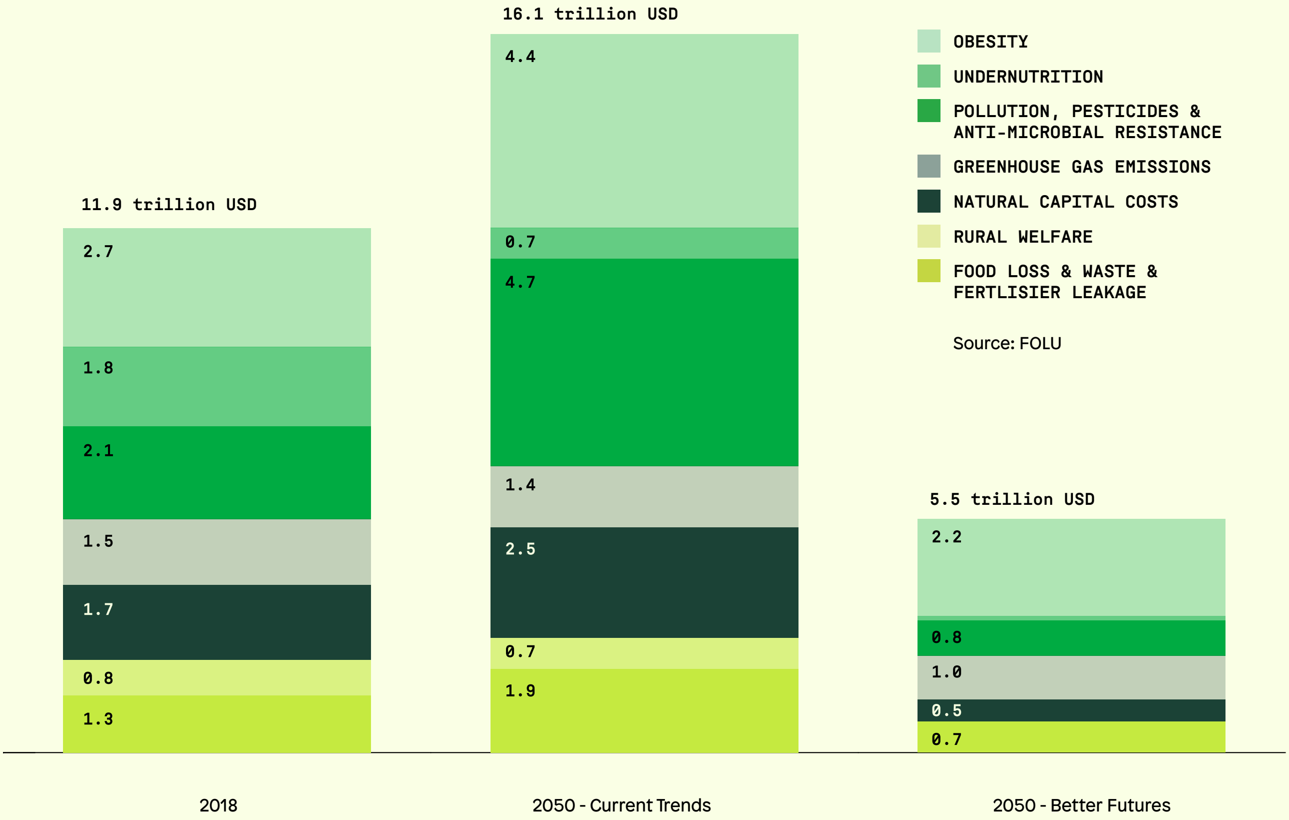
Tools to help model an innovation's impact at scale:

- Participatory Impact Pathway Analysis (PIPA)
- Development Evaluation
- Blue Marble Evaluation

The market is ready for a food system reformation

We view the rise of innovation as the spark required to ignite the food system reformation, and consumer demand and public policy as the fuel to drive it forward. Innovation has the power to introduce new feedback loops to support public policy shifts, while governments ultimately must enact them. Innovation brings a wider range of sustainable options to consumers, who ultimately make the purchase decisions. We're starting to see the impact of innovation in terms of both public policy and consumer demand, proving that the paradigm shift has already been set in motion.

A shift in public policy and regulations



Until now, governments and consumers have been paying the hidden costs of the food system. These costs range from rising health care fees to emergency relief in response to environmental catastrophes. As these hidden costs are reaching overwhelming levels, governments will have no option but to enforce a shift towards full-cost pricing to avoid debts spiraling out of control. This will make it progressively more difficult for food companies with negative externalities to remain profitable due to new regulations, taxes, and financial incentives favoring sustainable alternatives.

Public policy plans are often made official through high-level treaties and agreements, such as the Paris Agreement, the European Green Deal and associated EU Taxonomy for Sustainable Activities, and more recently the proposed Green New Deal in the United States. In turn, these are often inspired by the Sustainable Development Goals by the United Nations. These plans all require an inflow of innovation to reach stated goals.

Paradoxically, the same institutions are often pressured by large traditional industries to curtail the entrance of competing innovation. This can be traced back to the Margarine Act in 1886 when the U.S. government made margarine more expensive, or in some states illegal, to protect the dairy industry; to today's plant-based labeling battles, such as Amendment 171 seeking to ban the use of dairy-related terms for plant-based options.

With sufficient consumer backing, however, many incumbent companies have been able to use the strength of the institutions against themselves and ended up winning more customer trust in the end. These outcomes signal that the mental model of how a food system should operate is starting to unravel, which according to Meadow's model is one of the most powerful indicators of a paradigm shift is underway.

Rise in consumer awareness and demand

We're already witnessing impressive consumer support for companies taking a bold stance on sustainability. Our generation's habit of consuming baseline products such as dairy and meat was previously thought of as sticky habits: ones that weren't changing anytime soon. Yet, here we are with companies such as Oatly, Beyond Meat, and Impossible Foods sweeping up market share from the dairy and meat industry. Meat producers and traditional F&B corporations have even started investing in competing for innovation in order to stay afloat throughout this shift in consumer preferences (New York Times).

This rise in consumer demand will only grow stronger with younger generations. Twice as many American Gen Z's express that they're trying to consume more plant-based compared to millennials. Yet, almost one-third of millennials belong to this category. Also, American plant-based shoppers tend to spend up to 61% more at the grocery store, compared to the average shopper. This means that the surge in demand we've seen for sustainable food to date will be nothing compared to what's to come as gen Z's make up the next generation of households (Plant Based Foods).

Conclusion

As the true cost of harmful food practices unravels, consumers and governments worldwide are realizing they've been the ones picking up the tab. Simultaneously, the planet clearly signals that our current way of producing food cannot be sustained. Unless we reform the global food system into a sustainable and resilient state, the next generation will be left to face widespread starvation caused by irreversible damages to our cropland and oceans.

The good news is that there's still time to reverse this trajectory. This, however, will require a major reformation of the way we produce, distribute, and consume food driven by four major shifts. These are the protein shift, the regenerative farming revolution, the circular supply chain reformation, and the healthy diet transformation.

Given the scale and urgency of implementing these four shifts, we need to prioritize transformational innovation. There's simply not enough time to utilize the world's resources, talent, and capital for yielding incremental improvements to the food system's current ways of operating. Doing so would only delay the transformation we desperately need.

In response, new regulations favoring sustainable practices, combined with ever-rising consumer demand, global talent, and investments entering the food industry are powering an inevitable paradigm shift. Combined, these factors have opened up a new frontier of prosperous food companies with potential for significant social, environmental, and financial returns.

In the near future, corporate winners will successfully operate within our planetary and ethical boundaries. In contrast, companies that stick to their traditional practices will start seeing falling profits when hidden environmental and ethical costs start to impact their bottom line. It won't take long until the only sensible choice from a financial, environmental, and health aspect, is a sustainable shift for all stakeholders in the global food system.

We remain optimistic about the future based on daily interactions with purpose-driven entrepreneurs, who we believe have the potential to transform the global food system with support from investors, consumers, and public policymakers sharing a vision of a prosperous future. If you happen to be one of these entrepreneurs and need support scaling your food system solution, get in touch!

Appendix

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Organizations & reports
- EAT-Lancet (Food in the Anthropocene)
- Food and Land Use Coalition (Growing Better)
- The Good Food Insitute (State of the Industry Reports)

II. DEFINITIONS

The Re:food circle
An investment model defining the boundaries and ethical foundations of a prosperous food system, defined as being both sustainable and resilient. The food system is sustainable when it operates within the critical ethical and planetary boundaries. It's resilient when it's able to produce a sufficient food supply for a growing population despite external stress (i.e. harsh weather, draughts, pandemics, or financial crises).

Transformative investing
Investments with the ability to generate important and lasting change. For the purposes of this report, this lasting change refers to a transformation of the global food system into a sustainable and resilient state while operating within our planetary and ethical boundaries.

Transformational innovation
Innovation generating impact with positive externalities across more than one aspect of the food system (i.e. production, distribution, and consumption), and direct or indirect impact in more than two of the planetary or ethical boundaries defined by the Re:food circle.

Framework for Strategic Sustainable Development (FSSD)
"A process of continual learning that incorporates other methods, tools, and concepts into a shared, structured overview". The underlying goal of the FSSD is to help decision-makers "design the problem out of the system" by addressing the root cause of the problem, as opposed to symptom alleviation (BTH).

IFSSD sustainability principles
A set of principles stating that a truly sustainable solution cannot add increased pressure on our planetary or ethical boundaries.

Systems thinking
A system is "a set of elements or parts that is coherently organized and interconnected in a pattern or structure that produces a characteristic set of behaviors" (Donella Meadows). Systems thinking is a tool to analyze and implement change in a system consisting of complex interdependencies, feedback loops, and leverage points.

Global food system
"All elements and activities related to the production, processing, distribution, preparation, and consumption of food" (Lancet).

Leverage point
"Places within a complex system (a corporation, an economy, a living body, a city, an ecosystem) where a small shift in one thing can produce big changes in everything" (Donella Meadows).

Feedback loops
Information regarding how one person's behavior, or individual function, in a system impacts the system as a whole.

Root cause
"A factor that caused a nonconformance and should be permanently eliminated through process improvement. The root cause is the core issue—the highest-level cause—that sets in motion the entire cause-and-effect reaction that ultimately leads to the problem(s)" (ASQ).

Resilience
"The ability of a system to recover from perturbation; the ability to restore or repair or bounce back after a change due to an outside force" (Donella Meadows).

Harmful food practices
Practices within the global food system that compromise the planetary boundaries and/or the ethical foundation of the Re:food circle.

Prosperous food practices
Practices within the global food system that doesn't compromise the planetary boundaries and/or the ethical foundation of the Re:food circle when practiced at scale.

Planetary boundaries
"Thresholds set at the low end of the scientific uncertainty range that serves as guides for decision-makers on acceptable levels of risk. Boundaries are baselines, unchanging, and not time-bound" (Lancet). Planetary boundaries are based on complex systems containing multiple feedback loops and interactions, and must therefore be revisited and adjusted over time.

Animal factory farming
"A large industrialized farm, on which livestock are raised indoors in conditions intended to maximize production at minimal cost" (Merriam-Webster).

Prosperous food system
A sustainable and resilient global food system that operates within our planetary boundaries while providing an ethical foundation for everyone.

Restorative
A restorative function improves the conditions of a system or thing back to its former condition (e.g. soil health).

Regenerative
A regenerative function introduces renewal of a system (e.g. biological system or a forest) or rebuilding/restructuring an existing system after injury, harm, or a normal process.

The Three Horizons
A model describing waves of change where a dominant way of doing business ultimately gets replaced by another better way of working.

Dead-end innovation
Innovation providing incremental improvements to existing production practices

Stepping stone innovation
Innovations yielding transformational impact by introducing a new way of doing things that removes the root cause driving harm in the first place.

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