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The circular economy, human settlements and municipal government

Antony K Cooper ^{1,2}, Tinus Kruger ¹, Linda K Godfrey ^{3,4} & Mark Napier ^{1,5}

¹ Smart Places, CSIR, Pretoria, South Africa. {acooper, dkruger, mnapier}@csir.co.za

² Department of Geography, Geoinformatics & Meteorology, University of Pretoria, Pretoria, South Africa

³ Waste RDI Roadmap, CSIR, Pretoria, South Africa. lgodfrey@csir.co.za

⁴ Unit for Environmental Sciences and Management, North-West University, Potchefstroom, South Africa

⁵ Centre for Development Support, University of the Free State, Bloemfontein, South Africa

Abstract

The linear economy is where resources (including energy and space) move through the economy in one direction, from being harvested, collected or mined, through refining and processing to create products and services, to uses and consumption, until being discarded. This creates value only while available resources are entering at one end and the waste exiting at the other does not foul up anything, or even everything.

The circular economy goes beyond just repeated recycling of end-of-life materials. It aims at rethinking how the economy functions: designing out waste and pollution in the first place, keeping resources, materials and products in use for as long as possible (through reuse, refurbishing, repurposing, recycling, etc) and regenerating natural systems to improve ecosystem services (such as trapping carbon and pollutants) and renew natural capital.

A human settlement is essentially any collection of buildings, from hamlets and villages to cities and

megalopolises. Human settlements are diverse, comprising mixes of housing (informal and formal), retail, wholesale, commercial, manufacturing, social services, recreation, urban farming, and parks and other green and blue spaces. Circularity can occur at many levels within human settlements, within homesteads, neighbourhoods, suburbs, towns and cities, and between human settlements.

This chapter considers the current resources within human settlements for circularity, the expected trends, the potential resource constraints for future growth of circularity, key economic and socio-economic gains and losses associated with the linear economy, and opportunities for the circular economy in human settlements.

Note that this paper follows on from the book, *The Circular Economy as Development Opportunity: Exploring Circular Economy Opportunities across South Africa's Economic Sectors*, edited by Linda Godfrey and published by the CSIR in 2021, particularly the chapter, *Creating resilient, inclusive, thriving human settlements through a more circular economy* [Cooper et al 2021].

1 Human Settlements: Current development path

1.1 Brief overview

The *linear economy* is where resources (including energy and space) move through the economy in one direction, from being harvested, collected or mined, through being refined and processed to create products and services, to being used and consumed, until being discarded or thrown away. The linear economy creates value only while there are available resources entering at one end and the waste exiting at the other does not foul up anything, or even

everything. Unfortunately, many of the resources required for the linear economy are non-renewable (finite) and are running out or becoming uneconomical to obtain. At the other end of the line, waste disposal is becoming more difficult, with landfills filling up, everything becoming polluted, and the climate being changed by greenhouse gases. A key problem with breaking out of the linear economy is that there are too many incentives for not doing so, such as not having to pay for the pollution and other environmental and social damage caused by one's processes, products and waste [Cooper 2022; Cooper et al 2021; Godfrey 2021b; UNEP 2022].

The *circular economy* aims at changing this by rethinking how the economy functions: designing out waste and pollution in the first place, keeping resources, materials and products in use for as long as possible (through reuse, refurbishing, repurposing, recycling, etc) and regenerating natural systems to improve ecosystem services (such as trapping carbon and pollutants) and to renew natural capital. While the label *circular economy* might be recent, many of the actions considered to be circular have been practiced for a long time, such as recycling [Godfrey 2021b]. Godfrey [2021b] provides an overview of the circular economy in general, and within human settlements (or the built environment) specifically [Cooper *et al* 2021].

The charity, Tearfund [Gower & Schröder 2016], identified some obstacles to the circular economy in low and middle-income countries: mispricing of externalities and resources (eg: dirty energy is often subsidised), no access to credit, information failures (including limited access to intellectual property), coordination problems, and poor design incentives (planned obsolescence, products difficult to repair, and toxic materials).

A human settlement is essentially any collection of buildings, from hamlets and villages to cities and megalopolises. They are diverse, comprising mixes of housing (informal and formal), retail, wholesale, commercial, manufacturing, social services, recreation, urban farming, and parks and other green and blue spaces, and are used for many purposes [Cooper *et al* 2021; Petzer *et al* 2020]. There are many linkages (or networks) within and between human settlements for distributing goods, services, energy and people, such as roads, railways, water courses, pipelines, cables and other networks. These linkages consume energy, water and other resources, while increasing pollution, carbon emissions and waste [Cooper *et al* 2021].

About two-thirds of South Africans already live in urban areas [Statista 2021], but often with inappropriate spatial planning due to Apartheid and modernism, with sprawl, low densities, monofunctional neighbourhoods and informality [CSIR & DHS 2019]. Key problems with South African human settlements are that many municipalities do not provide adequate amenities, services and public spaces, and conduct inadequate maintenance [AGSA 2023]. Further, they are perceived to be energy- and carbon-intensive, and to produce inefficiencies and excess waste [SEA 2020]. Additional research is needed to explore these assumptions in South Africa, though the Auditor-General of South Africa has found that there is “*defective management and delivery of wastewater and solid waste services at 60% of the municipalities*” [AGSA 2022].

Nominally, the earlier circularity happens, the better, but we would suggest the opportunities are likely to

be limited with fewer resources available close to the source. There might be unexpected costs and lost opportunities. Closing resource loops (resource use and reuse) within a municipality can facilitate managing the loop, with only one municipality being responsible for the whole loop [Williams 2021]. The more wide-ranging the circular economy, the greater the logistical complexity and energy demand: fuel, electricity, human effort, etc – but the greater the opportunities for reuse, repurposing, renovating, recycling, etc.

1.2 Linear and circular economies

Unfortunately, “*Circularity is in reverse: our 2020 report communicated that the global economy is 8.6% circular, while our 2018 edition reported 9.1%. Alongside our widening Circularity Gap, the world is heating up*” [Circle Economy 2021]. Since then, various events have caused a worldwide energy crisis with shortages and high energy prices, particularly for natural gas, causing an increase in the use of coal [IEA 2022].

The waste and pollution of the linear economy cause about 16% of all deaths worldwide (over 44 000 in South Africa annually) and about 275m disability-adjusted life years (DALY), and squanders 6.2% of global output through welfare losses – yet deaths and DALYs from cadmium, chromium, endocrine disruptors, mercury, pharmaceutical wastes, plastics and radionuclides have not been determined [Landrigan 2018, GAHP 2019]. Air pollution kills about one million people annually in Africa, through strokes, heart disease and lung diseases. Reducing waste and pollution can also boost economic growth [Landrigan 2018, GAHP 2019]. In 2019, over 90% of the global population lived where PM_{2.5} concentrations exceed the 2005 Global Air Quality Guidelines (AQGs) of the World Health Organization (WHO) – based on better research and data, WHO has made many AQGs more stringent, without yet accounting for exposures to multiple types of pollution [WHO 2021].

The circular economy should decouple growth from exploiting resources (particularly water and dirty energy), to being derived from growing knowledge and productivity, which should help reduce conflicts over resources. The circular economy is about managing resources and development risks sustainably; and discovering and exploiting possibilities for creating jobs and flourishing activities [Nahman *et al* 2021]. This aligns with the *solidarity economy* (or social and solidarity economy) where social profitability (eg: cooperatives, fair trade, ethical purchasing, gifting, local currencies, and self-help organisations) should take priority over financial profitability [RIPESS 2023]. Further, circularity aligns with the environmental, social, and governance (ESG) criteria often used for investing [Feyertag & Bowie 2021].

It is claimed the circular economy will improve economic growth and employment and slash pollution, but the focus has been on high-income countries, while lower-income countries are becoming less resource efficient [Gower & Schröder 2016]. However, *“the costs of implementing social risk mitigation activities in emerging markets are around 2% of project costs”* – but the costs of not doing so are 2 to 4 times greater [Feyertag & Bowie 2021]. The most successful activities are community meetings, stakeholder mapping and grievance resolution mechanisms, then training and operational monitoring, and social impact assessments [Feyertag & Bowie 2021]. Circularity alone is insufficient to justify a project or intervention: it needs to be useful as well.

1.3 Overview of current resources within human settlements

“As places of concentrated economic activity, cultural diversity, learning, innovation and creativity, cities can enable a country to build a dynamic competitive advantage and allow its people to advance socially and economically. They are also critical for achieving national environmental objectives” [CoGTA 2016].

Due to loadshedding (rolling blackouts), oil prices, and rail and harbour constraints on exports, real GDP growth is now forecast to be 0.3% for 2023 and 1.0% for 2024, both lower than previous forecasts [SARB 2023]. The infrastructure development and maintenance grants from national government to municipalities were R 35.45 bn in 2020-21, of which 93% was spent, but this declined to R 33.31 bn in 2021-22, yet only 91% was spent [AGSA 2023].

Of the 257 municipalities, 78 received qualified audits with findings for 2021-22 (vs 83 in 2020-21), 6 adverse audits (vs 4 in 2020-21), 15 disclaimed audits with findings (vs 26 in 2020-21) and 16 had outstanding audits (vs 3 in 2020-21) – and 21 of these municipalities were under administration or intervention during 2022 [AGSA 2022]. Over a quarter of municipalities are in such poor financial positions it is unlikely they can function as going concerns soon – they owe too much already, and their revenue does not cover expenditure. Then, 47% of municipalities owed more than they had available, so they raided the following year's budget to pay for current expenditure [AGSA 2021, 2022].

Key problems are municipal debts not paid (R 41.2 bn was written off in 2020/1 alone); incorrect billing; not knowing what is owed; poor budgeting practices; not paying creditors (including small businesses), with creditor days increasing from 139 to 240 days over five years; ineffective supply chain and financial management; and not disciplining irresponsible municipal officials [AGSA 2022]. Municipalities owe Eskom over R 36 bn and water boards over R 14 bn [AGSA 2023]. Thus, much

municipal income must be spent on interest and penalties (R 1.2 bn during 2020/1 alone) – yet over the five financial years to 2020/1, R 14.1 bn went on fruitless and wasteful expenditure, but municipalities do not report all irregular expenditure [AGSA 2021, 2022, 2023].

Municipal reporting on performance is even worse: *“But most telling is municipalities' inability to plan for, and report on, their performance”* [AGSA 2022]. Many municipalities do not really know what they are doing to deliver services, making it difficult for them to improve service delivery: *“In our assessment, the senior management of only 11% of municipalities was fully effective”* [AGSA 2022]. There is also inadequate oversight by municipal councillors and instability amongst the political and administrative leadership [AGSA 2022], with the President stating at a recent meeting of Mayors, *“I am told that more than 300 councillors have been killed in the past few years by virtue of being councillors”* [Ramaphosa 2022].

Further, 40% of municipalities have indicators and targets that are useless [AGSA 2022], such as the target being holding meetings on a topic rather than being outputs or outcomes for the topic. As the AGSA [2022] points out, this hampers effectively managing the municipality and makes it difficult for anyone (councillors, community members, other government entities, etc) to monitor how well any municipality functions.

Many municipalities have poor and out-dated asset registers, so they cannot account for all their assets and might lose the documentation for operating and maintaining them [AGSA 2022]. Thus, assets could become inoperable prematurely; or could be stolen, lost or abandoned accidentally, without the municipality realising it. Such assets could be duplicated or replaced unnecessarily; abandoned assets could become hazards or pollution sources, as the contents leach out; records might not be kept of dangerous materials stores; or maintenance might be inappropriate, as the asset register does not keep track of when and what is required.

The Integrated Urban Development Framework (IUDF) aims for a sustainable urban growth model of *compact, connected and coordinated* cities and towns [CoGTA 2016]. The IUDF calls for urban areas to transition to *“resource-efficient infrastructure systems, which provide for both universal access and more inclusive economic growth”* [CoGTA 2016]. A review for National Treasury [2018] identified the following as key underlying issues for the IUDF's. Unsurprisingly, some are typical of problems with the linear economy.

- The over-emphasis on housing megaprojects most often on the peripheries of urban areas, that then trap the poor (because of the resulting transport costs and the lack of jobs) and exacerbate urban sprawl. The review proposes

that housing projects should rather “*stimulate infill, densification, conversion and refurbishment*” and improve existing backyard dwellings and informal settlements, such as through upgrades and better services, including ensuring that settlements conform to regulations, particularly for health and safety [National Treasury 2018].

- The focus on the supply of subsidies creates housing dependency and distorts the market. It would be better to focus on the demand for middle-income households, and subsidised rents and small-scale rental housing for lower income households [National Treasury 2018]. Encouraging housing supply by the private sector could, according to supply-demand modelling, reduce unmet demand and informality significantly [Napier *et al* 2022].
- Different modes of public transport are not integrated into comprehensive networks across the urban areas and there is the legacy of hub-and-spoke public transport, inappropriate technology choices and separated funding streams. Rather, there should be integrated, multi-modal public transport networks across urban areas, which are polycentric [National Treasury 2018].
- Municipal funding is constrained, increasing the risks with capital expenditure because of covering recurring costs to maintain and operate the infrastructure. Thus, new ways are needed for increasing municipal revenues and for more flexible grants from central government [National Treasury 2018].

In 2018, the total expenditure in South Africa on construction and related activities was over R430 billion, but the sector has been struggling, shedding 142 000 jobs in the first quarter of 2019. However, public sector expenditure on construction for residential buildings was only R 1 910m in 2018 and R 712m in 2020, and for other buildings was R 16 812m in 2018 and R 8 406m in 2020. The key problem has been the decline in spending on infrastructure, due to the poor local economy and the threats of expropriation of land and buildings without compensation [Potgieter *et al* 2020; Napier *et al* 2022]. There is still much demand for housing in urban areas: even with significant improvement of housing delivery, in Gauteng alone there is likely to be unmet demand of over 600 000 housing units in 2030 [Napier *et al* 2022].

Cities need to attract the people, businesses and diverse economic activities to make them competitive and boost incomes. Sustainability is integral to a resilient built environment [WEF 2021]. Urban economies often mirror their national economies and the global economy. Challenges of the linear urban economy include [EMF 2017, WEF 2021, Potgieter *et al* 2020]:

- Limited holistic planning and management.
- Limited awareness of circular economy opportunities and relevant vocational training.
- Increasing consumption of resources due to increasing urban populations and increasing wealth.
- Existing buildings are seldom refurbished, remodelled, recycled or deconstructed and they often produce significant emissions during operations and when demolished. This increases unnecessarily the demand for land and buildings, and for building materials, particularly cement, building sand, aggregates, metals and bitumen. These materials are often expensive because of shortages and transport costs, which can lead to illegal mining, particularly for river sand.
- Many buildings have poor energy efficiency and waste containment.
- Increasing demands and pressures on constrained government resources (particularly funding) and urban infrastructure.
- Structural waste and environmental impacts causing economic losses (such as materials lost to landfills and incineration) and health problems.
- Unfortunately, disposing waste to landfills is often so cheap that it discourages reuse, recycling or recovery at source, though many waste pickers recover materials from landfills.
- Many resources are idle, such as motor vehicles spending much of their time parked and offices being vacant for more than half the week (made worse by the lockdowns due to the COVID-19 pandemic).
- Traffic congestion, wasting time and fuel [EMF 2017, WEF 2021, Potgieter *et al* 2020].

Of about 875 Mt of materials extracted annually in South Africa, about 170 Mt are exported, about 221 Mt are extractive wastes (with limited recycling potential) and about 105 Mt are wastes that could be reused or recycled [Von Blottnitz *et al* 2022]. The material flows in South Africa's economy are dominated by export-oriented extractives; energy is dominated by fossil fuels (mainly domestic coal and imported oil); the rate of domestic stock building of infrastructure is low; there are pockets of significant circularity with much informal activity, but overall recycling is only 2%; and while bio-based flows are about 17% of domestic extraction, there are concerns about the sustainability of ecological cycling [Von Blottnitz *et al* 2022].

The circular economy goes beyond just repeated recycling of end-of-life materials. For example, the Demolition Depot in New York City trades in fixtures, fittings and building materials recovered from

buildings that have been demolished or altered, or after businesses have closed. Many of these decorative and functional artifacts are finely crafted original examples from iconic architectural styles of the past that are attractive and can be reused in different contexts [Demolition Depot 2022].

While South African households do not recycle much, South Africa has a relatively high rate of recycling due to waste pickers, who collect, sort and distribute recyclable and reusable waste. It is estimated that informal reclaimers collect about 1 445 567 tons annually, about three-quarters of all waste collected in South Africa for recycling [Godfrey 2021a]. These waste pickers recover from landfill sites, dump sites, kerbsides (including from waste bins) and directly from businesses and sell on to brokers and recycling businesses. Integrating the informal waste sector into the formal sector needs to maintain the dignity of the pickers and to create value to be sustainable [Potgieter *et al* 2020]. The waste pickers help prevent waste accumulation, lower costs for governments and businesses, and provide livelihoods. However, they probably need support to organise and improve their working conditions [Gower & Schröder 2016].

Urban Surfer aims to integrate the work of informal waste reclaimers. Urban Surfer claims there are over 140 000 informal reclaimers who recycle 80-90% of the plastic and paper packaging waste recycled in South Africa. They aim to support those doing the recycling and for example, track reclaimers who volunteer to show where they collect waste and how far and wide, they range [Urban Surfer 2022].

1.4 Expected trends in human settlements

South Africa's population is still growing at ~1.01% (though the rate is declining [Stats SA 2021b]) and there is much migration from rural to urban areas, including circular labour migration: migrants who do not consider the urban area to be their home, even though they have lived there for many years. Their rural "*landscape of home remains central to migrants' cultural identity, belonging and well-being*" [Njwambe *et al* 2019]. Over 2016-2021, Stats SA [2021a] estimates the total inter-provincial migration at 3 625 800, with most migration (56%) being to Gauteng (1 564 861 people) and the Western Cape (470 657). Stats SA does not estimate the rural-urban migration trends, but migration to Gauteng and the Western Cape is likely to be into urban areas. It is important to realise that both the rich and the poor migrate to urban areas, though for different reasons.

Migration can be voluntary (mainly due to pull factors), or involuntary due to unfavourable conditions, or forced due to environmental or socio-political conditions: refugees, asylum seekers and internally displaced persons [WEF 2017]. The World Economic Forum (WEF) lists various push and pull causes of migration, both internal and across

borders. Particularly relevant to migration to urban areas and the current linear economy in South Africa are the economic pull factors of perceived job opportunities and wealth prospects, and primarily for the better educated, the specialised education of universities and colleges and industrial innovation creating demand for scarce skills. Further pull factors are perceived freedom (such as from authoritarian tribal authorities), better social and recreational services and amenities, and family reunification – though this can be in the other direction as well, as people return to rural areas to retire (investing in the interim to upgrade their family's dwellings) or because they are dying of AIDS [WEF 2017; Nwambe *et al* 2019]. A key push factor from rural areas is probably safety and security, particularly for commercial farmers and their staff. This is likely exacerbated by the complexities of modern farming, poor rural infrastructure (hampering getting produce to markets) and political instability due to poverty and the threats of expropriation without compensation.

The impacts on the urban areas can be both positive and negative [WEF 2017]. On the positive side, growing urban populations should provide larger markets, more labour (though with surpluses and hence downward pressure on wages and employment), increase tolerance through the growth and integration of multi-ethnic and multi-cultural societies, and access to new services and thinking brought in by immigrants and migrants. Politically, growing urban populations are likely to push for more-inclusive policy making and integrated development, because of greater awareness due to the diversity of opinions they encounter [WEF 2017].

Many who migrate to urban areas remit value back home, be it through money transfers or investments in housing and farming equipment. These can have positive impacts, such as providing additional money to circulate in the rural economy. But they can have negative impacts in rural areas, such as encouraging others to migrate due to the urban wealth displayed or by creating entitlement and discouraging their beneficiaries from working productively in the rural areas. In urban areas, if such remittances are substantial, they could reduce the wealth available to support local consumption in those urban areas, potentially reducing available jobs and increasing risks for those making retail-oriented investments in those urban areas [WEF 2017].

The key impact of growing urban populations is increasing demand for urban services and social infrastructure, exacerbating the parlous state of many municipalities. These include housing, schools, clinics, hospitals, community centres, shops, recreation facilities and the road and rail networks to access them. Further, there is a need to improve social inclusion and integrate community development. However, these are limited by the availability and affordability of suitable land and housing units, and the risks of inappropriately

distributing the population, which can create congestion on roads and in pedestrian spaces, consume more resources and redirect scarce public funds [WEF 2017]. Between 1990 and 2020 in Gauteng alone, the urban land use (excluding smallholdings) grew from 1 309.1 km² to 2 145.5 km², over 11% of the province [Ballard *et al* 2021].

Cape Town is a major destination for migrants, receiving 125 528 between 2011 and 2016, being over 3% of its population in 2016 [Stats SA 2021a]. Key pull factors are that Cape Town provides better access to basic services and more economic opportunities, and to reconnect with family and friends who migrated previously. The challenges are housing (notoriously expensive in and around Cape Town), education, unemployment (23% for Cape Town), congested roads, metro rail system failures and integration and social cohesion (that is, preventing xenophobia). The municipality expects community and political leaders to set the tone for how residents respond, as some escalate volatile situations with their language and attitudes [WEF 2017].

These trends all increase consumption of resources and demands and pressures on urban infrastructure and government resources. Without an holistic approach to urban management, this results in economic losses due to structural waste and negative environmental impacts [EMF 2017].

Some indicators of spatial transformation in neighbourhoods facilitating the circular economy include the degree to which residents can access various freedoms, rights and benefits, particularly to enhance their quality of life and well-being. These include the density of neighbourhoods being sufficient to enable efficient service delivery, while houses themselves are not overcrowded; accessibility of job opportunities and public facilities and services, such as through affordable public transport; and walkability of a neighbourhood, where residents can walk safely to a range of facilities, services, activities and job opportunities [Petzer *et al* 2020].

There are many different models or paradigms for urban design and planning, possibly indicating that none is perfect. A recent term aligning with circularity is the *15-minute city* [Moreno 2016; Moreno *et al* 2021], with the intention that most people can meet most of their needs within a 15-minute walk or bicycle ride from their home (about 1 to 5 km). The concept in various forms has been proposed before, such as the *isobenefit urbanism* of D'Acci [2013]; the Leadership in Energy and Environmental Design for Neighbourhood Development (LEED-ND), launched in 2009 [US Green Building Council 2022]; New Urbanism and its many variations from the 1980s [CNU 2015]; car-free movements; and Jacobs' [1961] focus on active sidewalk life.

The 15-minute city is a flexible concept based on inclusive, mixed-use neighbourhoods with work opportunities and core services and amenities: education, healthcare, retail (particularly for fresh fruit and vegetables), green and other public spaces (including urban farms), digital connectivity, co-working spaces, public transport, cycle lanes, broad sidewalks, and active street life. The 15-minute city should reclaim the space dominated by motor vehicles and reduce vehicle pollution by reducing their need. These are also called *complete neighbourhoods* and they should be convenient and improve health, wellbeing and community cohesion and sustainability – and facilitate circularity. However, the community should not be isolated and confined to their neighbourhood. While some boundaries can be hard, such as rivers or highways, neighbourhood boundaries should be fluid [C40 2020, 2021b, 2021c; Moreno *et al* 2021; Chamberlain 2022; Weng *et al* 2019].

The 15-minute city also correlates with the guidelines of the Red Book for laying out human settlements in South Africa, such as compactness, and walkable neighbourhoods with a variety of housing choices and quality public transport [Van Niekerk *et al* 2015; CSIR & DHS 2019]. Essentially, the 15-minute city is a return to the mixed-use walkable neighbourhoods, towns and villages from before motor vehicles, but with much more available for residents. It should also support the principles of crime prevention through environmental design (CPTED): surveillance and visibility (with more pedestrians as eyes on the street), territoriality (as inhabitants take a sense of ownership as they are not isolated from the neighbourhood by their cars) and image and aesthetics (as people are more actively involved in their environment) [Kruger *et al* 2016].

1.5 Potential resource constraints for future growth

The IUDF recommends that urban areas be planned and managed well to benefit from productivity and growth and provide sustainable quality of life for all. This includes investing in integrated, inclusive and multi-functional social and economic development; reducing pollution, GHG emissions and noise; transporting goods and services efficiently; investing appropriately in land and property to provide municipal income for further investments; fostering entrepreneurialism and innovation; being stable, safe, just and tolerant; and enabling people to walk, cycle and use public transport in safety to access economic opportunities, social services, recreation and other needs [CoGTA 2016].

Waste management and waste disposal sites are critical constraints. It is estimated that in developing markets, solid waste collection and management can use up to half a municipality's budget [EMF 2017]. Some South African municipalities are running out of space in their landfills and suitable places to site new

ones. The further away landfill sites are, the more expensive it is to transport waste to them (yet much waste gets shipped around the world!). Thus, it should be more economical to recycle or otherwise reuse waste, rather than throw the waste away. Unfortunately, landfills are still considered the cheapest way of disposing of waste because of the lack of appropriate costs for the polluters. It can take five years to get a licence for a new landfill site and then a further year to build it, to ensure containment of the hazardous waste, etc [Githathu 2019]. There can be a significant correlation between changes in GDP and the increase in the size of a landfill site (such as Robinson Deep in Johannesburg) – but increasing the stringency of restrictions on movement (specifically for the COVID-19 pandemic) *increases* the sizes of landfills, despite the drop in GDP [van Zyl & Celik 2021].

Landfill sites can generate much methane as organic wastes decompose, but these gases are being harvested at some landfills to generate energy. However, if not managed properly, the methane can ignite, creating fire hazards and producing toxic fumes and an overpowering stench. Such fires can burn for many days and be difficult to control because of the dangerous conditions, thus taxing the limited resources of fire services. An example is the massive Ghazipur landfill in Delhi, India, which exceeded its capacity a decade ago, but is still being used. It catches fire occasionally, such as in March 2022 [Verma 2022]. Further hazards are illegal landfills and open dumping.

Some construction materials are becoming expensive due to shortages and the cost of transport, such as building sand and bitumen. The principles of the circular economy can alleviate this, by mixing certain wastes into concrete and asphalt, including furnace slag and crumb rubber. Because of the shortages, there is much illegal mining of sand and aggregates around the world, including in South Africa. The industry body representing legal miners feels the government and police are not taking illegal mining seriously. As well as damaging the environment (such as taking sand from rivers and wetlands), illegal mining causes pollution problems, leaves large and unrehabilitated pits causing safety risks for humans and animals, and threatens the viability of legal miners [O'Reilly 2021].

There is a limit to the availability of land, particularly for new or greenfield developments. Further, new developments should be sited appropriately, such as having residential areas close to employment opportunities and social services, and industrial areas close to resources and transport. As discussed above, urban areas already cover over 11% of Gauteng and there are suitable sites for brownfield developments, such as industrial areas that have lost tenants [Mthuli 2022].

Poor environmental conditions due to the linear economy impact on human health, which can undermine the competitiveness of a city and cause a brain drain (which is happening in China, for example), depriving a city of the skilled people who can help the transition to a circular economy [EMF 2017]. Replacing hard surfaces with green spaces and water-permeable surfaces can help combat urban heat islands, stabilise hills to prevent landslides, and improve liveability [UCCRN 2018].

With various other organisations, the Ellen MacArthur Foundation has developed toolkits for assessing circularity and implementing circularity [EMF 2021, 2022c]. These include:

- **Circulytics**, a toolkit for measuring circular economy performance, is aimed at private companies and other organisations. It covers 11 themes that are enablers (such as strategy, planning, innovation, people, skills and external engagement) and outcomes, such as products and materials (and waste), services, asset procurement and consumption of water and energy. It is updated annually [EMF 2022a].
- The **Circular Buildings Toolkit**, with a high-level framework (build nothing, build for long term value, build efficiently, and build with the right materials) to bring the circular economy to buildings and real estate, going beyond just energy efficiency and aiming to future-proof assets as policies change rapidly. The toolkit includes examples, such as material passports, hiring building materials for temporary structures, modular lighting, and prefabricated timber structures [EMF 2022b].
- An actionable toolkit for policy makers to deliver the circular economy, which has three principles (preserve and enhance natural capital, optimise resource yields and foster system effectiveness), using the **ReSOLVE** framework: REgenerate, Share, Optimise, Loop, Virtualise and Exchange [EMF 2022c]. Based on a pilot in Denmark, the toolkit has eight key insights:
 - Transitioning to the circular economy has lasting benefits of greater innovation, resilience and productivity; creating jobs; reducing the carbon footprint; reducing the use of virgin materials and boosting GDP.
 - Many circular economy opportunities are inherently profitable.
 - Sector-by-sector analysis is important due to the variety of opportunities and challenges.
 - Better measures of economic performance than just flow-based metrics are needed.
 - Industrial involvement and collaboration across government are crucial.
 - Even in advanced economies there are many circular economy opportunities.
 - Policy interventions need to be aligned as many value chains extend across borders.

- The outcomes of applying the toolkit will differ across countries [EMF 2022c].

ReSOLVE focuses on economic systems rather than societal benefits (such as social services), and on production systems, while many cities are more centres of consumption. Further, ReSOLVE does not consider land and infrastructure [Williams 2021].

1.6 Key gains and losses associated with the current path

It is difficult to identify potential socio-economic gains from the current path of the largely linear South African economy, which has been struggling for many years, with high inequality, much unemployment, corruption, and concerns over the state of public infrastructure and public services. It has been estimated that in comparison to the base line (the economy that is largely linear), moving significantly to a circular economy would boost South Africa's GDP by 0.8% and employment by 1.3%, but increase CO₂ emissions by 0.1% (because electricity production is currently dominated by coal) [Potgieter *et al* 2020]. Circular economy projects are also more likely to attract funding from international donors.

Key socio-economic problems (or losses) with the current linear economy include pollution, noise, biodiversity loss, health problems, greater travel costs (particularly for the poor), landfills that are over-full and become hazardous, scarce resources squandered on dealing with waste, infrastructure that is abandoned or underused, and shortages of key resources (and hence higher costs for them). Further, South Africa probably needs to move to a circular economy to ensure its exports are still accepted internationally. As discussed below, there are many opportunities for the circular economy in human settlements. For example, the industrialised production and 3D printing of building modules is likely to have the most significant impact for the circular economy in human settlements. Other key opportunities are reuse, high value recycling, sharing and multi-purpose buildings [EMF 2022c].

2 Human Settlements: Circular development path

2.1 Circular economy opportunities in human settlements

Circular economy interventions cannot be considered in isolation, but should deal with other issues, such as South Africa's triple threat of poverty, inequality and unemployment. For example, moving to renewable energy will increase significantly the jobs in the energy sector worldwide [Pai *et al* 2021]. The concepts behind, and components of, the circular economy are also part of resilience, sustainability, inclusivity, the sharing economy and so on. Thus, circular economy interventions overlap with other desirable outcomes, such as occupational health and

safety. For example, collecting and separating waste on a construction site not only facilitates reuse and recycling, but also neatens up the environment, removing tripping hazards, etc. The classic *circular economy principles*, such as of the Ellen MacArthur Foundation [EMF 2021] are:

- **Design out waste**, e.g., green, energy-efficient buildings, more compact cities, pedestrian-friendly neighbourhoods.
- **Keep materials in use**, e.g., circular construction value chains, circular organics, waste management.
- **Regenerate natural systems**, e.g., urban agriculture, renewable energy, green roofs, green and blue open spaces [EMF 2021].

Interventions can cut across all three of the principles, particularly as designing out waste could often keep materials in use or help to regenerate natural systems. For example, within a neighbourhood, one could design out organic waste (food and garden waste) by setting up a system for collecting, sorting and using the waste as compost for a regenerated natural system in the neighbourhood where useful resources are grown, such as vegetables, fruit and mushrooms. This has been done with Moja Gabedi, a site in Hatfield, Pretoria, that was an unofficial landfill – 4 metres deep – but is now a meaningful food garden. About 3000 tons of waste were removed and replaced with about 3000 tons of topsoil and 200 tons of compost [UP 2021].

We suggest that there are three further broad perspectives or views for understanding possible circular economy interventions in human settlements. There is the *rationale* for the interventions, such as improving how the economy is managed and society functions (governance); because people want it (culture); to reduce costs and improve performance (infrastructure); and to exploit new developments (technology – while being wary of technology push). Then, there is the *agency* of the interventions, that is, where the power and benefits lie and thus what is likely to make the intervention happen. Finally, we would suggest there is the *sector* where the intervention is made, which specifically for human settlements includes construction, existing buildings and structures, transport, formal and informal business clusters, and households (perhaps the most critical, to get everyone thinking about circularity and the benefits).

However, one circular economy intervention can clash with other perspectives of circularity, most obviously when new technologies are imposed on a community without consultation or considering cultural values. Further, the intervention might not have been considered carefully or might be primarily for circular washing or to tick boxes. The opportunities for the circular economy in human settlements can range from small interventions, such

as an individual consumer reusing shopping bags, to large infrastructure projects, such as for renewable energy. The opportunities could be for new products and services, but also for helping to change perceptions. For example, a poor neighbourhood might be sceptical about the reasons for banning plastic bags, as they can be very useful. In Côte d'Ivoire in 2013, "the production, import, marketing, possession and use of plastic bags" was banned, but despite the ban and other interventions, over 200 000 tonnes of plastic bags worth over US\$ 27 million are still produced annually in Côte d'Ivoire [Koumi 2020].

Each intervention needs compromises, most obviously over available resources, especially funding. Further, with many different types of stakeholders, the inputs and outputs, and the costs and benefits can easily be quite removed from one another. We would suggest it is relatively easy to sell initiatives where the costs and benefits occur quickly, but difficult to sell benefits that happen only in the long term while the costs occur in the short term. On the other hand, where the benefits occur in the short term but the costs in the long term, there is the risk future generations will have to carry the costs. When both costs and benefits occur well into the future, it is difficult to assess if the intervention is positive or negative, because so much can change. This correlates with the principles of *distributive justice*, how burdens and benefits are allocated; *procedural justice*, who decides; and *recognition*, basic respect and robust but fair engagement [Pörtner & Roberts 2022].

There is a risk of the *tragedy of the commons* where the common goods (such as air) get overused (such as by pollution) because few consider their own use excessive or inappropriate and can point to others who are far worse. Using the common goods can be regulated to ensure prudent use, but local communities can also mitigate against the tragedy of the commons through peer pressure, such as documented by Ostrom [1990].

Other concerns with the circular economy include:

- Basic, seemingly non-circular interventions might have a greater and quicker impact, such as maintaining infrastructure to prevent waste and inefficiencies (eg: leaks in potable water pipes).
- Conflict with consumerism where celebrities, influencers and the media thrust the glitzy, resource-intensive consumer lifestyle upon everyone: "Wealthy people set the tone on consumption to which everybody aspires" [Paddison 2021]. But on an individual level, happiness and status within the community could increase as circularity in their lives increase.
- Dangerous recycling with significant health and environmental risks, such as of used lead-acid

batteries and electronic waste by untrained workers in the informal sector or without enforcement of regulations.

- The circular economy and localisation could contradict national policies or create displeasure amongst neighbouring countries, such as in implementing the African Continental Free Trade Agreement.
- Circularity could cause sanitary problems, particularly with human waste.
- Circular or local food systems could contravene food safety regulations.
- Overly complicated waste separation requirements imposed on households can create resistance.
- Policies, taxes, incentives and subsidies should encourage rather than discourage sensible resource use – and not be changed often, creating confusion.

Circular economy loops are dynamic. They represent flows of resources, materials, parts, goods, by-products and so on. These loops bring together organisations with different cultures, such as municipalities, international corporations, small and/or informal businesses and community organisations. Circular Economy suggests that there are four types of flows for the circular economy: *narrow flows* (use less), *slow flows* (use for longer), *regenerate flows* (make the flow clean) and *cycle flows* (use again) [Circle Economy 2021].

The quicker low and middle-income countries can move to a circular economy, the greater the chance they can avoid the waste mountains and bloated landfills typical of linear economies, and hence avoid the associated health and environmental problems [Gower & Schröder 2016]. Thus, it is necessary to promote sustainable lifestyles, aspirational sufficiency and quality of livelihoods in urban areas, particularly focusing on the growing middle class, and the next generation of would-be consumers: reshaping the collective societal imaginaries of success is vital.

2.2 Governance, legislation and policy

Establishing the circular economy and problems with the linear economy should be dealt with explicitly in the job titles and descriptions of senior managers. For example, Athens in Greece has a Chief Heat Officer and leads the Cool Cities Network (an initiative of the C40 Cities Network, a network of Mayors worldwide), which aims at "tackling urban heat by building greener cities" [C40 2022].

Building and construction policies and regulations need to be integrated with those for other issues, such as climate change, energy efficiency, water efficiency and waste. A controversial issue is

legislating local content in procurement, such as South Africa's Industrial Policy Action Plan (IPAP) [The DTI 2018]. Proponents of localisation claim the benefits will be to grow and diversify the manufacturing sector, increase employment, reduce embodied energy (by reducing the required transport), ensure waste and pollution fall under local standards and legislation, and make it easier to repair and maintain components locally with local skills (which should also increase the life of components) [Gibberd 2020]. However, some claim that localisation protects inefficient local companies to the detriment of efficient ones, increases costs and reduces quality. There is also a concern that initiatives could be "locally clean" but "globally filthy" [de Stage 2022]. Further, given how much South Africa supports Lesotho, for example, it might benefit South Africa to include Lesotho (and other neighbours) under the ambit of localisation, as boosting their economies should boost South Africa's.

In the United Kingdom, the new Environmental Act became law in November 2021 [DEFRA 2021] and perhaps provides a model that South Africa could follow. The Act provides legally binding environmental targets, such as on species abundance for 2030, sewerage discharge, stormwater overflows, and PM_{2.5} concentrations in the air. It deals with labelling on products of their recyclability and durability, it regulates hazardous waste shipments and requires consultation on street tree felling. It also targets the whole supply chain, requiring due diligence and traceability of resources, to help combat illegal deforestation, and to control the export of waste, for example. Connected to the Act are consultations on deposit return schemes for containers, charges for single-use plastics, producer responsibility for packaging and recycling collections, electronic waste tracking, tackling fly-tipping (illegal dumping) and waste crime (illegal storage, abandoning, transport or use of hazardous waste; misclassification of waste and fake documentation) [DEFRA 2021].

A key part of this new Environmental Act [DEFRA 2021] is biodiversity net gain (BNG), requiring development and land management to put the natural environment in a better state, by at least 10% of the Biodiversity Metric [Natural England 2021]: it uses habitat as a proxy for biodiversity, so is obviously a simplification of the real world, assesses a baseline and forecasts (size, type, condition and location), assesses delivery risk (difficulty of creating, restoring or enhancing habitat; temporal risk, the time to target condition; and spatial risk, the distance between the habitat loss and habitat compensation; and habitat quality measures (distinctiveness, condition and strategic significance). The metric is relative, not absolute. Currently, BNG concerns terrestrial and intertidal habitats and assesses three types of biodiversity units separately (area, hedgerow and river habitats). BNG aims at bigger, better and

joined areas for biodiversity, encouraging enhancement not transformation, and coherent ecological networks more resilient to current and future pressures [PAS 2021].

2.3 Codes, standards and guides

Building codes provide rules or standards for construction to ensure safety and protect public health and welfare, during both construction and occupation. The key problem is they can become out of date and amending or revising them can take a long time. A code cannot just be changed without understanding the implications and without the new technologies having been tested properly. This can hamper some circular economy initiatives, such as reusing grey water (with health implications), reusing materials from deconstructed buildings or installing renewable energy systems that could feed back into the grid or use large batteries (where the electricity network has not been designed for such loads). Some considerations are:

- Reducing heat stress due to climate change, such as through low-cost, passive-cooling designs.
- Performance standards for energy use.
- Improving or tuning-up old buildings, such as when they are sold or leased.
- Restricting the rental of highly inefficient buildings [C40 2019a].

The International Organization for Standardization has established the Technical Committee ISO/TC 323, *Circular economy*, to develop standards for the framework of the circular economy, principles for implementation, guidelines on business models and value chains, measuring circularity and reviewing business models. ISO/TC 323 also collaborates with ISO/TC 324, *Sharing economy*.

As well as codes and standards, there are also useful guides, such as the South African *Neighbourhood Planning and Design Guide: Creating Sustainable Human Settlements*, known as the Red Book [CSIR & DHS 2019]. Sophisticated municipalities can use these codes, standards and guides to encourage inward investment by setting themselves up as being more advanced than other municipalities. They could promote the circular, green and sharing economies; green or zero-carbon buildings and public transport; and better building performance. The codes can nudge people and organisations towards better consumption patterns.

2.4 Recycling

Urban regeneration includes recycling buildings and land, and flexible uses of facilities and space. Improving the efficiency of buildings can be combined with removing all the toxic and unhealthy materials and residues, such as lead, asbestos and

mould, with the added benefit of creating jobs [Kammen *et al* 2020].

Leafline Washable Sanitary Wear, a small company in Bathurst, Eastern Cape, uses fibres from pineapple leaves (stronger than cotton and they absorb moisture, smell and bacteria) to make washable, reusable, affordable and biodegradable sanitary products for adults and children (nappies, breast pads, sanitary towels and chair and bed protectors). Leafline also employs disabled women to make the products [Zama 2022]. The Welsh company, NappiCycle, processes used nappies into pellets for making fibreboard and insulation panels, and mixed with bitumen to make roads, which they estimate will last twice as long as conventional roads. The used nappies are collected by the local authorities at the kerb side [Morgan 2022].

C40 suggests the foundation for a sustainable waste management system is the infrastructure and system for the universal collection, transfer and safe disposal of waste for the whole municipality – and this needs good data on the waste and waste flows to set priorities, etc. Proper logistics planning is needed to ensure appropriately sized vehicles are used and to prevent part loads and duplicated routes. The municipality needs to work with informal waste collectors (to improve working conditions), with the main producers of waste (to segregate at source), and harvest gas from landfills for energy. C40 considers incinerating solid waste to be expensive, inefficient, requiring good environmental controls and encouraging diverting waste to incineration rather than recycling, waste reduction, etc [C40 2019b].

The priority should be food and organic waste because they are major parts of municipal rubbish and have great potential for recycling. The options should be tested through pilot projects, to segregate and collect the waste, and implement composting (cheap and simple) and anaerobic digestion to generate biogas, heat, fertilisers and other products. Unsurprisingly, C40 recommends starting with the largest sources of food and organic waste, as that would provide the benefits of scale [C40 2019b].

Successful recycling needs services that are clearly communicated, easy to use and readily accessible, such as door-to-door collection; drop-off schemes; convenient, single-stream bins; accepting many different types of materials; and revenue-sharing with waste collectors. Incentives include pay-as-you-throw policies, deposit schemes and bans on items that cannot be recycled. Further, the municipalities must identify potential loops to recover materials and pass them on for further use. Municipalities also need to reduce waste generation in the first place, encourage the circular economy, set ambitious goals for zero-waste, support reuse and repair enterprises (including in the informal sector) and promote renting and sharing of goods [C40 2019b].

In Africa, much waste goes to uncontrolled dumping or burning. While only about 4% of municipal solid waste is recycled in Africa, much of this is by the informal sector. This could be improved through waste microgrids, where waste gets reduced, separated and treated locally, such as within a neighbourhood. Local recycling reduces the need for municipal waste collection. The organic waste can be composted and used locally. Other waste can be stored separately until there is enough to transport to appropriate recycling and other facilities. This reduces transport costs and provides recycled material and fertiliser locally [Gibberd 2020].

There is a growing understanding of the problems of how electrical and electronic equipment are produced, consumed and disposed: electronic waste (e-waste). Excluding PV panels, the consumption of electrical and electronic equipment is increasing, with about 53.6 Mt of e-waste generated annually (about 7.3 kg per capita!) and is expected to reach 74.7 Mt by 2030. Africa generates about 2.9 Mt of e-waste annually (about 2.5 kg per capita). Global recycling is about 9.3 Mt annually, with about 0.03 Mt in Africa [Forti *et al* 2020]. A key problem is the lack of repair options, but this is being addressed by companies such as Fairphone and Shiftphones, who make smartphones that are easy to disassemble and repair, which encourages community networks where those with the skills help others fix their phones, often without charge [Schweiger 2022].

E-waste contains toxins and hazardous substances, so should be treated by specialised facilities to recover precious, rare and critical metals in an environmentally sound manner. E-waste must be separated from other waste early and be pre-treated. Training on e-waste needs to be provided to government officials, as is being done by the Global E-waste Statistics Partnership. E-waste generated annually contains metals worth about US\$ 57 bn, particularly iron, copper and gold, with only about US\$ 10 bn recovered annually [Forti *et al* 2020].

2.5 Construction processes

The construction industry varies widely from large multinational companies to very small enterprises (one person and their bakkie). While there are very sophisticated organisations in construction, many are not and could be considered conservative in outlook. Globally, construction has been notorious for corruption and organised crime. In South Africa local “business forums” are hijacking projects and terrorizing government officials and managers of construction companies [Moatshe 2022]. Further, construction employs many workers with limited skills and education. Thus, it is difficult to initiate new ideas and processes.

There are many opportunities for making construction more circular. Construction waste is highly recyclable and with the likes of landfill taxes,

more than 90% of construction and demolition waste in the United Kingdom is being diverted from landfill. The circular economy can reduce the costs of both raw materials and waste. Key enabling factors are designing out the waste (planning for deconstruction, reassembly and future flexibility), information (costs, condition, resource productivity, life cycle, ownership, warranties and traceability) and collaboration (share incentives, provide transparency, encourage innovation and new products and processes, and moving from short- to long-term business models). This should improve operations (better use and more choices for consumers), maintain assets at higher values for longer, provide greater certainty over maintenance and replacement, reduce costs and reduce waste [Carra & Magdani 2018].

The circular economy needs appropriate planning, designing and monitoring of construction processes and the resulting buildings and structures. It is essential to calculate resource requirements accurately. Further opportunities include using standard sizes when specifying materials, sharing expensive equipment, recovering unused materials from building sites, reusing materials (particularly concrete), extending the lifetimes of existing stock and disassembly rather than demolition. Clients, tenants and investors are placing greater demands on the construction industry for more advanced processes, particularly for operational health and safety, and for the green and circular economies. New innovations include the Building Information Modelling (BIM) standards for sharing and managing information; product passports to track resources through the supply chain; sensors to monitor in real time the status of components; and 3D printing of components and even entire buildings [Carra & Magdani 2018].

Many buildings in South Africa and other African countries are in poor condition and should be replaced before collapsing. This is a waste because they were not designed, built, maintained and/or operated properly. Building to higher construction standards and designing for repairs and maintenance extends the life of components and buildings and reduces waste. Premature obsolescence can be prevented by using non-toxic materials; facilitating repairing by ensuring access to components; and understanding life expectancies and environmental impacts [Gibberd 2020]. Alternative construction materials provide opportunities for research and innovation. For example, hemp shives and fibres can be used for building, which would absorb carbon dioxide long afterwards, eventually making these buildings carbon negative. When growing, hemp is twice as effective as forests for sequestering carbon. A recent development in India is a device that extracts particulate matter from polluted air and uses the materials to make floor tiles [Gerretsen 2021].

Construction waste can be reduced, if not avoided, when building products and materials are sourced

locally and can be readily repaired locally. Further, waste can be reduced by simplifying buildings with standard components and fewer materials used and using locally grown and sustainable materials [Gibberd 2020].

Design should be at the core of sustainable human settlements. Opportunities include modular design; green and sustainable buildings; building fewer, but better, units; reducing overall floor space (small footprint); flexible and multi-functional space; co-housing; increased renovation and refurbishment; renewable energy technologies; environmentally-friendly construction constituents, such as natural or renewable materials; recycling and retrofitting concrete and other building materials; and leasing components, such as renting illumination from illumination experts, rather than buying oneself – that is, turning components into services.

Design must consider how buildings and infrastructure could be operated, by including flexibility to enable multiple functions and occupancy patterns. An old and simple example is having lanes in a road that can switch directions to accommodate rush-hour traffic, reducing the need for wider roads. Further, the circular economy is also about the existing stock in human settlements, through extending the lifetimes of stock, re-occupying underused and disused buildings, and retrofitting existing stock [Circle Economy 2021].

Designing out waste means planning to use only the resources needed, using them optimally, monitoring what is being done and communicating clearly with all stakeholders. Within human settlements, this has tended to be construction (and the waste from demolition, construction and excavation): prefabrication off site; avoiding virgin materials; recovering unused materials before they get discarded; keeping sites neat so materials don't become debris and in the way; separating waste; storing materials so that they do not deteriorate; and controlling pollution. Critically, designing out waste also covers planning for what happens afterwards: providing easy access for maintenance, repairing, refurbishing and replacing – and then doing them; extending the life of structures; reusing or repurposing structures; deconstruction (rather than demolition); and recovering materials for use elsewhere. Demolishing unwanted buildings wastes valuable resources and money, while deconstructing them salvages materials for reuse, creates more jobs, spurs innovation, and preserves local character and heritage. Even better is repurposing existing buildings [C40 2021a].

Setting targets (aiming at continual improvement), ongoing monitoring and reporting are essential to ensure all are aware of resource consumption and waste generation, such as by displaying on site reports on energy and water use; waste created, recycled or disposed of as debris; the carbon

footprint; and costs and savings. Tools are readily available, such as the Site Waste Management Plan of Zero Waste Scotland [ZWS *nd*].

Deconstruction is not easy or the best option, so it is important to do cost-benefit analyses of deconstruction and options for reusing materials. Many stakeholders must be involved in planning and implementing demolition or deconstruction. For example, where an area has been devastated, deconstruction can bring a 'dignified end' to destroyed dwellings, while demolition can make the community feel they, too, were demolished. Designing for disassembly from the start makes it easier to recover components and materials when buildings are renovated or deconstructed. Repurposing buildings is more sustainable and less disruptive and should be cheaper, while preserving building character and perhaps the block's frontage [C40 2021a].

2.6 Sustainable and green buildings and structures

The concepts of the circular, green and smart cities (and buildings, structures and components) overlap, but there are differences. For example, a smart city could be energy intensive, to drive all the smart devices and the intensive processing of big data. Key for sustainable buildings and structures is maintenance to prevent waste and inefficiencies and to prolong life. These buildings and structures can address other problems, such as extreme heat for those living in informal settlements in hot countries.

Service delivery requirements represent the critical alignment of circularity with local government mandates. Decision makers must be supported to see the links between delivering basic energy, water, sanitation, mobility and waste services, and circular design, processes and technologies. For example, if investing in urban street lighting, using decentralised solar helps reduce the burden on stressed national grids and fossil fuel power, while still delivering the service.

Neighbourhoods should also be walkable, with good penetration by public transport, cycle paths, green spaces and viable neighbourhood shops and services [Cooper & Sebake 2018]. Urban dwellings should be designed and built to be affordable and to epitomise the circular economy, such as with small footprints, rainwater harvesting, renewable energy, sewerage harvesting for fertilizer and as a source of household water, and recycling and retrofitting concrete and other building materials. It is necessary to promote social justice with informality through documenting and supporting the ingenuity, flexibility and varied circular opportunities offered by the informal economy for urban sustainability. This can include showcasing existing initiatives, indigenous knowledge and traditional practices, but support is needed from local government and businesses.

C40 proposes five ways municipalities can reduce building energy demand.

- Leading by example by setting targets for municipal buildings and social housing to be net-zero-carbon by some deadline. This includes reducing emissions; setting performance standards; using public buildings as testbeds and showcases; building relevant capacity locally; and leveraging dedicated financing for retrofits, such as green bonds and financing models for energy-cost savings [C40 2019a].
- Creating a transparent and open repository of evidence, with reporting and disclosure requirements, benchmarking of resource consumption, energy audits and reporting on energy efficiency levels and green building ratings [C40 2019a].
- Setting performance requirements for new and existing buildings, such as caps on energy use and GHG emissions; bylaws for requiring buildings to be up to code (such as when sold leased); green building rating and certification schemes; and ready-made, prefabricated parts for retrofits [C40 2019a].
- Providing incentives, such as training and guidance for developers, builders, inspectors and building owners; communicating the many benefits; stimulating the market; reducing transaction costs; appropriate financing models; reducing real and perceived investment risks; and incentives [C40 2019a].
- Shifting energy supply to renewables for buildings [C40 2019a].

2.7 Urban planning

The legacy of Apartheid spatial planning can discourage the circular economy. Perhaps, some isolated or scattered human settlements should be shut down and their populations consolidated into areas more amenable to service delivery, employment opportunities and the circular economy. Drivers include climate change, making some places too hot for habitation and working outdoors [CSIR 2019], and losing key parts of local economies, particularly mines at the end of their lives and agriculture impeded by climate change.

Goal 11 of the Sustainable Development Goals (SDGs) is to make cities and human settlements inclusive, safe, resilient and sustainable. Goal 12 is to ensure sustainable consumption and production patterns. Because the SDGs are so wide ranging and because of the complexities over measuring indicators, there are gaps within them. The circular economy is not mentioned explicitly in the goals, targets and indicators, but is implicit in much of SDG 12. For SDG 11, the key Target is 11.b, which covers resource efficiency. However, its Indicators are

specifically about disaster risk reduction strategies [UN 2022].

2.8 Synergies with other sectors

The circular economy interventions for human settlements generally overlap considerably with other sectors of the economy and society. The following examples draw on Godfrey [2021b].

Urban mining: the opportunities are primarily with processing various waste dumps and discarded objects, especially e-waste, to extract valuable materials, particularly metals such as gold, silver, copper and palladium. Urban mining can even offer higher grades for lower costs [Khan *et al* 2021].

Manufacturing: Premature de-industrialisation happened to South Africa's linear economy for two decades and manufacturing can reverse this sustainably and inclusively through circular opportunities [Fazluddin *et al* 2021]. There needs to be support for embryonic remanufacturing and repair industries, such as through public procurement and providing needed utilities. This is more effective when clustered together, to provide greater scale through collaboration and specialisation. Such small enterprises can be intensive in labour use [Gower & Schröder 2016], providing sorely needed jobs. Circularity can be due to happenstance, such as when one factory's waste can be reinterpreted as a by-product and used by another factory. However, it is better is to design in circularity from the start and to aim at continual improvement, rather than perfection at once.

Energy: Since 2008, South Africa has suffered with constrained electricity supply and loadshedding, hampering the economy. The extra generating capacity should come from renewables because they are generally cheaper, and to decarbonise [Msimanga *et al* 2021]. Energy interventions can contribute to the circular economy, with decentralised energy systems (renewable energy and from waste), reducing dependency on water intensive energy sources, reducing the energy consumption of existing buildings (such as mandatory solar water heaters), and zero-emission transport [UCCRN 2018]. Decentralised energy generation reduces the need for extensive energy transmission systems. Many organisations are now using rooftop solar for their power needs. Depending on the infrastructure, locally generated electricity can be fed back into the local or national grids with Golden Arrow Bus Services, for example, exporting over half of the power it generates to the City of Cape Town [Daniel 2022].

Mobility: An urban mobility system that is accessible, affordable, safe and effective, contributes to the

circular economy by encouraging the shift from private to public transport for both passengers and goods. Key is logistics planning to design out the waste of part and empty loads. Transitioning to public transport is constrained by criminals, such as cable theft encouraging Transnet to de-electrify train sets, and the theft and destruction of rails and infrastructure preventing services on some lines [Mokoena *et al* 2021].

Water: South Africa is a dry country, with 98% of the water supply already allocated and demand expected to exceed supply by 17% by 2030. Municipalities consume 27% and much of the projected increase in the water demand will be by municipalities. Circularity opportunities include decreasing water loss (leakage) and wastage; increasing efficiency; water sensitive design; on-site wastewater treatment and re-use; and for households, harvesting rainwater and reusing domestic greywater for watering [Seetal *et al* 2021].

Urban farming: About a third of food produced in South Africa is wasted due to inadequate or improper market infrastructures, cold chains, safe transport, standards, handling, packaging and processing. Sustainable urban farming includes vertical agriculture, hydroponics, aquaculture, aquaponics and aquafeed from agricultural waste [Okole *et al* 2021]. Food and organic materials provide great opportunities for circularity, as they are the largest material flows in most African cities. Generally, African cities have close ties to their hinterlands, providing incentives for processing urban organic waste into compost, mulch, fertiliser and feed for farms. Such waste can be used for growing algae, mushrooms and insects for food and feed; for fibres; for bioenergy; and for retrieving nutrients, bioplastics and bio-aromatics. Processing urban organic waste helps ecological restoration and regeneration, enhancing ecosystem services, reducing urban heat islands, and fixing atmospheric nitrogen and carbon. Urban farming can improve food security, supplement household incomes, provide jobs (especially for women and the youth), reconnect the urban environment with nature cycles, increase resilience amongst the urban poor to food price shocks, and smoothen seasonal food consumption fluctuations. Urban farming includes backyard, rooftop, school and community gardens. Establishing food markets in poor neighbourhoods can provide access to local, organic produce at controlled prices [WEF 2021; Mirzabaev *et al* 2021; UCCRN 2018; UC SAREP 2017]. Additional benefits include efficient land use close to consumers and markets, reducing transport costs and emissions; using treated wastewater, rainwater harvesting and return-flow systems; reduced water consumption; using renewable energy;

higher yields and less loss due to weather, drought or pests; and year-round fresh, healthy and nutritious food [Okole *et al* 2021].

3 Conclusions

This chapter has examined the circular economy opportunities and constraints in human settlements and with municipal government in South Africa. It has also provided overviews of the linear and circular economies and expected trends. There are many research questions, such as whether urbanisation enhances or defeats the circular economy; whether the circular economy increases or decreases costs, happiness, jobs, social cohesion, and delivery of suitable housing. Finally, it is critical to understand there can be no perfectly circular economy in human settlements, because of the need to balance competing requirements.

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5 References

- AGSA (30 Jun 2021) *Consolidated general report on the local government audit outcomes: MFMA 2019-20*. Auditor-General of South Africa (AGSA), Pretoria, South Africa [\[online\]](#).
- AGSA (15 Jun 2022) *Consolidated general report on the local government audit outcomes: MFMA 2020-21*. Auditor-General of South Africa (AGSA), Pretoria, South Africa [\[online\]](#).
- AGSA (31 May 2023) *Consolidated general report on local government audit outcomes: MFMA 2021-22*. Auditor-General of South Africa (AGSA), Pretoria, South Africa [\[online\]](#).
- Ballard, Richard; Hamann, Christian & Mosiane, Ngaka (15 Dec 2021) *Spatial trends in Gauteng*. Occasional paper #19, Gauteng City-Region Observatory (GCRO), ISBN 978-1-990972-20-1 [\[online\]](#).
- C40 (May 2019a) *Five impactful actions cities can take to reduce building energy demand*. C40 Cities Climate Leadership Group & C40 Knowledge Hub, New York, NY, USA [\[online\]](#).
- C40 (Sep 2019b) *Six city actions to improve waste management and reduce greenhouse gas emissions*. C40 Cities Climate Leadership Group & C40 Knowledge Hub, New York, NY, USA [\[online\]](#).
- C40 (Jul 2020) *How to build back better with a 15-minute city*. C40 Cities Climate Leadership Group & C40 Knowledge Hub, New York, NY [\[online\]](#).
- C40 (Jan 2021a) *How to start deconstructing and stop demolishing your city's buildings*. C40 Cities Climate Leadership Group & C40 Knowledge Hub, New York, NY, USA [\[online\]](#).
- C40 (Apr 2021b) *Mayors' Agenda for a Green and Just Recovery*. C40 Cities Climate Leadership Group, New York, NY, USA, 43pp [\[online\]](#).
- C40 (May 2021c) *15-minute cities: How to create 'complete' neighbourhoods*. Implementation guide. C40 Cities Climate Leadership Group & C40 Knowledge Hub, New York, NY, USA [\[online\]](#).
- C40 (2022) *Cool Cities Network*. C40 Cities Climate Leadership Group, New York, NY, USA, 7pp [\[online\]](#).
- Carra, Guglielmo & Magdani, Nitesh (2018?) *Circular Business Models for the Built Environment*. Ellen MacArthur Foundation & The Circular Economy 100 (CE100) [\[online\]](#).
- Chamberlain, L (25 Jan 2022) *The Surprising Stickiness of the "15-Minute City"*, Common Edge [\[online\]](#).
- Circle Economy (2021). *The Circularity Gap Report 2021*. Platform for Accelerating the Circular Economy (PACE) [\[online\]](#).
- CNU (20 Apr 2015) *The Charter of the New Urbanism*, Congress for the New Urbanism (CNU) [\[online\]](#).
- CoGTA (2016) *Integrated Urban Development Framework: A new deal for South African cities and towns* [\[online\]](#).
- Cooper Antony K (2 Sep 2022) *Circular economy and human settlements*. 4th SA-GEO Symposium and 3rd Space for National Development (SND), Pretoria [\[online\]](#).
- Cooper, Antony K; Kruger, DM "Tinus"; Godfrey, Linda & Napier, Mark (2021) *Creating resilient, inclusive, thriving human settlements through a more circular economy*. In Godfrey, Linda (editor), *The circular economy as development opportunity: Exploring circular economy opportunities across South Africa's economic sectors*, pp 36-43. CSIR, Pretoria. ISBN: 978-0-7988-5667-6 [\[online\]](#).
- Cooper, Antony K & Sebake, Nosizo (Oct 2018) *Neighbourhood 4.0: A response to urban futures*. Out-Of-The Box 2018 Conference, Pretoria, South Africa, pp 16–28 [\[online\]](#).
- CSIR (2019) *Green Book: Adapting South African settlements to climate change*. CSIR, Pretoria [\[online\]](#).
- CSIR & DHS (Jul 2019) *The Neighbourhood Planning and Design Guide: Creating Sustainable Human Settlements (Red Book)*. Department of Human Settlements, Pretoria. ISBN 978-0-6399283-2-6 [\[online\]](#).
- D'Acci, L (2013) *Simulating future societies in Isobenefit Cities: Social isobenefit scenarios*, *Futures*, 54:3-18 [\[online\]](#).
- Daniel, Luke (30 Jul 2022) *Golden Arrow has gone solar – and is now eyeing 60 locally built electric buses*. Business Insider SA [\[online\]](#).
- DEFRA (10 Nov 2021) *World-leading Environment Act becomes law*. Press release. Department for Environment, Food & Rural Affairs; Forestry Commission; Environment Agency; Natural England & Eustice, George (MP) [\[online\]](#).
- Demolition Depot (2022) *The Demolition Depot*, New York, NY, blog [\[online\]](#).
- EMF (2017) *Cities in the circular economy: An initial exploration*. Ellen MacArthur Foundation, UK [\[online\]](#).
- EMF (2021) *Circular Economy Introduction*. Ellen MacArthur Foundation, UK [\[online\]](#).
- EMF (2022a) *Measure business circularity: Circulytics*. Ellen MacArthur Foundation, UK [\[online\]](#).
- EMF (2022b) *Circular Buildings Toolkit*. Ellen MacArthur Foundation, UK [\[online\]](#).
- EMF (2022c) *Delivering the circular economy: a toolkit for policymakers*. Ellen MacArthur Foundation, UK [\[online\]](#).

- Fazluddin, S; Ojjo, VO; Nahman, A & Godfrey, LK (2021) *Supporting the development of a globally competitive manufacturing sector through a more circular economy*. In: Godfrey, LK (editor) *The Circular Economy as Development Opportunity: Exploring Circular Economy Opportunities across South Africa's Economic Sectors*, pp 27–35. CSIR, Pretoria. ISBN: 978-0-7988-5667-6 [\[online\]](#).
- Feyertag, Joseph & Bowie, Ben (2021) *The financial costs of mitigating social risks: costs and effectiveness of risk mitigation strategies for emerging market investors*. ODI, London [\[online\]](#).
- Forti, Vanessa; Baldé, Cornelius Peter; Kuehr, Ruediger & Bel, Garam (2020) *The Global E-waste Monitor 2020: Quantities, flows and the circular economy potential*. United Nations University & United Nations Institute for Training and Research SCYCLE Programme; International Telecommunication Union & International Solid Waste Association. ISBN 978-92-808-9114-0 [\[online\]](#).
- GAHP (Dec 2019) *Pollution and Health Metrics: Global, Regional, and Country Analysis*. Global Alliance on Health and Pollution, New York & Geneva [\[online\]](#).
- Gerretsen, Isabelle (13 Sep 2021) *How India's air pollution is being turned into floor tiles*. BBC [\[online\]](#).
- Gibberd, Jeremy (Oct 2020) *State of play for circular built environment in Africa*. Final report. United Nations One Planet Network Sustainable Buildings and Construction Programme [\[online\]](#).
- Githathu, Mwangi (7 Nov 2019) *'Waste crisis' in spotlight as SA is running out of landfill space*. Cape Argus [\[online\]](#).
- Godfrey, Linda K (2021a) *Quantifying economic activity in the informal recycling sector in South Africa*. South African Journal of Science, 117(9/10), Art. #8921 [\[online\]](#).
- Godfrey, Linda K, ed (2021b), *The circular economy as development opportunity: Exploring circular economy opportunities across South Africa's economic sectors*. CSIR, Pretoria. ISBN: 978-0-7988-5667-6 [\[online\]](#).
- Gower, Richard & Schröder, Patrick (2018) *Virtuous Circle: How the circular economy can create jobs and save lives in low and middle-income countries*. Tearfund, Teddington, United Kingdom [\[online\]](#).
- IEA (28 Jul 2022) *Global coal demand is set to return to its all-time high in 2022* (Press release). International Energy Agency (IEA), Paris, France [\[online\]](#).
- Jacobs, J. (1961) *The death and life of great American cities*. New York: Random House.
- Kammen, Daniel; Bozuwa, Johanna; Cha, J Mijin; Cohen, Daniel Aldana; Fleming, Billy; Goodman, Jim; Johnson, Ayana Elizabeth; Brave NoiseCat, Julian; Paul, Mark; Patel, Raj & Riofrancos, Thea (23 Mar 2020) *A Green Stimulus to Rebuild Our Economy: An Open Letter and Call to Action to Members of Congress*. Renewable & Appropriate Energy Laboratory, University of California, Berkeley [\[online\]](#).
- Khan, S; Nontso, Z; Magweregwe, F; Godfrey, LK & Sereme, BV (2021) *Placing the South African mining sector in the context of a circular economy transition*. In: Godfrey, LK (editor) *The Circular Economy as Development Opportunity: Exploring Circular Economy Opportunities across South Africa's Economic Sectors*, pp. 9–17. CSIR, Pretoria. ISBN: 978-0-7988-5667-6 [\[online\]](#).
- Koumi, Ahou Rachel (15 Sep 2020) *Regulations, actions and management process for plastic waste in Côte d'Ivoire, West Africa*. OECD [\[online\]](#).
- Kruger, DM "Tinus"; Lancaster, Lizette; Landman, Karina; Liebermann, Susan; Louw, Antoinette & Robertshaw, Rory (2016) *Making South Africa Safe: A Manual for Community-Based Crime Prevention*. CSIR, Pretoria, South Africa [\[online\]](#).
- Landrigan, PJ; Fuller, R; Acosta, NJR, et al (2018) *The Lancet Commission on pollution and health*, The Lancet, 391(10119), pp 462–512. doi: 10.1016/S0140-6736(17)32345-0 [\[online\]](#).
- Moatshe, Rapula (21 Feb 2022) *Violent 'business forum' terrorise human settlements officials, hijack service delivery projects*. IOL [\[online\]](#).
- Mokoena, R; Steenkamp, AJ & Godfrey, LK (2021) *Facilitating sustainable economic development through circular mobility*. In: Godfrey, LK (editor) *The Circular Economy as Development Opportunity: Exploring Circular Economy Opportunities across South Africa's Economic Sectors*, pp 44–52. CSIR, Pretoria. ISBN: 978-0-7988-5667-6 [\[online\]](#).
- Moreno, Carlos 5 Oct (2016) *La ville du quart d'heure: pour un nouveau chrono-urbanisme*, La Tribune [\[online\]](#).
- Moreno, Carlos; Allam, Zaheer; Chabaud, Didier; Gall, Catherine & Pralong, Florent (2021) *Introducing the "15-Minute City": Sustainability, Resilience and Place Identity in Future Post-Pandemic Cities*, Smart Cities, 4(1):93–111 [\[online\]](#).
- Morgan, Dafydd (26 Feb 2022) *Nappies added to roads 'doubles life of surfaces'*. BBC [\[online\]](#).
- Msimanga, XP; Godfrey, LK & North, BC (2021) *Decoupling South Africa's development from energy demand through a more circular economy*, in: *The Circular Economy as Development Opportunity: Exploring Circular Economy Opportunities across South Africa's Economic Sectors*, pp 53–60. CSIR, Pretoria. ISBN: 978-0-7988-5667-6 [\[online\]](#).
- Mthuli, Malusi (3 Apr 2022) *This trend in South Africa's property market is accelerating thanks to a changing workforce*. BusinessTech [\[online\]](#).
- Nahman, Anton; Godfrey, Linda K; Oelofse, Suzan H & Trotter, Douglas (2021) *Driving economic growth in South Africa through a low carbon, sustainable and inclusive circular economy*. In: Godfrey, Linda (editor), *The circular economy as development opportunity: Exploring circular economy opportunities across South Africa's economic sectors*, pp 36-43. CSIR, Pretoria. ISBN: 978-0-7988-5667-6 [\[online\]](#).
- Napier, Mark; Cooper, Antony K; Holloway, Jennifer P; Thanjekwayo, Londeka; Graham, Nick & Le Roux, Alize (Apr 2022) *A tale of two pathways: how the low-end Gauteng residential property market may be shaped either by state-driven supply or by a more enabled private sector*. Understanding African Real Estate Markets. Routledge International Real Estate Markets Series. ISBN 978-0-367-23310-5 [\[online\]](#).
- National Treasury (Jul 2018). *Managing Urbanisation to Achieve Inclusive Growth: A review of trends in South African urbanisation and suggestions for improved management of urbanisation*. South African Urbanisation Review [\[online\]](#).
- Natural England (7 Jul 2021) *Biodiversity 3.0 Metric Launched in New Sustainable Development Toolkit*. Press release. Department for Environment, Food & Rural Affairs, London, UK [\[online\]](#).
- Njwambe, Avela; Cocks, Michelle & Vetter, Susanne (2019) Ekhayeni: *Rural–Urban Migration, Belonging*

- and Landscapes of Home in South Africa. *Journal of Southern African Studies*, 45:2:413-431 [\[online\]](#).
- Okole, BN; Gordon, GE; Brown, B; Pillay, B; Schoeman, C & Godfrey, LK (2021) *Supporting food security and economic development through circular agriculture*. In: Godfrey, LK (editor) *The Circular Economy as Development Opportunity: Exploring Circular Economy Opportunities across South Africa's Economic Sectors*, pp 18–26. CSIR, Pretoria. ISBN: 978-0-7988-5667-6 [\[online\]](#).
- O'Reilly, Claire (22 Oct 2021) *Illegal sand mines continue to profit*. *Mining Weekly* [\[online\]](#).
- Ostrom, Elinor (1990). *Governing the Commons: The Evolution of Institutions for Collective Action*. Cambridge University Press, Cambridge. ISBN 978-0-521-40599-7.
- Paddison, Laura (25 Oct 2021) *How the rich are driving climate change*. BBC [\[online\]](#).
- Pai, Sandeep; Emmerling, Johannes; Drouet, Laurent; Zerriffi, Hisham & Jewell, Jessica (2021) *Meeting well-below 2°C target would increase energy sector jobs globally*. *One Earth*, 4(7):1026-1036 [\[online\]](#).
- PAS (Oct 2021) *Biodiversity Metric 3 Training for Planners*. Planning Advisory Service, Local Government Association [\[online\]](#).
- Petzer, Engela; Napier, Mark & le Roux, Alize (12 Feb 2020) *Developing a Tool to Monitor Neighbourhood Spatial Transformation*. Concept note prepared for the South African Local Government Association (SALGA). CSIR, Pretoria.
- Pörtner H-O & Roberts DC (2022) *Summary for policymakers*. In: Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, 37pp. Cambridge University Press, Cambridge, UK and New York, USA [\[online\]](#).
- Potgieter, JE; Rajput, J; Hemkhaus, M; Ahlers, J; Van Hummelen, S; McGovern, M & Artola, I (2020) *Circular Economy in Africa-EU Cooperation: Country Report for South Africa*. Submitted to the European Commission, ISBN 978-92-76-26834-5 [\[online\]](#).
- Ramaphosa, Cyril (8 Sep 2022) *President Cyril Ramaphosa: SALGA Council of Mayors*. SALGA Council of Mayors, East London [\[online\]](#).
- RIPESS (2023) *What is Social Solidarity Economy*. Red Intercontinental de Promoción de la Economía Social y Solidaria (RIPESS), Barcelona, Spain [\[online\]](#).
- SARB (17 Oct 2023) *Monetary Policy Review – October 2023*. Monetary Policy Committee (MPC), South African Reserve Bank, Pretoria, South Africa [\[online\]](#).
- Schweiger, Francesca (22 Feb 2022) *The mobile phones you can take apart and repair yourself*. BBC [\[online\]](#).
- SEA (2020) *State of Energy in South African Cities 2020*. Sustainable Energy Africa (SEA), Cape Town, South Africa [\[online\]](#).
- Seetal, AR; Mathye, SM & Godfrey, LK (2021) *Decoupling South Africa's development from water demand through a circular economy*. In: Godfrey, LK (editor) *The Circular Economy as Development Opportunity: Exploring Circular Economy Opportunities across South Africa's Economic Sectors*, pp 61–69. CSIR, Pretoria. ISBN: 978-0-7988-5667-6 [\[online\]](#).
- Statista (2021). *South Africa: Urbanization from 2010 to 2020* [\[online\]](#).
- Stats SA (19 Jul 2021a) *Mid-year population estimates, 2021*. Statistical Release P0302. Statistics South Africa, Pretoria, South Africa [\[online\]](#).
- Stats SA (13 Dec 2021b) *Stats in brief 2021*. Statistics South Africa, Pretoria, South Africa. ISBN 978-0-621-49663-5 [\[online\]](#).
- The DTI (2018) *Industrial Policy Action Plan IPAP 2018/19-2020/21*. Department of Trade and Industry, Pretoria, South Africa [\[online\]](#).
- UC SAREP (2017) *Urban Agriculture*. Sustainable Agriculture Research & Education Program, University of California Agriculture & Natural Resources [\[online\]](#).
- UCCRN (Feb 2018) *The Future We Don't Want: How Climate Change Could Impact the World's Greatest Cities*. Technical Report. C40 Cities, Global Covenant of Mayors, Acclimatise, and the Urban Climate Change Research Network (UCCRN) [\[online\]](#).
- UN (20 Oct 2016) *The New Urban Agenda*. Adopted at the United Nations Conference on Housing and Sustainable Urban Development (Habitat III), Quito, Ecuador [\[online\]](#).
- UN (2022) *The 17 Goals*. United Nations Department of Economic and Social Affairs [\[online\]](#).
- UNEP (2022) *Emissions Gap Report 2022: 2022: The Closing Window – Climate crisis calls for rapid transformation of societies*. United Nations Environment Programme (UNEP), Nairobi, Kenya [\[online\]](#).
- UP (2021) *UP's Moja Gabedi: From rubble to a meaningful garden*. University of Pretoria, Pretoria, South Africa [\[online\]](#).
- Urban Surfer (2022) *Urban Surfer: informal recycling solutions*, home page [\[online\]](#).
- US Green Building Council (2022) *LEED certification for neighborhood development* [\[online\]](#).
- Van Niekerk, Willemien; Petzer, Engela; Ndaba, Dumisani; Pieterse, Amy; Rajab, Azra & Kruger, DM "Tinus" (Dec 2015) *Revising the South African guidelines for human settlement planning and design (the Red Book)*. Smart and Sustainable Built Environment (SASBE) Conference 2015, Pretoria, pp 135-141. ISBN 978-0-7988-5624-9 [\[online\]](#).
- Van Zyl, Terence L & Celik, Turgay (2021) *Did We Produce More Waste During the COVID-19 Lockdowns? A Remote Sensing Approach to Landfill Change Analysis*. *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, 14:7349-7358 [\[online\]](#).
- Verma, Anshul (31 Mar 2022) *Ghazipur fire: Gasping for air as massive Delhi landfill burns*. BBC [\[online\]](#).
- Von Blottnitz, H; Virág, D; Wiedenhofer, D & Haas, W (23 Feb 2022) *An Economy-wide Material Flow Analysis to Develop Circular Economy Indicators for South Africa*. University of Cape Town [\[online\]](#).
- WEF (Oct 2017) *Migration and Its Impact on Cities – An Insight Report* [\[online\]](#).
- WEF (Apr 2021) *Five Big Bets for the Circular Economy in Africa*. African Circular Economy Alliance [\[online\]](#).
- Weng, Min; Ding, Ning; Li, Jing; Jin, Xianfeng; Xiao, He; He, Zhiming & Su, Shiliang (2019) *The 15-minute walkable neighborhoods: Measurement, social inequalities and implications for building healthy communities in urban China*, *Journal of Transport & Health*, 13:259–273 [\[online\]](#).
- WHO (2021) *WHO global air quality guidelines. particulate matter (PM_{2.5} and PM₁₀), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide*. Executive summary. World Health Organization, Geneva. ISBN 978-92-4-003443-3 [\[online\]](#).

Williams J (2021). *Circular Cities: A Revolution in Urban Sustainability*. Routledge Studies in Sustainability. [\[online\]](#).

Zama, Siphokazi (2 Mar 2022) *This Eastern Cape woman has turned pineapple-leaf fibres into cost-saving reusable nappies*. You [\[online\]](#).

ZWS (nd) *Designing Out Construction Waste: A guide for project design teams*. Zero Waste Scotland Ltd, Stirling. 46p [\[online\]](#).