Global State of Play for Circular Built Environment

A report on the state of play on circularity in the built environment across Africa, Asia, Europe, Gulf Cooperation Council countries, Latin America and the Caribbean, North America and Oceania

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February 2021

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Suggested citation:

Iyer-Raniga U. and Huovila, P. Global state of play for circular built environment. A report on the state of play on circularity in the built environment across Africa, Asia, Europe, Gulf Cooperation Council countries, Latin America and the Caribbean, North America and Oceania. Final report October 2020, United Nations One Planet Network Sustainable Buildings and Construction Programme.

Cover design: Ninni Westerholm
Cover photos: Pekka Huovila
Layout design: Ninni Westerholm
ISBN/ISSN: 978-952-361-403-1

This updated report contains a spelling correction in page 7 and corrections to figure 3 on page 12.

One Planet Network

The One Planet network has been formed to implement the 10-Year Framework of Programmes on Sustainable Consumption and Production (SCP), which supports the global shift to SCP and the achievement of SDG 12. The One Planet network brings together actors from all regions and all sectors to bring together expertise, resources, innovation and commitment towards a shift to more sustainable modes of production and consumption. The network comprises of six programmes: Sustainable Public Procurement, Sustainable Buildings and Construction, Sustainable Tourism, Sustainable Food Systems Programme, Consumer Information for SCP, Sustainable Lifestyles and Education.

Sustainable Buildings and Construction Programme

The Sustainable Buildings and Construction Programme (SBC) aims at improving the knowledge of sustainable construction and to support and mainstream sustainable building solutions. Through the programme, all major sustainable construction activities can be brought together under the same umbrella. The work involves sharing good practices, launching implementation projects, creating cooperation networks and committing actors around the world to sustainable construction. The goal of the programme is to promote resource efficiency, mitigation and adaptation efforts, and the shift to SCP patterns in the buildings and construction sector.

State of Play Reports

The Sustainable Buildings and Construction Programme has been preparing regional reports on the state of play for circular built environment in Africa, Asia, Europe, Gulf Cooperation Council countries, Latin America and the Caribbean, North America and Oceania. In addition to regional outlooks, a global report has been produced to summarise and compare the state of play regarding circularity in different regions. A crucial part of the reports are to not just provide a benchmark but also recommendations on how to move forward towards a sustainable and circular built environment.

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CDW	Construction and demolition waste
DESA	Department of Economic and Social Affairs
ECLAC	Economic Commission for Latin America and the Caribbean
EPA	Environmental Protection Authority
EU	European Union
GCC	Gulf Cooperation Council
GHG	Greenhouse gas
LAC	Latin America and the Caribbean
MR	Materials and Resources
NDC	Nationally Determined Contribution
OECD	Organisation for Economic Co-operation and Development
SBC	Sustainable Building and Construction
SDG	Sustainable Development Goal
SMM	Sustainable Materials Management
UN	United Nations
UNEP	United Nations Environment Programme
US	United States
USGCRP	United States Global Change Research Program
UN	United Nations
US	United States

Executive summary

The world is becoming increasingly urbanised, particularly in the Asian and African regions. Building stock is expected to double by 2050 in these regions. Global material use is expected to more than double by 2060, and the materials used in the building and construction sector will comprise a third of this rise. Greenhouse gas (GHG) emissions will also increase as a result of material use. Concrete alone is expected to contribute to 12% of global GHG emissions in 2060. Economic growth in construction and utlities is expected to increase by slightly more than 2.5 times between 2011 and 2060. Based on current trends, the new growth economies of Asia, Africa and Latin America are expected to be using more materials than ever before in 2060. It is estimated that the total waste generated in the world will double from nearly 2 billion tonnes in 2016 to about 4 billion tonnes by 2050.

Such trends call for an urgent questioning of current ways of operating the built environment. Present practices are locked into a linear way of planning, designing, building and operating the built environment and it is exigent to consider alternative approaches through which mitigation and adaptation goals may be achieved simultaneously. Circular approaches present a viable alternative to underpin the transition to a decarbonised world while at the same time meeting the goals of the 2030 Agenda for Sustainable Development.

The United Nations (UN) One Planet Network Sustainable Buildings and Construction programme initiated a study to understand the current state of play with regard to circularity in the built environment in the seven different geographic regions: Africa, Asia, Europe, Gulf Cooperation Council (GCC) countries, Latin America and the Caribbean (LAC), North America and Oceania. These studies show that the different regions are in various states of transition towards the adoption of circular economies, but that Europe is leading, largely due to having been engaged in this transition process for at least a decade. Other regions are still grappling with considering what circularity actually means for them and proactively drafting supporting policies and programmes with the goal of transitioning to a low-carbon future.

Tensions with respect to design, operation and deconstruction exist between new developments and existing stock. The focus in Asia, Africa and the LAC regions has been based on a linear framework for supporting the needs of the built environment, be it residential, commercial or infrastructure. It is anticipated that this global report will enable governments to consider the development (and review as appropriate) of their National Adaptation Plans and Nationally Determined Contributions. Policy-makers need to consider the quantum and quality of construction and deconstruction waste to ensure that it does not end up in landfill, and that promote policies and programmes to support the second and third lives of materials, while ensuring healthier built environments.

This linear thinking is entrenched in the practices of the various professions that together produce the built environment. Arising from this study, the following ten recommendations are presented:

1. **Think and act differently now and in the near future.** The current lock-in approach needs a concerted shift in thinking from linear to circular, and this should be a priority as governments consider catalysing economic recovery packages in a COVID-19 world.
2. **Monitoring and reporting is essential** to ensure that we stay on track and reach the goal of living and working in a world that enables efficient resource use, has little or no environmental impact, and ensures a just society. The SDGs can assist in monitoring and reporting as the foundational principles of circular economy and sustainability are the same.

3. **Lifecycle considerations at the outset of planning and design** will guarantee that the buildings built to stay are mindful of their operations and also consider the second life of buildings and materials post-deconstruction.
4. Related to the above, **building materials are the essential building blocks for the built environment.** Careful thought regarding alternative materials such as bio-based materials and existing materials in the system will mean that materials may be given second, third or even more lives rather than ending up as waste.
5. **Procurement processes need to be considered.** Procurement practices can drive supply chains and the transition from product to service procurement or mix of products and services will result in sustainability outcomes.
6. As the pressure to ensure mitigation of environmental impacts rises, **adaptation and resilience will be needed** as the world continues to warm. The incidence of natural disasters is also on the increase. Affordability, the use of local technologies and building resilience in the built environment also need to be encouraged.
7. **Locally adapted solutions and practices need to be encouraged.** One of the key lessons learned from the COVID-19 pandemic is that we are far too reliant on global supply chains which can hamper economic activity.
8. **New business models** that encourage cross-sectoral collaborations such as between IT and the built environment to support building passports or track and trace materials for reuse or repurpose also need to consider qualifications criteria for the reuse of construction and deconstruction waste. Supply and demand needs to be balanced.
9. A serious **overhaul of education and skills** is required so that the gap between competence and industry needs is bridged and skilled workers are available in the transition to a circular economy.
10. **Collaboration and financing agreements** are needed to ensure that engagement among all stakeholders is driven by genuine circular economy underpinnings.

The question is not where to from here, rather how fast do we need to transition to circularity?

Good practices already exist and their benefits are evident. To avoid a repeat of the same lock-in approaches, current challenges need to be overcome. Building knowledge, awareness and understanding around new and existing developments underpinned by a circular thinking approach is urgently needed. Some quick wins to achieve this are changes in legislation and regulation, improved building standards that focus on the end of life of buildings, changes in procurement practices and increased stringencies where environmental impacts are now only marginally considered.

The emerging economies need assistance in transitioning to a circular economy that will benefit everyone. The context within which they operate is very different from that of Europe and other developed regions. Climatically and culturally these regions are quite different. They often have a long history of indigenous settlements that has eroded over centuries, and a younger population that aspires to a ‘westernised’ lifestyle. A repository of good practices and case studies is urgently needed so that lessons learned may be shared. Enhanced collaboration between stakeholders towards a common goal will support innovations where flexible design and construction becomes the norm, so that maintenance and deconstruction are easy.

The transition to a circular economy presents an opportunity. Reuse and recycling are expected to continue to improve into the future, even leading to upcycling. Examples of sharing economy can spread. In a world that has been touched deeply by the coronavirus pandemic, shifts in our ways of working have already occurred. As industry practices are transiting to a ‘new normal’ that is supported by governments, it is timely to also consider the advantages of moving to circular built environments.

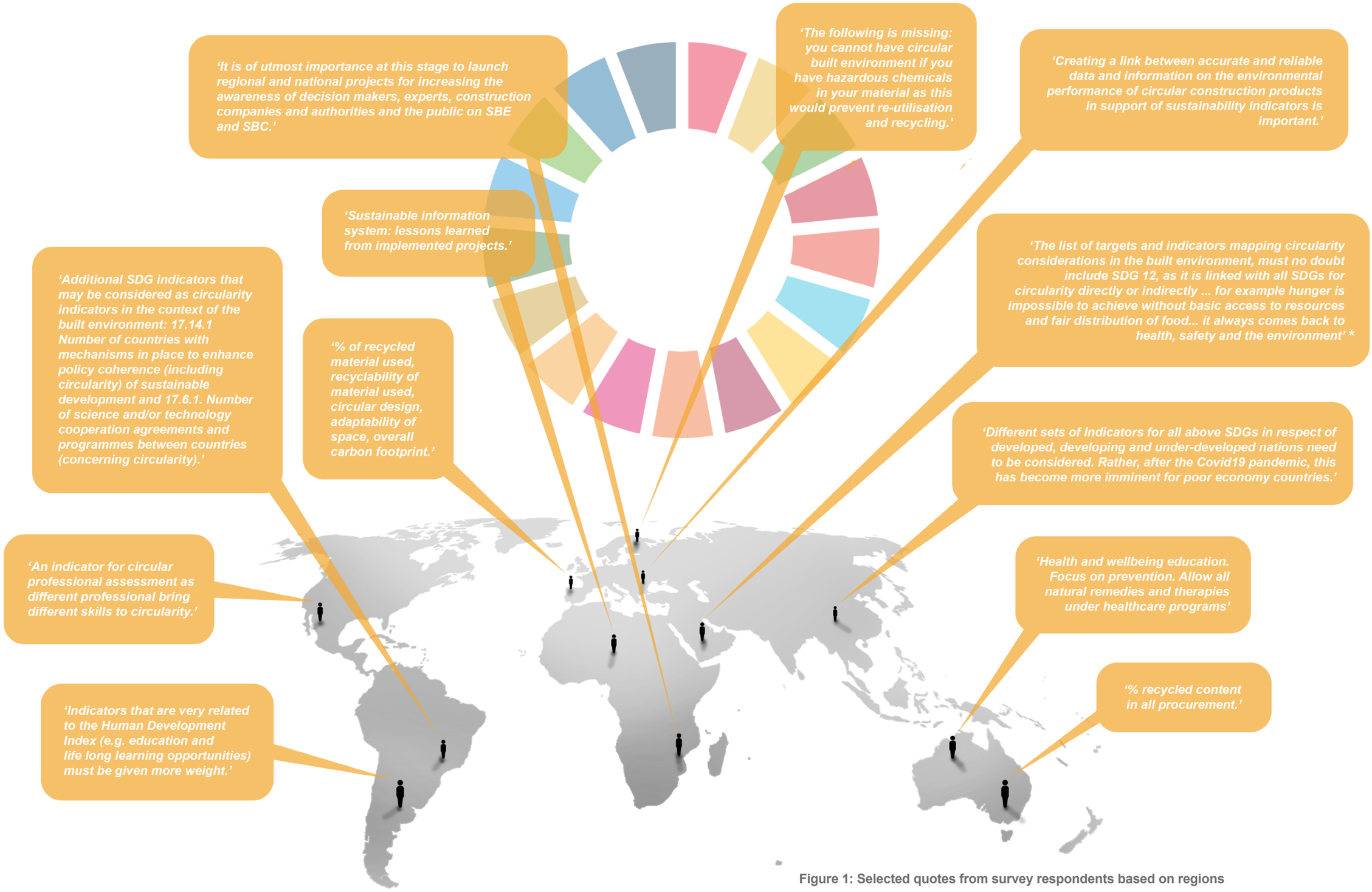

Figure 1: Selected quotes from survey respondents based on regions

NOTE: The survey respondents have been positioned on the map in the region they represent.
*quote's grammar slightly corrected.
Source: Authors
Graphics: Ninni Westerholm

1. Introduction

The world is becoming increasingly urbanised. Globally, more people live in urban areas than in rural areas. Over 55% of the world's population was residing in urban areas in 2018, in contrast to 1950, when 30% of the world's population was urban. By 2050, 68% of the world's population is projected to be urban (UN Department of Economic and Social Affairs [DESA], 2019). Also by 2050, almost 90% of the world's population growth is expected to be in the urban regions of Asia and Africa (UN DESA, 2019). While increased urbanisation has its problems, populations are expected to have higher incomes, leading to a global demand for more goods and services. Globally, the focus of higher usage of materials and increased materials intensity is shifting towards the emerging and developing economies. The building stock is set to double by 2050, with the greatest share occurring in these regions.

Global material use is projected to more than double from 79 Gt in 2011 to 167 Gt in 2060 (Organisation for Economic Co-operation and Development [OECD], 2018, p. 3). Of the total volume of material used, more than half will be comprised of non-metallic materials, while a third is expected to be used in the building and construction industry such as sand, gravel and limestone. There are signs of decoupling between materials use and the economy, as GDP will continue to increase but at a much slower rate than the global use of materials. Recycling is projected to become more competitive, establishing a good base for a circular economy as recycling is expected to increase by 3.7 times by 2060. Also by 2060, global economic growth in construction and utilities is expected to increase by 2.6 times (OECD, 2018, p. 4).

Material extraction and use has an impact on GHG emissions. By 2060, emissions are expected to reach approximately 50Gt CO_2-e (OECD, 2018). Concrete alone is expected to contribute to 12% of global GHG in 2060 (OECD, 2018). Global economic growth in construction and utilities is anticipated to increase by 2.6 times and recycling by 3.7 times (OECD, 2018, p. 4). The use of construction materials is expected to stabilise in China, with a slight fall during the 2025–60 period. Between 2011 and 2060, the Middle East and Africa are expected to consume 4.2 times more materials, non-OECD America is expected to consume 1.5 times more materials and non-OECD Asia is expected to use 2.1 times more materials.

Decarbonising the building and construction sector is therefore critical. The sector is responsible for almost 40% of energy- and process-related emissions and it has been touted that investment in building and construction is the best option for reducing GHG emissions. The final energy demand in buildings in 2018 rose 1% from 2017, and 7% from 2010 (GlobalABC, IEA and United Nations Environment Programme [UNEP], 2019).

With this background, it is clear that the emerging economies are going to be key growth areas for new construction and will be in the spotlight with respect not only to population and urbanisation, but also with respect to material use, building and construction processes, and attendant impacts. These economies need to start thinking seriously about not locking in practices and programmes that continue the current linear paradigms dominating operations within various sectors, including the built environment.

At the same time, the already built-up areas in industrialised countries require supplementary construction and renovation in a resource-efficient and climate-wise way. This can be achieved by following circularity principles, and taking into account the need for resilience and adaptation to climate change.

1.1 Aim of this report

The aim of this report is to 'put a line in the sand' to determine where we are with circularity in the built environment sector. This report attempts to understand at a high level the existence of circularity underpinnings in the built environment sector in the various regions of the world. As a starting point, it presents recommendations to incorporate circular economy into policy and programmes across all countries and regions. It also stresses the urgency of undertaking this work now as we are already locking in linear ways of operation, particularly in the new growth regions (which are learning from the trajectories of the developed world), making it increasingly difficult to change operations in the future for this cohort of the planet.

Circularity in the built environment can be understood at different scales. This report emphasises how nature's resources are used in buildings to provide more comfortable and healthier spaces while generating less waste and emissions. The aim is to change linear processes as shown in Figure 2 to circular processes, thereby increasing resource efficiency and reducing waste and emissions, while also providing local jobs. Certain important aspects of land use and urban planning or mobility in circular cities are not covered here.

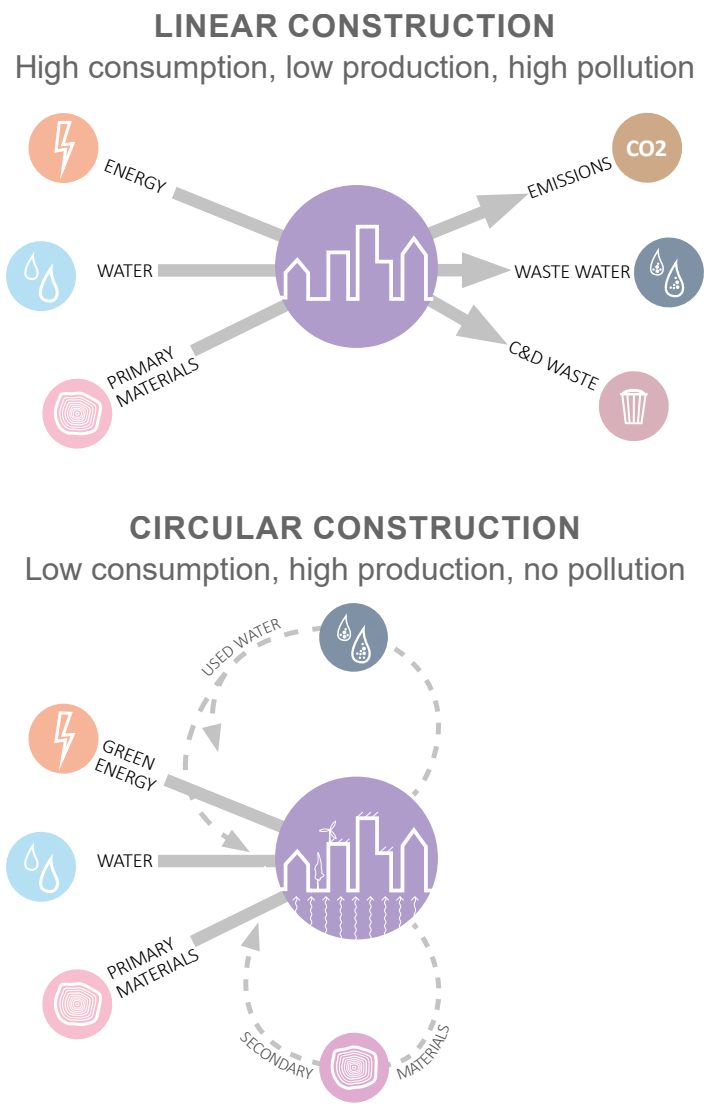

Figure 2: Basic inputs and outputs for a building

Source: Ninni Westerholm
Graphics: Ninni Westerholm

1.2 Structure of this report

Regional reports were commissioned across the following UN designated (UN, 2020a) geographic regions: Europe, North America, Oceania, GCC, Asia, Africa and LAC. Since the Gulf Cooperation Council (GCC) countries are different in climate and culture from Africa and West Asia, this was considered separately. Not all countries have been considered across these regions. For instance, North America includes the United States (US) only whereas Oceania includes Australia and New Zealand. There are similarities and differences between the regions, and even where situations are similar, this report presents a good overview with respect to circularity in the built environment.

This report commences with a discussion of the UN 2030 Agenda Sustainable Development Goals (SDGs) as far as the built environment sector is concerned. Following this are summaries of the reports regarding the state of play in the commissioned regions. The outcomes with respect to the state of circularity identified in the reports are then mapped against the SDGs, targets and indicators, followed by lifecycle considerations across the various phases of building and construction, thus presenting a holistic roadmap for circularity in the built environment. The report ends with the conclusion and recommendations for the future.

2. The built environment and the SDGs

The SDGs have an operational timeline of 2016–30 (UN, 2020b). They comprise 17 goals and 169 targets. The SDGs have been reviewed in depth in High Level Political Forums in 2017 (1, 2, 3, 5, 9, 14), in 2018 (6, 7, 11, 12, 15) and in 2019 (4, 8, 10, 13 and 16). SDG 17 was reviewed in all of these forums. In addition, the progress of each SDG towards 2030 has been reported annually since 2016 (refer to the UN SDGs).

Circular economy is not mentioned in the 169 targets or their associated indicators. However, the UN Secretary-General Report on progress towards the SDGs states: 'Measures have been taken, in both the public and private sectors, to decouple economic growth from the use of natural resources. The concepts of circular and low-carbon economies are gaining ground' (UN Economic and Social Council [UN EcoSoc], 2019). Yet, despite the apparent lack of connection between the SDGs and circular economy, the principles underpinning sustainability and circular economy are the same: the quest to give equal consideration to social, economic and environmental imperatives. The circularity aspects in the built environment are well covered by the SDGs, in SDG 6, SDG 7, SDG 8, SDG 9, SDG 11, SDG 12 and SDG 13, and more specifically addressed for example, in SDG 1, SDG 3, SDG 4, SDG 15 and SDG 17.

The building and construction industry is often a measure of how economies are generally performing as the sector employs at least 7% of people worldwide (Nieuwenkamp, 2016). Circular economy is also about ensuring that social and technological progress is made without adverse environmental impacts. While there are many definitions of circular economy, it is essentially about designing out waste, keeping materials and products circulating in the system, optimising resources, providing long-lasting solutions so that we do not draw on virgin resources, and regenerating natural systems. It has also been corroborated in recent documents, such as Habitat III, UNEA4 SCP innovative sustainable and consumption practices (UN, 2019a) and the SDG progress report (UN EcoSoc, 2019).

This report uses the SDGs to map the state of play of circularity in the built environment sector. Studying the indicators further associated with the various SDG targets and indicators, a list of 59 indicators for circularity in the built environment was compiled. A global survey was deployed in May 2020 to determine whether these indicators resonated with the Sustainable Building and Construction (SBC) programme's network partners and experts. The indicators that were associated with particular regions assisted in understanding the top ten core indicators for the region. These global circularity indicators and regional aspects are discussed further in section 4.

Figure 3: SDG indicators for the SBC programme shown in the SDG circle

Source: Authors
Graphics: Ashley King & Ninni Westerholm

Figure 4: SDG indicators for the SBC programme shown in the SDG house

Source: Authors
Graphics: Ninni Westerholm

The priorities for circularity for the SBC programme are based on the SDGs. Priority indicators align with those stated in SDGs 8, 11 and 12 and secondary indicators in SDGs 6, 7, 9, 11, 12 and 13, shown mapped against the SDGs in Figure 3 and also shown as the SDG house in Figure 4. A global survey was undertaken to determine the global and regional indicators, explained further in section 4.

3. Summary of the regional reports

The summary of the regional reports for, Europe, North America, Oceania, GCC countries, Asia, Africa and LAC are presented below.

3.1 Europe

Europe has a population of approximately 748 million people, of which 75% live in cities (Worldometer, 2020a). Population growth in the region is expected to peak in 2021, where after it will slowly start to decrease. While the overall population is expected to decrease by 15% by 2100, and Europe's regional population will slowly start to decrease, the region's urban population is expected to grow by 7–8%. The global population is expected to grow by almost 40% by 2100, something that is happening alongside rapid urbanisation, especially in the Global South.

Europe differs from the other regions not only because of its projected decrease in population and high development rate, but also because of the unity brought by the EU. The 27 European countries (out of 44) that are EU member states are committed to common legislation and to being leaders with respect to circularity in the built environment. When considered from a circularity perspective, Europe is further along than other regions, mainly because of its head start of more than a decade. However, circular economy practice is still in its infancy, even in Europe, and is yet to be mainstreamed. Furthermore, due to the projected decreases in population in Europe, the focus regarding circularity in the built environment needs to be on the existing building stock, in contrast to new construction practices in developing societies.

The construction industry in the EU produces 25–30% of the waste generated, making it one of the major waste producers (European Commission, 2019). Even though a recovery target of 70% has been set for construction and demolition waste (CDW) in the EU, and most countries are reporting such rates, the deconstruction recovery undertaken is mainly downcycling, meaning that materials recovered get converted into items of lower value.

The EU and many European countries already have legislation, guidelines and incentives that promote circularity. Thus, good guidelines and practices (even though they might not be widely used) already exist. The main issue is the existing building stock that has not been designed or built with circularity or adaptability in mind, leading to premature deconstruction of buildings. Innovative new solutions are needed to prolong the lifespan of the existing building stock. The transition to a circular economy is happening slowly, and new policies and incentives are in progress across the region. The present throwaway culture has to be systematically eliminated from construction, and buildings need to be seen merely as temporary material banks so that materials may be reused easily. When developing the required strategies and practices, cooperation and information flow between all actors involved are crucial to achieve a successful transition to circular economy. Construction needs to be reviewed holistically and changes need to be widely applied throughout society. Ideally, other regions of the world can learn from Europe's longstanding work towards more circular construction and thus avoid common pitfalls and fast-track to a sustainable circular economy (Westerholm, 2020).

3.2 North America (US)

Not only is the US population largely urban (Worldometer, 2020), but the projected population growth, from the current 328 million to 404 million by 2060, is also expected to be concentrated in urban areas (Colby and Ortman, 2015). By 2100, the country's population is anticipated to comprise nearly 700 million people (United States Global Change Research Program [USGCRP], 2018). In the US, construction materials constitute 73% of all raw materials (United States Geological Survey [USGS], 2020), and CDW accounts for 25–45% of the total solid waste stream by weight (Miflin et al., 2017).

While the US has a mature built environment, with a growing population that is largely urban, the built environment sector is expected to continue to change through upgrading and retrofitting. During the period 2008–16, the US was the second-highest producer of municipal solid waste worldwide, following Denmark (OECD, 2020). The total MSW generated in the US in 2017 was 268 million tonnes, of which 67.18 million tonnes were recycled, 27 million tonnes were composted, 34 million tonnes were used for energy and 140 million tonnes were landfilled (Environmental Protection Agency (US EPA), 2020). Metals comprised about a third of the MSW generated. For every 1000 tonnes of materials recycled in the US, there are 1.57 jobs created (US EPA, 2016). When considering CDW, concrete contributes nearly 70% of the waste, asphalt concrete 15%, wood 7%, and all other types comprise the remaining 8% (US EPA, 2020). It is estimated that 10–15% of waste is produced during construction, with the remaining 85–90% produced at end of life (Keena and Dyson, 2020).

Aligned with the principles underpinning circularity, the US EPA Sustainable Materials Management Program Strategic Plan (US EPA, 2015) includes a five-year plan from 2017–22 focusing on the built environment, organics recycling and reduction in packaging. It supports lifecycle thinking, sustainable and resilient construction techniques, and monitoring and quantifying environmental and socioeconomic benefits.

However, there are no clear policies or programmatic considerations for a move to a circular economy in the building and construction sector. The LEED assessment tool considers recycling and solid waste management as part of its various credit categories, and the AIA's framework for design excellence considers resources as a key part of its agenda. While not directly addressing solutions for a circular economy, the government and various local jurisdictions do provide incentives to support circularity practices. In some cases these incentives may be financial, such as energy-efficient home credits or structural incentives including expedited permit processing for deconstruction permits, or providing bonuses for heights and increased densities for supporting sustainable and therefore circular practices for building standards in design, construction and operation (Keena and Dyson, 2020). The CALGreen programme is another good example of the recovery of CDW from building and construction projects in California (CALGreen, 2019).

The sector is still very much entrenched in linear practices and ways of operation that make it difficult to move to circular practices. Recognition that the built environment churns materials through a series of inputs and outputs is needed to ensure that various built environment stakeholders can work together towards the same goal of circularity. When considering capital cost in the built environment, circular product developments need to be considered. When considering operational costs, better design and maintenance of materials and lower energy and water use are critical. Environmental impacts need to be considered, including the impacts of emissions and waste produced by materials use, and the potential of the sharing economy needs to be more fully explored.

3.3 Oceania

The populations of both Australia and New Zealand are expected to increase in the future, with Australia's population tipped to double to 50 million by 2066 (ABS, 2019), and New Zealand's population expected to reach 7.9 million in 2068 (Stats New Zealand, 2019), representing an increase of 150% on current figures.

The Oceania region has been affected by China's Sword policy platform to no longer take waste, particularly contaminated waste. Generally, Australia's performance with waste reduction needs to improve, as does that of New Zealand (Iyer-Raniga, 2020). Key drivers of waste reduction have been landfill levies and council engagement, recognition and prioritisation of the need to reduce the amount of waste produced by households, CDW and commercial and industrial waste. However, landfill levies are not set up to cover the true cost of the environmental and social impacts of waste generation, removal and reuse. South Australia's recycling rate of 80% is very good but the government has pushed for further reductions, with aspirations for zero waste by 2050 (Government of South Australia, Office of Green Industries, 2015).

While circular economy policies exist in some states in Australia, such as South Australia, New South Wales and Victoria, these policies are in the very early stages of implementation, with the exception of South Australia. State governments are still struggling to understand what circularity means for their jurisdictions and need to engage with industries, small to medium enterprises and the community. Likewise, New Zealand is seriously thinking about what circular economy means for its economy and has set up some initiatives such as landfill levies, but these have yet to demonstrate impact (Iyer-Raniga, 2020).

There are significant opportunities to scale up the transition to a circular economy, particularly in the building and construction sector. Current crises may be used as opportunities. For example, states such as Victoria and New South Wales are dealing with the cladding crisis (flammable cladding has been causing fires), yet the industry is not considering using the discarded cladding for other purposes. Thus, more holistic conversations on circularity in the sector have yet to commence. New Zealand is also examining in detail initiatives that support zero-waste lifestyles.

Space use influences our approach to the circular economy. The impact of building design and construction clearly plays a role in the use of resources during and post construction and operation. Energy, water and waste all impact the operation of a building and good design can lead to reduced energy use, provided that occupants support expected behaviours. Smart construction such as the use of prefabrication and 3D printing; the use of durable and eco-friendly materials, including local materials; smart technologies in spaces; and the use of modular and other value engineering techniques all support good design and construction. Planning or placing the building appropriately within the site, and using approaches such as pedestrian, transit-oriented and medium- to high-density developments, all enable smart building ecosystems, particularly when supported by appropriate nature-based and transit solutions. Such developments play a critical role in the transition to a circular economy in the two countries of the Oceania region.

3.4 Gulf Cooperation Council (GCC) countries

The population of the GCC for the 2017–18 period was 56 million, representing 0.7% of the global population. Expatriates make up over half of the region's population (Worldometer 2020b). Despite being one of the most urbanised parts of the world, urbanisation is expected to continue to increase to about 90% within the next 30 years (Al-Alawi et al., 2020).

The economy of the region commenced from and has been reliant on oil and gas. However, this has started to change with the recognition that the region cannot continue to be reliant on oil alone. Therefore, investment in other sectors such as tourism, logistics, transportation and financial services is being supported such that oil and gas now comprises only 30% of the total. Of the remaining 70%, building and construction comprises 8.5% (UAE Government, 2019). Although the building and construction sector is a key source of employment, there has been a continuing decline since 2014 (Deloitte and Touche, 2019). Regardless, when considered in terms of the value of contracts awarded, construction employs the highest proportion of people compared to transport, oil, power, water, gas and chemicals. In terms of a country comparison, in 2018, the UAE was the highest in terms of value of contracts awarded, with Saudi Arabia, Qatar, Kuwait, Oman and Bahrain following in descending order (Deloitte and Touche, 2019).

In terms of consumption and production, it is not surprising that the GCC region has the highest ecological footprint, at 14.4 ha/person, compared to the global average of 1.7 ha/person (Global Footprint Network, 2020) due to the fact that almost everything is imported into the region. Many resources are under strain, but predominantly water. The construction sector in the GCC accounts for 35–40% of the total solid waste produced, most of which ends up in landfill (Bejjani et al., 2019). The region also has some of the highest energy consumption per capita rates in the world. Qatar tops the list of the highest energy use, followed by Kuwait (Al-Alawi et al., 2020). Renewable energy is currently a very small proportion of the total energy generation, but the potential remains high (Al-Alawi et al., 2020).

The GCC countries Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and the UAE all have plans to consider sustainability by 2030 (Acharya, Boyd and Finch, 2018). Of all the GCC countries,

the UAE has the most ambitious plans to design out waste and pollution, including energy and water recycling, and regulations on energy-efficient buildingsKeeping products and materials in use has yet to be fully developed in the region. Presently, single-use plastics are expected to be banned from 2021 in Abu Dhabi (Environment Agency, Abu Dhabi, 2020). In Sharjah and Ras Al-Khaimah, recycled materials are being used for the reconstruction of roads. The regeneration of natural systems is being targeted through the use of renewable energy and the phasing out of fossil fuel use (IRENA, 2019). Considering the future, the region is estimated to have a higher proportion of jobs in green economy and renewable energy by 2030. The UAE is expected to generate the highest number of jobs (IRENA, 2019), specifically in the photovoltaic industry.

The incentives being explored in the GCC region are green building regulations, waste management plans including the diversion of CDW, and domestic solid waste management through separation. The future proofing of buildings by ensuring that they are better adapted, retrofitting rather than demolishing buildings, and developing new business models in real estate such as adaptable assets, relocatable buildings, flexible spaces, performance procurement and residual value are all areas that need to be further explored. Maintaining or improving the material value, implementing performance procurement and product-as-a-service models for building and construction products, and regenerating natural systems through renewable energy are some of the policy frameworks being considered.

3.5 Asia

The Asia-Pacific region is home to over half the world's population (World Population Review, 2019). The level of urbanisation in Asia is 50% and is home to 54% of the global population (UN DESA, 2019). While the major cities experience the highest rates of increases in population, the second- and third-tier cities are expected to have the greatest growth. Inherent problems in the region resulting from urbanisation are the rise of informal settlements in urban areas, causing distress from a number of perspectives, including health and environmental impacts. Depending on the country and the urban centre, there is a booming construction industry, particularly in housing, often in the form of higher-density living, mainly in the major metropolitan areas.

In terms of resource use, most construction is expected to follow the trends of the developed regions of the world in the use of steel, glass and concrete. By 2050, the Asia-Pacific region is expected to be using up to 80 billion tonnes of materials (Niazi, Singh and Sen, 2020) per annum. Not only the use of materials, but also rates of consumption by an increasingly wealthy middle class are also expected to rise. This, of course, will also lead to attendant increases in the use of resources, raising questions around resource efficiency and environmental impacts. As construction outputs grow, they also affect jobs as the construction sector has the highest levels of employment in a growing economy.

In terms of circular policies, there are some positive developments in some countries in the region. Japan and South Korea have focused on recycling and China has its own circular economy policy. Laos is exploring a circular economy policy and India has prepared a draft policy on resource efficiency. Opportunities exist to explore circularity at all stages of construction, very similar to the opportunities in LAC and Africa. Examples of greater resource efficiency in material use, such as that observed in China by improved rates of recycling, the reuse of building materials following the earthquake in Nepal, and the use of fly-ash as materials in the construction industry in India, have the potential to become mainstream (Niazi, Singh and Sen, 2020).

It is possible to scale up and mainstream construction debris through recovery and re-manufacture in commercial, industrial, residential and infrastructure settings. There is also potential for collection and reuse via the informal sector, which supports the creation of jobs. The use of biomass and regenerative materials as well as renewable energy technology needs to be encouraged in the region. The increased use of IT can support digitisation in the industry, in turn supporting zero waste or less waste, improving productivity and reducing the need to undertake rework. Combining indigenous practices with modern technology can also enable culturally appropriate responses while increasing the life of buildings and reducing the operational resources used. There are also opportunities to improve the sharing economy through sharing spaces, be they residential or commercial.

3.6 Africa

Africa has some of the world's fastest-growing populations and rates of urbanisation globally. In the absence of proper planning and government support, cities in many areas are struggling to keep pace with this growth. This has resulted in the growth of informal settlements with no or limited access to basic services such as electricity, water, sanitation and solid waste collection. In 2019, about 1.25 billion (about 17%) of the global population was from Africa. Africa comprises countries with very large populations, such as Nigeria with over 200 million, as well as countries with less than 15 million, such as Rwanda (World Population Review, 2019). The median age of the Africa-wide population is very young, at less than 30 years, which brings its own challenges in relation to education, employment and social factors.

Urbanisation is on the rise in Africa, leading to large informal settlements that are struggling to cope with the high densities of people residing within them. In the years leading to 2018, the annual growth rate in Uganda was 5.7%, in Nigeria 4.3% and in South Africa 2% (World Bank, 2018), leading to some countries, such as Nigeria, having more than half their population living in urban areas, while countries like Uganda remain 83% rural.

Per-capita carbon emissions in metric tonnes are some of the lowest in the world in the African region. According to the World Bank (2018), a country like Malawi produces emissions of 0.75 compared to 8.98 for a wealthier country like South Africa, which is comparable to countries in the European Union (EU) such as Finland, with 8.66. To complete this picture, a country like the US has much higher emissions, at 16.49 metric tonnes per capita (World Bank, 2018).

Municipal solid waste across the African continent has been estimated at 125 million tonnes a year in 2012, providing an average of 0.78 kg per capita per day, significantly lower than the global average of 1.2 kg per capita per day (UNEP, 2018), but the volume of this waste is expected to double by 2025 due to rapid urbanisation and population increases. Not all solid waste is collected or disposed of in an organised manner. The levels of CDW have been generally on the increase and such waste is estimated to constitute about 20% of all solid waste, yet only about 16% of this CDW is recycled (Department of Environmental Affairs, 2012). Opportunities abound for improved waste management or reduction as waste is not always directed to landfill or recycled. Rates of collection are expected to increase to 69% by 2025 (UNEP, 2018). The value of municipal solid waste in 2018 was estimated to be about USD8 billion, with 96% of this lost through waste disposal (UNEP, 2018). The informal sector plays a role in recycling and using this as an opportunity to build and support recycling practices will also create jobs while keeping materials in the system.

Design guidelines, standards and legislation all support the transition to a circular economy. For instance, fly-ash and slag – by-products of industrial waste – offer significant recycling potential in the building and construction industry. Locally sourced building materials not only support

lower embodied energy, but also increase rates of recyclability and reuse, and local jobs. In addition, significant cost savings for business and municipalities can arise by supporting the informal economy. For instance, in Lusaka, Zambia, the net cost of informal waste collection is USD1.60 per tonne, compared to USD10.40 per tonne for formal collections (Aparcana, 2017). Another opportunity worth pursuing are waste microgrids, which enable waste to be reduced, separated and treated before being disposed of or brought back into the system. Increased urbanisation also provides opportunities for organic bio-waste (Gibberd, 2020) as higher numbers of people contribute to more waste generation.

Diverse and resilient indigenous construction practices offer opportunities for local job creation, and to maintain heritage practices and use local materials that produce little or no waste. The large informal sector that exists throughout Africa supports jobs in recycling, and the use of local materials, thereby supporting a circular economy. With the support of local procurement practices, it is possible for local manufacturing processes to flourish. Complemented by education and training, local know-how can be used to replace imported materials (which are more expensive and need specialist skills) with local materials, support local jobs and maintain local technology. The current lack of maintenance impacts the life span of buildings and reduces performance. Good building design with high-quality materials and a recognised professional group supporting maintenance such as facility or building management are essential for a future based on circular economy.

3.7 Latin America and the Caribbean (LAC)

The population of the LAC region is expected to continue to grow until 2059 (Economic Commission for Latin America and the Caribbean [ECLAC], 2016). Currently, the population is about 650 million, representing about 8.5% of the world's population (Worldometer, 2019). The largest countries – by territory, economy and population – are Brazil, Mexico, Colombia, Argentina and Peru. It is noteworthy that only Cuba will decline in population by 2025, while all other countries in the LAC region are expected to keep growing population-wise to 2059 (ECLAC, 2016).

Every person in Latin America generates an average of 1 kilogram per day of waste. The entire LAC region generates more than 540,000 tonnes of waste per day, which represents about 10% of the world's total. One-third ends up in open dumps and only 10% is reused or recycled (ONU Ambiente, 2018). Countries with high GDP produce more waste. Although waste collection can reach 90% in certain countries, only 10% of waste is recycled or recovered. Waste has a negative environmental impact, and more than 50% of the waste generated is organic and can be used for composting and recovering energy. The environmental impact, and the costs in terms of health and development in general, can be 5 to 10 times greater than the appropriate waste management would generate (Moreno, 2020).

In most of the cities of the LAC region, the municipality collects waste without separation. Only 19.8% of all municipalities have plans for solid waste management (BID, 2015). CDW are not separated at the source. The solid waste collection practices in the LAC countries vary and need to be further developed alongside incentives for supporting circular practices. The reuse of second-hand materials is rarely encouraged. The informal economy supports recycled waste collection, but CDW collection in the informal economy is minimal due to the high volume of waste production. However, windows, doors, metal pipes and copper wires, among other materials, are collected to be sold by weight to private collection centres.

Opportunities in manufacturing include awareness and skill development around reuse and remanufacturing prospects. In terms of lifecycle operational considerations, the use of renewable energy and water and long-term thinking need to be inculcated among all stakeholders involved.

The LAC region has a long way to go regarding waste reduction and circular practices. Cultural and geographical differences in LAC make it necessary for governments to seek creative solutions tailored to their country's needs. Educational campaigns about no-waste generation are absent from the media, so there is no public awareness. Only recycling and repurposing (for instance, plastic bottles or wood pallets) are reported in the mass media. Education and capacity-building about producing zero waste are thus needed. In addition, raising awareness and training of construction workers in the efficient use of construction materials, selective deconstruction and waste separation in situ, and the reuse of CDW is needed. All this requires concerted efforts across all sectors of the government, community and industry.

4. Regional considerations and priorities

As outlined in section 2, the SDGs were mapped against the principles underpinning circular economy. Discussions with regional authors assisted in identifying a core sample of primary and secondary SDGs indicators that became the basis for a global survey. This survey was undertaken in two parts. The first part focused on prioritising the SDGs and the second part on the primary indicators essential for circular transitions at global and regional levels. Based on our survey of 100 responses from all regions, 12 SDGs out of 17 seem to have high importance on circularity, in the following order of priority:

- SDG 12 *Ensure sustainable consumption and production patterns*
- SDG 11 *Make cities and human settlements inclusive, safe, resilient and sustainable*
- SDG 13 *Take urgent action to combat climate change and its impacts*
- SDG 9 *Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation*
- SDG 7 *Ensure access to affordable, reliable, sustainable and modern energy for all*
- SDG 8 *Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all*
- SDG 6 *Ensure availability and sustainable management of water and sanitation for all*
- SDG 17 *Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development*
- SDG 3 *Ensure healthy lives and promote well-being for all at all ages*
- SDG 15 *Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably managed forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss*
- SDG 4 *Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all*
- SDG 1 *End poverty in all its forms everywhere*

The next step was choosing the indicators. The pool of indicators selected to be surveyed was undertaken using an inclusive approach, with a set of 59 indicators directly or indirectly impacting circularity in the built environment. Primary indicators are core to the circular economy in the built environment while secondary indicators are considered to be important. For the SBC programme, from these 59 indicators, the global survey of 100 expert responses worldwide provided a clear set of 14 indicators. Of these 14 indicators, 4 were primary (making the top 25 of responses) and 10 secondary (making over 50% of responses). Percentage of occurrences determined the ranking and the split into primary and secondary indicators. The primary indicators are 12.2.1/8.4.1 (same indicator), 12.5.1 and target 11.c.1. These indicators are expressed as key performance indicators (KPI) of the SBC programme. SDG indicator 12.2.1/8.4.1 focuses on material footprint, 12.5 on material recycling and 11.c.1 on local materials. A better indicator is still sought for the latter in the annual refinement and comprehensive review process.

More than half the survey respondents judged ten indicators to be important in circular built environment assessment. Secondary indicators are 9.4.1, 11.6.1, 7.2.1, 6.3.1, 6.4.1, 7.1.2, 13.2.1, 12.7.1, 11.1.1 and 12.a.1 (from the highest occurrence of an indicator at 66% to the lowest at 51%). These indicators and their respective targets are now listed in a chronological order for ease:

- 6.3.1 Proportion of domestic and industrial wastewater flows safely treated relating with target 6.3 *By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally*
- 6.4.1 *Change in water-use efficiency over time* corresponding to target 6.4 *By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity*
- 7.1.2 *Proportion of population with primary reliance on clean fuels and technology* corresponding to target 7.1 *By 2030, ensure universal access to affordable, reliable and modern energy services*
- 7.2.1 *Renewable energy share in the total final energy consumption* corresponding to target 7.2 *By 2030, increase substantially the share of renewable energy in the global energy mix*
- 9.4.1 *CO_2 emission per unit of value added* corresponding to target 9.4 *By 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes, with all countries taking action in accordance with their respective capabilities*
- 11.1.1 *Proportion of urban population living in slums, informal settlements or inadequate housing* corresponding to target 11.1 *By 2030, ensure access for all to adequate, safe and affordable housing and basic services and upgrade slums*
- 11.6.1 *Proportion of municipal solid waste collected and managed in controlled facilities out of total municipal waste generated, by cities* corresponding to target 11.6 *By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management*
- 12.7.1 *Degree of sustainable public procurement policies and action plan implementation* corresponding to target 12.7 *Promote public procurement practices that are sustainable, in accordance with national policies and priorities*
- 12.a.1 *Amount of support to developing countries on research and development for sustainable consumption and production and environmentally sound technologies* corresponding to target 12.a *Support developing countries to strengthen their scientific and technological capacity to move towards more sustainable patterns of consumption and production*
- 13.2.1 *Number of countries with nationally determined contributions, long-term strategies, national adaptation plans, strategies as reported in adaptation communications and national communications* corresponding to target 13.2 *Integrate climate change measures into national policies, strategies and planning.*

Section 4.1 outlines the SDGs relevant to circularity in the built environment for each of the regions as primary or core indicators. The selected SDGs for the regions are presented in Figure 5.

In addition to the SDGs, the lifecycles of buildings need to be studied. The lifecycles are considered from the perspectives of capital and operational cost, green business opportunities, new jobs and skills required to transition to and work in a circular economy. This is presented in section 4.2.

4.1 Mapping the regions against SDG indicators

The regional priorities for a circular economy in the built environment mapped against the SDGs are presented below for Europe, North America, Oceania, GCC, Asia, Africa and LAC (see Figure 5). As explained, the global survey received 100 responses from experts internationally, resulting in the indicators associated with SDG 8 and SDG 12 as the top ten priority in all seven regions. While each of the regions (except Europe) have not received sufficient responses at a regional level to definitively determine the priority indicators, nevertheless, it does provide a starting point indicating opinions on priorities for the region. It is anticipated that these will be developed further through workshops with experts in each region.

Among the primary indicators for the circular built environment in Europe, SDGs 6, 7, 8, 9, 11, 12 and 13 have been selected. Indicators 8.4.1 and 12.2.1 are about material footprint which is a common thread across all the regions as stated earlier. Indicator 6.3.1 focuses on water treatment and use while indicator 7.2.1 is about the use of renewable energy and linked with indicator 9.4.1 regarding CO_2 emissions. Europe also has concerns about its housing as indicated by 11.1.1 and waste collection as indicated by 11.6.1. While the indicator for 11.c.1 has yet to be developed, the target is about providing technical and financial assistance to least developed countries that Europe is in a clear position to provide. Given Europe's history with circular economy, the region is also well placed to measure proactively, its recycling rate and tons of materials recycled making up indicator 12.5.1. It is also well placed to strategically include climate change measures into national policies, planning and strategic development – the intent of indicator 13.2.1.

When mapped against the SDGs, the situation in the US highlights that circularity in the built environment is a cross-cutting issue. The state of play in the US underscores the necessity of fostering an integrated, system-based approach in implementing a circular economy for the country. The goals, targets and associated indicators that best map to the US include SDG 4, 6, 7, 8, 9, 11, 12 and 15. Indicator 4.7.1 (and 12.8.1) are about education for sustainable development and its application across education and policy. Water and energy are linked to SDGs 6 and 7. Wastewater treatment in the domestic and industrial settings need to be considered as described by indicator 6.3.1. Indicator 7.a.1 is about financial support for facilitation and supporting developing countries to build their technical and research knowledge in renewable energy. As already stated earlier, indicator 8.4.1 (and 12.2.1) on material use is a core indicator, and this is closely linked with CO_2 emissions in upgrading infrastructure and adopting other sustainable patterns of development, stated in indicator 9.4.1. SDG 11 on making cities and human settlements resilient and sustainable has highlighted 11.6.1 focusing on municipal solid waste collection, as also 12.5.1 on national recycling rates. Target 11.c is on providing financial and technical assistance to countries in need, particularly in using local materials which the US is well placed to support, as is the case also with Europe. Indicator 15.1.2 focuses on biodiversity loss and protection of our natural habitat while indicator 15.a.1 is about mobilising financial resources to conserve and sustainably use our ecosystems.

In the Oceania region, Australia and New Zealand are facing population challenges that impact their land masses. Water is not an issue in New Zealand, but Australia has experienced (and is expected to continue experiencing) periods of drought. Indicator 6.4.1 focuses on water use efficiency to better manage water use in the built environment in Australia. While New Zealand's primary and secondary energy use has relatively low environmental impact, Australia has a long way to go in ensuring the use of clean fuels and technology, which is the focus of SDG 7. SDG 7 on the use of modern and reliable energy is highlighted through the core indicator 7.1.2 on clean energy use and 7.2.1 on renewable energy use and 7.3.1 on energy intensity measured in terms of primary energy and GDP. This also links to indicators 9.4.1 on CO_2 emissions per unit of value. Both Australia and New Zealand need to consider their environmental footprints,

supporting efficient consumption and production patterns while creating jobs. This would address SDGs 8 and 12. There is an urgent need to better manage material footprints as highlighted by indicator 8.4.1 and 12.2.1, and 12.5.1 focusing on recycling rates in tons. SDG 11 focuses on making cities and human settlements inclusive, safe, resilient and sustainable. Indicator 11.6.1 focuses on municipal solid waste and target 11.c focuses on providing financial and technical assistance particularly geared to the Pacific Islands.

The GCC is a highly urbanised region and almost all products and materials are procured elsewhere from other regions. SDGs 4, 7, 8, 11, 12, 13 and 17 have been identified as the core indicators for the GCC countries considered. Indicators 4.7.1 and 13.3.1 focus on inclusive and equitable quality education with lifelong learning opportunities for all. This is an essential factor impacting the knowledge for setting a future trajectory on low carbon transitions, not just for the built environment but also other sectors. Due to the desert climate and its historical association with fossil fuels a deliberate move to reliable, sustainable and modern energy for all, embodied in indicator 7.2.1 needs attention and the installation of renewable energy generating capacity is outlined in indicator 7.b.1. Thus, changes to design and construction is critical. The use of local materials is promoted through target 11.c, linked to sustainable buildings and construction. Promoting a sustained, inclusive and economic growth for the GCC and the expat population that makes up the bulk of labour in the country offers win-win opportunities for all. The expat population in turn, support economic growth in their own countries through remittances. Such efforts of productive employment while decoupling economic growth from environmental degradation embodies the intent of SDG 8, and indicator 8.4.1 (and 12.2.1) notes the importance of decoupling material footprints in an environmentally benign manner. SDG 12 on sustainable consumption and production patterns draws attention to the current material footprint of the region, which is clearly unsustainable, and emphasises the need to develop more sustainable patterns in the built environment that also support better patterns for daily existence measured through national recycling rates and tones of materials recycled as per indicator 12.5.1. Climate change underpinning SDG 13, is also impacting the region that in turn, has significant comfort, health and well-being issues bringing the focus on integrating climate change measures through indicator 13.2.1. Indicator 17.18.1 focuses on statistical indicators for sustainable development monitoring critical to move away from current linear ways of operation to developing.

The building and construction sector is a major employer in the Asian region, yet employment in this sector is characterised by significant informality. Thus, there is tremendous opportunity to reskill current professionals, decision-makers and workers, leading to opportunities to formalising the informal sector and create new businesses in recycling, refurbishment and repair services. Like Africa, the Asian region is concerned about the treatment of domestic and industrial wastewater, the focus of indicator 6.3.1. The footprints associated with production and consumption patterns is linked to indicator 8.4.1 (and also indicator 12.2.1). The building and construction sector is the largest consumer of mineral resources and energy, and a pressure point in the urban areas of Asia is housing, as measured through indicator 11.1.1 and appropriate planning of cities with access to open spaces, including people with disabilities, determined by indicator 11.7.1. Target 11.c is about supporting a large proportion of the Asian countries through financial and technical assistance particularly supporting the use of local materials. The shift to patterns of production and consumption in countries is supported by indicator 12.1.1. The importance of recycling is expressed in indicator 12.5.1 and procurement policies with proactive actions are embedded in indicator 12.7.1. Indicator 13.2.1 deals with the long-term strategies associated with national determined contributions and national adaptation plans for climate change.

The ten primary indicators selected for the African region cut across a number of the SDGs, including 6, 7, 8, 11, 12 and 13. Many African countries are not highly industrialised so there is

the opportunity to avoid mistakes made by other countries and develop cleaner, lower-waste industries that create local jobs, aligned with SDGs 6, 7 and 8 on the use of water, energy and creating gainful employment. Indicators 6.3.1 refer to safe treatment of water. Indicator 7.2.1 is about the use of renewable energy in final energy consumption and 7.3.1 is about energy intensity. Indicator 8.4.1 (and 12.2.1) is about material footprint, material footprint per capita, and material footprint per GDP. In addition to the mentioned indicators, there is a need to develop extensive additional infrastructure in the form of new roads, services, housing and social infrastructure to address rapid urbanisation, linking to SDGs 11, 12 and 13. Indicator 11.1.1 is about urban population living in slums and informal settlements, and signals a commonality across the developing regions. 11.6.1 is about the proportion of urban solid waste collected and discharged and works well alongside target 11.c focusing on providing financial support to the construction and retrofitting of sustainable, resilient and resource efficient buildings using local materials. The intent of these indicators are well aligned with indicator 12.5.1 on recovery and recycling rates. Indicator 13.2.1 is about the number of countries that have established or operationalised an integrated policy/strategy/plan for adapting to the adverse impacts of climate change and fostering climate resilience while reducing environmental impact, so as to enable food production.

The future of the LAC region is threatened by urbanisation, with increased population putting pressure on services on affordable, reliable and sustainable energy use. Like all the other regions, indicator 8.4.1 (and indicator 12.2.1) on reducing our material footprint is a core indicator for circular built environment. This links closely with indicator 9.4.1 on the CO_2 emissions per unit of value added for retrofitting and upgrading or building new infrastructure. SDG 11 is about making cities and human settlements safe, inclusive, resilient and sustainable. Indicator 11.1.1 focuses on housing for the same reason this indicator comes up as a core indicator for the African and Asian regions as well. Indicator 11.6.1 is associated with solid waste collection and 11.b.1 is about adopting and integrating national disaster risk reduction strategies due to increasing focus on disasters in the region. Not surprisingly, technical and financial assistance focusing on target 11.c is also part of the core indicators for circularity in this region. Linked to these indicators are skills and education for developing and implementing sustainable lifestyles focusing on consumption and production patterns – indicator 12.8.1.

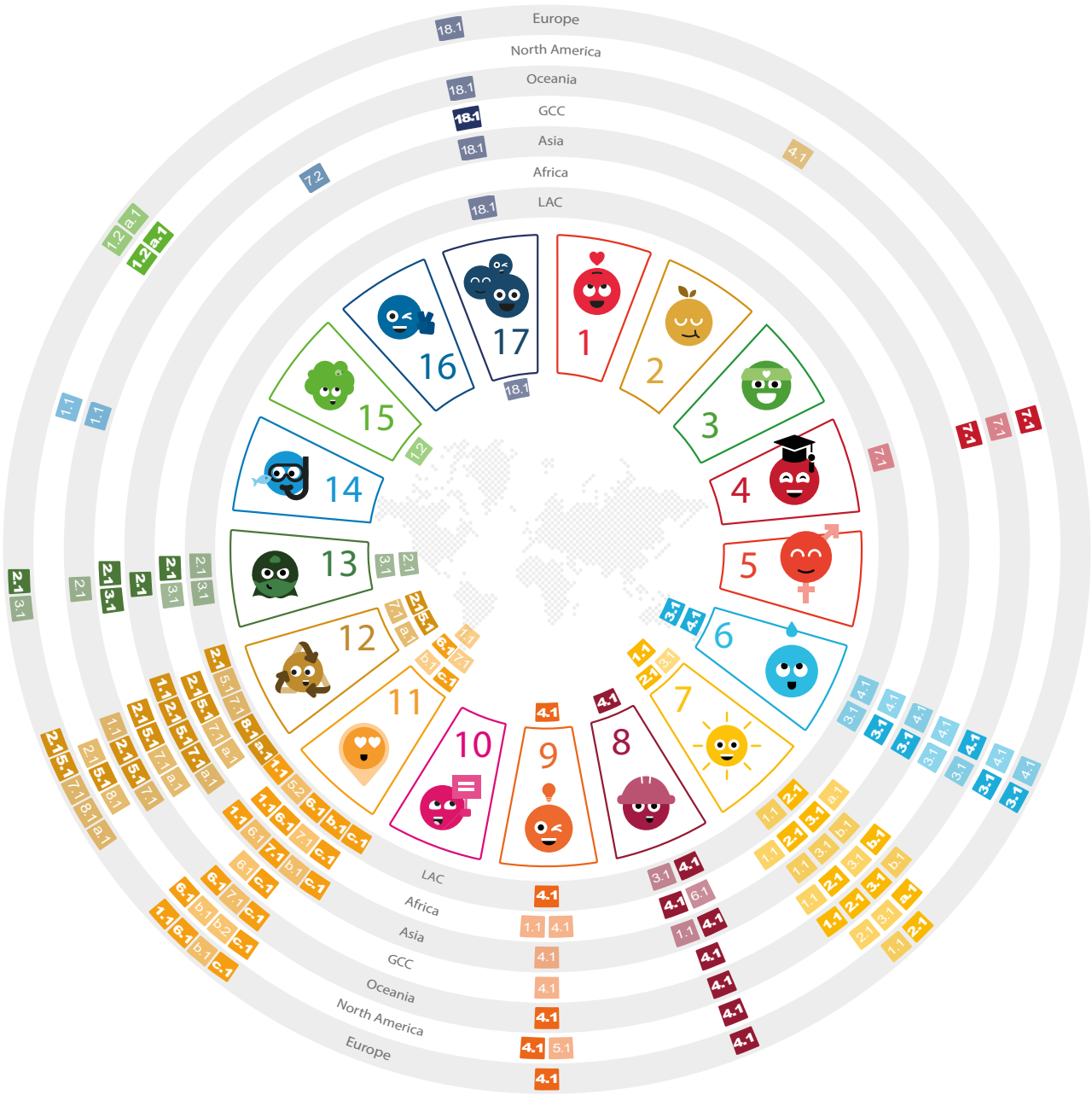

Figure 5: Primary and secondary SDG indicators mapped for circular built environments across various regions

NOTE: Core indicators are denoted by darker colour and bold text

Source: Authors
Graphics: Ashley King & Ninni Westerholm

4.2 Lifecycle considerations in the built environment

Buildings usually last for 80 to 100 years, or more. Therefore, whether it is conversion of existing building stock or planning new buildings, the lifecycles of buildings must be considered as a priority. The regional reports have shown that, with rising populations and urbanisation, the African, Asian and LAC regions are going to see a phenomenal increase in the number of greenfields developments. These need to be considered carefully.

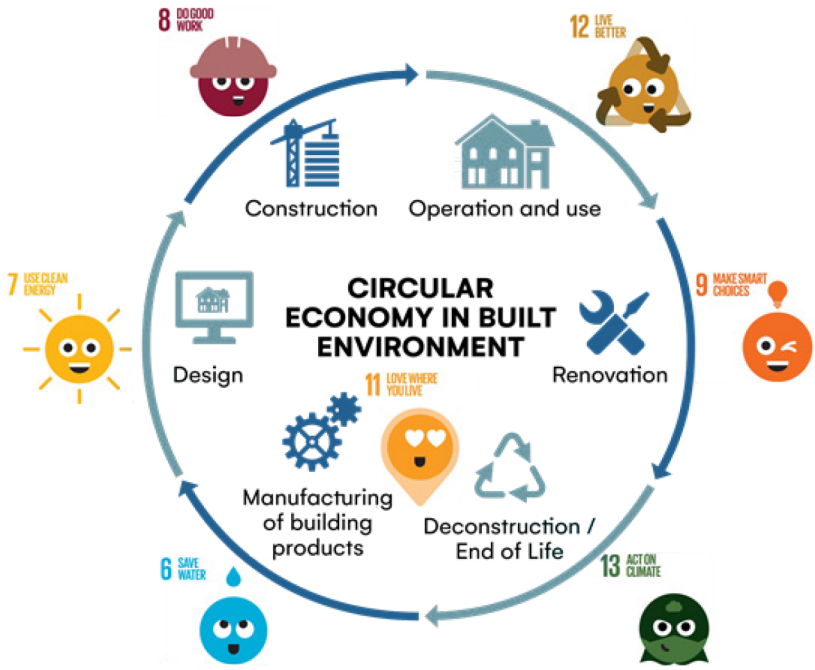

Figure 6: Circular lifecycle of buildings

Source: Adapted from Ministry of Environment, Finland

Greenfields allocated for farming, market gardens, agriculture and green spaces supporting biodiversity are being sacrificed for raw material extraction and new infrastructure, housing or other built environment amenities. At the same time, the already large, highly populated cities in these regions are being confronted with increased urbanisation, putting pressure on basic services such as electricity, water supply and sanitation, while also creating tensions related to people movement such as transport and the infrastructure associated with this movement. In the quest to find work, most of the migrated populations end up working in the informal housing sector. Thus, the cities in these regions need to be well planned and some pockets may need redesign and rebuilding, while other areas, particularly in the city outskirts, may require a focus on greenfield developments.

In the European, North American and Oceania regions, increased urbanised populations will bring similar tensions. As the built environment is already mature in these regions, the focus here will be more on sustainable redesign, rebuild and more efficient use of existing spaces with increased densities, as well as on using materials in their second life where possible. Material use will continue. This material use needs rethinking and replanning so that virgin material use is arrested if not eliminated. This will call for closing local feedback loops wherever possible. Figure 6 shows the typical lifecycle phase of a building from a circular perspective so as to move away from the current linear practices of procurement, construction and operation.

Table 1 provides a detailed insight into the various lifecycle considerations from the perspective of capital and operational costs, green business opportunities, new jobs and skills required.

Table 1: Lifecycle considerations of buildings in various regions

Source: Authors and regional authors
Graphics: Ninni Westerholm

CAPITAL COSTS

PHASE	MANUFACTURE	DESIGN	CONSTRUCTION	OPERATION AND USE	RENOVATION	DECONSTRUCTION / END OF LIFE
AFRICA	Most building materials and products are imported. Local potential need to be tapped including local enterprise and jobs.	Traditional practices still exist. The best of indigenous and modern may be combined to support local materials and support bio-climatic/passive designs.	The volume of construction waste is quite high due to unskilled labour and poor practices. New bio-based materials combined with prefabrication technology will produce lower carbon emissions and support local economies.	Maintenance is an issue highlighting the need to repair and rebuild. A culture of maintenance will support maintenance standards, including setting up and recognising the role of facility managers as professionals.	Building assemblies need to become more modular, so that they are easy to repair and reuse. New enterprises may be set up to support the use of modular repair and reconstruction, supported by capacity-building.	Opportunities can be tapped to consider end of life, recycling and upcycling so that materials may remain in the system and not be sent to landfill.
ASIA	Almost always virgin materials are mined and used in Asia. Resources from industrial wastes and by-products offer untapped opportunities for manufacture.	Currently, green design practices are not mainstreamed. They need wider market engagement and acceptance. Higher value for green design needs to become the norm.	Construction does not consider the reduced use of expensive resources. Opportunities for tax and interest incentives for green construction need to be pursued.	In general, lifecycle thinking is not widely practised. The focus is usually on the capital costs; thus, operational costs are not considered. There are clear opportunities to consider the true costs of resource use during operation.	Renovations are not considered during the building and construction process. Modular construction makes it easier to renovate and repair.	The value of the materials used is not considered during the building process. Such materials may be used as building elements in a new building.
EUROPE	Manufacturing from a capital cost perspective needs to support the cost benefits of using waste and by-products. Circular product development needs to be mainstreamed.	Lifecycle approaches need to be considered more to encourage better designs.	Economic benefits of circular building products from a construction perspective need to be explored fully.	Lifecycle cost savings provide increased value over the life of the building. This needs upfront recognition in the manufacturing process.	Reusability and replaceability of building products and systems can support a growing renovations sector.	Opportunities for end of life need to be understood in terms of the value of recovered building products and upcycling should be investigated.
GCC	Importing materials into the GCC is common due to lack of resources and the hot and dry climate. Local material use needs to be explored.	Green design practices need to be mainstreamed despite the existence of green building codes and guidelines. Clear business case needs development to ensure widespread adoption.	Construction models are linear with very little consideration of end of life, including the use of materials. Some punitive measures may need to be considered to ensure virgin material use is reduced.	Lifecycle thinking is not reflected in building practices. Greater focus is on the capital cost. Clear opportunities exist in considering the operational phase and end of life.	Modular construction needs to be encouraged. Supported by capacity building in the repair and reuse sectors, new enterprises may be developed.	Inherent value of building materials are not considered which locks-in singular use and linear economy. Alternatives needs to be explored.
LAC	Currently, products and by-products are generally thrown away. No recovery is undertaken or even planned for in most cases. A circular built environment needs rethinking away from these linear models.	The importance of design in green building and design is being recognised. Added value in new technologies such as solar or reuse of water is now being supported.	Current construction processes do not support reuse or repurpose. Education, awareness-raising and capacity-building across all sectors of the building and construction industry are urgently required.	Currently, lifecycle thinking is not properly understood. Value is not well understood and is confused with cost. To reduce capital cost, quality is usually compromised.	Currently, there is only a very small market for second-hand renovation products. This can be tapped further to improve understanding and increase the use/reuse of products for renovations.	The end of life value of materials is not well understood. Only certain types of materials are currently reused such as iron/iron products.
NORTH AMERICA	Mainstreaming opportunities for the cost benefits of using waste and by-products need to be tapped. Circular product development needs to be pursued.	Considerations for lifecycle design needs to be incorporated. A higher value is associated with USGBC LEED certified buildings.	Productivity and economic benefits of circular building materials and activities in the construction process need to be fully explored.	Lifecycle cost savings need to be understood. Design and construction need to consider full lifecycles.	Reusability and replaceability of building products and systems need to be fully explored and studied for the renovations sector.	The value of recovered building products needs to be understood at the end of life of a building. Upcycling materials or those that can retain value need to be identified and piloted where possible.
OCEANIA	Options for trial and experimentation (R&D) need to be pursued, the cost benefits of using waste and by-products need to be understood and studied, circular product development needs exploration, including, where possible, cross-sectoral engagement.	Design and lifecycle thinking need to be considered for product stewardship and holistic thinking is needed.	Government policy and regulation for a circular economy need to be supported by resource use. The economic benefits of circular building products need to be fully explored.	Lifecycle cost savings need to be considered at the outset and become the norm; increased value of full lifecycles also needs to be understood. With the support of behaviour change programmes, operational resource use may be reduced even more.	The renovations market needs better understanding of reusability and replaceability of building products and systems and flexible planning for the long term. Regulatory support, where appropriate, for the use of recycled/reused products will drive the market away from virgin construction materials.	End of life considerations require appropriate planning. The value of recovered building products needs to be understood so that upcycling or reuse becomes the norm.

OPERATIONAL COSTS

OPERATIONAL COSTS

PHASE	MANUFACTURE	DESIGN	CONSTRUCTION	OPERATION AND USE	RENOVATION	DECONSTRUCTION / END OF LIFE	PHASE
AFRICA	Buildings made from local materials and the use of passive or bio-climatic design reduces the dependence on energy and other utilities so that high operating costs may be avoided.	Promoting the use of passive design, renewable energy, water harvesting, local materials, and longer material lifecycles supports better design and ongoing operation.	Good-quality construction and higher performance standards are required. The lack of investment in maintenance needs to be changed. Upskilling contractors in maintenance will provide jobs.	Buildings need to be better maintained. Improving the stock of buildings will enable a longer shelf life of buildings, reducing wastage.	Renovation of the existing stock is not currently considered, leading to a waste of building materials. Improved capacity for management of waste can lead to creative solutions.	Buildings are demolished rather than deconstructed. Lack of maintenance and high operational costs cause owners to bring down the buildings rather than consider reuse. Better design and better maintenance can prolong building life and ensure that materials are reused at end of life.	AFRICA
ASIA	Materials are not necessarily manufactured locally and local skills are not always used for local manufacture. There are untapped opportunities in the manufacturing process for water and heat recovery.	Operational considerations and initial design need to be considered hand in hand. Passive design, renewable energy, water harvesting and design for durability should be considered upfront.	Promoting the use of modular elements in construction will reduce waste, support improved quality and timelines for construction, and reduce overall maintenance.	Operational costs are almost never considered at the design and construction phase. If considered, options to lower energy and other utility expenses will lead to a better return on investments.	The renovation of existing buildings, if properly undertaken, will support cheaper and easier renovation of assembly-based elements and a second-hand market will support access to used building materials.	If materials are modular, it will be easy to deconstruct and use them again. There will be little waste, it will be cheaper in the long run and buildings can be deconstructed and the materials reused again and again.	ASIA
EUROPE	The running costs for manufacturing need to account for the service life of buildings and their equipment.	Operational costs considerations for design for multi-use spaces are needed. Flexibility and adaptability need to be thought through at the outset.	Construction for reduced waste needs to be explored. Attendant emissions will also be reduced through this process.	Operational considerations need to focus on better maintainability. This prolongs shelf life and allows for repairs and maintenance to take place.	Renovation sector can engage with building products that use the principles of de-mountability and re-usability of building products.	The end of life of buildings needs to consider the value of recovered building products. Where possible, upcycling opportunities need to be explored.	EUROPE
GCC	Local skills are not used as materials are imported. Local skills need to be tapped. Manufacturing processes where water and heat can be recovered needs further exploration.	A holistic design approach needs to be considered. Passive design, renewable energy, water harvesting and efficiency, and design for durability should be explored at the design phase.	Modular construction provides many benefits which can be adapted to the region. Some of these are reduced waste, improvement in quality and precision, reduced project time and reduction in overall maintenance costs.	Operational costs should be considered at the design phase which will provide benefits beyond the design and construction into operation and end of life.	Affordability and ease of renovation can be supported if assembly-based materials are used with access to second hand market.	Modular buildings will support flexible use and reuse, and repurposing where required. Waste will be reduced and if designed and planned well, will be cheaper to operate in the long run.	GCC
LAC	There are opportunities for using renewable energy to condition spaces. The operation of buildings needs to incorporate optimising resources.	Good passive design supports reduced utility use. The use of renewable energy, water harvesting, design for durability and reuse all offer opportunities for optimising resources and creating circular built environments.	Construction processes are not always undertaken professionally. Cheap hand labour and an informal economy support the construction process. Skills need to be improved.	Operational considerations for the built environment offer opportunities for lower energy and other utility expenses. They support a better return on capital investments and represent better options in the current milieu.	Renovations are not always considered as part of design and operations. Usually, only new products are considered in the marketplace. Opportunities exist for extending to renovations and these need to be tapped.	End of life considerations should be part of the full design process. At present, very little construction and deconstruction waste is recovered, and there are almost no opportunities for reuse and recycling.	LAC
NORTH AMERICA	The consideration of running costs in manufacturing require full attention to the service life planning of buildings.	Design for operations may consider design for multi-use, flexibility and adaptability as per the AIA's 'Framework for Design Excellence', including measures for 'Designing for Economy' and 'Designing for Resources'.	Construction processes with operational considerations offers many opportunities. Such considerations lead to reduced waste, e.g. LEED v4.1 Waste Management credits for CDW, and the national standards programme Certification of Recycling Rates, which provides an ISO-level third-party certification of CDW – all of which improve recycling rates.	Better maintainability, design and material choices contributing to energy efficiency, i.e. lower energy and other utility expenses, and a better return on investments should be sought and adopted as the industry norm.	The renovation sector needs more exploration and further development. Options for de-mountability and reusability of building products, design for disassembly and reassembly need to be studied.	The value of recovered building products needs to be fully understood, and upcycling opportunities need more exploration.	NORTH AMERICA
OCEANIA	Service considerations need to be highlighted for operational use of buildings. Where possible, collaborations with stakeholders throughout lifecycle of buildings should be considered. The use of renewables and enhanced resource efficiency should be mainstreamed.	Designing for operational considerations may focus on the multi-use of spaces, design for flexibility and adaptability, disassembly and longer lifecycles.	Resource optimisation in the construction process will also reduce waste. Where possible, prefabrication may be used for timely construction and optimisation of waste, the use of local materials should be supported, and construction that leads to reduced maintenance should be favoured.	Existing operational assessments as provided by the National Australian Built Environment Rating Scheme should be considered. Better maintainability, longer shelf life and low operational costs should be the target at the outset during design and construction.	Currently, the renovations sector is not fully explored. Lifecycle considerations are not included in the process. Disassembly/de-mountability and reusability of building products and materials need to be examined more and the cost benefits understood.	End of life considerations are yet to be fully explored. The value of recovered building products and upcycling opportunities need further investigation, including market uptake.	OCEANIA

ENVIRONMENTAL IMPACT

PHASE	MANUFACTURE	DESIGN	CONSTRUCTION	OPERATION AND USE	RENOVATION	DEONSTRUCTION / END OF LIFE
AFRICA	Highly energy intensive and high waste processes are currently the norm in the construction industry. Access to capital and stringent standards will support the use and manufacture of less energy-intensive products and materials.	Understanding of the full lifecycle and of the impact of the materials used is currently absent. Awareness needs to permeate the industry, supported by legislation, codes and capacity-building.	There are limited regulations and construction standards, and where they exist, they are not enforced. More stringent standards and regulations supported by enforcement and education will support the alleviation of environmental impacts.	There is limited provision and understanding of recycling and associated practices. Better service models need to be explored to reduce environmental impacts in terms of energy, water and waste.	In general, buildings are not designed to be renovated, leading to damage and waste. Better building design enables renovation. The skills gap in relation to renovation needs to be addressed.	There is significant value to be unlocked in waste. Developing legislation supported by addressing the skills gap in relation to deconstruction and materials reuse are needed.
ASIA	Currently, environmental impacts are often not considered during the various lifecycle phases. Increased use of bio-based and renewable materials will reduce dependence on the current mining and manufacture of virgin materials.	Design needs to support reducing material and energy footprints, and to focus on zero emissions throughout the lifecycle.	Construction does not currently consider broader environmental impacts, including waste. With less use of virgin materials, and reuse of existing materials, less waste will be sent to landfill.	The operational phase of buildings has to be considered at the design phase. A longer life with no emissions or pollution, closed water loops and a focus on domestic nutrients recycling should support regeneration where possible.	The environmental impacts of renovations need to be considered. Keeping materials and energy flow in the system can support value chains and reduce the waste and associated emissions.	The end of life of buildings has an environmental impact, especially if it ends in landfill. The reuse of CDW reduces waste to landfill and associated emissions.
EUROPE	Consideration of environmental impacts needs to include reduced emissions and reduced or no waste.	Design considerations should focus on lifecycle assessments, design for multi-use and flexibility, and design for disassembly where appropriate.	Construction materials and techniques should focus on reducing emissions and waste.	Considerations of the environmental impacts of operations should focus on reduced emissions and waste.	The renovations market should focus on materials and techniques that result in reduced emissions and waste.	The deconstruction phase should focus on reduced emissions and waste and consider the use of materials that can be used again in second life.
GCC	Environmental impacts are not considered at all presently, given that materials are imported. Bio-based and renewable materials will reduce dependence on continuing to use natural resources.	Design considerations have not fully explored reducing material and energy footprints and focusing on zero emissions of energy, water and waste. Modular construction offers untold opportunities that have yet to be fully explored.	Construction materials should be focusing more on reducing emissions and waste across the full lifecycle. Presently, waste is considered to be something that is sent away rather than being a conscious design decision.	Regenerative design, planning and operational considerations have yet to be explored. Longer building life, with zero emissions, closed water and domestic nutrient loops offer opportunities.	Keeping materials and energy flow in the system can support value chains and reduce waste and associated emissions of buildings. Renovations market needs to be explored.	The environmental impacts of deconstruction phase need to be understood. Material use in second and third life needs further investigation.
LAC	A concerted effort is required to consider environmental impacts. Practices leading to no waste, reduced or no emissions, carbon-negative policies and programmes are all important considerations. Renewable energy sources and bio-based materials can play an important role.	Design considerations have yet to be fully understood and explored with respect to environmental impact. Skills need to be developed further. For example, zero-carbon design is not known or understood in the LAC region.	The environmental impacts of construction are not fully understood. Generally, debris is not separated in situ. Landfills are generally scarce so not all waste ends up in landfill; it ends up in the local landscape as visual pollution and pollution to air, water and land.	Alleviation of environmental impact through operation and use is yet to be mainstreamed across the region. Some technologies such as water harvesting and solar lights are currently known and used but there is a lot more that can be done.	The environmental impact of renovations is yet to be fully understood and options for renovations have yet to be explored.	The environmental impacts of end of life have not yet been studied in the region. There is no practical use for construction and deconstruction waste as no best practice or guidelines have been developed. 90% of the waste is not used and ends up in landfill or as an eyesore in the local environment.
NORTH AMERICA	Considerations of the environmental impact of manufacturing should focus on reducing emissions and waste.	Lifecycle assessment considerations for design for multi-use spaces and flexibility, design for disassembly, USGBC LEED certified buildings, net zero energy, the AIA's 'Framework for Design Excellence', and encouraging the use of bio-based materials including high-rise timber construction are all areas that have potential to be mainstreamed.	The use of construction materials and techniques that reduce emissions and waste has to be further investigated and adopted.	Operational considerations from an environmental impact perspective should cover reduced emissions and waste.	Renovation processes should also consider reduced emissions and waste to ensure that environmental impacts are minimised.	End of life considerations need to support reduced emissions and waste, including in second life.
OCEANIA	The environmental impact of emissions and waste, the use of renewable sources, the reduction of resource use, particularly of virgin materials, all need further investigation.	Understanding the environmental impact of operational considerations and services, lifecycle assessment considerations for design for multi-use and flexible designs, and design for disassembly at end of life all need more investigation.	Construction should consider materials and techniques that lead to reduced emissions and waste and low or no use of virgin materials in the process of design and construction. More work needs to be done in this area.	Reduced emissions and waste, longer life in current construction and better service models need to be fully explored.	Reduced emissions and waste considerations should drive the renovations sector. With the support of regulation and industry collaboration, the environmental impact of renovations can be reduced.	The reuse of building materials and products should also account for environmental impacts that can be minimised through reduced emissions and waste, not only in the first life but also in the second life of materials and products.

NEW BUSINESSES

NEW BUSINESSES

PHASE	MANUFACTURE	DESIGN	CONSTRUCTION	OPERATION AND USE	RENOVATION	DECONSTRUCTION / END OF LIFE	PHASE
AFRICA	A lot of imported materials are currently used. Procurement standards to improve the use of local materials are required.	Designs are generally not optimised. The use of appropriate building materials, particularly local materials, will support low-waste, low-polluting materials that can remain in the system.	Current construction practices and techniques need to be questioned. The use of circular construction methods and bio-based materials will enable new businesses to be set up.	Currently, high levels of waste are the norm. Tapping into renewables, appropriate use of materials and considering resource efficiencies can lead to new business opportunities.	Renovation knowledge is not currently part of the building and construction landscape. New business opportunities need to be tapped to identify and develop the potential of existing buildings through renovation, thereby avoiding unnecessary deconstruction.	Currently construction waste ends up in landfill. There are opportunities to tap into material reuse by rebuilding existing stock and extracting materials to be reused and resold.	AFRICA
ASIA	New businesses have plenty of opportunities. Small to medium enterprises can support material production, material aggregation and availability of secondary resources for production.	Design opportunities abound, with new innovations such as green design services and green certification and valuation. Skills in these areas need to be taught.	In the construction phase, green building businesses have a market such as in affordable housing, higher value of real estate and the provision of green construction services.	New business opportunities can be found in areas such as rental and shared ownership models for various sectors such as shared housing and other space sharing models. Local energy and water capture can support existing grids.	The renovation sector has yet to be set up in Asia. There are opportunities for repair and renovation service providers, second-hand product suppliers and the like.	End of life opportunities for new business need to be considered, such as secondary resource aggregation services and new resource streams, to ensure that materials do not end up in landfill.	ASIA
EUROPE	New business opportunities abound in a digital marketplace and for upcycling or developing new types of product from those that are in the system already, focusing on products with a second life.	Designs should consider lifecycle assessments to enable multi-use and flexibility, design for disassembly and the development of building passports for material use and reuse.	Construction should focus on circular construction practices and building passports should become the norm.	Operational considerations should focus on building passports and operating a building as a material bank for reuse in its second life.	Renovations provide options for the assessment of high-value recovery of building products, material passports and supporting reuse where possible.	The end of life should support the high-value recovery of building products and systems so that virgin materials need not be used.	EUROPE
GCC	New businesses have plenty of opportunities. Small to medium enterprises can support material production, material aggregation and availability of secondary resources for production	Design opportunities abound, with new innovations such as green design services and green certification and valuation. Skilling up in these areas needs development.	Construction should focus on circular construction practices. Track and trace materials and such types of building passports pave the way for new practices and business development opportunities.	Rental and shared ownership models offer further areas of investigation. Shared housing and other space sharing models as used in other parts of the world may be trialled. Combined with local energy and water capture, operational impacts may be reduced.	There are opportunities for repair and renovation service providers, second-hand product suppliers and the like. Such options need to be fully explored.	End of life opportunities for new business need further exploration, such as secondary resource aggregation services and new resource streams to ensure that materials do not end up in landfill.	GCC
LAC	A concerted effort is required to consider environmental impacts. Practices leading to no waste, reduced or no emissions, carbon-negative policies and programmes are all important considerations. Renewable energy sources and bio-based materials can play an important role.	Design considerations have yet to be fully understood and explored with respect to environmental impact. Skills need to be developed further. For example, zero-carbon design is not known or understood in the LAC region.	The environmental impacts of construction are not fully understood. Generally, debris is not separated in situ. Landfills are generally scarce so not all waste ends up in landfill; it ends up in the local landscape as visual pollution and pollution to air, water and land.	Alleviation of environmental impact through operation and use is yet to be mainstreamed across the region. Some technologies such as water harvesting and solar lights are currently known and used but there is a lot more that can be done.	The environmental impact of renovations is yet to be fully understood and options for renovations have yet to be explored.	The environmental impacts of end of life have not yet been studied in the region. There is no practical use for construction and deconstruction waste as no best practice or guidelines have been developed. 90% of the waste is not used and ends up in landfill or as an eyesore in the local environment.	LAC
NORTH AMERICA	Manufacturing opportunities for new businesses can take the form of a digital marketplace. Upcycling product developments also need to be further investigated.	Lifecycle assessment considerations for design for multi-use and flexibility, design for disassembly, green design services, green certification (e.g. LEED) and valuation services, including those for net zero energy, are all areas for potential design innovation.	Construction focusing on green building business, such as affordable housing, higher value of real estate, and green construction services driven by certification programs such as USGBC's LEED – offer new business opportunities.	New businesses focusing on a building's operational phase may include next-generation building systems maintenance and servicing, space sharing platforms, rental and shared ownership models.	The renovations phase needs to consider the feasibility of the high-value recovery of building products so that virgin materials are not used and may be eliminated.	The end of life should tap into the high-value recovery of building products and systems.	NORTH AMERICA
OCEANIA	Manufacturing opportunities can be supported by government. There are also other opportunities such as a digital marketplace that can be further investigated. Upcycling products and understanding secondary use and reuse need to be explored fully.	Lifecycle assessment considerations for design, focusing on multi-use and flexibility where possible, design for disassembly, tracking products and materials to understand digital supply chain maps, product stewardship, operational considerations all have impacts on design, representing potential new business opportunities in this area.	Construction businesses that focus on new skills for circular construction, tracking products and materials to understand digital supply chain maps, product stewardship and mainstreaming some techniques such as prefabrication present opportunities for new business ideas.	A building's operation and use phase may provide business opportunities in the use of renewables, material tracking, understanding supply chains, moving from ownership to service models of maintenance and fully investigating zero waste opportunities – all resulting in overall reduced emissions.	The renovations sector has yet to be fully and properly explored. Assessment (which may be undertaken using digital platforms) of the high-value recovery of building products, material tracking and product stewardship all represent new businesses opportunities.	The high-value recovery of building products and systems and new resource streams need to be investigated so that recovered products are brought back into the system rather than ending up in landfill.	OCEANIA

GREEN JOBS AND SKILLS

GREEN JOBS AND SKILLS

PHASE	MANUFACTURE	DESIGN	CONSTRUCTION	OPERATION AND USE	RENOVATION	DECONSTRUCTION / END OF LIFE
AFRICA	Currently, there is limited knowledge of circular approaches. There are opportunities to support local materials manufacture and new supply chains, including waste streams.	Planning, designing, constructing and managing for circular built environments do not exist. Education in design for a circular economy needs to be supported by regulations and codes.	Construction waste or green materials are not part of the building and construction practice. Skills in green construction and optimisation are urgently needed.	Limited understanding of circularity currently exists. Operational maintenance and repair skills represent a gap that needs immediate attention.	Current practices of renovation take waste materials to landfill. The existing stock of renovation offers opportunities across all stages of construction, operation and end of life.	Materials are not currently mined or separated during the deconstruction process. There is a skills gap in this area that needs to be addressed. Waste microgrids offer opportunities for sorting and stockpiling materials.
ASIA	There are possibilities for the development of a new production workforce that possesses new skills related to the use of bio-based and other types of green materials.	In the design realm, new jobs for certification and rating consultants, green design skills and the like should be created. Education and upskilling for these are also required.	The construction phase also requires new assembly skills and green construction skills, which will need to be taught.	The building operational and use phase requires jobs for new management skills in relation to material aggregation platforms, rental and space sharing businesses.	People who are able to carry out retrofitting and repair will be in demand in a circular built environment. The use of local materials and technologies will provide jobs to locals.	There is already an informal economy in place for recyclers and the assembly workforce. This needs to be extended to the deconstruction phase of buildings.
EUROPE	Manufacturing opportunities for green jobs and new skills need to be investigated in order to develop quality products from waste streams.	Design skills should support the quality assurance of recycled products and design for disassembly so that components can be reused many times over.	Construction skills should focus on building passports in circular construction and guidance for users to make the best and optimal use of the building as a resource.	The operational and use phase of buildings require new skills to support building passports and providing updates/options for circular maintenance in buildings.	The renovation sector can support the high-value recovery of materials, and skills need to be developed so that the materials for recovery can be identified.	The deconstruction of buildings requires skills in identifying high-value recovery in circular deconstruction so that materials may be reused.
GCC	A new production workforce may be created that possess new skills related to the use of bio-based materials and other such types of green materials.	New jobs for certification and rating consultants may be created. Green design skills need to be mainstreamed. Education and upskilling are also required.	New jobs demand upskilling and retraining/reskilling. Training in assembly and green construction needs to be developed and promoted.	New skills in repair but also in management such as in material aggregation platforms, rental and space sharing business may be studied further.	The renovation sector needs retrofitting and repair personnel. If local materials and technologies are used, there is less dependence on global supply chains and provides local jobs.	An informal economy for recyclers and an assembly workforce exists. It needs to be nurtured to the end of life of buildings.
LAC	A new production workforce that will facilitate lower costs for the built environment has yet to be explored in the region.	Training and formal education in design for a circular economy is required as this is not yet understood.	Training requirements for construction materials optimisation, zero waste and reuse of materials need to be understood. The potential green jobs that a circular built environment might offer will require training.	Lifecycle designs focusing on operations of buildings requires a skilled hand labour force for maintenance and repair. Local job opportunities in this area can be explored.	Opportunities in the renovation sector are not currently being explored. Examining what is feasible in other regions will identify potential options for the sector, and capacity-building plans for reskilling need to be put in place.	There are currently some opportunities in metal recycling. These base recyclers learn selective deconstruction and reuse of parts from buildings. This needs to be expanded across the sector.
NORTH AMERICA	Developing quality products from waste streams offers new opportunities for green jobs and skills development in this area.	The design community needs quality assurance of recycled products before they can specify these products for use in buildings. Certification and rating consultants, green design skills have a place in a circular economy.	The construction sector in the circular built environment needs green construction skills, and construction and deconstruction waste recovery certification and processing.	Retrofitting and repair artisan jobs will be needed for the operations phase of buildings in a circular built environment to ensure prolonged lifecycles.	Renovations need to focus on high-value recovery materials, which will lead to the development of new skills.	The end of life is generally not considered in current practices. Skills are needed in the high-value recovery of materials in circular deconstruction, thus creating a new market for recyclers and assembly workforce.
OCEANIA	The manufacturing sector needs to further investigate green jobs and skills. Opportunities to develop quality products from waste streams, new business innovation models and scouting new supply chains for material reuse all have to be further explored.	If there is regulatory support for the use of recycled products then the design profession can have confidence in the use of these products. This will also provide jobs in quality assurance, design for disassembly and similar entrepreneurial roles.	The construction sector needs to move quickly into a circular platform for operation, but this requires professional education. Other types of jobs and skills required will be in material tracking/product stewardship, prefabrication and digitisation.	The operations phase in the building sector facilitates jobs in material tracking, circular maintenance (new service rather than traditional ownership models) and remodelling/construction of flexible spaces. Consideration of how space is used by people is also needed; therefore, behaviour change mentors are also needed.	The renovation sector needs skills in no-waste/low-waste materials, no/low-emission materials, use of existing materials and products (high value recovery of existing products) and options for upcycling also need to be explored.	Skills in disassembly to retain value or to upcycle are needed. Also, tracking and tracing of materials to put back into supply chains are also other markets that require capacity building.

5. Conclusions

As illustrated in this report, the built environment directly affects the achievement of the UN 2030 Agenda Goals as the building and construction industry is highly resource-intensive and provides a significant number of jobs. Thus, decisions regarding the built environment sector will continue to impact global sustainability trajectories for decades. To understand this interdependence is critical as governments in the emerging economies are charting plans to build new infrastructure, house people, 'skill-up' the built environment workforce and provide jobs. The interdependence of the built environment and achievement of the SDGs can also be understood as a guide for policy-making. Governments and policy-makers interested in seriously reducing the use of materials and attendant GHG emissions should integrate the built environment into their National Adaptation Plans and Nationally Determined Contributions (NDCs).

This report has presented the global state of play for circularity in the built environment. Undertaking regional studies across each of the regions of Europe, North America, Oceania, GCC, Asia, Africa and LAC, the research presented provides a broad picture to understand the similarities and differences in circularity practices across these regions. Even though the 2030 Agenda does not mention circularity, it refers to important components of the core indicators for building circular thinking. All regions need to consider the impact of material use, whether this is through new builds or renovations. The use of virgin material needs to be reduced, if not completely eliminated. This report now outlines key recommendations to assist decision-makers and policy-makers at the regional and country levels to develop their own policies and set up programmes to support engagement in circularity practices.

5.1 Recommendations

These recommendations provide the beginning of a dialogue that supports countries to acknowledge the growth of consumption and to put in place circularity policies that endorse keeping materials within the system rather than using virgin resources that have attendant environmental impacts. The recommendations also encourage business enterprise and innovation, the creation of jobs and opportunities ensuring the social, technical and economic underpinnings of sustainability, now and into the future.

The UN SDG progress report (UN, 2019b) calls for building resilience through 'climate-proof and sustainable new construction or the retrofitting of existing buildings. Changing consumption and production patterns is critical, although differences in this regard will exist between developed and developing countries' (p. 37). In emerging economies, the biggest need is for new construction to meet the needs of rapid urbanisation; whereas in the industrialised countries the main challenges relate to retrofitting the existing stock.

In greenfield developments in the emerging economies, there is a need to immediately begin lowering the environmental impact through industry's practices to the built environment. Rather than relying on the design and construction trajectories of the developed world, where cement, glass, steel and aluminium have predominantly been used to date and where climate-responsive designs are not the norm, leading to little variety in the designs themselves, there are opportunities to support indigenous design and local construction materials and technologies, described further in 5.1.7.

There are opportunities in brownfield or greyfield developments and renovations to revive economies and neighbourhoods by considering what has already been developed through brownfield and greyfield sites. Such areas need further refurbishment to align them with current standards and needs. Therefore, alternative approaches will support:

- Developments that are currently lying derelict or unused are spaces that can be easily converted to current needs and use. This approach is better than destroying land that may compromise biodiversity.
- Types of refurbishments and renovations that also offer future-proofing opportunities.
- Jobs that are created during the renovation process will continue through the building management process. If the space is commercial, commercial businesses provide jobs.
- Innovation in sharing spaces, which also regenerates the economy.

Further recommendations are provided below.

5.1.1 Linear to circular

The regions considered in this report are in various stages of development in relation to a circular economy. Europe is the most advanced, having had a good head start compared to the other regions for over a decade. The increasing urbanisation and population growth in Asia, Africa and Latin America call for circular thinking to permeate all policies and programmes. Education across the board will play a big role in this process.

- Governments need to seriously consider options for changing the status quo. They need to encourage circular thinking by changing the current rhetoric and investigating and supporting incentives for circularity where possible.
- Industry needs to reconsider practices and introduce more innovativeness into its supply chains. It also needs skilling or reskilling where appropriate. All stakeholders in the supply chain need to move away from the current linear thinking to embrace circular thinking. This will take time and require effort.
- Clients and consumers also need to move away from current linear cycles and start accepting circular practices as the norm.

5.1.2 Monitoring and reporting

Ultimately, the principles underpinning circularity are the same as those of sustainability. The goals, targets and indicators set in the 2030 Agenda for Sustainable Development are a good starting point for achieving circularity in the built environment. While some of the indicators are specific to the year 2020, nevertheless, they provide a good measure for monitoring and reporting progress. As the SDGs also support other UN-related programmes such as the NDCs, alignment where possible supports efforts towards achieving social, economic and environmental sustainability.

Based on our survey of 100 responses from all regions, 12 SDGs out of 17 were selected by the respondents. In the order of priority, these are:

- SDG 12 on sustainable consumption and production
- SDG 11 on resilient and sustainable cities
- SDG 13 on climate change
- SDG 9 on sustainable industrialization
- SDG 7 on access to energy
- SDG 8 on economic growth and productive employment

- SDG 6 on water and sanitation
- SDG 17 on global partnerships
- SDG 3 on health and well-being
- SDG 15 on halting biodiversity loss
- SDG 4 on education
- SDG 1 on ending poverty.

At the indicator level, three indicators addressing four SDG targets scored highest with over three fourth of the respondents representing the key performance indicators for circular built environments. These are:

- 12.2.1/8.4.1: Material footprint (same indicators under two different SDGs)
- 12.5.1: Material recycling
- 11.c.1: Local materials (a better indicator is still sought for the latter in the annual refinement and comprehensive review process).

More than half the survey respondents judged a further ten indicators to be important in circular built environment assessment. These indicators are listed in a chronological order:

- 6.3.1 *Proportion of domestic and industrial wastewater flows safely treated*
- 6.4.1 *Change in water-use efficiency over time*
- 7.1.2 *Proportion of population with primary reliance on clean fuels and technology*
- 7.2.1 *Renewable energy share in the total final energy consumption*
- 9.4.1 *CO_2 emission per unit of value added*
- 11.1.1 *Proportion of urban population living in slums, informal settlements or inadequate housing*
- 11.6.1 *Proportion of municipal solid waste collected and managed in controlled facilities out of total municipal waste generated, by cities*
- 12.7.1 *Degree of sustainable public procurement policies and action plan implementation*
- 12.a.1 *Amount of support to developing countries on research and development for sustainable consumption and production and environmentally sound technologies*
- 13.2.1 *Number of countries with nationally determined contributions, long-term strategies, national adaptation plans, strategies as reported in adaptation communications and national communications.*

Two indicators are core for circular built environments in all seven regions. These are 8 and 12, as detailed below:

- 12.2.1/8.4.1 on material footprint (same indicators under two different SDGs).

As the development of circularity indicators are in the early stages, the work is expected to continue beyond the publication of this report. Further probing of the indicators will be undertaken through inputs by experts in selected regions.

5.1.3 Lifecycle considerations of buildings

The very process of building and construction impacts land, air and water. The lifecycle impacts of buildings are usually lower during construction than during operation in the developing world, and this is still the norm in developed countries like Australia and New Zealand.

Every phase during a building's lifetime needs to fulfil the different functions required by the various owners and users. This has impacts on nature, and on the economy. Buildings should be considered holistically, from the manufacturing and design phases, to deconstruction and end of life.

- Capital cost in a circular economy should support manufacturing that ensures that materials are given a second life. Manufacturing processes should use renewables, reuse water and exploit the waste streams of its own sector as well as those of other industries. Long-term optimisation and efficiency should drive the process. Capital cost should also support designs that ensure operating costs are low. Modular, de-mountable and prefabricated design and construction support waste reduction. Low-waste and highly efficient construction technologies, such as vernacular construction, have a place in a circular economy.
- Operating costs should be focused on prolonging life for multi-use where possible, and using renewables and resource-efficient utilities as appropriate. Operation and maintenance in the emerging economies are often not considered and the life of buildings is not prolonged as a result of poor maintenance. Yet maintenance also creates jobs.
- The land within the built environment or its vicinity should be used as a green space for agriculture or forestry, to support biodiversity. Buildings do not exist in isolation, so the services that connect buildings such as mobility, the use of water, food, products and materials that are used functionally in the space or for living are also important considerations.
- New business opportunities may be tapped depending on the region. Where greenfield developments occur, good design and upskilling in construction may take place. Where the market is also geared for the renovations sector, reuse and repurposing of materials can support new forms of entrepreneurship.
- Green jobs and green skills support new business opportunities. If innovation in various digital and non-digital platforms occurs, education and reskilling for a circular economy will be required.

5.1.4 Building materials and waste

The SDG 12 progress report (UN, 2019b) noted that worldwide material consumption has expanded rapidly, as has material footprint per capita, seriously jeopardising the achievement of SDG 12 and other goals more broadly. Urgent action is needed to ensure that current material needs do not lead to the over-extraction of resources or to the further degradation of environmental resources, and should include policies that improve resource efficiency, reduce waste and mainstream sustainability practices across all sectors of the economy.

The SDG 11 progress report 2019 (UN, 2019b) stated that, in relation to SDG 11, globally, 2 billion people do not have access to waste collection services and 3 billion people lack access to controlled waste disposal facilities. With increasing urban populations and the existence of consumer-oriented economies amid rising income levels and rapid urbanisation, it is estimated that the total waste generated in the world will double from nearly 2 billion tonnes in 2016 to about 4 billion tonnes by 2050. While from 2010 to 2018 the proportion of solid waste collected was about 81% globally, in sub-Saharan Africa it was only 52%. Therefore, attitudes towards waste and how we manage it are critical.

Buildings cannot be constructed without materials. Global material use is anticipated to more than double to the year 2060 (OECD, 2018). Of this total material use, more than half is expected to be comprised of non-metallic materials, and a third of the total is expected to be used in the building and construction industry, such as sand, gravel and limestone. These materials are expected to be used mostly in the new growth regions of the world.

Therefore, where deconstruction works are undertaken, they should include high-class recovery to ensure quality so that materials may be reused or repurposed for use. Materials that are still manufactured from non-renewable resources need to be recognised as 'special' and this thinking needs to be reflected in mainstream building and construction practices. Materials need to be considered carefully:

- As building developments continue, materials are needed. Using the current stock of materials will avoid further depletion of already fragile resources that puts further stress on the environment.
- It is time for a serious investigation of alternative material resources. This may take the form of bio-based materials in a cradle-to-cradle approach, industrial symbiosis or circular practices where waste from one part of the system becomes the raw material for another part of the system. For example, coconut husks may be used to create building materials such as tiles.

5.1.5 Sustainable procurement practices

Sustainable consumption and production practices may be underpinned by a market that drives sustainable products and services. Rather than thinking about a product, a shift in thinking and developing business models that consider service models or product and service model focus on results or outcomes to be achieved. Such an approach can lead to cost reductions, it can also enable efficiency gains and promote further energy and resource efficiencies (UNEP, 2015). Such types of 'new' approaches are critical when considering the life of a building. When services are used for lifecycle management of assets such as buildings, there are gains to be made for all parties. Rather than blindly following examples of procurement guidance from other regions, a first step may be to localise to enable including local products to tendering processes.

- Value added services for buildings assists in staying ahead of the competition.
- Changing needs may be anticipated, thus, new markets may be explored. Flexibility allows adaptation or allows offering new services that enables staying ahead of the competition.
- Long term gains such as increasing the repairability and durability of products within the supply chain is supported. Collaboration with stakeholders can provide shared gains which the building industry can benefit from.
- Potential risks may be identified or anticipated due to close collaboration with the users that benefits industry. It may allow businesses to anticipate new standards and regulations and stay ahead by testing and innovating new solutions.

5.1.6 Affordability and resilience

Climate change impacts are being felt the world over. Buildings of the future not only need to be supportive of low environmental impact, but also to be resilient and to adapt to changes in the climate. The more that greenfield building and construction take place, the worse will be the environmental impact. In addition, rebuilding after disasters needs to be affordable so that people can get on with their lives. SDG 9 is about resilient infrastructure, promoting inclusive and sustainable industrialisation and fostering innovation. SDG 11 relates to making cities and human settlements inclusive, safe, resilient and sustainable. SDG 7 seeks to ensure access to affordable, reliable, sustainable and modern energy for all. Low-cost materials should be considered as a priority:

- Responsibly sourced affordable materials and local technologies that use renewable energy will support rebuilding efforts and the creation of local jobs.
- Locally sourced sustainable materials will also support diversity in the supply chain, create local jobs, stimulate the local economy, support bio-climatic and passive approaches, and provide diversity in material use so that the pressures on commonly used materials can be lifted.
- Educational support to skill and re-skill will ensure that there is little or no reliance on global supply chains.

5.1.7 Local solutions and practices

In a world whose daily activities have been arrested by the pandemic, it is time to start seriously thinking about and supporting local. In the emerging economies of the world particularly, there is a danger in adopting cookie cutter approaches of the west, with the use of high impact building materials such as concrete, glass and steel. Deliberately planning a move away from intensive material use relying on global supply chains will enable more robust and agile solutions, supporting greater resilience:

- Local engagement and understanding will come to the fore. Such understanding will support the use of bio-climatic and passive designs, local skills and techniques, and local materials.
- Deeper involvement at the local levels will support economic outcomes, providing jobs and support skilled labour that might otherwise not be used.
- Diversity of approaches allow flexibility and ability to respond quickly. The use of local or indigenous methods provide variety, low-cost solutions and preserve heritage, indigenous knowledge and culture. Supporting local supply chains provide a multiplicity of solutions.

5.1.8 New business models and technologies

Opportunities for new business models may be created through shared spaces and digital platforms. Sharing economy platforms such as Airbnb and Uber are already well known. Material passports will support the reuse and repurposing of materials, even upcycling, as the composition and components of materials will be clearly identified. Innovative models are needed:

- Shared ownership and new rental models are already found in the market. Moving from owning to sharing or renting is already showcasing the possibilities for co-sharing spaces. Shared spaces can be multi-use, for example, the function may be used for both office and retail.

- Green design and valuation services and design for multi-use and flexibility can provide new opportunities. Modular and flexible spaces can be easily converted for various functions, avoiding the need to rebuild.
- Procurement models can trigger advances in technology. Government procurement practices, including social procurement, can engage and drive industry to advance novel solutions and achieve desired social outcomes. Procurement standards can support the use of local materials, digital marketplaces and the investigation of upcycling in manufacturing.
- Providing building passports in construction supports the tracking of products and materials across the supply chain.
- The high-value recovery of building products in renovation needs to be developed. Material reuse and exploring new resource streams offer circular options that ensure that deconstructed materials do not end up in landfill or as waste.

5.1.9 Skills and education

The 2018 SDG 8 progress report (UN EcoSoc, 2018), in relation to SDG 8, stated that one-fifth of the world's youth were not engaged in education, employment or training, meaning that they were neither gaining professional experience nor acquiring or developing skills through educational or vocational programmes in their prime years. Education at all levels supports the spread of a circular economy and the exploitation of its benefits.

Both higher education and vocational skills have a role to play. Higher education skills need to be built on a platform of systems thinking and recognising the importance of feedback loops. Cross-disciplinary education is fundamental to this understanding. Along with systems thinking, cross-disciplinary education also recognises and supports holistic outcomes. Thus, the collaboration of other disciplines with the building and construction sector needs to be further investigated. As an example, ICT and digitisation will facilitate the reuse and repurposing, and sometimes even upscaling, of materials to support a circular economy. Tracking and tracing of building materials ensures that such materials maintain their quality, and so can be reused easily in a second life or converted into something else for use in a second or third life.

Considering current and future challenges, there is an exigent need to look beyond skills that only support a linear economy. Education and skills for a circular economy will support systems thinking and recognise the limitations of continuing to work linearly. The regional reports identified new skills needed to support local building material manufacturing, such as around bio-based materials and better managing waste streams. Circular design requires educational support: design for multi-use, design for disassembly and the like. Priorities identified are:

- Vocational/trade skills will need to focus more on repairing products and materials, using indigenous knowledge and technical skills to support local artisans. Training for construction materials optimisation, zero waste and reuse of materials in construction is required.
- Skilful operation and management of buildings ensures prolonged building lifecycles. Circular maintenance is a new service requiring skills including modelling flexible spaces.
- Circular renovation requires skills in low to no waste materials and low to no emissions, while also exploring upcycling options.
- Waste microgrids offer opportunities to sort and stockpile materials. Material tracking and recovery to re-engage materials in the supply chain requires specialist skills.

5.1.10 Collaboration and financing

The UN SDG progress report (2019b) has indicated that international cooperation on tax and cross-border financial flows, debt relief and trade, technology, migration and remittances is desired. Countries must preserve their multilateral trading systems, resist the temptation to impose trade-restrictive measures and implement provisions that support exports from least-developed countries. The circular built environment provides opportunities for increased South–South, even South–North, trade if the logistics infrastructure supports it and is not constrained by trade barriers.

- Apolitical collaboration between various levels of government, industry and community, supported by cross-cutting engagement between various types of business, is needed so there is alignment around achieving circular practices and ultimately genuinely sustainable outcomes.
- Changing existing practices and thinking with circularity in mind can support aligned outcomes as well as the creation of jobs. Unwanted building materials from a construction site may be reused elsewhere rather than being diverted to landfill, and may also be resold, offering economic opportunities.

References

Acharya, D., Boyd, R. and Finch, O. 2018. From Principles to Practices: First Steps towards a Circular Built Environment. Arup and EMF. Acessed 20 September 2020 from https://www.ellenmacarthurfoundation.org/assets/downloads/First-steps-towards-a-circular-built-environment-2018.pdf

Al-Alawi, B., Tibi, G., Cavallari, G., Cindric, H., Shaka, H., Gargallo, M., Hegazy, N. and Saqib, S. 2020. State of Play for Circular Built Environment in Gulf Cooperation Council (GCC) Countries. Sustainable Building and Construction Programme regional report for GCC, Final report October 2020, ARUP and United Nations One Planet Network Sustainable Building and Construction Programme.

Aparcana, S. 2017. Approaches to Formalization of the Informal Waste Sector into Municipal Solid Waste Management Systems in Low- and Middle-Income Countries: Review of Barriers and Success factors. Waste Management, 61, 593–607.

Australian Bureau of Statistics (ABS) 2019. 3222.0 - Population Projections, Australia, 2017 (base) – 2066. Canberra: ABS.

Bejjani, M., Anouti, Y., Klat, A. and Batal, J. 2019. Putting GCC Cities in the Loop: Sustainable Growth in a Circular Economy. Ideation Centre. Strategy& PwC. Accessed 20 September 2020 from https://www.strategyand.pwc.com/m1/en/reports/putting-gcc-cities-in-the-loop.pdf

BID 2015, Situación de la gestión de Residuos Sólidos en América Latina y el Caribe.

CALGreen 2019. Construction Waste Recycling Requirements effective 1/1/2020. 2019 CALGreen Building Code as amended by County Ordinance 2019-31. California Green Building Standards. Accessed 13 March 2020 from https://www.contracosta.ca.gov/DocumentCenter/View/44118/CalGreen-Project-Recycling-Requirements-as-Amended-eff-1-1-2020?bidId=

Colby, S. and Ortman, J. 2015. Projections of the Size and Composition of the U.S. Population: 2014 to 2060. Accessed 13 March 2020 from https://www.census.gov/content/dam/Census/library/publications/2015/demo/p25-1143.pdf

Deloitte & Touche (M.E.) 2019. Has the Industry Turned the Corner? Deloitte GCC Powers of Construction 2018. Accessed 20 September 2020 from https://www2.deloitte.com/content/dam/Deloitte/xe/Documents/realestate/construction/gccpowersofconstruction/me_construction_gccpoc-2018.pdf

Department of Environmental Affairs 2012. National Waste Information Baseline Report. Pretoria, South Africa.

Economic Commission for Latin America and the Caribbean (ECLAC) 2016. Demographic Observatory, 2016 (LC/PUB.2017/3-P), Santiago, 2016.

Environment Agency Abu Dhabi 2020. Abu Dhabi Emirate Single Use Plastic Policy 2020. Accesssed 20 September 2020 from https://www.ead.gov.ae/storage/SINGLE%20USE%20PLASTIC%20POLICY%20FINAL%20ENGLISH%20313.pdf

European Commission 2019. European Commission Reports. Accessed 16 June 2020 from https://ec.europa.eu/environment/waste/construction_demolition.htm

Gibberd, J. 2020. State of Play for Circular Built Environment in Africa. Sustainable Building and Construction Programme regional report for Africa, Final report May 2020, Guage and United Nations One Planet Network Sustainable Building and Construction Programme.

Global Alliance for Buildings and Construction, International Energy Agency and the United Nations Environment Programme (GlobalABC, IEA and UNEP) 2019. Global Status Report for Buildings and Construction: Towards a Zero-Emission, Efficient and Resilient Buildings and Construction Sector. Accessed 14 March from https://www.worldgbc.org/sites/default/files/2019%20Global%20Status%20Report%20for%20Buildings%20and%20Construction.pdf

Global Footprint Network 2020. Ecological Footprint. Accessed September 2020 from https://data.footprintnetwork.org/?_ga=2.90226714.1245478955.1598341316-1771067374.1598341316#/>

Government of South Australia, Office of Green Industries 2015. South Australia's Waste Strategy 2015-2020. Office of Green Industry SA. Accessed 20 March 2020 from https://www.greenindustries.sa.gov.au/sa-waste-strategy

International Renewable Energy Agency (IRENA) 2019. Renewable Energy: Market Analysis: GCC 2019. Accessed 20 September 2020 from https://www.irena.org/publications/2019/Jan/Renewable-Energy-Market-Analysis-GCC-2019

Iyer-Raniga, U. 2020. State of Play for Circular Built Environment in Oceania. Sustainable Building and Construction Programme regional report for Oceania, Final report April 2020, RMIT University and United Nations One Planet Network Sustainable Building and Construction Programme.

Keena, N. and Dyson, A. 2020. State of Play for Circular Built Environment in the USA. Sustainable Building and Construction Programme regional report for the USA, Final report May 2020, Yale CEA and United Nations One Planet Network Sustainable Building and Construction Programme.

Miflin C., Spertus J., Miller B., and Grace C. 2017. Zero Waste Design Guidelines: Design Strategies and Case Studies for a Zero Waste City. AIA Center for Architecture, New York. Accessed 13 March from https://www.zerowastedesign.org/wp-content/uploads/2017/10/ZeroWasteDesignGuidelines2017_Web.pdf

Moreno, P. 2020. State of Play for Circular Built Environment in Latin America and the Caribbean (LAC). Sustainable Building and Construction Programme regional report for LAC, Final report May 2020, Ecosur Network and United Nations One Planet Network Sustainable Building and Construction Programme.

Niazi, Z., Singh, A. and Sen, I. 2020. State of Play for Circular Built Environment in Asia. Sustainable Building and Construction Programme regional report for Asia, Final report April 2020, TARA/Development Alternatives and United Nations One Planet Network Sustainable Building and Construction Programme.

Nieuwenkamp, Roel 2016. The global construction sector needs a big push on corporate social responsibility. Accessed 12 May 2020 from http://oecdinsights.org/2016/08/22/global-construction-sector-corporate-responsibility/

ONU Ambiente 2018. Perspectiva de la Gestión de Residuos en América Latina y el Caribe.

Organisation for Economic Co-operation and Development (OECD) 2018. Global Material Resources Outlook to 2060: Economic Drivers and Environmental Consequences – Highlights. OECD Publishing: Paris.

Organisation for Economic Co-operation and Development (OECD) 2020. Municipal Waste OECD Data. Accessed 13 March from https://data.oecd.org/waste/municipal-waste.htm

Stats New Zealand 2019. National Population Projections: 2016 (base) – 2068. National population projections. New Zealand: Statistics New Zealand.

United Arab Emirates (UAE) Government 2019. Annual Economic Report 2019. Accessed 18 Sepetmber 2020 from https://www.economy.gov.ae/EconomicalReportsEn/MOE_Annual%20Economic%20Report_2019_.pdf

United Nations Department of Economic and Social Affairs (UNDESA), Population Division 2019. World Urbanization Prospects 2018: Highlights (ST/ESA/SER.A/421).

United Nations Economic and Social Council (UN ECOSOC) 2018. Progress towards the Sustainable Development Goals, Report of the Secretary-General. E/2018/684 High-level political forum on sustainable development, Report of the Secretary-General. Accessed 28 May 2020 from https://sustainabledevelopment.un.org/content/documents/18541SG_SDG_Progress_Report_2018_ECOSOC.pdf

United Nations Economic and Social Council (UN ECOSOC) 2019. Special Edition: Progress towards the Sustainable Development Goals, Report of the Secretary-General. E/2019/68, High-level segment: ministerial meeting of the high-level political forum on sustainable development, convened under the auspices of the Economic and Social Council. Accessed 28 May 2020 from https://undocs.org/E/2019/68

United Nations 2019a. United Nations Environment Assembly of the United Nations Environment Programme, Fourth session, Nairobi, 11–15 March 2019. Innovative Pathways to Achieve Sustainable Consumption and Production UNEP /EA.4/L.2. Accessed 28 May 2020 from https://papersmart.unon.org/resolution/uploads/k1900824.pdf#overlay-context=node/243

United Nations 2019b. Report of the Secretary General on SDG Progress 2019 Special Edition. UN New York 2019. Accessed 28 May 2020 from https://sustainabledevelopment.un.org/content/documents/24978Report_of_the_SG_on_SDG_Progress_2019.pdf

United Nations 2020a. Department of Economic and Social Affairs Population Dynamics. World Population Prospects 2019. Accessed 13 October 2020 from https://population.un.org/wpp/DefinitionOfRegions/#:~:text=These%20regions%20are%20further%20divided,%3B%20Northern%20America%2C%20and%20Oceania

United Nations 2020b. Seventieth session Agenda items 15 and 116 Resolution adopted by the General Assembly on 25 September 2015, 70/1 Transforming our world: the 2030 Agenda for Sustainable Development. Accessed 20 March 2020 from https://www.un.org/ga/search/view_doc.asp?symbol=A/RES/70/1&Lang=E

United Nations Environment Programme (UNEP) 2015. Using Product-Service Systems to Enhance Sustainable Public Procurement. Technical report. May 2015. Acccessed 15 September 2020 from https://www.oneplanetnetwork.org/sites/default/files/using_product-service_systems_to_enhance_sustainable_public_procurement.pdf

United Nations Environment Programme (UNEP) 2018. Africa Waste Management Outlook. United Nations Environment Programme, Nairobi, Kenya.

United States Environmental Protection Agency (US EPA) 2015. Sustainable Materials Management Program Strategic Plan for Fiscal Years 2017-2022. United States Environmental Protection Agency. Accessed 9 March 2020 from https://www.epa.gov/smm/epa-sustainable-materials-management-program-strategic-plan-fiscal-years-2017-2022

United States Environmental Protection Agency (US EPA) 2016. Recycling Economic Information Report. United States Environmental Protection Agency. Accessed 13 March 2020 from https://www.epa.gov/smm/recycling-economic-information-rei-report

United States Environmental Protection Agency (US EPA) 2020. Facts and Figures about Materials, Waste and Recycling, Guide to the Facts and Figures Report about Materials, Waste and Recycling. Accessed 5 May 2020 from https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/guide-facts-and-figures-report-about-materials#Materials_and_Products

United States Geological Survey (USGS) 2020. Mineral commodity summaries 2020: U.S. Geological Survey, Accessed 13 March 2020 from https://doi.org/10.3133/ mcs2020.

United States Global Change Research Program (USGCRP) 2018. Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II. [Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart (eds.)]. US Global Change Research Program, Washington, DC, USA, 1515 pp. doi: 10.7930/NCA4.2018.

Westerholm, N. 2020. State of Play for Circular Built Environment in Europe. Sustainable Building and Construction Programme regional report for Europe, Final report June 2020, United Nations One Planet Network Sustainable Building and Construction Programme.

World Bank 2018. World Bank Open Data | Data. Accessed 15 April 2019 from https://data.worldbank.org/

Worldometer 2019. World Population Live. Accessed 20 November 2019 from https://www.worldometers.info/world-population/

Worldometer 2020a. World Population Live. Accessed 18 April 2020 from https:www.worldometers.info/world-population/

Worldometer 2020b. World Population: GCC Countries by Population. Accessed 20 September 2020 from https://worldpopulationreview.com/country-rankings/gcc-countries

World Population Review 2019. World Population Review, Worldpopulationreview.com. Accessed 15 April 2019 from http://worldpopulationreview.com/countries/median-age/