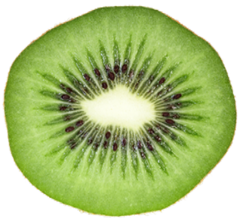
CITIES AND THE CIRCULAR ECONOMY FOR FOOD

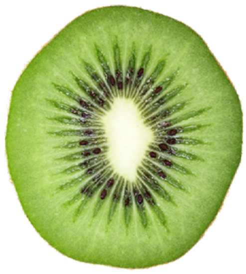


ELLEN MACARTHUR FOUNDATION

CITIES AND THE CIRCULAR ECONOMY FOR FOOD

This document includes a **project brief** for a major initiative focused on cities and the circular economy for food, and a supporting paper with an **introduction and background** to the bio-cycle economy and food system.

PROJECT BRIEF	4
APPENDIX 1	11
BIO-CYCLE ECONOMY AND FOOD — INTRODUCTION AND BACKGROUND	18
APPENDIX 2	30



PROJECT BRIEF

An outline for a study and systemic initiative to stimulate, inform and mobilise new approaches for restorative and regenerative urban food systems and related bio-cycle economic activity.

The need to transform today's food system towards one that is regenerative and restorative is generally well known. The main driver for this need has been thoroughly analysed: providing healthy food for nine billion people by 2050 under today's degenerative food and agriculture system will lead to substantial further environmental and social damage across rural and urban communities globally. Rural agriculture production centres need to shift towards regenerative as well as socially inclusive practices, while (mainly urban) consumption centres will need to transition to healthier diets, minimize food waste and (re) build biological nutrient loops. As with any major system-level change, these transitions will provide both new opportunities and additional risks, which public and private players will need to navigate.

The discussion on the transition towards a new food system over the last two decades has almost exclusively focused on the agriculture production system. However, it is becoming increasingly clear that demand-side measures – which will mainly take place in an urban context – are not only the missing vector required to achieve the target food system end-state, but also deliver additional health and economic benefits.

Therefore, a clear need exists for a concerted action agenda focused on building regenerative and restorative urban food systems. The Ellen MacArthur Foundation, through its application of circular economy principles, its system-level change approach, and strong experience in leading multi-stakeholder coalitions, is uniquely positioned to build such an agenda.

INTRODUCTION

This document outlines a new project by the Ellen MacArthur Foundation that will form the starting point for a major new initiative aimed at accelerating the transition to a circular economy for food. This project brief recognises the complexity and challenges facing global food systems, both upstream in (mainly rural) agricultural areas and downstream in (mainly urban) consumption centres (see Appendix 1: Project context, page 11). This project aims to both profile the overall landscape of circular economic opportunities in the food system, and focus on a sub-set of the value chain where circular principles are deemed to have the highest potential for positive economic, environmental, and social impact, namely peri-urban food production and consumption systems.

This project builds on the Foundation's previous work with the World Economic Forum on critical systemic materials challenges in the global economy, undertaken as part of Project Mainstream (see Appendix 1: Project MainStream, page 13). It also builds on the system-level change knowledge gained from the Foundation's recent and on-going initiatives that resulted from two major research publications: *The New Plastic Economy – Rethinking the future of plastics*, and most recently *A New Textiles Economy – Redesigning fashion's future*. In addition this work will build on the research and economic modelling undertaken by the Foundation on the European food system published in 2016 (*Growth Within - A circular economy vision for a competitive Europe*), circular economy case studies developed in Brazil, and most recently analysis undertaken for a major study in China including modelling of the food system (preview findings to be released at the WEF Davos meeting 2018).

AIMS AND OBJECTIVES

The objective of this study is to examine the economic opportunities and broader benefits that would be derived from adopting circular economic principles for food systems, with an emphasis on cities.

It aims to demonstrate these benefits by taking a systems perspective to food as part of a broader bio-cycle economy. This includes the valorisation – for high value uses beyond composting and biomass recovery – of food by-products along the value chain from production, processing, preparation, distribution, retail sales to consumption. The study will include a quantitative analysis of the economic benefits of following this approach.

The research will also identify the beneficial solutions offered by, and challenges faced by, emerging innovations, including case examples. Further, it will outline new forms of orchestrated collaboration with potential to scale and make a meaningful contribution to a more restorative and regenerative system.

THIS PROJECT HAS THREE MAIN OBJECTIVES:

1. **Provide a diagnosis of current urban food systems.** This will be achieved through examining the economic, environmental and social issues embedded in today's urban food systems. The research will aim to provide a new synthesis of the challenges of the current linear industrial food system, including projections of the risks inherent in continuing along a business as usual pathway.

2. **Create the design for a restorative and regenerative system by highlighting the main levers required to achieve system level change**, such as policy options, innovation scaling and public-private collaboration. This will be underpinned by analysis of both the economic conditions required to achieve the change and the opportunities arising from them. The study will also provide quantitative analysis to estimate the order of magnitude of the potential opportunities of a circular food economy in cities. This analysis will derive a simple set of measures to demonstrate the potential, ranging from monetary terms for the economic benefits to, for example, reductions in million tonnes of GHG emissions.

3. **Start implementing change through the consortium of key actors from across the value chain**, who will be assembled not only to participate in the analysis and review of the report key findings, but also to actively shape and mobilise the subsequent initiatives and prototypes to deliver the report recommendations.

This first two objectives are in scope for the initial analytical phase of this project which will last throughout 2018. The subsequent implementation phase – scheduled to start towards the end of 2018 - will aim to achieve the third objective.

These three objectives will be underpinned by three principles:

- The work done will be complementary and add value to other relevant food and regenerative agriculture initiatives already in progress or development.
- It will contribute to a broader understanding of the issues, innovation opportunities, and benefits of an urban focus on the circular economy for food, and the need for a new system-level change approach to addressing these issues and capturing the value and broader benefits.
- The study will build upon the Foundation's established relationships and network of public and private actors from across the value chain who have influence on the food system and the urban bio-cycle economy, as well as academics (from the existing Foundation network as well as others brought into the consortium), knowledge partners, and platform partners who will be engaged to assist in the dissemination of the findings and promotion of the topic in order to significantly raise its profile.

KEY QUESTIONS TO BE ADDRESSED DURING THE ANALYTICAL PHASE

The analytical phase of the study will take a systemic view of urban food system and be governed by circular economy principles and characteristics. The research will explore the opportunities, economic rationale, and the required enabling conditions for change, focusing in particular on exploring the following key questions:

1. **How can a Circular Economy for food in urban areas contribute to sustainably feeding the global population in a healthy way?**
   a. What are opportunities across food systems to shift towards a more circular economy approach (e.g. regenerative agriculture, valorisation of by-products and waste, closing nutrient loops, protein substitution)
   b. What is the economic value of getting this right?
   c. What other system benefits would result from a circular economy of food, such as improved food system security and supply resilience, contribution to renewable energy sources, reduced GHG emissions, better water use, social benefits, and better quality of life in cities?
2. **What is the potential for value recovery from food waste in an urban bio-cycle economy and what would be the system benefits?**
   a. What are the opportunities for valorising the by-products of food production and consumption in the urban bio-cycle economy at scale, including leapfrogging opportunities in emerging markets (e.g. application of digital tools to enable informal economy, improve economics of small-hold agriculture etc.)
   b. What are the barriers to capturing this value and what are the enabling conditions required to overcome them?
   c. What is the potential for more coordinated food waste collection from: food processors; retailers; event caterers; other commercial food preparers such as restaurants, hospitals, prisons, and schools; and households to improve the economics and increase the volume of nutrient recovery?
3. **What role could urban/peri-urban farming play in future food systems and to what extent could the recovery of food nutrients in cities support this production?**
   a. What role could urban/peri-urban production play in future food systems (what share of production, what are target crops/ geographies)?
   b. How could the recovery of food nutrients in cities support this production?
   c. What are the systemic stalemates and other challenges/barriers (infrastructural, investment-related or other) to the utilisation of nutrients collected in cities to urban/peri-urban food production?

4. **How and to what extent could a circular economy of food contribute to improving diet and nutrition-related health outcomes?**
    a. To what extent could food innovation play a role in shifting dietary patterns, and to what extent could this shift contribute to improving the economics of nutrient looping?
    b. What is the role of food producers, packaged consumer goods companies, and retailers in promoting and enabling this shift in dietary patterns, and in the sourcing of food produced locally by urban/peri-urban producers?
    c. Can circular urban/peri-urban food production based on regenerative practices contribute to improved health outcomes?

APPROACH

The study will aim to understand the potential of larger scale collaborations across food producers, retailers and the major commercial actors involved in food preparation, in combination with cities and providers of solid/liquid waste infrastructure and services. It will also aim to understand the potential of emerging innovations to disrupt the current linear system and enable a circular one.

The study will bring a representative group of organisations from across the food value chain and the urban bio-cycle economy, to contribute to the qualitative and quantitative analysis, provide cases on emerging innovations and solutions and help identify and problem solve systemic stalemates and overcome barriers.

The approach to the quantitative analysis will include identifying and summing the main contributory factors to the headline potential of a circular economy for food in cities. In the case of reductions in greenhouse gas emissions as an example, these could include: avoiding direct methane emissions by treating waste in emerging countries (potential benefit of up to 10% of global CO_2, as estimated by the World Bank); avoiding GHG emissions from fossil fuels by using bio-energy, bio-chemicals, and bio-fertilizers (large potential – as demonstrated by multiple studies); and capturing CO_2 by regenerating soils by returning nutrients to nature (as demonstrated by Project Drawdown and others).

Important actors in the industrial food chain will be studied, including the packaged food producers, the major food retailers, and commercial food preparers. These actors will be of particular interest to the study, as together they play a major role in sourcing food and bringing it into cities.

The project will also identify a number of cities to profile and model as representative case studies (examples such as: Milan, which increased separate organic waste collection from 35% to 54% between 2011 and 2015; Meknés, Morocco, development case of a sanitary landfill site and a new composting plant; and Adelaide, Australia which composts 70% of its organic waste). The selected cities will include examples from the major geographies and different city sizes and types.

Other members of the consortium will include corporate or small scale businesses of the following types:

- Producers
- Distributors/wholesalers
- Retailers
- Processors
- Innovators/entrepreneurs
- Major caterers such as hospitals, other institutions, and event organisers
- Utilities
- Waste processors

The Ellen MacArthur Foundation will engage members of its existing network of formal relationships. These include: knowledge partners SYSTEMIQ, McKinsey & Company, Arup, IDEO; more than fifty academic partners and relevant institutions; 22 members of its governments and cities programme; members of the C40 cities network (also a formal partner of the Foundation).

A consortium has been formed of businesses (large incumbents and representative emerging innovators) from across the food system, including those providing food waste infrastructure and services, as well as relevant NGOs and other actors. This consortium contributed to the initial scoping paper (Urban Biocycles) for this study published at the World Economic Forum meeting in Davos, January 2017, as well as many additional members currently being assembled (see Appendix 1: Project Consortium, page 14).

In addition to businesses, the consortium will include key influencers and institutional organisations already engaged in complementary projects such as the United Nation’s Food & Agriculture Organisation, SRC and the EAT Foundation (see Appendix 1: Other related initiatives, page 15).

TIMEFRAME

The initiative will be formally launched at WEF Davos in January 2018 and the study will be undertaken during 2018 with the full report completed by November 2018 in advance of the report launch at Davos 2019.

The final project consortium set-up, research scoping, key analyses, timetable of reviews and major milestones will be developed over the coming months, and aligned with other related initiatives to ensure this project is distinctive, complementary, adds value to the understanding of the systemic opportunities, and has the potential to effect system-level change.

"It can be called, without being hyperbolic, the mother of all systemic problems"

Zaid Hassan, Author 'The Global Food System'

APPENDIX 1

PROJECT CONTEXT

CHALLENGES FACING TODAY'S INDUSTRIAL FOOD SYSTEM

The global food system is highly complex and interlinked. These interlinkages reach far beyond the food system itself, extending to many other important human physical and social systems such as energy, water, land use, climate, biodiversity and culture. This interconnectivity means that potential multiplying effects are wide-ranging and inevitably compounding.

The diversity of food production systems across the globe is well documented. In terms of size two major approaches can be categorised: large scale 'industrial chain' and smallholder 'peasant food webs'. However, international NGO ETC estimates the former feeds 30% of the planet but uses 70% of resources; the latter feeds 70% and uses only 30% of resources. The shortcomings of the industrial food system are numerous and varied, but for simplicity could be grouped under the following broad categories:

THE SYSTEM IS WASTEFUL

According to the Food and Agriculture Organization of the United Nations (FAO), roughly one third of the food produced in the world for human consumption every year — approximately 1.3 billion tonnes — gets lost or wasted. Food losses and waste amounts to roughly USD 680 billion in industrialized countries, where they happen mostly in retail and consumption, and USD 310 billion in developing countries, where they are more intense in early stages of food production in rural areas, and at the processing stage, although are also significant in cities. In China, 500 million people could be fed by the food that is produced but does not make it to the plate. 76% of the calories grown by the industrial food system are wasted, and only 5% of artificial fertilisers contribute to actual edible plant parts the rest is wasted.

Furthermore, growing populations and rapid urbanisation in emerging economies could lead to a significant rise in organic waste generation and its associated negative impacts. Indeed, by 2025 emerging economies are expected to generate 70% of global waste. At present, 60% of this total is organic, the primary generators of methane, and 80% of collected waste is disposed of in open dumps or sub-standard landfills.

THE SYSTEM CONTRIBUTES TO ENVIRONMENTAL DEGRADATION

For every $1 spent on food, $2.27 is required to clean up the damage (KPMG). Each year in the US we lose 4 tons of topsoil per acre, meaning that by some estimates we may only have 60 years' worth of topsoil remaining (Nikki Silvestri).

Industrialised farming practices cost the environment some USD 3 trillion per year (more than UK annual GDP) in negative environmental externalities across the value chain (FAO). Many agricultural industries would be unprofitable if such externalities were priced in, as they exceed industry revenue, sometimes many times over (Trucost). These externalities include: land degradation, which affects roughly a quarter of the global land surface (about 75 billion tonnes of fertile topsoil are lost each year, with an estimated annual loss of USD 490 billion - UN), and fertiliser run-off from agricultural land, which leads to nutrients accumulating in rivers, lakes and oceans and eventually to dead zones (ocean dead zones now affect 240,000 km2, an area approximately the size of the UK - Diaz and Rosenberg).

THE SYSTEM DOES NOT PRODUCE HEALTHY OUTCOMES

The nutritional value of food has diminished over time. Many foods contain traces of toxic chemicals and plastics. 50% of the world is hungry or undernourished, while 2.1 billion people are obese or overweight. 60% of human infectious diseases come from domesticated animals.

NUTRIENT FLOWS ARE DISRUPTED

The food system is overwhelmingly linear – it does not cycle nutrients effectively. Modern agricultural practices, such as excessive tillage and the use of heavy machinery, accelerate erosion and water runoff, carrying nutrients out of the soil and into water systems. As crops are harvested, nutrients and organic matter are removed; if they are not replaced, soil fertility decreases. Excessive use of pesticides and synthetic fertilisers, which may not contain all the necessary nutrients and organic matter, can also lead to increasing toxicity levels, reducing the soil's capacity to support growth. As more and more nutrients are lost and soil quality decreases, farmers increasingly turn to the use of synthetic fertilisers. Global demand for fertilisers was estimated at 185 million tonnes in 2014, and is forecast to grow 1.6% a year 2015-2019 (FAO).

Producing synthetic fertilisers typically involves mining finite resources such as phosphate rock, requires significant energy, and generates GHG emissions. Producing synthetic nitrogen fertilisers, for example, consumes 2% of the world's energy and, in 2007, generated 465 million tonnes of CO_2 emissions.

Megatrends such as globalisation, increasing population and urbanisation contribute to disrupt the nutrient cycle. The global food system and trade networks, for instance, can require extracted nutrients to be transported vast distances from their source. Urbanisation leads to nutrients being concentrated and discharged as food waste into solid waste streams, and into wastewater systems as sewage sludge. Concentration and discharge of nutrients in wastewater systems can also contribute to the dead zone problem mentioned above.

The challenge of recovering nutrients lost in cities and returning them to the soil or making other valuable use of them is formidable. For example, among the EU-27, 70% of the phosphorus in sewage sludge and biodegradable solid waste is not recovered and in Bangkok, an estimated 90% of the 26,000 tonnes of nitrogen that enters the city each year is lost, primarily through the city's waterways.

The crux of the issue is that nutrients are extracted from the biosphere as harvested food, and become concentrated in cities, subsequently causing damage where they are discharged, rather than being beneficially looped back to the soil.

CITIES AS A CATALYST FOR CHANGE

The world's cities are engines of economic growth and huge consumers of materials. A recent report by the Foundation highlighted that cities are home to 54% of the world's population and generate 85% of global GDP. Cities are also aggregators of materials and nutrients, accounting for 75% of natural resource consumption, 50% of global waste production, and 60- 80% of greenhouse gas emissions.

Cities' economic importance, large material flows, the diverse and concentrations of human talent, mean they are well positioned to catalyse a transition to a circular economy for food. As municipalities gain increased legislative independence and become political powerhouses on the global stage, they develop an unprecedented ability to shape their infrastructure and choose their development path.

They are therefore credible catalysts for change and already lead on topics like climate change and air pollution. Food production and distribution is on their agenda and is likely to become the next urban frontier.

PROJECT MAINSTREAM

Project Mainstream is a CEO led initiative, jointly established by the World Economic Forum and the Ellen MacArthur Foundation as a platform for tackling complex systems challenges related to global material flows. Project Mainstream recognises that new approaches and forms of collaboration are required in order to accelerate development of scalable solutions and to address stalemates that present barriers and challenges to their implementation.

PROJECT CONSORTIUM

An initial consortium was established for the scoping of this project, and others listed are currently being approached to provide input as a project participant, including:

MAINSTREAM BOARD MEMBERS

Averda

Royal DSM

Suez

Veolia

Ecolab (Nalco)

Philips

Royal DSM

Tarkett

CONSORTIUM CORE MEMBERS, PARTICIPANTS AND TARGET CONTRIBUTORS

EUROPE

Anglian Water

Bio-based industries

BioCycle

Bio Innovators Europe

CCM Research

Coca-Cola

Co-op

Danone

Desso

European Sustainable Phosphorus Platform

Global Green

Google

Intesa Sanpaolo

McDonalds

M&S

Novamont

Sainsburys

Soil & Shadow

Syngenta

Tesco

Toilet Board Coalition

Unilever

USA

Aerofarms

Amazon/Whole Foods

Better Food Ventures

CapGrow

Coca-Cola

Compass Group

Danone

Food System 6

Google

Gotham Greens

IKEA

Land O'Lakes

ReFED

Sweetgreen

Unilever

Walmart

Wegmans

Western Growers Association

BRAZIL

CBPak

Coca-Cola

Danone

Embrapa

Grupo Pão de Açúcar

Native

Refettorio Gastromotiva

Rock in Rio

Saladorama

Sapore

Unilever

University of São Paulo

Zebu

Zona Sul supermarkets

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Sean de Cleene, Head of Food Systems, WEF

Professor Edgar Hertwich, Yale University

Dr David Montgomery, University of Washington

Justin Mundy, International Sustainability Unit

Professor Nabil Nasr, Rochester Institute of Technology

Jane Nelson, Mossavar-Rahmani Center for Business and Government, Harvard University

Raymond Offenheiser, University of Notre Dame

Janez Potočnik, International Resource Panel

NOTE: Our intention is to ensure representation from across the bio-cycle economy and food system value chain, including growers/producers, processors, retailers, commercial food preparers, key influencers, cities and regulators, food innovators, the venture community, the waste and waste water industry, academics and experts.

OTHER RELATED INITIATIVES

The final project design will be informed through consultation with other key initiatives to ensure the work undertaken is both distinct and complementary and beneficially additive to these efforts.

EAT FOUNDATION (2014) SCANDINAVIA

Transformation in food system under the following themes: metrics for healthy and sustainable diets; synergies, trade off and spillover effects; the economies of food systems; consumer behaviour and choices; food stewardship and culture; and multifunctional landscapes and seascapes. Convenes annual Stockholm Food Forum.

FRESH (2017)

Joint program between EAT and WBCSD that aims to catalyse change across food systems taking into account local eating patterns and focusing on five work streams. Puts large and small businesses at the heart of the equation for transformational change, and works with 200 leading global companies to deliver sustainable business led solutions.

SUSTAINABLE FOOD LAB (2004) VERMONT

Global network of organisations accelerating progress towards a more sustainable food system. Advise on sustainability strategy and procurement programs, pre-competitive collaboration and provide leadership development.

WRI-WORLD RESOURCES REPORT (2013-2016), WASHINGTON

How can the world adequately feed nearly 10 billion people by 2050 in a manner that advances economic development and reduces pressure on the environment? 11 working papers and a menu of workable and scalable solutions.

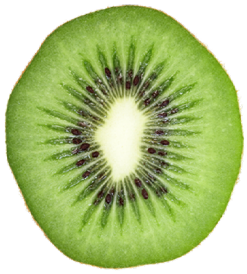
MILAN URBAN FOOD POLICY PACT (MUFFP) (2015)

An international pact signed by 160 cities with more than 450 million inhabitants committing to working together to develop sustainable food systems that are inclusive, resilient, safe and diverse. Includes a voluntary framework for action with 37 recommended actions.

C40 THE FOOD SYSTEMS NETWORK

Builds on the activities of MUFFP, supporting efforts to create and implement comprehensive solutions that reduce carbon emissions and increase resilience throughout the urban food system. Knowledge sharing, best practices and collaborative projects in four food focus areas: procurement, production, supply and distribution and waste.





BIO-CYCLE ECONOMY AND FOOD — INTRODUCTION AND BACKGROUND

INTRODUCTION

At the World Economic Forum's 2017 Annual Meeting in Davos, the Ellen MacArthur Foundation, within the framework of Project Mainstream, published a scoping paper 'Urban Bio-cycles', which described the unrealised potential of the 'urban bio-cycle economy'. This is the sector of the bioeconomy encapsulating the considerable quantity of organic nutrients flowing through the world's cities. The paper set out the substantial economic benefits that could be gained by adopting more circular approaches to the way we manage organic nutrients, primarily through more effective recovery of valuable energy and materials. The report also highlighted the many consequential positive environmental and social impacts that could result from such approaches.

Since then the Foundation, through continuing consultation and research efforts, has been building on the report's findings. For example, the China Cities project undertaken with knowledge partners Arup and McKinsey & Co., focuses on a number of aspects of the bio-economy in the Chinese urban context. The Foundation's research on the topic during 2017 has been bolstered by extensive consultation with industry and academics, participation in and knowledge building from many international conferences, as well as lessons learnt from ongoing systemic initiatives on plastics and fibres.

One clear lesson that has emerged, with fairly universal agreement, is that the global food system, comprising a significant part of the bioeconomy, is increasingly challenged. The industrial production model that we use to produce and distribute much of our food does not use resources effectively and has a number of serious associated problems, not least that an estimated 30% of food grown is wasted,[1] and the way we produce food causes widespread degradation of natural capital. This troubling situation will be significantly exacerbated by significant population growth and shifting demographics in the next 30 years.

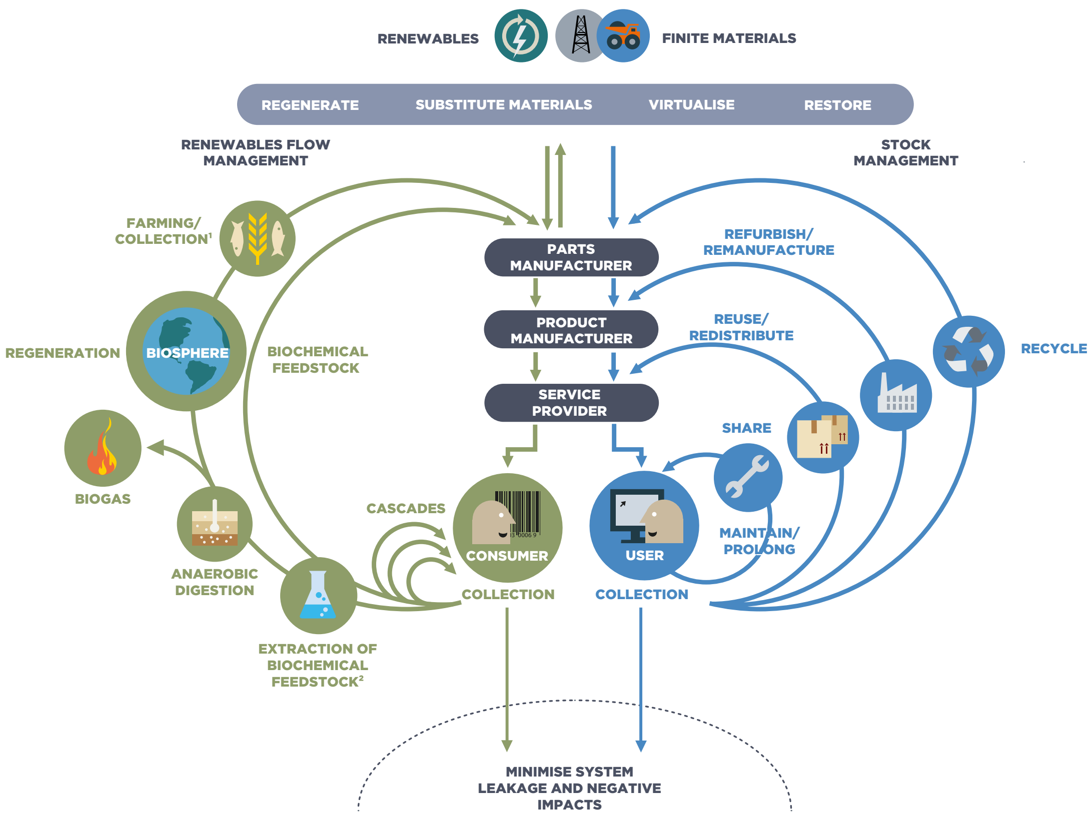
1 http://www.un.org/apps/news/story.asp?NewsID=45816#.WjpwgVSFhTY

Concisely put, our current food system operates on a wasteful linear model with many lost opportunities and consequential negative social and environmental impacts, all of which are set to increase.

A circular economy of food, rooted in the bio-cycle side of the circular economy system diagram (see Figure 1), emphasises the regeneration of natural capital by closing nutrient loops, as well as the potential for cascading additional value from organic nutrients as they metabolise on their journey back to the biosphere, or to be used for energy recovery. The theory offered by the Ellen MacArthur Foundation is that shifting to a circular economy of food could lead to more economic prosperity, contribute to natural system re-building rather than degradation, and lead to better health outcomes.

The global food system is huge and complex, comprising a long value chain of direct stakeholders, which in developed markets can extend across regional and national boundaries (for example, average 'farm to fork' distance in the US extends over 1,500 miles).[2] As well as large agribusinesses, the sector includes chemical companies, equipment suppliers, insurers, investors, and other industry players. More simply, the food value chain can be separated into upstream producers: the 'agricultural system' and downstream consumers: 'the urban food system'.

FIGURE 1: CIRCULAR ECONOMY SYSTEM DIAGRAM



1 Hunting and fishing
2 Can take both post-harvest and post-consumer waste as an input
Source: Ellen MacArthur Foundation, drawing from Braungart & McDonough, Cradle to Cradle (C2C)

2 https://cuesa.org/learn/how-far-does-your-food-travel-get-your-plate

THE IMPORTANCE OF CITIES

Cities are the largest consumers of resources, as well as the greatest producers of harmful emissions and waste. A large proportion of this material usage is directly associated with the urban food system.

The hypothesis of this paper is that, because of these high levels of demand, material aggregation, and negative externalities, the urban/peri-urban production and consumption system is a part of the food value chain where circular economy principles will have a high potential for positive impact.

This paper sets out the context for this hypothesis, describing in more detail the challenges facing the food system, including its many connections to other key physical and social systems. It will begin to describe the economic opportunities that exist in a circular economy for food in a city context as well as the other systemic benefits, highlighting in particular the potential to reduce greenhouse gas emissions.

BACKGROUND

NATURAL SYSTEMS IN THE BIOSPHERE

Natural systems are based on the production of complex organic compounds from simple materials via photosynthesis powered by the sun. This natural production process combines with biodegradation/nutrient cycling, which breaks down complex organisms back into fundamental building blocks (‘nutrients’) contributing to the regeneration of soil and allowing new generations of life to prosper.

The regenerating qualities of natural systems are the inspiration for the flow of biological nutrients in a circular economy, where, just like in nature, waste does not exist but is always valuable feedstock for the next stage in the cycle.

In the bio-cycle of the circular economy, organic matter, free of toxic contaminants, gradually breaks down, cascades through different value-extracting stages, before returning safely to the soil. In so doing, the cycle regenerates, and thus in the words of biomimicry pioneer Janine Benyus “creates conditions conducive for new life”.

THE WORLD’S BIGGEST INDUSTRY

The economic activities that stem from natural systems and nutrient cycling are categorised as the ‘bio-economy’. This is the sector of the economy that cultivates and collects plants, animals and funghi for food, energy, structural materials, medicines and other products to benefit humans. The bio-economy accounts for 17% of all global economic activity annually, generating USD12.5 trillion of value. Within the bio-economy, the food and beverage industry is the largest sector.

The food industry, the sector of the bio-economy that feeds the majority of the world’s population, has been called by some the ‘world’s largest industry’,[3] with over 1 billion people working each day to grow, process, transport, market, cook, pack, sell and deliver food. In Europe, the food and drink industry is the largest manufacturing sector in terms of jobs and value added.[4] In emerging

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3 https://www.forbes.com/2007/11/11/growth-agriculture-business-forbeslife-food

4 https://ec.europa.eu/growth/sectors/food_en

and developing economies, over 500 million smallholder farmers feed about 70% of the world.[5]

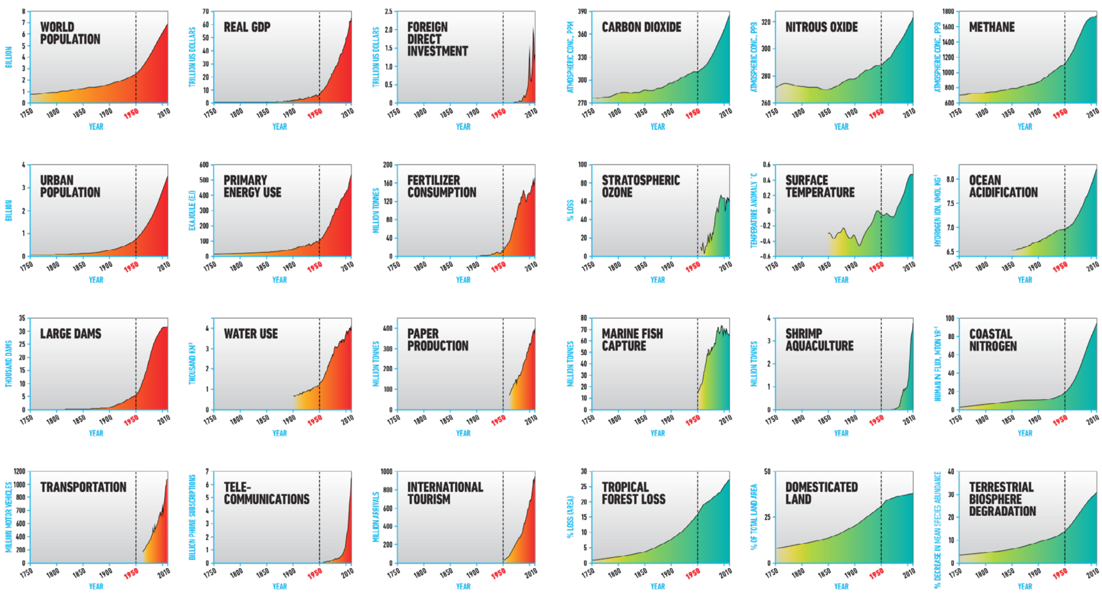
The global food industry requires huge volumes of resources (energy, water, land, equipment) to sustain it. In turn it generates vast amounts of waste and harmful emissions:

- 50% of the planet's habitable land is taken up by agriculture
- Agriculture accounts for 70% of freshwater consumption
- One third of greenhouse gas emissions come from agriculture[6]
- Cities produce about 700 million tonnes of organic waste per year, a figure expected to double by 2025.

CURRENT FOOD SYSTEM LANDSCAPE

The Green Revolution, along with other recent technological and medical advances, have led to what the Stockholm Resilience Centre calls the 'Great Acceleration', a period of human development over the past 50 years where many key socio-economic indicators and earth system trends has gone from linear to exponential (see Figure 2, and Appendix 2: History of food production, page 30).

FIGURE 2: THE GREAT ACCELERATION



Since the industrialisation of agriculture, the system that feeds the human population has evolved from predominantly local farms serving local markets into a complex network of farmers and stakeholders (the 'food value chain') operating in a fully global marketplace, one that allows many people to eat most foods, in most places, most of the time.

At the same time, market forces that drive yield and efficiency, as well as practical reasons such as ease of storage, have transformed a small number

5 http://www.fao.org - Coping with the food and agriculture challenge: smallholders' agenda
6 https://www.nature.com/news/one-third-of-our-greenhouse-gas-emissions-come-from-agriculture

of plants species such as corn, rice, soya, sugar, oil palm, and a few others into 'commodity crops'. This small group of grains and legumes, now the 'backbone of the human diet', have come to dominate (see Appendix 2: Land use, page 30). In the US, 30% of arable land is planted with corn, although only a small proportion of this is used to feed people (40% of the harvest, for example, is used for biofuels).[7] Between 2000 and 2012, Indonesia replaced almost 10,000 km^2 of virgin rainforest annually with palm oil plantations. The primacy of these few crops has led to the emergence of a significant new player, the food processor, engaged in the business of converting commodity crops into branded food products.

THE FOOD VALUE CHAIN

The shift from local farms serving local markets to today's complex modern food industry is more easily understood through the concept of the 'food value chain' (see Appendix 2: Food value chain, page 31). This term is used to describe the sequence of activities from farm to fork to waste.

A distinction can be made in the chain between: the agricultural system (the upstream material extraction and production end of the chain); and the – mainly urban – food system (the downstream supply chain and consumption end of the chain). From an analytical perspective, these two groups could be considered separately, while other actors (e.g. finance, insurance, digital) act as enablers across the entire chain. Businesses such as 'waste processors' and logistics companies play an important interface role between the two groups.

The agricultural system has been the main focus of most previous and current efforts to improve the global food system. The reasons for this are self-evident: most of the resource use issues and environmental impacts are connected to this part of the value chain.

The global food production system can be simplified into two distinct parts: the industrial system and the smallholder farmer system. This distinction allows us to describe concisely the problem that exists. The industrial part of the system produces 30% of food, using 70% of the resources, while at the same time degrading the environment. The smallholder/peasant system, produces 70% of the food, using 30% of resources, with a very low environmental impact (see Appendix 2: Production systems, page 32).

The potential of the urban food system to drive positive transformation is less well-analysed, which on the surface is well-justified; after all, from a production perspective, the crop types suited to urban production can only realistically represent 10% of our needs.[8] However, how we produce food is only part of the story. The type and quality of food products we manufacture, the impacts they have on our health and living environment, and the effectiveness with which we use our food resources and recover the nutrients within them are determined by the non-production, non-farming actors in the food value chain.

This may be the time that, just like in other industries such as mobility and the built environment, certain drivers and enablers, for example predictions on macrotrends and other forces, the looming water crisis, technological advances,

7 https://www.ers.usda.gov/topics/crops/corn/background.aspx

8 https://www.washingtonpost.com/lifestyle/food/why-small-local-organic-farms-arent-the-key-to-fixing-our-food-system/2017/09/21/

and emerging health issues, the conditions are right for the urban food system to play an important role in bringing about change.

MACRO TRENDS AND FORCES

There are a number of macro trends that will put increasing pressure on global food systems in the next 30 years. By 2050, global population is estimated to grow by nearly a third to 9.1 billion. More people on the planet, combined with increased urbanisation and growing affluence, will mean not only a rise in the overall volume of food produced and consumed, but also in demand for high protein food types such as red meat and fish. The overall impact has led some experts to estimate that accommodating these changes will require a doubling in crop production over this time.[9]

To exacerbate the challenge, at the same time as demographics shift, climate change and land degradation could significantly reduce the area of reliable arable and pasture land. The industrial food system is responsible for 75 billion tonnes of topsoil loss each year.

The majority of the population growth is expected in emerging and low income economies. In India, the growth forecast is estimated as 20% from about 1.3 to 1.6 billion by 2050. However, the largest growth projection is for sub-Saharan Africa, where the population is expected to more than double from 1.2 to 2.5 billion. The urban population, which represents currently about 54% of the world's population, could increase up to 70%, so that by 2050 there could be 2.5 billion more city dwellers. This would be a greater increase than the overall global population growth over the same period.

Changes in dietary patterns, rather than population growth, may exert a greater pressure on global food systems. Economic growth generates an expanding middle class, which leads to patterns of higher protein consumption, and the increased use of convenience and processed foods. In the last three decades demand for meat has tripled in developing economies, and egg consumption has increased sevenfold. Since 1990, as China's economy has grown, pork consumption has more than doubled and consumption of beef and poultry has quadrupled. Even though China has the world's largest overall demand for livestock and poultry, its per capita demand (about 54kg/year) is only just above the global average, and far below countries like New Zealand, Australia and the US that have a per capita consumption greater than 100kg/year.

THE CHALLENGES FACING TODAY'S INDUSTRIAL SYSTEM

The problems arising from the industrial food system are numerous and varied, but they mostly stem from a linear approach to the management of biological nutrients (see Appendix 2: Disrupted nutrient flows, page 33). Instead of regenerating the biosphere, these nutrients are discarded in ways that lead to costly externalities.

Crucially, the food system is just one way in which the human economy interacts with nature. Therefore, the negative impacts of a wasteful and polluting food system extend into many other important earth and socio-economic systems. For simplicity, the shortcoming of the global food system can be grouped under three broad categories:

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9 https://www.nationalgeographic.com/foodfeatures/feeding-9-billion/

THE SYSTEM IS WASTEFUL

According to the Food and Agriculture Organization of the United Nations (FAO), roughly one third of the food produced in the world for human consumption every year — approximately 1.3 billion tonnes — gets lost or wasted. Food losses and waste amounts to roughly USD 680 billion in industrialized countries, where they happen mostly in retail and consumption, and USD 310 billion in developing countries, where they are more intense in early stages of food production in rural areas, and at the processing stage, although are also significant in cities. In China, 500 million people could be fed by the food that is produced but does not make it to the plate. 76% of the calories grown by the industrial food system are wasted, and only 5% of artificial fertilisers contribute to actual edible plant parts the rest is wasted.

Furthermore, growing populations and rapid urbanisation in emerging economies could lead to a significant rise in organic waste generation and its associated negative impacts. Indeed, by 2025 emerging economies are expected to generate 70% of global waste. At present, 60% of this total is organic, the primary generators of methane, and 80% of collected waste is disposed of in open dumps or sub-standard landfills.

THE SYSTEM CONTRIBUTES TO ENVIRONMENTAL DEGRADATION

For every $1 spent on food, $2.27 is required to clean up the damage (KPMG). Each year in the US we lose 4 tons of topsoil per acre, meaning that by some estimates we may only have 60 years' worth of topsoil remaining (Nikki Silvestri).

Industrialised farming practices cost the environment some USD 3 trillion per year (more than UK annual GDP) in negative environmental externalities across the value chain (FAO). Many agricultural industries would be unprofitable if such externalities were priced in, as they exceed industry revenue, sometimes many times over (Trucost). These externalities include: land degradation, which affects roughly a quarter of the global land surface (about 75 billion tonnes of fertile topsoil are lost each year, with an estimated annual loss of USD 490 billion - UN), and fertiliser run-off from agricultural land, which leads to nutrients accumulating in rivers, lakes and oceans and eventually to dead zones (ocean dead zones now affect 240,000 km2, an area approximately the size of the UK - Diaz and Rosenberg).

THE SYSTEM DOES NOT PRODUCE HEALTHY OUTCOMES

The nutritional value of food has diminished over time. Many foods contain traces of toxic chemicals and plastics. 50% of the world is hungry or undernourished, while 2.1 billion people are obese or overweight. 60% of human infectious diseases come from domesticated animals.

KEY RELATED SYSTEM ISSUES

"*It can be called, without being hyperbolic, the mother of all systemic problems*"
ZAID HASSAN, AUTHOR, 'THE GLOBAL FOOD SYSTEM'

The global food system is highly complex and interlinked. These linkages reach far beyond the food system itself, extending to many other important human physical and social systems, in particular climate, energy, water, land use, biodiversity, and culture. This interconnectivity means that potential multiplying effects are wide-ranging and compounding.

Consider climate for example. Agriculture is among the largest contributors to global warming, emitting more GHGs than the entire transport sector, largely through methane and CO2 released by cattle, rice farms, forest clearance, fertilizer use and production. The potential for reducing GHG emissions through more circular approaches is explored later in this document.

The impact of the food system on global freshwater resources is huge. Agriculture is the planet's thirstiest economic sector, consuming about 70% of the freshwater used by humans, while at the same time being a major pollution vector through fertiliser and manure run-off from fields that can suffocate fragile aquatic ecosystems. Moving water, for example to use for irrigation, requires energy, as does harvesting and processing food. The water-food-energy nexus concept acknowledges the inseparability of these critical life systems.

OTHER SYSTEMIC IMPACTS

- **Land use –** to grow crops humans have cleared an area of land equivalent to South America; to rear livestock we have cleared an area equivalent to Africa
- **Soil degradation –** leading to less nutritious food, reduced water infiltration, loss of biodiversity, smaller farm profits, carbon release, and heat island effects
- **Energy –** industrial agriculture consumes 3-5% of the world's annual natural gas supply to manufacture synthetic fertilisers; the average American uses 2,000 litres of oil equivalent a year to put food on the table
- **Biodiversity –** mono-cropping and pesticides creates vast single species areas that eliminate biodiversity; conversely, higher yield farming means less forest has to be cleared so this biodiversity is retained
- **Disease –** 60% of all human infectious diseases are transmitted by domesticated animals; antibiotics used as livestock growth promoters have contributed to antibiotic resistance that costs USD 55 billion a year
- **Culture –** industrialised agriculture, which is viable only at scale, drives down food costs forcing small and medium size farms to close down. These farms get absorbed by large farms and an important part of the cultural fabric of rural areas disappears. Ex-farmers move to cities to find work, increasing pressure on urban resources
- **Inequality –** heavily subsidised rich country farms lower global food prices, flooding cheap exports into poor, unsubsidised farmers who can no longer compete.

The many internal and external linkages mean that potential multiplying effects are wide-ranging, inevitably compounding, and can often to lead to unpredictable and unwanted emergent effects.

CITIES AS A CATALYST FOR CHANGE

The world's cities are engines of economic growth and huge consumers of materials. A recent report by the Foundation highlighted that cities are home to 54% of the world's population and generate 85% of global GDP. Cities are also aggregators of materials and nutrients, accounting for 75% of natural resource consumption, 50% of global waste production, and 60- 80% of greenhouse gas emissions.

Cities' economic importance, large material flows, the diverse and concentrations of human talent, mean they are well positioned to catalyse a transition to a circular economy for food. As municipalities gain increased legislative independence and become political powerhouses on the global stage, they develop an unprecedented ability to shape their infrastructure and choose their development path.

They are therefore credible catalysts for change and already lead on topics like climate change and air pollution. Food production and distribution is on their agenda and is likely to become the next urban frontier.

THE CIRCULAR ECONOMY POTENTIAL FOR URBAN FOOD SYSTEMS

The Foundation has previously undertaken a number of studies that have analysed food systems in different socio-economic contexts, including Europe, Brazil, India, and China's cities.

Debate over the last decades on the need to transform the food system has focused almost exclusively on the agricultural system. However, it is clear that downstream actors, residing mainly in an urban context, are a crucially important vector required to achieve the target food system end-state – the right food in the right place at the right time. These actors can also catalyse systemic change in the urban food system and could therefore play an important role in closing nutrient loops and reversing natural system degradation.

CITIES AND THE CIRCULAR ECONOMY FOR FOOD

A number of key questions need to be addressed in order to understand the potential of circular food systems in an urban context and the extent to which this could both contribute to feeding the global population in a healthy way and to what extent it can add value to the economy. Additionally, it needs to take into account questions including:

1. How can a Circular Economy for food in urban areas contribute to sustainably feeding the global population in a healthy way?
2. What is the potential for value recovery from food waste in an urban bio-cycle economy and what would be the system benefits?
3. What role could urban/peri-urban farming play in future food systems and to what extent could the recovery of food nutrients in cities support this production?
4. How and to what extent could a circular economy of food contribute to improving diet and nutrition-related health outcomes?

The potential benefits from transitioning to this new approach are wide-ranging. They include increased economic activity (including new revenue streams and jobs); reduced operating costs for utilities; greater food security; more pleasant city spaces; greater urban-rural connectivity; preservation of rural green spaces; less packaging; reduced water demand; educational benefits, including greater appreciation of food provenance; and improved physical and mental health.

As well as direct benefits, because of the linkages described previously, there are also many potential systemic benefits. One crucial one is the significant reduction in the carbon footprint associated with the food system.

CARBON REDUCTION POTENTIAL

Agriculture generates more GHG emissions than cars, planes, and all other forms of transport combined. Cities are responsible for over 75% of all global GHG emissions. Within cities a large proportion of emissions are associated with a linear approach to food production systems and the mis-management of discarded organic nutrients. There is therefore significant potential to reduce carbon emissions by shifting to more circularity in urban food systems.

According to a study by Circle Economy, applying four circular economy levers in the urban bio-economy could reduce Amsterdam's carbon emissions by 600,000 tonnes a year (3% of its annual emissions), and save 75,000 tonnes of raw materials.[10]

In emerging economy cities, where waste volumes are increasing rapidly and a large proportion of organic matter is landfilled, the potential for carbon reduction is even greater. Listed below are three circular economy levers applicable to the urban food system and how these levers can contribute to a lower carbon footprint:

1) CLOSING NUTRIENT LOOPS AND EMPLOYING REGENERATIVE AGRICULTURE

The organic/carbon content of soil is a close approximation for its health and ability to produce abundant future generations of nutritious crops. Soil carbon is also a very important 'sink' in the global carbon cycle, holding three times more than the atmosphere.

Regenerative agriculture views the farm as one part of a larger ecosystem, the central concern being the preservation of soil health. By returning organic matter to the soil in the form of composted by-products, food waste or digestates from treatment plants, organic content in topsoil increases and soil structure improves, protecting it from erosion.

The potential for carbon sequestration through regenerative agriculture is very significant. Project Drawdown, a comprehensive plan to reduce GHG emissions co-ordinated by Paul Hawken, concluded that it could reduce emissions by 23.2 billion tonnes annually. A white paper by the Rodale Institute,[11] estimates that it could sequester the equivalent of all current carbon emissions. The benefits of healthier soils also include a reduction in both irrigation water demand and chemical inputs, higher yields, and more nutritious crops.

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10 https://www.circle-economy.com/developing-a-roadmap-for-the-first-circular-city-amsterdam/

11 https://rodaleinstitute.org/assets/WhitePaper.pdf

Examples of regenerative nutrient cycling on a large scale is well documented. The application of such approaches at a smaller scale in an urban or peri-urban context is less well explored. In this context, the small distance between farm, consumer and waste producer would suggest that from a logistics perspective, such an approach holds potential.

2) RECOVERING VALUE FROM ORGANIC NUTRIENTS

Left to rot, for example in landfills, organic matter will release methane, a potent greenhouse gas, which worldwide contributes to 28% of overall global GHG emissions.[12] Better management of discarded biomass can reverse this contribution, not only by reducing landfill emissions, but also by displacing carbon emitted from other processes and sources.

The controlled production of biogas, through engineered anaerobic digestion (AD) systems, can either be injected into the natural gas network or converted to electricity, transforming problematic methane into useful, revenue earning carbon-neutral energy. Biogas generating systems located in wastewater treatment plants enable these plants to directly offset their energy demand from the grid, in some cases generating a surplus that can be sold to the local utility. Board members of Project Mainstream, Suez and Veolia, have both demonstrated the clear business case for energy recovery from organic matter through AD in their Ametyst and Artois sites.

In India, 70% of urban wastewater treatment plants do not function because of unreliable or expensive energy supplies, costing an estimated 6% of national GDP. If all future Indian wastewater plants could be designed to be energy positive, the impact on the economy and quality of urban life would be tremendous.

Energy recovery from organic matter represents a direct way that circular economy thinking can lead to a reduction in GHG emissions from urban food systems. There are also less direct, but no less impactful ways. Biorefineries, described in the Urban Bio-cycles report, could be the workhorses that unlock this carbon reduction potential. To give one example, Agriprotein is a London based start-up that has developed a process for converting food waste from restaurants, canteens and shops, as well as by-products from farms and processors, into highly nutritious meal made of insects. The product is marketed primarily as feed for the aquaculture sector but can also be used for poultry and pig rearing. The carbon reduction potential for the aquaculture industry, a fast expanding sector due to growing demand for fish coupled with diminishing wild stocks, has been estimated at 80%. Much of this carbon reduction is associated with reduced transport distances if feed production is sited close to raw material inputs and to consumers.

12 https://www.skepticalscience.com/methane-and-global-warming.htm

3) URBAN AND PERI-URBAN AGRICULTURE

Growing food closer to where it will be consumed can reduce its carbon footprint in a number of ways. A study from the city of Seoul, analysing 13 crops appropriate for urban agriculture, estimated that the potential carbon reduction was equivalent to 12,000t a year, the same amount of CO2 absorbed annually by 20 km2 of mature pine and 10 km2 of oak forest.[13] Food transport distances, which account for 11% of food-related emissions (an average evening meal travels 30,000km), are also greatly reduced. The amount of food packaging, which accounts for 80% of food related emissions[14] (each plastic cup generates 17g of carbon), is also reduced. The proximity of food producer and consumer also means lower energy demand and carbon emissions to return nutrients to the soil by transport or pumping.

The method of food production can reduce carbon emissions in a number of direct and indirect ways. Locating farms on urban roofs can have a cooling effect in summer and an insulation effect in winter. This combination can reduce the energy consumption of the building below. Harvesting water falling on the roof surface both reduces irrigation water demand from municipal supplies and the volume of water entering the sewage system. Hydroponic systems allow food to be cultivated in areas where soil or climatic conditions are unfavourable such as the Gulf states. Growing food in this way displaces carbon intensive logistics and packaging associated with importing food. Hydroponic systems also recycle water and nutrients, both of which have an associated energy demand and hence carbon footprint.

13 https://www.sciencedirect.com/science/article/pii/S0169204615000663

14 https://www.amsterdam.nl/bestuur-organisatie/organisatie/ruimte-economie/ruimte-duurzaamheid/making-amsterdam/publications/sustainability-0/towards-the/

APPENDIX 2

HISTORY OF FOOD PRODUCTION

The history of agriculture is the history of civilisation. The domestication of wild plant and animal species allowed for a more sedentary existence, giving rise to cities and culture.

For most of human history, food production was mainly seasonal and local. However, the emergence of new technologies such as silage (fermented feed), which allowed cattle to survive winter and led to increased herd sizes, and mechanisation that allowed refrigerated storage, food canning, and new forms of farm equipment, precipitated the shift towards an industrialised food system.

In the first half of the 20th century a number of innovations triggered a step change in agricultural productivity, the amount of crop that could be grown per hectare, and in the efficiency with which these crops could be harvested. The Haber-Bosch process, an artificial nitrogen fixing process led to the mass production of chemical fertilisers. The internal combustion engine allowed the mechanisation of sowing, harvesting, and processing. The hybridisation of seeds allowed the development of high yield, drought resistant plant strains. Mechanised irrigation allowed previously unproductive lands to be watered. Chemical pesticides were developed to target crop-devouring bugs and weeds.

The combination of these technologies created a 'Green Revolution' in agriculture, the impact of which was significant enough to earn its 'father' Norman Borlaug, the Nobel Peace Prize. In the US it led to a 5x increase in agricultural productivity, shifting US maize yields, for example, from 1.8t/ha in 1940 to 8.6t/ha in 2000, creating huge surpluses. In Mexico it transformed the country to being food dependent to self-sufficient. In India, rice yields tripled from 2 tons/ha to 6 ton/ha in three decades. In the same period rice costs fell from $500/ton to $200/ton and the country became a major rice exporter.

However, just like its analogue the industrial revolution, two centuries of productivity gains were coupled to the consumption of finite resources and numerous environmental and social externalities.

LAND USE

The crops and biomass cultivated for the food industry use a vast amount of land, but often quite ineffectively. In the industrial food system, for example, only 24% of the food calories grown make it to the plate. At the same time as being wasteful, intensive cultivation methods rely heavily on chemical fertilisers, leading to pollution and extensive loss of topsoil. The result has been that in 40 years the earth has lost about a third of its arable land, requiring 7.5 million hectares of forest to be cleared each year.

Livestock rearing for meat production is particularly problematic. Of the earth's land area about 70% is habitable. Of this habitable area, 50% is taken up by agriculture and over three-quarters of this area is dedicated to livestock grazing and production of livestock feed. However, meat only provides 17% of calories and 33% of protein for global consumption. Demand for more crops to feed livestock is the reason that many experts believe we will have to double crop production by 2050.

Land use is inextricably linked to the carbon and water cycles. Forested areas sequester carbon (the soil holds 4x more carbon than the atmosphere) and hold the soil together, helping water absorption and preventing erosion. When land is converted from its natural state to conventional agriculture, the percentage of organic soil carbon drops significantly. This can be countered by different approaches to cultivation such as permaculture or regenerative agriculture.

As indicated earlier, food production may need to increase by as much as 70% by 2050. This production, using conventional methods, will need to take place on currently available farmland, or an even smaller area as much of this land is being degraded. Clearing more forest or other natural areas cannot be viewed as an option due to the reduced carbon sequestration described above and loss of biodiversity. New methods of food production in deserts and the ocean should also be explored.

FOOD VALUE CHAIN

AGRICULTURAL SYSTEM

- Production – farming or wild food collection, large or small scale, industrialised or artisanal. Modern food production is dominated by a small group of commodity crops such as rice, soya, corn, sugar and coffee.

URBAN FOOD SYSTEM

- Processing – the preparation of fresh food for markets, the conversion of commodities into food products. Includes meat slaughtering and processing, grain and seed milling, bakeries, dairies, snack manufacturing, and product packaging.
- Retail – from large supermarkets to small convenience stores, and increasingly online sales channels. Such markets can be highly concentrated. In the UK, for example, four supermarkets control between them 75% of the food market, and therefore exert great influence over the agricultural sector.
- Preparation – includes catering companies, restaurants, staff canteens, hotels, cafes, hospitality companies, schools, and hospitals.
- Consumption – consumers whose tastes and habits vary hugely both across and within countries. Consumer trends are affected by cultural factors as well as new scientific evidence, and can change rapidly. The growing affluence of many consumers is probably the main driver of shifting dietary habits.
- Waste processors – these actors recover, separate, transport, manage, and process organic matter once it has been discarded. This group includes municipal waste facilities, waste management companies, biorefineries, anaerobic digestion facilities, utilities, and others.

CROSS-VALUE CHAIN

- Logistics – the transportation and distribution services required to match supply and demand. Logistics has evolved rapidly in the last few decades to cater for new sales channels such as convenience stores and online sales channels.
- Regulators, institutions, and NGOs – this is the group that aims to ensure safe, affordable, and sustainable food supplies.

PRODUCTION SYSTEMS

There is great diversity in the way food is produced across the globe, but in terms of size two basic production systems can be discerned: large scale 'industrial chain' and smallholder 'peasant food webs'.[15] The differences between the two production systems are stark.

COMPARISON OF INDUSTRIAL V SMALLHOLDER PRODUCTION

	Industrial	Smallholder
% of world fed by	30%	70%
% of agricultural resources used	70%	30%
Wasted calories	76%	n/a
Externality costs	224% of EBITDA[16]	n/a
% of world's agricul-tural land	75%	25%
% of agricultural fossil fuel	90%	10%
% of agricultural freshwater use	80%	20%
Plant breed varieties	0.1 million	2.1 million
Animal breed reared	100 species	8774 species

Adapted from ETC report

15 http://www.etcgroup.org/files/files/etc-whowillfeedus-english-webshare.pdf
16 KPMG - Expect the Unexpected

DISRUPTED NUTRIENT FLOWS

The food system is overwhelmingly linear – it does not cycle nutrients effectively. Modern agricultural practices, such as excessive tillage and the use of heavy machinery, accelerate erosion and water run-off, and carry nutrients out of the soil and into water systems. As crops are harvested, nutrients and organic matter are removed – if they are not replaced, soil fertility decreases. Excessive use of pesticides and synthetic fertilisers, which may not contain all the necessary nutrients and organic matter, can also lead to increasing toxicity levels, reducing the soil's productivity. As more and more nutrients are lost and soil quality decreases, farmers increasingly turn to the use of synthetic fertilisers. Global demand for fertilisers was estimated at 185 million tonnes in 2014, and is forecast to grow 1.6% a year 2015-2019 (FAO).

Synthetic fertilisers face supply risks since they are typically produced by mining finite resources such as phosphate rock in a limited number of countries. The transformation process into commercial fertiliser involves significant energy and GHG emissions. Producing synthetic nitrogen fertilisers, for example, consumes 2% of the world's energy and, in 2007, generated 465 million tonnes of CO2 emissions.

Megatrends such as globalisation, increasing population, and urbanisation contribute to disrupting nutrient cycles. The global food system and trade networks, for instance, can require extracted nutrients to be transported vast distances from their source. Urbanisation leads to nutrients being concentrated and discharged as food waste into solid waste streams, and into wastewater systems as sewage sludge. The crux of the issue is that nutrients are extracted from the biosphere as harvested food, become concentrated in cities, and subsequently cause damage where they are discharged, rather than being beneficially looped back into the soil.