

Article

# Circular Cities: What Are the Benefits of Circular Development?

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**Abstract:** If cities could become regenerative and adaptive urban ecosystems, in which resource loops were closed and waste was obsolete, their ecological footprint would diminish. In addition, urban resource security would increase, the health of urban populations would improve and urban greenhouse gas emissions would be reduced. These are the principle goals under-pinning the circular city. Circular cities emerge through the process of circular development. Circular development alters cities' systems of provision to enable circular practices of inhabitants to develop. This manifests as circular food systems and construction, water and nutrient recycling; adaptive reuse of spaces and pop-up activities; bioremediation of contaminated sites and integration of blue-green infrastructure throughout cities. To transform our cities will require significant investment, political support and public engagement. If the benefits of adopting such an approach can be identified, this will begin to make the case for support. The research presented in this paper draws on an inductive and deductive content analysis of relevant literature and interviews with those implementing circular projects in European cities (London, Paris, Amsterdam and Stockholm). It provides a clear definition of the normative concept of circular development. It creates a framework of benefits which are likely to accrue from adopting this approach. It points to the synergistic benefits emerging from circular development. It also highlights problems around valuation of those benefits, the unintended consequences of circular development and the inequalities in accessing benefits across society.



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## 1. Introduction

Currently cities consume 60–80% of the world's natural resources and produce 50% of global waste. They also emit 75% of global greenhouse gas emissions [1]. Thus, they are major contributors to global resource depletion, waste mountains and climate change. Urban resource security issues are also increasingly a problem, particularly for water, food and energy [2–4]. This is further exacerbated by climate change. The health of urban ecosystems is also declining, resulting in flooding, drought, heating, pollution, reduced biodiversity, loss of vegetation and soil degradation. These problems impact on the urban economy and the health of urban populations.

If cities could become regenerative and adaptive urban ecosystems, in which resource loops were closed and waste was obsolete, their ecological footprint would diminish. In addition, urban resource security would increase, the health of urban populations would improve and urban greenhouse gas emissions would reduce. These are the principle goals under-pinning the circular city. Circular cities emerge through the process of circular development. Circular development alters cities' systems of provision—urban infrastructure, processes and activities—to enable the circular practices of inhabitants to develop. Thus, a circular development approach to the regeneration and renewal of our cities, could help address these problems. The paper analyzes the evidence for this claim.

To date, much of the literature has concentrated on a narrow view of the circular economy, which focuses on improving the resource efficiency of supply chains and production processes to maximize economic savings for industry [5–8]. Within this literature, circular

cities are defined as those in which urban industrial actors adopt closed-loop production processes and business models [9]. Urban systems of provision (energy, water, transport), the social practices and lifestyles of those living in cities which affect resource consumption, are overlooked. In terms of the sustainable development goals, the focus is on responsible production, industrial innovation and economic development.

In contrast, circular development is a new normative model for urban development, conceived by the author and reported elsewhere [9–11], which focuses on the processes creating the infrastructure and urban activities supporting circular urban systems. These systems are natural, social and artificial, supporting technospheric, biospheric and socio-economic cycles. Circular development allows cities to adapt to shocks and long-term changes in the wider landscape, with minimal ecological impact. It aims to reduce urban resource consumption (materials, land, water, infrastructure and energy), waste and greenhouse gas emissions (GHGs), whilst regenerating the urban ecosystem and building urban resilience [10,11]. Circular development enables the healthy renewal of cities. It could also help to deliver many of the sustainable development goals.

In circular cities, three actions—resource looping, adaptation and ecological regeneration—are implemented in combination to deliver circular development. Figure 1 illustrates some of the processes, activities and material manifestations of circular development in cities. Resource looping (reuse, recycling and recovery) is encouraged through the provision of circular infrastructural systems (e.g., gray-water recycling systems, recyclable infrastructure) and the introduction of new circular processes (e.g., conversion of organic waste to energy, biochemicals or feedstock) in cities. Urban form may also alter to accommodate these new activities, for example through the provision of space to store recyclates or reusable objects. Changes in local systems of provision (e.g., local food banks, recycling websites, repair workshops) also encourage urban inhabitants to reuse and recycle resources.



**Figure 1.** Circular development (Source: Author’s own).

Circular development produces adaptable cities, offering space to transform (e.g., pop-up spaces) and grow, and infrastructure (e.g., scalable, movable, refit-able, flexible) that

evolves with changing needs. It also introduces processes (e.g., collaborative planning, co-provision, tactical urbanism) which support learning within communities and encourage self-organization. Urban experiments (often pop-up activities) provide an opportunity to test new circular systems of provision and enable communities to quickly adapt to changing contexts. This adaptiveness enables infrastructure and communities to transform to meet the new demands placed on them, thus increasing urban resilience.

Circular development also protects and enhances urban ecosystem services, which reinforce natural cycles and improve the health of those living in cities. Ecologically regenerative actions are often operationalized through the inclusion of green and blue infrastructure in the urban fabric, the management of urban ecosystems (e.g., water management, conservation, farming, forestry) and bioremediation processes (e.g., phytoremediation of contaminated urban sites).

The process of implementing circular development in our cities is likely to be costly and disruptive. It will require a wholesale shift in the way we plan, design and manage our cities. It will necessitate changes in social practices, lifestyles and systems of provision. Support for this transformation will be needed, from politicians, service providers and the public, if it is to be successful. To gain support, the benefits of adopting this approach will need to be clear. Examples of circular urban development have already emerged in European cities. The introduction of the new Green Deal in Europe is galvanizing more cities to join them. Thus, there is an expanding evidence base which we can analyze to determine the benefits of adopting the approach. There is also an imperative to do so, as funding is provided to support this transformation.

This paper contributes theoretically to the urban sustainability and circular cities literature. Firstly, it provides an analysis of the potential ecological, social and economic benefits (and disbenefits) of urban circular development. Secondly, it supplies initial evidence of the synergistic benefits created through combining the three circular actions in cities, rather than applying them separately. Thirdly, it identifies the potential benefits of adopting specific circular urban systems (e.g., circular construction, circular food systems, water and nutrient systems) using examples from 4 European cities. Finally, the paper highlights important issues around the fair evaluation of the benefits identified, the unintended consequences of circular development and inequalities in accessing the benefits of circular development across society.

The paper begins by introducing the research methodology (Section 2). It presents the results from an inductive content analysis of academic and gray literature, which generated a framework of the potential benefits of adopting the three circular actions (Section 3). It goes on to introduce the four case study cities, in which examples of circular development have been implemented (Section 4). The benefits which emerged from these examples, were identified through a mixture of expert interviews and reviews of relevant gray literature, which are presented in Section 5. The findings of both analyses are discussed in Section 6. This section also highlights some of the problems associated with circular development.

## 2. Aims and Methods

The aim of the first stage of the research was to identify the benefits (and disbenefits) of adopting a circular development approach in cities. A systematic analysis of Scopus' indexed publications and research-based, technical reports (published by reputable consultancies) was completed in 2020 to determine the benefits. Three inclusion criteria were used: relevance (papers focused on circular development actions in cities—see the search terms in Table 1), language (publication in English) and validity (a peer-reviewed article or technical report published by a reputable consultancy).

**Table 1.** Search terms for circular development.

<b>Circular Action</b>		<b>Definition</b>	<b>Search Terms</b>
<b>Loop</b>	Reuse	Where resources are used again without any further processing	reuse; repurposing; change in use; refurbishment; grey-water reuse; repair
	Recycle	Where resources are reprocessed for the original or other purposes	recycling; composting; landfill mining; urban mining; infrastructure recycling; black-water recycling; waste-water treatment; circular economy; circular construction; bioeconomy;
	Recover	Energy is produced from the reprocessing of resources	waste-to-energy; gasification; pyrolysis; landfill gas collection; anaerobic digestion; heat recovery; biogas; thermal hydrolysis
<b>Ecologically Regenerate</b>	Infrastructure	Infrastructure which helps to regenerate the urban ecosystem and the ecosystem services it provides	green infrastructure: blue infrastructure: sustainable urban drainage systems
	Ecosystem management	Activities which help to regenerate the urban ecosystem and the ecosystem services it provides	urban agriculture; urban forestry; conservation; water management; soil management, phytoremediation; bioremediation
<b>Adapt</b>	Infrastructure	Infrastructure which adapts to changing needs in the city.	Adaptable; expandable; flexible; moveable; pop-up; scalable; refitable; convertible; versatile; adaptive reuse
	Communities	Communities which can organise and adapt to changing needs	Pop-up economy; pop-up enterprises; co-provision; community farming & energy; farming & energy cooperatives; transition towns; co-building; cohousing & cooperative housing.
	Urban form	Urban form which can adapt to changing needs	Pop-up spaces, meanwhile spaces, temporary urbanism, temporary uses, temporary planning permissions; multi-use spaces

Source: Author's own.

Over 300 documents were reviewed. The papers appeared to segregate into three categories, reflecting the three circular actions: looping actions and circular economy; ecological regeneration and nature-based solutions; urban resilience and adaptation—with some overlap. Two sets of search terms were used to identify relevant papers. The first set referred to the urban focus (“cities” and “urban”) and the second set to circular development actions (see Table 1 for terms searched for circular actions).

There were many query strings used. For example, the query string for reuse would be “cities” OR “urban” AND “reuse” OR “repurpose” OR “refurbishment”. The search identified 214 potentially relevant papers with key words and abstract text matching the queries.

An inductive content analysis (using NVIVO) was then completed to identify the benefits of adopting circular development in cities. Open coding was used to identify benefit categories and clusterings across the literature (and reduce bias). Initial full text reads immersed the researcher in the literature, enabling her to gain a sense of all the benefits emerging from circular development. The second reading was used to derive an initial set of codes. These codes were sorted into categories and coding tree diagram was created. Three benefit categories (ecological, economic and social benefits) emerged (Table 2). These categories were then used to organize and group codes. In total, 33 coding themes emerged: 12 ecological, 10 economic and 11 social benefits. The social category subdivided into two themes: health and community benefits.

**Table 2.** Coding framework—benefits of circular development.

Categories	Sub Themes	Codes	Sub-Codes
Ecological Benefits		Reduce consumption	Water, material, energy, land
		Ecosystem Services	regulation provisioning, support, cultural
		Reduce greenhouse gas emissions	-
		resource sufficiency	-
		Adapt to environment change	-
		Increase environmental Awareness	-
Social Benefits	Health	Health benefits	Physical health, mental health, stress, nutrition, obesity, longevity
	Community	Builds local symbiotic capital	-
		Empowers communities	-
		Stabilizes existing communities	-
		Opportunities to socialize	-
		Access to resources for the excluded	Affordable heat, food, goods, accomodation, energy
		Increases community resilience	-
Economic Benefits		Creates jobs	-
		Avoid costs	Health, insurance, landfill
		Creates economic value	-
		new industrial sectors and businesses	-
		removes redundancies	Vacancies, undeveloped sites, “waste”, inefficiencies in production processes
		Reduces supply and production costs	-
		Activates vacant and unused spaces	-
		Increases value of properties and land	-
		Localized value chain	-
		Localized production	-

Source: Author’s own.

The second stage of the research identified the benefits accrued from adopting circular urban systems in four European cities: Amsterdam, Paris, London and Stockholm. These cities were chosen because they are pioneers in implementing circular systems of provision and offer well-established examples [11]. They have engaged in implementation, over a longer period and thus have a richer understanding of the benefits emerging. Therefore, the data collected is better informed. The cities offered a diversity of circular urban systems including: circular construction and food systems; adaptive reuse of spaces and infrastructure; water and nutrient recycling systems; waste heat recovery and waste-to-energy systems; ecological restoration systems (bioremediation, environmental management, integration of blue-green infrastructure). These represent the most common circular systems found in European cities. Thus, they provide a representative sample.

Primary data was collected through 52, one-to-one, key stakeholder interviews with providers of services and infrastructure who had implemented circular systems within those cities (Table 3). A range of representative stakeholders were interviewed across the private, public and community sectors. These interviews took place during the period June 2017–June 2019 and lasted between 40–60 min. Open ended questions were posed to reduce bias. For example, “In your experience, what benefits emerged from adopting this circular system/process/project”. Open ended probes were used to follow-up the respondents’ answers. For example, “can you provide more information illustrating these benefits”. In addition, interviewees were asked to identify instances where synergistic benefits emerged from adopting circular actions. The interviews were recorded and transcripts were generated. Where possible, responses were corroborated by studies measuring the actual benefits of circular systems provided by technical reports (to increase reliability).

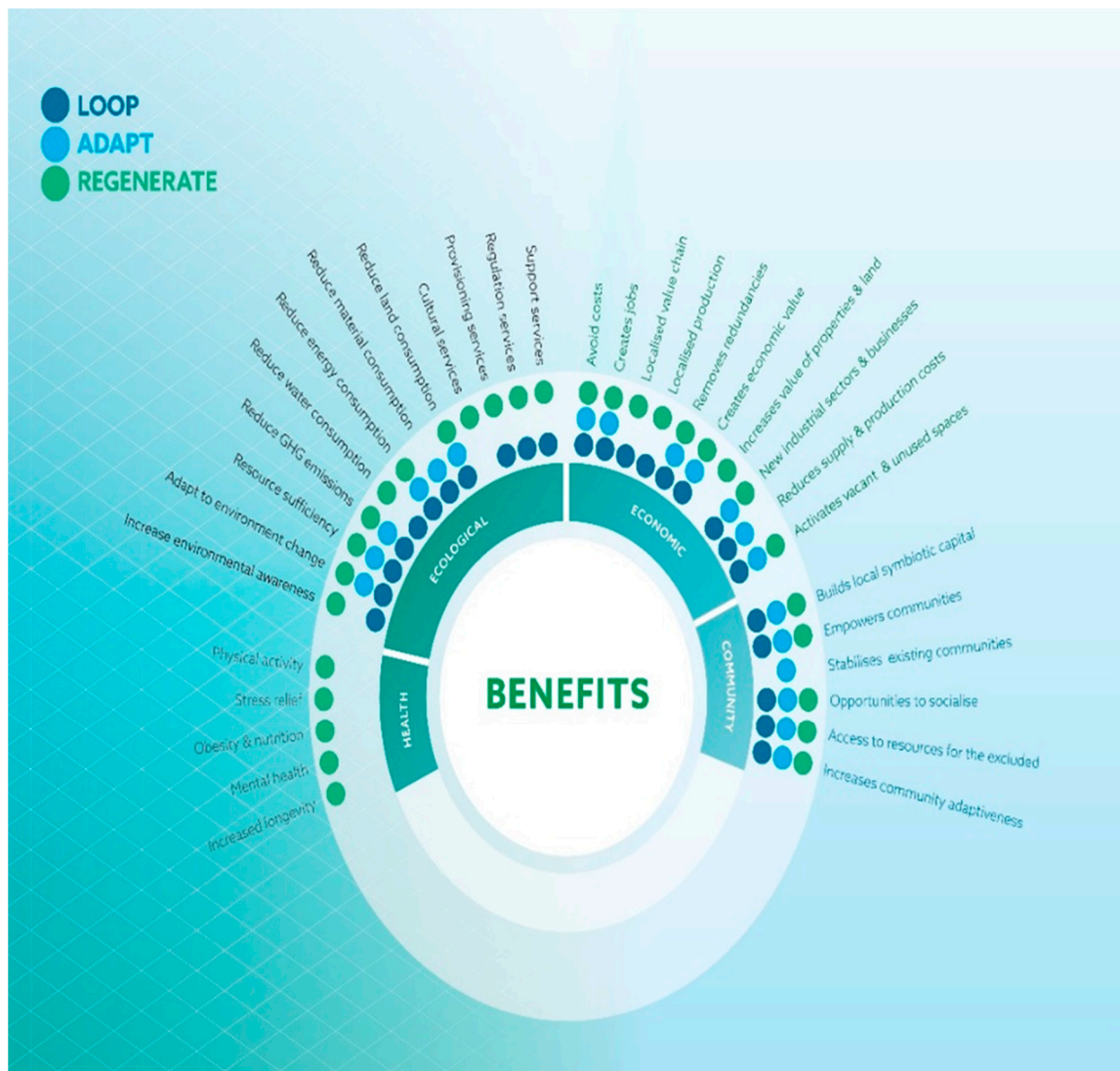
**Table 3.** Key stakeholder interviews.

Group	Type	Number Stakeholders Interviewed	Amsterdam	Paris	London	Stockholm
Private	Developer	4	X	X	X	X
	Construction manager	2	X		X	
	Engineering/planning consultant	3	X		X	X
	Architect	1				X
	Landscape architect/green infrastructure consultant	3		X	X	X
	Water and waste water engineer	4	X	X	X	X
	Industrialist	2	X		X	
	Temporary use consultant	2		X	X	
	Property consultant	2		X	X	
Public	Local politician	4	X	X	X	X
	Strategic planner	4	X	X	X	X
	Economic development officer	4	X	X	X	X
	Circular economy officer	2	X		X	
	Sustainable development officer	3	X		X	X
	Ecologist	1			X	
Community	Academic	4	X	X	X	X
	Circular economy/waste recycling foundations	1			X	
	Conservationists	1			X	
	Social enterprises	2		X	X	
	Urban farmers	2		X	X	
Total		52	11	11	19	10

Source: Author’s own.



This provided an understanding of the perceived benefits of circular development amongst those implementing it. The interview transcripts were read by the researcher to gain an overview of the responses. Notes of the benefits reported were made for each transcript. A comparison was made between the initial codes emerging from the interviews and those from the literature. The same categories were emerging. Thus, the results from the interviews validated the benefits framework produced by the initial inductive content analysis of the literature. The interviews were then analyzed with NVIVO, using the coding framework developed from the first stage of the analysis (Figure 2). Various search terms were then used to analyze the transcripts (Table 4).



**Figure 2.** Benefits of adopting circular development in cities (Source: Author's own).

**Table 4.** Key stakeholder interviews—themes, codes and search terms.

Theme	Code	Sub-Code	Search Terms
<b>Ecological Benefits</b>	Reduce consumption	Water, material, energy, land	“reduce consumption” AND “water” OR “material” OR “land OR “energy”
	Ecosystem Services	regulation provisioning, support, cultural	“ecosystem services” AND “regulation” OR “provisioning” OR “support” OR “cultural”
	Reduce greenhouse gas emissions	-	“greenhouse gas emissions” OR “ climate mitigation”
	resource sufficiency	-	“ resource security” OR “resource sufficiency”
	Adapt to environment change	-	“ urban adaptation” OR “climate adaptation” OR “adaptive systems”
	Increase environmental awareness	-	“ environmental awareness” OR “pro-environmental behaviour”
<b>Social Benefits</b>	Health benefits		“ health benefits” OR “physical health” OR “stress relief” OR “obesity “ OR “ good nutrition” OR “mental health” OR “increased life-span”
	Builds local symbiotic capital	-	“ local capital” OR “social capital” OR human capital” OR “financial capital” OR “physical capital” OR “natural capital”
	Empowers communities	-	“ community empowerment”
	Stabilizes existing communities	-	Community AND “stabilisation” OR “retention”
	Opportunities to socialize	-	“social events” OR “social opportunities”
	Access to resources for the excluded	-	“social solidarity” OR “affordable” OR “ affordable warmth” OR “affordable food” OR “affordable accommodation”
	Increases community resilience	-	“resilience” OR “adaptive capacity” OR “community organisation” OR “community learning” OR “ sufficiency”
<b>Economic Benefits</b>	Creates jobs	-	“jobs” OR “employment”
	Creates economic value	-	“ valorisation” OR “economic return”
	new industrial sectors and businesses avoid costs	-	“new industries” OR “new businesses”
	removes redundancies	-	“redundancies” OR “vacant” OR “waste”
	Reduces supply and production costs	-	“ supply costs” OR “production costs”
	Activates vacant and unused spaces	-	“site reuse” or “regeneration” or “renewal”
	Increases value of properties and land	-	“land values” OR “property values”
	Localized value chain	-	“local value chain”
	Localized production	-	“local production”

Source: Author’s own.



### 3. The Sustainability Benefits of Circular Development

This section summarizes the findings of the inductive content analysis of the literature and illustrates the benefits of the three circular actions identified using examples from key texts. The analysis suggests many sustainability benefits will accrue from adopting a circular development pathway. The benefits framework produced from the analysis is presented in Figure 2.

#### 3.1. Ecological Benefits

The inductive content analysis highlighted 12 ecological benefits associated with adopting circular development in cities. Broadly, these fall into five categories: reducing resource consumption (energy, water, materials and land); restoring urban ecosystem services; reducing greenhouse gas emissions; increasing urban capacity to adapt to climate change; and increasing environmental awareness amongst the public.

All three circular actions contributed to a reduction in urban resource consumption (energy, materials, water and land). For example, reusing heat emitted from buildings and anaerobic digestion of organic waste, reduces fossil fuels consumed [12]. The adaptive reuse of buildings bypasses the wasteful process of demolition and reconstruction whilst producing energy savings [13]. Green infrastructure can reduce air and surface temperature in cities, thus reducing energy used for air conditioning [14]. Gray-water recycling and reuse combined with rainwater collection and storage in blue-green infrastructure reduces consumption of potable water for non-drinking purposes [15,16]. Overall, a reduction in resource use can also increase resource security within urban systems.

Circular actions also improved the health of urban ecosystem services. Looping and ecologically regenerative actions helped to restore urban ecosystem services essential for tackling pollution [17]; supporting carbon sequestration; regulating local climate [18]; managing hydrology [19]; increasing biodiversity and producing fertile soils in cities. The restoration of ecosystem services also supports local resource production (e.g., food, fuel). It provides clean water and air, which are essential for a healthy population. It also provides access to areas for recreation [14,15,20].

All three circular actions reduce greenhouse gas emissions [20–22]. Looping designs out waste, reducing greenhouse gas emissions across the value chain [22,23]. Thus, the reuse of steel in construction can reduce the carbon footprint of buildings [24] and the reuse of food reduces methane emitted from landfill [25]. Adaptation keeps infrastructure and materials in use to retain the embodied energy in both. For example, the adaptive reuse of infrastructure avoids the emissions generated by the demolition, fabrication, transportation and construction of buildings [26]. The regeneration of urban ecosystems aids in the sequestration of carbon in soil and vegetation [14,27,28]. It also increases urban capacity to adapt to climate change [14,29,30].

Finally, localized looping (e.g., local circular food systems, community energy) and regenerative actions (e.g., community gardening, conservation projects, urban farming) heighten environmental awareness amongst the public [31,32]. However, increasing resource efficiency and resulting reduction in supply costs may also produce a rebound effect [33].

#### 3.2. Health Benefits

The social benefits identified by the literature subdivided into two themes: health benefits and community benefits. The inductive content analysis highlighted that ecological regeneration produced significant health benefits in urban populations. Green infrastructure regulates local climate, water, noise and air pollution, all of which have a direct impact on the mental and physical health of those living in cities [34,35]. It could also increase the resilience of the urban population to pandemics (e.g., sars cov-2) by addressing the health co-morbidities (i.e., respiratory, cardiac problems, type II diabetes and obesity) that increase mortality rates amongst those with disease [36].

However, green spaces must be accessible (within 1 km of people's homes) to have a significant effect on the mental and physical health of urban inhabitants [34]. This is particularly important for children, the elderly and people from lower socio-economic groups, who spend the most time close to home. However, there is still a great deal of variation in access to green space across socio-economic groups in cities [37–39].

The provision of green infrastructure can also encourage active lifestyles amongst the wider population [40]. Green corridors with integrated active transport networks reinforce walking and cycling in cities [41,42]. Active lifestyles reduce obesity, levels of stress and improve the mental health of city dwellers, helping to build long-term health resilience [43–45].

### 3.3. Community Benefits

The inductive content analysis highlighted that all three circular actions help to strengthen and empower local communities, through the operation of community projects (e.g., energy and farming cooperatives; food-reuse and repair schemes). These projects build stronger social capital (social networks) and human capital (skills and experience) through people's engagement in circular actions [14,46,47]. For example, repair cafes: develop technical skills; reduce costs of goods for low income groups; provide meeting places and increase social cohesion within communities [48]. Similar benefits were identified amongst those engaged in community farming cooperatives [49]. However, community projects often encounter significant barriers to scaling up [48].

Community projects can also generate local economic (financial return) and physical capital (infrastructural systems supporting circular activities), which increase the resilience and adaptiveness of communities. For example, renewable energy cooperatives provide new infrastructure and generate economic capital, as well as encourage greater social cohesion and pro-environmental behavior [50,51]. Adaptively reused buildings also provide spaces for new pop-up activities. This form of *tactical urbanism* increases adaptiveness, creating more resilient and stable communities [52,53].

All three circular actions may also increase access to resources (e.g., goods, accommodation, heat, clean air, green spaces) in communities. For example, furniture reuse schemes have been shown to reduce hardship and help to build human capital [47]. However, in practice there is also evidence to suggest that the benefits of circular actions may not be experienced equally across communities. For example, green space is often less accessible to the urban poor [54]. Low income households are also less likely to participate in and benefit from urban farming projects [55].

### 3.4. Economic Benefits

Finally, the inductive content analysis highlighted 10 economic benefits, which could emerge from circular development, particularly in the circular, bio and pop-up economies. These focused on four key areas: reduced supply and production costs to producers; creation of economic value; diversification of the economy and job creation.

Looping actions can reduce supply and production costs by reducing "waste", using recyclates and localizing supply chains [56]. The circular economy will create new economic sectors, industries and businesses, thus generating new job opportunities [22,56,57]. Valorizing construction and organic waste streams appear to be particularly viable in city-regions.

Research suggests that the circular economy will require a heterogenous skills base, offering opportunities to all [58]. However, experience in India and China with informal waste recycling sectors suggest that poorer groups will tend to be employed in these less secure, poorly paid and potentially hazardous jobs. There is also disagreement over the scale of economic opportunities provided by the circular economy. The OECD suggests the opportunities maybe more modest than first predicted and will vary between countries [59].

Research indicates that the bioeconomy has the potential to address many sustainability goals [60]. The urban bioeconomy exploits latent urban assets in the form of biological

models and processes for various direct or indirect economic benefits [60,61]. Two processes are integral to the bioeconomy. The first involves harnessing biological assets offered by ecosystem services (e.g., carbon sequestration, producing resources, reducing pollution and flooding, bioremediation). This process of ecological regeneration enhances land and property values. It can also bring brownfield sites back into use.

If ecosystem services are properly valued, ecological regeneration can be a source of value creation [62]. Ecosystem services can also help avoid health, flood and pollution remediation costs. Managing these biological assets, produces new resources and creates local employment opportunities in a range of areas: urban forestry, conservation, agriculture, energy, water management, carbon sequestration, recreation, health and tourism [63].

The second process focuses on the valorization of biological waste. This is the circular urban bioeconomy, which overlaps with activities in the circular economy. Biological waste is valorized through bio-prospecting or biological processes which reduce waste. New industrial sectors and businesses are already emerging in the bioeconomy, generating jobs [64]. In 2017, over 17 million people were employed in the European bioeconomy. This added EUR 614 billion to the European economy. Growth areas included bio-based electricity, biochemicals and forestry.

The pop-up economy could also make a significant contribution to economic growth. It has been estimated that pop-up activities are worth more than GBP 2.3 billion to the UK economy alone and employ over 26,000 people. The temporary nature of urban pop-up activities also increases a city's ability to adapt to changes in the landscape. Pop-up activities remove redundancies (e.g., vacant sites, properties, under-utilized utilities) in the urban system produced by economic shocks [65,66].

Pop-up activities reactivate unused sites, enhancing local vitality, which increases local land values and revitalize the local economy [20,65,67]. This process extracts latent value from temporarily disused sites [68]. Tactical urbanism is a valuable urban model, which reduces economic risk, unlocks potential of sites and generates a capital flow [68]. However, the gentrification process associated with increasing value can also result in social exclusion.

The inductive content analysis clearly demonstrates the benefits of adopting circular actions in cities. It also begins to highlight some of the problems.

#### 4. European Examples of Circular Development

To validate these findings, an analysis of the benefits emerging from the adoption of circular systems of provision across four European cities was completed. We begin here with a brief description of the four cities and the circular systems they have adopted.

##### 4.1. Amsterdam

Amsterdam encourages a strategic, city-regional approach to resource looping, of construction and organic waste. The producers and users of "waste" are linked throughout the city-region. Smart data and online marketplaces are used to enable the exchange of construction "waste". Material passports, databases (e.g., CIRCLE SCAN which maps material flows and PUMA which identifies buildings in which reserves of valuable metals can be found) and resource banks (space for storing recyclates) facilitate the circular construction process. Public procurement (of recycled building materials), circular tendering and land release have also generated demand for recyclates in construction.

Organic waste is also looped within the city-region. Waste separation, smart reverse logistics and cascading organic waste flows, ensure the residual flows retain their highest value. The development of bio-refineries in the city region enable organic materials to be recycled or energy to be recovered locally and at scale. In addition, nutrients are recovered from residual food for reuse (by restaurants or foodbanks) or composting.

Amsterdam is also encouraging the emergence of neighborhood-scale, pop-up circular experiments. Vacant, often contaminated, municipally owned sites, are made available temporarily for circular experiments. De Ceugel (Buiksloterham), is one such experi-

ment, constructed on a contaminated site in the Port of Amsterdam. It adopts all three circular actions.

Houseboats have been adaptively reused for workshops, offices and a café. Phyto-remediating plants have been used to decontaminate the soil on site. Off-grid, above surface infrastructure has been integrated into the development, to avoid sub-surface infrastructure from needing to be buried in contaminated land. Dry composting toilets and separated urine collectors are used, to produce fertilizer for local food crops. Helophytic filtration systems enable on-site, gray-water recycling, whilst waste heat from the houseboats is captured and reused. Thus, the site is ecologically regenerated, resources are looped and a temporary home for businesses adopting the circular development model is provided.

#### 4.2. Paris

Paris has also adopted a city-regional approach to looping construction materials, food and water. It has taken a similar approach to Amsterdam in facilitating circular construction, through the provision of material flow data, online marketplaces and resource banks. It has been particularly successful in dealing with the soil excavated from construction sites (using the sol-dating app).

Paris aims to create a local circular food system through the reuse of food waste and the regional production of food, both in the city and in surrounding districts. This is encouraged by the *Parisculteurs* initiative, which aims to cover the city's roofs and walls with 100 hectares of vegetation by 2020. One third of this space will be dedicated to urban farming. There is a stronger "solidarity" narrative in Paris suggesting that feeding the urban poor is a priority, when compared to Amsterdam. Food reuse is also legally enforced. Examples of food-reuse schemes include public service contracts with food markets; food reuse cafes (e.g., Freegan Pony) and community fridges (les Frigos Solidaires). Any food which cannot be reused in the city is converted into biogas and supplements the local energy supply.

Paris also has a gray-water recycling system, which has existed for two centuries. Most of the graywater (98%) is consumed by the municipality to maintain public infrastructure. The graywater is very inexpensive and used in large quantities. However, the city is considering replacing the existing gray infrastructural system with a blue-green alternative. This could help to reduce water consumption and regulate pollution and urban temperatures, enabling the city to adapt to climate change.

Paris also co-ordinates the strategic, adaptive reuse of sites and buildings through initiatives such as *Paris Reinvented* and *Paris Culteurs*. Paris Reinvented is an initiative which has formalized the process of the strategic adaptive reuse of sites and buildings in Paris since 2014. Temporary planning permissions, space brokers and online marketplaces help to facilitate tactical urbanism, which has precipitated many pop-up activities in the capital, including urban farming. A variety of projects have emerged, including: Les Grands Voisins, Freegan Pony, Friche Miko and Jardin d'Alice. Les Grands Voisins—a pop-up social enterprise—was particularly successful, providing a homeless hostel, workshop for artisans, pop-up shops and start-ups, allotments and recreational facilities.

#### 4.3. London

London also provides examples of circular systems of provision. The Queen Elizabeth Olympic Park (QEOP), is a new eco-district, built for the 2012 London Olympics, which has integrated three circular actions into its construction and operational processes. The QEOP is the largest urban park to have been created in Europe over the last 150 years. It is undergoing a process of ecological restoration to create a healthy urban ecosystem. Bioremediation, local clean-up programs and conservation schemes have helped to ecologically regenerate this previously industrial area. Residents live within 300 m of at least two hectares of green space. Diverse, natural species have been planted across the park. Waterways have been improved, whilst sustainable urban drainage systems have been fully integrated into the public realm.

Circular construction systems (e.g., soil-washing, materials exchange platforms, resource banks) have limited material waste from the site and adaptive infrastructure integrated into the Olympic development, which was repurposed post-games. For example, nine modular cabins that formed the 'High Street' in the Athletes' Village are now used as a community hub in Hackney Wick. QEOP provides an example of how, by designing for adaptability from the outset, buildings, products and materials continue to provide high value return beyond their initial purpose. An Asset Disposal scheme was introduced in QEOP to help contractors re-use items and materials after the Olympic Games by selling them or gifting them to charities and good causes.

In contrast, Brixton provides an example of tactical circular urbanism in an existing urban neighborhood. Brixton is a *transition town* with twin aims to tackle climate change and resource consumption. A series of sustainable community-led schemes, integral to circular development, have emerged in the neighborhood (e.g., Pop-up Brixton, Brixton Café, Loughborough Farm and the Remakery). These were facilitated by the release of municipally owned sites and granting of temporary planning permissions/leases. Local food reuse (e.g., Brixton Café) and urban farming schemes (e.g., Loughborough Junction Farm), supported by the local currency (Brixton Pound), have been established which help to reinforce a circular food system. The Remakery provides a space in which the community can learn to repair or recycle unwanted or broken goods and materials. Pop Brixton provides employment opportunities for local people in the pop-up economy.

#### 4.4. Stockholm

In Stockholm, circular thinking has been embedded into development decisions for 25 years. Circular principles first manifested in Stockholm (as Ecocycles I.0) in Hammarby. The district developed the infrastructure required to create a closed-loop, waste-to-energy system. The system utilized the existing city-wide infrastructural systems (district heating system; the Högdalen combined heat and power plant and the Hammarby thermal power station) together with new technologies for converting sludge into fertilizer and biogas. The heat produced from the process of purifying wastewater is used by the thermal power station. The biogas is used for cooking and to power the public transport system. Refuse is burnt to provide heating for homes and businesses. Thus, sewage, waste-heat and refuse are used to produce energy.

More recently, circular development has manifested in Stockholm Royal Seaport [69]. Here, Ecocycles 1.0 was modified to encompass resource cycles from both the living and port environments (Ecocycles 2.0). Organic waste produced on ships and from the maintenance of green spaces in the seaport are also used to feed the waste-to-energy system. It is also used to produce compost, which can substitute for fertilizers made with petrochemicals.

A gray-water reuse system has been added to Ecocycles 2.0. The system stores stormwater in retention ponds or caverns, which limits flash-flooding in SRSP. The system reduces the damage to the aquatic environment caused by the release of wastewater into the harbor. The stored water can be reused for watering vegetation in the port. The green-blue infrastructure protects gray infrastructure in the port. Finally, bioremediation has been used to restore soil, caverns and waterways.

### 5. City Analysis

The sustainability benefits of adopting circular systems in these cities were investigated through interviews with key stakeholders (Table 5). This section presents the broad findings of those interviews and where possible supports these findings with examples, quotes and extracts from the gray literature.

**Table 5.** Benefits of circular systems identified by service and infrastructure providers.

Circular Systems	City	Scale	Loop	Adapt	Ecologically Regenerate	Benefits Indicated by Interviews		
						Ecological	Social	Economic
<b>Circular Construction</b>	Amsterdam London Paris	City-region Neighborhood (QEOP) City-region	✓	✓		Reduce material consumption; reduce GHG emissions	Reuse of structures for community projects	Creates economic value; localized value chain; creates jobs; avoids landfill costs.
<b>Circular Food System</b>	Paris London	City-region Neighborhood (Brixton)	✓	✓	✓	Reduce food waste; reduce GHG emissions; increases resource sufficiency; restores ecosystem services, increase in environmental awareness	Empowers communities; opportunities to socialize; offers access to affordable food for low income groups; builds new skills in the community; increases community resilience	Creates economic value; localized value chain; creates jobs; activates vacant and unused spaces; avoids landfill costs
<b>Adaptive Reuse of Spaces/Infrastructure</b>	Amsterdam Paris London	Neighborhood (De Ceuvel) City-region Neighborhood (QEOP & Brixton)	✓	✓	✓	Reduce material and land consumption; reduce GHG emissions; restores ecosystem services; increases resource sufficiency; provides cultural services;	Stabilizes existing communities; increases community resilience; builds local symbiotic capital; builds new skills in the community; access to affordable accommodation; provides affordable accommodation	Reduces accommodation costs; creates economic value; localized value chain; creates jobs; activates vacant and unused spaces; increases value of property and land
<b>Water and Nutrient Recycling</b>	Amsterdam Paris Stockholm	City-region & Neighborhood (De Ceuvel) City-region Neighborhood (Hammarby & SRSP)	✓	✓	✓	Reduce potable water consumption; reduce GHG emissions; increases resource sufficiency; restore ecosystem services; increase in environmental awareness, increases resilience to climate change; increase food security		Creates economic value; localized value chain; creates jobs; reduces cost of water purification for non-drinking uses, increases value of property and land, avoids costs of grey infrastructure to present flooding.
<b>Waste Heat Recovery</b>	Amsterdam Stockholm	Neighborhood (De Ceuvel) Neighborhood (Hammarby & SRSP)	✓			Reduce fossil fuel consumption; reduce GHG emissions; increase in environmental awareness	Provides affordable heat	Reduces energy costs



Table 5. Cont.

Circular Systems	City	Scale	Loop	Adapt	Ecologically Regenerate	Benefits Indicated by Interviews		
						Ecological	Social	Economic
Waste to Energy	Stockholm	Neighborhood (Hammarby & SRSP)	✓			Reduce fossil fuel consumption; reduce GHG emissions; increase resource sufficiency		Creates economic value; localized value chain; creates jobs.
Ecological Restoration	London Stockholm Amsterdam	Neighborhood (QEOP) Neighborhood (SRSP) Neighborhood (De Ceuvel)	✓	✓	✓	Reduce land consumption outside the city; restore ecosystem services; increase in environmental awareness; reduces GHG emissions; increases resilience to climate change	Health benefits; opportunities to socialize and for recreation.	Activates vacant & unused spaces; increases value of property & land; avoids costs of grey infrastructure to prevent flooding; avoids health costs; avoids chemical remediation costs
Reuse of Goods	London	Neighborhood (Brixton)	✓			Reduce material consumption and waste; reduce greenhouse gas emissions.	Empowers communities; opportunities to socialize; access to affordable goods for low income groups; builds new skills in the community	Creates economic value; localized value chain; creates jobs; avoids landfill costs

Source: Author's own.

### 5.1. Ecological Benefits

All the interviews confirmed that looping (e.g., circular construction, circular food systems, water and nutrient recycling) and adaptive actions (adaptive reuse of buildings and sites) reduce the consumption of resources. In Amsterdam, it is estimated that the high-value reuse and recycling of construction waste saved 500,000 tonnes of materials per annum [70]. In the Queen Elizabeth Olympic Park (London), soil-washing operations resulted in 80% of excavated soil being reused on site [71]. In Paris, the *sol-dating platform* (which facilitates soil exchanges between sites) recovered more than 30,000 m<sup>3</sup> of soil in the Île-de-France region, producing a 50% reduction in inert soil management costs [72].

Unfortunately, increased resource efficiencies may also result in a rebound effect. The interviews in Stockholm and Paris highlighted this problem with the ecocycles and gray-water reuse systems [73,74]. In Hammarby, ecocycles reduced fossil fuel consumption by 28–42%, water consumption by 41–46% and waste going to landfill by 90% [75]. This produced cost savings for households, which enabled them to increase their overall consumption of energy [74,76].

*We found in Hammarby, resource savings were lower than expected. We thought this resulted from a lack of understanding of how to use the system effectively amongst residents. However, we later found that the rebound effect was largely responsible. The savings made by the system, reduced the cost of energy for the consumer, and so residents increased the overall quantity of energy they consumed. [74]*

Similarly in Paris, the gray-water reuse system has reduced the quantity of potable water consumed. However, the low cost of gray-water, has led to over-consumption [73]. The city is considering replacing the gray-water system and charging for all water consumed, in response to this rebound effect.

The interviewees also mentioned that looping could increase urban resource security [73,74,77–83]. For example, the Paris strategic plan encourages land designation for urban agriculture throughout the region [84].

*Increasing local food security provided the rationale for creating a local circular food system in Paris. [73]*

In Stockholm, ecocycles were introduced to reduce Stockholm's reliance on fossil fuels, making it more energy secure [85]. Amsterdam is also attempting to increase food security. The power-to-protein project (which extracts ammonia from sewage to create high value proteins) could provide Amsterdam's population with 35% of their primary protein requirement [86]. The scheme will also reduce land and water needed to grow feedstock crops, as well as reduce energy consumed in the production and transportation of feedstock [87].

Interviews [77,78,88] in Amsterdam suggest that looping construction and organic waste can reduce greenhouse gas emissions.

*Circular systems are fundamental to achieving a reduction in greenhouse gas emissions here in Amsterdam. They may also help us to adapt to climate change by increasing resource security". [78]*

This is supported by the findings from the circle scan project. It calculated high value recycling and reuse of construction waste could save 75,000 tonnes of CO<sub>2</sub> per annum, whilst the dismantling and separation of components and materials from buildings could save 100,000 tonnes of CO<sub>2</sub> per annum [70]. The circle scan project calculated that cascading of organic waste flows (300,000 tonnes of CO<sub>2</sub> per annum), organic waste separation (100,000 tonnes of CO<sub>2</sub> per annum), recovering nutrients from organic waste (100,000 tonnes of CO<sub>2</sub> per annum), and the establishment of a bio-refinery hub (300,000 tonnes of CO<sub>2</sub> per annum) could save 800,000 tonnes of CO<sub>2</sub> per annum in Amsterdam [70]. Equally, energy recovery from organic waste helps decarbonize the local energy supply. For example, waste biomass is used to produce biogas in Paris, which is injected into the

heating system to decarbonize it [73]. In Stockholm, ecocycles have reduced CO<sub>2</sub> emissions by as much as 29–30% [75].

The importance of ecological regeneration in restoring ecosystem services was reported in several interviews [73,77,78,89–91]. In De Ceuvel site, bioremediation and above ground services were critical to the project's success. In the longer-term, bioremediation will enable the site to be used for commercial activities [78]. This raises the value of the land. De Ceuvel indicates a potential mechanism for the remediation of contaminated, post-industrial sites, as part of a wider tactical urbanism strategy. Bioremediation was also successfully used in the Queen Elizabeth Olympic Park (QEOP) and Stockholm Royal Seaport (SRSP) to treat contaminated ground water and caverns (now used as garages).

Blue-green infrastructure was integrated across the QEOP and SRSP sites. This increased biodiversity, created green corridors for active transport and aided soil formation [90,92]. It also regulated local hydrology, to address both drought and flooding conditions for the QEOP site [90]. In SRSP, a mixture of permeable surfaces and retention ponds were used to prevent flash-flooding and enable watering vegetation and reducing pollution in adjacent waterways [74,91].

*The ecological regeneration of the port system in the Royal Seaport helps to support natural cycles. This in turn helps with local water management, both flash flooding and pollution. [91]*

For both sites, the integration of blue-green infrastructure into the built environment was also seen as a solution for adapting to climate change, particularly in terms of water management. In Paris, the replacement of gray with blue-green infrastructure as a means for rainwater capture and gray-water recycling, was also seen as a climate adaptive response [73].

De Ceuvel and Brixton provided evidence that community engagement in circular projects would increase environmental awareness [74,93]. De Ceuvel is a circular living lab. It has materialized the principles of circular development and made them sharable. According to the interviews [78,89], a co-design process involving De Ceuvel's inhabitants and circular designers, was fundamental to its success. It helped to raise inhabitants' awareness of circular resource flows, the systems needed to facilitate them and benefits of adoption [89]. This approach enabled residents to adopt circular practices quickly. De Ceuvel's residents identified strongly with their neighborhood and were proud of its ecological achievements [89]. This helped to further reinforce circular practices.

A similar (albeit less powerful) dynamic was reported by Brixton's Transition Towns team [92]. The various local projects (e.g., community food and energy production, repair workshops, pop-up enterprises) combined with a local currency, were badged as actions to combat climate change. These helped the community to become more aware of how and where resources were produced [92]. Community engagement in the projects helped develop the expertise and skills needed to adopt circular practices [92–95]. The creation of local jobs (attached to the projects) reinforced local support for the schemes [79,92,93,96–98]. Thus, environmental awareness has grown in the community, alongside circular practices and support for these schemes.

*Awareness of climate change and resource consumption has grown amongst the local population over the period of several years. This is as a result of people's engagement in the local projects, and also their local visibility. However, environmental awareness for many has grown because of the projects offering other social and economic benefits, and not because of an initial interest in the environment. [92]*

## 5.2. Social Benefits

The interviews identified a number of social benefits derived from circular development.

*In Paris, we see social solidarity as the key goal for the circular strategy. It is essential we use circular strategies to provide better access to resources for those most in need". [73]*

Looping actions can provide more affordable resources (e.g., heat, accommodation, goods and food) for low-income groups [73,79,82,92,95,98]. This was exemplified by the food reuse schemes (e.g., *Brixton café*, *Freegan Pony* and *Les Frigos Solidaires*) and repair cafés (e.g., remakery in Brixton and recycleries in Paris) in Paris and London [73,92,95,96]. De Ceuvel and Hammarby also demonstrated how waste heat could be captured and reused, reducing the costs of heating [83,89]. However, neither explicitly benefitted low income groups.

Circular actions which engage communities, offer opportunities for people to socialise, gain new skills and earn money [73,79–82,90,92,93,95–98]. Thus, they can help to build local social, economic and human capital. *Transition Towns Brixton* actively encouraged the creation of these capitals through its support of various social enterprises and a local currency.

*The intention (in Brixton) was to create a stronger, more skilled, resource secure community, which was more resilient and thus able to address climate change. [92]*

The interviews indicate that these projects have strengthened local symbiotic capital [79,81,92,93,95–97]. They also provide an arena in which the local people can test different social practices, which offer ecological, social and economic opportunities.

The interviews [96–98] highlighted that the adaptive reuse of space in Paris and London, for a variety of pop-up activities (some circular activities) built local social, economic and human capital. Temporary planning permissions and leases offered affordable spaces for lower value activities for a short period [92,97,98]. The Brixton cluster of projects and Parisien pop-up projects (*Reinvented*, *Paris Culteurs*, *Leas Grands Voisins*) demonstrated how these activities helped to empower and stabilize local communities [92,98]. They revitalized areas culturally and economically. This resulted in greater investor interest and increasing land values. Unfortunately, this also meant the eventual loss of many social enterprises [92,96–98]. These cases highlight a significant problem with securing the longevity, or scaling-up circular projects, particularly if they have a social solidarity focus.

The health benefits of ecological regeneration were highlighted by interviews [74,90,91]. In Stockholm Royal Seaport and Queen Elizabeth Olympic park, the population had excellent access to blue-green infrastructure. The neighborhoods were well connected to the city via blue-green active transport corridors. The development agencies believed this would be beneficial for residents' health, although it has not been monitored [90,91].

*It is expected that the inclusion of green infrastructure throughout the site will offer health benefits to those living in and around the park (Queen Elizabeth Olympic Park., Due to it's sheer size, health benefits are also expected for the rest of Greater London. However, there is an issue about how to measure this effectively. If we could measure all the benefits offered by the park, it might help to preserve it long-term. This will be more important as pressure builds to develop it. [90]*

However, in both instances, those benefitting from the ecological regeneration of the urban system, were affluent households. Property prices and rental costs in both urban districts were extremely high. Interviewees [90,91] suggested that a process of green gentrification had effectively excluded low-income groups from both neighborhoods.

### 5.3. Economic Benefits

The interviews highlighted that looping, adaptive and regenerative actions could help service providers, insurance companies, residents and local authorities avoid costs [73,74,77,78,88–90,98,99]. For example, the reuse of buildings or waste heat will avoid construction or heating costs [89]. The reduction of construction and organic waste will reduce the cost of landfill [73,77,88,99]. Increase in the use of green infrastructure will help to reduce the cost of gray infrastructure to prevent flooding and the cost of insuring properties in the flood-prone zones [74,90,91]. The integration of blue-green infrastructure into the urban fabric could also help to avoid health costs [73,74,90,91]. However, these avoided costs need to be estimated to make a stronger case for circular systems.

The majority of service providers interviewed suggested that economic value and jobs would be created by adopting looping actions in cities. Circular construction [73,77,88,90,99,100], circular food systems [73,79–82], the looping of organic waste, nutrients and water [88], will all create local economic value and generate employment opportunities. However, there is limited data (particularly at a city-level) to support this assumption. Projections have been made for London that a circular economy could create 12,000 new jobs by 2030, of which 5% would be in the construction industry [101]. Circular construction could generate an economic value of between GBP 3 bn and GBP 5 bn annually by 2036 [102]. The capital's circular food economy could add GBP 2–4 billion annually to GDP by 2036 (ibid). Similar projections have been made for Amsterdam. Estimates suggest that circular construction could produce EUR 85,000,000 annually and 700 jobs; meanwhile, the organic waste (including food waste) sector is expected to generate EUR 140,000,000 annually and create 1250 jobs (ibid).

Monitoring is needed to determine the actual impact on the economy and jobs created. The OECD suggested that the economic value and number of jobs created by a circular economy may have been over-estimated. This requires more research at a city-level. It is also unclear what jobs might be displaced by a shift towards circular actions. It is uncertain whether the jobs created would be secure and well paid. For example, circular social enterprises in Brixton relied on volunteers, donations and access to cheap space [92,96]. These activities were neither well paid nor secure. There is no data to identify who benefits from the circular employment opportunities generated. It has been suggested that a wide range of jobs requiring a diversity of skills is likely to emerge from the circular, pop-up and bio-economies. However, the accessibility of these jobs to the socially excluded requires further investigation.

*It is important to ensure that everyone can access good employment opportunities generated by the circular strategy (in Paris). This will require the introduction of skills development programs. [73]*

The interviews [73,78,89,90,92,96,98] reinforced the findings in the literature that the reuse of vacant and unused spaces in cities results in economic revitalization and boosts local real estate value. In the early stages, these circular activities tend to be social enterprises (e.g., Brixton Café, Remakery, Les Grands Voisins). But the cases demonstrate the insecurity of social enterprises. If these pop-up, social enterprises are not sustained, as they are replaced with commercially successful enterprises [79,92,97–99]. Thus, the knowledge, human and social capital generated by the projects, which could set urban systems onto new sustainable development trajectories, is lost [79,92,97].

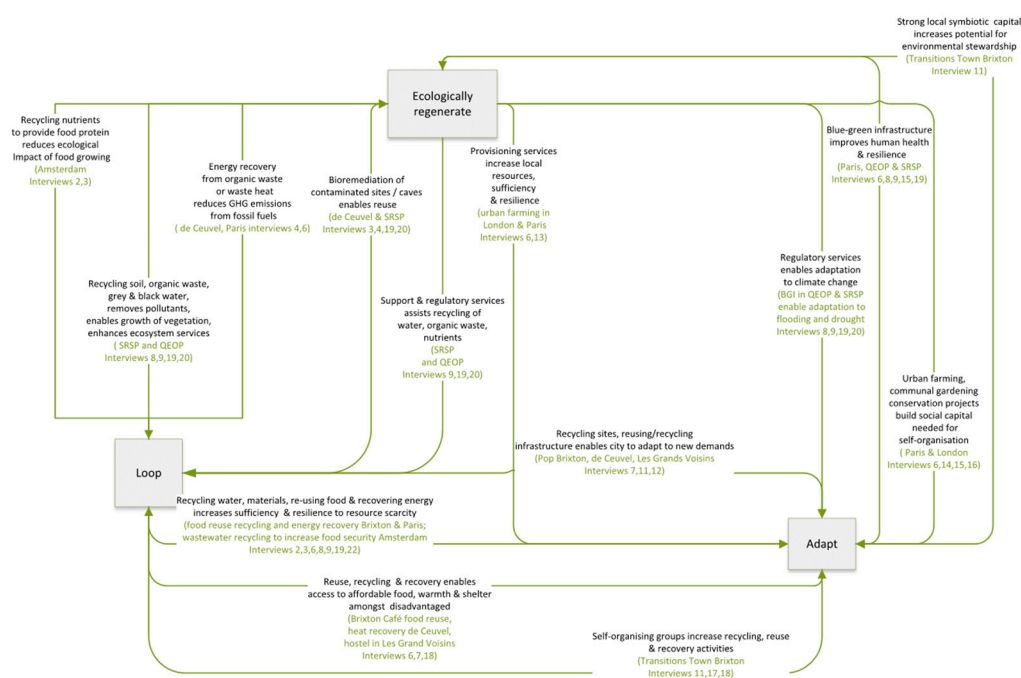
*The problem with the approach taken here in Brixton, is that these innovative projects can't be sustained long-term. They rely too heavily on good will, volunteers, donations and temporary spaces. If we value them, then local government will need to protect them and help them to succeed. Otherwise all the valuable benefits and capital generated by the projects are lost. [92]*

Furthermore, the interviews suggested that low income groups are unlikely to benefit from the ecological regeneration of neighborhoods [90,100]. In both QEOP and SRSP, a lack of affordable housing and relocation of some existing low-income residents to new neighborhoods had resulted from the green gentrification process. Interviewees suggested that poorer groups were less likely to benefit from the rising land and property values in these districts [90–92,96]. Thus, an important question to answer is who benefits from the economic outcomes of circular development.

#### 5.4. Synergistic Benefits

The case studies provide some evidence (originating from the interviews and technical reports indicated in the text below and Figure 3) that the three circular actions can work synergistically together to reinforce or amplify the benefits of circular development. For instance, looping actions help to regenerate urban ecosystems. Recycling soil, organic waste,

gray and wastewater removes pollutants and regenerates the local ecosystem. In SRSP, rainwater storage and graywater recycling reduced localized flooding and the dispersal of pollutants into the harbor, which helped to restore the marine environment [74,91]. In QEOP, the soil recycling schemes improved soil quality and enabled the successful planting of vegetation in the park. This helped to reduce air pollution, reduce surface run-off and enable local carbon sequestration [90,100]. Energy recovery from organic waste (as operated in Paris) or heat capture (as used in de Ceuvel) reduce greenhouse gas emissions [73,89]. The recycling of residual nutrients to provide food protein (as in Amsterdam) reduces the land needed to grow food and the emissions from transportation, which helps to restore ecosystems [78,88].



**Figure 3.** Synergistic benefits from adopting a circular development pathway (Source: Author's own).

The regeneration of the urban ecosystem may also boost support and regulatory ecosystems services, which enhance the natural loops for water, organic waste and nutrients. The provision of blue-green infrastructure (BGI) moderates water flow and storage; it limits overspill from sewers and thus reduces the contamination of the potable water supply, an approach adopted in QEOP [100]. BGI also produces organic waste, which can be composted and used to improve local soil quality (as seen in SRSP). It also reduces the greenhouse gas emissions associated with fertilizers and burying organic waste [74,91]. Bioremediation increases the potential for the reuse of contaminated sites in cities. Phytoremediation enabled the contaminated site in De Ceuvel to be reused for commercial and leisure activities [78,89]. The microbial remediation of naphtha in caves in SRSP enabled their reuse for storm-water storage, which was then used to water vegetation locally [74,91].

Ecologically regenerative actions also increase the adaptiveness and resilience of urban ecosystems. Healthy urban ecosystems support the production of resources, which increases urban resource security. The clearest example of this is urban farming. Both in London and Paris, urban farming is seen as part of the solution for increasing local food security [73,80]. Local food production increases access to fresh food and thus can improve human health [79–81]. More broadly, the integration of BGI into cities will improve the health of the population and increase urban resilience to pandemics. Interviewees in SRSP, Paris and QEOP all highlighted the link between a healthy ecosystem, a healthy population and urban resilience [73,80,91,100]. BGI also helps to regulate local climate and water



cycles, which enables urban systems to adapt to climate change. This was a key motivation for introducing BGI into the SRSP and QEOP developments [74,90,91,100].

Looping actions can also help increase the adaptiveness of urban ecosystems, which helps to build urban resilience. Recycling sites and infrastructure enables the city to adapt. The use of temporary planning permissions and leases allow cities to react quickly to rapid changes in the landscape, like economic and health crises [97,98]. This process provides temporary sites for pop-up circular activities, as seen in London and Paris [92,97,98]. It also provides space for activities which reflect local needs, for example by providing a hostel and allotments in Les Grands Voisins [98]. This flexibility in the way in which space is used in cities increases urban resilience.

Recycling water, re-using food and recovering energy can all help increase local sufficiency and resilience to resource scarcity. Black-water recycling in QEOP was introduced to decrease problems of drought in the area. This is a problem that is expected to get worse with climate change [90,98]. In Paris, the re-use of food is part of the capital's food security strategy [73]. In Stockholm energy recovery from residual materials and heat reduces reliance on fossil fuels. Thus, the city is more energy secure [83,91].

Looping actions also increase urban resilience by making affordable resources available to low-income groups. This is particularly important when there are rapid economic changes, and the proportion of low-income groups in the population expands. For example, repair cafes and food reuse schemes in Paris and London have increased access to affordable food and goods amongst the urban poor [73,82,95]. The temporary reuse of buildings to provide affordable shelter was also highlighted [73]. The capture of waste-heat from buildings (as in de Ceudel) or from cleansing of wastewater (as in Stockholm) could also potentially offer affordable heating for low income households [83,89].

Public engagement in all circular activities (both looping and regenerative) helps to build local human, social, physical and economic capital (i.e., local symbiotic capital). This increases community adaptiveness and resilience [73,79–81]. It is best demonstrated by the Brixton case. Here, local expertise has developed in growing food, generating renewable energy, repairing old goods and reusing vacant spaces. The infrastructure and spaces needed to support these activities have emerged. Some economic capital has been generated and social networks have been strengthened in this process [81,92,93,95–97]. The generation of these local capitals provide the infrastructure needed for the community to remain agile and resilient to external pressures. It also provides the resources to enable environmental stewardship [92]. Thus, the evidence suggests the need to take a more holistic approach to circular development, to profit from the synergistic benefits which are indicated. However, these findings rely largely on anecdotal evidence. It is important that the synergistic benefits of circular development are monitored if a strong case is to be made for its adoption.

## 6. Discussion

The results from the case studies validated the benefits framework, produced from the inductive content analysis of the literature. The research demonstrates the ecological, economic and social benefits of adopting circular actions and circular systems in cities. It also highlights the importance of applying all three circular actions in a development strategy, to maximise benefits from the synergies created. These findings provide an evidence-base for urban policymakers when considering circular development as a strategy for urban development. However, more data needs to be collected, which measures the impact and monitors the benefits of circular development, to further support the case.

The research does suggest that the benefits produced by different circular systems are likely to advantage different groups in society. For example, circular construction largely benefits developers and construction companies. Food reuse benefits the urban poor and local authorities who would otherwise need to deal with the food waste. Of course, this may alter with new regulatory frameworks. If dumping food waste is illegal (as in Paris), then those generating the waste stand to benefit the most from reuse systems (i.e., all the

producers of waste). Currently, it is easier to determine who benefits directly from circular systems than determine the scale of benefits which accrue.

The research also suggests that timing may affect the benefits of circular actions taken in cities. For example, the benefits of ecological regeneration will take longer to present than those accruing from the adaptive reuse of buildings. Equally, those initial benefits may produce new problems over time. This is the case with green gentrification. Thus, the point at which benefits are measured almost certainly matters.

The findings from the case studies provide policymakers with more information about the benefits of specific circular systems (e.g., circular construction and circular food systems). The benefits emerging from implementing circular systems are similar across the cities studied. The corroboration between cases strengthens the findings for each system. Thus, benefits of circular food systems are likely to be the same across similar, relatively prosperous, western European cities. However, we might expect to see a different set of outcomes if we compared these cases with cities in the developing world or cities at different stages of economic development. We may also find different circular systems in different contexts, or at least variations in the way they are implemented.

The case studies and the inductive content analysis of the literature also highlight several shortcomings of circular development. The first relates to the rebound effect identified in the literature [33]. Resource efficient, looping systems reduce the cost of the resource to the producer (and eventually the consumer), which encourages an overall increase in direct (or indirect) resource consumption. This rebound effect is illustrated by the Paris gray-water recycling system [73] and Stockholm Ecocycles [74,76,91,103]. In both instances, the low cost of resources (energy and graywater) resulted in higher levels of consumption. The rebound effect may be addressed through resource pricing (as is being considered for Paris) or consumer education (as was the case in Hammarby Stockholm). Regardless, these experiences highlight the need to also examine the unintended consequences of adopting a circular development path in cities.

The second shortcoming which emerged from the research was the problem of evaluating sustainability benefits. This was discussed in the literature and pivots on the need to internalize ecological and social externalities into the economic evaluation of development decisions. The case studies demonstrated how ecosystem services are under-valued. Yet the health and security of the urban ecosystem is threatened if these services are undermined. Interviewees pressed the need to value ecosystem services to avoid unnecessary health, insurance, gray-infrastructure and climate adaptation costs [73,74,78,89–91,98,103], as well as to protect space for ecologically regenerative systems in cities [70,73,74,90,100].

The case studies also demonstrated that the social benefits emerging from circular social enterprises were under-valued. Thus, social enterprises were often under-resourced [79,81,92,93,95]. The benefits to society offered by these social enterprises, in terms of developing people's skills, strengthening communities and enabling access to resources for low-income groups, were demonstrably under-valued. Thus, social circular enterprises seem unable to compete with commercial alternatives, particularly in cities where land values were high [92,97,98]. New approaches to valuing these societal benefits are needed, in order for societal goods to be given equal weight in development decisions. A more holistic approach to evaluation would ensure those making development decisions were better informed.

Finally, the literature suggested that the benefits of adopting a circular development approach were not spread equally across society [47,54,55]. Both SRSP and QEOP cases support this notion. In both cases, circular development resulted in green gentrification, rising land values and loss of low-income groups from both areas [90,98,103]. Therefore, low-income groups did not benefit from access to green space and adjacent ecosystem services provided by circular development. Yet the health benefits of locally accessible green space are greatest for these groups, because they tend to remain in their local area.

Circular solidarity activities particularly benefit the urban poor (e.g., food reuse schemes, community farming or energy, repair cafes, temporary affordable accommoda-

tion). However, the case studies show these projects are more likely to fail because they rely on donations, volunteers or are accommodated in spaces with temporary leases [92,96,97]. This lack of commercial viability means solidarity projects are less competitive, yet they are important for the wellbeing of low-income groups [73].

Circular development also has the potential to provide a variety of sustainable job opportunities, for a range of skills sets. However, it is more likely that low-income and poorly educated groups will be employed in activities which are low paid, insecure or hazardous. It is important that these potential inequalities are addressed if circular development is to benefit those most in need.

## 7. Conclusions

In conclusion, the research contributes to the urban sustainability and circular cities literature by providing an analysis of the sustainability benefits of circular development. The findings suggest that circular development could address many of the ecological, social and economic problems currently facing cities. It supplies some evidence of the synergistic benefits created through combining the three circular actions in cities. It also identifies the potential benefits of adopting select circular urban systems. Thus, taking a circular approach to development could help to reinvigorate our cities and is likely to be worth investing in.

However, there are limitations in this research, particularly around the reliability of the benefits framework and synergistic benefits. Both could be directly tested with a larger group of key stakeholders to increase their reliability. A limited amount of data has been collected to quantify the benefits which accrue from circular development. Some data identifying reduction in resource consumption, greenhouse gas emissions, jobs and income created by circular construction, circular organic waste and circular food systems has been collected. The data monitoring many of the socio-ecological benefits of circular development is lacking. Thus, it is hard to identify the scale of the benefits which accrue from adopting a circular development approach. Thus, more quantitative data is needed to test the framework and synergistic benefits.

In addition, investigations into cities operating across different contexts (i.e., in different geographical regions or with different economic profiles) are needed to explore the variety of possible circular urban systems and the benefits which may accrue from adopting them. More research focused on the costs of circular development, the unintended consequences and the unequal distribution of benefits across society is also needed. More monitoring to determine who is affected by circular development and the scale of the benefits which accrue is additionally required. This information could help policymakers to ensure that circular development is implemented in an equitable and socially-just fashion.

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