ELLEN MACARTHUR FOUNDATION

CITIES AND CIRCULAR ECONOMY FOR FOOD

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The report aims to highlight the often-underappreciated role urban food actors can play to drive food system transformation, and to spark a global public-private effort to build a circular economy for food. Cities and Circular Economy for Food is an affiliate project of the World Economic Forum's Platform for Accelerating the Circular Economy (PACE). The report has been produced as part of Project Mainstream, a CEO-led global initiative created by the Ellen MacArthur Foundation and the World Economic Forum, which helps to scale business driven circular economy innovations.

IN SUPPORT OF THE REPORT

"This excellent report is well-grounded in good analysis and provides fresh thinking about how cities will have to play a pivotal role in transforming the food system, from a model that fundamentally cannot work in the long term – whether from an environmental or people's health perspective – to one that works for people and the planet. Given the strong leadership of many cities in encouraging healthy lifestyles with positive environmental impacts, this is a timely report that can catalyse real action."

PROFESSOR TIM BENTON, DEAN OF STRATEGIC RESEARCH INITIATIVES, UNIVERSITY OF LEEDS AND DISTINGUISHED VISITING FELLOW, CHATHAM HOUSE

"By 2040, feeding 9 billion people in the world will be one of our greatest challenges. As noted in this new report, there are solutions to change the way we produce food, creating a better food system through a better use of resources. This will require moving towards a circular economy, especially in cities where 80% of food will be consumed in 2050. Transforming organic waste into compost, fertiliser, or bioenergy are concrete circular solutions that can be implemented and scaled-up today."

ANTOINE FRÉROT, CEO, VEOLIA

"We cannot achieve a healthy planet and healthy population without a fundamental transformation of our entire food system. This report describes an approach starting with cities and presents a vision of a future where the way we produce and consume food contributes to environmental and health benefits, instead of damaging human health and the environment. Achieving this is urgent, but no quick fix will get us there. We do have the knowledge and tools to act – and the circular economy approach will be a critical component."

DR. GUNHILD STORDALEN, FOUNDER AND EXECUTIVE CHAIR, EAT

"Cities, where 80% of the world's food will be consumed by 2050, have a vital role to play in shaping the future of the food system. 'Cities and Circular Economy for Food' represents a valuable contribution to the conversation about food's future."

MICHAEL POLLAN, AUTHOR, PROFESSOR

"Cities are key to the shift to healthier food systems — food systems that support ways of producing food that nurture the soil and enhance agrobiodiversity, that nourish people better, and that contribute to local economic development."

OLIVIER DE SCHUTTER, FORMER UN SPECIAL RAPPORTEUR ON THE RIGHT TO FOOD (2008–2014) AND CO-CHAIR, INTERNATIONAL PANEL OF EXPERTS ON SUSTAINABLE FOOD SYSTEMS (IPES-FOOD)

"This report provides an insightful look at how cities can move towards a food system that is good for both people and the planet. It highlights the opportunity that businesses, retailers, government and institutions have to work together to create a system that is healthier and that works for generations to come. It also ties in with elements of the City of Toronto's Long Term Waste Management Strategy, Toronto Food Strategy and Transform TO Climate Action Strategy."

COUNCILLOR JAMES PASTERNAK, CHAIR OF THE INFRASTRUCTURE AND ENVIRONMENT COMMITTEE, CITY OF TORONTO

"This report provides us with a sound analysis, along with insightful and concrete options for a more regenerative food system. It also demonstrates that the circular economy is not about the rich or the poor, the developed or the developing, or the political left or right. It connects us all, with the same challenges and responsibilities, while at the same time offering a huge opportunity for large scale innovation and creativity-building resilience, new distributed business and market competitiveness for a common good."

PEDRO TARAK, CO-FOUNDER AND PRESIDENT, SISTEMA B INTERNATIONAL

"This report not only educates decision-makers on the role cities can play in activating a circular economy – it inspires them to act with urgency. The health of people, economies, and the planet depends on cities shifting from 'end consumer' to part of the solution. Let's get to work."

MARK R. TERCEK, CEO OF THE NATURE CONSERVANCY
AND AUTHOR OF NATURE'S FORTUNE

"This report highlights the role of localised urban food systems as essential elements of wider food and agriculture systems, a topic with increasing importance for the 2030 Sustainable Development Agenda"

DAVID NABARRO, STRATEGIC DIRECTOR 4SD SWITZERLAND
PROFESSOR OF GLOBAL HEALTH, IMPERIAL COLLEGE LONDON

"Beyond the fact that agriculture is responsible for a quarter of greenhouse gas emissions globally, the report demonstrates for the first time that the current linear food system not only will face challenges feeding a growing population, but is also generating significant health issues. We call all willing parties to join hands to invent a new circular food system for our cities that will put human health at the centre."

JEAN-LOUIS CHAUSSADE, CEO, SUEZ CHAIRMAN, PROJECT MAINSTREAM

"Today's food system has an enormous social and environmental footprint, from climate change to food waste; wellbeing to biodiversity loss; water availability to inequality. But it can change. This report outlines a pathway to building a circular approach to food by 2050, and crucially grounds it in the reality that 80% of the world's populations will live in cities by then."

MIKE BARRY, DIRECTOR OF SUSTAINABLE BUSINESS, M&S

***"The food system can unlock solutions to climate challenges. Basing these solutions on circular economy principles results in cascading benefits not only to the climate, but to food security, water, forest and wetlands, biodiversity, pollution, and human health.
The rewards are truly incalculable."***

CHAD FRISCHMANN, VICE PRESIDENT & RESEARCH DIRECTOR, DRAWDOWN

"We are in the midst of an important global movement which calls into the very concept of consumption. The quality, the safety and the origin of our food should be at the heart of every citizen's concerns. Carrefour intends to support this movement in favour of healthier eating for all, and supports all research and collaborative work that can help bring about the circular economy for food."

BERTRAND SWIDERSKI, SUSTAINABILITY DIRECTOR, CARREFOUR

"Global food production is a major contributor to climate change. This report highlights some practical steps we can take and the important role that cities can play. At the London Waste and Recycling Board, we are already working with the hospitality sector and supporting and financing innovative start-ups so that we can promote and accelerate an innovative food economy. I welcome this report and see it as making a significant contribution to tackling UN Sustainable Development Goal 12.3."

DR LIZ GOODWIN OBE, CHAIR, LONDON WASTE AND RECYCLING BOARD

GLOSSARY

ANAEROBIC DIGESTION (AD)

Microbial (mainly bacterial) breakdown of organic matter in the absence of oxygen, under managed conditions at a temperature suitable for naturally occurring microbial species to produce biogas (mainly methane) and digestates (also known as 'biosolids').

ANTIMICROBIAL RESISTANCE

The capacity of microorganisms – such as bacteria, viruses, and some parasites – to stop antimicrobial substances working against them.[1]

BIOECONOMY

The parts of the economy that use renewable biological resources from land and sea – such as crops, forests, fish, animals, and microorganisms – to produce food, materials, and energy.

BIOFERTILISERS

A specific subset of organic fertilisers, which contain living microorganisms that help with nutrient cycling, thereby activating the soil to enrich its own fertility. Sometimes also referred to as inoculants.

COMPOST

A soil-type matter produced from decomposed materials, which can contain more than 50% organic dry matter. The nutrient constitution depends on the feedstock and includes nitrogen, phosphorus, and carbon.

COMPOSTING

Microbial (bacteria and fungi) breakdown of organic matter in the presence of oxygen to produce soil with high organic (humus) content. Composting produces carbon dioxide, and also methane, though at a lower rate than landfilling. In commercial composting, the process can be carried out using a variety of methods, including 'in-vessel' for post-consumer food waste and 'open-windrow' for non-food 'green waste'.

DIGESTATES

The biosolid output from anaerobic digestion. Digestate constitution is dependent on the AD feedstock. Human waste-derived digestates are high in P (phosphorus) and K (potassium), reflected in the characteristics of human urine and excreta. The nutrients in digestates are much more 'available', meaning they can be easily integrated in crop-nutrient planning, but care is required as they can also leach or run-off.

FOOD BY-PRODUCTS

Materials arising from the process of converting food ingredients into food products, e.g. oil seed cake, brewer spent grains, fish guts; as well as human waste. Also from food preparation or consumption that are not edible under normal circumstances, such as egg shells, tea bags, meat bones, coffee grounds or vegetable peelings.

FOOD WASTE, EDIBLE

Food and drink that, at the point of being thrown away, was edible. Generat for a number of reasons, including overproduction, past use-by-date, aesthetic appearance, or mislabelling.

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1 World Health Organization (WHO), *Antimicrobial resistance*, https://www.who.int/antimicrobial-resistance/en/

FOOD SYSTEM

Encompasses the full value chain of producing food for human consumption, from agricultural activities and other means, through handling, transportation, storage, processing, distribution, and consumption to organic (including human) waste management and disposal / reintroduction into productive use ('looping').

INDUSTRIAL FOOD PRODUCTION

A wide spectrum of farming models based around specialised commodity-crop production and the use of synthetic inputs. This definition thus encompasses smaller-scale 'conventional agriculture' as well as larger-scale industrialised systems.[2]

NUTRIENTS FOR PLANT NUTRITION

Substances used by plants for healthy growth and metabolism. The principal macronutrients derived from the growth medium are nitrogen, phosphorus, and potassium (NPK), as well as calcium, sulphur, and magnesium. Micronutrients are trace minerals required in much smaller quantities, including iron, zinc, copper, and nickel.

NUTRIENT LOOPING

The processes by which discarded organic resources can be turned into an array of valuable products. From low-tech organic compost to innovative, high-value biomaterials (see Figure 7), nutrient looping can help regenerate peri-urban farming areas and create new bioeconomic activity in the city.

ORGANIC FERTILISERS

Fertilisers derived from natural materials and processes, such as animal, human or insect excreta; decomposing plant matter; animal or fish waste including bone meal; marine flora including seaweed or kelp. Organic fertilisers can be added to the soil to improve soil structure and/or enhance the growth of plants and crops.

ORGANIC MATTER

A large group of carbon-based compounds found in terrestrial and aquatic ecosystems, known as 'biomass'.

PARTICULATE MATTER

Microscopic solid or liquid matter, generated by human or natural activity that are suspended in the atmosphere and affect human health, climate, and precipitation. A subtype is referred to as PM2.5, which indicates fine particles with a diameter of 2.5 µm or less. These smaller particles are a particular risk to human health due to their ability to penetrate deep into the lungs or bloodstream.

PERI-URBAN

The area located within 20 km of the city boundary.

REGENERATIVE FOOD PRODUCTION

Food production, in its broadest sense, using approaches that contribute to the improved health of the surrounding natural ecosystem.

SMALLHOLDER FARMS

Over 500 million small (<10ha) normally family-owned farms that depend on family labour to meet their own living needs. The sale of surplus 'cash crops' provides the basis for income for non-food needs, such as medicine, education, and housing. It is estimated that such farms provide food for approximately 70% of the world.

SYNTHETIC FERTILISERS

Also known as 'chemical' or 'mineral') fertilisers, these are derived from mineral rocks, synthetic origins or produced industrially. They are added to the soil to enhance the growth of plants and crops.

URBAN FARMS

Farms located within a city's boundary that produce food primarily for consumption in that city.

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2 International Panel of Experts on Sustainable Food Systems (IPES-Food), *Breaking Away from Industrial Food and Farming Systems* (2018)

EXECUTIVE SUMMARY

Few things are as interwoven with human existence and culture as food. At the most basic level, we need it to survive. Beyond sustenance, food can bring joy and takes a central place in cultures around the world, often as the centrepiece of celebrations and festivities.

The current food system has supported a fast-growing population and fuelled economic development and urbanisation. Yet, these productivity gains have come at a cost, and the model is no longer fit to meet longer term needs. Shifting to a circular economy for food presents an attractive model with huge economic, health, and environmental benefits across the food value chain and society more broadly.

THE LINEAR FOOD SYSTEM IS RIPE FOR DISRUPTION

There are well-known drawbacks related to our consumption of food, including the twin scourges of malnutrition and obesity. Less well-known is the extent of the negative impacts of current food production methods. Overall, for every dollar spent on food, society pays two dollars in health, environmental, and economic costs. Half these costs – totalling USD 5.7 trillion each year globally – are due to the way food is produced.

The extractive, wasteful, and polluting nature of current food production costs society as much as all costs related to food consumption (e.g. from obesity and malnutrition) combined.

These USD 5.7 trillion costs are a direct result of the 'linear' nature of modern food production, which extracts finite resources, is wasteful and polluting, and harms natural systems. Currently, the agrifood industry is responsible for almost a quarter of greenhouse gas emissions globally, degrades the natural resources on which it depends, and pollutes air, water, and soil. The equivalent of six garbage trucks of edible food is lost or wasted every second. In cities, less than 2% of the valuable biological nutrients in food by-products and organic waste (excluding manure) is composted or otherwise valorised.

Perhaps most surprisingly, even when apparently making healthy food choices, people's health is still being harmed by the way we produce food and deal with its by-products. By 2050, around 5 million lives a year – twice as many as the current obesity toll – could be lost as a result of current food production processes. Among the harmful impacts of such methods are diseases caused by air pollution and water contamination, health consequences of pesticide use, and increased antimicrobial resistance. Some of the principal causes are overuse of fertilisers, excessive reliance on antibiotics in animals, and untreated human waste.

THE CIRCULAR ECONOMY OFFERS A VISION FOR A FOOD SYSTEM FIT FOR THE FUTURE

The report offers a vision for a healthy food system fit for the 21st century and beyond, underpinned by the circular economy principles of designing out waste and pollution, keeping products and materials in use, and regenerating natural systems. In this vision, food production improves rather than degrades the environment, and all people have access to healthy and nutritious food. While far from the current reality, we believe this vision is completely achievable. After all, food comes from natural systems in which organisms have thrived for billions of years and, when they reach the end of their life, become food for new cycles to begin.

CITIES CAN TRIGGER A SHIFT TO A BETTER FOOD SYSTEM

Cities have a unique opportunity to spark a transformation towards a circular economy for food, given that 80% of all food is expected to be consumed in cities by 2050. The report focuses on the ability of urban food actors to catalyse this change by getting more value out of their food, and substantially influencing which food is produced and how. The ambitions presented are intended to complement the range of valuable ongoing initiatives that together aim to shift the food system onto a better trajectory. Work conducted with four focus cities (Brussels, Belgium; Guelph, Canada; Porto, Portugal; São Paulo, Brazil) during the development of the report suggests cities have a major opportunity to apply these ambitions, regardless of their unique physical, demographic, and socio-economic profiles. By shifting towards a circular economy for food, cities can help realise the vision and generate significant environmental, economic, and health benefits within and beyond their boundaries.

DEFINING CITIES

In the report we define cities as urban areas and the combination of all businesses, public bodies (e.g. city governments), organisations, institutions (e.g. schools, hospitals), communities, and citizens located within them.

CITIES CAN WORK TOWARDS THREE AMBITIONS FOR A CIRCULAR ECONOMY FOR FOOD

SOURCE FOOD GROWN REGENERATIVELY, AND LOCALLY WHERE APPROPRIATE

Since 80% of food will be consumed in cities by 2050, cities can significantly influence the way food is grown, particularly by interacting with producers in their peri-urban and rural surroundings. Regenerative approaches to food production will ensure the food that enters cities is cultivated in a way that enhances rather than degrades the environment, as well as creating many other systemic benefits.

In the report, regenerative food production is considered in a broad sense as encompassing any production techniques that improve the overall health of the local ecosystem. Examples of regenerative practices include shifting from synthetic to organic fertilisers, employing crop rotation, and using greater crop variation to promote biodiversity. Farming types such as agroecology, rotational grazing, agroforestry, conservation agriculture, and permaculture all fall under this definition. Regenerative practices support the development of healthy soils, which can result in foods with improved taste and micronutrient content. Cites cannot of course implement these techniques alone. Collaborating with farmers, and rewarding them for adopting these beneficial approaches, will be essential. In parallel, cities can use circular urban farming systems, such as those that combine indoor aquaculture with hydroponic vegetable production in local loops.

The feasibility and benefits of increasing local sourcing have been the subject of intense debate. While urban farming can provide cities with some vegetables and fruits, it is currently limited in its ability to satisfy people's broader nutritional needs. However, cities can source substantial amounts of food from their peri-urban areas (defined in the report as the area within 20 km of cities), which already hold 40% of the world's cropland. While local sourcing is not a silver bullet, reconnecting cities with their local food production supports the development of a distributed and regenerative agricultural system. It allows cities to increase the resilience of their food supply by relying on a more diverse range of suppliers (local and global), and supporting native crop varieties. It offers city dwellers the opportunity to strengthen their connection with food and the farmers who grow it, often increasing the likelihood that people will demand food grown using regenerative practices that benefit the local environment and their own health. Local sourcing can also reduce the need for excess packaging and shorten distribution supply chains.

MAKE THE MOST OF FOOD

Cities can play an important role in sparking a shift to a fundamentally different food system in which we move beyond simply reducing avoidable food waste to designing out the concept of 'waste' altogether. As the place where most food eventually ends up, cities can ensure inevitable by-products are used at their highest value, transforming them into new products ranging from organic fertilisers and biomaterials to medicine and bioenergy. Rather than a final destination for food, cities can become centres where food by-products are transformed into a broad array of valuable materials, driving new revenue streams in a thriving bioeconomy.

DESIGN AND MARKET HEALTHIER FOOD PRODUCTS

In a circular economy, food products are designed not only to be healthy from a nutritional standpoint, but also in the way that they are produced. From breakfast cereals to takeaway meals, a significant proportion of food eaten today has been designed in some way by food brands, retailers, restaurants, schools, hospitals, and other providers. These organisations have shaped our food preferences and habits for decades, particularly in cities, and can now help reorient them to support regenerative food systems. One example is for food designers to innovate new plant-based protein options as alternatives to meat and dairy, and encourage consumers towards them. Designers can also develop products and recipes that use food by-products as ingredients, and that can – for example by avoiding certain additives – be safely returned to the soil or valorised in the wider bioeconomy. In this way food designers can play their part in designing out food waste. Marketing can position these delicious and healthy products as easy and accessible choices for people on a daily basis.

SOURCE FOOD GROWN REGENERATIVELY, AND LOCALLY WHERE APPROPRIATE
FOOD INTO CITIES
DESIGN AND MARKET HEALTHIER FOOD PRODUCTS
INFLUENCE
MAKE THE MOST OF FOOD
BY-PRODUCTS INTO BIOECONOMY
ELLEN MACARTHUR FOUNDATION

THERE ARE CLEAR BENEFITS OF ACHIEVING A REGENERATIVE SYSTEM

The three ambitions will have greatest impact if pursued simultaneously. Designing and marketing food products that appeal to people using more locally available and seasonal ingredients would increase cities' connection with local farmers and could help spark the transition to regenerative practices. Using more local ingredients would likely increase the traceability of food and therefore potentially its safety. Similarly, making the compost and fertilisers derived from food by-products attractive to peri-urban farmers would help drive efforts in cities to collect and make the most of these by-products and other organic materials. As hubs of innovation and connectivity, cities are ideally placed to successfully link up all elements of the food value chain.

Achieving these three ambitions would allow cities to move from passive consumers to active catalysts of change, and generate annual benefits worth USD 2.7 trillion by 2050 that can be enjoyed by people around the world.

These benefits include reducing annual greenhouse gas emissions by 4.3 billion tonnes of CO_2 equivalent, comparable to taking nearly all the 1 billion cars in the world off the road permanently; avoiding the degradation of 15 million hectares of arable land per year; and saving 450 trillion litres of fresh water. Health benefits include lowering the health costs associated with pesticide use by USD 550 billion, as well as significant reductions of antimicrobial resistance, air pollution, water contamination, and foodborne diseases. Cities can also unlock an economic opportunity upwards of USD 700 billion by reducing edible food waste and using nitrogen and phosphorus from food by-products and organic materials for new cycles. From producers and brands to processors and retailers, businesses across the food value chain can tap into high-growth sectors such as biomaterials or delicious plant-based protein products.

MOBILISING THE TRANSFORMATION AT SCALE DEMANDS A NEW APPROACH

While the principles of healthier, regenerative food systems are well understood in broad terms, and many examples already exist, the challenge is realising the vision at scale. **Realising the vision at scale will require a global systems-level change effort that is cross-value chain, spans public and private sectors, and complements existing initiatives.** This effort will need to mobilise unprecedented collaboration between food brands, producers, retailers, city governments, waste managers, and other urban food actors. It will entail an orchestration of multiple efforts to build mutually reinforcing momentum, including connecting local flagship demonstration projects in key cities around the world with global scaling mechanisms that use the reach of multinational businesses and collaborative platforms. The orchestration of supportive policy frameworks, innovations, financial instruments, and communications to engage the wider public will also all be needed to create the enabling conditions for a systems shift.

The report has clearly demonstrated that using the catalytic potential of cities to spark change can be a powerful addition to the landscape of efforts needed to transform our relationship with food.

Now is the time to make it happen.

1. THE LINEAR FOOD SYSTEM IS RIPE FOR DISRUPTION

Few things are as interwoven with human existence, culture, and the economy as food. At the most basic level, we need food to survive. Beyond sustenance, food can bring joy and has a central role in cultures around the world, often as the centrepiece of celebrations and festivities. The global food industry is also the world's largest sector,[3] employing over 1 billion people and accounting for around 10% of global GDP.[4]

3 Defined as the combination of all activities to produce and distribute food, and manage its waste and by-products

4 Murray, S., *The world's biggest industry*, Forbes (15th November 2007), https://www.forbes.com/2007/11/11/growth-agriculture-business-forbeslife-food07-cx_sm_1113bigfood.html#53190a5d373e

THE WAY FOOD IS CURRENTLY PRODUCED IS EXTRACTIVE, WASTEFUL, AND HARMFUL TO HUMAN HEALTH

While the food system has made significant productivity gains over the past two centuries, it is unfit to meet long-term needs. The industrial food system has worked wonders in increasing global food production to meet rising demands from the expanding world population. Food production has enabled population growth thanks to the widespread adoption – accelerated during the Green Revolution of the 1960s – of high-yielding crop varieties, synthetic fertilisers and pesticides, and farm machinery.

Yet, the industrialisation of the food system has had many negative consequences. In the current food system, for every USD 1 spent on food, USD 2 is incurred in economic, societal, and environmental costs.[5] Half of these costs are related to consumption: obesity, malnutrition, and micronutrient deficiency; and, perhaps surprisingly, the other half is associated with the way our food is produced (see Figure 1).[6]

FIGURE 1: FOR EVERY USD 1 SPENT ON FOOD, USD 2 IS INCURRED IN ECONOMIC, HEALTH, AND ENVIRONMENTAL COSTS.

*Excluding obesity; **Due to diet
Based on Cities and Circular Economy for Food analysis – for details see Technical Appendix.

The negative societal costs from producing food are USD 5.7 trillion each year, as high as those of obesity, malnutrition, and other food consumption issues combined.[7] These costs are related to what happens to food before and after it is consumed, and are a result of the 'linear' nature of modern food production (see Figure 2). This linear model sees food production that:

- **Extracts finite resources.** Vast amounts of phosphorus, potassium, and other finite resources are mined and extracted for farming. From tractors on the field to food-processing plants and fleets of distribution trucks, most activities in the food system are powered by fossil fuels. For every calorie consumed in the US, the equivalent energy of 13 calories of oil are burned to produce it.[8]

5 Cities and Circular Economy for Food analysis – for details see Technical Appendix
6 Ibid.
7 Ibid.
8 Includes energy used to produce discarded food. Qualman, D., *Earning negative returns: energy use in modern food systems* (1st August 2017), https://www.darrinqualman.com/energy-use-in-modern-food-systems/

- **Is very wasteful.** A third of all edible food continues to go uneaten, even though more than 10% of the global population goes hungry.[9] The equivalent of six garbage trucks of edible food is wasted every second.[10] Less than 2% of the valuable nutrients in food by-products and human waste generated in cities is valorised safely and productively (see Figure 2).[11] Instead, these nutrients are typically destined for landfill, incinerators or, worse, languish in open dumps or are released untreated, where they pose health hazards to nearby residents and the environment.

- **Pollutes the environment.** Pesticides and synthetic fertilisers used in conventional farming practices, along with mismanagement of manure, can exacerbate air pollution, contaminate soils, and leach chemicals into water supplies. Poor management of food waste and by-products generated during food processing, distribution, and packaging further pollutes water, particularly in emerging economies. The agrifood industry is the world's second largest emitter of greenhouse gases, responsible for approximately 25% of all human-caused emissions.[12]

- **Degrades natural capital.** Poor agricultural practices are a significant contributor to the 39 million hectares of soil that are degraded each year globally.[13] Approximately 70% of global freshwater demand is used for agriculture.[14] Large-scale commercial agriculture and local subsistence agriculture were responsible for about 73% of deforestation between 2000 and 2010.[15] The world relies on just three crops for more than 50% of its plant-derived protein,[16] contributing to a dramatic loss of biodiversity (over 60% in the last 40 years),[17] increased vulnerability to diseases and pests, and greater reliance on chemical inputs.

Out of the USD 5.7 trillion worth of negative societal costs from producing food each year, USD 1.6 trillion is the cost of the human health impacts[18], nearly as much as the estimated global cost of obesity.[19] The harmful nature of food production for human health has only recently become clear. Pesticide exposure; antimicrobial resistance, caused by excessive use of antibiotics in fish and livestock farming and inadequately treated human waste; air pollution, caused by excessive use and poor management of fertilisers and manure; water contamination; and foodborne diseases all significantly damage human health. These impacts are projected to be amplified in the future due to increased use of and exposure to these pollutants.

- **Farm worker exposure to pesticides currently costs USD 0.9 trillion**. Long-term exposure to low levels of pesticides has been linked to cancer, asthma, depression,[20] reduced IQ, and higher rates of attention deficit hyperactivity disorder (ADHD) – the last two alone are costing the EU an estimated USD 150 billion annually.[21]

9 Hunger Notes, *How many people are hungry in the world?* (2016), https://www.worldhunger.org/hunger-quiz/how-many-people-are-hungry-in-the-world/

10 Estimate based on 1.8 billion tonnes of food lost or wasted every year (see Technical Appendix), a food density of 500 kg/m3 (WRAP, *Material bulk densities*, summary report (2010)) and a volume of 17.5 m^3 per truck

11 Cities and Circular Economy for Food analysis – for details see Technical Appendix; World Bank, *What a Waste 2.0: a global snapshot of solid waste management to 2050* (2018); WWAP (United Nations World Water Assessment Programme), *The United Nations world water development report 2017: wastewater, the untapped resource* (2017). ('Valorised' defined here as put to new use safely and productively; not including manure)

12 Smith, P., *et al*., *Climate change 2014: mitigation of climate change. Contribution of Working Group III to the fifth assessment report of the intergovernmental panel on climate change* (2014)

13 Cities and Circular Economy for Food analysis – for details see Technical Appendix

14 AQUASTAT – FAO's global water information system (2014)

15 WWF (Grooten, M., Almond, R.E.A.), *Living planet report – 2018: aiming higher* (2018)

16 Biodiversity International, *Mainstreaming agrobiodiversity in sustainable food systems* (2017). https://www.bioversityinternational.org/fileadmin/user_upload/online_library/Mainstreaming_Agrobiodiversity/Mainstreaming_Agrobiodiversity_Sustainable_Food_Systems_WEB.pdf

17 WWF (Grooten, M., Almond, R.E.A.), *Living planet report – 2018: aiming higher* (2018)

18 Cities and Circular Economy for Food analysis – for details see Technical Appendix

19 Estimated to amount to USD 2 trillion annually. McKinsey Global Institute, *Overcoming obesity: an initial economic analysis* (2015)

20 Pesticide Action Network UK, *Impacts of pesticides on health* (2017) http://www.pan-uk.org/health-effects-of-pesticides/

21 Trasande, L., *et al*., *Burden of disease and costs of exposure to endocrine disrupting chemicals in the European Union: an updated analysis* (2016), https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5244983/

FIGURE 2: THE FLOW OF MATERIALS IN THE FOOD SYSTEM IS OVERWHELMINGLY LINEAR.

In the linear food system, a very high proportion of food flows into cities where it is processed or consumed, creating organic waste in the form of discarded food, by-products or sewage. In cities, only a very small proportion (<2%) of the valuable nutrients in these discarded organic resources gets looped back to productive use.

1. Such as fertilisers or pesticides; 2. As per FAOSTAT 'Production' definition, i.e. typically reported at the first production stage (farm level for crops and animal products; live weight for seafood); 3. Human waste includes solid and liquid waste, expressed in wet mass; 4. Food wasted in cities includes distribution and consumption stages

Source: FAOSTAT, *Food Balance Sheets* (2013); FAOSTAT, livestock manure (2013); WBA, Global Bioenergy Statistics (2017); The World Bank, *What a Waste* (2012); Scialabba, N., et al., *Food wastage footprint: impacts on natural resources* (2013), United Nations University, *Valuing human waste as an energy resource* (2015), *Cities and the Circular Economy for Food* analysis

- **Antimicrobial resistance currently costs USD 0.3 trillion** and could have by far the largest food production health impact on the next generation. Inadequate wastewater treatment and misuse of antibiotics in fish and livestock farming contribute to resistant pathogens and antibiotics leaching into waterways and other natural systems, allowing antimicrobial resistance to grow and spread. The result is that the efficacy of many antibiotics against previously treatable diseases is lost. Antimicrobial resistance is a major looming public health crisis, with the societal cost by 2050 projected to be ranging from USD 2 trillion to 125 trillion dollars,[22] with food and agriculture accounting for 5% to 22% of these costs.[23]

- **Air pollution from agriculture currently costs USD 0.2 trillion[24] and contributes 20%[25] of particulate air pollution, which causes 3.3 million premature deaths per year.** Agriculture is estimated to be responsible for up to 20% of air pollution deaths, mainly due to excess fertiliser

22 The Wellcome Trust (Taylor, J., *et al.*), *Estimating the economic costs of antimicrobial resistance: model and results* (2014)

23 The Global Alliance for the Future of Food and IPES-Food, *Unravelling the food–health nexus: addressing practices, political economy, and power relations to build healthier food systems* (2017)

24 Cities and the Circular Economy for Food analysis – for details see Technical Appendix calculations based on costs: McKinsey Global Institute, 2012 [obesity]; share due to agriculture: The Global Alliance for the Future of Food and IPES-Food, *Unravelling the food–health nexus: addressing practices, political economy, and power relations to build healthier food systems* (2017)

25 Max Planck Institute (Pozzer, A., *et al.*), *Impact of agricultural emission reductions on fine-particulate matter and public health* in *Atmospheric Chemistry and Physics* (2017), 17, 12813–12826

and manure releasing ammonia into the atmosphere.[26] Ammonia is a powerful pollutant because of its capacity to combine with other gases to form PM2.5 fine particles that are particularly harmful to human health.

- **Water contamination and foodborne diseases currently cost USD 0.2 trillion.** Poor wastewater management and unsafe irrigation using untreated human waste take a heavy toll on human health through contaminated drinking water and foodborne diseases. According to a 2017 UN report, 80% of human waste goes untreated globally,[27] contributing heavily to diarrhetic diseases, which are a leading cause of child mortality in some regions of the world.

Given current trends, the food system will have catastrophic impacts by 2050:

- Air pollution and water contamination (caused by excessive use of fertilisers, animal farming, and untreated human wastewater); alongside antimicrobial resistance facilitated by excessive use of antibiotics in animal farming and inadequately treated wastewaters, could contribute to the loss of around 5 million lives a year by 2050, twice as many as the current obesity toll.[28]
- The food system alone will have used up two-thirds of the remaining global carbon budget, which has been agreed to have a reasonable chance of limiting global warming to 1.5°C or less compared to pre-industrial levels.[29]
- Particularly in industrialised areas, agriculture will be responsible for more harmful air pollution than all other human activities combined, due to ammonia emissions from animal farming and fertiliser use.[30]
- Negative environmental impacts from the food system could increase by 50% to 90% due to growing populations and greater food consumption as incomes rise.[31]

NOW IS THE TIME TO SHIFT TOWARDS A FUNDAMENTALLY BETTER FOOD SYSTEM

It does not have to be this way. If there is any sector in the global economy with the intrinsic potential to build rather than deplete natural capital and to support the long-term wellbeing and development of the economy, society, and natural systems, it is arguably the food system. After all, food is part of nature, which is inherently regenerative. For billions of years, organisms in living systems have grown, thrived, and, at the end of their cycle, become food for a new cycle to begin.

Multiple trends suggest now is the time to shift to a new model for food:

- **Customer preferences are evolving.** There is evidence of a growing shift among more affluent, health-conscious consumers towards eating an increase in plant-based protein and more regeneratively grown food, which may be indicative of long-term global trends:
  - **People are changing their diets.** People in OECD countries are eating less meat and shifting towards more plant-based protein sources. In the US, the demand for non-dairy beverages has grown by 61% over the past five years,[32] and beef demand declined by 16% between 2005 and 2014.[33] While this trend seems to be prevalent across wealthier nations, in developing economies meat consumption

26 Ibid.

27 WWAP (United Nations World Water Assessment Programme), *The United Nations world water development report 2017: wastewater, the untapped resource* (2017)

28 EASO (European Association for the Study of Obesity), Obesity Facts and Figures (2018), http://easo.org/education-portal/obesity-facts-figures/

29 Cities and Circular Economy for Food analysis – for details see Technical Appendix; IPCC (Masson-Delmotte, *et al.*), Summary for policymakers. In: *Global warming of 1.5°C*. An IPCC special report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty (2018)

30 Bauer, S.E., *et al.*, *Significant atmospheric aerosol pollution caused by world food cultivation*, Geophysical Research Letter (2016), Vol. 43, 5394–5400, https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2016GL068354

31 Springmann, M., *et al.*, *Options for keeping the food system within environmental limits, Nature* (2018), Volume 562, pp.519–525

32 Mintel, *US non-dairy milk sales grows 61% over the last five years* (4th January 2018), http://www.mintel.com/press-centre/food-and-drink/us-non-dairy-milk-sales-grow-61-over-the-last-five-years

33 World Resources Institute, *2018 will see high meat consumption in the U.S., but the American diet is shifting* (24th January 2018), https://www.wri.org/blog/2018/01/2018-will-see-high-meat-consumption-us-american-diet-shifting

is, by contrast, predicted to increase by 70% by 2050[34] due to rising incomes. Providing more accessible delicious plant-based products to the market can support existing trends towards increasingly diverse protein sources in some regions, as well as reverse rising meat consumption trends in others.

- **People are reconnecting with how and where their food is grown.** Organic food sales represented a USD 90 billion market in 2016, with double-digit growth in many regions, including India, Europe, and Latin America.[35, 36, 37] The number of farmers' markets multiplied in the US by nearly five times from 1994 to 2017, totalling 8,600 farmers' markets across the US selling local products.[38]

- **Technology and innovation are opening up new possibilities:**
  - **New plant-based proteins are coming to market.** New technologies are making it possible to create delicious meat, dairy, and fish alternatives, as demonstrated by innovators such as Impossible Foods, Beyond Meat, Terramino Foods, Protix, and Entocycle.
  - **Investment in food and agriculture research is reaching new highs.** Global investment in food and agriculture businesses tripled from 2004 to 2013, totalling more than USD 100 billion.[39] Institutions are investing in cutting-edge research across food production (e.g. the University of California's Alternative Meat Lab)[40] and by-product transformation (e.g. the University of Guelph's Bioproducts Discovery and Development Centre), leading to technological breakthroughs.[41]
  - **New technological innovations are emerging.** From solutions such as IBM's Food Trust blockchain technology, which provides transparency for retail supply chains[42] to SiembraViva's e-commerce platform connecting rural organic smallholder farmers in Colombia with growing urban consumer markets,[43] digital technologies provide new capabilities that could not exist even a decade ago. Artificial intelligence (AI) technology can support the food system revolution through a range of potential solutions.[44] AI can be applied in ways that accelerate the transition to a circular economy for food at-scale, by providing farmers with rich information about what is actually going on in their fields; automating food sorting during transport and distribution; and creating platforms that rapidly generate recipes to replace animal proteins with plant proteins.
  - **Innovative technologies offer tools for cities in emerging economies to 'leapfrog' over linear industrial models.** By leveraging available digital tools, cities in emerging economies can not only avoid the mistakes and damaging industrialised food systems of the past, but also reorient onto a trajectory for healthy, regenerative food systems.

- **Regulations and standards are enabling a better food system to emerge.**
  - The European Bioeconomy Strategy, updated in October 2018, supports circular economic activities related to nutrient looping, industrial strategy, and climate policy.[45]
  - City governments are adopting new policies to address all areas of the food

34 World Resources Institute, *How to sustainably feed 10 billion people by 2050, in 21 charts* (5th December 2018), https://www.wri.org/blog/2018/12/how-sustainably-feed-10-billion-people-2050-21-charts

35 Ernst & Young and Assocham, *The Indian organic market – a new paradigm in agriculture* (2018)

36 Fresh Plaza, *Organic food consumption continues to increase in Europe* (26th February 2018), https://www.freshplaza.com/article/2189746/organic-food-consumption-continues-to-increase-in-europe/

37 Organics News Brasil, *ORGANIS divulga primeira pesquisa nacional com consumidores de orgânicos* (7th June 2017), https://organicsnewsbrasil.com.br/consumidor/organis-divulga-primeira-pesquisa-nacional-com-consumidores-de-organicos/; Agrimundo, *Latinoamérica: mercado de alimentos orgánicos crece significativamente* (12th August 2016)

38 USDA Local Food Directories: National Farmers Market Directory (2018), https://www.ams.usda.gov/local-food-directories/farmersmarkets

39 McKinsey & Company Chemicals, *Pursuing the global opportunity in food and agribusiness* (July 2015), https://www.mckinsey.com/industries/chemicals/our-insights/pursuing-the-global-opportunity-in-food-and-agribusiness

40 Alternative Meats Lab, UC Berkeley, https://scet.berkeley.edu/alternative-meats-lab/

41 Bioproducts Discovery and Development Centre, University of Guelph, https://www.bioproductscentre.com/

42 IBM Food Trust: *Trust and transparency in our food*, https://www.ibm.com/blockchain/solutions/food-trust

43 SiembraViva, https://siembraviva.com/home/

44 Ellen MacArthur Foundation, *Artificial intelligence and the circular economy: AI as a tool to accelerate the transition* (2019)

45 European Commission (DG Research & Innovation), *A sustainable bioeconomy for Europe: strengthening the connection between economy, society and the environment*, Updated Bioeconomy Strategy (October 2018)

value chain: 63% of cities surveyed in a 2017 EU report have at least some food-related programmes.[46]

- A regenerative organic certification pilot programme was launched in 2018 in the United States.[47]
- Since 2003, strong political commitment in the Indian state of Sikkim led to the state becoming 100% organic by 2015 and winning a UN Future Policy Gold Award in 2018.[48] The ambitious programme, still in its infancy, involves 66,000 farmers and is proving to be a good test bed for consumer buying habits and behaviour.
- In 2012, Brazil launched the first country-level policy in the world with a focus on agroecology and organic food production in response to the high rates of agrochemical use and simplification of biodiversity in a model dominated by monoculture; it also favours a more labour-intensive agriculture model.[49]

Given the complexity of the food system, a multifaceted approach is required to successfully tackle its greatest challenges. As a recent study produced by the EAT-Lancet Commission and published in Nature stated: "No single solution is enough to avoid crossing planetary boundaries. But when the solutions are implemented together, our research indicates that it may be possible to feed the growing population sustainably."[50] This report agrees that to be effective change needs to be at the system level. It makes the case that a food system based on the principles of a circular economy is one that is healthy for people and natural systems.

46 European Commission, *Food in cities: study on innovation for a sustainable and healthy production, delivery, and consumption of food in cities* (July 2017)

47 Regenerative Organic Certified, *ROC Pilot Program and Participants*, https://regenorganic.org/pilot/

48 India Today, *Sikkim becomes world's first organic state, wins Oscar for best policies by UN* (16th October 2018), https://www.indiatoday.in/education-today/gk-current-affairs/story/sikkim-becomes-world-s-first-organic-state-wins-oscar-for-best-policies-by-un-1369158-2018-10-16

49 Brasil agroecológico, https://www.indiatoday.in/education-today/gk-current-affairs/story/sikkim-becomes-world-s-first-organic-state-wins-oscar-for-best-policies-by-un-1369158-2018-10-16

50 Springmann, M., *et al.*, *Options for keeping the food system within environmental limits, Nature* (2018), Volume 562, pp.519–525

2. THE CIRCULAR ECONOMY OFFERS A VISION FOR A FOOD SYSTEM FIT FOR THE FUTURE

Looking beyond the current 'take, make, and waste' industrial model, a circular economy aims to redefine growth, focusing on positive society-wide benefits. It entails decoupling economic activity from the consumption of finite resources and designing waste out of the system. Rather than simply aiming to do less harm, the circular model builds economic, natural, and societal capital. Underpinned by a transition to renewable energy sources, it is based on three principles – design out waste and pollution, keep products and materials in use, and regenerate natural systems.

These core principles go hand in hand with the understanding that for an economy to work in the long term, it should work at all scales. This means it should feature active participation and collaboration between businesses both small and large, and from countries and cities to local communities and the people within them. Such a distributed, diverse, and inclusive economy will be better placed to create and share the benefits of circularity.

The circular economy model considers two distinct material flows within the economy: the technical cycle and the biological cycle.

Consumption happens only in biological cycles, where food and products made from biologically-based materials (such as cotton or wood) are designed to feed back into the system through processes like composting and anaerobic digestion. These cycles regenerate living systems, such as soil, which provide renewable resources for the economy.

A circular economy for food consciously emulates natural systems of regeneration so that waste is does not exist, but is instead feedstock for another cycle. In such a system organic resources, such as those from food by-products, are free from contaminants and can safely be returned to the soil in the form of organic fertiliser. Some of these by-products can provide additional value before this happens by using them for a chain - called a cascade - of other purposes, such as new food products, fabrics for the fashion industry, or as sources of bioenergy.

These cycles regenerate living systems, such as soil, which provide renewable resources for the economy.

FIGURE 3: PRINCIPLES OF A CIRCULAR ECONOMY.

DESIGN OUT WASTE AND POLLUTION

A circular economy reveals and designs out the negative impacts of economic activity that cause damage to human health and natural systems. These costs include: the release of greenhouse gases and hazardous substances; the pollution of air, land, and water; and structural waste, such as underutilised buildings and cars.

KEEP PRODUCTS AND MATERIALS IN USE

A circular economy favours activities that preserve value in the form of energy, labour, and materials. This means designing for durability, reuse, remanufacturing, and recycling to keep products, components, and materials circulating in the economy. Circular systems make effective use of biologically based materials by encouraging many different economic uses before nutrients are returned to natural systems.

REGENERATE NATURAL SYSTEMS

A circular economy avoids the use of non-renewable resources where possible and preserves or enhances renewable ones, for example by returning valuable nutrients to the soil to support natural regeneration.

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3. CITIES CAN TRIGGER A SHIFT TO A BETTER FOOD SYSTEM

Cities have unique characteristics, assets, and capabilities to spark a transformation of the food system. By 2018, more than half of the world's population lived in cities; this number is expected to grow to 68% by 2050.[51] Cities consume 75% of the world's natural resources and 80% of the global energy supply.[52] The average consumption of food per person tends to be higher in cities due to urban citizens earning higher average incomes than rural workers, and it is estimated that 80% of all food will be destined for cities by 2050.[53]

Cities are also equipped with technology and have dense networks of highly skilled workers creating ideal conditions for innovation. Their citizens, retailers, and service providers are all in close proximity, making new types of business models possible. This combination of factors means that cities, businesses, and the governments in them, have a unique opportunity to spark a transformation towards a circular economy for food.

Cities have tremendous demand power due to the sheer volume of food eaten within them. They also accumulate large, mostly untapped, volumes of valuable food by-products and waste. Given this, businesses and governments in cities are ideally placed to not only better manage and get more value out of food, but also to substantially influence the type of food that enters the city as well as how and where it is produced.

Cities can use their unique assets and capabilities to transform themselves from black holes sucking in food, energy, and other resources to engines of a regenerative food system and bioeconomy. By taking an approach based on circular economy principles, cities can reimagine today's food system and realise their potential to help shape a healthier, more diverse, and resilient future food system.

Of course, while they can catalyse change, cities cannot transform the food system alone. To shift to a circular economy for food, cities need to collaborate with rural producers in the peri-urban area and beyond.

Cities can realise three ambitions to catalyse a circular economy for food:

1. ***SOURCE FOOD GROWN REGENERATIVELY, AND LOCALLY WHERE APPROPRIATE***
2. ***MAKE THE MOST OF FOOD***
3. ***DESIGN AND MARKET HEALTHIER FOOD PRODUCTS***

The following three chapters will explore each of these ambitions in more detail.

51 United Nations, Department of Economic and Social Affairs, Population Division, *World urbanization prospects: the 2018 revision* (2018)

52 United Nations Environment Programme – Division of Technology, Industry and Economics (UNEP-DTIE), *Cities and buildings* (2013)

53 Cities and Circular Economy for Food analysis – for details see Technical Appendix

FIGURE 4: THREE AMBITIONS FOR CITIES TO BUILD A CIRCULAR ECONOMY FOR FOOD.

In the circular economy vision for food, cities send clear demand signals to support regenerative production and better food design, while turning by-products from food eaten in cities into organic fertilisers for peri-urban farmers to use.

4. SOURCE FOOD GROWN REGENERATIVELY, AND LOCALLY WHERE APPROPRIATE

Since 80% of food will be consumed in cities by 2050,[54] they have a great potential to influence the way in which food is grown. By sourcing food grown regeneratively, and locally where appropriate, cities can use their public and private demand power to motivate a shift to more regenerative food production practices. While urban farming has some potential, the bulk of food eaten in cities will continue to come from outside their boundaries. However, cities can form mutually reinforcing relationships with their peri-urban surroundings – where 40% of the world's cropland already exists.[55]

CITIES CAN INFLUENCE WIDESPREAD ADOPTION OF REGENERATIVE AGRICULTURAL PRACTICES

With the bulk of all food produced destined for cities by 2050, cities have a great opportunity to use their demand power, and work with key food system players located beyond city boundaries, to positively influence how food is grown. The current way in which we produce the food that supplies our cities causes natural system degradation, a multitude of health problems, and creates large volumes of harmful greenhouse gas emissions. There is a much healthier and regenerative alternative to this approach.

By producing our food regeneratively we can shift from a degrading model to one that rebuilds the health of our ecosystems. The focus of regenerative farming practices, described in their broadest sense, is to build healthy, biologically active ecosystems. The regenerative philosophy is most associated with soil farming, but not exclusively. A number of approaches could already be categorised as regenerative, for example: rotational grazing (see Box 3: How can we rear livestock in more regenerative ways?), natural system restoration, agroecology, agroforestry, conservation agriculture, new seafood production methods (see Box 4: How can aquaculture and fisheries be more circular?), and Zero Budget Natural Farming (ZNBF). While some organic farms use practices that regenerate natural systems, the primary focus for many organic farming operations is the elimination of synthetic inputs: pesticides, fertilisers, and growth hormones; and the overall impact on the environment is not always positive.[56]

The regenerative mindset focuses on desired outcomes (see Figure 5) rather than on what to avoid, including healthy soils indicated by improved soil organic material, water-holding capacity, and microbial population; along with improved diversity of crops, animal species on the farm, and the biodiversity of the local environment. While conventional farming practices can erode soils and deplete nutrients, thereby necessitating an increase in synthetic

54 Cities and Circular Economy for Food analysis – for details see Technical Appendix

55 Thebo, A. L., *et al.*, *A global, spatially-explicit assessment of irrigated croplands influenced by urban wastewater flows*, Environmental Research Letters (July 2017), Vol. 12; Cities and Circular Economy for Food analysis – for details see Technical Appendix

56 Ritchie, H., *Is organic really better for the environment than conventional agriculture?*, Our World in Data (19th October 2017), https://ourworldindata.org/is-organic-agriculture-better-for-the-environment

fertiliser application, regenerative practices help bring soils to life, ensuring that they are rich with the microorganisms and nutrients needed to support long-term food production. Shifting to a regenerative food system requires widespread adoption of such practices not only on large-scale commercial farms but also on smallholder farms, where, perhaps counterintuitively, most of the world's food is produced (see Box 1: How can regenerative agriculture improve the lives of smallholder farmers?).

FIGURE 5: REGENERATIVE FOOD PRODUCTION SUPPORTS NATURAL SYSTEMS.

The outcomes of conventional farming practices tend to degrade ecosystems and pollute the air and waterways, whereas regenerative practices rebuild and enhance ecosystems while preserving air and water quality.

CONVENTIONAL FARMING PRACTICES	REGENERATIVE FARMING PRACTICES
Weak, easily erodible soils	Biologically active soils
High input costs	Low input costs
Ever-increasing quantity of synthetic fertilisers and pesticides needed	High water infiltration and storage
High irrigation requirement	High crop diversity
Low crop diversity	High biodiversity
Low biodiversity	Healthy local ecosystem
Polluted water bodies	High water holding and filtration capacity
Health risks of chemical exposure for farm workers	Low health risks to farm workers
Low resilience	Tasty crops with high micronutrient content
Threat to long-term yields due to soil degradation	Increased resilience
	Support long-term yields
	Multiple revenue streams

BOX 1: HOW CAN REGENERATIVE AGRICULTURE IMPROVE THE LIVES OF SMALLHOLDER FARMERS?

The importance of smallholder farmers in feeding the world cannot be overstated. There are approximately 500 million smallholder farms globally, and these small farms feed 70% of the population using only 30% of the resources and 12% of the agricultural land.[57] In Africa and Asia, smallholder farms provide 80% of the population's food and support up to 2 billion people.[58] As such, the smallholder farm sector is highly relevant in the shift to a more effective food system.

As countries become more affluent, farm sizes tend to increase and farmers as a proportion of the population decrease, leading to a *reduction* in smallholder farming. This shift has many contributing factors, a key one being that farm work is very labour intensive, with low profit potential especially when undertaken at small scale. In countries where there is no insurance, even one bad harvest can be disastrous. With growing affluence, agriculture becomes more industrialised and better suited to larger farms. At the same time, as education and job opportunities improve, the pool of agricultural workers decreases. The change is both understandable and inevitable.

The hope is that the resource-efficiency, agrodiversity, and accumulated wisdom inherent in the smallholder system can be preserved and carried forward so that emerging economies can leapfrog directly to circular food systems as they develop. Smallholder farmers who choose to continue farming can be supported to use regenerative farming practices that can produce higher yields long term, while benefiting environmental and human health, and building greater resilience than realised using conventional practices. One example of a regenerative approach is *Zero Budget Natural Farming (ZBNF),* which is used by smallholder farmers.

Zero Budget Natural Farming is a set of agroecological farming methods that originated in the State of Karnataka, India. The movement's aim was to establish an approach to farming that could decouple smallholder farmers from the risk of debt associated with the high costs of seeds, fertilisers, and other inputs. For many subsistence farmers, just one poor harvest caused by late rains or a powerful monsoon, could tip the balance and lead to desperation. ZBNF directly tackles the debt issue by removing the requirement for costly inputs. This method has also been proved to be more efficient than 'conventional' farming, producing higher yields, more nutritious food, and increasing resilience.

The four pillars of ZBNF are: (1) creation of biologically active soils through the addition of a fermented microbial culture; (2) natural treatment of seeds and other planting materials against diseases; (3) layering of organic material on ground surface to protect and enhance topsoil; (4) more effective water management, including the avoidance of overwatering. Applying these principles leads to raised profits for farmers, as costs are reduced and yield increases can be typically 40% or higher. ZBNF also prevents exposure to harmful chemicals that cause illness, medical costs, and lost opportunities.

57 ETC Group, *Who will feed us?* 3rd edition (November, 2017), http://www.etcgroup.org/content/who-will-feed-us-industrial-food-chain-vs-peasant-food-web

58 http://www.fao.org/fileadmin/templates/nr/sustainability_pathways/docs/Factsheet_smallholders.pdf

A powerful example of the benefits of ZBNF is the story of a farmer called Satya from the West Godavari district in Andhra Pradesh. In 2017, a hailstone storm passed over his village, destroying many of the neighbouring farms. However, his 6-acre banana plantation escaped mostly unscathed, due to the stronger plants resulting from the regenerative farming approach.[59] The government of Andhra Pradesh clearly sees the benefits in farms such as Satya's. Currently, there are more than 160,000 farmers in Andhra Pradesh practising ZBNF, which the state government plans to scale to 6 million farmers by 2024.

CITIES CAN EMBRACE THE OPPORTUNITY TO RECONNECT WITH PERI-URBAN AGRICULTURE

Opinions vary on the potential and benefits for cities to act as food production hubs. While urban farming can only provide a limited amount of nutrition required for human health (see Box 2: What is the true potential of urban farming?), cities can source a large share of food from their surrounding areas: 40% of the world's cropland is located within 20 km of cities (see Figure 6).[60] By understanding their existing peri-urban production, cities can demand food that is not only grown regeneratively, but also locally, when it makes sense. However, rather than planning to source all food locally, cities should aim to form resilient food supplies that rely on a diverse set of local, regional, and global sources, according to where food types grow best.

Local sourcing can play a significant role in supporting the development of a distributed and regenerative agricultural system.

- It allows cities to increase the resilience of their food supply by relying on a more diverse range of suppliers (local and global).
- Supports diversification of crops by selecting varieties best fitting local conditions, thereby building resilience.
- Through a renewed sense of connection with the food system that supports them, people in cities may feel encouraged to adopt healthier diets and reduce food waste because they place a higher value on food than they might otherwise.
- It can also improve the taste, shelf-life, and micronutrient content of food,[61] by reducing the need for excess packaging and shortening distribution supply chains.

FIGURE 6: CITIES CAN CONNECT WITH THE EXISTING FOOD PRODUCTION IN THEIR PERI-URBAN SURROUNDINGS.

With 40% of the world's cropland already located in peri-urban areas (the land within a 20 km radius around urban boundaries), cities can demand locally produced food. Cities can use their demand power to influence peri-urban farmers to adopt more regenerative practices and, at the same time, return nutrients to peri-urban farms in the form of organic fertilisers derived from urban food by-products.

59 Livemint, *How Andhra Pradesh is taking to 'natural farming'* (12th June 2018), https://www.livemint.com/Politics/RR91lCVqVKPaQuBovNeYGM/How-Andhra-Pradesh-is-taking-to-natural-farming.html

60 Thebo, A. L., *et al.*, *A global, spatially-explicit assessment of irrigated croplands influenced by urban wastewater flows*, Environmental Research Letters (July 2017), Vol. 12; Cities and Circular Economy for Food analysis – for details see Technical Appendix

61 Barber, D., *The third plate* (2014), p.93–99

NEW TECHNOLOGY OFFERS UNPRECEDENTED OPPORTUNITIES TO GROW FOOD REGENERATIVELY AND LOCALLY

There are many reasons that transitioning to more local and regenerative production will be challenging. Many farmers are already operating on low margins and the investment in time, equipment, and operational changes required to adopt regenerative practices may be difficult to finance. Additionally, it is not yet proven that regenerative practices can provide – in all contexts – the yields required to feed a growing human population. Finally, the 'rewiring' of food supply chains to favour local sourcing will be a hugely complex exercise.

Technologies and innovation may hold some of the answers to these challenges. With the **rise of food-tech and ag-tech, and financial enablers,** a new set of food and agricultural solutions are emerging:

- **Innovations in creating sophisticated, effective, and consistent organic fertilisers** are critical enablers to a regenerative food production model reliant on food by-products and organic materials as primary farming inputs. For example, Finnish technology company SoilFood is pioneering innovation in this field.
- **Innovations such as biological alternatives to synthetic pesticides** are increasingly available to help meet a growing demand, e.g. the start-up Vestaron uses spider venom to create products with the same effects as synthetic pesticides.
- **New developments in food production technologies** allow cities and peri-urban areas to produce more food in urban and semi-urban areas and improve the ecological footprint of the food produced (See Box 2: What is the true potential of urban farming?).
- **Improved traceability technologies**, particularly logistics solutions supported by blockchain, can help provide consumers and buyers with the production details (i.e. origin, farming techniques used, environmental impacts, nutritional content) needed to make informed purchasing decisions and enhance the food shopping experience.
- **Application of artificial intelligence** can provide farmers with rich information about farm conditions – such as soil quality, crop and livestock health – to enable better decision-making; can simulate field trials and agricultural ecosystems under different variables; and can identify microbes that farmers can use to promote crop yields without fertilisers. PlantVillage, a research and development unit of Penn State, offers an example of AI being used to obtain a better understanding of crop health by smallholder farmers via the project's mobile app AI assistant, called 'Nuru', which uses machine learning to train algorithms to recognise plant disease symptoms from pictures taken using a smartphone camera.

BOX 2: WHAT IS THE TRUE POTENTIAL OF URBAN FARMING?

Urban farming can play a role in building a diverse and resilient food system, reconnecting people with food, and delivering a range of societal and environmental benefits to cities. However, as a lone initiative urban farming is unlikely to significantly contribute to satisfying urban food needs, especially as cities continue to grow. Even by using an array of high-yielding indoor urban farming methods, ranging from vertical farms and aquaponics to lab-like aeroponic systems, analysis suggests a theoretical maximum of one-third (by weight) of the food needed for urban consumption could be grown within cities.[62] It is also unlikely that this theoretical maximum could ever be reached on a global scale in the foreseeable future, due to three main challenges:

1. **Competition for land.** Approximately 1.5% of the existing urban area would be needed to reach this maximum urban farming potential.[63] While seemingly small, accessing this land can prove challenging, given zoning laws, technical feasibility, and competition for other revenue-generating uses.
2. **Non-suitability to most food types.** Crops that are typically produced in indoor urban farms are limited to highly perishable leafy greens, herbs, other vegetables, and selected fruit, such as strawberries. Even if a city produced all the required volumes of these food types in indoor urban farms, it would still depend on food from peri-urban and rural areas for other food types.
3. **Challenges to becoming circular.** Furthermore, indoor urban farm types (multi-storey soil-less – hydroponic or aeroponic, soil biointensive greenhouse, aquaponic greenhouse, hydroponic greenhouse, and soil conventional greenhouse) face challenges to becoming entirely circular. Currently, high-tech soil-less farming solutions often require highly specialised synthetic liquid fertilisers to provide plants with tailored nutrients. The highest-yielding indoor farming solutions tend to also demand high-energy inputs for lighting and heating, which, at present, are generally reliant on fossil fuels to replicate the effects of the sun. In order to be circular and regenerate natural systems, urban farms would need to:
    - Run on renewable energy
    - Loop water
    - Use nutrient inputs sourced from food by-products
    - Avoid synthetic pesticides
    - Use circular fish feed (for fish production)

Innovations can help overcome this circularity gap and ensure that urban farming solutions can be truly regenerative at scale. Such an example is BIGH's Femme Abattoir, a rooftop urban aquaponic facility in Brussels that combines aquaculture with hydroponic vegetable growing to create virtuous cycling of nutrients and produce 35 tonnes of high-quality fish (bass) per year.[64]

Urban farming may lack the potential to fully satisfy the need for food in cities and, in many

62 Cities and Circular Economy for Food analysis – for details see Technical Appendix
63 Ibid.
64 https://bigh.farm/farm/

cases, high-tech indoor farming has yet to achieve circularity. Nevertheless, urban food production can provide several high-value services to people in cities, including helping people reconnect with food and better understand where and how it is grown.

Outdoor production appears to have the most limited yield potential of all urban farm types. However, it does lead to an array of socio-environmental benefits, if carried out in a regenerative way. These benefits can include:

- Expansion of green space in urban living environments, e.g. City Slicker farm in Oakland, which has transformed a blighted area of the city into a thriving community farm.
- Social fabric improvement through potential involvement and engagement with citizens.
- Reconnecting people with food production and allowing citizens to make money from their garden plot, e.g. SPIN farming, which teaches and equips small garden owners to grow and market fresh food effectively.
- Increased carbon sequestration within cities.
- Cleaner air and better mitigation of urban heat island effect.
- Improved water retention of soil, reducing flood risk.

BOX 3: HOW CAN WE REAR LIVESTOCK IN MORE REGENERATIVE WAYS?

Meat, dairy, and eggs can be produced in a way that supports and enhances natural systems. Throughout history, the balanced breeding of animals has played a fundamental role in maintaining soil fertility and ecosystem health. Natural fodder or by-products that are inedible to humans, can be eaten by animals. These non-food resources are transformed into useful and valuable protein in the form of meat, milk, eggs, and even blood. The animal manure produced can then be applied as a prime source of nutrients for the cultivation of new grains and vegetables, as well as other having uses, including as fuel and construction material.

Animal breeding that contributes to beneficial nutrient-cycling without depleting the environment can therefore play a key role in conserving and even enhancing local ecosystems. Grasslands, which are incredibly important planetary ecosystems for biodiversity and act as active carbon stores, thrive due to the nutrient-cycling that has taken place during the millions of years in which they have been grazed by animals. However, as a report by the World Resources Institute (WRI) recently estimated, by 2050 demand for animal-based products is projected to increase by 70%,[65] as such action needs to be taken to increase the productivity of pastureland, mixed-use, and smallholder farms to avoid expanding into important virgin natural areas.

65 World Resources Institute, How to sustainably feed 10 billion people by 2050, in 21 charts (5th December 2018), https://www.wri.org/blog/2018/12/how-sustainably-feed-10-billion-people-2050-21-charts

Increasing productivity will require the combination of traditional approaches optimised using the latest scientific knowledge and the application of appropriate technology.

The examples below describe just some of the ways in which farmers, large and small scale, around the world are demonstrating that it is possible to breed livestock in a way that supports the health of natural systems.

SMALL-SCALE 'AGROECOLOGY, WHICH INTEGRATES MULTI-SPECIES

Vuon – Ao – Chuong (VAC) are the Vietnamese words for garden, fishpond, and pig or poultry shed, and combined they refer to a small-scale system of intense and highly productive domestic agriculture. VAC integrates different types of plant and animal cultivation into a compact space, linking the varied growing enterprises to create an interconnecting and beneficial flow of materials, powered mostly by gravity. In areas where VAC is practised, farmers' revenue can be three to five times, even 10 times, higher than growing two crops of rice per year.

LARGE-SCALE 'HOLISTIC MANAGEMENT'

Managed and holistic grazing practices raise livestock in a way that works with natural systems and encourages soil health. Such an approach shifts away from single animal species, favouring instead multiple 'stacked' enterprises that support and complement each other, at the same time as creating multiple revenue streams. On Brown's ranch in Northern Dakota, the farmer integrates grazing and no-till cropping systems (for cash and multi-species cover crops), so that grazing pastures have a 360-day recovery period. Pigs, hens, and broilers provide more nutrient-cyclers, allowing the ranch to thrive without any synthetic inputs. The 5,000-acre farm, which was heavily degraded 20 years ago, is now profitable and doesn't require any government subsidies. Organic soil content has increased from 1 to 14%, sequestering carbon, nurturing beneficial microbes, and improving soil structure so that water storage is now more than three times more than before, providing a buffer against years of lower rainfall.

MILK AND CARBON FARMERS

In Finland, Valio, the country's largest dairy company, supported by the NGO Baltic Sea Action Group, will soon begin to train dairy farmers in new ways to sequester carbon in the soil, in an effort to make a carbon-neutral milk chain. Atmospheric carbon is captured in the soil via photosynthesis and, depending on the condition and functioning of the soil, it is either quickly recirculated or stored in the soil in permanent forms. The 5,300 farmers who provide milk to Valio, through its cooperatives, can play a key role in taking care of soil health and, as a consequence, in mitigating climate change.

BOX 4: HOW CAN AQUACULTURE AND FISHERIES BE MORE CIRCULAR?

Fish, molluscs, and crustaceans provide between 13% and 17% of our total protein intake. Consumption has been expanding at 3.6% a year for the last five decades,[66] double the rate of population growth. Currently, 800 million small-scale fishers harvest 25% of the global marine catch to feed 3 billion people.[67] The source of these fish is changing. Since 2014, according to the Food and Agriculture Organization of the United Nations (FAO), for the first time in human history we are eating more farmed fish than wild-caught fish.[68] Circular economy principles can be applied to both aquaculture and to wild fisheries to ensure that fish and other seafood can be enjoyed in the long term without degrading natural systems. Figure 7 provides examples of companies designing out waste by transforming discarded organic resources into feed for aquaculture. Below are two examples of circular economy practices being applied in aquaculture and fisheries:

AQUAPONICS

Combining aquaculture with hydroponic vegetable and grain growing is a way to cycle nutrients and reduce the need for external inputs that are non-renewable or damage natural systems. The Plant in Chicago, a collaborative community of food producers, goes even further in applying this practice of aquaponics by integrating fish farming with energy production, water treatment, baking, and brewing, to ensure that over 40% of by-products are captured and repurposed in another enterprise.

3D OCEAN FARMING

Imagine 30 tonnes of kelp and 250,000 shellfish grown in 0.4 hectares off the coast of New England over five months. This is the promise of 3D ocean farming, a vertical seafood production model developed by US organisation GreenWave. This innovative technique not only yields high volumes of food, but is resilient to storms, requires no inputs, and absorbs nutrients that have run off nearby farmland. Kelp, one of the main crops, is a highly versatile ingredient not only of food, but also for medicine, fertiliser, and biofuels.

66 World Health Organisation, Global and regional food consumption patterns and trends, https://www.who.int/nutrition/topics/3_foodconsumption/en/index5.html

67 ETC Group, *Who will feed us?*, 3rd edition (2017), http://www.etcgroup.org/sites/www.etcgroup.org/files/files/etc-whowillfeedus-english-webshare.pdf

68 FAO, *The state of world fisheries and aquaculture* (2016), http://www.fao.org/3/a-i5555e.pdf

5. MAKE THE MOST OF FOOD

Cities can play an important role in sparking a shift to a fundamentally different food system in which the concept of 'waste' no longer exists. In a circular economy, food is grown, processed, transported, prepared, and by-products managed in ways that benefit the health of people and natural systems. Food is designed to cycle, so the by-products from one enterprise provide inputs for the next. Cities can make the most of food by redistributing surplus edible food, while turning the remaining inedible by-products into new products, ranging from organic fertilisers for regenerative peri-urban farming to biomaterials, medicine, and bioenergy.

IN A CIRCULAR ECONOMY, FOOD WASTE IS DESIGNED OUT

Cities can play an important role in designing out food waste and keeping food at its highest value.

Currently, a third of all food produced – worth USD 1 trillion – is thrown away annually,[69] which is both a huge loss of nutrients and a major cause of environmental issues. Food loss and waste can be designed out along the entire food supply chain, including once it enters cities. Food value chain players located in cities can undertake a range of food waste prevention interventions. From better matching supply with fluctuating demand for different food types, to discounting soon-to-expire products, and using overripe produce for in-store food outlets, retailers can reduce their food waste. Interventions that help people avoid over-buying food and letting it spoil, can help people save money while also creating new business opportunities.[70] Food brands can use 'ugly' fruits and vegetables as ingredients for food products, such as baby food and spreads, while ensuring expiration dates reflect the true shelf-life of products. Cities can play an important role in ensuring any surplus edible food is redistributed for human consumption, helping divert food waste from landfill and providing high-quality nutrition to food-insecure populations. Redistribution initiatives are already being championed by organisations such as Feedback and FoodShift,[71] and are enabled through digital platforms such as Too Good to Go.[72]

Food waste prevention has surfaced as a global agenda item, formalised by the United Nations' Sustainable Development Goal 12.3, which sets the ambition to halve per capita food waste and losses globally by 2030. Food waste prevention efforts are being addressed by a number of organisations around the world as well as in many technological developments. The report acknowledges the need to reduce edible food waste, but focuses instead on the numerous options for creating value from organic by-products in the bioeconomy.

MAKING THE MOST OF FOOD REQUIRES THE COLLECTION OF UNCONTAMINATED STREAMS OF ORGANIC MATERIALS

A fundamental prerequisite for nutrient looping is effective collection systems.

Even if all surplus edible food was redistributed, a large volume of inedible food by-products, human waste, and green waste would continue to be produced by cities. These organic materials contain valuable nutrients that can be used for a range of purposes. With less than 2% of the valuable nutrients in food by-products and human waste in cities currently

69 FAO, *Food loss and food waste*, http://www.fao.org/policy-support/policy-themes/food-loss-food-waste/en/

70 In the UK food waste prevention could save a family household £700/year. (Crewe, P., 'How to reduce food waste: organise, categorise and love your leftovers' in *The Independent* (27th October 2016), https://ind.pn/2QmR7mi

71 Feedback, https://feedbackglobal.org/; FoodShift, http://foodshift.net/

72 Too Good to Go, https://toogoodtogo.co.uk/en-gb

being valorised,[73] there is a great opportunity for cities to fully capture the benefits contained in organic waste. Converting organic waste from an economic, health, and environmental burden for cities, into a source of value begins with effective collection systems and pure waste streams. Cities such as Milan, Sardinia, Parma, and Ferrara have demonstrated how the adoption of new technology, supporting policy frameworks, and community engagement can rapidly transform collection systems, increasing organic waste collection rates from as low as 4% to more than 60% in just over a decade.[74, 75]

While all countries can benefit from improved collection systems, emerging economies are especially well-positioned due to their high shares of organic waste and often early-stage infrastructure. Global organic waste is expected to double from 2016 volumes by 2025, with 70% of this increase taking place in emerging economies.[76] A wealth of new infrastructure systems are also expected to be built in these regions as economic development continues. By recognising the potential benefits of organic material collection now, emerging economies can design and build waste management infrastructure that effectively collects organic streams, allowing for the maximum benefits of this material to be realised.

Food design and upstream innovations are essential for keeping organic material streams uncontaminated. Keeping collected organic materials in their purest form can allow them to be used at their highest value. Some food ingredients, plastic packaging, and other materials can contaminate organic material streams and make it challenging to extract the nutrients at their highest value. Food design has an important role to play in ensuring food products are free from ingredients that pose a risk to by-products being safely used as inputs for new uses in the bioeconomy. Similarly, the packaging that preserves food can be made from materials that can compost as safely and easily as the food it contains. Examples of compostable packaging include CBPAK's material made from cassava plant (also known as yucca),[77] and VTT Technical Research Centre's compostable cellulose material made from wood.[78] While technical innovations can help create compostable packaging, reimagining food product delivery models can eliminate some packaging needs altogether. Decentralised systems that separately collect biological nutrients as close to the point of source as possible can then capture these pure organic material streams, making them available for valuable uses.

ONE MAJOR USE FOR COLLECTED ORGANIC MATERIALS IS TO REGENERATE SOILS

Cities can transform collected organic materials to drive regenerative peri-urban food production.

Currently in cities, the most common management processes for organic materials are composting, anaerobic digestion, and wastewater treatment. The organic fertilisers resulting from these processes include compost and biodigestate, which – when compliant with regulations – can be returned to peri-urban farms to rebuild soils and potentially increase yields without putting crop quality or safety at risk.[79]

Compost and biodigestate both contain carbon and nutrients. However, their properties vary due to their respective treatment processes, and the type of organic materials from which they are made. For example, biodigestate derived from wastewater is generally rich in nitrogen because it is made from human waste, whereas compost tends to have a high carbon content as well as beneficial fungi and microbes. Compost is particularly useful for quickly rebuilding soil organic matter, which alongside other benefits, can allow soil to sequester more carbon and help flip agriculture from being a cause of climate change to being part of the solution. Just half an inch of compost spread out over 50% of California's rangeland (equivalent to half of the total land area of the UK) would offset all the annual greenhouse gas emissions of California's commercial and residential energy sectors.[80]

73 Cities and Circular Economy for Food analysis – for details see Technical Appendix; World Bank, *What a Waste 2.0: a global snapshot of solid waste management to 2050* (2018); WWAP (United Nations World Water Assessment Programme), *The United Nations world water development report 2017: wastewater, the untapped resource* (2017). (Not including manure)

74 Zero Waste Europe, *The story of Sardinia, case study #11* (2018)

75 Ellen MacArthur Foundation, https://www.ellenmacarthurfoundation.org/our-work/activities/cities-and-the-circular-economy-for-food

76 Ellen MacArthur Foundation, *Urban biocycles* (2017), https://www.ellenmacarthurfoundation.org/publications/urban-biocyles

77 Ellen MacArthur Foundation, https://www.ellenmacarthurfoundation.org/case-studies/bio-based-material-for-single-use-packaging

78 VTT Technical Research Centre, https://www.vttresearch.com/media/news/creating-a-bio-based-and-easily-recyclable-packaging-material

79 WRAP, *Field experiments for quality digestate and compost in agriculture* (2016)

80 Institute for Local Self-Reliance, *Infographic: compost impacts more than you think* (19th April 2017), https://ilsr.org/compost-impacts-2/

Many existing solutions that produce organic fertilisers and bioenergy are ready to scale.

From small to large scale, operating in both centralised or decentralised modes, solutions for generating outputs for food production can be seen around the world.

For example, the first Organic Resources Recovery Center (ORRC) started operating in Hong Kong in 2018.[81] Through its Environment Protection Department (EPD), the Government of the Hong Kong Special Administrative Region (SAR) is developing an Organic Resources Recovery programme, which will include up to three ORRCs. The first ORRC has been designed to treat over 200 tonnes per day (up to 80,000 tonnes per year) of source-separated organic waste. After pre-treatment, organic resources go through an anaerobic digestion (AD) plant, producing biogas and compost. A combined heat and power (CHP) unit transforms biogas into electricity, which is sold to the grid, as well as useful heat. One tonne of biowaste generates approximately one MWh of biogas and 100 kg of compost.

In New South Wales, Veolia's EarthPower facility is Australia's first food waste-to-energy plant designed and licensed to accept solid and liquid food biomass from municipal, commercial, and industrial sectors in the Sydney region. The plant located in the suburb of Camellia, co-generates enough electricity for 3,600 homes from biogas and produces a nutrient-rich organic fertiliser as a by-product.

Expanding the use of compost and biodigestate is dependent on a number of factors, including the relative price of synthetic fertilisers, the stage in growing season, the quality of the products (for example the possible contamination with microplastics), transport distances, and spreading costs. In digestate derived from human waste, there are also challenges that need to be overcome regarding the presence of micropollutants, such as heavy metals and pharmaceutical residues.

Innovation can make organic fertilisers easier to use and economically competitive with conventional synthetic fertilisers. A number of companies such as Lystek Inc., Soil Food, Ostara, and WISErg are demonstrating that such innovation is possible. Several interventions help enhance the quality of organic fertilisers:

- **Quality assurance schemes** such as BSI PAS 100 (for compost) and BSI PAS 110 (for biodigestate) guarantee higher quality organic fertilisers.
- **Improved scientific evidence regarding micropollutants** and their related health impacts can alleviate concerns about the perceived risks of using biosolids as organic fertilisers for food production.
- **Innovation can accelerate the development of new types of commercial products that support regenerative food production**, such as biofertilisers (see Glossary) and other soil-enhancing products.
- **Using mineral by-products to increase value of organic fertilisers**. For example, recycling and recovery company SUEZ produces compost enriched with calcium carbonate extracted from sludge produced by a paper mill plant located in the southwest of France. Product certification was achieved by local authorities. The plant produced 30,000 tonnes per year of enhanced compost, sold via two main cooperatives at twice the value of traditional compost, responding to the needs of local farmers to reduce soil acidity.

ORGANIC MATERIALS CAN ALSO BE USED FOR PURPOSES BEYOND FOOD PRODUCTION

Cities can transform food by-products into an array of products for diverse uses.

Designers, engineers, and other 'bioeconomy entrepreneurs' around the world are proving this theory can actually be realised by creating an array of high-quality products (see Figure 7), from innovative foods and liquid biofuels to beautiful new textile materials for the luxury fashion industry. No product is better than an another in absolute terms, the choice of what to make should be based on local demand and feedstock availability.

The following examples demonstrate the broad range of outputs that can be made from food by-products, turning what otherwise would be 'waste' into value and helping fuel a thriving bioeconomy.

Emerging technologies and innovations can be harnessed to make the most of food by-products. Digital platforms can play an important role in getting organic resources from where they are produced to where they are needed. One such example is the partnership of Rochester Institute of Technology with New York

81 Hong Kong Environmental Protection Department, *Organic waste treatment facilities project* (2018), http://www.organicwastetreatmentfacilities-phasei.com.hk/projectbackground.html

State to create an Organic Resource Locator,[82] a web-based mapping tool that provides state-wide information on organic production and utilisation. Similarly, SUEZ has developed Organix, a digital marketplace for organic resources,[83] that allows organic producers to find the right and proximate solutions for their waste, for example to locate AD recovery centres.

While digital capabilities allow new marketplaces for by-products to emerge, advancement in food-processing biotechnologies – in particular relying on the use of microbes – expand the range of potential uses for food by-products. By employing these new biotechnologies, food by-products can be transformed into valuable outcomes such as food, fibres, energy, and agricultural inputs.

FIGURE 7. FOOD BY-PRODUCTS CAN BE TRANSFORMED INTO A WIDE ARRAY OF VALUABLE PRODUCTS.

Besides ensuring that edible food is distributed to citizens, there is no strict hierarchy to the remaining different product types described in the table. The choice of 'best' valorisation option depends on the local context, including the type of available feedstock and the demands for particular products in that specific region.

82 Rochester Institute of Technology, Organic Resource Locator, https://www.rit.edu/affiliate/nysp2i/OrganicResourceLocator/
83 SUEZ, Organix, https://www.organix.suez.fr/

PREVENTION

LeanPath and Winnow – creating kitchen technologies that use artificial intelligence to track food waste and provide information to prevent edible food waste

REDISTRIBUTION

Refettorio Gastromotiva – a global initiative, set up in Brazil aiming to eliminate food waste while promoting social inclusion through the concept of 'social gastronomy', which includes serving meals using redistributed food to vulnerable populations

MAKING NEW FOOD PRODUCTS

Planetarians – upcycled seed cake by-products from cooking oil production into an array of food products and cooking ingredients

INPUTS FOR AGRICULTURE

LIVESTOCK AND FISH FEED:
Agri Gaia System co – transforming discarded food into safe and healthy feed for the pig industry, enabled by government legislation

Agriprotein – converting discarded food and processing waste into insect meal for aquaculture, nutritional supplements for livestock, and fertiliser

Recyfish – a collaboration between Veolia and STEF, transforms fish by-products into standardised fertilisers

ENHANCING SOILS:
Soilfood – converts several different types of urban industrial waste streams into a fertilisers and soil enhancers tailored for specific agricultural contexts

CREATING NEW MATERIALS AND BIOENERGY

BIOMATERIALS:
Ricehouse – transforming rice husks into high-performance construction materials for buildings

Pigmento and Mancha – creating safe 'organic' dyes for textiles and other products from food by-products, such as coffee, saffron, and cabbage

Peel Pioneers – turning chemicals from citrus peels into cosmetics and cleaning products

BIOENERGY:
St1 – processing sugars in inedible bread from retailers and bakeries into bioethanol, which is then sold to petrol station networks to be mixed with 'traditional' fuels

Suez and Total – turning used cooking oils into biofuel, both for cars and planes (bio jet fuel)

Billund biorefinery – transforming human waste, and domestic and industrial solid waste into fertilisers, electricity, and heat for district heating, enabled by Veolia's innovative Exelys process

Pyreg – carbonising various biomass to reduce its mass, create soil improvers, produce healthy feed additive, and capture carbon

Leeming biogas plant – operated and managed by Veolia, generates 6 million m^3 of biomethane per year, which is injected into the local gas grid to be used by households in the area as well as producing fertiliser sold to local farms

6. DESIGN AND MARKET HEALTHIER FOOD PRODUCTS

Food brands, retailers, restaurants, schools, hospitals, and other providers have a major influence on what we eat. From breakfast cereals to takeaway meals, a significant proportion of food eaten today has been designed in some way by these organisations. They have shaped our food preferences and habits for decades, particularly in cities, and can now help reorient them to support regenerative food systems (see Figure 8). In a circular economy, food products are designed not only to be healthy from a nutritional standpoint, but also in the way that they are produced. This means designers need to create products that use ingredients that are – regardless of their source, animal or vegetable – produced regeneratively and, where possible, locally and therefore seasonally. Organisations have the ability to market and position these delicious and healthy products so they become an easier, more accessible choice for people on a daily basis.

FOOD DESIGNERS CAN DEVELOP AND MARKET ATTRACTIVE NEW PLANT-BASED PROTEIN OPTIONS

Food designers can develop new plant-based proteins. Animal proteins can under some conditions fit in a regenerative model, for example if produced using holistic management, agroecological or silvopasture methods (see Box 3: How can we rear livestock in more regenerative ways?). However, these regenerative approaches are unlikely to meet the fast-growing demand for animal protein worldwide. With the majority of animal protein production negatively impacting the environment today, there is a strong consensus that meat consumption needs to be reduced.[84, 85, 86] To facilitate this shift, there is an urgent need and great opportunity to provide consumers with plant-based protein options as a delicious alternative.

To this end, food design and marketing has the power to create and position attractive options leveraging innovative new protein sources (e.g. plants or insects). For example, Dutch company Vivera makes a range of products such as mince, steaks, and kebabs using wheat and soy, while UK-based Rude Health has found new ways to use high-protein pulses such as chickpeas, lentils, and field peas to create a popular line of snacks. Leguminous crops require few resources to cultivate, can be intercropped or used as cover crops, providing important ecosystem services such as nitrogen fixation and weed suppression. Other companies are creating innovative new ingredients, such as US-based Impossible Foods Inc., which uses a compound derived from soya beans to create a plant-protein burger with a texture and taste like meat. Beyond new ingredient options, emerging technology, such as AI algorithms and processes of continuous feedback, is equipping designers with the tools needed to entirely redesign products. NotCo (The Not Company) has used an AI platform to create a recipe for a mayonnaise called Not Mayo, which tastes like mayonnaise but replaces eggs with plant-based ingredients.[87]

Marketing activities can promote food products made with regeneratively grown ingredients. From promotional pricing and product placement to menu features, food

84 Springmann et al., *Options for keeping the food system within environmental limits*, Nature (2018) limitshttps://www.nature.com/articles/s41586-018-0594-0

85 WRI, *Creating a Sustainable Food Future* (2018) https://www.wri.org/our-work/project/world-resources-report/world-resources-report-creating-sustainable-food-future

86 Willett, W., et al., *Food Planet Health*, EAT-Lancet (16th January 2019), https://eatforum.org/content/uploads/2019/01/EAT-Lancet_Commission_Summary_Report.pdf

87 Shieber, J., *The Not Company is looking to start a food revolution from Chile*, TechCrunch (2018)

brands, restaurants, and other providers can use their marketing influence to promote a widespread shift to food products made with regeneratively produced ingredients. As highlighted by organisations such as the World Resources Institute (WRI), "improving the marketing of plant-based foods"[88] is an important action for helping overcome some of the current challenges that result from animal production.

FOOD PROCESSING COMPANIES CAN DESIGN OUT WASTE AND MAKE THE MOST OF BY-PRODUCTS

Food products can be designed with downstream valorisation in mind. Currently, food products contain ingredients that may make it unsafe to use their by-products as inputs for new cycles. For example, high concentrations of certain additives in food may be unsafe to return to soils as organic fertilisers. In a circular economy for food, any ingredients that may be unsafe to cycle are designed out during the initial product design stage. Ultimately all food by-products generated during the production and consumption of food – ranging from food-processing side-streams to human waste – should be safe to use as inputs for new products in the bioeconomy. By making and promoting food that is fit to safely cycle, food design and marketing can support the ambition to make the most of food. While open-source datasets, such as the FAO's Codex Alimentarius,[89] can help establish international food safety standards, further scientific research can help empower food designers with the tools and information needed to effectively identify and use ingredients that are safe for human health and that allow for safe nutrient looping.

Designers can create delicious food recipes that include by-products from other food processing. By considering the by-products generated during the production and consumption of the food they make, food brands and providers can design products that make the most of food. The wide array of by-products created during the various food-processing steps can be harnessed as ingredients for new food products. Companies are taking advantage of the technological innovations to do this. For example, Canvas uses the spent grains from AB InBev's beer brewing to create a high-fibre prebiotic boost, while Renewal Mill turns fibrous by-product from almond milk and soy milk production into gluten-free flours that can be used in a range of products for human consumption. Food designers can follow their lead by creating recipes that substitute 'traditional' ingredients with food-processing by-products, helping to ensure that valuable nutrients in by-products do not go to waste.

FIGURE 8: FOOD DESIGN AND MARKETING HAS THE POWER TO INFLUENCE WHAT WE EAT.

Food designers have the power to ensure their food products, recipes, and menus are healthy to both people and natural systems. Marketing activities can then be shaped to make these products attractive to people.

88 World Resources Institute, *How to sustainably feed 10 billion people by 2050, in 21 charts* (5th December, 2018), https://www.wri.org/blog/2018/12/how-sustainably-feed-10-billion-people-2050-21-charts

89 FAO, *Codex Alimentarius,* http://www.fao.org/gsfaonline/index.html

BOX 5: WHAT IS THE ROLE OF RESTAURANTS IN A CIRCULAR URBAN FOOD SYSTEM?

One of the pleasures of urban living is the wide choice of restaurants available. In large cities such as New York and London, there is one restaurant or café for every 30 people. The evidence indicates that the popularity of restaurants is increasing steadily. In May 2015, research from the US suggested customers were, for the first time, spending more in restaurants than in grocery stores. This shift now applies globally with 50% of every dollar spent in the food industry being restaurant related. This shows that restaurants and chefs are hugely influential in deciding the type of food that enters cities and what is offered to citizens.

Restaurants are also significant producers of waste. According to a 2011 WRAP report, in the UK, approximately 1 million tonnes of waste is generated by restaurants each year, around 22% of which is organic waste. This represents a cost to the restaurant sector of £630 million (USD 1.1 billion).[90]

Chefs and menu designers for large franchises are key decision-makers when it comes to the meals that are served in restaurants, and therefore play a critical role in the transition to a circular economy for food. If these actors can design and popularise meals originating from ingredients that are created as by-products of regenerative farming methods, it is likely that, through their influence, such ingredients will be adopted more widely. Initiatives such as the SDG2 advocacy hub's **Chef's Manifesto** acknowledge this important role, as well as individual chefs, for example Dan Barber, who recognises that: "supporting the continual improvement of the whole system should be the goal, and this leads to better flavour".

Three restaurants in Helsinki are attempting to disrupt some of the entrenched linearity of the sector. Restaurant Ultima has tried to bring more food production into the city, by using its building both as a dining space as well as a laboratory for innovative growing systems such as hydroponic, aeroponic, insect farming, and algae production. Restaurant Nolla challenges existing waste management conventions by completely doing away with bins. Food waste is directed to an Oklin composting machine, transforming organic discards into soil-enhancing material, which is then handed back to suppliers to loop back to their farms. Interiors, crockery, glassware, and napkins have all been selected from suppliers using reused or recycled materials. Restaurant Loop takes a small proportion of the annual 65 million kg of perfectly edible food thrown away in Finland each year and transforms it into tasty meals and products. All of the raw ingredients are perfectly edible and tasty, but have been withdrawn from the supply chain due to aesthetics or labelling conventions.

Asked what makes a good circular economy restaurant, Carlos Henrique replies without hesitation: "Good food of course, then it has to make money and finally it has to be circular".

90 Wrap, *Restaurants: Taking Action on Waste*, http://www.wrap.org.uk/sites/files/wrap/Restaurants.pdf

7. INVESTIGATING THE BENEFITS OF A CIRCULAR ECONOMY FOR FOOD IN FOUR FOCUS CITIES

The* Cities and Circular Economy for Food *report has collaborated with four focus cities to explore the potential benefits of applying the ambitions in different contexts. Over the course of several months, the team analysed available data and worked with local food players to understand the unique food systems and urban–rural dynamics of the these cities: Brussels, Belgium; Guelph, Canada; Porto, Portugal; and São Paulo, Brazil. With distinct physical, demographic, and socio-economic profiles, along with governance, policies, and surrounding areas, each city can take actions to shift towards a circular economy for food in different ways. The following section shares one scenario for each city, detailing the array of health, environmental, and economic benefits that could be generated. The focus city work offers real world examples of what applying the ambitions could look like, and the impact of the benefits that could be generated. These stories aim to inspire cities around the world to reimagine their urban food systems, effectively leveraging their power to trigger a shift to a regenerative global food system underpinned by circular economy principles.

FOR FULL DETAILS ON THE ANALYTICAL APPROACH AND DATA SOURCES, SEE THE FULL STORY FOR EACH FOCUS CITY (SOON TO BE RELEASED).

BRUSSELS,
BELGIUM

GUELPH,
CANADA

PORTO,
PORTUGAL

SÃO PAULO,
BRAZIL

BRUSSELS, BELGIUM

SUPPORTING THE DEVELOPMENT OF LOCALLY SOURCED AND REGENERATIVELY GROWN FOOD

CONTEXT

Brussels is a high-income, well-connected city at the heart of Europe, with a stable population of 1.2 million. It is home to many European and international institutions. The Region of Brussels-Capital is run by a complex, multi-layered, and bilingual governance system, requiring high levels of cooperation and effective dialogues between different parties.

SCENARIO

What if 30% of the food available to the citizens of Brussels was produced in the peri-urban area using regenerative practices?

DETAILED DESCRIPTION

Approximately 50% of the peri-urban land around Brussels is dedicated to agriculture. According to a study from Wageningen University, this 1,500 km^2 area could meet the food needs of more than 90% of Brussels citizens, or 40% of Brussels urban and peri-urban population.[91] There is no data available to determine the proportion of food produced in the peri-urban area that currently goes into Brussels, but there are indicators that it is very small, even in categories of food that are grown locally in great quantities. For example, the production of apples and pears in the peri-urban is 10 times what Brussels consumes (i.e. 150,000 tonnes per year), yet 60% of it is still imported.[92]

The practices used on this agricultural land are mostly conventional (only 6% of land in Belgium is organically cultivated, and this is concentrated in the south;[93] less than 1% is classed as regenerative agriculture)[94] and is heavily reliant on the use of synthetic fertilisers (synthetic fertiliser use in Belgium is twice the world average).[95] Soil is particularly at risk in Belgium where nearly all soil types under cropland indicate a decrease in soil organic carbon.[96]

There is already momentum towards a better food system in Brussels. The demand for fresh locally grown produce has increased over the past decade, resulting in a rapid acceleration of sales from direct-to-consumer channels from local farmers (e.g. 76% increase in revenues between 2014 and 2016, although still marginal).[97] In addition, the city of Brussels adopted in 2015 its Good Food Strategy,[98] setting ambitious quantified targets and practical commitments for 2020. One of these targets is to source 30% of the fresh fruit and vegetables consumed by Brussels citizens from the urban and peri-urban areas by 2035. If such a policy was extended to the whole food basket and done in a way that ensures regenerative practices are used, the following benefits could be achieved.[99]

BENEFITS:

Healthier citizens: USD 31 million in health costs could be saved each year due to lower pesticide exposure, cleaner air and water, and decreased microbial resistance.

Healthier soils: soil health could be enhanced by replacing synthetic fertilisers with organic alternatives, leading to an estimated USD 11 million of cost savings every year from avoiding soil degradation.

Climate change mitigation: 42,000 tonnes of greenhouse gas emissions would be avoided each year.

Water savings: over 21 million m^3, equivalent to half of the city's residential consumption of drinking water, could be saved every year due to healthy soils having a higher water retention capacity.

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91 van Dijk, W., *et al.*, *Closing the life cycle of phosphorus in an urban food system: the case Almere (NL)* (2017), Assumptions of the study: 1. The food basket includes meat and dairy products, which represent 90% of the land requirement (animal feed); 2. Only 300 km2 are needed for plant-based products (65% cereals, 15% sugar beet, 10% fruit, 10% potatoes and vegetables); 3. 15% of the food basket is still imported (e.g. coffee, exotic fruit)

92 See Appendix of separate focus city report for Brussels

93 StatBel, *Chiffres Clés de l'Agriculture* (2018)

94 *Imagine* Magazine, *Agroecology in action* (2018)

95 280 kg per hectare in Belgium. The World Bank, *Fertilizer consumption (kg per hectare of arable land)* (20th November 2018), https://data.worldbank.org/indicator/AG.CON.FERT.ZS

96 Meersmans, J., et al., *Spatial analysis of soil organic carbon evolution in Belgian croplands and grasslands, 1960–2006* (2010)

97 CODUCO, *Conclusions circuits courts* (2018)

98 Bruxelles Environnement & Bruxelles Economie et Emploi, *Stratégie Good Food – Vers un système alimentaire durable en région de Bruxelles-Capitale* (2015)

99 Assuming an unchanged food basket

GUELPH, CANADA

USING BIOSOLIDS FROM WASTEWATER TREATMENT FOR REGENERATIVE FARMING

CONTEXT:

Situated 100 km west of Toronto, Ontario, the City of Guelph and surrounding County of Wellington are working together to form a circular economy for food. Guelph has a growing population of 132,000 and is a high-income community located in Ontario, Canada with a wealth of agrifood industry players and institutions. As a major Canadian agri-food hub, research powerhouse, and pioneer of residential organic waste collection schemes, this area is uniquely positioned to develop a regional food system built on the principles of a circular economy.

SCENARIO

What if Guelph used 100% of its biosolids from wastewater treatment to support regenerative peri-urban farming?

DETAILED DESCRIPTION

Guelph is located in the County of Wellington, which is home to over 2,300 farms. The city supports the adoption of regenerative practices on these farms by turning organic waste into high-quality organic fertiliser and compost. The city already has a robust household organics collection programme, which it can continue to expand, while simultaneously implementing new innovative solutions to turn additional food by-products, such as inedible food by-products and human waste, into soil-enhancing products.

Biosolids from the wastewater treatment facility can play an important role in supporting regenerative farming. At the end of 2018, Guelph initiated a contract with Lystek Inc., to help convert and manage the 4,500 tonnes of biosolids generated each year by the city's tertiary wastewater treatment facility and turn them into a commercially viable liquid organic fertiliser. Lystek Inc. is contracted by the city to manage, sell, and safely apply the high-nutrient organic fertiliser on farms in the surrounding area of the wastewater treatment facility. It is estimated that Guelph's wastewater treatment generates a number of annual benefits.

BENEFITS[100]

New business models and revenue streams: enhance the value of the biosolids generated from the wastewater treatment facility by turning them into a high-quality liquid organic fertiliser that is applied by Lystek Inc. By providing both the product and application service, Lystek Inc.'s innovative business model helps local farmers to overcome the common challenge of needing to purchase new equipment to apply organic fertilisers that come in a different format from conventional synthetic fertilisers.

Make the most of food by-products: recover valuable nitrogen and phosphorus worth an estimated USD 34,000 annually for organic fertiliser

Nutrient-rich organic fertiliser for cropland: enough to cover 1,000 hectares of cropland in the region.

100 Interview (via email) with Lystek Inc. (August 2018)

PORTO, PORTUGAL

COLLABORATING ACROSS MUNICIPALITIES TO MAKE THE MOST OF FOOD

CONTEXT

Porto is the second largest city in Portugal. Located in the coastal North Region, Porto is a global, middle-income, well-connected community. The city, of just over 214,500 inhabitants, is surrounded by 16 other municipalities that combine a unique range of activities, from industries and universities to agriculture, which are central to enabling the transition to a circular economy for food. The region has a strong innovation profile, an existing circular economy roadmap, and wide variety of food production. There are multiple ongoing initiatives linked to food and the circular economy in the area, ranging from urban vegetable gardens and green roofs, to separation of organics at source, solidarity restaurants that provide balanced food to people in need, and initiatives influencing portion sizes.

SCENARIO

What if Porto prevented 50% of all edible food waste?

DETAILED DESCRIPTION

Just under 14,000 tonnes of food are wasted in the Municipality of Porto every year,[101] with only a fraction of this waste currently being valorised. However, both Porto itself as well as the Porto Metropolitan Area (PMA) have ongoing initiatives, such as Refood and Fruta Feia (Ugly Fruit) Cooperative, to combat this. Refood works to divert edible food waste from landfill by redistributing it, while Fruta Feia ensures that imperfect fruits and vegetables are eaten by effectively marketing products that producers find hard to sell. Currently, donations to food banks alone account for 13% of edible food waste in the Municipality of Porto. Preventing food waste not only helps bring food to those in need, but also reduces the amount of food and food waste that is produced, lessening the negative impacts stemming from food production and food waste processing.

There is an opportunity to further enhance and expand existing food waste prevention programmes across the PMA. If 50% of edible food waste was avoided rather than sent to landfill or incineration, the following benefits could be generated each year:

BENEFITS

Healthier citizens: USD 14 million for the PMA and USD 1.85 million for the Municipality of Porto, due to a reduction in the negative health impacts from food production and food waste. This is in addition to the impact that preventing food waste would have on issues such as malnutrition.

Economic savings: USD 92 million for the PMA and over USD 11.3 million for the Municipality of Porto, representing the value of the food that is no longer wasted.

Climate change mitigation: 92,600 tonnes of CO_2 equivalent for the PMA and 12,200 tonnes CO_2 equivalent for the Municipality of Porto, stemming from a reduction in emissions from the production of food and treatment of food waste.

101 Calculations based on: Lipor, *Mapping of the food surplus (loss and waste) in the LIPOR area* (2016)

SÃO PAULO, BRAZIL

POTENTIAL FOR A MORE RESILIENT, SOCIALLY INCLUSIVE URBAN FOOD SYSTEM

CONTEXT

Brazil's largest city and main consumer market, São Paulo, is a developing mega-hub situated at the heart of the São Paulo Metropolitan Region (SPMR). The city region is an economic powerhouse that accounts for approximately 18% of the country's GDP. Following years of unplanned demographic expansion, the region faces significant challenges associated with a landscape of profound disparities. The food system is being increasingly regarded as an important vector for economic, societal, and environmental development. Valuable assets, such as a thriving gastronomy landscape and a high innovation capacity within its numerous research institutions, universities and corporations, suggest that São Paulo is uniquely positioned to develop a distributed and inclusive regional food system based on the principles of a circular economy.

SCENARIO

What if São Paulo re-localised food production while moving towards regenerative practices?

DETAILED DESCRIPTION

São Paulo's metropolitan agricultural area is already a significant production area for fresh food. Approximately 54% of the existing peri-urban cropland would be needed to fulfil the city's total demand for fruits, vegetables, and leafy greens. Re-localising food production in São Paulo could offer its citizens a more resilient food supply, less vulnerable to shock incidents such as the 2018 truckers' strike, which paralysed food distribution routes. Local production could also make food more affordable and more widely available, as well as offering a source of income for the vulnerable population in the rural–urban fringes and, equally importantly, a means of their reintegration into the societal and economic dynamics of the city. This would address two of the city's 2020 goals: to improve its position on the Food Insecurity Map from medium to low and to create jobs for its underprivileged population through production.[102]

While approximately 40% of peri-urban farmers currently use no-till and crop rotation practices,[103] the agroecology movement in São Paulo, aided by city and state government initiatives, indicates that in time further support mechanisms and incentives could help all local farmers to adopt regenerative practices. Public procurement alone could generate enough demand for 71,500 hectares of regenerative cropland (equivalent to 73% of the total peri-urban cropland) provided that the city of São Paulo adopts purchasing guidelines favouring local and regenerative production.[104] Corporate procurement also has an important role in driving demand.

If all cropland in the São Paulo Metropolitan Region was farmed regeneratively, the following benefits could be generated each year.

BENEFITS:

Healthier citizens: USD 67 million cost saving in health due to reduced pesticide exposure and lower air pollution.

Avoided soil degradation: USD 25 million worth of soil saved from degradation in conventional farming practices. Alongside avoided irregular housing settlements that also threaten the natural environment.

Climate change mitigation: 92,000 tonnes of greenhouse gas avoidance, worth USD 10 million to society.

Water savings: 46 million m^3 freshwater saved, relieving the pressure on local water sources that are already threatened by urban sprawl.

More diverse crops and revenue streams: farmers grow a wider range of crops to serve São Paulo's gastronomy menus, while enhancing biodiversity and diversifying farmers' revenue streams.

102 Prefeitura de São Paulo, *Plano de Metas 2017–2020* (2018), http://programademetas.prefeitura.sp.gov.br/

103 Instituto Brasileiro de Geografia e Estatística, *Censo Agro 2017 (preliminary results)* (2018), https://censos.ibge.gov.br/agro/2017/

104 Calculations based on: Prefeitura de São Paulo, Portal de Transparência (2018), http://transparencia.prefeitura.sp.gov.br

8. BENEFITS OF A CIRCULAR MODEL FOR FOOD IN CITIES

By achieving the three ambitions set out in this report at a global scale, cities could generate benefits worth USD 2.7 trillion a year in 2050.[105] On the environmental side, annual benefits could include reducing greenhouse gas emissions by 4.3 billion tonnes of CO_2 equivalent and avoiding the degradation of 15 million hectares of arable land. The health benefits are mostly driven by the reduction in health costs associated with pesticide use with estimated savings of USD 550 billion as well as a reduction in antimicrobial resistance. An economic opportunity of over USD 700 billion a year can be realised by reducing edible food waste and using organic materials to produce new products. Besides the quantifiable benefits, an array of further systemic benefits could be generated, many of which will directly improve the lives of urban populations, such as cleaner air and water, as well as healthier food options.

USD 2.7 TRILLION OF ECONOMIC, HEALTH, AND ENVIRONMENTAL BENEFITS

Realising the vision of a circular economy for food would result in economic, societal, and environmental benefits.

In the report we have only quantified the benefits of cities achieving two of the ambitions: (1) sourcing food regeneratively and locally where appropriate and (2) making the most of food. Achieving these together would generate benefits worth USD 2.7 trillion annually by 2050.[106] Added to this, there could be significant further revenue and public health benefits that would arise through the design, marketing and sale of healthier food products. Besides the specific benefits that have been modelled and quantified, the proposed vision would also make a significant contribution to achieving many of the Sustainable Development Goals, create better living conditions in cities, improve biodiversity and resilience in farming communities, increase food security, and create more favourable conditions for citizens to make healthy food decisions.

Cities catalysing the shift from waste to value capture in a circular economy for food presents a massive economic opportunity, estimated as USD 700 billion annually (representing a quarter of the USD 2.7 trillion of annual benefits expected to be generated by 2050). The economic opportunity includes valorisation of organic materials and potentially USD 26 billion[107] worth of nitrogen and phosphorus that otherwise would have been lost. The bulk of the economic opportunity lies in designing out food waste, which can ensure surplus edible food and the significant market value it represents is not lost. Through edible food redistribution efforts, cities can keep valuable food from going to landfill and address food security issues. By 2050, redistributing surplus edible food that would otherwise be wasted could theoretically provide additional food to feed 1 billion hungry people worldwide.[108]

Environmental improvements are expected to account for nearly half of the annual benefit opportunity. Avoided greenhouse gas emissions and soil degradation represent the major anticipated environmental benefits. By 2050, cities catalysing the shift to a circular economy

105 Cities and Circular Economy for Food analysis – for details see Technical Appendix
106 Ibid.
107 Ibid.
108 Cities and Circular Economy for Food analysis – for details see Technical Appendix; United Nations, *Sustainable Development Goals: Goal 2: Zero Hunger*, https://www.un.org/sustainabledevelopment/hunger/

for food could lead to annual greenhouse gas emissions savings of 4.3 billion tonnes of CO_2 equivalent,[109] comparable to taking 1 billion cars off the road permanently, and an area of arable land larger in size than England saved from degradation.[110, 111] Additional benefits include saving enough fresh water to fill the Three Gorges Dam, the world's largest hydroelectric dam, 12 times over each year.[112]

Health gains are expected to represent a third of the annual benefit opportunity. The reduction of pesticide exposure is the most significant of these benefits with savings of USD 550 billion in health costs from pesticide-related illnesses expected by 2050.[113] Another sizeable potential health benefit is the reduction in antimicrobial resistance, seen by many scientists as a deeply worrying future public health threat. Regenerative practices applied to livestock and fish breeding coupled with improved wastewater treatment, could help alleviate the threat that antimicrobial resistance may pose to millions of lives by 2050. Reduction in water contamination, air pollution, and foodborne diseases are other health issues that will be positively impacted. It is estimated that a circular economy for food catalysed by cities could save 290,000 lives otherwise lost to outdoor air pollution per year by 2050.[114]

INCREASED RESILIENCE AND BIODIVERSITY, AND OTHER WIDER BENEFITS COULD BE REALISED WITHIN AND BEYOND CITIES

Apart from the benefits quantified in the USD 2.7 trillion estimation, several wider positive impacts are expected, following the realisation of a circular economy for food. By sourcing regeneratively grown food and local produce where appropriate, cities will increase the resilience of their food supply by relying on a more diverse range of suppliers (local and global) and improved soils. This sourcing model will also support the diversification of types by selecting varieties best fitting local conditions. Through a renewed sense of connection with the food system that supports them, people in cities may feel encouraged to adopt healthier diets and reduce food waste because they place a higher value on their food than they might have done previously. Finally, regenerative and local sourcing can also improve the taste,[115] shelf-life, and micronutrient content of food, as well as reducing the amount of packaging by shortening the distribution supply chains. Farms that avoid synthetic fertilisers, use best practice management for applying manure to fields, and optimise for better soil health can mitigate oceanic dead zones by reducing nutrient run-off, as well as reverse land degradation, avoiding the need to expand into natural land use areas.

Cities themselves will become better places to live in through the actions they take to tackle some of the biggest food system challenges. For example, cities achieving more circular food systems can enjoy cleaner streets, better air and water quality, reduced risk of foodborne diseases, and realise new bioeconomic opportunities through the valorisation of organic materials. By reconnecting with the food system, including integrating food gardens into the urban landscape, cities will become a more pleasant place to live.

109 A significant contribution to the 11 gigaton greenhouse gas mitigation gap estimated by the WRI to hold global warming below 2 degrees Celsius, the level necessary for preventing the worst climate impacts. World Resources Institute, *How to sustainably feed 10 billion people by 2050, in 21 charts* (5th December 2018), https://www.wri.org/blog/2018/12/how-sustainably-feed-10-billion-people-2050-21-charts

110 Cities and Circular Economy for Food analysis – for details see Technical Appendix; Statista, *Number of passenger cars and commercial vehicles in use worldwide from 2006 to 2015* (2018), https://www.statista.com/statistics/281134/number-of-vehicles-in-use-worldwide/; EPA, *Greenhouse gas emissions from a typical passenger vehicle* (2018), https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100U8YT.pdf

111 Cities and Circular Economy for Food analysis – for details see Technical Appendix

112 Cities and Circular Economy for Food analysis – for details see Technical Appendix; Three Gorges Dam capacity: 39.3 billion m3. FAO AQUASTAT, *China water resources* (10th November, 2018), http://www.fao.org/nr/water/aquastat/countries_regions/Profile_segments/CHN-WR_eng.stm

113 Cities and Circular Economy for Food analysis – for details see Technical Appendix

114 Ibid.

115 Barber, D., *The third plate* (2014), pp.93–99

CONTRIBUTE TO STAYING WITHIN PLANETARY BOUNDARIES AND MEETING UN SUSTAINABLE DEVELOPMENT GOALS

In a global context, there is great potential to have a positive impact on many of the 'planetary boundaries'. This refers to the framework developed by the Stockholm Resilience Centre describing the nine most critical earth system processes that are being threatened by the recent 'great acceleration' in human industrial activity. Regenerative food production and better cycling of nutrients from cities could positively impact phosphorus and nitrogen run-off and genetic diversity – two boundaries that are currently being exceeded to the greatest degree.[116]

The Sustainable Development Goals (SDGs) are a universal blueprint to "address the global challenges we face, including those related to poverty, inequality, climate, environmental degradation, prosperity, and peace and justice."[117] The 17 goals are broad-ranging but also interdependent, recognising for example that ending poverty and hunger are interconnected with goals to address issues such as health, education, and gender equality.

At the 2016 EAT Forum in Stockholm, Johan Rockström and Pavan Sukhdev showed how food connects all of the SDGs, creating a new food-focused configuration (see Figure 9).[118] Adopting the positive vision set out in the *Cities and Circular Economy for Food* report could be a critical and transformative step towards a circular urban food system that can address not only global food system challenges, but also global development issues more broadly.

FIGURE 9: IMPROVING THE FOOD SYSTEM CAN CONTRIBUTE TO MEETING ALL THE SDGS.

A food-focused configuration for the SDGs showing how a productive and prosperous economy requires that fundamental societal needs are met, which in turn rests on the foundation of a healthy biosphere.

Source: Stockholm Resilience Centre (2016)

116 University of Leeds, *A good life for all within planetary boundaries* (2018), https://goodlife.leeds.ac.uk/countries/

117 United Nations, *Sustainable Development Goals* (2015), https://www.un.org/sustainabledevelopment/sustainable-development-goals/

118 Rockström, J., Sukhdev, P., EAT Forum (2016), https://www.stockholmresilience.org/research/research-news/2016-06-14-how-food-connects-all-the-sdgs.html

9. MOBILISING THE TRANSFORMATION AT SCALE DEMANDS A NEW APPROACH

Realising the vision laid out in this report needs a new approach with unprecedented levels of collaboration between food brands, retailers, city governments, waste managers, and other urban food actors. It will require local demonstration projects in key cities around the world combined with global scaling mechanisms, using the reach of global businesses and collaborative platforms. The development of supportive policy frameworks, innovations, financial instruments, and communications to engage the wider public will also all have to be orchestrated to build mutually reinforcing momentum towards the vision.

GLOBAL SYSTEMS-LEVEL CHANGE WILL BE REQUIRED TO ENSURE OPPORTUNITIES ARE FULLY REALISED

Local efforts will play a crucial part in catalysing change, but these need to be complemented with a global systems-level change effort to ensure that the opportunities are fully realised.

Many local efforts to realise various aspects of the vision of a circular economy for food in cities have been initiated in the past decade, including an increasing number of food policies at city level and neighbourhood composting schemes. Those efforts are absolutely crucial and can, if done well, influence local food flows. However, to realise the vision at scale, these local efforts need to be complemented with a global, orchestrated, public-private systems-level change effort that matches the scale of the challenge and the opportunity.

While systems-level change has gained increased attention in recent years as a required approach to overcome complex systemic issues, it is still a new science with only a few case studies and enabling tools available to support industries to transform. Even if such tools were available, changing a complex system is not something that can be planned and executed in a static, deterministic way. A design-thinking approach is required, bringing together actors from across the system to collaborate, prototype, learn, refine, and scale what works.

The key characteristics of an approach to mobilise a circular economy for food in cities globally are emerging. They are listed below, and are based on the Ellen MacArthur Foundation's prior research on the theory and practice of systems-level change and the experience of the Foundation from working with business and government on the transition to a circular economy, including the New Plastics Economy, and analysis and stakeholder interviews conducted as part of the development of the report.

Realising the vision will require unprecedented collaboration between food brands, retailers, city governments, waste managers, and other urban food actors. It is clear that only a multi-stakeholder approach, involving both private and public actors, will help to shift such a complex system. The elements needed to influence the shift towards a regenerative food system could include:

- **Demonstrating that the vision is achievable in practice**, through pilot projects in flagship cities where public-private collaborations drive change in a diversity of urban contexts. Those demonstration projects would seek to establish new ways of working between municipalities, local and global food businesses, and waste collectors through pre-competitive collaboration. They would aim to substantially raise awareness in the food system and the broader public of the extent of the issues, and demonstrate the potential of a shift towards a circular economy for food. They would aim to inspire others to follow their lead by working closely with city networks to disseminate the learnings from the demonstration projects as well as engaging food companies with a global footprint to replicate circular initiatives in multiple locations.
- **Engaging a global consortium of multinational food companies** (e.g. supermarkets, food brands, hospitality players) to champion the circular model for food and engage on specific projects both locally, in flagship cities, and crucially also at a global level to scale circular initiatives.
- **Disseminating compelling stories about early innovators and successes**, to inspire municipalities, businesses, and people to realise the vision. Beyond inspiring stories, there is also a need to communicate and bring together key stakeholders to agree a common ground when it comes to critical definitions, such as the meaning of 'regenerative agriculture'.
- **Establishing supportive enabling conditions**, including setting policies that support a circular model without compromising on health, hygiene, and safety. Innovation and new technologies can help create the conditions needed to set the food system on a regenerative path. New financial instruments can also play a role in de-risking the transition to regenerative agriculture and reward farmers who make positive environmental and societal contributions. The Upper Tana River Water Fund set up by The Nature Conservancy in Kenya, could be an inspiration for this. The fund, paid into by downstream water users, provides education and support for over 20,000 farmers in agricultural methods that increase yields and revenue streams, as well as reducing the cost of annual maintenance for Nairobi's water and power infrastructure.[119]

COLLABORATIVE ACTION FROM ALL STAKEHOLDERS IS NEEDED TO ACHIEVE THE THREE AMBITIONS

The three ambitions are mutually reinforcing and need to be pursued at the same time. Designing and marketing food products that appeal to people using more locally available and seasonal ingredients would increase the connection between cities and local farmers, and could help drive the transition to regenerative practices. Using more local ingredients would likely increase the traceability

119 The Nature Conservancy, *The Upper Tana-Nairobi Water Fund* (2018), https://www.nature.org/en-us/about-us/where-we-work/africa/stories-in-africa/nairobi-water-fund/

of food and therefore potentially its safety. Similarly, making the compost and fertilisers derived from food by-products attractive to peri-urban farmers would encourage efforts in cities to collect and make the most of these by-products and other organic materials. As hubs of innovation and connectivity, cities are ideally placed to successfully link up all elements of the food value chain.

Different organisations can contribute to the transition in unique ways (see Figure 10). From production to post-consumption, each step of the value chain has a role to play in transforming the food system. Food producers have a critical role in making sure food is produced according to circular principles at the outset of the value chain. Food brands can leverage processing to valorise or minimise food waste while sourcing ingredients grown regeneratively. Retailers play a key role in determining the food that is available in cities, especially in developed markets (see 'Investigating the benefits of a circular economy for food in four focus cities' section). Through the food they source, in-store product placement, and marketing, food retailers can support efforts in cities to eat food grown regeneratively and sourced locally, where appropriate. The purchasing power of municipalities to cater to public institutions, such as schools and hospitals, should equally be leveraged to source ingredients in line with circular principles. Finally, waste managers and municipalities hold the power to collect and valorise organic waste.

It is through the collaboration of these stakeholder groups that true change can be achieved. The challenges of the global food system can sometimes seem daunting in their breadth and sheer complexity. It has, after all, been referred to as the 'mother of all systemic problems.'[120] The report has sought to show that there are tremendous opportunities available to businesses and governments in cities to take a long-term view of the future of food and catalyse a fundamental shift in the system. While it does not offer a detailed blueprint, it does set out three concrete circular economy ambitions upon which such a shift can be based: source food regeneratively and locally grown where appropriate; make the most of food; and design and market healthier food products.

There is no silver bullet to fix our troubled food system. As with all complex situations, the three ambitions need to be pursued in a way that recognises and acts upon their interdependence both with each other, and with complementary initiatives being developed by other organisations.

If realised, the proposed circular economy approach could yield huge benefits to city economies, human health, and the environment as well as helping to achieve many of the Sustainable Development Goals. The challenge for all of the city food players around the world is to seize the chance to get behind a common vision of a truly healthy and regenerative food economy and then **make it happen – at scale and at pace.**

120 Hassan, Z., *The global food system – a brief guide to the conflicting logics of food* (2015)

FIGURE 10: ALL STAKEHOLDERS HAVE A ROLE TO PLAY IN BUILDING A CIRCULAR ECONOMY FOR FOOD IN CITIES.

Mobilising the three ambitions will require contributions from all the main urban food system actors, working together in a collaborative way. The following table describes a few examples of actions diverse food system stakeholders can take.

ACTORS	ROLE
FOOD PRODUCERS	• Use available tools and technologies to help shift to regenerative practices for growing food and measure the impacts • (Peri-urban farmers) Connect with local consumer markets and use organic fertilisers made from urban food by-product streams • Take advantage of educational and funding programmes that support the adoption of regenerative practices
FOOD BRANDS	• Redesign food products that: • Use innovative plant-based protein in place of animal protein • Use food processing by-products as ingredients • Are safe to cycle • Use marketing influence to increase popularity of circular products
RETAILERS AND COMMODITIES/FOOD BUYERS AND TRADERS	• Prioritise sourcing products produced regeneratively, and locally where appropriate • Preferentially market, price, and promote regeneratively grown products • Prevent edible food waste through improved logistics, matching food volumes to demand, redistribution, using 'ugly' produce as ingredients, etc.

RESTAURANTS, AND OTHER FOOD PROVIDERS	• Redesign food products so they:
	  • Use by-products as ingredients
	  • Use innovative plant-based protein in place of animal protein
	  • Generate by-products that are safe to cycle
	• Create seasonal product offerings that use locally-grown ingredients
	• Use by-products from making one product as ingredients for new products

WASTE MANAGEMENT COMPANIES	• Innovate for advanced organic waste collection and treatment systems • Reconnect urban nutrient flows with peri-urban farmers • Work with public and private sector players to develop valuable bioeconomy products made from their food by-products • Implement wastewater treatment systems that make the most of nutrients contained within urban human waste
CITY GOVERNMENTS	• Collaborate with regional/national governments to introduce programmes that provide educational and financial support for farmers to adopt regenerative practices • Shape public procurement policies to source food grown regeneratively, and locally where appropriate • Put in place infrastructure and policies for separate organic waste collection and wastewater treatment systems • Advance infrastructure to enable local food sourcing and the return of organic fertilisers to peri-urban farms • Provide incentives through policies and funding programmes for food businesses to take actions based on circular economy principles
LEARNING INSTITUTIONS	• Integrate food as an important component of circular economy courses • Advance the research needed to further build the evidence for shifting to a circular food system • Partner with local organisations and government to establish innovation hubs to help find solutions to overcome the challenges to achieving the vision • Implement the three ambitions on campuses
FINANCIAL INSTITUTIONS	• Provide financial tools to de-risk and stimulate the transition from conventional to regenerative food production • Steer capital towards businesses leading the shift towards a circular economy for food

NOTE ABOUT THE REPORT

Cities and Circular Economy for Food (2019) is designed to initiate a deeper exploration of the role that cities, and the businesses and governments in them, can have in the creation of a circular economy for food. It acknowledges cities as only one key driver of change among many others. It advocates the circular economy as one of several approaches that can support the development of a healthier and regenerative food system.

The authors of the report collected information from more than 200 articles, publications, and reports, and consulted more than 100 experts during its preparation. However, uncertainties remain within the report as the scientific understanding of the various components of a circular economy for food supply continues to evolve.

While most of the trends and examples listed in the report relate to OECD countries, the broad principles underpinning the vision for a circular economy for food laid out are intended to be applicable globally, with relevance to both the industrial and the smallholder food systems.

The report does not intend to provide diet recommendations or advice on food consumption, although it does highlight the role that food brands, manufacturers, and providers have in offering healthy foods with positive environmental impacts.

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CORE PROJECT TEAM

ELLEN MACARTHUR FOUNDATION

Andrew Morlet, Chief Executive

Rob Opsomer, Systemic Initiatives Lead

Clementine Schouteden, Project Lead and Lead Author

Emma Chow, Project Manager

Nick Jeffries, Case Study Programme Manager

Luisa Santiago, Brazil Lead

Del Hudson, North America Lead

Aurélien Susnjara, Research Analyst

Camille Gillet, Research Analyst

Marco Meloni, Research Analyst

Victoria Almeida, Brazil Associate

SYSTEMIQ

Martin Stuchtey, Managing Partner

Jaap Strengers, Senior Associate

Lauren Boutillier, Associate

Tilmann Vahle, Associate

Florian Fesch, Intern

Lisa Griebel, Intern

Mayra Buschle, Working Student

FURTHER CONTRIBUTORS

ELLEN MACARTHUR FOUNDATION

Ian Banks, Editorial Lead

Joe Iles, Editor

Jocelyn Bleriot, Executive Officer; Head, International Institutions & Governments

Clementine d'Oiron, Network Manager

Sarah Churchill-Slough, Design and Branding Manager

Ross Findon, Media and Social Media Manager, Systemic Initiatives

Katie Schuster, Communications Executive, Systemic Initiatives

Alix Bluhm, Communications Manager, Systemic Initiatives

Sebastian Egerton-Read, Social Media Manager

Vicky Deegan, Digital Project Manager

CONKER HOUSE PUBLISHING

Jo de Vries, Editor

Emma Parkin, Editor

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Brandi DeCarli, Founding Partner, Farm from a Box

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Christian Schader, Head of Sustainability Assessment, Research Institute of Organic Agriculture (FiBL)

Evan Fraser, Director and Canada Research Chair, Arrell Food Institute, University of Guelph

Experts from GAIN

Experts from the Global Alliance for Incinerator Alternatives (GAIA)

Gauthier Boels, Senior Innovation Manager – Circular Economy, Yara International ASA

Hunter Lovins, President of Natural Capitalism Solutions; Professor of Sustainable Management at Bard MBA

René van Veenhuizen, Senior Programme Officer, RUAF Foundation

Jean de Barrau, Regenerative Agriculture Director, Danone North America

Jim Harris, Professor of Environmental Technology, Cranfield Soil and Agrifood Institute

Jun Axup, Scientific Director & Partner, IndieBio

Kevin Bayuk, Senior Research Fellow, Project Drawdown

Marco Ricci, CIC-Italian Composting and Biogas Association and ECN-European Composting Network

Marine Legrand, Research and Network Animation, Programme OCAPI, Laboratoire Eau Environnement Systèmes Urbains, École des Ponts ParisTech

Mark C.M. van Loosdrecht, Chair Professor, Environmental Biotechnology, Delft University of Technology

Michael Doane, Managing Director of Agriculture and Food Systems, The Nature Conservancy

Miriam Otoo, Senior Economist and Research Group Leader – Resource Recovery and Reuse, International Water Management Institute

Patricia Minaya, Project Manager – Nutrient Recovery Processes, Hamburger Umweltinstitut

Patrick Holden, Chief Executive, Sustainable Food Trust

Pay Drechsel, Strategic Program Leader 'Rural-Urban Linkages', International Water Management Institute

Philippe Ciais, Researcher, LSCE

Ruerd Ruben, Professor, Wageningen University & Research

Susanna Gionfra, Policy Analyst in Natural Resources and Circular Economy, Institute for European Environmental Policy

Tim Benton, Dean of Strategic Research Initiatives, University of Leeds and Distinguished Visiting Fellow, Chatham House

Weber Amaral, Professor, University of São Paulo – ESALQ (Luiz de Queiroz College of Agriculture)

PARTICIPATING ORGANISATIONS

ACR+ (ASSOCIATION OF CITIES AND REGIONS FOR SUSTAINABLE RESOURCE MANAGEMENT)
Jean-Benoit Bel, Senior Project Manager

Philippe Micheaux Naudet, Senior Project Manager

AGRIPROTEIN
David Drew, Executive Director

BARILLA CENTER FOR FOOD & NUTRITION
Marta Antonelli, Research Project Manager

BIOPOLUS
Erzsébet Poór-Pócsi,
Senior Circular Economy Specialist

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Matilda Ho, Founder and Managing Director

BRIGHTLANDS CAMPUS GREENPORT VENLO
Maikel Borm, Business Developer

C40 CITIES CLIMATE LEADERSHIP GROUP
Zachary Tofias, Director, Food, Water and Waste Programme

CITY OF MILAN
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CENTER FOR ECOLITERACY
Leyla Marandi, California Thursdays Network Coordinator

CITY OF TORONTO
Annette Synowiec, Acting Manager, Unit for Research Innovation & a Circular Economy

EAT
Sudhvir Singh, Policy Director

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FROM WASTE TO TASTE – ASSOCIATION
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Michiel Van Meervenne, Founder

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MAPLE LEAF FOODS INC
Tim Faveri, Vice President, Sustainability & Shared Value

OREGON DEPARTMENT OF ENVIRONMENTAL QUALITY
David Allaway, Senior Policy Analyst

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Coen Bakker, Marketing Manager

TINY LEAF RESTAURANT AND SATIVA RESTAURANT
Justin Horne, Eco-Chef/Director

UNIVERSITY OF LINCOLN
David May, Senior Project Manager

VERT D'IRIS INTERNATIONAL
Frédéric Morand, Founding Manager

WBCSD
David Bennell, Manager of Food, Land and Water

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Marc Zornes, Chief Executive Officer

FOCUS CITIES

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BRUSSELS ENVIRONNEMENT
Joséphine Henrion,
Food and Consumption Service Manager

CIRCLEMADE.BRUSSELS BY HUB.BRUSSELS
Anthony Naralingom,
Circular Economy Cluster Coordinator

SHORT CHAIN SUPPORT FLANDERS
Clara Moeremans, Advisor Steunpunt Korte Keten

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Simon De Muynck, Research-action Coordinator

UNIVERSITÉ LIBRE DE BRUXELLES (LA CAMBRE-HORTA)
Stephan Kampelmann,
Chair in Circular Economy and Urban Metabolism

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ARRELL FOOD INSTITUTE
Evan D.G. Fraser, Director, Arrell Food Institute and Canada Research Chair, University of Guelph

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Kevin Litwiller, Director, Marketing and Communications

Mike Dougherty, Director, Product Management

LOBLAW COMPANIES LTD
Jennifer Lambert, Senior Manager, Sustainability

MICHAEL KEEGAN AND ASSOCIATES,
Michael Keegan, President

ONTARIO AGRI-FOOD TECHNOLOGIES
Tyler Whale, President

PORTO, PORTUGAL

ALIADOS – THE CHALLENGES CONSULTING
Vasco Sousa, Co-founder & Managing Partner

FÓRUM OCEANO – ASSOCIATION OF MARITIME ECONOMY
Carla Domingues, Project Officer

LIPOR – INTERMUNICIPAL WASTE MANAGEMENT OF GREATER PORTO, PORTUGAL
Susana Lopes, Senior Technician, Environmental Engineer

MUNICIPALITY OF PORTO, DEPARTMENT OF ENVIRONMENTAL PLANNING AND MANAGEMENT
Sara Velho, Senior Technician

Nuno Morais, Senior Technician

Pedro Pombeiro, Head of Department

SONAE MC
Pedro Lago, Director, Sustainability and Circular Economy

SÃO PAULO, BRAZIL

AB INBEV (AMBEV BREWERY)
Filipe Barolo, Environment Sustainability Manager

Richard Lee, Corporate Sustainability Manager

ABRELPE
Carlos R.V. Silva Filho, Executive Director

BASF SOUTH AMERICA
Emiliano Graziano, Corporate Sustainability Manager

CARREFOUR BRASIL
Felipe Luiz Alves, Sustainability Specialist

CEAGESP – GENERAL WAREHOUSING COMPANY OF SÃO PAULO STATE
Flávio Godas, Economist

CETESB – ENVIRONMENTAL AGENCY OF THE STATE OF SÃO PAULO
Flávio de Miranda Ribeiro, Manager, Department of Public Policy in Solid Waste and Resource Efficiency

COCA-COLA BRASIL
Andréa Valle Mota, Sustainability Director

IMPACTO ENERGIA
Danilo Trevisan, Director of Development and Technology

INSTITUTO ARQFUTURO
Beatriz Vanzolini Moretti, Project Developer

MORADA DA FLORESTA
Victor Hugo Argentino de Morais Vieira, Project Coordinator

PAULISTA STATE UNIVERSITY "JULIO DE MESQUITA FILHO" / ENGINEERING SCHOOL OF BAURU
Gustavo Henrique Ribeiro da Silva, Professor, Environmental and Sanitary Engineering

PLANT FAZENDAS URBANAS
Le Andrade, Founding Partner

Jean Roversi, Founding Partner

Jeison Cechella da Silva, Entrepreneur

SISTEMA B BRASIL
Flavia Pascowitch, Communications and Community Manager

Tatiana Mendizabal, Business and Strategic Alliances Manager

UNILEVER BRASIL
César Maida Freire, Sustainability and Communications Manager

Luísa de Moura Roberto, Marketing Coordinator

Michael Amorim de Oliveira, Sustainability Coordinator

UNION OF SÃO PAULO COMMUNITY GARDENS
Claudia Visoni, Member

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