ARUP

Exploring sustainable food systems

Foreword

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Our food system is a sheer miracle in its complexity, scale and the way it transcends physical and cultural boundaries. Yet it faces unprecedented challenges from rising demand, over levelling arable land, to the impacts of climate change and biodiversity loss. To the latter two issues, today's food system is one of the biggest contributors. Meanwhile, the sector is undergoing enormous transformation at speed, whether in response to environmental pressures, new technologies, changing policy or shifting consumer demand.

This prospect may seem daunting, but the future of food is actually very exciting. There has never been a greater opportunity to imagine and create a resilient and equitable food system, one that provides both healthy food for everyone, and supports the biosphere of a thriving planet. We need a food system that can continue to work in perpetuity, freeing us from the over-use of pesticides and fertilisers, and the finite chemicals that they depend on.

As a firm, we have committed to creating a sustainable future for people, places and our planet. Creating a sustainable, resilient and equitable food system will be fundamental to feeding a growing and increasingly urban population in the future.

So, let's explore together what the future of a sustainable food system could look like. It's time to identify the solutions we must develop and start to inspire everyone to play their part in developing a saner, smarter, more sustainable food system.

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Food is the system that links all systems of the built environment and cities. Agricultural land has been squeezed out of cities and people are increasingly disconnected with the origins and supply chain of the food that they eat. From Governments to social enterprise and start-ups a continued movement towards a sustainable food system is emerging.

Inspired by the Government of Singapore's commitment to locally produce 30% of their nutritional needs by 2030, Arup's Foresight team set out to explore what a sustainable food system would look like on a global scale.

In late 2019, Arup Foresight brought together a range of industry stakeholders for a learning journey and series of workshops to explore the future of urban agriculture. The event explored urban food production, the urban food supply chain, moving to sustainable consumption and eliminating food waste. We engaged with stakeholders across the food production journey, from farmers, academia, start-ups, to designers and engineers and those with the vision to rethink our food systems.

The lessons from this work have been expanded through engagements with global experts and a detailed literature review to develop the discussion presented in this report. We hope that it inspires both conversation and action towards a sustainable food system that works for everyone and in harmony with nature and the planet.

Introduction

A sustainable and regenerative food system is the single strongest lever[1] we have for improving the health of people and planet. It requires us to rethink all aspects of the food system - from growth to supply chain, consumption to waste. It asks us to revaluate many of the fundamentals of our current approach to food production. This will be challenging, yet the rewards are enormous.

In this publication, we explore what a sustainable food system might look like, and investigate some of the tools, methods, policies and technologies that would help achieve such a goal.

A vision for a sustainable food system

The narrative of what a sustainable and regenerative food system might look like in the future is told through stories from the perspective of people in the year 2040.

A regenerative and sustainable food system

It is spring in the northern hemisphere in 2040, and Jean is looking forward to a delivery of fresh fruit and vegetables from her city's neighbourhood farm. Picked that day by robots, the crop is delivered by a fairly-paid bicycle courier to her door. The firm behind the city farm was once a big name in industrial agriculture, yet pulled by consumer demand and pushed by government regulations, they now use innovative techniques to grow seasonal, organic produce close to their customers. Since eating food from the neighbourhood farm, she feels more energetic and healthy. There has been less illness in her family, her partner lost weight and their son's skin rash has cleared.

Jean's delivery also includes a package of quinoa ordered through the city farm but supplied by a decentralised cooperative of African farmers. Although native to South America, this grain was found to be drought tolerant and resistant to extreme weather and salinity, thus perfectly suitable to growing in the Sahel. Through a mobile app, Jean can trace the journey of her quinoa across the supply chain, showing growing methods and origin.

She can even connect directly to Amadou, the farmer in Mali who grew the quinoa. She thanks him directly when the package arrives and buys him a virtual coffee through the app.

Amadou and his family adopted regenerative farming methods 15 years ago with the help of Groundswell Mali, the local network of regenerative farmers. quinoa is his main export crop, but he also grows the vegetables for his local community while his wife Marian looks after the goats. Since the switch, the family has been able to diversify their business and grow the income stream which now includes regular payments from a global tech giant offsetting their carbon as well as a fee from the world biodiversity fund. They no longer need to spend money on expensive fertiliser and pesticides and save money on machinery. As a result, all their children now go to school and Amadou has been able to take on two apprentices. Amadou loves seeing the happy faces of his satisfied customers when he scrolls through his messages in the evening. He praises his family's courage to go regenerative instead of following so many other families in the community who left their village behind in despair to search for a livelihood in the slums of the city.

What makes a truly sustainable food system?

That is a vision of what a sustainable food system could look like in the future. But what makes such a system sustainable? Figure 1 on the next page summarises the six features of a truly sustainable food system.

Features of a sustainable food system

Figure 2
Six features of a sustainable food system

Social values

Social values affect how people make decisions about what they choose to eat and could include views on animal welfare or innovations like genetic modification. It also integrates with the taste of food, and the enjoyment of sharing food with family or friends.

Quality

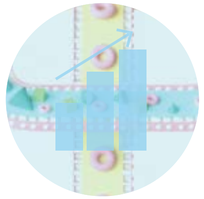
Quality refers to freshness, taste, and cosmetic appeal. A sustainable food system must be nutritious, supporting the health of all people, (not to mention flora and fauna, and the planet). Quality food must also be affordable and available with access for all.

Environment

A vicious circle emerges when food systems contribute to climate change, and then become less productive due to changed weather patterns. Energy, water, waste and land-use must be considered in an integrated system to allow for sustainable consumption whilst maintaining soil health and biodiversity.

Governance

Governments must provide policy that ensures ethical values are upheld and that the system is accountable and transparent. Science and technology must be supported to improve the system and international aid must help those who need it.



Economy

The economy must support a sustainable food system in everything from competition to working conditions. It must allow for food to be affordable and allow for a secure and resilient system.

Health

The availability and affordability of the food that corresponds with a healthy diet is integral to human health. It is also important for education programs to provide suitable information so that people understand the benefits of eating a balanced diet.

Current state of play

Food is much more than the nutrients that sustain life. It is integral to our health, it brings us together, it defines our cultures, it provides jobs and it underpins our societies. Indeed, humanity's first civilizations emerged in fertile agricultural regions as people learned to farm.

In many regions of the world, food is now abundant. Rich world consumers almost never experience shortages, and they have access to an enormous variety of ingredients. This abundance of food is largely thanks to farming techniques that have been developed over the past century that increased yields to meet the demands of growing populations. Since 1961, a 30% increase in food supply per capita has been achieved using fertilisers, irrigation and other modern farming methods.[2]

This is an impressive achievement. But it has come at a cost. The increases in yields we have seen in the last 50 years cannot continue at existing rates. Excess nitrogen (used in fertiliser) and freshwater use is having profoundly detrimental effects on the environment. In terms of climate change, 26% of greenhouse gas emissions are attributed to the food system.[3] Meanwhile some 50% of habitable land is now being used for agriculture.[4] Ancient forests, which are vital to tackling climate change, are being cleared for grazing. And even with increases in food production, around 821 million people remain undernourished worldwide.[1]

The global food system itself is facing unprecedented threats too. These include climate change, environmental degradation, water scarcity, unplanned urbanisation, and rapid population growth. If we continue with the 'status quo', existing stresses will be further exacerbated.

Take population growth. The global population is expected to increase by 24% to 9.7 billion by 2050[5], yet the total area of land use suitable for agriculture has peaked[6], and crop yields are at risk of a 50% reduction[7] due to climate change impacts by 2050. Our existing food system is also not fit for purpose. In 2020, 30% of the world's population, roughly 2.3 billion people, did not have access to adequate food. Nearly 12% of the global population (928 million people) were severeley food insecure as a result of the COVID-19 pandemic (148 million more than in 2019).[8] At the same time worldwide obesity has nearly tripled since 1975.[9]

Current state of play

Without preparation and concerted change today, humanity and the environment will be faced with much larger food system problems tomorrow.

We need a sustainable and resilient food system to address multiple problems. It would support thriving communities in mitigating and adapting to climate change, averting catastrophic loss of ecosystems, while balancing economic, social and environmental value. It could be achieved through better policies, markets, infrastructure, and governance that prioritise efficient and circular supply-side practices which in turn promote healthy and sustainable diets.

Several international programs and organisations have recognised the social and environmental impacts of the food system and are working to transform it. Food is represented in many of the United Nations Sustainable Development Goals (SDG). For instance, SDG 2 advocates for a world with zero hunger. The World Food Programme also highlights the importance of food in improving lives and was awarded the Nobel Peace Prize in 2020. For 25 years La Via Campesina[10] have been fighting for food Sovereignty – a fair and equitable system with no hunger. The Ellen MacArthur Foundation's food initiative is helping to deliver a healthy, regenerative food system and has provided actions for Fast Moving Consumer Goods (FMCGs) companies and retailers in "The big food redesign".[11] In April 2021, the Agricultural Innovation Mission for Climate (AIM for Climate)[12] announced it would focus on increasing and accelerating global innovation on food systems.

A sustainable, resilient and regenerative global food system can deliver more than just the quantity of food required to meet the nutritional needs of the growing world population. With a more holistic and circular approach, we can unlock better future outcomes across health, governance, and environment while reducing cost and creating more value in the process. Most importantly, we could reverse the negative impact that the food system has already had on the Earth and contribute positively to support the biosphere of a thriving planet.

Global trends in food

The COVID-19 pandemic has caused widespread disruption to an already fragile food system. This is both a challenge and an opportunity. The crisis has changed how consumers perceive and interact with food systems and infrastructure (see, for example, increased demands for local production). It has also brought vulnerabilities, inequalities and inequities across the global food system to light.

What is more, a renewed focus on nutrition and related health issues such as obesity has emerged as COVID-19 demonstrated the impact that a public health crisis can have on society. COVID-19 survival data shows that people who were in good health before contracting the disease had much high chances of survival than those who were not healthy.[13] This is a stark reminder of the importance of quality nutrition.

Lockdowns and supply chain disruptions (affecting global trade, exports and transport) also exacerbated food insecurity, price volatility and supply-demand discrepancies.

In addition, supply chain delays and disruptions helped foster interest in localised production. Many suppliers had to pivot their business models during lockdowns, often leading to shorter supply chains such as selling direct to the local area rather than through a centralised distribution system.

In a variety of ways, the pandemic accelerated a number of emerging food system trends and provides an opportunity to reimagine how we produce food.

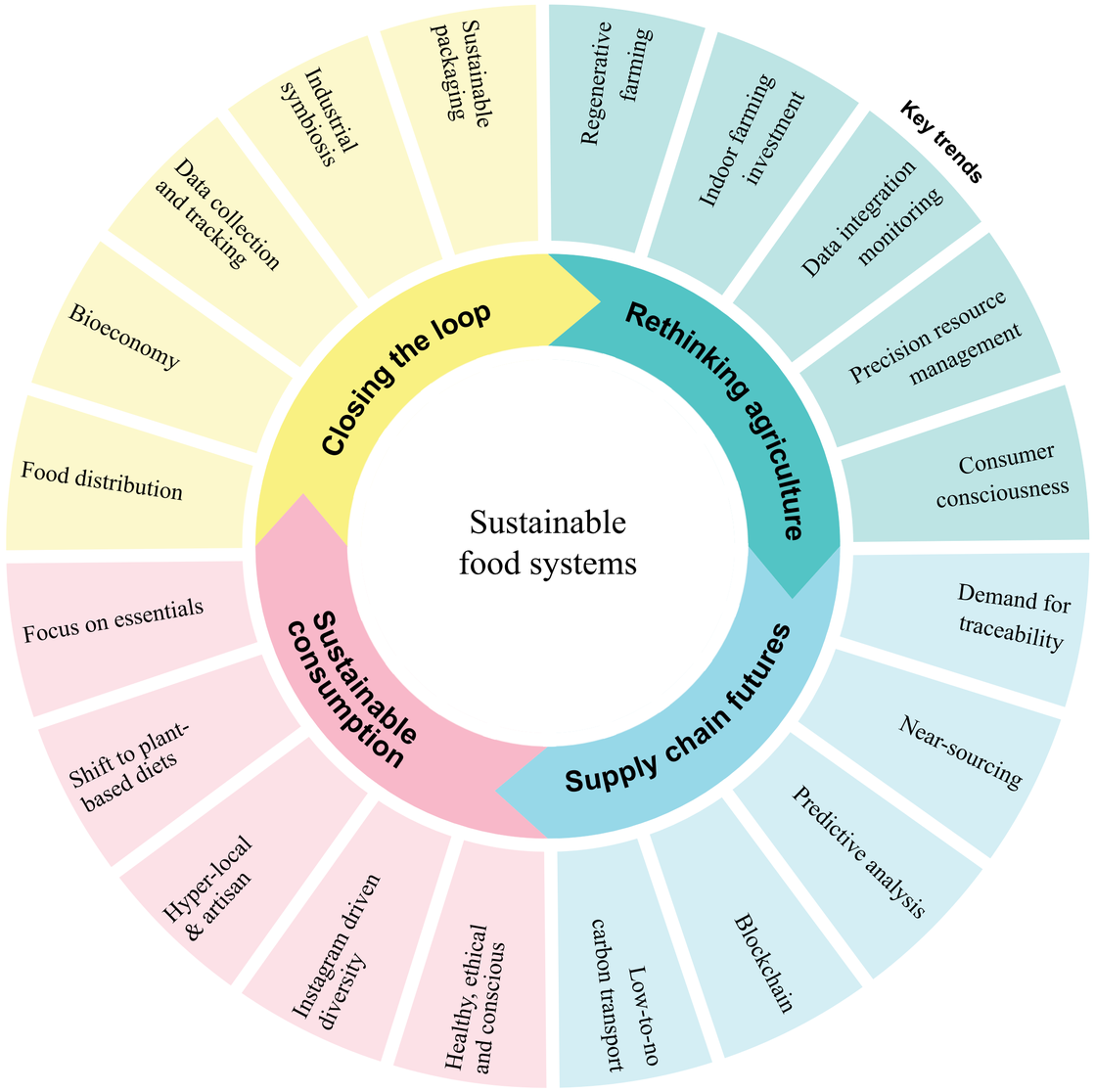


Figure 1
Trends shaping the future of a sustainable food system

Click here to see how the future of sustainable food systems can be reflected in the UNSDGs

Food and the UNSDGs

The UN Sustainable Development Goals (SDGs) provide a holistic framework to drive change and shape the future vision of the global food system. Click on the hot points to explore how a circular food system can drive sustainable development.

1 No poverty
Improved food security and good nutrition results in higher labour productivity, greater mental capacity and longer, healthier lives.

2 Zero hunger
Equitable distribution of food supplies coupled with an elimination of food waste could end hunger throughout the world.

3 Good health and wellbeing
A renewed interest in health and wellbeing and an understanding of the integral role that food plays in this is increasing the demand for healthy diets.

4 Quality education
A good understanding of nutritious food can significantly decrease malnutrition while a sufficiently nutritious diet supports learning ability.

5 Gender equality
A just and inclusive transition to sustainable food systems can create opportunities to reduce gender inequality.

6 Clean water and sanitation
Circular principles of food production reduce global freshwater use.

7 Affordable and clean energy
Opportunities to achieve a food-energy-water-waste nexus will help the affordability and sustainability of energy as well as the other systems.

8 Decent work and economic growth
A sustainable food system can ensure long term growth in the agriculture industry. It can also reduce malnutrition resulting in economic prosperity and reduced healthcare costs.

9 Industry, innovation and infrastructure
A circular and localised food system can increase city resilience and foster innovation.

10 Reduced inequality
Addressing food loss and waste will close the ‘food gap’ and reduce nutrition inequities, which can in turn reduce income inequalities.

11 Sustainable cities and communities
Integrated urban and rural food systems can help to create sustainable cities.

12 Responsible consumption and production
A circular food system can eliminate food loss and waste and create new circular business models within the food system.

13 Climate action
Sustainable food systems reduce emissions and regenerate natural resources.

14 Life below water
Sustainable production methods and better nutrition reduces pressure on oceans.

15 Life on land
A circular food system promotes biodiversity and healthy soils.

16 Peace and justice
Peace and justice cannot be achieved without nutrition security

17 Partnership of the goals
A global shift towards a collaborative and circular food system can benefit everyone!

What's on the menu?

Overview of the report

This report looks at all stages in the food system and explores how they can work together to become truly sustainable. The publication is broken into the following chapters:

1 Rethinking agriculture

Regenerative, integrated and innovative production and processing techniques will enable supply-side practices to capture carbon and increase their capacity to absorb and store water and support more biodiversity. The food system needs to be equitable and sustainable from grower to consumer. Local farms and community gardens that provide fresh and nutritious food help connect people to what they eat.

2 Future supply chain

Careful planning for transparent and controlled supply chains will reduce food loss and empower consumers to make informed purchasing decisions that meet their ethical, nutritional, taste and cultural expectations.

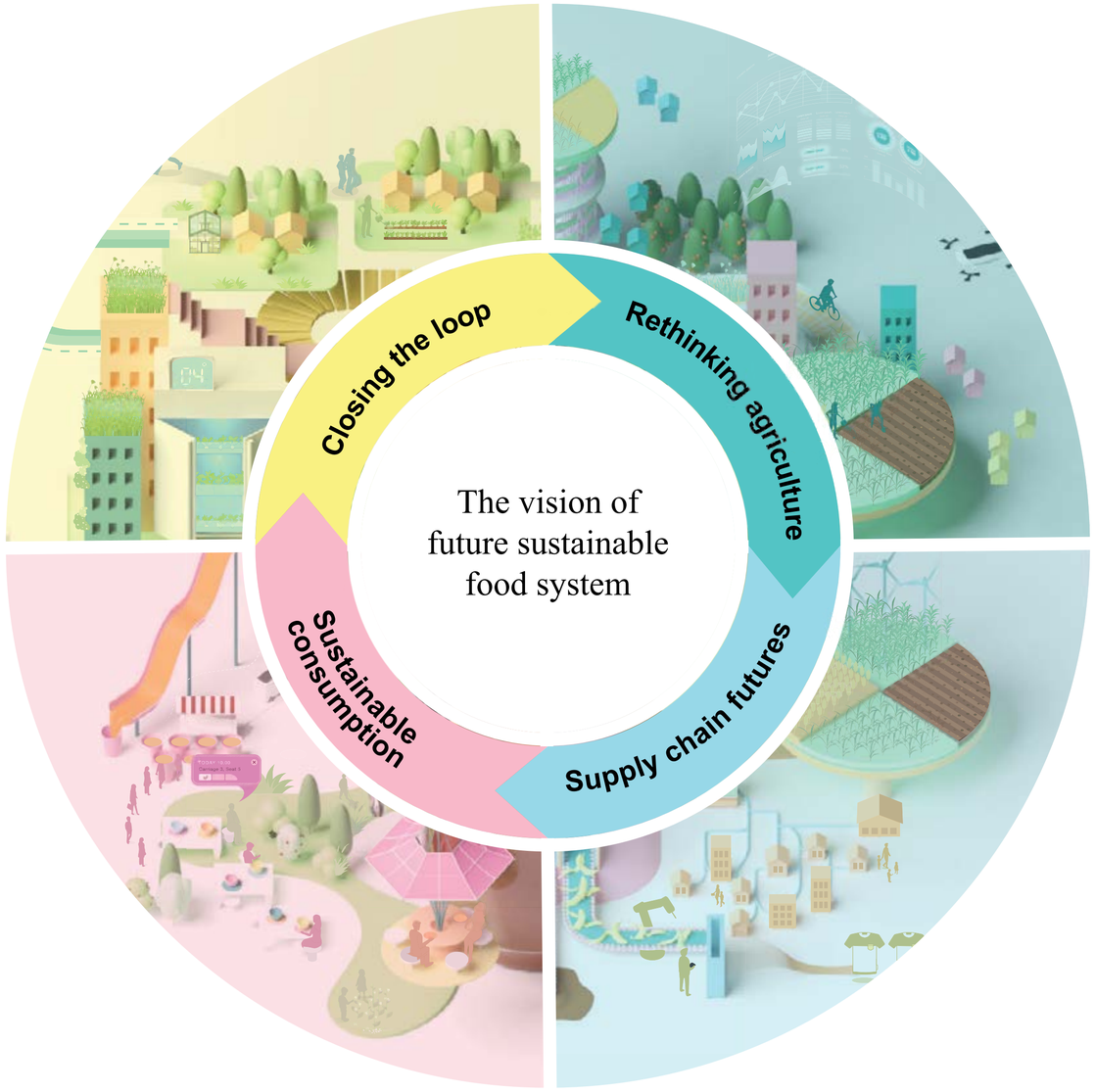
3 Sustainable consumption

Behaviour change to achieve healthy diets for nearly 10 billion people by 2050 will be key to unlocking critical environmental benefits. Empowered consumers will be more integrated in a circular food system, rather than end-users in a linear process.

4 Closing the loop

Connecting elements of the food system in order to eliminate waste. This includes thinking about all waste in the food system from fertilisers to packaging and rehabilitating soil. Technical solutions can increase the viability of some of these options, but the most important catalyst is behavioural change.

Agriculture is the cornerstone of our food system. In the next chapter we look at how it can be made sustainable.



Rethinking agriculture

To create a sustainable food future, we must embrace tens of thousands of years of indigenous knowledge of working in harmony with the land to return to farming practices that regenerate the environment whilst simultaneously growing the food we eat. The latest innovations in sensor technology and controlled environment farming will also be needed to meet the needs of our growing population.

1

Overview

The development of agriculture 12,000 years ago allowed cities to form and grow.[14] When hunter-gatherers learned to cultivate crops and farm animals this allowed them to access a more reliable food supply. Initially, crops and animals were farmed for local consumption. But as demand grew, new farming techniques using artificial fertiliser, mechanical irrigation and mechanisation enabled larger yields. This allowed for the global population to grow from a few million to around 7 billion in the 2020's.[9]

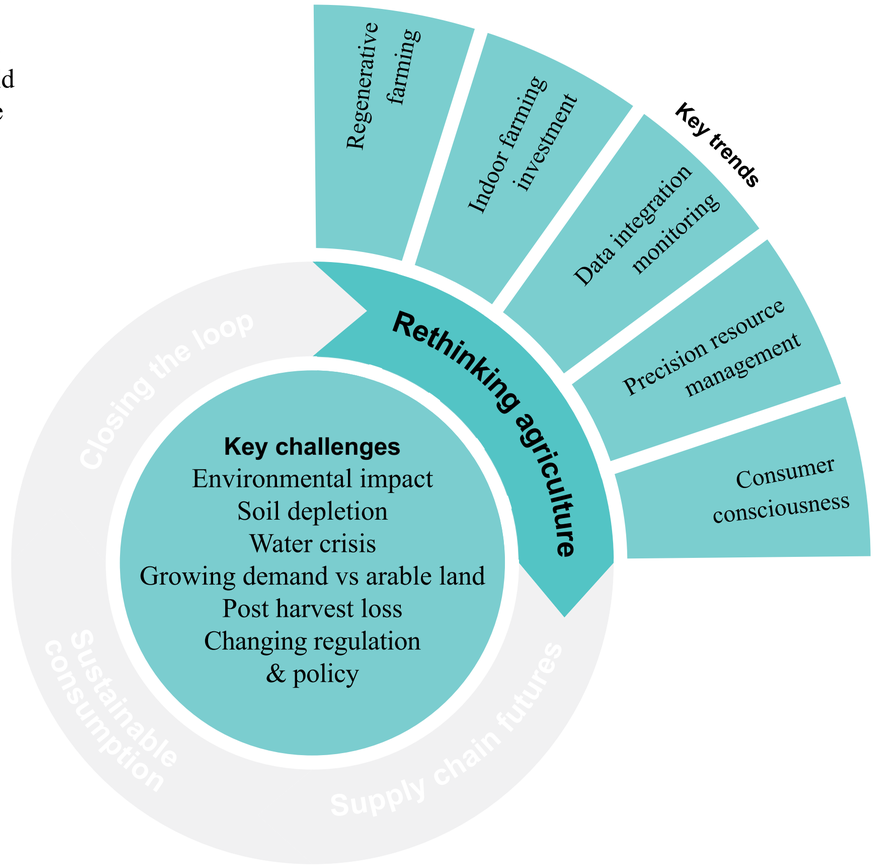
Today, over 50% of our planet's terrestrial surface is dedicated to agriculture[4], potentially producing enough food for everyone. Yet one third of all food is wasted and we live with both hunger among the poorest and an obesity crisis in wealthier countries.

And in tandem with that disparity, our food system and agriculture in particular threaten the very existence of our planet. The food system is not only contributing to climate change by being responsible for a third of all anthropogenic GHG emissions[15], but is also suffering from changes in weather patterns, drought and temperature rises.

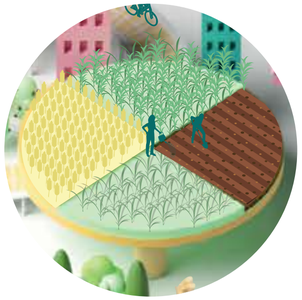
Irrigation for agriculture accounts for 70% of global freshwater use as well as being a major contributor to water pollution.[16] And our approach to agriculture is also the primary driver for large losses of biodiversity seen over the past 100 years.[17] Land clearing plays a significant role here, as it removes native habitats.

Transitioning to a regenerative and sustainable food production model focussing on soil health would allows us to: 1) reduce or reverse greenhouse gas emissions, biodiversity loss and water pollution; 2) increase bio-sequestration of carbon in soils and biomass; 3) alleviate pressure on food-energy-water-waste nexus; 4) improve security and resilience of food supply. Exploring new methods of food growth that requires significantly less land and water might help us to meet growing demand without the need to clear more land for farming.

In this chapter...
We explore several ways in which agriculture could become more sustainable in the coming decades.



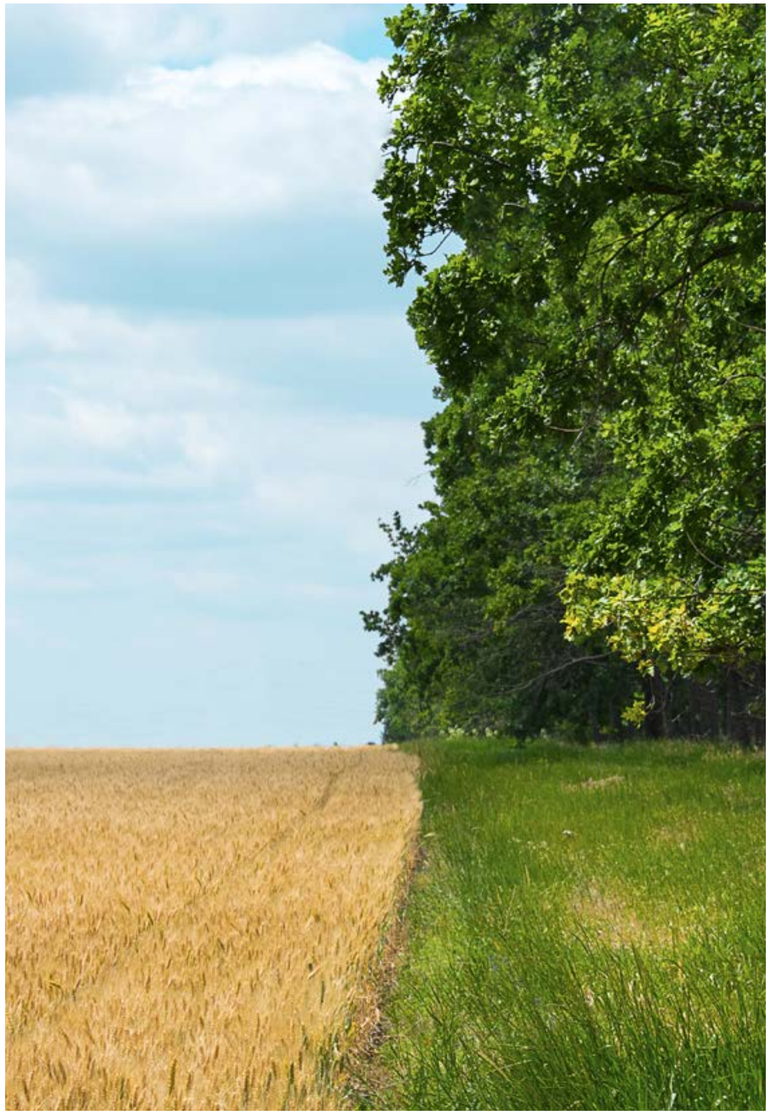
Regenerative agriculture



Regenerative agriculture is as much a process as it is an approach to farming that mimics natural systems. It focuses on improving topsoil, thus maximising food production and regenerating natural ecosystems. It considers farming holistically as part of the local ecosystem and uses methods and practices most suitable for local conditions.

A number of techniques are commonly associated with regenerative farming. These include low or no-till practices that reduce the disturbance of soil - resulting in reduced carbon dioxide release and improved soil health. Plant diversity and crop rotation allow for greater variety and a better balance of nutrients, carbon and water cycling with the soil. Strategically using cover crops increases soil organic matter and reduces pest problems and disease. Another key concept in regenerative agriculture is minimising the use of chemical fertilisers and pesticides as these disrupt natural plant and organism cycles and cause pollution in surrounding waterways due to run-off.[18]

Regenerative agriculture has numerous benefits which stem from the focus on improving soil health. A healthy soil contains a rich ecosystem of bacteria, fungi, earthworms and termites[19], making it a living organism in itself. The natural symbiotic relationship between plants, bacteria and fungi within healthy soil drives healthy root growth and makes plants naturally more disease-resistant.[20] It encourages the development of mycorrhizal fungi which support plant and increases water absorption capacity, thereby optimising the use of natural rainfall and reducing the need for irrigation. By allowing dead organic matter to remain in the soil, it breaks down into humus and provides nutrients for plants while supporting carbon dioxide absorption.[18]



Project: Natural regeneration of trees to prevent desertification[21]

Location: Niger

After several years of attempted forest regeneration in Niger with minimal success due to challenging climatic conditions, Tony Rinaudo, working with Serving in Mission, discovered what was termed an ‘underground forest’ of living root systems. These root systems, when given the chance to grow, enabled the reforestation and regeneration of 6 million hectares of Niger that had previously become barren due to farmers preventing their growth through their farming practices. This approach to land regeneration termed ‘Farmer Managed Natural Regeneration’ has started to be implemented across other parts of Africa. In 2021, it is estimated that over 24 million hectares of land across Africa are being regenerated using this approach. This regeneration has resulted in roughly a 50% increase in income for farmers that are seeing greater yields as well as other sources of income from the use of products from these trees.

Regenerative agriculture

Healthy soils are also key to making our food healthier[22] as conventional farming practices have led to a reduced nutritional value of food. A study of 43 fruits and vegetables between 1950 and 1999 found a decline in protein, calcium, phosphorus, iron, riboflavin (vitamin B2) and vitamin C.[23] Regenerative farms can also produce more calories per hectare compared to conventional farms, albeit not from one single crop. And, when no chemicals are used, they can produce the higher value organic foods that are increasingly in demand among conscious consumers.

A more natural approach to farming means growing seasonal crops best suited to the local climate. This could promote a healthier relationship to food, as eating in season tends to be healthier and tastier too.[24]

On a larger scale, regenerative farming will have a positive impact on the environment. Soil health improves drought and flood resilience by allowing for natural water absorption. It cleans up waterways by reducing or eliminating artificial fertilisers and run off.

It can support soil carbon sequestration too. Soil holds three times as much carbon as the Earth's atmosphere, yet modern agriculture has substantially reduced soil carbon. It is estimated that soil could sequester 2–5 $GtCO_2$ per year by 2050.[25] This figure is as much as 15% of 2020 global energy and industrial process emissions.[26]

Regenerative farming can be aided and enhanced by using new technologies. IoT sensors can provide detailed real time insights from farms, including water use, yields, nitrogen and potassium levels. This information can be used to streamline farming techniques. Sensors can also measure long term impacts of agriculture on waterways, climate and biodiversity and can be used by governments, scientists and policymakers for continual improvement and decision making.

Automation of food harvesting and processing is increasing too, as detection, object recognition and handling and gripping robotics improve to allow more tasks to be performed by robots and machines.[27] Automation can both improve quality and reduce costs.

Project: Vision of Circular Agriculture[28]

Location: The Netherlands

"The Netherlands is one of the world's largest agricultural producers, exporting 65 billion Euros worth of vegetables, fruit, flowers, meat and dairy products each year."

Government of the Netherlands

The Dutch government's Vision on Circular Agriculture sets out the ambition of the Netherlands to be a global leader in circular agriculture by 2030. The vision entails a paradigm shift from growth in production volumes and cost price reductions towards optimisation in resource use and food production in harmony with nature. The Dutch government has introduced a suite of policies, incentives and investment in research and development and pilots.

Reducing emissions and increasing resilience

Carbon emissions in agriculture is attributed to land-use change, fossil-fuel intensive fertilisers and demand for protein in diets.[29] Decarbonisation across the food system is required to combat climate change.

Land use change for agriculture is a major contributor to global emissions but as discussed in the previous section regenerative farming practices can help to reverse this impact. Land clearing, however, needs to stop in order to maintain a healthy planet.[30]

Fertilisers can be made without fossil fuels. This has been done using enzymes or a man-made material called chalcogel.[31] This process has yet to be carried out at a scalable level, but is likely to feature heavily in a decarbonised future.

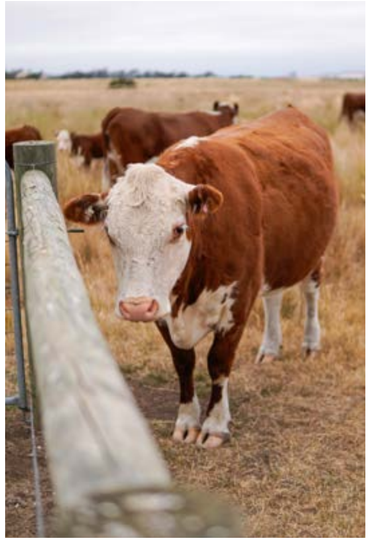
In climates that utilise heating in agriculture (such as greenhouses), geothermal energy is a potential solution for decarbonisation.[32] Up to 2.7 billion tonnes of greenhouse gas emissions each year are caused by livestock digestion.[33] Innovative methods are being developed to decarbonise livestock farming. These methods include changing feed, farming practices and genetics.

Climate change is already having significant impacts on farming and agriculture, including increased extreme weather events and effects on yield[34]. Solutions vary depending on the effect and the region but common approaches include changing crops or farming practices.

Project: Fruit picking drones[35]

Location: Israel

An Israeli start-up has created a system of drones to pick fruit. They operate in teams of six linked to a collection hub. Each drone has a soft touch grip to prevent damage to the fruit. Neural networks allow the drones to detect fruit amongst foliage and assess ripeness and position. This technology allows for efficient harvesting of trees up to 20% taller than traditional picking methods.

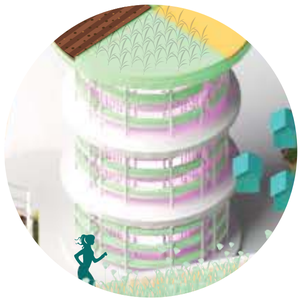


Project: CSIRO - Reducing the impact of cow burps[36]

Location: Australia

In Australia the CSIRO (Australia's agency responsible for scientific research) has found a red seaweed that significantly reduces methane emissions in cattle and sheep when it is introduced into their diet in small doses.This kind of discovery could reduce emissions while still allowing consumers to enjoy some red meat.

Controlled environment agriculture



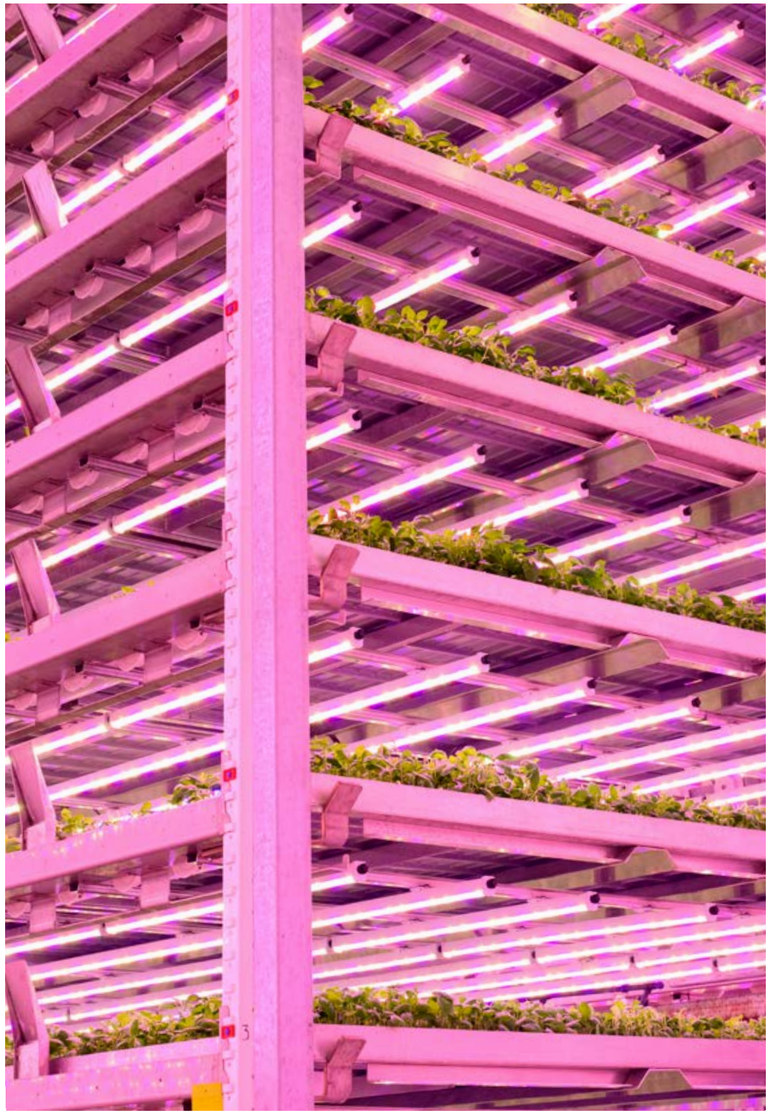
Controlled environment agriculture (CEA) is a growing system which gives the grower full control of all environmental conditions, including lighting, temperature, air flow, water and nutrients, allowing them to optimise growth and quality. CEA facilities typically use hydroponic, aquaponic or aeroponic growing systems with no pesticides involved. They often use robots and automation, and hold the promise of a reliable supply of fresh food as they are less impacted by extreme weather, drought or availability of workforce.

Compared to soil based, open land farming, CEA delivers much higher yields per square metre, while being around 90% more efficient in terms of land take and water use. Despite significant advances in the efficiency of LED lighting, they are still very energy intensive.

The relatively high investment cost, their small footprint and minimal use of water makes CEA particularly attractive for high income regions with severe limitations on land for farming (such as Singapore) or in places that have limited freshwater resources yet abundant potential for zero carbon energy (such as the Gulf states).

CEA is also attractive for growing high value foods close to consumers in densely populated urban contexts as their produce can be fresher and thus more nutritious. Control of the light spectrum enables growers to develop distinct flavours and thus allows the creation of niche, customised products. Investment in these technologies and support from legislation, such as the Farm Bill introduced in the USA in 2018, will continue to see these methods rapidly expanding in use and development.[37]

CEA requires highly skilled operatives and research to optimise the complex interactions between light, nutrients air and temperatures for yield and quality. This could help attract young people into the farming industry - which in many parts of the world has struggled to attract and retain younger workers.



Project: AeroFarms aeroponic vertical farming[38]

Location: USA

AeroFarms specialise in aeroponic farming: the process of growing plants without soil or an aggregate medium. Growing their produce indoors in monitored, modular compartments, they mist moisture and nutrients directly onto plant roots, using 95% less water than open-field farming, but with yields 390 times higher per square foot annually. AeroFarms are suitable for urban and regional farming – minimising travel costs and emissions, and engaging cities in food production.

AeroFarms has developed a patented, reusable cloth medium for seeding, germinating, growing, and harvesting. The cloth medium is made out of BPA-free, post-consumer recycled plastic, taking water bottles out of the waste stream. The cloth can be fully sanitized after harvest and reseeded with no risk of contamination, acting as a barrier between the mist and the plants.

Localised production

Cities are generally located on or close to highly fertile land. Although some of this fertile land may now be urbanised, the local (peri urban) areas surrounding cities have great potential for local food production. Around 80% of food will consumed in cities by 2050[39] so transport requirements will be reduced if these areas are utilised.

COVID-19 lockdowns boosted interest in self-sufficiency in many countries. Some forward-thinking cities are therefore looking to facilitate the growing trend towards urban farms and home production. Urban planners are also making provision for micro-plots, freight farm containers, rooftop farming and at-home facilities within new urban developments as well as repurposing underutilised areas into new community spaces for residents.

To promote a resilient food supply, food production will likely become increasingly decentralised and diversified to support a growing range of local suppliers and native species.[40] Regions can then adopt new ways of supporting more localised production, given that 40% of the world's cropland sits within just 20km of cities.[41] Peri-urban areas are well-placed to benefit from access to staff, local markets, transport networks and agglomeration of support services. This can increase resilience and food security, create new jobs, and foster a positive relationship between urban and rural communities.

Community supported agriculture encapsulates this positive relationship between farmers and consumers, where citizens not only buy direct from the producer, but can also take a stake in the farm, share the risk or help during harvest.

Some places will seek to engage communities through education or information sharing programs, enabling people to learn more about what they are eating and see first-hand where it comes from. In some cases, people form communities that combine living with farming in so called 'agrihoods'. These communities jointly decide which crops to grow and animals to raise while sharing production risks. Some will live around the farm, sharing electric cars and guest rooms, while others will live within the urban core.

Linking food growing to urban infrastructure creates other opportunities, including the recovery of nutrients from wastewater, the connection to local distribution systems and cold chains and integration with urban energy systems. Anaerobic Digesters, for example, can generate both gas for energy and fertiliser for farming by processing food and other organic waste collected in cities.

Project: Singapore's food producing region

Location: Singapore

Singapore has become an environment to support 'disruptive technologies' and innovation in production methodologies. New farming and food processing paradigms are replacing labour intensive production with technology-based practices. The government set up the Singapore Food Agency (SFA) under the Ministry of Environment and Water Resources (MEWR). These innovation bodies have helped make the nation an ideal market for international Agrifood-Tech investment.[42]

Community growing

Community food growing has many benefits. In developed countries, community gardens tend to be more focused on recreational activities, while in developing countries these gardens may be a vital supplement to other food supplies.

Locally grown food provides fresh, seasonal produce that people might otherwise not have access to. And at the same time it can bring communities together through the common experience of tending to an allotment, the physical sharing of seeds, swapping produce and exchanging cooking recipes.[43] Direct connection to the growing process gives people total control over the use of fertiliser and pesticides, and gardening can be a form of regular exercise.

It also allows immigrants to grow herbs and vegetables that are essential for their traditional cuisine that might otherwise be unavailable at local markets.

Connecting people to food can also help urban dwellers to understand healthy eating and consider the impact that their diets have on the environment. All these benefits combined can play an important role in improving community health. Most importantly, food is integral to indigenous cultures and many societies that have survived on the land for millennia have significant insight into food production in local areas. These indigenous learnings are sought after due to the deep connection between these communities and the land.[44]

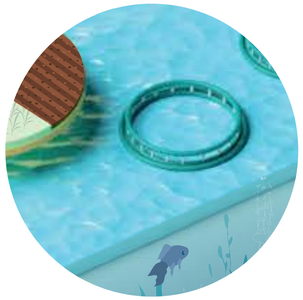
© Wyatt Dooley - Ngāti Whātua Ōrākei

Project: Native plant nursery[45]

Location: New Zealand

Auckland-based iwi (tribe), Ngāti Whātua Ōrākei, are leading the restoration of 33 hectares of cleared inner-city pasture land into a community māra kai and rongoā (food and medicine garden), native plant nursery, compost facility, bird sanctuary and education centre. The project applies mātauranga Māori (traditional ancestral knowledge and storytelling) to bring back the mauri (life essence) of the whenua (land), healing it both physically and spiritually. The core ambition of the project is to make healthy food available and affordable for people not only through what is produced on site but through helping the wider community produce their own food at home and educating them on healthy lifestyles. It is about rebuilding connections with Papatūānuku (Mother Earth) for urban Māori who have become disassociated with her and restoring relationships in our food systems that look after the environment and us.

Mariculture and fisheries



The ocean is both an over-exploited and an underutilised resource for food production. At present, over-fishing and intensive fish-farming are detrimental to the oceans and far from sustainable. However, a sustainable approach to farmed fisheries is possible and can improve the surrounding environment while bringing new economic opportunities.

Managed well, the ocean could play an important role in global food provision. Underwater sustainable agriculture can eliminate the need for pesticides, reduce fresh water use and cut carbon emissions while having the potential to feed the world's population with only 2% of the ocean.[46]

The expansion of sustainable mariculture - such as edible seaweed - will also have positive effects on biodiversity, as kelp farms provide a home to other sea life.

More traditional fruits and vegetables can also be grown underwater in pods such as those used by Nemo's garden in Italy.[47] Algae also shows potential as a future superfood and can be grown in saltwater either in a marine environment or other controlled environments.[48]

Healthy waters that result from the shift towards regenerative mariculture, meeting emissions targets and significant reductions in plastic pollution will ensure life in the ocean can thrive.

If 2% of the world's ocean was used for sustainable agriculture it could feed the global population.

Project: GreenWave regenerative ocean mariculture

Location: USA

An example of successful mariculture it the GreenWave polyculture farming model which can produce 22.68 tonnes of kelp and 250,000 bivalves annually in a 10-acre area - worth roughly $100,000 USD.[49]

The polyculture farming system requires zero inputs to grow seaweed and shellfish, it helps rebuild reef ecosystems while sequestering carbon and can be considered as one of the most sustainable form of food production.[42] GreenWave's farming model has a low barrier of entry to start an offshore aquaculture farm: 20 acres of land, a boat and around $30,000 USD is everything needed.[42] GreenWave's model can be used to produce goods for food, animal feed, bioplastic or fertilizer industry.[42]

The recipe for rethinking agriculture

This regenerative and sustainable recipe uses local ingredients and circular principles to connect you with your food while improving planetary health. Its combination of traditional methods with a modern twist makes it a real showstopper to impress your guests. It consolidates logistics and boosts resilience, while also leading to economically efficient production. Best of all, the ingredients are inexpensive.

Ingredients

500g fresh indigenous knowledge

1 tbsp smart technology

1 vertical farm

A sprinkling of urban agriculture

Time

10 years – to get permaculture and circular economy principles embedded in net zero carbon growth and production.

20 years – to achieve agriculture that is regenerative and net positive

Serves

This light and healthy approach to land management reduces emissions and deforestation. Ideal for a party with many guests including growers, producers, planners, and policymakers.

Method

1. Combine the indigenous knowledge to achieve afforestation, add organic matter to the soil and intertwine biodiversity with crops

2. Now carefully drizzle the smart technology into the mix – this helps with digital soil monitoring and optimisation.

3. Turn on your vertical farm (an underground farm or aquaculture facility will also do fine) and place the mixture inside.

4. Once it's taken on a nice colour, sprinkle the urban agriculture over the top and serve.

Pairs well with

Traditionally served with organic farming methods to really minimise greenhouse gas emissions. For something more robust, choose a lovely upcycled freight to farm or comprehensive urban food plan.

2 Supply chain futures

The global supply chain needs to transform to meet the needs of a sustainable, equitable and resilient food system of the future. This means embracing digital technology, end to end data collection and collaboration to create the transparency, reliability and fairness needed while minimising waste and environmental impacts.

Overview

The global food supply chain is both hugely impressive and hugely wasteful. At one end, it provides those who can afford it with a growing variety of food types all year around regardless of season or local ability to grow. On the other hand, 30% of all food is either lost or wasted along the journey from farm to fork. What is more, approximately 4.5% of global greenhouse gas emissions are linked to the food supply chain (processing, packaging, transport and retail).[50]

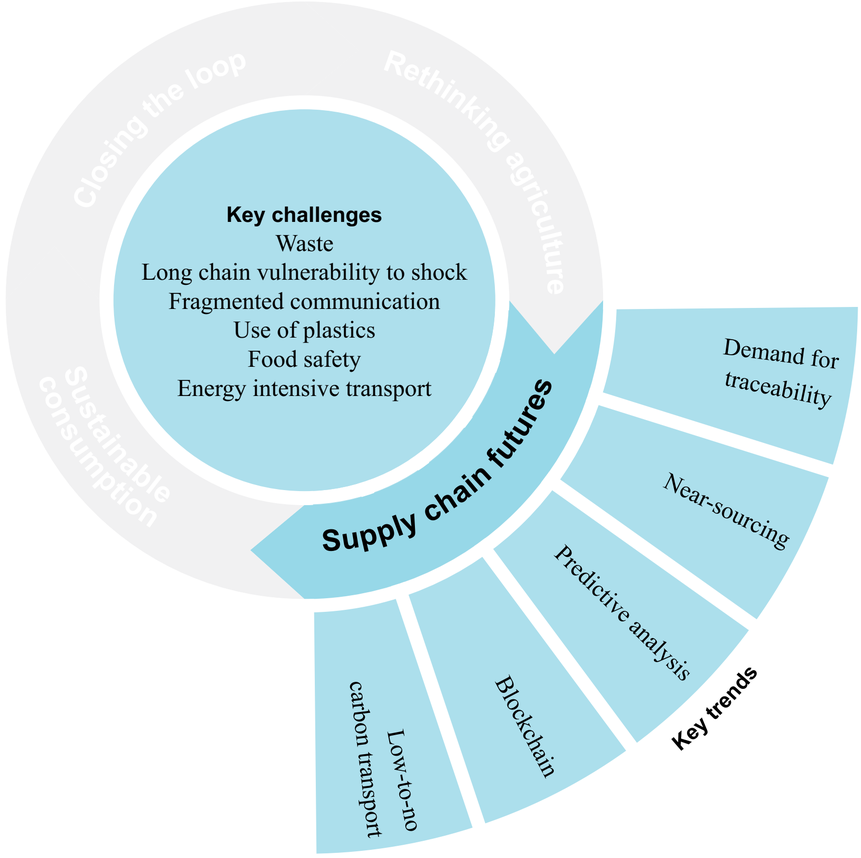
Ever longer and more complex supply chains, combined with an industrialised approach to farming have driven down the cost of food for many. But they have also meant that food is grown for shelf life and export instead of nutrition and feeding the communities closest to where it is grown.

To better manage complexity, allocate resource more efficiently and create the level of transparency, trust and resilience the food system needs, supply chains will need to explore technologies such as blockchain, open and shared data collection or machine learning.

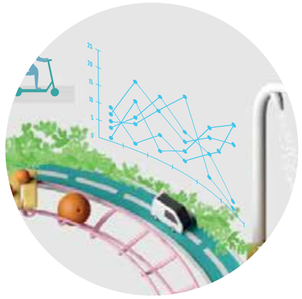
Decentralising aspects of our global food system should disrupt current structures that cause and maintain the status quo, without compromising trilateral goals of health, sustainability, and equity. While localism bolsters the resilience of local food systems, specialisation based on variable climates and available land has many advantages too. Global supply chains imbued with ecological sustainability principles may be a more transformational pathway to an inclusive and sustainable food future.

Creating more sustainable and balanced supply chains will provide many benefits, including 1) meeting the growing expectation of transparency and traceability of food as well as creating more fairness; 2) addressing waste and inefficiencies in the supply chain and 3) minimising negative environmental impacts from packaging and emissions.

In this chapter...
We explore emerging approaches to make the food supply chain more sustainable, resilient and transparent.



Digitisation and big data



Digitisation will be invaluable in making the supply chain more efficient, traceable, and transparent for both consumers and growers.[51] It leverages advances in interconnectivity, automation, blockchain technology, digital twins, machine learning and real-time data. Adopting these innovations will offer oversight to suppliers and distributors across entire supply networks, helping them to predict demand, optimise transport routes and identify key strategic points, as well as benefit from expanded trade and exporting.

Blockchain ledgers and tracking will provide traceability and transparency to consumers, allowing them to access source and distribution information. These technologies will also prove essential for food safety and security, reducing the risk of importing diseases, pathogens and counterfeit foods. Efficiency strategies can help to address these shortfalls as can automation of processes.

Digital tracking will help identify supply chain bottlenecks by mapping flow rates through distribution networks, while artificial intelligence (AI) tools will predict demand, enabling businesses to prepare more astutely for a range of scenarios, reducing both cost and risk. These technologies can also be applied to the operation of processing facilities, helping to improve energy and water footprints. Meanwhile, the use of digital twins could improve safety and efficiency of products in cold chain storage management - a market forecasted to reach a value of $271.30 billion USD by 2022.[52]

AI and Big Data solutions will also help tackle food waste. End-to-end cold chain solutions tailored at each point to regional and local needs will use AI to predict precisely when to delay and trigger ripening of food, optimise the flow of raw materials, and processing through a diverse network of automated distribution and consolidation centres at increasing speeds. AI sales forecasting algorithms will also allow the industry to accurately predict demand in supermarkets and food outlets.

Blockchain can be used to verify the origin of produce across the supply chain and connect the customer right back to the grower. With the demand for transparency to address ethical considerations there is a growing market for traceable products, in particular for those with a poor reputation for worker exploitation and environmental damage.

Project: Nestle Australia: Chain of Origin Coffee Brand[53]

Location: Australia

Nestle Australia uses blockchain to provide transparent information to customers and prove authenticity for its single origin coffee. The technology creates a verifiable system to track every step of the process and making this information available to customers and partners. Customers can see where the coffee was grown, the growing conditions and how and where it was roasted and packaged. Members of the blockchain can see, verify and audit each others activities.

Improving storage and packaging

Improving storage and transport across the global food chain will significantly reduce post-harvest losses and spoilage. Both high- and low-tech investments in refrigeration and cooling technologies will play an important role.[54]

To reduce food waste and meet the need for refrigeration, storage system solutions will have to become both more resilient and energy efficient. This is especially important in countries with more extreme weather and routine peak power outages. Simple and low-cost solutions to improve storage can be very effective here. For example, using crates rather than bags and sacks to store food can reduce spoilage significantly.

When considering the future of packaging, both high and low-tech solutions need to be explored and implemented. Intelligent packaging solutions can help monitor, and even control, temperature, microbial and oxidation levels. This means consumers know when their goods are perished, and distributors can identify and refine storage procedures to reduce wastage and prolong shelf life.[55]

Project: Evaptainers[56]

Location: USA

In Africa, almost 45% of food is spoilt in the supply chain due to lack of refrigeration.[57] Evaptainer offers a low-tech solution to this problem. The containers are made with two layers with sand between each. Water is added in the sand area evaporates, cooling the inner chamber of the container by up to 20C through evaporative cooling – and this keeps food fresher for longer.

Project: Edipeel[58]

Location: USA

Apeel Sciences has created a micro-thin edible coating that extends the shelf-life of produce by up to five times. The coating is made of plant extracts and acts as a shield to natural gases like oxygen and ethylene that cause decay. It can be applied at any stage of the ripening process and allows for staggered ripening times to dramatically reduce waste.

Project: SmartLabels [59]

Location: USA, Norway

SmartLabels are small, low-cost printed sensor tags that can monitor environmental data on the inside or outside of packages and wirelessly transmit that data to users via Near-Field Communication (NFC). The technology addresses economic and public health concerns associated with food shipment and storage by reducing spoilage and waste.

Decarbonising processing and distribution

In the UK, the average bite of food a person eats has travelled up to 4,023 km before reaching their mouths.[60] Transitioning transport and delivery models away from fossil fuels towards clean fuel sources, such as hydrogen and electricity, will substantially reduce the carbon intensity of food miles. And localising production as described in the previous chapter will reduce the mileage embedded in food. The adoption of renewable energy, improved energy efficiencies and optimised process management will help decarbonise a number of energy-intensive food manufacturing and processing applications. This includes chilling and freezing, canning (use of steam), heating, and baking.

Significant energy savings are possible by chilling and freezing using thermoacoustic-, optical-, hydraulic-, and electrocaloric-refrigeration innovations.[51] These technologies offer more energy efficient cooling and freezing solutions and reduce or eliminate the use of fluorocarbon refrigerants.

Optimising the configuration of processing lines, plant units, and hot and cold utilities will reduce the energy intensity of food processing and manufacturing facilities. The milk powder industry has already reduced thermal energy by more than 50% through the adoption of 'pinch technology'[61], which minimises energy consumption by optimising energy recovery methods in the heat exchange network.

Project: Pr04Bake[62]: Optimization of bakery processes by a computational tool

Location: Belgium

EIT Food's PrO4Bake is a computational tool designed to optimise the mass baking process, taking into account preparation stages, consumer feedback and the capacity of the humans and machines involved in the process. The tool combines a flow shop model, evolutionary algorithms, digital twins and artificial intelligence, considering parameters such as the time required for different baking stages, machine idle time, product demand fluctuations (how weather affects sales for example) and simulating optimised baking processes in response.

PrO4Bake also incorporates consumer feedback via a survey developed by social scientists at University of Aarhus, factoring in whether consumers would, for instance, accept a reduced range of products later in the day. Corresponding to consumer preference, reducing machine idle time and streamlining the baking process will result in the minimisation of food waste, ecological footprint, energy consumption and production cost.

Decarbonising processing and distribution

Meanwhile, there are significant innovations occurring in food shipping - a major contributor to greenhouse gas emissions. High quality fuels and engine lubricants, air lubrication, hull streamlining, wind technology, weather routing, port optimisation, and just-in-time arrivals are some of the measures the industry will adopt throughout the decarbonisation journey as low-carbon alternate fuels become viable.[63] Planning transport interchanges to enable streamlined transfers between air, sea and land freight, can unlock additional fuel savings along supply chains to mitigate carbon emissions.

Finally, sustainable last mile freight delivery modes such as e-cargo bikes, drones and automated vehicles can assist in eliminating last mile delivery emissions. Support from quality infrastructure and effective management of streets enables safe and seamless deliveries. The 15-minute neighbourhood concept will foster walking and cycling to local suppliers, which will also help reduce food miles and alleviate strains on the transport network caused by food distribution.

Sustainable last mile freight delivery modes such as e-cargo bikes, drones and automated vehicles can assist in eliminating last mile delivery emissions

© Clean Cold Power

Project: Nitrogen Powered Mobile

Location: UK

Clean Cold Power UK Ltd. has developed the Dearman Engine™, a piston engine driven by liquid nitrogen to produce clean cold air and power, with the ability to both power a trailer and keep it cool. The Dearman Engine uses extremely cold nitrogen (below -196°C) that is then put under high pressure (120 bar) in order to produce both power and cold air. Even though the engine is less powerful than one powered by gasoline, it is capable of producing a larger cooling power than gasoline and generates two cooling cycles for the trailer used to transport food, keeping the food fresh. By harnessing the cold of liquid nitrogen, the engine also has the advantage of a more reliable and precise temperature control.

Customisation and decentralising processing

As food production is localised, direct relationships between producer and consumer are likely to gain more importance, requiring localised and streamlined processing facilities that offer better financial, social, and environmental outcomes for all.

‘Product in place’ approaches can mitigate carbon emissions from transport, unnecessary packaging, and storage, as well as protecting and promoting regional foods and traditional methods of production. For food, they can also mean fresher and healthier produce. For example, by placing factories in close proximity to the fields, growers will be able to improve freshness and shelf life of products by reducing the exposure time to uncontrolled conditions and lowering the likelihood of damage during initial transport.

‘Process in place’ frameworks will improve livelihoods and local wellbeing through producer and consumer participation in local food systems, which also enhance resilience through more cohesive and connected rural and urban communities. Shorter supply chains will make way for new models of consumer end processing to accommodate responsive, flexible, and customisable systems.

Alongside the proliferation of more seed-to-table models, the built environment will evolve to provide more communal and flexible areas for producers to sell their products, consolidated pick-up points for residents, supported by digital technology enabling seamless and flexible payment options.

Project: Instafactory

Location: Italy

Italian tomato sauce manufacturer Mutti developed Instafactory, a mobile processing unit transforming tomatoes into puree in the field within seconds from being harvested. This approach reduces the need to transport tomatoes to a separate, centralised processing unit – instead it can get to market faster.[64]

Project: Foodlogica[65]

Location: The Netherlands

Launched in 2016, FOODLOGICA has begun transforming the last mile delivery of food in Amsterdam. Contributing to the localisation of food, it offers an affordable carbon-neutral fleet of bicycles and vans for local sustainable food producers, restaurants and caterers to use. Their vehicles include solar-powered e-trikes of different sizes equipped with modular and refrigerated storage units that enable them to deliver a range of quantities and produce across multiple delivery stops.

Project: Food Connect[66]

Location: Australia

Food Connect is a social enterprise with a mission to get local, seasonal and ecologically-grown food direct from farmers into people’s homes. All farms are located with 500 kilometres of Brisbane, varying in scale and produce. One Food Connect box may hold 20 different foods grown by 20 different farmers. The boxes are distributed via a city-cousin network, consisting of local pickup points in neighbourhoods across Brisbane and the Gold Coast.

The recipe for the future of supply chains

There's nothing like a robust sandwich to sate your hunger. Biting into this creation connects you to your food using simple, reliable ingredients. It's a meal for everyone - affordable and accessible while also being ethical and transparent. You'll be coming back for second rounds!

Ingredients

2 thick slices of smart technology

4 lean strategic links

A dash of consolidated solution sauce

1 tbsp consumer connections

A good dollop of sustainable last mile delivery

Time

20 years – for food loss to be eliminated in the supply chain

40 years – for food supply chains to be net zero

Serves

This tasty tech-enhanced sandwich is a perennial favourite. It's popular with growers, producers, planners and policymakers.

Method

1. Gently toast the smart technology so you get some nice cold chain management, improved demand prediction and reduced food spoilage. Our preference is the use of Biotech for preserving produce, FIFO inventory or any good supply chain analytics.

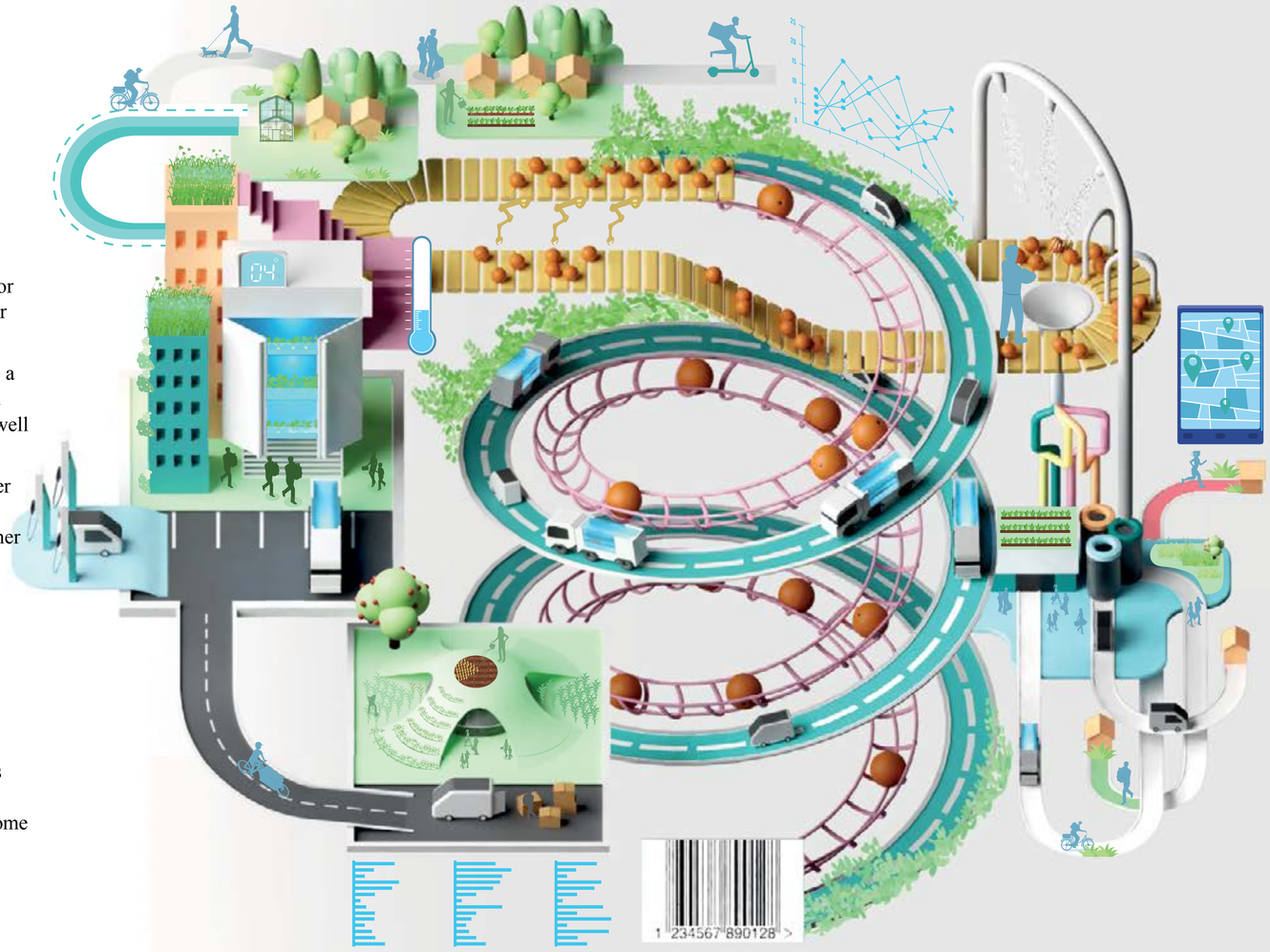
2. Now onto those strategic links. Use a renewable refrigerator, e-mobility and charging points to make sure they're well primed.

3. Dash the consolidated solutions over the links – this will really meld the flavours together. Season with consumer connections, such as labelling for provenance.

4. Place the links between the smart technology and serve fresh with sustainable last mile delivery.

Pairs well with

Great with friends, the sandwich aligns supply and demand of sustainable and ethically produced food. Crack open some cold low emission transport and enjoy some reduced climate change impacts.



3 Sustainable consumption

Food has been recognised as the single strongest lever to deliver both human health and environmental sustainability on earth.[67] Thus shifting consumer choice in the developed world will be key for creating a healthier, sustainable food system. At the same time getting access to food, let alone healthy and nutritious remains the biggest challenge for many people.

Overview

Consumer choice shapes the food system in many ways and often has unintended consequences. Worldwide rates of meat and dairy consumption for instance are rising.[68] This leads to an increase of the high levels of greenhouse gas emissions associated with livestock industries. A focus on health and wellbeing means there is also a trend of switching to plant-based diets through veganism or a 'flexitarian' approach and limiting their intake of animal products.[69]

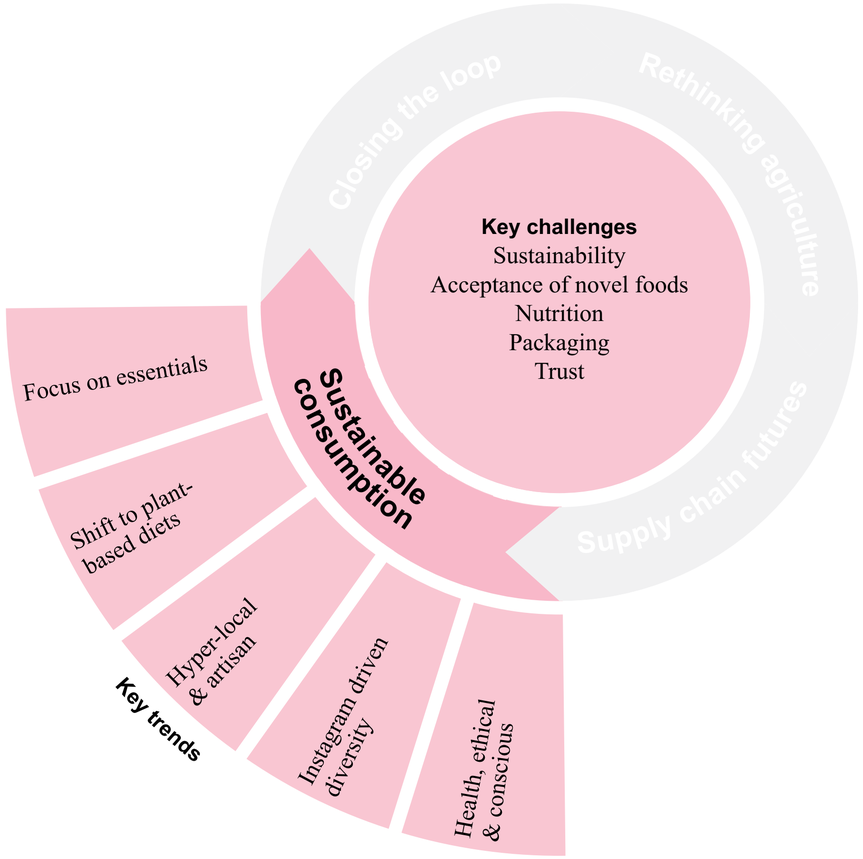
But this is just part of the story. Significant numbers of people do not have the luxury of making such choices, as they struggle to meet basic nutritional needs. Even in wealthy cities, the proportion of people living with food insecurity can be up to 20%.[70] While there is more than enough productive agricultural land to feed our growing global population, but poor land use, food waste, inefficient distribution and economic imbalances mean that access to healthy food is not yet universal.

Future policies, institutions, infrastructure, and governance can help us to address these issues and shift to sustainable consumption.

Doing so at the individual, social and cultural levels is highly challenging; imposing change on people's diets would produce an inevitable backlash. However, societies that move towards more sustainable consumption will experience multiple benefits, including: 1) a greater understanding of food and its effect on health; 2) new sources of protein; 3) less food insecurity and: 4) tastier, cheaper food.

In this chapter...

In this chapter we explore how individuals, communities and institutions can all make food decisions that have better outcomes for planetary and personal health.



Food citizenship

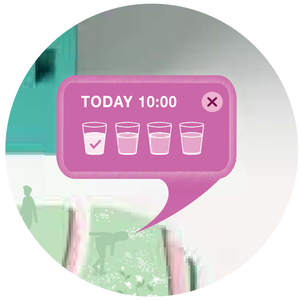
Food citizenship is a people-led movement that shifts the focus away from the idea of ‘consumerism’ and its passive, transactional relationship with food. It recognises that people have many different ways of contributing to and driving change that goes far beyond purchasing power alone.

Food citizenship enables a closer relationship between producer and consumer. Consumers can increase their understanding of how food is produced, the risks, challenges and valuable inputs of time, energy, resources and care that are required to keep plates full and bodies nourished. Producers can reciprocate by extending their offering directly to consumers, keeping the benefits of spending within the local economy and strengthening links with local communities.

Community supported agriculture schemes already enable this – with a model where consumers pay, often via a combination of membership and in-kind labour - to give farmers a stable income and share some of the risks within production. In exchange, they benefit directly from the produce grown.

Digital technology can facilitate more of these mutually beneficial relationships. We are already seeing platforms that connect suppliers with demand[71], cutting out the additional time and logistics required for food to be passed through large traders, and reducing supply chain waste.

Food as medicine



In Chinese culture, the concept of 'shí liáo' (食療) describes the relationship between food and health by considering food as medicine. In this approach, different foods have specific medicinal properties. Thus, people change what they eat to address any health concerns they might have, how they feel or in anticipation of possible illnesses. Conventional Western medicine has traditionally been based on reactive care but is increasingly recognising the importance of prevention alongside cure, especially where diet and nutrition is concerned.

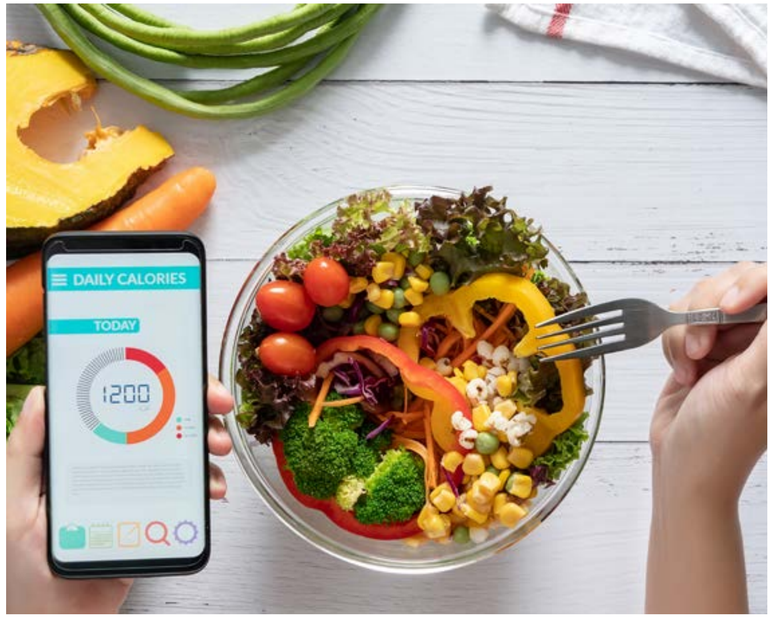
In the digital era, personalisation is a competitive advantage in nearly every industry. In the USA, almost 10% of all homes purchased a meal kit in 2018 and 65% of these customers are making repeat purchases. AI and machine learning will enable improved tailoring of prepared meals and meal boxes, featuring nutritionally optimised meal plans, enriching flavour and health benefits whilst keeping it affordable.

Experimental tools that can measure nutrient content will allow people to select for optimum health as they shop. Sophisticated production technologies can tailor the nutrient content of fresh vegetables through varying growing conditions and controlling the light spectrum to increase or decrease certain compounds within the produce.

Wearable technology could extend to monitoring real-time health and nutritional requirements, going as far as pre-filling people's online shopping baskets with the best food to rebalance their health on a daily basis.

Extending this personalised approach, the wider public health sector may begin to integrate personalised food planning within the healthcare system.

This might include tailored nutrition for patients as part of treatment plans for optimised recovery, addressing nutrient deficiencies and setting a trajectory for healthier lifestyles. Going further, integrating food growing into or around hospitals will bring even wider benefits, with green spaces improving mental as well as physical wellbeing for convalescing inpatients, while improving the sustainability of the hospital food supply chain.



Project: Thriva and VitaMojo - Personalised diet based on your blood[72]

Location: UK

Combining Thriva's at-home blood testing service and VitaMojo's food ordering software, customers can design menus to meet their exact dietary needs for optimal health. Blood biomarkers such as hormones and proteins are analysed from a blood sample to provide data on how your lifestyle is impacting your overall health. Meals are then personalised around nutritional macros and any identified deficiencies based on the blood biomarkers.

Alternative Protein

As we look for ways to achieve planetary and human health, alternative protein will have an important role to play. With new breakthroughs in food technology taking place all the time, we will have more opportunities to balance taste preferences with health as well as ethical and environmental concerns.

Protein is a key area for novel food development that can make a big difference to the impact from food we consume, given that most greenhouse gas emissions in agriculture are linked to meat and dairy production.

Insect protein is already an important part of diets in many places – two billion people already eat insects on a daily basis.[73] It is now seen as a sustainable alternative source of protein replacing meat for human consumption and feed for livestock/fish farms.

Lab grown meat is another emerging innovation, with recent advances in technology getting closer to matching the structure of traditional meat.[74] The potential for custom-grown meat products from highly efficient laboratories to replace traditional animal protein in our diets provides an option that may be preferable for ethical as well as environmental and health reasons. Even more radical is protein formulated from precision fermentation, which offers the potential for pure nutrient content grown from bacteria with much cheaper production costs – by 2035 such products could be ten times cheaper than animal protein.[75]

Other plant based alternatives to animal protein such as soy beef or Quorn are also becoming increasingly popular. As consumers are increasingly aware of the environmental impact of meat and dairy, they seek out alternatives that have a similar flavour and texture to meat.

Project: Lab-grown chicken approved for sale [76]

Location: Singapore

In 2020, Singapore gave the world's first regulatory approval for lab-grown meat to be sold in commercial retail. Chicken cells are isolated and grown in a bioreactor to create chicken protein. Eat Just worked with the Singapore Food Agency for two years to develop the product and ensure that it met food standards. The product will be sold in restaurants.

New ways of consumption

Changing consumption trends do not just relate to what we eat but also to how food is delivered. E-commerce is transforming the way people shop, providing a convenient, safe and accessible shopping experience. Online grocery shopping is predicted to grow by 25% between 2020 to 2027 with COVID-19 further accelerating this uptake.[77]

This extends to restaurants and deliveries too – pre-pandemic, over 50% of consumers ate away from home at least once a week[78] and restaurants have rapidly adapted to delivery and 'meal kit' models, supplementing the already growing range of food delivery providers and 'dark/ ghost kitchen' operators. Online meal delivery had already hit US$120 billion in gross food sales globally and is growing by 20% annually.[79] It is estimated that by 2030, about 2.8 billion people will be able to afford and access home meal delivery globally. This will be a 150% increase from the 1.8 billion who can do so today.[80]

Bricks and mortar venues will still have an important role to play, providing the communal dining experience that cannot be replicated at home. This includes for businesses and charitable organisations - community kitchens play an important role in bringing communities together whilst also providing a healthy, hot meal for anyone in need, and improving social cohesion and nutritional health.[81,82] In the future, these areas may blend further as 'co-cooking' spaces that support start-up businesses alongside community-focused food provision.[83] Innovative, aesthetic and modular hospitality spaces will be an important aspect of future land use and city planning.

Increasingly conscious consumerism and 'food citizenship' is also driving change - the 'farm-to-fork' ethos has led to an increasing focus on locally grown menus, influencing more than 40% of consumers when it comes to choosing a restaurant.[84] Hyper-local food production is likely to increase as a result of this demand, with rooftop gardens and controlled environment urban farming for 'grow-to-order' supermarket provision and local food delivery models.

The digital economy will support an increasingly tailored experience, rapidly diversifying the options available to buyers. Rather than picking up a slightly wilted bag of packaged herbs at the supermarket, consumers will be able to select from a wide range of different flavours and varieties, including local and heritage options.

Accessible food for everyone

Although today, we are producing enough food to feed 1.5 times the world's population[85], 821 million people suffer from chronic undernourishment.[86] This includes both poor and wealthy nations – in the UK 20% of children live with food insecurity.[87] As this is often linked to poverty and the wider socioeconomic system, it is not something that just pushing food prices down can solve. A sustainable future food system needs to be more equitable and societies need to find ways of ensuring access to this basic need for everyone.

The World Bank has made three recommendations to accelerate the shift towards a more sustainable food future that will balance inequality and increase resilience of food supplies. They suggest public policies should focus on de-concentrating markets and supply chains, decentralising traceability, and disseminating data.[88]

In future, digital food co-operatives will allow neighbours to club together and benefit from economies of scale in food purchasing. Increasing the connections between producers and consumers could offer more scope for non-monetary exchange of goods and skills, allowing people to give their time to directly or indirectly support growers and receiving harvests in return.

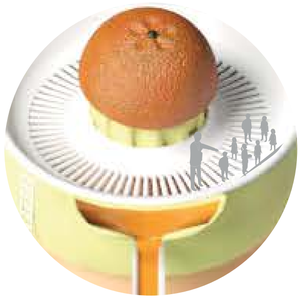
We may see the emergence of dedicated public provision such as a 'National Food Service'[89] to complement existing health and social care provided by the state. This would provide free, community-based meals that are accessible to anyone at any time. Alternatively, food shares may be allocated to every person to spend on healthy, sustainably produced food. This could strengthen local economies and provide secure income for food growers as well as ensuring access to food.

Project: 'Beetroot Bond'[90]

Location: UK

Beetroot Bond is a concept where each person receives an allowance to spend on fresh food. The money is only allowed to spent on healthy food and therefore encourages the consumption of produce that is beneficial to people's health. The availability of this money encourages communities to band together to build suitable supply systems.

Sustainable procurement



Larger organisations which serve food, including schools, hospitals and workplaces, are well-positioned to influence healthy and sustainable diets through sustainable procurement.

Hospitals, for instance, are increasingly sourcing sustainable and nutritious food for patients and staff. Companies that offer staff canteens can influence more sustainable food choices through procurement, food labelling and catering choices. They may also offer access to vegetable gardens, functional green spaces and communal kitchen areas, and subsidies for healthier choice cafes and restaurants. Gamification and monitoring of workplace waste can also trigger behaviour change around circular packaging alternatives and food waste.

In school settings, vegetable gardens, worm farms and compost bins can serve as important teaching tools in the future. Experiential learning around food production and preparation in schools will support healthier lifestyles, food security, more sustainable food choices, and better valuing of food and waste for children and their households.[91]

Project: Green Schools[92]

Location: Indonesia and international

The Green School model offers students a nature-oriented curriculum, in schools designed to be low-carbon, low waste and self-sufficient. Children in kindergarten to high school are taught to be responsible, sustainable, community-minded leaders of the future.

The recipe for sustainable consumption

An ideal salad to bring to a party, this delicious dish will have your guests coming back for more. Designed to get people involved in their food, it's plant-based, accessible for everyone, makes consumers engaged and accountable and revitalises institutions. It's also a great option if you're watching your waste.

Ingredients

200g affordability

500g chopped convenience

600g diced planet-centric behaviours

1 quantity experiential spaces vinaigrette:

1 tsp event classes

1 tsp waste themed restaurants

4 tbsp breakout areas

2 tbsp food banks

50ml accessible nutritional data

Time

10 years - all people follow a planetary diet

30 years - there is zero consumption food waste

Serves

This nutritious and delicious salad is all about getting people engaged with what they eat. It's perfect for manufacturers, retailers, restaurants, consumers, planners, and policymakers of all ages.

Method

1. Put the affordability in a bowl, cover with water and leave to soak.

2. Combine the convenience with the planet-centric behaviours. You can either use your hands to mix it up yourself, use on-demand ordering or digital utensils.

3. Combine the vinaigrette ingredients in a recycled jam jar, screw the lid on (tightly!) and shake together.

4. Drizzle the vinaigrette over this plant-based salad and serve up at events where the community comes together.

Pairs well with

Serve on a buffet that includes valuing food and food by-products, education and awareness of food provenance, and organic waste being well separated.

Closing the loop

Our food system is heavily dependent on non-renewable resources such as artificial fertiliser and pesticides. A sustainable food system must shift from being linear to becoming circular by embracing the principles of the circular economy. This requires minimising waste throughout the system including packaging, collecting and composting food waste, feeding by-products back into the system to enhance processes and create new sustainable products and regenerating natural systems by using compost to improve soil quality.

4

Overview

With around a third of all food going to waste, and only minimal amounts being fed back into the growing cycle, there are considerable opportunities to improve the environmental impacts of the food system.

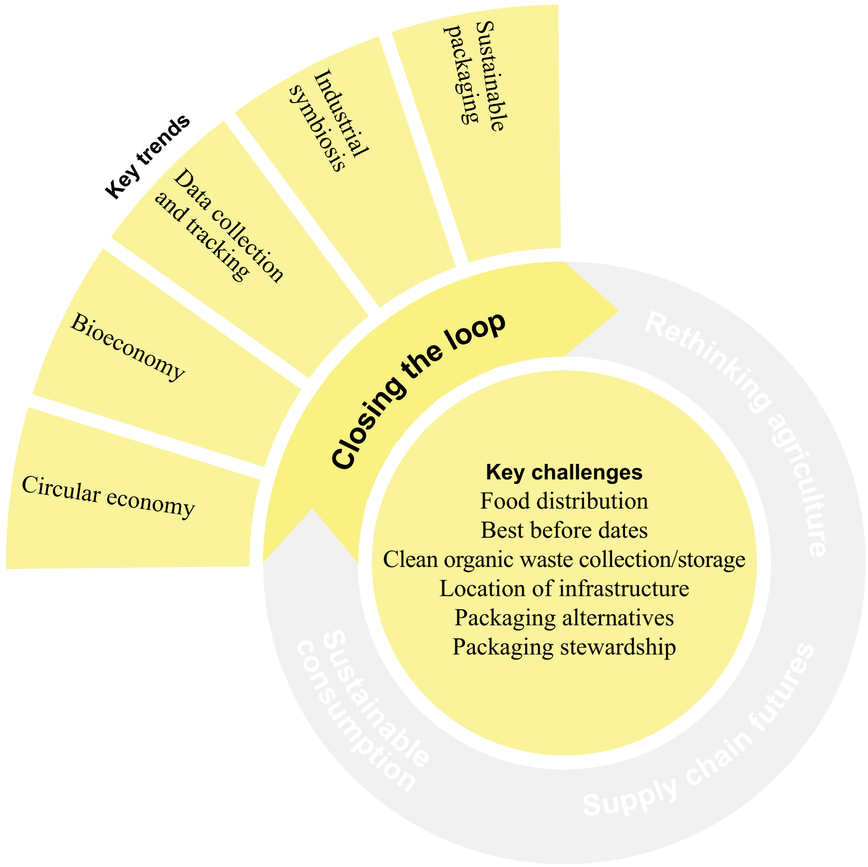
Reducing food waste in the system is one of the simplest and most effective ways to make it more sustainable. At one end, that means reducing post-harvest loss, particularly in developing countries, to make sure that more of what is grown ends up feeding people. At the other end, this means people throwing away less food after purchase.

Consumer behaviour underpins this opportunity as awareness of the impact of food waste may be enough to make less wasteful choices. On a larger scale, organisations can distribute unutilised food after they pass sell-by dates, to those who can use the food and therefore reduce waste.

Inevitably there will be some waste food. This can be collected and used to enrich soils or create energy. So called 'waste' products have the potential to be reintroduced into the system as inputs for other products.

Packaging for food comes in a wide range of materials, colours and sizes. This makes sorting, storing, washing and recycling difficult for recycling businesses. Consolidation of packaging types, reduction of single use packaging and providing suitable processing infrastructure are all required to reduce the amount of packaging sent to landfill.

Shifting to a circular food economy could achieve enormous benefits: 1) significant sums of money would be saved by returning unused food to the system; 2) new technologies could capture additional value from perished food resources; 3) composting and anaerobic digestion could disrupt the linear flow of resources from agricultural to urban areas and re-establish sustainable cycles of nutrients, water and carbon in food production; 4) better food packaging systems would reduce problems associated with plastic waste.



In this chapter...
We explore how circular economy principles could be applied to the food system.

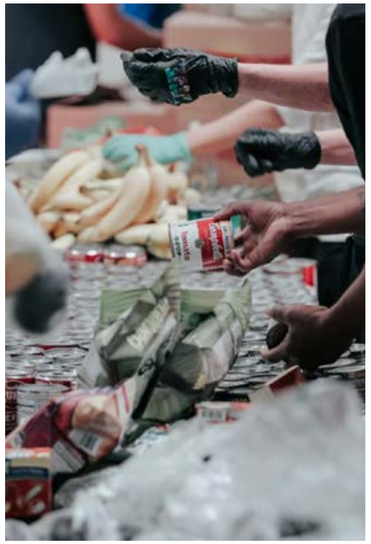
Waste not want not

As a global society, we waste enormous quantities of food. In the US alone this is estimated to be some 160 billion lb (~73 billion kg) of food annually. Retail outlets, restaurants and consumers all share responsibility for this wasteful approach.

Awareness campaigns such as Love Food Hate Waste[93] help to educate people on the issues of food waste and also present practical ways for people to take action.

Food rescue and redistribution is one valuable method for minimising this waste. Transportation of surplus from restaurants, retailers and households to local homeless shelters, schools, non-profit organisations and neighbours will increasingly be enabled by shifting cultural attitudes combined with intelligent systems and technology.

Apps such as Olio, Good to Go and Yume (which in various ways help to redistribute food) will become pervasive as both businesses and consumers become more conscious of food rescue and try being more flexible in their purchasing habits.



Project: Ozharvest [94]

Location: Australia

Launched in 2004, Ozharvest is a charity that collects surplus food and distributes meals to help in reducing food waste while feeding those in need.The organisation aims to reduce food waste by half by 2030.

Project: AI-powered smart bin[95]

Location: UK

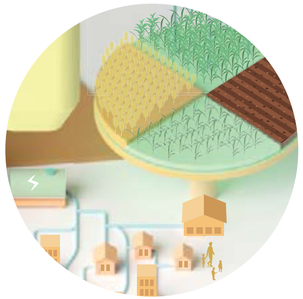
Winnow Vision helps professional kitchens to run more efficiently and sustainably by automating food waste capture. Enabled with AI technology, it tracks what food is being wasted as it is thrown into the bin. As part IKEA's Food is Precious initiative, in 2018 the technology enabled the business to cut 37% of food waste by value across all stores, saved 800,000 meals and £1.4m in cost savings.[96]

Project: Nolla [97]

Location: Finland

Nolla ('zero' in Finnish) is an innovative zero waste restaurant in Helsinki. The owners removed all garbage bins in order to embed their zero-waste ideology. This dramatic change achieved 80% waste reduction in two weeks. The minimal residual food leftovers are shredded and fed into an onside composting machine.

Returning to the earth



The linear flows of food resources from agricultural areas to urban centres depletes precious soils. At the same time, the production of synthetic fertilizers contributes to GHG emissions, and fertilizer runoff damages waterway health and can lead to ocean dead zones (where there is not enough oxygen in the water to support life).

Recovering food waste and returning it to agricultural land as compost and soil conditioners helps to rebalance these cycles and regenerate productive land. Applying compost to soil improves soil structure and increases moisture retention. It also returns nutrients to the soils, improves soil health and water retention, increases yields and reduces dependence on the use of synthetic fertiliser.[98]

Processing food waste into agricultural products increases the level of carbon stored in soils, contributing to climate change mitigation.[99] In contrast, when food waste is disposed of in landfill, the nutrients are lost and it generates methane, with a global warming potential of 2.1 tonnes CO2-e per tonne of food wasted.[100]

Behavioural changes in homes and businesses will shift towards separate collection of organic wastes, unlocking a natural resource which can be processed through composting or anaerobic digestion to return carbon and nutrients to farms.

Composting is a mature and low-tech solution for processing solid food waste. Meanwhile, anaerobic digestion can unlock value at the waste-water-energy nexus, converting solid and liquid organic wastes into energy-rich biogas, while capturing nutrients in solid digestate.

Placing higher value on clean, renewable energy and establishing new partnerships across the food processing, food retail and waste management industry will unlock massive opportunities for this circular infrastructure. Co-digestion of food waste with sludge at water treatment plants or wastewater at food-processing sites will generate higher biogas yields too.[101]

Project: Unlocking organic resources

Location: UK

Since 2012, the Scottish government has required all food businesses to separate food waste for collection and recovery, and from 2021, biodegradable waste is banned from landfill.[102] By 2019, 80% of households already had access to separate collection for food waste. The quantity of recycled food waste increased by 40% and new infrastructure was developed to meet this demand.[103]

Project: Anaerobic digestion

Location: Australia

Since 2015, compost-producer Richgro has been accepting 35,000 tonnes of commercial and industrial waste feedstock each year for anaerobic digestion. Food waste from markets, supermarkets and breweries is converted into electricity, which powers the composting facility. An additional 1.7 megawatts of renewable energy is exported to the electricity grid. Digestate from the anaerobic digestion process is added to Richgro's composting process, recycling nutrients back into the soil.[104]

Project: Walkers Crisps

Location: UK

Walkers Crisps plans to reduce its carbon emission by 70% by adopting more circular approaches. Potato waste from their food manufacturing operations will be anaerobically digested, producing renewable energy. The solid 'potato cake' that remans after anaerobic digestion will be combined with CO2 captured from brewery operations to make an enriched fertilizer, which will then be returned to fields to nurture the next crop of potatoes.[105]

Growing the bioeconomy

With less than 2% of the nutrients from human waste and food by-products currently re-used, the potential for the bioeconomy is significant.[106] Creating high-value products from waste provides opportunities to replace finite inputs with organic waste streams.

Food by-products can be turned into bioplastics, fabrics, leather, paper and building materials. Fibres of root vegetables can be used in concrete, and rice husks can be used in cement, insulators, absorbents and lightweight bricks that are fire-resistant.[107] Potato waste can be used in health supplements, enhancing food security and addressing hunger and malnutrition, particularly in poorer countries.[108]

Project: Bananatex®[109]

Location: Philippines

Bananatex® is a company from the Philippines that uses sustainable forestry to grow banana plants in a natural ecosystem with no chemicals. The plants are harvested and made into a durable waterproof fabric which is fully bio-degradable. The self-sufficient process contributes to reforestation of eroded palm plantations and provides farming jobs.

Project: Protix[110]

Location: Denmark

Protix is a Danish firm which uses black soldier flies to turn low-grade food waste into high-value proteins and fats which are used in pet-food, intensive fish farming and poultry farming. Soldier fly larvae consume the food waste and convert it into proteins. The larvae are harvested and turned into high-quality protein-rich products.

Project: Bundaberg biohub

Location: Australia

Bioenergy company Utilitas is redeveloping a retired wastewater treatment plant site in regional Australia into a bioeconomy precinct.[111] Utilitas will use anaerobic digestion to produce biogas from organic waste, supporting nutrient cycling back into local agricultural production and linking into existing supply chains.[112]

Project: Biobean[113]

Location: UK

Biobean works with the biggest companies in the UK to transform spent coffee grounds into value at industrial scale. The company has developed proprietary technology to make biomass fuels for both consumers and industry, extract residual natural compounds for natural flavour additives and provide dried grounds for a multitude of sustainable products and services. This includes uses in automotive parts, tableware and sunglasses.

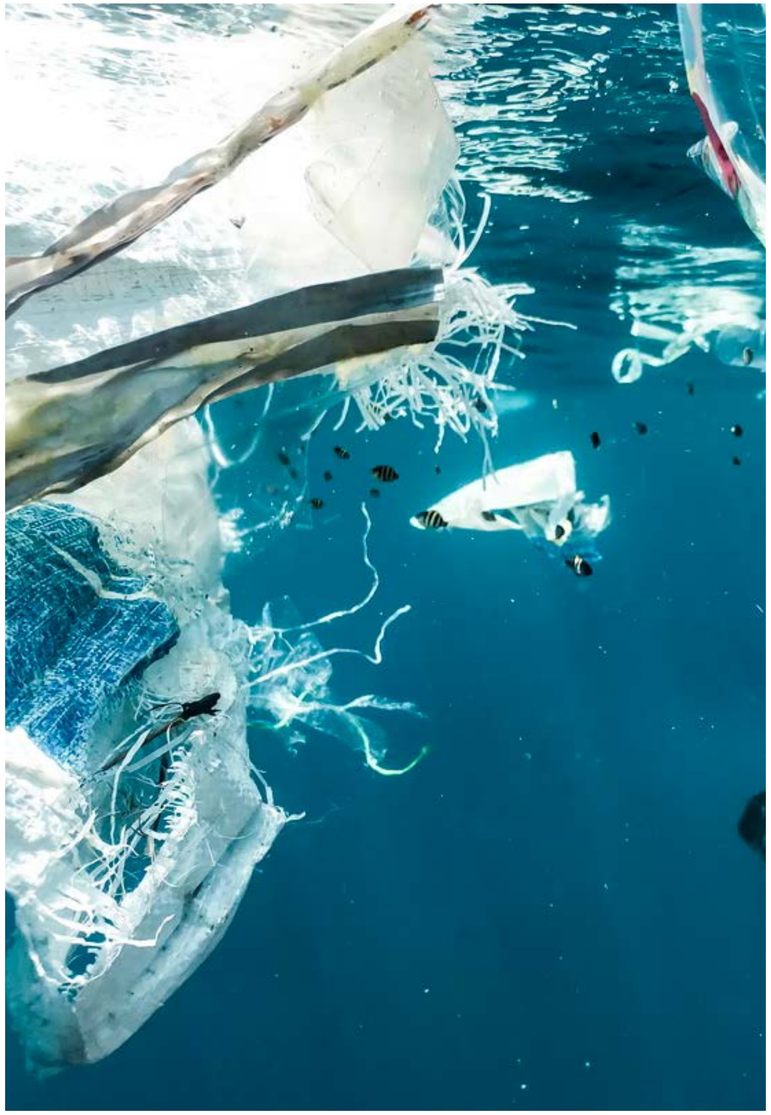
Unpacking our food

As food supply chains shift towards separating, capturing and valuing food resources and food by-products, food packaging will co-evolve to complement new food waste recovery systems and take advantage of new bio-based materials.

In the future, packaging will be reusable, biodegradable or non-existent. The use of virgin materials in food packaging will be obsolete as manufacturers move to a range of new and affordable forms of biodegradable, compostable or food-based packaging.

Organic edible coatings will extend shelf-life with tiered coating to deliver staggered ripening times and food deliveries will arrive in packaging made from compostable mycelium. Where packaging is a necessity, it will be simplified and clearly labelled, made from bio-based or recycled and recyclable materials. Retailers will support and enforce sustainability standards for the packaging on their shelves. Consumers will also be able to easily identify standard packaging materials and correctly sort them for recycling or composting along with food waste, keeping materials in circulation.[114]

Food packaging will co-evolve to complement new food waste recovery systems and take advantage of new bio-based materials



Project: A bioplastic made to degrade in seawater[115]

Location: Japan

Japanese researchers have developed a new kind of low-cost biodegradable plastic that is both water resistant and strong but can also degrade in seawater over time. Unlike other bioplastic alternatives, it is made from starch and cellulose – both common and cheap natural biological polymers – enabling cost-effective mass production. This can both help solve the growing problem of marine debris as well as having a major social impact.

The recipe for sustainable food systems

This rich and flavoursome soup can be made with any leftover ingredients in your store cupboard to minimise food loss and will make you feel in synergy with nature. Providing plenty of surplus energy, it gives a warm, glowing community feel and offers a wonderful, closed loop system.

Ingredients

1 circular design (finely sliced)

500g organic leftovers (any local produce will do)

1 smart technology cube

2 tbsp demand management

Time

10 years - there is zero food loss and waste.

30 years - a regenerative and resilient food system.

Serves

Popular with everyone, this dish eliminates waste, reduces your shopping bill and offers a nutritious and efficient source of energy.

Method

1. Gently fry the circular design in a deep pot until you see neighbourhood self-sufficiency, exchange of produce and local composting facilities start to appear.

2. Chuck in the organic leftovers, and watch the waste turn to energy.

3. Now pour over the smart technology, it will start to simmer nicely with digital waste bins, sorting facilities and data collection and monitoring systems.

4. Sprinkle over the demand management, with intelligent packaging and nudging. Taste for seasoning. If required, add new infrastructure to optimise waste usage. Then leave to simmer in a bio digestion facility for at least a decade.

Pairs well with

Great for anyone on a planetary diet and trying to improve soil health. You might enjoy it with a craft beer brewed from leftover bread. A great meal to share with consumers and producers who are collocated to shorten supply chains.

Conclusion

Food has been recognised as the single strongest lever to deliver both human health and environmental sustainability on earth. Thus shifting consumer choice in the developed world will be key for creating a healthier, sustainable food system.

Conclusion

Today's global food system is complex, vast and in urgent need of rapid transformation. If left unchanged, it will have a disastrous impact on both people and the planet.

But there is good news. We already have all of the tools, skills and knowledge we need to create a sustainable and resilient food system that goes hand in hand with better health outcomes for people and planet. What's more, there is plenty of opportunity for everyone to get involved and be part of this transformation. The power is in everyone's hands to use their specific knowledge, behaviours, networks and talents - at different stages of the food supply chain - to create a better system for all.

Be it farmers adopting regenerative practices, innovators and entrepreneurs inventing new forms of protein or methods of production, governments developing policies and rules to support the transition, processing companies adopting circular economy principles and turning waste into value or consumers connecting with growers and recycling nutrients, there are plenty of ideas and solutions that everyone can begin using today.

What is needed is a coalition of the like-minded to come together, collaborating across disciplines, industries and countries to capture the opportunities for change across the whole food cycle.

Are you interested, already deeply involved or recently committed to be part of this change? Reach out to connect with us, and explore what the like-minded can achieve together.

What is needed is a coalition of the like-minded to come together, collaborating across disciplines, industries and countries to capture the opportunities for change across the whole food cycle.

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Contact us

About Arup's food and agriculture services

As part of our commitment to shape a sustainable future, we are helping to shape resilient and equitable food systems that provide healthy food for everyone and support the biosphere of a thriving planet.

About Arup

Arup is the creative force at the heart of many of the world's most prominent projects in the built environment and across industry. Working in more than 140 countries, the firm's designers, engineers, architects, planners, consultants and technical specialists work with our clients on innovative projects of the highest quality and impact.

About Arup University

Arup University is the firm's global excellence programme of directed learning, expert skills development, collaborative research, foresight, and knowledge and information management. Arup's Foresight team analyse the major trends shaping the future of the built environment.

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