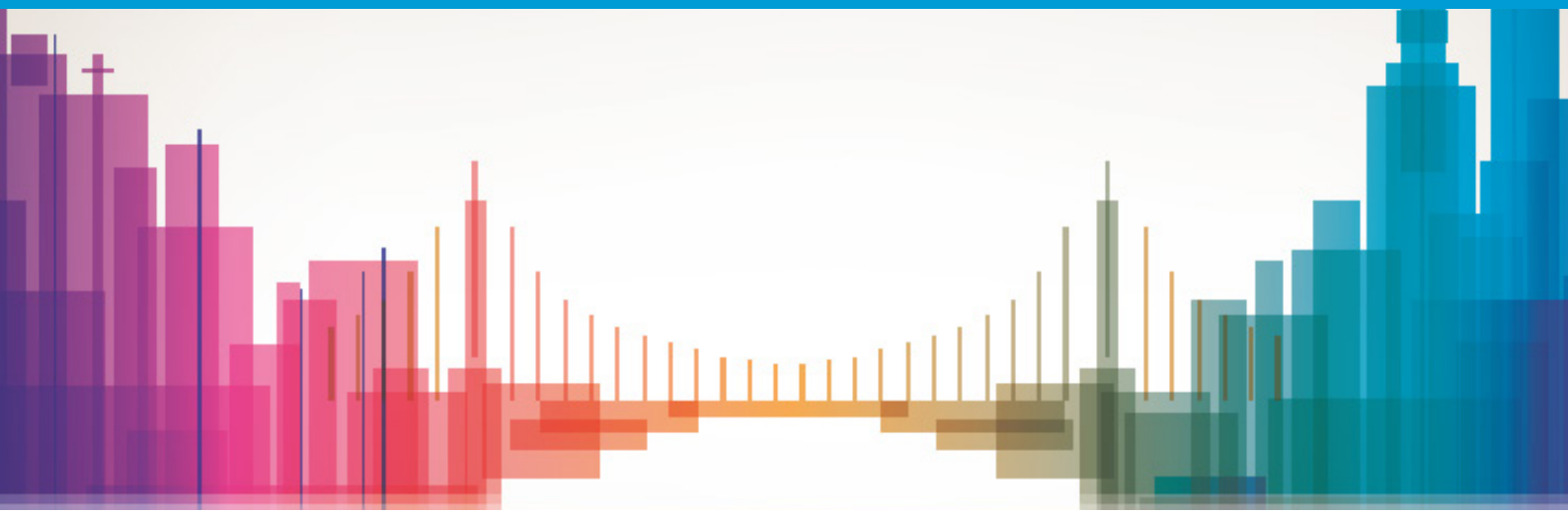
United 4 Smart Sustainable Cities

A guide to circular cities

June 2020



Convention on Biological Diversity

United Nations ECLAC

Food and Agriculture Organization of the United Nations

ITU

UNDP Empowered lives. Resilient nations.

United Nations Economic Commission for Africa

UNECE

UNESCO United Nations Educational, Scientific and Cultural Organization

UN environment programme

UNEP FINANCE INITIATIVE

United Nations Framework Convention on Climate Change

UN HABITAT FOR A BETTER URBAN FUTURE

UNIDO

UN OFFICE 4 PARTNERSHIPS

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WORLD METEOROLOGICAL ORGANIZATION


SUSTAINABLE
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GOALS

United 4 Smart Sustainable Cities

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June 2020

Foreword

This publication was developed within the framework of the United for Smart Sustainable Cities (U4SSC) initiative.

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Executive summary

The United for Smart Sustainable Cities (U4SSC) initiative is a global platform dedicated to supporting cities worldwide in becoming smarter and more sustainable. The U4SSC is coordinated by the International Telecommunication Union (ITU), the United Nations Economic Commission for Europe (UNECE) and the United Nations Human Settlement Programme (UN-Habitat), along with the support of 14 other UN agencies and programmes. The U4SSC is working to develop strategic guidelines and measurement tools to assist cities in implementing the Sustainable Development Goals.

The Guide for Circular Cities contains a circular city implementation framework that is designed to improve circularity in cities and support stakeholders in implementing circular actions. The framework consists of a four-step methodology that provides a consistent method for assessing, prioritising and catalysing different circular actions. This deliverable is developed in response to the growing sustainability challenges that cities are facing and the emergence of the circular economy concept and its applicability and extension in the city setting.

The Guide starts with an assessment of the main developmental and sustainability challenges that cities are facing and the ways in which the concept of circular economy can be extended beyond the economic sphere and be applied to different city assets.

It further defines key components of the circular city implementation framework. These components include: city assets and products (i.e. various city infrastructures, city resources, city goods and services available for use in a city); circular city actions (i.e. outcome-orientated actions that can be applied to city assets and products); circular city outputs (i.e. the outputs of circular city actions applied to city assets and products); and circular city enablers (i.e. complementary activities which support or accelerate implementation of circular city actions). Each of these components contains different quality and potential for facilitating circularity in cities. The interactions between these components form the basis of the circular city implementation framework.

Finally, the Guide explains the circular city implementation framework. This framework utilizes four different steps to assist city stakeholders in enacting circular actions. The first step is to establish a baseline for circularity. The second step is to determine the potential of circularity in different assets and to prioritize circular actions based on the availability resources. The third step is to apply city enablers to catalyse different circular actions. The last step is to evaluate the impacts of these actions.

Cities are invited to use this Guide to identify a course of action for improving circularity. The Guide also includes practical recommendations for preparing circular city actions and their implementation. The Guide is complemented with 17 case studies that illustrate the application of the circularity concept based on experiences from cities around the world.

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AI	artificial intelligence
API	application programming interface
IoT	internet of things
ICT	information and communication technologies
RFID	radio-frequency identification

1. Introduction

The way we produce and consume physical goods remains largely linear: goods are manufactured from raw materials, sold, used (consumed) and then mostly disposed of as waste. At the same time, the sheer quantity of physical goods far outweighs our actual needs, with most consumer products not in use over 90% of the time – and some purchased solely for single use.

This linear model has been successful in providing affordable goods, services and resources to consumers and material welfare. However, this linear model of production and consumption is material- and energy-intensive; it relies on the principle of economies of scale to produce large amounts of goods at minimal costs, and typically builds on more complex and international supply chains, and creates large amounts of waste, much of which is not only avoidable, but potentially valuable. This model of production and management of goods, services and resources encourages short-term consumption, creates a range of negative externalities and it is leading the planet to a potentially unsustainable future. In this context, the concept of a circular economy has recently emerged as a vision for how to gradually move away from this linear model to one that, by using resources better, is not only more sustainable, but creates a range of new opportunities for inclusive economic growth.

The circularity concept can be extended beyond the sphere of economy. Cities are home to a staggering amount and variety of assets and resources that can not only be produced, but also used much more efficiently and sustainably. The efficiency of each item can be improved by applying circular design, bringing positive social, economic and environmental impacts on a much larger scale. Transitioning to a circular economy will also support city leaders in reaching the Sustainable Development Goals and other global climate objectives.

Promoting circularity in cities is one of the strategic topics of the United for Smart Sustainable Cities (U4SSC) Initiative, which brings together 17 UN agencies with the International Telecommunication Union (ITU), United Nations Economic Commission for Europe (UNECE) and UN-Habitat serving as the secretariat. The U4SSC's Key Performance Indicators (KPIs) for Smart Sustainable Cities (SSC) is one of the most effective tools for evaluating circularity in cities. The KPIs are developed based on the international standard, Recommendation ITU-T Y.4903/L.1603 'Key performance indicators for smart sustainable cities to assess the achievement of sustainable development goals'. These indicators support cities' efforts in evaluating their smartness and sustainability performance. The KPIs were endorsed by the UNECE Intergovernmental Committee on Urban Development, Housing and Land Management (CUDHLM) (ECE/HBP/188, para 41), as well as the ITU-T Study Group 5 'Environment, Climate Change and Circular Economy', which is a global expert group under ITU that develops standards on sustainable and circular cities.

This Guide to Circular Cities, which was developed within the United for Smart Sustainable Cities initiative, will be very useful for cities to implement circular activities and to promote circularity and urban sustainability.

2. Concept of circular cities

2.1 Challenges facing cities

More than half the world's population now lives in urban areas. In 2016, an estimated 54.5 per cent of the human population lived in urban settlements, and that figure is expected to rise to 60 per cent by 2030. These urban areas consume 75 per cent of natural resources, produce between 60 and 80 per cent of global greenhouse gas emissions, and generate 50 per cent of all waste.

The number of cities with at least 1 million inhabitants was estimated to be 512 in 2016. This number is projected to reach 662 by 2030. In the same year, there were 31 'megacities', that is, cities with more than 10 million inhabitants. The number of megacities is expected to reach 41 by 2030.[1] Hence, cities play a crucial role in driving sustainability in production and consumption of goods and services.

Cities are dense and highly congested physical spaces that are prone to a myriad of challenges such as population growth, urban sprawl, climate change, environmental degradation and fiscal pressures.[2] In 2014, more than 80 per cent of cities were located in areas vulnerable to a high risk of mortality or economic losses associated with natural disasters or other environmental challenges. Demographic changes such as ageing populations, volatile economic growth, unemployment, low-wage, low-skilled jobs, income inequality, social polarisation and segregation are fuelling urban sprawl. Furthermore, the current consumption levels in cities are starting to exceed their economic capacity and biocapacity, ultimately affecting the well-being of all city dwellers.

Each city has its own unique characteristics and specific social and economic structure, along with the associated challenges. In order to start injecting circularity into different city assets, it is important for cities to assess their current status and identify the appropriate starting points with respect to circularity. The gap between the current state and the intended circular future creates an enormous innovative potential for cities and communities.

Stakeholders, including the public and private sector, NGOs, civil society and the city dwellers themselves, can work collectively as partners to close this gap. Creating public-private-people partnerships (PPPP) through the involvement of relevant stakeholders is crucial for circularity. These partnerships enable innovative and alternative financing mechanisms for circular city initiatives. In addition, engaging and working with stakeholders through global platforms such as the U4SSC offer a reliable way to make the best use of cities' collective capital and to ensure inclusivity throughout the implementation process.

2.2 Moving from a circular economy to a circular city

This document attempts to identify a list of city assets and products that would broaden the circularity concept beyond economy to include different aspects of city management, hence the term 'circular' cities. For example, public spaces in the city (which are not economic products but public assets) may be used for different social activities at different times (i.e. sharing public spaces as a city asset). Similarly, household items may be shared among individuals and households or re-used for different

purposes. These examples transcend economic activities and enhance the utilization of city assets beyond the economic ones.

The circularity approach proposed in this study is meant to increase the efficiency and effectiveness of city assets and products by extending either their own or their constituents'/components' utilization and life span. This increase is achieved by applying targeted action items (referred to in this study as circular action items) on city assets and products, such as sharing, recycling, refurbishing, re-using, replacing, and digitising. Action items are a set of specific, discrete, outcome-orientated tasks that can be applied to the city assets and products to improve their utilization and life span.[3][4]This document explains the purpose and vision behind a circular economy, while providing an implementation framework on how to establish circularity within the context of cities.

2.3 Definitions of circular economy

The 'Guide to Circular Cities' does not provide a new definition for circular economy. Instead, it has compiled a list of existing definitions of circular economy, in order to illustrate the concept. In general, a circular economy is an economic system where products and services are traded in closed loops or cycles**.** Table 1 lists some of the well-known circular economy definitions and their interpretations.

Table 1: Existing definitions of circular economy

Definition
A circular economy is restorative and regenerative by design, and aims to keep products, components, and materials at their highest utility and value at all times, while reducing waste streams. A concept that distinguishes between technical and biological cycles, the circular economy is a continuous, positive development cycle. It preserves and enhances natural capital, optimizes resource yields, and minimizes system risks by managing finite stocks and renewable flows, while reducing waste streams. *Source*: Recommendation ITU-T L.1020: 'Circular economy: Guide for operators and suppliers on approaches to migrate towards circular ICT goods and networks'.
Circular economy refers to the 'production and consumption of goods through closed loop material flows that internalize environmental externalities linked to virgin resource extraction and the generation of waste (including pollution)'. *Source*: Sauvé, S., S. Bernard and P. Sloan (2016), 'Environmental sciences, sustainable development and circular economy: Alternative concepts for trans-disciplinary research', *Environmental Development*, Vol. 17, pp. 48-56.
'Circular economy is an approach that would transform the function of resources in the economy. Waste from factories would become a valuable input to another process – and products could be repaired, re-used or upgraded instead of thrown away'. *Source*: Preston, F. (2012), 'A Global Redesign? Shaping the Circular Economy', Briefing Paper, London: Chatham House.
Circular economy 'refers mainly to physical and material resource aspects of the economy – it focuses on recycling, limiting and re-using the physical inputs to the economy, and using waste as a resource leading to reduced primary resource consumption'. *Source*: EEA (European Environment Agency) (2014), 'Resource-efficient Green Economy and EU policies', Luxembourg: Publications Office of the European Union.

Definition
'A circular economy is an alternative to a traditional linear economy (make, use, dispose) in which we keep resources in use for as long as possible, extracting the maximum value from them whilst in use, then recovering and re-using products and materials.'
Source: Mitchell, P. (2015), 'Employment and the circular economy – Job Creation through resource efficiency in London'. Report produced by WRAP for the London Sustainable Development Commission, the London Waste and Recycling Board and the Greater London Authority.
Circular economy is 'an industrial system that is restorative or regenerative by intention and design. It replaces the 'end-of-life' concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals, which impair re-use, and aims for the elimination of waste through the superior design of materials, products, systems, and, within this, business models'. The overall objective is to 'enable effective flows of materials, energy, labour and information so that natural and social capital can be rebuilt'.
Source: Ellen MacArthur Foundation (2013a), 'Towards the Circular Economy. Economic and Business Rationale for an Accelerated Transition' (https://tinyurl.com/hzfrxvb).- Ellen MacArthur Foundation (2013b), 'Towards the Circular Economy, Opportunities for the Consumer Goods Sector' (https://tinyurl.com/ztnrg24).- Ellen MacArthur Foundation (2015a), 'Towards a Circular Economy: Business Rationale for an Accelerated Transition' (https://tinyurl.com/zt8fhxw).
The circular economy is an economy 'where the value of products, materials and resources is maintained in the economy for as long as possible, and the generation of waste minimised'.
Source: European Commission (2015a), 'Closing the loop – An EU action plan for the Circular Economy', Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, COM (2015) 614 final.

Circular economy in cities aims to create a sustainable system that allows for the optimal use of city assets and products through re-using, refurbishing, remanufacturing and recycling and other circular actions. This Guide explains the concept of 'circular cities' and provides a methodology for the implementation of circular actions at city level, as well as offering good practices and concrete recommendations for promoting circularity in cities. It also demonstrates the positive impacts and challenges of the implementation of circularity concept.

3. Guide to circular cities

Components of the circular city implementation framework

The four components listed below constitute the key components in the circular city implementation framework. They are the necessary components for implementing circularity in cities.

- City assets and products – encompass various city infrastructures, city resources, city goods and services available for use/consumption in the city.
- Circular actions – specific, outcome-orientated actions that can be applied to city assets and products that include sharing, recycling, refurbishing, re-using, replacing, and digitizing.
- Circular city outputs – they are the results of when circular action items are applied to city assets and products.
- Circular city enablers – various supplementary and complementary items that are used to catalyse and support circular city outputs.

3.1 City assets and products

Figure 1 presents various city assets and products. They are classified into three categories: city infrastructure, city resources, and city goods and services (as potential inputs to circular action items described in sub-section 2).

Figure 1: City assets and products categorization

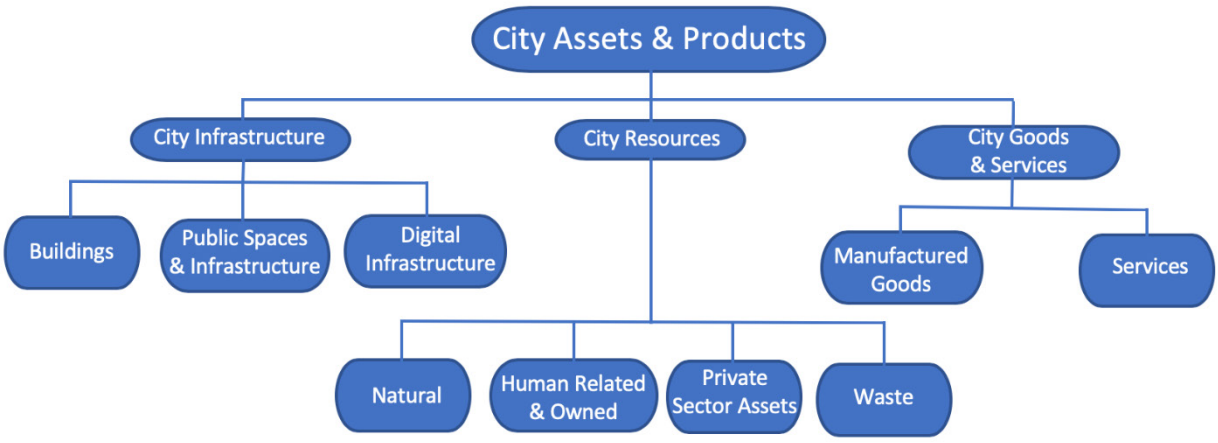

Figure 2: City assets and products detailed categorization

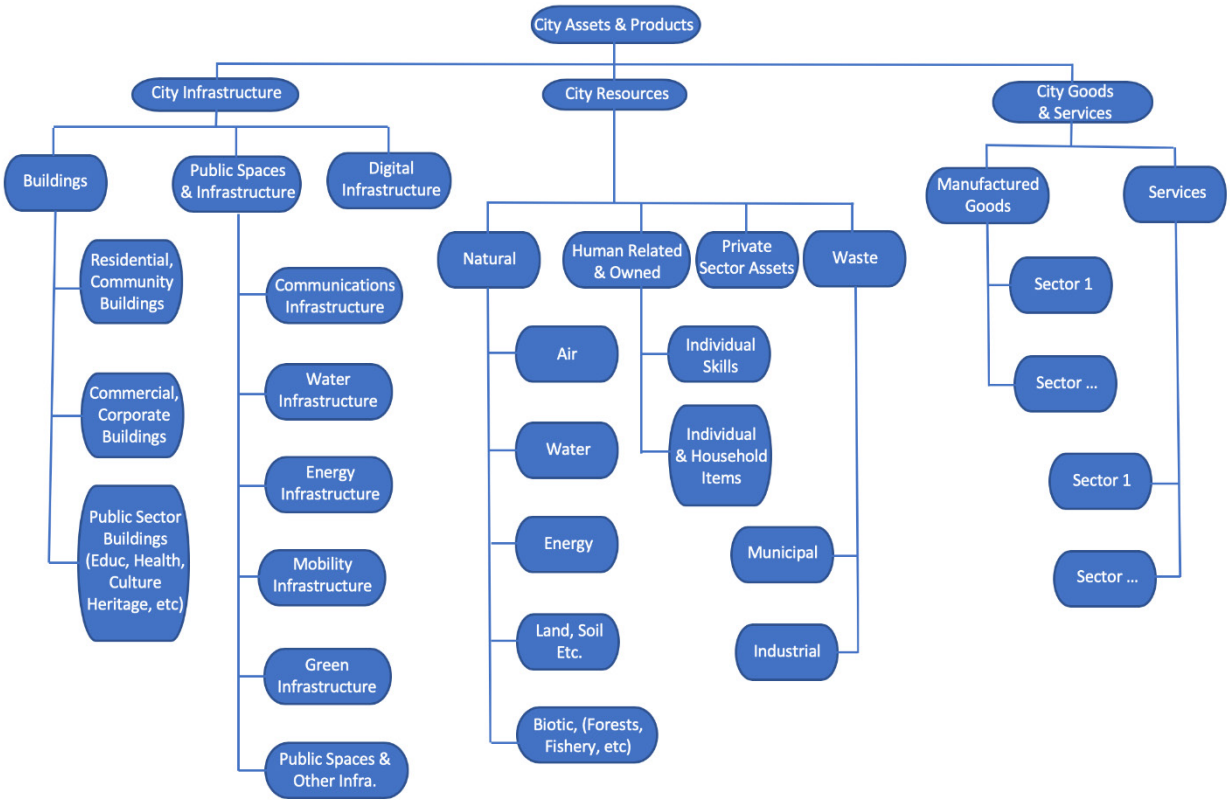

Figure 2 has further broken down the three categories hierarchically.

City infrastructure: It refers to buildings, public spaces and infrastructure, and the digital infrastructure (see figure 1).

a) *Buildings:* Buildings provide the essential space for a city to function, such as living and working places, storage places for belongings and shelters for the needy. The types of different buildings in a city include residential building such as apartments and houses, commercial buildings such as offices and shopping malls, and public buildings such as hospitals, schools, religious, heritage, government, military-related buildings, and other civic buildings that belong to the public sector.

b) *Public spaces and infrastructure:* A public space is an urban place that is generally open and accessible to people in a city. They may include public squares, sports fields, and beaches. Infrastructures are connective structures that enable people in a city to get the resources they need (e.g., from the environment) and bring them to the city; or they may enable flows or cycles in city.[4] Infrastructure types include communication, water, energy, mobility (transport) infrastructure, digital and green infrastructures, as specified below.

   - *Communication infrastructure:* This includes telecommunications, radio, television, and internet infrastructures (including analogue and digital transmissions through various physical media such as copper, coaxial, fibre).

- *Water infrastructure:* This includes supply, sanitation and the management of clean waste and surface waters, including irrigation, drainage and collection.
- *Electrical energy infrastructure:* This includes generation, transmission and distribution infrastructures for various available energy sources (e.g. power plants, nuclear plants, hydroelectric dams, solar installations, wind farms, bio-energy systems).
- *Mobility infrastructure:* Includes human and goods transportation and general mobility infrastructures (e.g. roads, airports, railways, ports, promenades, bridges, pavements, footpaths, bicycle paths).
- *Green infrastructure:* Is composed of natural elements present into the city in a structured manner (e.g. parks, trees, horticultural areas such as gardens).

c) *Digital Infrastructure:* Digital infrastructure includes equipment and services needed for delivering digital services (excluding the communications infrastructure), e.g. data centres, information technology and data processing equipment and systems, cloud computing.

City resources: A resource is defined in the Oxford Dictionary as a stock or supply of assets (e.g. money, materials and staff) that can be drawn on by a person or organization in order to function effectively. Included in city resources are natural resources, human-related and human-owned resources, private sector assets, and waste in a city.

a) Natural resources: They are materials or substances occurring in nature that can be exploited for economic gain.[5] Natural resources include abiotic resources, air, water, oil, wind resources, natural gas, iron and coal, land and soil; and biotic resources such as forests and fisheries. Resources can be broadly classified upon their availability as renewable and non-renewable. They can also be classified as actual and potential, based on their level of development and use.

b) Human-related/owned resources: They refer to inherent qualities of individuals such as skills and knowledge. Human-owned resources are various household items, and other materials and goods owned and used by individuals.

c) Private sector assets: They are tangible assets owned by private-sector organizations that are used to produce products in the form of goods and services. Private sector assets include machinery, warehouse items, company cars and various other tangible assets owned and used by the private sector organizations.

d) Waste: it refers to anything that no longer has a use or purpose and needs to be collected, potentially transported and discarded or disposed of. It includes municipal and industrial waste. Some examples of waste are household trash, wastewater, hazardous waste (e.g. containing hazardous chemicals) and radioactive waste (may require special processing and disposal).

City goods and services: City products include all products of economic sectors and industries in the form of goods and services. In general, they can be categorized by different economic sectors or industries (e.g. by SIC – Standard Industrial Classification[6]) of a city.

3.2 Circular city actions

Circular city actions refer to specific, discrete, outcome-orientated tasks that can be applied to the city assets and products shown in Figure 1, to improve their utilization and lifespan. Sharing, recycling, refurbishing, re-using, replacing, and digitising have been identified in this Guide as the potential circular action items.

Sharing: Sharing is the joint use of city assets and products.

Recycling: Recycling is the process of converting city assets and products arriving at their end of life into new materials and objects to make them consumable or usable again. What is treated as waste and being thrown away as trash could potentially be useful again through recycling. It is an alternative to 'conventional' waste disposal (i.e. incineration and landfilling) that can save materials and, among other positive environmental impacts, help lower greenhouse gas emissions. It can also reduce energy usage, air pollution (from incineration), and water pollution (from landfilling), and so on.

Refurbishing: Refurbishing is about restoring an old city asset or product to bring it to a functional or better condition. Refurbishing is a potential circular action that can be applied to extend the lifespan of city assets and products.

Re-using: It involves using a product or material again, with the same function or a new one.

Replacing: Replacing refers to filling the place of, or providing a substitute for, a city asset or product. Replacement of city assets and products or their components may enhance their circularity potential by extending their life span and utilization.

Digitizing: Digitization refers to "taking analogue information and encoding it into zeroes and ones so that computers can store, process, and transmit such information"[7]. Digitization of information about city assets and products allows the cities to reach more customers, reduce cost and reduce environmental impacts.

3.3 Circular city outputs

When applying circular action items to a city asset, a circular city output is produced. There are many potential circular city outputs given the large number of city assets and products and the number of circular city actions identified in the previous two sub-sections. Table 1 below provides a template for plotting the potential circular city outputs when a circular action item is applied on a city asset or product. The circular city output is plotted on the cell where circular action item intersects with city asset or product.

Table 2: Template for defining potential circular city outputs

Circular action items							
		Sharing	Recycling	Refurbishing	Re-using	Replacing	Digitizing
City assets and products*	Buildings						
	Public spaces and infrastructure						
	Air						
	Water						
	Energy						
	.....						

For instance, the circular action item 're-using' when applied to the city asset, such as reuse of water resources at city level where used water is purified and reused.

Similarly, the circular action item 'sharing' can be applied to the service sector. For example, a day care facility for children could be combined with a facility for older adult by placing a day care centre in a nursing home.

Waste such as bottles, metal, footwear and plastic cups could be separated into compostable and non-compostable; the non-compostable items could then be sold to scrap dealers and the remaining compostable items sold to farmers. This is an example of the application of the recycling and re-using circular action items to city resource 'household items'.

The sharing action item can also be applied to public spaces. Public spaces can be used with alternating distinct purposes. For example, a public square can be used as a general place for public gatherings and for various art events and festivals at times.

The above examples are given in order to illustrate the concept of circular city outputs. There are many more combinations of circular action items and city assets and products that can be used to generate circular city outputs.

3.4 Circular city enablers

A circular city enabler is any entity, activity or initiative that, through its functions, can catalyse and promote circularity in cities. The following are examples of enablers that a city can use to boost its circular city outputs.

a. **Circular KPIs and their baseline and target values:**[8] Key Performance Indicators (KPIs) are useful for measuring progress and evaluating outcomes of activities supporting circularity. Indicators to measure cities' performance have been formulated, some of which measure circularity in cities. Examples of earlier formulated circular city-related KPIs are provided below:

   i. U4SSC KPIs for Smart Sustainable Cities: The U4SSC has developed the KPIs for Smart Sustainable Cities to evaluate the smartness and sustainability of a city. The KPIs focus on measuring three

key city dimensions: economy; environment; and society and culture. They are useful for measuring the impacts of circular city outputs and informing planners to make better design choices. The specific KPIs that could be particularly useful include the KPIs on public building sustainability, green spaces, solid-waste collection and treatment, shared vehicles and so on. In addition, each indicator is connected to one or multiple targets of the Sustainable Development Goals (SDGs), making them the ideal tools for measuring progress towards the SDGs.

ii. The Ellen MacArthur Foundation has undertaken a project called 'The Circularity Indicators Project'. The project provides a methodology and tools to assess the performance of a product or company in the context of a circular economy. The project has published a toolkit and methodology for circularity indicators.[9]

iii. ISO 37120: The International Organization for Standardization (ISO) has developed the Standard ISO 37120 under the ISO/TC 268 to help cities measuring their performance in improving quality of life and sustainability.[10] Some of the KPIs in ISO 37120 can be utilized in the framework of circular cities (e.g. waste management-related KPIs).

iv. ITU, through its ITU-T Study Group 5, has developed a series of international standards to help cities assessing their sustainability. For example, Recommendation ITU-T *L.1440: Methodology for environmental impact assessment of information and communication technologies at city level* provides guidance on assessing the environmental impacts of ICTs at city level. It takes into consideration multiple factors, including the process of raw material acquisition, production, use and end-of-life treatment of ICTs, which could be extrapolated to assess circularity in cities.[11]

There are several other circularity indicators developed by different organizations to address various aspects of circularity.[12] Cities can explore these KPIs to determine which one would be the most applicable to their operation depending on their own context. In addition, the implementation framework depicted in this document is flexible enough to incorporate other specific KPIs that can be formulated by cities themselves for their circularity implementations. Additional KPIs can be included during implementation by a city.

b. **Awareness building of circular city initiatives and actions**: The success of circular city initiatives depends largely on the awareness of their stakeholders. The uptake of circular city initiatives is highly dependent on city-wide awareness and their adoptability to their potential users. Promoting and explaining their benefits may help to drive cultural and behaviour changes towards embracing circularity.

c. **Training and circularity skills enhancement**: Targeted skills enhancement programmes may help in institutionalizing circularity in cities. Academic programmes (e.g. university degrees and courses, related curricula changes) will help to enhance circularity skills through formal education. Vocational and professional training programmes could also help in this regard. Moreover, sharing and disseminating, for example, circularity-related publications, reports and research may also help to further develop circularity-related skills. These programmes help in creating highly skilled human capital for implementing circularity actions at the city level, as well as bridging skills and expertise gaps that have traditionally been a major obstacle towards circular economy.

d. **Measures to promote trust in circular activities**: Circularity includes circular action items such as sharing being applied to various city assets and products. Sharing may be applied to commercial

items or to products (e.g. shared accommodation or ride sharing) and non-commercial items (e.g. sharing of household items on a complementary basis in a city among its inhabitants). In sharing, it is important to introduce trust among city users. Hence, in sharing services, service providers should ensure that they address the concerns of their customers, protect their rights, and provide them with reliable and high-quality services to gain their trust. Additionally, it is important for these service providers to ensure the safety and security of shared city assets and products. Over time, addressing issues consistently and reliably builds trust for service providers.

e. **'Urban industrial symbiosis'**: It is a subfield of industrial ecology that takes a collective approach to engage separate industries, in order to gain competitive advantages by facilitating the physical exchange of materials, energy and services among them.[13] For instance, waste resulting from one production process can be used as primary inputs (materials or energy) in another production process. This allows the creation of closed loops within, and across, industries, which, in turn, enhances circularity in cities.

f. **Circularity-related strategic planning and policy making**: Holistic circularity strategies and policies led by a city administration can align city stakeholders to a common target and mobilize them for successful implementation. Impact investment and corporate social responsibility initiatives undertaken by the private sector can also catalyse circularity in a city.

g. **Utilizing procurement as a lever for circularity**: Procurement is a strong lever for emphasizing and enforcing circularity in the public and private sectors. Incentive plans can be used as a tool to avail the supply of circular city assets and products during their procurement (e.g. raw materials, components).

h. **Financial incentives for boosting circularity**: City administrations and public sector organizations may utilize financial incentives to boost circularity in a city. Monetary (financial) benefits can be offered to consumers and suppliers of circular city outputs, which would encourage their participation in circularity. Financial incentives include, but are not limited to, tax breaks, tax reductions, tax exemptions, tax holidays, lower loan rates, impact investment alternatives, excise taxes, VAT, and so on.

i. **Public Private Partnerships for circularity**: City administrations (public sector organizations) and private sector organizations may collaborate and form partnerships to improve circularity in the city. This approach would allow partners to align and unify their goals, and share the risks and rewards of implementing circularity actions.

j. **R&D programmes for circularity**: Circularity provides enormous innovative potential for cities in addressing their sustainability challenges. In some cases, further research and development would be required to turn circularity ideas into reality. Well-designed research and development programmes that target actual city challenges and are led by academia, private and public sector organizations may help to overcome various obstacles of implementing circular actions.

k. **Circularity regulations**: City administrations can set out various regulations and standards to boost circularity in the city. They may take the form of circularity-related technical standards, product regulations, compliance standards, trade regulations, and waste and safety regulations. Regulations are, in general, ancillary or subordinate to laws. However, they are enforceable and, therefore, constitute a strong lever for circularity.

l. **National laws and directives**: Law is a system of rules created and enforced through governmental institutions to regulate behaviour. Laws can take the form of legislation, directives and acts of parliament and so on, and they are influenced by the constitution. Laws can potentially be used as an alternative tool to change the behaviour of a society towards embracing circularity (in general, laws are made at the national level rather than city level).

m. **Certifications for circularity**: Cities can leverage existing certifications or create new ones to encourage and incentivize circularity. Certifications rely on well-defined and verifiable standards to measure or optimize performance and allow certified organizations to demonstrate their commitment towards a specific goal (i.e. circularity in this case). Certifications are usually voluntary in nature, rather than mandatory; however, they can provide a competitive advantage for certified organizations. They are an indicator of compliance to well-defined standards or criteria and are usually issued by a credible third party after an independent auditing process.

n. **Engaging and ensuring participation of stakeholders**: It is important for cities to engage and ensure the participation of all their stakeholders during the formulation and implementation process of circularity initiatives/action items. An inclusive and participatory implementation process would be highly beneficial for maximizing collective city capital. Collaborative platforms that facilitate multi-stakeholder engagements among the public and private sectors, academia, NGOs, civil society and cities' inhabitants can also be used by cities to ensure broad engagement.

o. **Circularity related city innovation ecosystem**: Fostering a robust and productive ecosystem will help in boosting circularity in cities. Entrepreneurs can be encouraged and incentivized to establish start-ups for addressing circularity challenges in cities. Accelerators and incubators can also be utilized to support circularity-related SMEs. City circularity challenges would drive concrete demand to be met by entrepreneurs and SMEs in the city innovation ecosystem.

p. **Integrated urban services**: Such urban services will help in realization of circularity in cities. E.g., WMO is developing the Integrated Urban hydrometeorological, climate and environmental Services (IUS)[14] to support safe, healthy, resilient and climate friendly cities. Such services involve combining heterogeneous observation networks, high-resolution forecasts, multi-hazard early warning systems and climate services. They should assist cities in setting and implementing mitigation and adaptation strategies that will enable the management and building circular cities.

City assets and products, circular city actions, circular city outputs and circular city enablers are the four components for formulating circular city strategies. The next section details the circular city implementation framework and the necessary steps for achieving circularity in cities.

4. The circular city implementation framework

This section describes a four-step circular city implementation framework according to the four components described above.

The framework includes four steps:

1. Assessing current circularity (baselining).
2. Determining potential for future circularity and prioritizing circularity actions.
3. Catalysing circularity.
4. Assessing projected circularity impact.

Each of the four steps is explained below.

Step 1: Assessing current circularity (establishing a baseline)

This step entails conducting a swift baseline audit, which determines the status of a city with respect to its circularity. More specifically, it evaluates a city's baseline with respect to the following three components:

a. Key performance indicators (KPIs) related to circularity of cities.
b. City-level circular initiatives and relevant action items.
c. Various circular city enablers to assist in implementation.

Each of the above components is explained briefly below.

a. Baselining based on existing circular city KPIs

Evaluating cities' performance using the KPIs may guide the implementation of the circularity approach; not only does it measure the performance of circular city initiatives, but it is also an effective way to monitor their progress. Some examples of circularity-related KPIs include percentage of wastewater receiving treatment, percentage of solid waste recycled, percentage of renewable energy consumed in the city. Cities can further define other circularity KPIs at the sector/industry level such as percentage of refurbished, remanufactured, re-used, recycled, shared materials and products. Potentially, all circular city outputs defined in this document can be associated with circularity KPIs.

Table 3 below offers a template that a city can use to collect the necessary data according to the selected KPIs and evaluate its progress on the circularity.

Table 3: Template to data collection for evaluating city circularity using KPIs

City circularity key performance indicator (KPI)	Baseline value (if known)	Target value and timeframe (if known)	Measurement frequency	KPI owner	Comments
KPI 1					
KPI 2					
.....					
KPI N					

b. List of initiatives / action items to promote circularity in cities

Cities should prepare a list of its initiatives and actions that promote circularity. Some of these initiatives and actions may be formulated based on the assessment using the circularity KPIs. It may also include other projects based on the city's overall approach to implementing circularity (e.g. pilot projects). In some cases, there may be national level initiatives that are being implemented in a city as well.

Multiple initiatives and actions can be implemented at the same time to achieve circularity targets.

The following table 4 provides a template for preparing a list of circularity initiatives and action.

Table 4: Template for developing a list of city circularity initiatives and actions

City circularity initiative / action item name	City circularity KPIs (if any)	Brief explanation	Milestones	Owner	Comments
Initiative/Action item 1					
Initiative/Action item 2					
.....					
Initiative/Action item N					

c. Enablers

Circular city enablers are actions and initiatives that can boost circular city output. The utilization of these enablers could elevate the likelihood of success for a city in implementing its circular initiatives/ action items.

A simple template is provided below for establishing a baseline and assessing the current status of circular city enablers of a city.

Table 5: Template for assessing circular city enablers

Assessment Element	Currently exists	Brief description	Comments
Are there awareness programmes for circularity-related initiatives in the city?	☐		
Are there skills boosting programmes to enhance and enrich circularity knowledge in the city?	☐		
Are there existing certification programmes in the city for circularity-related implementations?	☐		
Is there a vibrant and rich innovation ecosystem in the city to address and implement circularity-related implementations?	☐		
Are there regulations and laws (e.g. laws, directives, legislations, standards) supporting or impeding circularity-related implementation projects in the city?	☐		
Are there established trusted intermediaries (or plans in place) for sharing initiatives in the city?	☐		
Are there existing circularity-related strategies and policies in the city public and private sectors?	☐		
Is public procurement utilized as a lever for circularity-related implementation projects?	☐		
Are there mechanisms in place to ensure the security and safety of shared city assets and products?	☐		

Assessment Element	Currently exists	Brief description	Comments
Are there existing collaborations and partnerships in place among city industrial organizations for circularity implementations?	☐		
Are there existing skills in place within public and private sectors to implement circularity?	☐		
Are there existing PPP partnerships in the city for circularity-related implementation projects?	☐		
Are there existing R&D programmes and other targeted academic programs for circularity-related implementation projects?	☐		
Are the city stakeholders currently aware of circularity initiatives/ action items in the city?	☐		
Are broad stakeholders defined for city circularity initiatives/ action items?	☐		
Are the stakeholders in the city engaged broadly for circularity-related implementations?	☐		
Is there an established financial framework that can promote city circularity implementation?	☐		
Are there existing financial incentives in the city for circularity-related implementation projects?	☐		

Step 2: Determining potential for circularity and prioritizing circular city actions

Following step 1, the city can then formulate its own circularity initiatives and actions. The city can engage a broad range of stakeholders to not only define the city's own circularity priorities and needs but also determine a list of actions to promote circularity for implementation.

The potential list of circular city outputs (i.e. different combinations of circular city action items applied to city assets and products) can assist in identifying a list of potential circularity innovations in the city. Specific city needs and priorities may help to emphasize certain circular city outputs among the potential ones, or conversely de-emphasize/eliminate others. Each city may have to go through this exercise based on its own context, aspirations and goals. This Guide defines an output as an individual result of an action taken within the implementation framework with respect to promoting city circularity.

Another important input to this step is to compare with the benchmarking of other cities' successful circularity initiatives/action items. The city needs to be careful in assessing the applicability of international benchmarks as the context of cities and their aspects may vary significantly.

In this step, a long list of circularity initiatives/action items can be formulated for implementation. It is recommended that a city utilizes its collective capital extensively to come up with various ideas contributing to circularity in its own urban context.

Circularity prioritisation approach

The city might not be equipped to implement the list of circularity actions in its entirety or may lack the requisite resources to do so. In such cases, a prioritisation mechanism will be highly beneficial. A pragmatic prioritisation approach used in this implementation framework has two main criteria. The first criterion is the value, which refers to the projected value of the circular city idea. The second criterion identifies the projected costs of implementing the selected idea, which is dependent on the city's own context. Each criterion is composed of several sub-criteria, which are briefly explained below.

i. Value

- The degree of alignment with the city circularity vision and strategy: This sub-criterion refers to circularity actions overall fit to a city's existing circularity vision and strategy, (if it exists).
- City circularity KPI(s) impact: This sub-criterion indicates the extent of the circularity actions contribution to existing circularity KPI(s) in the city.
- Social impact: This sub-criterion assesses the impact of the circularity actions on people and communities in the city. It would include issues such as people's lifestyle, culture, participation and engagement, health and well-being, personal freedom and privacy, concerns and aspirations. It is also important to assess whether circularity impacts the entire city or its part.
- Economic impact: This sub-criterion assesses the impact of the circularity actions to the city's economy. Economic impact can be measured by indicators such as the city's Gross Domestic Product (GDP), rate of employment, wealth, disposable income, labour-force skills, among others.

- Environmental impact: This sub-criterion assesses the impact of circularity actions to the city's overall environment. Environmental impact captures effects of the circularity action on urban natural environment and resources (e.g. city water, energy, emissions, air, land, waste).

ii. Ease of implementation

- The cost of implementation: This sub-criterion measures the total cost and required financial resources for implementing circularity action.
- The timeframe of implementation: This sub-criterion refers to the total implementation time of the circularity actions.
- Implementation risk: This sub-criterion encapsulates various risks which may potentially arise during the implementation of circularity actions. The following factors may help in assessing various risks.
    - 'PESTEL' barriers: This factor captures the political, economic, social, technological, environmental and legal (PESTEL) barriers that exist in the city and may hinder circularity.
    - Complexity: This factor reflects the complexity of implementing circularity action in terms of number of stakeholders involved, various uncertainties involved in implementation, dependencies and connections to other initiatives/action items in the city, among others.
    - Availability of competence and knowledge for the implementation: This factor includes the extent to which the circularity can be implemented by harnessing existing knowledge and skills in the city.
    - Health and safety concerns: This factor entails various concerns and ramifications related to health and safety aspects within the city regarding circularity.
    - Ethical issues: This factor captures various ethical concerns which may potentially arise during and after the implementation of the circularity actions.

The city can use a simple scoring system for various criteria and sub-criteria. For example, a simple three-level (low, medium, high) or five-level scoring system can be adopted by the city to determine priorities. The scores can be determined either quantitatively or qualitatively based on available data and conducted analyses. Having a well-defined prioritisation approach helps cities facilitate their priority circularity actions.

The figure below provides an illustration on how to determine the potential of and prioritize different circular actions using a simple scoring system.

Figure 3: Evaluation of circular city actions

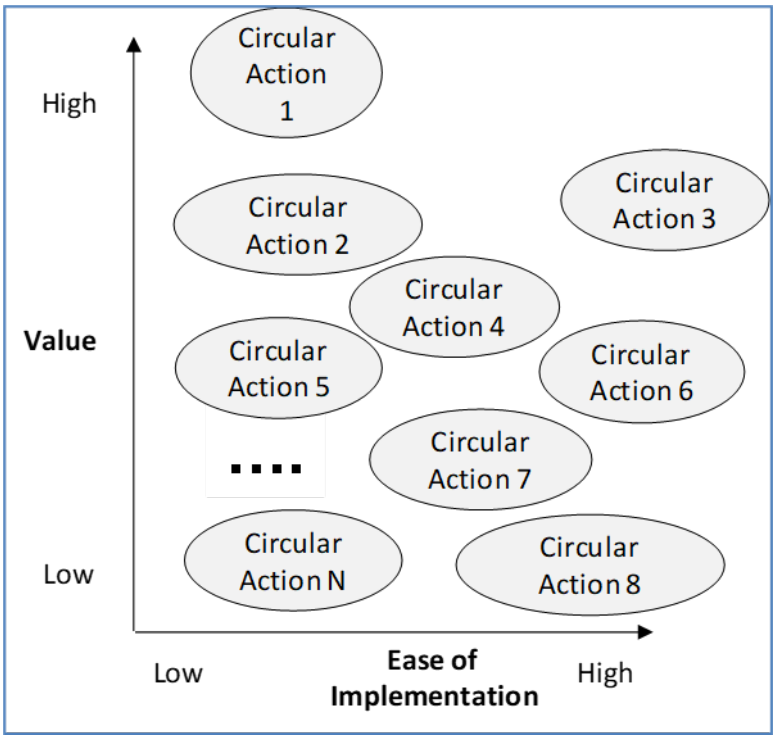

Figure 3 shows how the prioritisation approach can be used to facilitate the selection of a subset of circularity actions by applying the two criteria: value, and ease of implementation. City administrators can subsequently short list circular city actions that are of high value and easy to implement. Similarly, low-value and relatively difficult-to-implement circular actions may either be eliminated or given low priority during the implementation process.

Hence, by the end of Step 2, the city will have a concrete list of circularity initiatives and actions for implementation. The city can then elaborate an implementation plan by deciding which circularity initiatives and actions to kick-off and evaluating constraints such as resource availability to determine the actual implementation timing. It is also important to minimize implementation risks during the process.

Step 3: Catalyzing circularity

Some of the enablers discussed earlier can be utilized in this step to enhance the effectiveness of selected circularity initiatives/action items. The city can utilize an appropriate mix of enablers to maximize the chance of successfully implementing the selected circular initiatives. In other words, a combination of enablers can be used during the implementation. Some examples of potential enablers are given below to illustrate the concept.

Various tools such as education and training programmes, university programmes, and vocational programmes can be used to promote circularity, overcome awareness gaps and enhance skills and competencies. Existing literature and publications can also be distributed and disseminated to the public, as well as to various related entities. Circular action items in different industries require specialized knowledge and skills (e.g. e-waste management, refurbishing manufactured items). Expertise, knowledge, and even awareness of different circularity topics may not necessarily be readily available in cities. Hence, training and awareness programmes can be developed to close these skills gaps.

Lack of skills and expertise among the public, as well as among policymakers, can be a potential barrier. Hence, capacity building, peer learning and twinning among cities can boost potential action items (policy levers). Formal professional programmes in the form of skill building trainings may help to build capacity for circularity. However, other mechanisms can also be used for this purpose. Experts and individuals who are knowledgeable about circularity may train potential and promising individuals in a city. Additionally, cities that have vast experience in implementing circularity may assist other prospective cities in their journey towards becoming circular.

Cultural and behavioural (e.g. in recycling) patterns may represent barriers to enacting circular city actions. It might be beneficial to inform and explain the benefits of circular actions to related stakeholders. In such cases, behavioural changes will be required from city inhabitants and circular service providers. Nudging techniques, targeted communication and various incentives may be utilized to induce behavioural changes in a city.

Urban industrial symbiosis initiatives may be utilized for exchanging resources (i.e. by-products, waste) within an industry, or across industries at city level. Such resource flows between organizations creates significant benefits and opportunities. The by-products or waste of an industry could act as raw materials for another industry. This enables the creation of material looping among industries by using each other's by-products or waste, consequently reducing industrial waste in a city and thereby contributing to circularity.

A holistic, high-level approach to circularity, from strategic planning to policymaking in the public and private sectors, can also boost circular city outputs. Different cities worldwide, as well as nations, have already developed comprehensive circular strategies within their jurisdictions. Amsterdam is an example of a city that has formulated a holistic vision and action agenda for the city and metropolitan area. It recognises the circular economy as an important pillar in its sustainability agenda.[15] Similarly, Scotland in the UK and Denmark have formulated circular economy strategies[16].

Procurement can be used as a lever for circularity (e.g., procuring circular materials). Municipal governments have significant purchasing power in city economies. City procurement contracts may be prepared with a circular lens in mind. The case study 'Development of a Circular Procurement Framework – City of Toronto – Canada' provides an example of using procurement as a lever for circularity. Procurement policies and procurement contracts can specify purchased goods and services to comply with various circular targets in a city. Circular action items can provide guidance in formulating specifications for procured goods and services. The re-use, recycling and remanufacturing of materials, components and their packaging may be indicated during procurement. Procurement can play an important role not only in changing behaviour but also in overcoming the lack of circular economy markets.

Financial incentives can be used for boosting circularity (e.g. tax breaks, reductions, exemptions, holidays, lower loan rates, impact investment). Suppliers of circular goods and services can be made eligible to receive the benefits of these financial incentives. Favourable loan rates and green bonds can also be used to assist suppliers of circular goods and services.

Public Private Partnerships and other appropriate financial mechanisms may be used to boost circularity. Circular action items have significant benefits and positive impacts; hence, both the public and the private sector have a favourable stake in achieving them. This allows the forming of public and private sector partnerships (PPPs)[18] whereby costs and benefits of circularity are shared among them.[19] The public sector can opt to utilize PPP as a procurement alternative for implementing circular city initiatives. PPPs require upfront systematic thinking about various decisive factors such as the costs of implementing different circular city actions, their benefits and timing.[20] However, sufficient benefits and positive impacts exist in most cases to justify a PPP approach whereby incentives are aligned among the partners.[21]

R&D programmes may be formulated and implemented in collaboration with the academia and private sector to boost circularity.[22] R&D programmes may be undertaken at the city or national levels, as well as at the regional level.[23] Circularity contains new areas of research, which require further exploration and development. R&D programmes may play a key role in enhancing innovation in circular cities and boosting intellectual property, which can then be put into practical use and potentially commercialized.

Regulations may be used as policy levers and tools to catalyse circular city actions (e.g. technical standards, product regulations, compliance standards, trade regulations, waste and safety regulations). Existing circular related regulations such as waste management regulations, industry (vertical) regulations (e.g. chemical regulations,[24] CLP)[25] need to be taken into account during the implementation. Furthermore, new regulations, national laws and directives (legislation) may provide an enabling framework to encourage and boost circularity. At the city or national level, a supportive regulatory framework can direct the circularity processes and enable stakeholders to coordinate efforts and operate in an appropriate manner.

International standards also offer one of the most consistent and reliable ways to measure and improve circularity in cities. Often developed through a collaborative and participatory process, they contain guidelines and frameworks that provide a solid foundation for overcoming different challenges of circular cities. Multiple global platforms have already taken the initiative to facilitate this transition.

For example, ITU-T Study Group 5 on 'Environment, climate change and circular economy' has been working with its membership to develop international standards (also called ITU-T Recommendations) that improve circularity in cities. One of these standards is Recommendation ITU-T L.1020 'Circular economy: Guide for operators and suppliers on approaches to migrate towards circular ICT goods and networks', which provides guidance on how operators could work with their supply chain to improve the circular economy aspect of ICT goods and networks. ITU-T Study Group 20 on 'the Internet of Things, smart cities and communities' has also developed international standards that enable the deployment of IoT technologies in a coordinated and sustainable manner. In addition, the Focus Group on 'Environment efficiency for artificial intelligence and other emerging technologies' is also working as a global platform to identify the standardisation needs for developing a sustainable approach to AI and other emerging technologies. The work of these groups provides valuable guidance for implementing circular actions and city stakeholders are encouraged to participate in their work.

Certification programmes may be formulated to incentivize and encourage the public and the private sectors to support circular actions. Successful implementation would be recognized under certification programmes and would encourage similar or novel implementation in a city.

Engaging a broad range of stakeholders may increase the likelihood of success for implementation of circularity actions (e.g. public sector, private sector, academia, individuals, NGOs and civil society in general). Global platforms, such as the U4SSC, provide a collaborative space in which to engage in dialogue and foster innovations in circular cities.

Nurturing a rich innovative ecosystem, one that encourages entrepreneurs and SMEs to address circularity challenges, would help in boosting circularity in a city. Incubators, accelerators, hackathons, and so on might be leveraged for enriching the city innovation ecosystem based on the principles of circularity. Since circularity is predominantly a novel area which requires significant innovation, start-up and SME support would be highly important in increasing the likelihood of its success in the long run.

The above examples illustrate a list of potential enablers that can catalyse different circular city actions. Each city can formulate a set of enablers based on its own characteristics. The appropriate set of enablers can be selected based on their applicability, expected impact, cost and various other requirements.

Step 4: Assessing projected circularity impact

This step involves either interim or final assessment of the results of implementing circularity initiatives/action items. Cities are strongly recommended to retrospectively and objectively conduct assessments and compare the actual outcomes with the intended ones.

If the city had adopted circularity KPIs with target values and target implementation timeframes for circularity initiatives/action items, it would be highly beneficial for the city to evaluate whether the targets have been met.

Similarly, the city can evaluate various enablers based on their effectiveness during implementation. Any identified implementation gaps should be addressed and corrected in due course. Lessons learnt can be used to understand the positive and adverse consequences of circularity initiatives/strategic action items. Positive aspects of successful circularity initiatives may potentially be cross utilized among other circularity initiatives/action items. For example, a successful policy in one initiative may trigger the use of a similar policy approach in another. Such examples can be extended to other enablers as well. On the other hand, ineffective enablers should be relinquished in due course.

Circularity initiatives/action items are interventions in an urban context and, inevitably, will lead to various transformations. Therefore, it is important to assess their impact retrospectively. An ex-post impact assessment would be highly beneficial in understanding various social, economic and environmental changes that have occurred in the city and compare them to the intended ones prior to implementation.

The comparison of ex-ante and ex-post impact assessments will indicate deviations in terms of intended and actual outcomes. Such impact assessments may aid in planning more accurately in due course or fine-tuning circularity initiatives/action items.

5. Conclusions and recommendations

Circularity in the context of cities is a relatively novel concept that offers significant opportunities. This document has identified a generic approach to promoting circular actions in cities. This Guide is complemented with 17 case studies. The case studies illustrate non-exhaustively the substantial opportunity for promoting circularity inherent in cities across the world. The following conclusions could be drawn based on the research conducted to prepare this Guide as well as the case studies:

- The circularity concept can be extended beyond solely economic activities to other social and environmental areas.
- City assets and products can all be considered as potential inputs for circular actions.
- Circular cities optimize their resources consumption by extending their lifetime and by using them efficiently.
- Circular actions reduce the quantity of waste in cities, contributing significantly to the more efficient use of natural resources and protecting the environment.
- Circular economy not only stimulates economic growth but also creates a positive social and environmental impact.
- Circularity provides innovative opportunities for cities and encourages entrepreneurship for new businesses, the creation of new industries, as well as social and environmental entrepreneurship.
- Cross-sectorial collaboration through public-private partnerships is crucial for the implementation of circularity. The successful implementation of circularity actions may require adjustments in supply chains and may create new synergies within and across industries (e.g. industrial symbiosis).
- Circularity is a novel concept that necessitates a new approach in the way cities acquire, manage and consume their vast number of resources and assets.
- Circular cities contribute positively to achieving SDGs within their own context.
- The likelihood of success for circular cities is significantly increased by broadening stakeholder engagement and participation.
- An appropriate mix of enablers (defined in this document) will be beneficial for accelerating and sustaining circular cities.
- The case studies demonstrate the successful circular initiatives carried out by different cities. Disseminating success stories and creating awareness among stakeholders are critical to scaling up circular initiatives at the national, regional and international levels. Hence, international cooperation will be the cornerstone for expediting uptake of circularity in cities.
- Circularity can be used as a tool to address the most pressing global challenges faced by cities such as climate change, economic growth and scarcity of resources.
- Circularity as a novel field requires investment in pertinent knowledge and skills enhancement, as well as long-term R&D programmes.

The case studies below address the following circularity topics.

Energy efficiency in buildings

Toronto: A case study of cooling systems for buildings using Deep Lake Water Cooling

City solid waste management

Spain: Promoting recycling of municipal waste

India: Recycling of plastic waste through use in road construction

Affordable housing and social inclusion

City of Vienna: House sharing in urban areas as a tool for social inclusion

Kirinda, Sri Lanka: Wild Coast Tented Lodge as best practice of building affordable housing using local construction materials

Urban mobility

Dubai: Mobile solutions for ordering taxis and other transportation services, 'E-hailing'

Re-use of consumer goods and tools loaning

Toronto: Sharing/collaborative city, loaning home and gardening tools

London: Crystal Palace Library of Thing

Delhi: Recycling discarded textiles to premium ware

Munich: Halle 2 second-hand store as a hotspot of the local circular economy

Finland: Consumer goods and tools loaning

Reducing food waste

Mumbai: Collects surplus food at hotels and distribute to the poor

Oslo: Circular bioresources – treatment of food waste, garden waste and sludge from wastewater

Participatory urban planning

Melbourne: Participatory planning of public spaces

Circularity to promote local businesses and digitization

Amsterdam: Circular economy into the ICT industry effectively

Dubai: Circular ICT devices and infrastructure

Toronto: Circular procurement framework

Endnotes

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