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Circular Food Futures: What will they look like?

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Abstract

Potentially dramatic changes in the organisation of the food system are being driven by both consumers and producers. Consumers are demanding higher quality produce and more direct connection to producers. For farmers, more extreme weather events and global competition are increasingly making industrial agriculture less economically viable. This paper explores how circular economy (CE) debates might contribute to, and support, the changes needed for a sustainable future.

Full compliance with the three objectives of a CE identified by the Ellen Macarthur Foundation might help to describe a sustainable and circular food future. An analysis of the food system is therefore carried out to determine how food systems may be organised to (a) design out waste and pollution, (b) keep products and materials in use, and (c) regenerate natural systems.

One critique of CE debates is its failure to explore systemic shifts and possible futures that are not an extrapolation of current conditions. This analysis of the food system points to the need for a decentralised network of diverse, polyculture farms, each with integrated energy and water micro-grids, and managed at a local level. Co-locating food producers with food consumers, as much as possible, creates an integrated village system at the food-water-energy-housing nexus. Villages may then be networked to enable collaboration for sharing of rarer skills or the satisfaction of more complex needs and wants, forming a trading network of circular economy villages.

It is therefore posited that the transition to a fully circular economy will require a paradigm shift—another agricultural revolution—the transition away from large-scale industrial agriculture to a decentralised network of circular food systems.

Keywords: Circular Economy, Food Systems, Economic Efficiency, Regenerative Agriculture, Regenerative Development, Urban Planning

Introduction

Potentially dramatic changes in the organisation of food systems are being driven by both consumers and producers. The demand for fresh, organic, and seasonal produce, growing interest in urban agriculture and new platforms connecting farmers with consumers, all suggest that there is growing consumer demand for higher quality produce and more direct connection to producers. For farmers, change is increasingly becoming a necessity. Increased incidences of extreme weather conditions including droughts, floods, bushfires, and hailstorms are making farming more difficult, while global competition lowers the price they receive for produce.

This paper explores how circular economy debates might contribute to, and support, the changes needed for a sustainable food future. As suggested by Korhonen et al [1] the Circular Economy (CE) remains a contested concept, with the literature review by Kircherr et al [2] identifying 114 definitions, mostly variations of the 4R strategies: reduce, reuse, recycle and recover. The Ellen Macarthur Foundation's (EMF) definition [3] focuses on objectives rather than strategies: (a) design out waste and pollution, (b) keep products and materials in use, and (c) regenerate natural systems. A future food system that achieves these objectives could therefore be described as a circular food economy.

Weigend Rodríguez et al [4] highlight the limitations of present CE debates in that they offer no methods to explore alternative futures. They propose future studies (FS) as a complementary discipline. FS starts with the premise that the future is unknowable and not simply an extrapolation of present conditions. What would a future food system look like if it was fully circular?

This paper analyses the present industrial food system, examining how well it aligns with the three objectives proposed by EMF. The first section examines waste in the food system, a well-known problem throughout the food supply chain. This is followed by a study of pollution, which arises through the dependence on fossil fuels. The third section considers how to keep materials in use and regenerate natural systems. This requires consideration of organic recycling processes and whether they support the next cycle of food production. To regenerate natural systems, it is necessary to compare current extractive practices with more peripheral practices such as regenerative agriculture, also known as agroecology. Through this analysis, a possible future food system is identified and developed. The analysis points to the need for a decentralised network of diverse, polyculture farms, each with integrated energy and water micro-grids, managed at a local level. Co-locating food producers with food consumers, as much as possible, creates an integrated village system at the food-water-energy-housing nexus. Villages may then be networked to enable collaboration for sharing of rarer skills or the satisfaction of more complex needs and wants, forming a trading network of circular economy villages.

Having analysed the food system by reference to the objectives of a CE, the next step is to compare this possible future with the four constructions of a CE developed by Bauwens et al [5]. This allows for the comparison of centralised with decentralised systems, supply-side with demand-side strategies as well as micro, meso and macro scale systems. Meso-level strategies that are place-based and manage the flow of energy and resources offer an important perspective that is consistent with the identified possible future. Networking between CE precincts aligns with peer-to-peer circularity. Peer-to-peer trading using internet platforms, is not usually understood as part of the circular economy but is included by Bauwens [5] as it can reduce demand for new assets by utilising spare capacity of existing assets.

A key message is that the imperative to strive for long-term sustainability demands a paradigm shift—another agricultural revolution—the transition away from large-scale industrial agriculture to a decentralised network of circular food systems.

Waste in the food system

According to Bellotti [6], Australia currently wastes 30% of food produced. Worldwide, one-third of the food produced is wasted [7,8]. This includes food that never leaves the farm, and that which is lost, destroyed, or spoiled along the supply chain, including by households and the hospitality industry at the end of the supply chain.

Parfitt [9] suggests that there is no consensus on the proportion of global food production that is lost, with estimates varying between 10 and 50 percent. Nevertheless, the wastage is significant and Parfitt [9] notes that global trends of urbanisation, dietary transition and globalization of trade are exacerbating losses along the food supply chain. Increased urbanization has lengthened supply chains, resulting in more losses due to increased distances, more handling and longer time taken from production to consumption. This problem is compounded by the shift from starchy staples to shorter shelf-life products as income increases.

Parfitt [9] also notes that the globalization of the food system has undermined the viability of small local producers in many countries. Prior to the impact of globalisation, family and community farms could save seeds and cycle materials and resources on their land, often producing food with no or negligible input costs. Surplus food sold at a local market was often their only source of monetary income. With the industrialisation of the food system, local markets disappeared, and small-scale farms were no longer viable.

Viewed at a macro scale, this does not appear to be a problem. According to Bellotti [6]: “61 million people will eat Australian food in 2017”. Given Australia’s population of about 25 million, Australia’s farmers produce and supply enough food to feed every person in the country twice over, with a significant surplus for export. This ignores the unequal access to food and resulting food insecurity even in wealthy countries like Australia. Seivwright [10] notes that “even the arguably conservative estimate of 5% of the population translates to 1 million Australians affected by food insecurity”. A preferred food future would address food distribution as well as production, with distribution referring to both the problems of long supply chains as well as ensuring that food supply reaches everyone.

The objective of this paper is to identify future scenarios in which waste has been designed out. Improvements to handling and logistics along supply chains may provide some marginal reductions in waste but could not be adopted as a strategy to design out waste. The most effective strategy for designing waste out is to considerably shorten the supply chain. This means, where possible, co-locating food production with consumption. Where this is not possible or efficient, food would be sourced from within a bioregion, with longer supply chains used only as a last resort.

Pollution in the food system

Although pollution occurs in many forms, this section will focus on pollution due to the burning of fossil fuels for food production, storage and distribution. Several studies have examined the energy return on investment (EROI) of the food system. Bajan et al [11] note that studies of EROI focus only on crop production, and their study fills a gap by including both crop and animal production. According to Bajan et al [11] the methodology adopted by the United Nations Food and Agriculture Organization (UN FAO), calculates EROI by measuring how much edible biomass, suitable for human consumption, is produced from the invested unit of energy. This methodology measures only the direct energy used in production and appears to ignore the considerable energy required to transport food from the farm gate to the consumer, as well as the wastage along that supply chain. Note that an EROI must be greater than 1 for a system to be sustainable in the long term. An EROI less than 1 would mean that more energy goes into the process than comes out at the end. As energy dissipates from a system it degrades and eventually collapses.

Bajan et al [11] found that the EROI in Oceania is 1.72, in North America it is 2.29 and in Europe, 2.45. This means that in these areas, one unit of fossil fuel energy produces approximately two units of food energy. In less developed regions, the output is much higher: South America, 3.87; Asia, 4.61 and Africa, 11.78. As expected, the more developed countries use more fossil fuel energy and less human and animal labour to produce their food, resulting in more pollution per unit of food produced.

These figures represent the most recent values recorded over the study period, which commenced in the 1970s. The trend over that time, in all regions except Europe, has been a falling return on energy investment, meaning that collectively, we are progressively increasing the amount of pollution per energy unit of food. Multiply this by the increasing populations and the total pollution from food production is escalating.

The anomaly of Europe was attributed to the role of the EU's Common Agricultural Policy in encouraging investment in more sustainable farming methods. The policy reforms and investment strategies adopted in Europe therefore informed the recommendations offered by Bajan et al [11] to improve the energy efficiency of agricultural production in other parts of the world. These are:

> *i.* *measures promoting and supporting the production and use of renewable energy sources such as biofuels, wind energy, solar energy and hydropower systems;*
>
> *ii.* *incentives for changing the structure of food consumption and production toward limiting the consumption of meat and switching to the consumption of local and seasonal products;*
>
> *iii.* *measures promoting and supporting conservation agriculture and organic farming; and*
>
> *iv.* *support for R&D and implementation of innovative farming techniques, such as precision agriculture or irrigation technologies.*

These strategies are clearly very useful for reducing pollution from fossil fuels used in agriculture and are strongly supported by the author. Yet, the question posed in this paper is not how to make incremental improvements to the current system but rather what is necessary to design out pollution from the food system. By reference to the above measures, swapping out all fossil fuel energy for renewables would be an important start. This would address energy supply. This can be complemented by measures to reduce energy demand. Changing consumption patterns, including less meat, with more seasonal and local produce would all help in reducing energy demand.

The recommendation for more local produce is interesting as the study explicitly excluded the energy required for food distribution from the farm gate to the consumer. Long supply chains require energy to be used for processing, packaging, transport, refrigeration, warehousing, and retailing. A report by the UN FAO [8], suggests that one-third of the greenhouse gases emitted by the agri-food sector occur beyond the farm gate and that about one-third of food produced is not consumed due to losses along the supply chain.

Food waste and food transport represent enormous losses in energy. If EROI is calculated based on food consumed rather than food produced at the farm gate, then input energy is one-third greater (accounting for energy in transport) and output energy (food consumed) is one-third less.

Acknowledging that these losses will vary between regions, the EROI figures above would be somewhat more accurate if multiplied by a factor of 44.4%. For illustrative purposes therefore, the EROI for Europe will fall from 2.45 to only 1.09. For every 1.09 kJ of food consumed, 1 kJ of fossil fuel energy is expended. In Oceania, 1 kJ of fossil fuels delivers just 0.76 kJ of energy to the consumer. A system that requires more energy input than is output is degrading and unsustainable. The food system in Australia is deteriorating thermodynamically as it is constantly dissipating energy.

Perhaps it could be argued that this is just a problem for Australia? Markussen & Ostergard [12] assessed the fossil fuel dependency of the Danish food system. They considered farming, processing, and transportation, and found that each joule of fossil fuel energy invested produced just 0.25 joules of food energy, concluding that the system is therefore unsustainable.

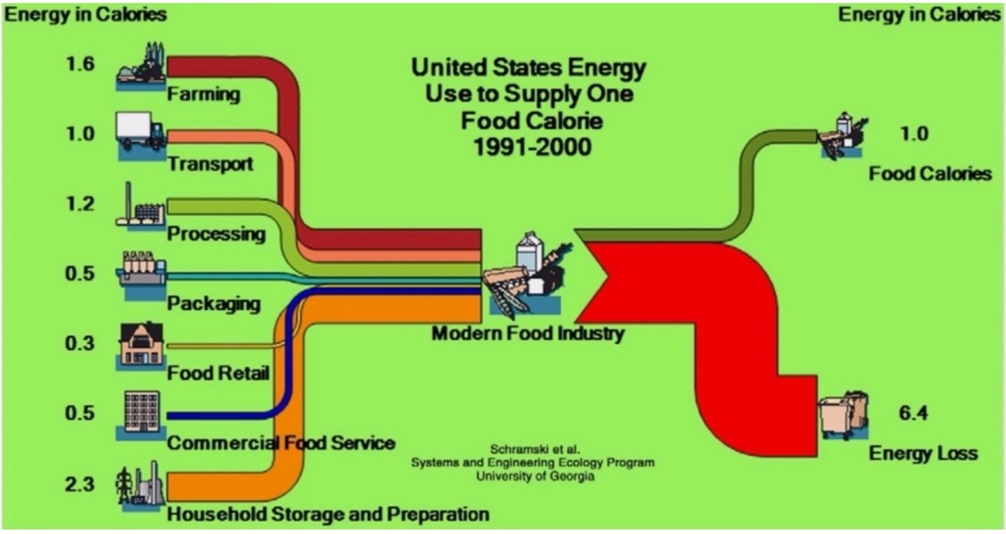
The figures vary wildly, and, in part, this reflects differences between countries. Distances in Australia are vast, so transport and other supply chain costs are necessarily much greater than in smaller countries. A more significant methodological problem for the variation in figures relates to the problem of determining what proportion of the infrastructure beyond the farm gate can reasonably be included and calculated as part of the food supply chain.

Consider the process of industrialisation. Prior to mechanisation, all the energy input needed to produce food came from humans and animals. The introduction of fossil fuels though, is not simply a replacement of one type of energy for another. As agriculture is mechanised, the amount of energy needed for agriculture on the farm may have decreased, but off-farm energy substantially increased.

Without this off-farm economic support system, for processing, packaging, transporting, warehousing, and selling food, the industrial agricultural system could not function. Also, before any food production can occur, factories must make tractors and a range of other farm equipment, farm sheds must be built, fencing constructed and on it goes. Then there are the production inputs, including seeds, chemical fertilisers, and diesel. The fossil fuel inputs to the farming process embody the energy needed for research, exploration, mining, refinement, and distribution of these fossil fuels. For all this to function, a transport network is needed, including roads, air and seaports, trucks, ships, and airplanes. Then there are the countless, regulators, managers and researchers who are establishing policy frameworks and administrating the system.

The economic system is a complex web, and it is entirely subjective as to which parts are—and which are not—part of the food system. Schramski et al [13] summarises some of the more comprehensive studies examining the energy requirements of the entire food system. They note that the most often

Figure 1 Energy efficiency of food production and distribution in the US. Source: Schramski et al (2011)



cited study by Gussow shows that “15 Calories of energy input were used for each Calorie of energy produced in the American food supply system in the 80s”. This equates to an EROI of 0.07 (1/15). Schramski et al [13] note that the estimates continue to vary but they developed a visual illustration from a comprehensive study by Heller and Keoleian, which assessed the total life-cycle energy demand of the food system in the US. Reproduced in Figure 1, the study found that 7.4 calories of fossil fuel energy are required to produce one calorie of food (EROI = 0.14, i.e. 1/7.4). Note that in this study even on-farm production has an EROI of 0.625 (1/1.6).

Even acknowledging the subjectivity of defining boundaries for the food system, there is no doubting the significant dependence on fossil fuels. Any system that requires more energy in than the energy that comes out is clearly wasteful and unsustainable. Furthermore, to depend indefinitely on a finite resource would represent a spectacular failure of imagination.

To imagine a circular food system in which pollution is eliminated, such a system must be designed to require no fossil fuels for production, storage or delivery of food.

Keep materials circulating and regenerate natural systems

The remaining two objectives of a CE, as defined by EMF are to keep materials circulating and regenerate natural systems. With respect to the food system, these require that organic materials be recovered and recycled, improving soil health for the next cycle of food production.

Waste management strategies that focus on household composting, kerbside pick-up, and other ways of diverting food waste from landfill, while important, do not create a closed-loop food system. Niles [14] notes that these policy solutions, developed in and for urban areas, do not recognise that rural communities are already managing their food waste by composting or feeding it to pets and livestock. It is these systems of feeding livestock or composting to create soil *on the farm*, that close the loop and create a circular food economy—by recovering organic material and regenerating natural systems to produce more food.

Such an approach would be consistent with the conclusion reached by Schramski et al [13] for making agricultural systems material and energy neutral, with the local community in balance with and directly connected to, their local ecosystem:

> *As natural resources continue to be depleted locally, sustainable agricultural systems will eventually move towards material- and energy-neutral balances with regard to their adjacent ecosystems (e.g., carbon, nitrogen, water, biota, energy, etc.). The luxury of distal supplies or deposits to accommodate unbalanced local environmental relationships is diminishing. System approaches such as low-input agriculture (House and Brust, 1989; Pimentel et al., 1989) or traditional ecological knowledge (TEK) approaches (Martin et al., 2010; Stinner et al., 1989) will become mainstream practices rather than soft science concepts pursued only by a few. They will comprise the systems tools to comprehensively support a better understood input–output, balanced relationship with local environments to sustain a large-scale food supply network that may be much less centralized. One challenge attributed to this era of agroecology (Gliessman, 1990, 2006; Jackson, 1980) will be to determine the boundaries of these input–output calculations such that future communities will reconnect with their local habitat in ways not currently envisioned. Essentially, a systems oriented ecologically balanced agriculture is inevitable (Francis and Madden, 1993), although the timeline of implementation is unknown. (Schramski et al [13])*

In creating a circular food system that strives for zero waste, the localisation of that system is essential. Rather than large-scale monocultural systems, managed and regulated at a state level, Schramski et al [13] identify the need for a much more *decentralised network of diverse, polyculture farms, each managed at a local level*. This would be a viable circular economy food future, dramatically reducing waste and energy losses due to long supply chains, also allowing for food waste to be recovered and recycled, regenerating natural ecosystems, to support future food production.

Schramski et al [13] refer to the coming era of agroecology. This is the study of ecological processes applied to agricultural production systems and is sometimes used interchangeably with the term 'regenerative agriculture'. In *Call of the Reed Warbler: A New Agriculture, A New Earth,* Charles Massy [15] studied numerous regenerative farming practices around Australia, identifying the principles that were consistently applied:

i. *Maximise the capture of solar energy by fixing as many plant sugars as possible via photosynthesis,*

ii. *Improve the water cycle, maximising water infiltration, storage and recycling in the soil,*

iii. *Improve the soil-mineral cycle by creating healthy soils that contain and recycle a rich lode of diverse minerals and chemicals,*

iv. *Maximise biodiversity and health of integrated, dynamic ecosystems at all levels.*

Massy [15] further argues that a fifth requirement is a change in human attitudes. Only human agency can trigger landscape regeneration by working in harmony with natural systems. The necessary shift in attitude is from an extractive to a regenerative mindset. Instead of just taking from the land, we take and give back in equal measure. This concept of regeneration is equivalent to the 'closing the loop' narrative of the circular economy.

All regenerative agricultural systems apply systems thinking as the approach to land management. They seek to integrate people and food systems into the ecological systems of a locality. Aligning with local ecological cycles requires local governance and not national standards. Whereas national standards may establish *minimum* standards for food quality to minimise the risk of harm to consumers, a community producing its own food would likely seek to *maximise the health benefits* for people, reducing waste and cost, where possible, to zero.

By utilising the energy of natural ecosystems, the need for fossil fuel energy is reduced. Chemical fertilisers can also be eliminated, together with associated wasted energy and impact on biodiversity. The systems approach and local application allows for the integration of a renewable energy micro-grid as the main input energy source, and this can also be used to cycle water through the farm for irrigation. This emphasises the food-water-energy nexus, which the UN FAO [16] and others [17] recognise as an important framework for understanding the interdependencies of different resource uses. The proposal to integrate food-water-energy systems, together with the housing where the producers/consumers live, addresses the critique by Biggs et al [18] that the water-energy-food conceptual tool fails to incorporate sustainable livelihoods perspectives. Nikolaou [19] have similarly highlighted that CE debates rarely consider social issues.

In summary, the possible future circular economy food system anticipated by this analysis is of a decentralised network of diverse, polyculture farms, each with integrated energy and water micro-grids, and managed at a local level. Co-locating food producers with food consumers as much as possible creates an integrated village system at the food-water-energy-housing nexus. The empowerment of local communities in this manner, enabling them to collaborate to ensure access to necessities for all, offers an important conceptual approach for addressing social issues.

Revisiting circular economy definitions

The proposed systemic shift in the organization of food systems, developed in the above analysis, would respond to critiques by Kirchherr et al [2] and Weigend Rodríguez et al [4], that there is currently insufficient focus on systemic shifts and possible futures in CE debates. Therefore, having identified this possible future, let us examine how the CE debates might add further value.

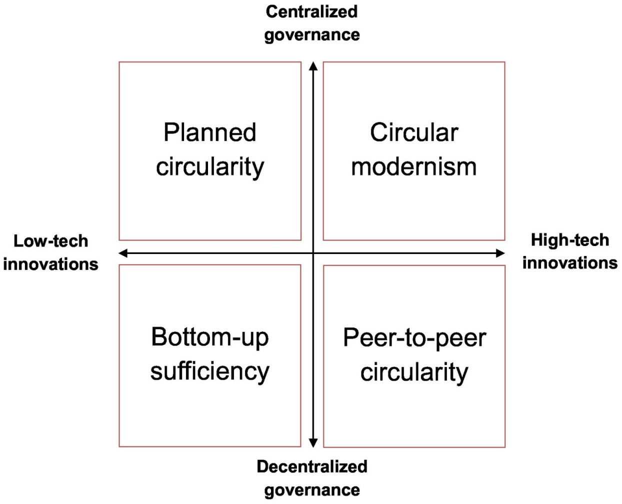
The systematic analysis of 114 CE definitions conducted by Kirchherr et al [2] examined how the various definitions addressed the 4R framework—reduce, reuse, recycle, recover. They found that CE is most commonly used in reference to reduce, reuse and recycle activities, often not highlighting that CE necessitates a systemic shift. The need to recover materials and keep them circulating within the production-consumption-production cycle was generally ignored. Furthermore, CE theorists differed from practitioners who frequently neglect 'reduce' in their CE definitions, "since this may imply curbing consumption and economic growth".

This last point is an important critique of much of the CE debate. CE is often regarded as a strategy for continued economic growth, implicitly suggesting that this is the only pathway to prosperity. Increasing the output from the economy purportedly demonstrates increasing abundance. Yet, as previously demonstrated, this abundance is rarely, if ever, distributed fairly to all the participants in the economic system. In addition to this social justice critique of economic growth, there is also the environmental critique that infinite economic growth is not possible on a finite planet.

These critiques are well known and need not be discussed further here as there is a third critique that simply relates to the way in which the abundance or surplus is calculated. This brings us back to the formulation of EROI—energy return on investment. In the pursuit of endless economic growth, CE is perceived as a strategy that benefits businesses, increasing sales opportunities and output, or reducing costs, always with the aim of increasing profits. CE could also be understood as a system for reducing the cost of living, particularly by reducing amount of work (energy invested) to access food (energy output). EROI can be more effectively increased by reducing input work and energy, than by increasing output.

To clarify this further, consider the different types of CE identified by Bauwens et al [5] in *Circular Futures: What will they look like?* To synthesise the various ways of understanding the Circular Economy (CE), Bauwens et al [5] developed the 2x2 matrix shown in Figure 2. The matrix has two axes—centralised to decentralised governance on the Y-axis, high-tech to low tech on the X-axis. This generates four CE typologies, planned circularity, circular modernism, bottom-up sufficiency, and peer-to-peer circularity.

Figure 2 Types of Circular Economy. Source: Bauwens et al (2020)



Circular modernism represents the principal conception of a CE in European countries and adopted in Australia. It emerges as an extension of the waste management hierarchy: reduce, reuse, recycle, recover. Recovering waste and valuing it as a resource closes the loop and converts a linear economy to a circular economy. William McDonough's *Cradle to cradle: Remaking the way we make things* [20], highlighted the importance of the initial product design in enabling resource recovery at the end of a product's useful life. The cradle-to-cradle model also distinguishes between the technical (inorganic) cycle and the biological (organic) cycle.

In the circular modernism approach to a CE, the governments set certain eco-efficiency standards, identify priority areas, offer funding or other incentives, and generally set the direction for the transition to a CE. Corporations then respond, innovate, or adopt appropriate technologies and adapt their business practices. Sometimes corporations lead and governments follow. Either way, in this model, the whole society is guided by central governments and large corporations who set the pace and scope of the transition to a CE. This is a supply-side, production-focused, profit-maximising strategy, wherein the goods supplied to the market incorporate circular innovations, while consumers have negligible influence on driving these innovations.

This can be contrasted with the strategy described in the Bauwens matrix as bottom-up sufficiency. This primarily relates to small-scale, self-sufficient communities who focus on the circular economy of organic materials, integrating various agricultural processes to minimise waste and reduce costs. Eco-villages that adopt permaculture principles are examples of bottom-up sufficiency. Permaculture is a holistic system-thinking approach to land management that seeks to integrate people and food systems into the ecological systems of a locality [21].

Circular modernism and bottom-up sufficiency are vastly different approaches to the circular economy. The former seeks to maximise production and supply, generally ignoring the costs, wastage, and inequalities involved in distribution. The latter seeks to match local supply with local demand. This empowers local communities, requiring that they manage themselves, their land, and local ecosystems. In contrast, circular modernism retains the current system, whereby communities remain dependent on external authorities motivated by outside interests.

Planned circularity is the third type of CE and is also centrally managed by government. This approach has been most readily advanced in China, with implementation lagging elsewhere. CE practices in China consist of three strategies at three different scales—micro, meso and macro [22, 19, 2]. The micro scale relates to individual products, product life cycles and cleaner production, consistent with circular modernist strategies. At the meso level the aim is to develop symbiotic relationships between different but complementary economic activities through co-location. Examples include eco-industrial parks, eco-agricultural systems, environmentally friendly parks, waste trade markets and venous industrial parks. Zhang [23] describes eco-industrial parks as "practical examples illustrating the environmental and economic advantages that can be achieved through the process of industrial symbiosis". Industrial symbiosis is the cooperative management of the resource flows of geographically clustered firms. This appears to be a key approach to establishing a link between CE and sustainability practices in China [24].

One similarity between planned circularity, as it applies to eco-industrial parks, and bottom-up sufficiency, is that they are place-based strategies. They don't apply to one product or industry but to a place. The circularity relates to the management of resource flows and energy, so that the waste from one activity can be fed as input into another complementary activity, benefiting both.

The macro level in China relates to the scale of the city, province, or state. This seeks to create still more symbiotic relationships such as by creating a regional network of eco-industrial parks. This concept of networking CE precincts could be applied to eco-villages and regenerative villages [25]. As these tend to focus on necessities, such as food, water, energy and housing, the ability to network with other villages can enable the collaboration for sharing of rarer skills or the satisfaction of more complex needs and wants. This would result in the formation of a trading network of villages leading to improved resilience and increased capacity due to the network effect.

Networking between villages need not be limited to physical connections. Online platforms, blockchain and other distributed, internet-enabled, technologies can build virtual connections. The fourth type of CE identified by Bauwens et al [5] is peer-to-peer circularity, which relates to the formation of virtual connections in this way. Like bottom-up sufficiency, this is a demand-side strategy and relates to the shift from ownership to access in the sharing economy. Loosely defined as the sharing or gig economy, mobile platforms allow people to share, barter, swap or access goods and assets without buying to own them. Using the 4R waste management framework, bartering and swapping allows people to refuse or reduce their purchase of new products. Utilising the spare capacity in existing assets also enables a reduction in demand for new assets. As these sharing economy platforms are invariably not directed by government and industry incumbents, they are referred to as economic disruptions.

Food, health and reshaping our cities

The future food scenario proposed by Schramski et al [13] and advanced in this paper is of a decentralised network of diverse, polyculture farms, each managed at a local level. Farms would be supported by integrated energy and water micro-grids, together with housing for farmers and consumers, physically creating a food-water-energy-housing nexus.

The outcomes of such a systemic shift would not only be less negative—less waste and less pollution—but also provide significant positive outcomes. The regeneration of natural ecosystems has already been mentioned but there can also be improved health outcomes for people by co-locating food production with the housing of food consumers [26,27]. In a review of literature at the intersection of the built environment and public health [26], three key interventions for supporting human health were identified. These are: getting people active, connecting and strengthening communities, and providing healthy food options. A regenerative farm adjacent to where people live, would require active management by that community working collaboratively. In return, the land would provide fresh, seasonal food for all. All three interventions would be simultaneously achieved.

Barton [27] speculated that improved health and well-being outcomes would be significantly advanced by an integrated settlement theory:

> *The next 40 years will see the development of an integrated theory of settlement function, form and evolution. It will be based in eco-system theory, linking human activity and well-being with development processes, the structure of the built environment and the natural bioregion.*

In an earlier article 'Implementing a new human settlement theory: Strategic planning for a network of regenerative villages', [25] the author sought to outline such an integrated settlement theory. In this article, the role of food systems is articulated in more detail to assist in realising that possible future.

It is appropriate, of course, that the arrangement of food systems should be of central importance in the organization of human settlements. The first cities arose together with the development of agricultural systems. Similarly, the urban environment as we know it and the growth of large-scale cities was made possible by the mechanisation of agricultural systems since the beginning of the Industrial Revolution. The system of food production is instrumental in the shaping of cities and food is, of course, essential for the sustenance of urban populations.

Another agricultural revolution—the transition from industrial agriculture to a circular food system—would once again reshape our cities and patterns of human settlements.

Conclusion

This paper acknowledges the significant changes that are already occurring in the food system with respect to changing expectations of consumers, increasing interest in urban agriculture and online platforms providing a direct connection with farmers. From the perspective of producers, the early effects of climate change, land degradation and water mismanagement are already being experienced. These are compounding the dire economic circumstances of farmers who are at the mercy of large corporations that do not pay the appropriate price for food.

In this context it is appropriate to examine possible futures in which the entire food system—production, distribution, consumption, and post-consumption management—is reorganised. The CE debate can contribute to this discussion if there is a willingness to examine more than waste management and, counter-intuitively, consider options beyond those that are profitable to producers. There is widespread support for the circular economy but even some advocates are critical of certain limitations in the debate, particularly the failure to consider the necessity for systemic shifts towards possible futures that are not simply adjustments to the status quo. We asked: what would a future food system look like if it was fully circular?

The definition of a CE provided by the Ellen Macarthur Foundation [3] focuses on three objectives: (a) design out waste and pollution, (b) keep products and materials in use, and (c) regenerate natural systems. This paper analysed the food system by reference to each of these objectives with the aim of describing a possible future circular food economy. The analysis points to the need for a decentralised network of diverse, polyculture farms, each with integrated energy and water micro-grids, and managed at a local level. Co-locating food producers with food consumers as much as possible creates an integrated village system at the food-water-energy-housing nexus.

A further examination of CE definitions identifies four different ways in which a CE can be constructed. Two of these, relate to place-based approaches that intentionally cluster activities geographically to cooperatively manage the flow of resources, materials, and energy. Of these, one is centrally planned by governments, the other is locally managed by the community living in the subject place. Bottom-up sufficiency aligns with the identified possible food future in that it refers to small-scale, self-sufficient communities, such as villages that maintain traditional ecological knowledge. This traditional knowledge can be substantially enhanced by incorporating modern technologies for energy and to manage the water cycle.

It was recognised that an economic system must provide more than basic necessities. The ability to network with other villages enables collaboration for sharing of rarer skills or the satisfaction of more complex needs and wants. This would result in the formation of a trading network of villages leading to improved resilience and increased capacity due to the network effect. Networking between villages need not be limited to physical connections. Online platforms, blockchain and other distributed, internet-enabled, technologies can build virtual connections.

The positive health benefits of the identified food future were then outlined, corroborating the imperative of a more direct connection between people and the food system. The analysis concluded that another agricultural revolution is required—the transition from industrial agriculture to a localised, decentralised and circular food system—once again reshaping our cities and patterns of human settlements.

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