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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 acts as an enabler bringing actors from all regions to pool their expertise, resources, innovation and commitment towards a shift to more sustainable modes of production and consumption. The network comprises of six programmes: Sustainable Buildings and Construction, Sustainable Public Procurement, Sustainable Tourism, Consumer Information for SCP, Sustainable Lifestyles and Education and Sustainable Food Systems Programme.

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 is to promote resource efficiency, mitigation and adaptation efforts, and the shift to SCP patterns in the buildings and construction sector. The SBC work in 2021-2022 focuses on circularity and responsible sourced materials.

Circular Built Environment Highlights

SBC has published 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 role of the reports is not only to provide a benchmark but also recommendations on how to move forward towards a sustainable and circular built environment.

These highlights from Africa provide a deep dive on circular built environment in Burkina Faso, Rwanda, Senegal and Uganda presenting good practice case studies covering different life cycle stages and impact categories. Most important sustainable development goals and indicators for circularity from the UN2030 Agenda for Sustainable Development were identified through a survey.

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List of abbreviations

ABNORM	Burkinabe Agency for Standardization, Meteorology and Quality
ASN	Senegalese Association for Standardization
C+D	construction and demolition
CBE	circularity in the built environment
CE	circular economy
CO ₂	carbon dioxide
CO ₂ e	carbon dioxide equivalent
DMC	direct material consumption
EIA	environmental impact assessment
EIS	environmental impact statement
EU	European Union
GDP	gross domestic product
GGGI	Global Green Growth Institute
GHG	greenhouse gas
GKMC	Greater Kampala Metropolitan City
NUA	New Urban Agenda
PANEE	National Energy Efficiency Action Plan
PANER	National Renewable Energy Action Plan
PES	Plan for an Emerging Senegal
PV	photovoltaic (solar panels)
SDG	Sustainable Development Goal
SEA	strategic environmental assessment
UNFCCC	United Nations Framework Convention on Climate Change
UGGDS	Uganda Green Growth Development Strategy
USD	American dollars

Executive summary

Population growth and urbanization in the African region are expected to continue at the current high rates over the coming decades. The corresponding demand for housing and public infrastructure from this growth is challenged by the depleting natural resources, climate change induced weather impacts and the urgent need to switch from carbon intensive means of infrastructure provision. Circularity provides a holistic opportunity for the industry to switch from a cradle to grave planning towards maximising the longevity of resources, primarily materials, energy and water.

This report focuses on four countries in Africa, Burkina Faso, Rwanda, Senegal and Uganda. Through policy analysis and stakeholder interviews, this report presents the operating context for the building industry in these countries. While the conception of circularity has not been formally developed and communicated in the focus countries, the research team found strong examples demonstrating circularity throughout all phases of the building life cycle. Nineteen of these examples are featured as Case Studies in this report and provide insights to the current initiatives on circularity in buildings. Case Studies featured also include projects and practices from Malawi, Morocco, Nigeria and South Africa.

Some barriers to mainstreaming circularity discussed in key stakeholder interviews include the poor control of building standards and processes, resulting in low quality in buildings constructed, with direct implications on occupant safety and comfort. Overall, public and private sector stakeholders did not have much awareness about circularity or the principles underpinning it, apart from recycling of waste materials. The lack of testing and certification facilities in the region also deter the development of local circular or “green” building materials. Many people working within the sector lacked formal training and skills, keeping them in low wage employment and limiting the prospects for innovation and improvement in building processes. Poor enforcement of waste disposal for construction and demolition waste and the absence of a culture for building maintenance and retrofit reduces the possibility of old buildings being retrofitted and reused.

There was also a substantial of informal movement of materials across the building value chain, either in the form of sharing, giving or waste salvage and resale. This was discussed and practiced to varying extents by about half of the stakeholders interviewed for this study. Additionally, there was also an element of capacity and technology transfer, often from overseas. This interaction is often to fill a gap for a specific technical function and enables local teams of industry professional to customize the knowledge or technology to local needs and conditions. There were also small companies in each of the focus countries experimenting with waste products or local resources to develop building materials. Such endeavours support the wider adoption of circularity within the building industry.

In line with these findings, the SDG analysis concluded that SDGs 8, 9, 11, 12 and 13 were closely related with the circularity of the built environment. Prioritized indicators for measuring the extent of circularity focused on waste reduction and recycling and the use of local materials. Based on the findings, the report recommends for the enhancement of the policy and regulatory environment for buildings, the prioritization of training and upskilling for workers in the building industry, establishment of regional standardization and certification facilities and promotion of capacity transfers at different scales.

1. Introduction

The building and construction sector of Africa is worth USD 5.4 billion and is expected to grow at a compound annual rate of 6.4% by 2024 (ReportLinker, 2020). In 2019, buildings used 57% of the total energy and accounted for 32% of the process-related CO₂ emissions in Africa (United Nations Environment Programme [UNEP], 2020). This may partly be ascribed to the linear operation of the built environment whereby materials are extracted, used in buildings and discarded as waste. Transitioning to a circular approach could reverse this trend, keeping materials and resources in use for as long as possible and reducing the carbon footprint of buildings. A circular building value chain does this and preserves the value of resources to manage demand on virgin materials and reduce waste generated. Consequently, it extends the longevity of natural resources and decreases the emissions associated with the production and transportation of materials, the construction process, and the waste management at the end of building life.

Circularity and sustainability are closely related. Even though circularity is not a distinct Sustainable Development Goal (SDGs), it contributes to attaining these goals. The following SDGs contribute towards circularity in the built environment; SDG 3 (Good Health and Well Being), SDG 6 (Clean Water and Sanitation), SDG 7 (Affordable and Clean Energy), SDG 8 (Decent Work and Economic Growth), SDG 9 (Industry, Innovation and Infrastructure), SDG 11 (Sustainable Cities and Communities), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate Action) (Arcadis, Circular Economy and WBCSD, 2018). The interlinkages between circularity and the SDGs are discussed later in this report, with a particular focus on the context of African countries.

To guide the rapidly urbanizing world, the New Urban Agenda (NUA) (UN HABITAT, 2017) prioritizes achieving a circular economy through strengthening sustainable resource management especially for land, energy, water, materials and forests. It also seeks to minimize environmental impact and shift cities towards more sustainable consumption and production patterns. The NUA also highlights the role of clean energy and sustainable use of land and resources in mitigating climate change and its impacts. Circular practices in the built environment such as diverting construction and demolition waste from landfills, substituting cement and steel with more regenerative materials, and using renewable energy for heating and cooling, can save 13.61Gt of materials and 11.82Gt of emissions globally. Ultimately, a circular economy will limit global temperature rise to less than 2°C instead of 3.4°C that is predicted from a linear economy (Circular Economy and Shifting Paradigms, 2021).

2. Significance of this work

2.1. Current trends and arising challenges and opportunities

Africa has the fastest-growing population in the world. From 2016 to 2050, the population is projected to double from 1.2 billion to 2.5 billion. The projected population expansion is matched by rapid urbanization. Africa has the highest urbanization rate in the world, at an average of 4% per year. Fifty percent of the population is expected to dwell in urban areas by mid-2030, compared to only 14% in 1950 (AfDB, OECD and UNEP, 2016). Currently, the only 3 megacities with populations of over 10 million include Cairo, Kinshasa, and Lagos. By 2050, Luanda, Dar es Salaam, Johannesburg, Abidjan, Nairobi, Ouagadougou, Addis Ababa, Bamako, Dakar and Ibadan will have surpassed the 10 million population mark bringing the

number of megacities in Africa to 14 (Toesland, 2019). The majority of the urban dwellers are young people, with 9 out of 10 of them classified as poor or nearly poor (AfDB, OECD and UNEP, 2016).

While urbanization is often accompanied by infrastructure and economic growth, it can create a myriad of challenges when not accompanied by proper policies and strategies. New demands for housing and infrastructure, and increased consumption habits of the population leads to challenges like municipal solid waste management, environmental degradation, air pollution, sanitation overload among many others.

The volume of waste produced in Africa is estimated to triple to 516 million tonnes per year by 2050, from 174 million tonnes per year in 2016. However, 90% of this waste is disposed of at uncontrolled dumpsites and landfills. In addition, 19 of the world's 50 biggest dumping sites are in Africa. The waste is largely composed of plastic (13%) and organic waste (57%). Further, the collection rates are low at about 55% of all the existing waste materials. While 70-80% of the municipal waste generated in Africa is recyclable, only 4% is currently recycled (UNEP, IETC and CSIR, Undated).

A circular economy has gained traction as a viable solution to some of the challenges of urbanization, and to sustainable development in a broader sense. It is restorative by design and focuses on keeping products, components, and materials at their highest utility and value at all times (Geissdoerfer et al., 2017). The concept also encourages the reduction of waste while providing new opportunities for economic diversification, value creation, skill development and curbing climate change. As much of Africa's urbanization is still to be undertaken the continent still has a chance of incorporating circularity into the business models by building infrastructure with consideration of their next life cycle.

The following section of the report describes the conceptual framework and research methods employed. After that, the analysis is structured in three sections: impacts of resource flows of the built environment on sustainability outcomes, policy mapping for circularity and key findings from Case Studies and SDG surveys.

3. Concept and methods

3.1 Strategies for circularity

While there are multiple ways of conceptualizing circularity, this research takes a broad understanding of the term, which can be applied across any or multiple phases of the life cycle of buildings. This research is focused on the flows of **energy, material** and **water** across all major phases of the building life cycle, starting from material production. Taking reference from the EU Principles for (Circular) Building Design, (European Commission, 2020), the following strategies are also highlighted in the case studies for this study, together with initiatives directly reusing or recycling materials in buildings.

Extending the useful life – This is achieved through improving the quality of materials and building design to reduce repairs and replacements. This also includes a well-planned maintenance regime to ensure minor defects are rectified early to prevent deterioration. The strategy is demonstrated in the case studies emphasising the enhancement of the quality of local and low carbon materials to improve construction processes and extend building life spans.

Flexible use – Buildings integrate features such as reconfigurable spaces, moveable furniture and minimal internal structural walls to accommodate changes in functions over time. The same buildings could also be used in a number of different ways by different groups throughout the day or week, optimising the occupancy and reducing the requirements for additional buildings.

Pro-active waste management – The strategy seeks first to minimize the generation of waste. Pre-fabrication and modular designs are some proven means to achieve this. Building materials are designed for reuse after end of building life, these can include designing for deconstruction and using standard dimensions for compatibility of components in multiple projects. Where waste minimization and direct reuse are not possible, construction and demolition/deconstruction waste should be properly segregated to maintain as much of the component value for recycling.

These circularity strategies discussed above are illustrated in whole or in part throughout the case studies presented in this study. The findings in this report are focused largely in four countries – **Burkina Faso, Rwanda, Senegal** and **Uganda**. Where possible, interviews and data collection were conducted in person. However, there were periods during the research period where travels and meetings were restricted in these countries. Engagements were carried out virtually during those periods. Additionally, a few case studies outside of the four focus countries are presented.

3.2 Research methods

This research depends on multiple forms of information as basis for the analysis in the later sections.

Policy review – For the focus countries, policies and plans concerning the building industry and waste management are reviewed to explore any support or barriers to circularity in material, energy and water in buildings. These are described in the following section of the report.

Desktop research – Internet-based search on potential projects and good practices to be highlighted in the study. This was the primary means of reaching the Case Studies in this report that were outside of the focus countries. Open-sourced reports and databases were also referred to provide background for the discussions in the report.

Stakeholder interviews – Relevant stakeholders influencing or working on circularity in the building sector were mapped out for each of the focus countries. Formal letters seeking an interview were sent out, followed up with phone calls and emails. In some instances, visits to the offices were made to set up appointments. Despite this, interviews with some stakeholders could not be organized during the research period. Stakeholder interviews tended to be free flowing, depending on the nature of engagement with circularity. For project managers, the discussion would be centred around data collection for the Case Studies. For other stakeholders, the interviews focused on what was being done to promote circularity and what barriers were faced. The stakeholders from the focus countries interviewed for this research are listed in Table 1 Stakeholders interviewed in each of the focus countries.

Online (SDG) survey – In parallel to the interviews, building industry stakeholders have been invited through the One Planet Network to participate in an online survey on the relevance of the Sustainable Development Goals (SDGs) and SDG indicators for monitoring circularity in the built environment. Survey respondents indicate their geographical region of operations, which is later used as a filter in assessing regional variations in responses. Stakeholders interviewed for this study were also invited to participate in the online survey.

3.3 Stakeholders' map

In each of the focus countries for the research, key stakeholders were consulted, first through an in-depth interview (either in person or virtual) and later through a joint validation, again, in person where possible. Stakeholders in the public and private sectors, academia and the informal sector were interviewed to map out their roles in promoting circularity within the building sector. These stakeholders are listed below.

Table 1: Stakeholders interviewed in each of the focus countries

Burkina Faso	Rwanda	Senegal	Uganda
Government offices			
DGAHC (General Directorate of Housing Architecture and Construction) ANEVE (National Agency for Environmental Assessments)	Rwanda Housing Authority City of Kigali (Waste management)	APIX (Investment promotion & Major works Agency) UCG (Waste management company)	Ministry of Works & Transport (MOWT), National Building Review Board (NBRB), Uganda Housing Cooperative Union (UHOCU)
Development partners			
YAAM Solidarity Village Opera Women Health Center Home Kisito	N. B. Skat	GIZ – National Programme for Energy efficiency in Building (PNEEB)	Nsambya youth sharing centre
Architectural companies			
Albert Faus Architecture META FARE Studio Agence AIC Archi Bati Consult	Mass Design Patrick Schweitzer et Associes Vavaki Architects 3D Gasabo GMK Designs Landmark Studio		Associated Architects, Technology for Tomorrow
Construction companies			
SOGEA- SATOM ECW	Real Contractors Ltd. CCECC Ndosa Build NPD COTRACO SUMMA Spotico Ltd Seyani Brothers Demolition contractors (informal)	Elementerre (Green construction Company)	Construction Design Africa- Bweyogerere Up Cycle Africa Justev Building Systems Urban Green

Burkina Faso	Rwanda	Senegal	Uganda
Real Estate Developer			
CGE Immobilier Azalai Group	Kigali Business Centre Convention Center Soras Towers Kigali Heights Remote group		Wandar Village, Stone Roofing, Uganda
Material suppliers			
ZI MATERIAUX TECO ² DSF CIM METAL SA KANAZOE Group Market of Used Metal Parts (informal sector)	Strawtec Building Solutions Mt Meru Soyco, Atelier Umuvanganzo Earth Enabel Steelrwa Ltd	Dangote (Cement Production Company) Ecopave (Recycling Company) Used materials market vendors (informal sector) Mbeubeuss Landfill pickers (informal sector)	Lafarge/Hima Cement, Uganda; David Ssenyondo (Salvaged materials- Informal sector)
Researchers			
University 2iE	International Growth Center University of Rwanda	Cheikh Anta Diop University TyCCAO: Typha exploitation project	Eco Concrete Uganda, Makerere University

4. Impact of the built environment

Africa, as a region, is one of the least developed in the world. Among 189 countries evaluated, 29 out of the 32 countries with the lowest Human Development Indices are from Africa (UNDP, 2020). In addition, Africa is also the world's fastest growing region – the population is projected to grow from 1.3 billion in 2020 to 2.5 billion in 2050 (UN, 2019). On average, the region is urbanizing at 4% per year, twice that of the global average. Figure 1 shows Africa is the least urbanized region globally, based on 2018 data. Continent-wide, the urban population is projected to reach 59% of total population by 2050.

This rapid increase of urban population corresponds to an increased demand for buildings in cities within the next 3 decades. With only 30% of households living in formal housing (World Bank, 2013), there is pressure and opportunity to enhance the quality of housing for the vast majority living in African cities through a change in approach. Existing cities already consume much more material resources than is sustainable, this report explores opportunities to increase the circularity of materials through highlighting pathfinding practices in Africa.

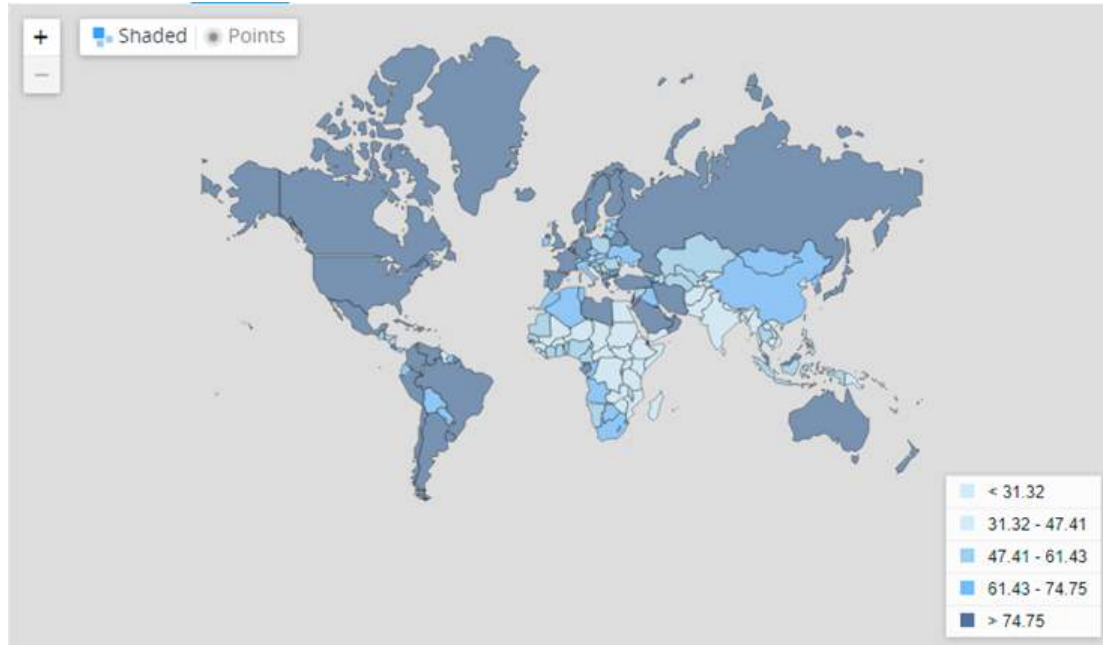


Figure 1: Urban population (as % of total population)

Source: World Bank data 2018

Some characteristics of the African population and urban growth, also noted in the previous CBE Africa Report are elaborated in this section:

- **Youthful population in Africa**

With a median age of 18.3, 43% of its population under 15, and less than 5% of the population aged 65 or over. (World Bank, 2013). This young population is concentrated mainly in sub-Saharan Africa and it is considered an important growing labor source. Almost 95% of youths (15-24 years old) are informally employed, with significant variation between Northern Africa and Sub-Saharan Africa. (ILO, 2020)

- **Low carbon emissions**

Based on 2018 World Bank data, 27 out of the 30 countries with lowest carbon emissions per capita are African. While carbon emission reduction may not be a key priority in promoting circularity, increased efficiency in the use of materials, water and energy in the buildings will result in reduced emissions from the sector.

- **Material intensity of African economies**

Material intensity is measured as the amount of materials used to generate a unit of manufacturing value. This is useful for assessing activities in the building sector as it is typically one of the sectors with the highest material consumption rates. As noted earlier, there is significant difference in the level of development between countries in Africa. The level of industrial development inversely affects the material intensity of the economies. In countries with lower levels of industrial development, the import of processed materials for construction is common. Figure 2(a), shows the material consumption in Burkina Faso and Rwanda surpassing the regional average. This trend drives up costs and reduces affordability of goods for the poor. Material productivity is also linked to the economic output per unit of material consumed and Figure 2(b) shows that among the focus countries, Senegal produces significantly higher value from the materials consumed.

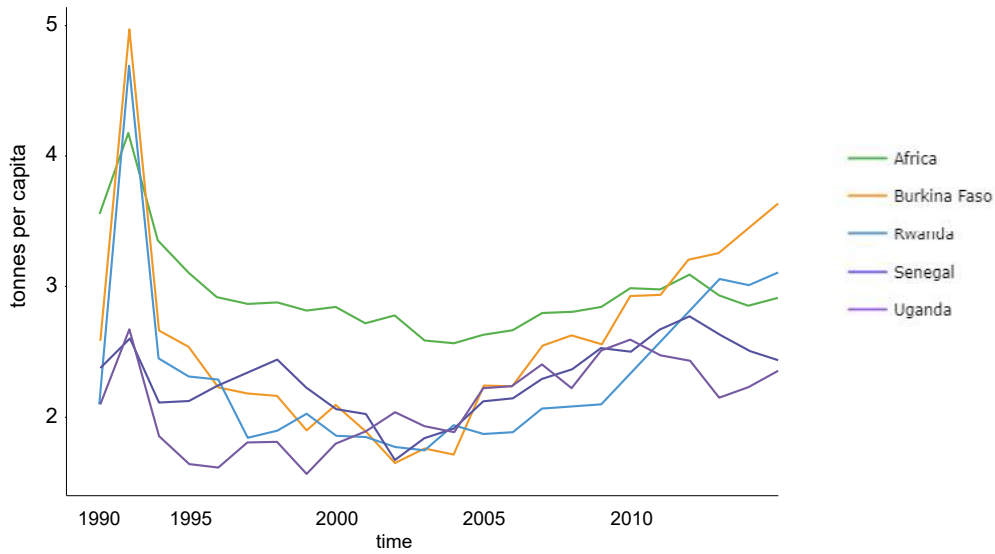


Figure 2a: Raw Material Consumption per capita

Source: <http://www.materialflows.net/>

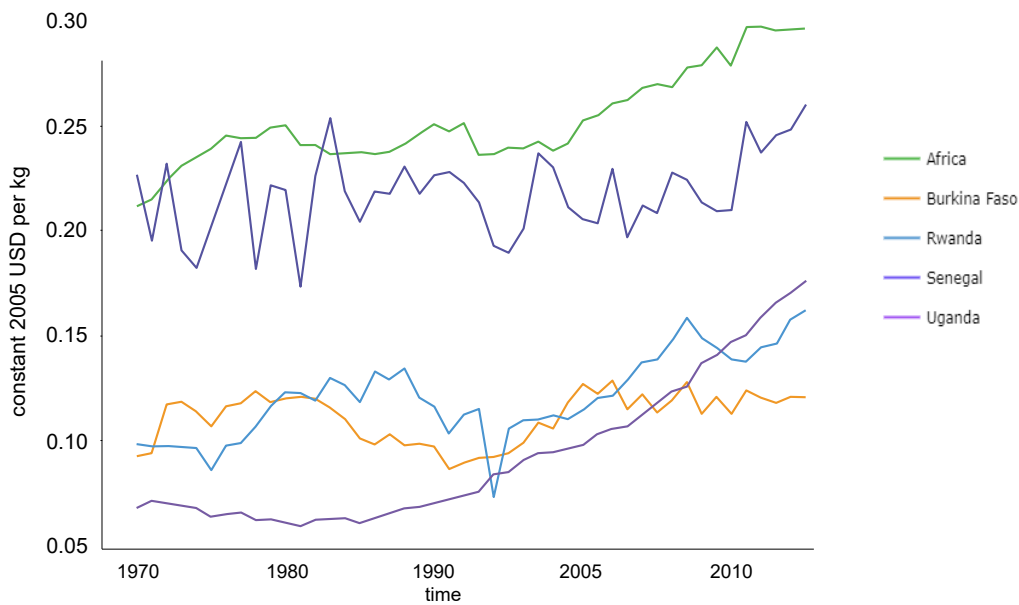


Figure 2b: Material Productivity (DMC).

Source: <http://www.materialflows.net/>

• **Unequal development across countries**

Largescale construction activities in Africa declined by about 15% in 2020 from the previous year, with considerable variation between countries. Almost half of total valued construction are taking place in Egypt, Nigeria and South Africa while less than 2% are in Central African countries. (Deloitte, 2020). Most of the mega-building projects are concentrated in Northern and Western Africa. Among these, buildings take up 35.8% of the total value (about US\$ 143 billion). The Covid-19 pandemic disrupted global supply chains, which affected construction in Africa through material and equipment shortages, since much of these are imported from outside the region.

- **Uncontrolled urban sprawl and informal settlements**

The rapid pace of urbanization in many African countries has meant a backlog in planning and delivery of adequate basic services, including housing. UN Habitat estimates that 55.9% of the African urban population live in slums, or informal housing. (UN Habitat, undated). Figure 3 shows this informality is most pronounced in Central and East African countries. These settlements consist of self-built homes, mainly using cheap and temporary materials. These have negative impacts on the quality of life of communities, the urban landscape and on the environment. To demonstrate the demand for reusable, inexpensive construction materials, there are salvage markets for such materials in most African cities.



Figure 3: Percentage of urban population living in slums.

(Source: World Bank data)

5. Environmental, social and economic impacts

5.1 Common building materials

All across Africa, the demand for building materials is increasing, to meet the infrastructure expansion during this period of rapid urbanization. Imported materials are often heavily taxed, (Construction Review, 2021) reducing their affordability for many. For a significant majority, local or recycled building materials are the only affordable option. The flows and impacts of some common building materials in the region are described below.

5.1.1 Clay (Bricks)

Brick production in Africa takes place at many scales, from individual builder-producer, making bricks for self-consumption, to registered companies mass producing for sale. Construction bricks are often locally produced, using local labor and raw materials. While the local scale of raw material extraction, production and use substantially reduces the embodied energy of the material, bricks need to be fired in kilns fuelled by fossil fuels. Different kilns perform at different levels of energy efficiency, with many makeshift kilns being the most inefficient. In addition, brick walls alone do not provide good thermal insulation, resulting in higher energy consumption during building operations for heating and cooling.

Where the volume of clay extraction for brick production is large, the resultant land degradation and water pollution negatively affects the local ecosystem and communities living nearby. Supervision and regulation of clay mining activities have been limited as such activities were mostly small-scale and informal. Where companies have been requested to rehabilitate mining sites, the common form of remediation has been to fill the pits with demolition rubble. (Fuyane, Athlopheng and Mulale, 2013). This exacerbates the environmental impacts at the mining pits. Clay production has generated employment, particularly in rural communities and small companies, where this is most needed. (Clay Brick Association, undated). For brick construction to keep expanding across Africa, governments and environmental organizations need to ensure the sustainability of clay extraction. The Clay Bricks Association supports members in Southern Africa with technical resources on improving the sustainability of brick construction through reducing carbon emissions in production and designing to enhance thermal insulation. (Clay Brick Association)

5.1.2. Earth

In many parts of Africa, construction with rammed earth or earth blocks is still commonly practiced. Earthen buildings are cheaper and better insulated compared with building envelopes made of materials such as concrete or brick. (Adegun and Adedeji, 2017). Earth structures also require minimal energy inputs during production. A major challenge with earthen buildings is the quality, and hence durability. Rammed earth and compressed earth blocks improve the durability and strength of earthen buildings. Stabilizers, such as gypsum, can also increase the quality of earth construction without significantly increasing the embodied carbon. Despite the numerous advantages of earth buildings, homeowners are reluctant to adopt the material due to the perception that it is backward and low in quality. People in wetter climates are less receptive to earth buildings (Bosman, G. and Van der Westhuizen, 2014). Earthen houses are more commonly found in rural areas where traditional materials and architecture are still widely practiced in many African countries.

RWANDA

Waste Management

The Government of Rwanda estimates that, in 2017, over 800 tonnes of municipal waste is generated each day in the capital city of Kigali (REMA, 2017), with less than half of this waste collected and transported to the city's sole landfill site for disposal (Institute of Rwanda Engineers, 2017). Some researchers project that daily municipal waste generation in Kigali could reach 1,300 tonnes by 2030 (Rajasheker, Bowers and Gatoni, 2019). Municipal waste in Kigali is made up of almost 70% of organic material, most of which is unsorted. Up to 12% of the waste in Kigali is recycled, mostly specific types of plastic and paper waste. One company, Agruni, is permitted to sort through the landfill, salvaging about 20 tonnes of recyclable materials each month (REMA, 2010).

Building materials

In Rwanda, over 30% of urban and rural households construct walls from mud bricks covered with cement mortar. The use of oven-fired bricks is also gradually increasing in popularity, about 8% of houses using these for walls.

5.1.3 Cement

With construction activities for buildings and infrastructure projects driving up demand for cement, African countries have been increasing production capacity over the past decade. However, cement producers in Africa face key challenges such as the high cost of energy, fragmented supply chains and competition from cheaper imports.

Tanzania, for example, has an annual production capacity of 10 million tonnes of cement, Kenya 13 million tonnes, South Africa 20 million tonnes, and Nigeria, the largest cement producer in Africa, 45 million tonnes (Construction Review, 2021).

Whilst some countries such as Mozambique and Uganda are rich in raw materials for cement production, other countries like Rwanda and Burundi face geological constraints that also affect the price of the cement. The cement industry of Africa has limited variety with ordinary Portland cement and limestone blended cement dominating the sector. (Schmidt et al., 2018).

Impacts of cement production in Senegal

Senegal is a cement producing country so concrete is cheap and commonly used for buildings, especially in urban areas. Compared with other traditional building materials, concrete blocks require much more energy to produce. Moreover, concrete buildings do not provide adequate insulation from the heat in the country, resulting in increased electricity usage for space cooling. *75% of Senegal's energy consumption and greenhouse gas emissions come from building-related activities* (Dione, 2019).

Limestone is a key material in cement production among the 3 major production companies in Senegal: Sococim, Le ciment du Sahel and Dangote. In 2002, Le ciment du Sahel started limestone mining in Bandia, a small town that is close to an hour's drive from Dakar. 20 limestone quarries were established around the protected baobab forest in the area. Overtime, the baobab forest degraded into barren craters due to the extensive mining activities. Local communities also complained about the pollution from cement dust and the resultant health impacts (Ngounou, 2019). There are similar reports on the large Dangote factory near Thies. (Dunya-Ethic, 2020) Despite these negative environmental and health impacts, cement factories bring jobs, roads and essential services to often underserved communities.

Communities with cement production factories have seen development in infrastructure, economy and education. Improving the roads makes the area more accessible which attracts more businesses and also boosts the transportation of people and local goods. Cement factories support the development of schools to educate their employees and families (Kusena, Shoko and Marambanyika, 2012). People in the local community are directly employed in the cement industry for example as truck loaders. In Senegal, Sococim industries creates 5 indirect jobs for every direct job in its cement plant (Vicat, undated). On the other hand, cement production has adverse environmental impacts such as pollution of air, water and soil with heavy metals (Ogedengbe and Oke, 2011). Communities around the plants have experienced a spike in diseases like bronchitis, asthma, tuberculosis and impaired vision, as well as contamination of hawked food (Etim et al. 2021). Despite the presence of three cement factories whose product is used in nearly 70% of construction, costs are known to be high in Senegal. This is also largely due to imported secondary materials, which account for 50% of costs. This is largely due to imported building materials, which account for 50% of costs. The majority of buildings are built with cement for the carcass and imported materials for the finishing touches. This makes the construction costs higher.

5.1.4 Steel

Steel is widely used in construction projects, particularly as reinforcing bars, which contributes to its demand in the building sector of Africa. Despite this, the quantity of steel is still limited. In 2019, the crude steel production in Africa was estimated at 17.1 Mt, while imports of steel products were 21.9 Mt. Egypt (7.3 Mt), South Africa (6.3 Mt) and Algeria (2.4 Mt) generate 94% of the continent's production, whereas the largest importers are Algeria (3.1 Mt), Nigeria (1.5 Mt) and Kenya (1.4 Mt) (World Steel, 2020).

Some of the challenges facing the steel sector include the low product quality and quantity, and shortage of raw materials. The limited availability of steel scrap, which is a major raw material, leads steel plants to resort to either low grade scrap, that produces low quality products or to import raw materials (Senfuka, Kirabira and Byaruhanga, 2011). Uganda imports 67.11% of the raw materials to meet its steel production needs (National Planning Authority, 2018).

The Steel Industry in Uganda

The construction industry accounted for 5.5% of Uganda's GDP in 2020. Numerous infrastructure projects such as dams on the Nile and oil development in the Albertine region, have escalated the consumption of steel in the country. In addition, Ugandan households are increasingly using iron sheet roofs, from 57% in 2000 to 75% in 2017 (Taylor, 2021).

Uganda's steel production currently stands at 585 000 tonnes per annum which is only 35% of the installed capacity. The country exports 30% of its iron and steel products to Tanzania, South Sudan, The Democratic Republic of Congo, Rwanda, Burundi and Central African Republic. Five hundred tonnes of iron core deposits in commercial quantities have been confirmed in the eastern and southwestern parts of the country (Rupiny, 2021). Despite this, steel manufacturing depends mainly on scrap as a raw material due to lack of a reducing agent for ore smelting. The limited availability of scrap leads manufacturers to resort either to low grade scrap, that produces low quality products or to import raw materials (Senfuka, Kirabira and Byaruhanga, 2018). Uganda imports 67.11% of the raw materials to meet its steel production needs. (NPA, 2018)

Even though steel plants provide employment and foster development of the local areas, tensions have risen between the plants and community, in particular due to pollution. Pollution of the rivers and soil threaten the very livelihood of the communities as most depend on fishing and agriculture. Complaints of the health implications from the black carbon emissions have forced the companies to operate at night (Saka and Busari, 2020).

5.1.5 Reused materials



Figure 4: Salvaged materials at resale market in Rwanda.

Photo: GGGI



Figure 5: Storage facility for resold materials in Burkina Faso.

Photo: GGGI

In all the focus countries for this study, there exist markets where salvaged construction materials are being sold for reuse. Some commonly resold materials include steel bars and pipes, metal sheeting and mesh, and window and door frames. This recovery and on selling of materials takes place at multiple scales, though it is mostly done informally, with no records of the volume of materials that is sold by each vendor. The group of metal resellers pictured in Figure 5 buy and sort the salvaged materials and sell to metal processing companies in Burkina Faso and neighbouring countries. The local material resale markets (as in Figure 4) cater more to small scale builders and homeowners constructing their own homes within the area. Despite the lack of quantifiable data, the salvage and reuse of building materials provides an important stream of affordable and reliable construction inputs for a significant group of builders in Africa. In Senegal, construction materials such as aluminium, steel, toilets, wood are sold and reused in secondhand markets such as "Parc Lambay". In the Mbeubeuss landfill, there are also waste pickers who live near the landfill to pick the most sellable items they can get to sell it in the market. Similar means of informal resource recovery were described by many stakeholders interviewed for this study.

5.2 Energy use in buildings

Energy consumption in Africa accounts for only 6% of the global level, even though the continent represents 16% of the world's population (IEA, 2019). The inequity is particularly acute in Sub-Saharan Africa where more than two thirds of the population (568 million people) lack access to modern energy (UNSTATS, 2021). This difference in access to electricity also plays out within countries, between urban and rural areas. Further breakdown in electricity access by country in Africa is found in the Annex. In some African countries, the variation in access to electricity between urban and rural communities is extremely stark, pointing to potential opportunities to promote renewable energy sources for electricity in rural areas. Without increased effort to expand access to electricity, the number of people living without modern energy in the region will keep growing. The International Energy Agency has identified renewable sources as a key enabler in meeting energy needs across the region.

Table 2: Energy overview for deep dive countries in Africa

Country	Burkina Faso	Rwanda	Senegal	Uganda
Population with access to electricity (2018) (IEA, 2019)	22%	53%	71%	56%
Carbon emission from energy consumption (2019) (EC, undated)	3.643 Mt CO ₂ /yr	1.153 Mt CO ₂ /yr	9.809 Mt CO ₂ /yr	5.340 Mt CO ₂ /yr
Increase in energy demand from buildings 1990-2019(IEA, 2019)	476%	13%	46%	306%
Percentage of primary energy needs met by renewable energy in 2018 (IRENA, 2021)	68%	85%	35%	92%
Carbon emission factor in 2019 (IRENA, 2018)	1009 tCO ₂ /GWh	275 tCO ₂ /GWh	1327 tCO ₂ /GWh	216 tCO ₂ /GWh
Annual PV output per unit of capacity (IRENA, 2021)	1800 kWh/kWp/yr	1600 kWh/kWp/yr	1800 kWh/kWp/yr	1800 kWh/kWp/yr
Percentage of land area for solar generation	75%	85%	90%	50%

From Table 2, Burkina Faso's high dependency on biomass for energy corresponds to the high proportion of population living in rural areas. The chart in Annex 1 shows that while access to electricity has improved in the country over the past decade, gains were overwhelming made in the urban areas. While 69% of urban population were connected to the power grid, only 2% of rural population had access to electricity. Electricity in Burkina Faso is mostly generated by fossil fuels imported from neighbouring countries, resulting in the high carbon emissions factor of the grid. The Government of Senegal has made immense efforts in recent years to expand grid connectivity across the country. The results of this effort shows in Table 2, with Senegal having the highest grid connectivity among the focus countries, despite significant disparity between rural and urban connectivity. National connectivity to electricity in Senegal is partially facilitated by the higher rate of urbanization compared with the other focus countries.

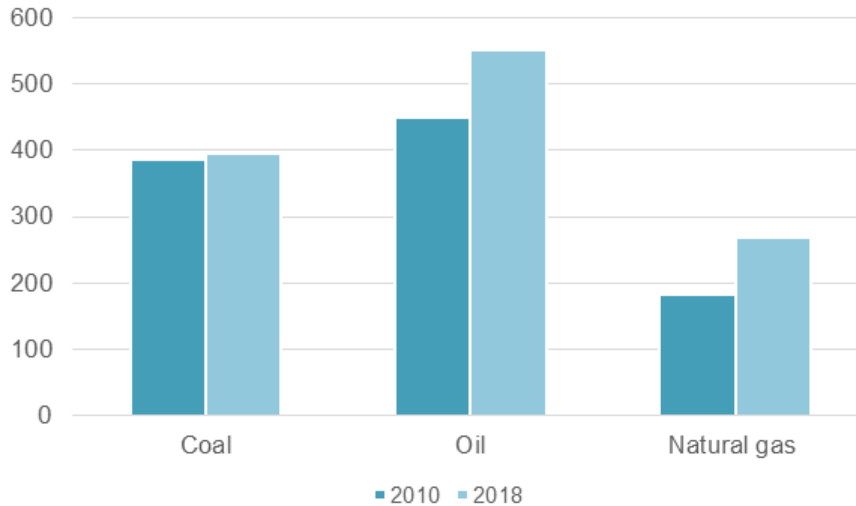


Figure 6: Total CO2 emissions in Africa
(IEA, 2019)

Similar to Burkina Faso, a large proportion of the populations in Rwanda and Uganda depend on burning biomass for the energy needs. Inferring from the case of Senegal, increased urbanization leads to reduced dependence on biomass for energy needs. Similar to Senegal, both countries have dramatically increased access to electricity over the last decade, though there is still much work to be done. The use of hydropower and other renewable sources for electricity generation maintains the carbon emission factor for heat and electricity generation in both Rwanda and Uganda relatively low. The key difference between Rwanda and Uganda's energy profile is in the growth in energy demand over the past 30 years. Both countries' economies grew over the period, however, more research is needed to explain how the energy consumption in the two countries differed so significantly.

In Africa, buildings alone consume over 50% of energy supply (UNEP, 2020), making it the biggest consumer of energy compared to other sectors. Table 2 shows Senegal with the highest carbon emission from energy use, among the deep dive countries for this study. Apart from the dependency on fossil fuels for power generation, it is also due to the larger extent of electrification in Senegal, compared with the other countries. As African countries work to expand access to electricity, the push for non-carbon energy sources needs to expand simultaneously to keep carbon emissions associated with energy demand from rising. As Figure 6 shows, the current push by governments, companies and development organizations to improve access to electricity in recent years has driven up CO2 emissions from fossil fuel consumption in Africa. With countries such as Burkina Faso and Uganda on their rapid growth phase in energy demand, the decarbonization of energy and introduction of new efficiencies can be strategic in mitigating CO2 emissions. The significant potential for electricity generation from renewable sources in many countries in Africa points to the immense opportunities for decarbonization of electricity generation to expand access, create jobs and reduce greenhouse gas emissions.

5.3 Water

Africa's transboundary river basins cover 64% of its land area and account for 93% of the total surface area of the continent (UNEP, 2010). One in three Africans is facing water shortages regardless of the abundant water resources. Water scarcity is particularly predominant in the arid northern part, as well as the southern and eastern parts of the continent. The central part that experiences tropical and equatorial climate has a significant amount of surface water (Mason, Nalamalapu and Corfee-Morlot, 2019).

Trends such as urbanization and population growth are exerting enormous pressure on water resources. In addition, climate change and poor management of water resources contribute to the high-water stress in the region. Africa’s water resources also face heavy pollution from waste and wastewater which limits the access to clean basic drinking water. All these challenges threaten not only health, but also agriculture on which 70% of Africans depend for their livelihoods (Biteye, 2016).

Table 3: Water overview of deep dive countries
(Aquastat, 2017)

Country	National Rainfall Index (mm/yr)	Renewable water resources (km3/yr)	Total water withdrawal (km3/yr)	Freshwater withdrawal as % of total renewable water resources	Water stress (%)	Water use efficiency (US \$/m3)
Burkina Faso	759	13.5	0.818	6.05	7.8	11.00
Rwanda	1052	13.3	0.184	1.38	6.1	31.52
Senegal	576	38.97	2.221	5.70	11.8	6.95
Uganda	1350	60.1	0.637	1.06	5.8	28.47

Table 3 provides the overview of access to and use of water resources in each of the focus countries. Countries receiving lower volumes of rainfall (Senegal, Burkina Faso) are also less efficient in the use of water. This is an issue of concern as water scarcity is anticipated to affect more people with the warming climate. In east Africa, where rainfall is abundant, there is less freshwater withdrawal. This is significant compared with the two focus countries in west Africa, where they receive less rainfall per year. Increased volume of freshwater withdrawal suggests a lower resilience to cope with prolonged periods of dry spells. For the interest of this study, the building sector, including material production, should focus on reducing water consumption in processes and to promote increased efficiency in water usage.

6. Policy mapping for circularity

The informal recycling and reuse of materials occurs widely across countries in Africa, even though the formalization of circularity is relatively new. In the continent, only Tunisia, Algeria, Egypt, Gabon, Kenya, Rwanda and Madagascar have national green growth plans which incorporate CE policies (Chatham House, 2020). In all these plans, buildings are mentioned, and in most cases, with reference to energy efficiency and sustainability of buildings. In the Nationally Determined Contributions submitted to the UNFCCC, Burkina Faso, Uganda, Rwanda and Senegal include commitments on buildings or housing, to improve aspects such as the use of local materials and energy efficiency.

The African Circular Economy Alliance is a government-led coalition of African countries working to mainstream circularity in economic development, ensuring environmental sustainability and inclusive benefits as countries progress. The alliance has identified the built environment as one of five key sectors where increased circularity can bring substantial benefits for the environment, economy and society for the region. This platform brings private sector and development partners in collaborating with governments and is supported by the African Development Bank.

6.1 Burkina Faso CE Policy Overview

In Burkina Faso, numerous commitments, policies and programmes exist that could promote circularity in the built environment, through material efficiency and energy decarbonization. These policies largely describe sustainability and waste minimization, but do not specifically describe how circularity could be integrated in the building and other sectors. More interventions are required to demonstrate how circularity can be mainstreamed throughout all phases of building life cycles. Increased experimentation will also be instrumental in identifying policy barriers, capacity gaps and opportunities for innovation.

Nationally Determined Contribution (NDC) (Government of Burkina Faso, 2021)

Burkina Faso submitted its First NDC in 2016 and updated this in 2021. In the updated NDC, the need for energy efficient cooling is considered through the promotion of local materials for the building envelope and energy efficiency in both urban and rural housing.

Environment Code (National Assembly of Burkina Faso, 2013)

The Environment Code of Burkina Faso establishes fundamental principles to preserve the environment and improve the living environment. These principles combat desertification and provide effective strategies for sanitation. They also aim to improve the living conditions of urban and rural populations, and to implement international agreements ratified by Burkina Faso on environmental preservation and disaster prevention and management. The Code requires the government to prevent and reduce the production of waste, including through reuse and recycling of materials. However, Construction and Demolition (C+D) waste was not listed as a waste stream regulated by this requirement. According to the Environment Code, activities likely to have a significant impact on the environment are assessed through a Strategic Environmental Assessment (SEA), an Environmental Impact Assessment (EIA) or an Environmental Impact Statement (EIS).

National Policy of Sustainable Development in Burkina Faso (NPSD) (Government of Burkina Faso, 2013)

The overarching framework for sustainable development is based on principles including intergenerational equity, precautionary and prevention of harm, full life cycle costing and sustainable production and consumption.

LOCOMAT: Programme d'Appui et de Valorisation des Matériaux Locaux (Local Materials Support and Valuation Programme) (Nko'o, 2006)

This government programme ran from 1997 – 2011 to promote local materials and reduce dependence on imported construction materials. Research was conducted to investigate local materials suitable for construction and the appropriate construction techniques. The project also included trainings on building with local materials for small businesses and awareness raising to generate demand from the general public.

Standardization of Compressed Earth Block by ABNORM (Burkinabe Agency for Standardization Metrology and Quality) (ABNORM, 2009)

In 2009, ABNORM published the compressed earth block standards for Burkina Faso. The standards broaden the range of applications of the compressed blocks without compromising on the quality and minimizing wastage of resources. These standards closely reference those developed by knowledge institutions (CDI and CRATerra EAG Basin, 1998). This points to

the importance of knowledge institutions in researching and disseminating information to be adapted and revised by developing countries.

Guidelines for the Implementation of the National Green Cities Policy in Burkina Faso (GGGI, 2019)

The Guidelines, developed with support from GGGI, include tools for institutional readiness, planning and developing an action plan for achieving green cities in Burkina Faso. Major challenges in the process are identified, with means of addressing challenges assessed for green jobs potential. The Guidelines highlight economic opportunities through sustainability urbanization to stimulate engagement from civil society.

6.2 Rwanda CE Policy Overview

In Rwanda, policies call for increased resource efficiency and offer guidance in water and energy conservation. The Building Code, in particular, includes specifications for energy and water usage in buildings and provides guidance for material efficiency.

National Green Growth and Climate Resilience Strategy (Republic of Rwanda, 2011)

This policy instrument addresses resource-efficient, low carbon and climate-resilient development for sustainable economic growth and poverty reduction. It promotes resource efficiency, in particular, water efficiency and conservation and material efficiency in buildings. National Environment and Climate Change Policy (Ministry of Environment of Rwanda, 2019) The policy identified fossil-fuel dependency, over-exploitation of natural ecosystems, lack of low-carbon materials for buildings and infrastructure development and inadequate waste treatment, among others, as key threats to sustainable development. It lays out the principles for addressing these threats.

Rwanda also has policies on the management of e-wastes and plastic waste.

National Housing Policy (Ministry of Infrastructure of Rwanda, 2015)

The Rwandan National Housing Policy calls for the use of local green building materials, use of renewable energy and the adoption of easy-to-construct designs for functionality and durability. Rainwater harvesting is also urged, especially from public buildings and other structures that require large amounts of water in their operations.

Rwanda Building Code (Republic of Rwanda, 2019)

The building code is aligned with the National Housing Policy and proposes incentives such as permit fee reductions, technical assistance, expedited permitting, rebates on environmental products and leasing assistance to promote green building practices. The code encourages the use of local materials and minimization of construction waste.

National Sanitation Policy Implementation Strategy (Ministry of Infrastructure of Rwanda, 2016)

The Rwanda Government targets to achieve a recycling rate amongst non-organic solid waste of 30% by 2019/2020 and 40% by 2029/30. It also aims to properly dispose of at least 30% (2019/2020) and 40% (2029/30) of non-organic solid waste.

6.3 Senegal CE Policy Overview

The Senegalese Association for Standardization (ASN) developed a set of standards for industry reference. These are not mandatory and include the following:

- Architectural, Building and Civil Engineering Drawings → 16 standards
- Construction materials and products → 44 standards
- Energy Efficiency → 30 standards
- Construction Techniques and Rules → 5 standards.
-

National Green Growth Strategy (GGGI, 2018)

National Green Growth Strategy developed to support the PES programme by implementing and developing recommended actions for green city development in pilot secondary cities.

Green Secondary City Development Guidelines (GGGI, 2019)

GGGI supported the Government of Senegal (GoS) to formulate the Senegal Green Secondary City Development Guidelines on how to develop green secondary cities. The roadmap for the implementation of the Guidelines details a development programme for 25 secondary cities across the country. The Guidelines are structured around five “pillars”: 1) Energy and Energy Efficiency, 2) Urban Mobility, 3) Land Use Planning, 4) Water and Sanitation and 5) Solid Waste Management.

Plan for an Emerging Senegal (PES) (MEPC, 2014)

This plan sets out development priorities for Senegal with the aim of poverty reduction. It defines a new economic model for the country based on just, timely and fair transition to a low-carbon, resource-efficient, and equitable economy.

Law n° 2008-43 of 20 August 2008 on the Urban Planning Code (Government of Senegal, 2008)

The ongoing updating of the Urban Planning and Building Codes integrates the principles of urban sustainability and energy efficiency in buildings to promote sustainable development.

Law 2001-01 of 15 January 2001 on the Environment Code (Government of Senegal, 2001)

The Environmental Code No 2001 complements the Construction Code. It addresses waste management through specific requirements on waste disposal and recycling. Senegal also has a separate policy banning single use plastics (Anti-plastic Law No. 2020-04.)

Law No. 2009-23 of 8 July 2009 on the Building Code (Government of Senegal, 2009)

The Code regulates relations between the real estate developer and the applicants for housing permits. In the Article R.36, the Code encourages the reduction of energy consumption for air conditioning and lighting, which constitutes an achievement from the perspective of promoting ecological construction in Senegal. There is no mention of material and resource circularity in the codes. The building code is being revised and the opportunity will be taken to integrate the principles of green building to encourage the decarbonization of the construction and property sectors and the greening of housing. The Directorate General of Construction and Housing is working with the World Bank on a building certification project.

Ministerial Decree No. 9317 establishing the organization and functioning of the National Greenhouse Gas Reduction Programme through energy efficiency in the building sector and related regulation (Government of Senegal, 2013)

Decree No. 9317 establishes the National Greenhouse Gas Reduction Programme through improving energy efficiency in the building sector. The overall objective of the programme is to develop energy-efficient practices in the residential and commercial buildings construction sector. The programme aims in particular at:

- increasing the number of energy efficient building construction projects using innovative building materials and practices;
- developing standards for energy efficient construction;
- increasing the number of construction professionals integrating the energy efficient building standards in their project design and construction process.

Senegal 100 000-housing units' Programme (CAHF, undated)

The “Senegal Zero Slum Programme” aims to eradicate slums by 2035 and prevent the creation of new slums. The cross-sectoral and multi-institutional programme aims to improve the living conditions of more than 500 000 households living in slums before 2035. Green building principles are integrated to the affordable housing units. Within the Government's 5-year programme, 100 000 housing units will be constructed in urban centers across the country to address the urgent housing gap.

Senegal Green Building readiness programme (GGGI, 2019)

In 2019, GGGI consulted with key stakeholders in Senegal to assess the opportunities for widespread delivery of green buildings in Senegal. This report identified the obstacles and barriers to the adoption of a green building policy in Senegal and made a series of recommendations to increase investment in the sector to facilitate the mainstreaming of green buildings in the country.

Energy Efficiency & Renewable Energy policies (ECREEE, 2015)

Through support from ECOWAS, Senegal developed a National Energy Efficiency Action Plan (PANER) and a National Renewable Energy Action Plan (PANEE) in 2015. In the same year, the Government developed the Senegal Energy Management Strategy (SMES). These documents describe a range of incentives and policy instruments to promote renewable energy and energy efficiency in Senegal. However, the building and transport sectors are not well-covered in policy guidance for increased efficiency (BA, 2018).

6.4 Uganda CE Policy overview

In its policies, the Government of Uganda recognizes the building sector as a strategic sector for addressing greenhouse gas reductions and resource efficiency. Several enabling tools are introduced in the policies that promote circularity and resource efficiency. These need to be operationalized by industry through increased government support.

Uganda National Housing Policy (MLHUD, 2016)

This policy addresses key issues around housing, such as adequacy of affordable housing, energy and resource efficiency and security of tenure for property owners. The policy also

touches on building materials and construction technologies. Locally available materials such as adobe clay bricks, soil stabilized bricks, fired clay bricks, granite, limestone, gypsum, cement, iron and steel are encouraged for housing. The policy promotes the creation of a building materials databank for local building materials. This databank should include design specifications and costs of materials to facilitate the use of local construction technologies that are energy efficient and preserve the environment.

Uganda has banned single use plastics in the National Environment Act; it has also adopted policies on e-waste and urban solid waste.

Uganda Green Growth Development Strategy (UGGDS) (National Planning Authority, 2017)

The Government of Uganda, with support from GGGI, developed the UGGDS focusing on 5 core areas, including green cities and energy. The Strategy details the development of 5 planned green cities including the Greater Kampala Metropolitan City (GKMC), Gulu, Mbarara, Hoima and Mbale, leading to 1.1 million tonnes reduction in GHG emissions from business as usual. The strategy promotes building energy efficiency, diversification of energy sources and improved waste management.

Uganda National Climate Change Policy (Ministry of Water and Environment, 2015)

This policy was developed to drive the country towards a low-carbon approach to sustainable development. Regarding the building environment, it emphasizes the utilization of alternative renewable energy, energy conservation and efficiency through passive designs, use of stabilized bricks and efficient brick kilns, It also highlights the importance of accounting for climate change in the national building code.

In the policies reviewed, all countries described a vision for a sustainable future. Many mentioned the need for adequate waste management, starting with waste reduction. Some countries discuss resource efficiency in more detail, covering energy and water efficiency and reuse. However, in the area of material circularity, there was no specific guidance on how this could be implemented in buildings. Policies and manuals assessed can provide more specifications on the various ways circularity can be practiced and encouraged in the building and construction sector.

6.5 *CASE STUDIES*

Introduction

Circular Built Environment case studies showcase good practices of various project types in different life cycle phases across various countries. Environmental, social and economic impacts in selected projects are explained, and related Sustainable Development Goals identified. Compact illustrated overviews of the case studies summarize their main challenges and success factors. In providing these examples, it is expected that they can be successfully replicated, adapted to different environments and scaled up. The SBC programme thanks the authors, experts and other stakeholders contributing to the collection and dissemination of the case study data.

Life Cycle Phase(s)



Webpage

https://www.oneplanetnetwork.org/sites/default/files/2021-11/SBC_cases_web_AFRICA_211102.pdf

Project type



Impacts



Related SDGs



Table 4: CBE Research Case Studies Overview

	Manufacture	Design	Build	Operation	Renovation	Deconstruction
Malawi	Ecokiln Efficient brick kiln					
Marocco	Casamémoire Heritage conservation					
South Africa	DigiYard Digital platform					
Nigeria	Primetech office building Resource efficient design and construction					
Burkina Faso	Hotel Dunia Local materials, resource circularity		Hotel Azalai Renovation, reuse		Compressed Earth Blocks Guidelines for standardization	
Rwanda	Modern Bricks EE brick kiln Strawtec Panels Materials from waste Adobe Bricks Guidelines for standardization		Rwanda Green Building Minimum Compliance Guidelines Policy – Part of Building Code promoting, EE, RE, water efficiency and recycled materials		Norrskén Kigali House Adaptive reuse, resource efficiency	
Senegal	Dangote Cement Efficient heating		Elementerre Design and construction using local materials		Allo Gravats C+D Waste recycling	
Uganda	Hima Cement Biomass fuel Stone Roofing Reusable stone tiles		Upcycle Africa Waste plastic for buildings		Nsambya Flexible use facility	

Hotel Dunia/ Loumbila Multi-Purpose Centre Burkina Faso, 2015-2018

Project type

New project



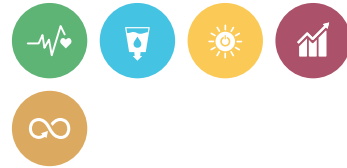
Impacts

Social impacts (human health and wellbeing), environmental impacts (energy use, water use, waste reduction), Green jobs and skills.



Related SDGs

SDG3, SDG6, SDG7, SDG8, SDG12



Life Cycle Phase(s)



Keywords

Material reuse, ecological construction, water reuse, local resources

Contact information

<https://www.croix-rouge.mc/wp-content/uploads/2018/05/croixrouge.pdf>

<https://www.croix-rouge.mc/en/inauguration-of-the-future-training-centre-in-loumbila-burkina-faso/>



Figure 7: Training Centre for Red Cross Burkina Faso

Credit: GGGI

Overview

In 2009, Red Cross Burkina Faso collaborated with the Monaco Red Cross to create a training center on a 6.5-hectare piece of land close to Ouagadougou. When the Monaco pavilion for Expo 2015 in Milan was deconstructed, the shipping containers used in the pavilion were shipped to Ouagadougou to form part of the Loumbila Multi-Purpose Centre. Within the Centre, the containers serve as a restaurant, a meeting/training room and 19 meeting rooms. Other buildings on the compound include 48 hotel rooms, a swimming pool and life-saving center, a 56kWh solar park and an organic gardening which provides for the restaurant.

The Multi-Purpose Centre also features water treatment and reuse: Gravel is used as an initial filter system, with secondary water piping and filter beneath the gravel. Wastewater is treated and reused for food garden and lawn irrigation.

Impacts

This Hotel and Training Centre contributes to the empowerment of local communities by creating jobs for the surrounding communities by providing hospitality training and promoting the production of organic food.

Replicability, scalability

The project designer is keen to replicate the design approach in other parts of West Africa to promote the reuse and recycling of building materials and minimize demand on other resources.

Main challenges

- Lack of skilled workforce for the hospitality sector among the local community. While the project aimed to create local jobs, the lack of suitable skills locally necessitated the establishment of a hotel training school within the facility.
- Difficulties in accessing project finance, coupled with political changes and general unrest in Burkina Faso, resulted in delays in construction.



Figure 8: Back view of reused containers for training centre

Credit: GGGI



Figure 9: Water filtration and treatment for reuse

Credit: GGGI

Standardization of Compressed Earth Blocks Burkina Faso, 2009

Project type

Government policy



Impacts

Capital costs, operation costs, environmental impacts (CO2 emissions, waste reduction), green jobs and skills



Related SDGs

SDG8, SDG12, SDG13



Life Cycle Phase(s)



Keywords

Low carbon materials, local resource, green jobs, affordable buildings, circular materials

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Figure 10: Construction project using CEB

Credit: Hassane Zoungana

Overview

Compressed earth blocks (CEB) are masonry units of regular and controlled characteristics obtained by static or dynamic earth compression. The properties of the CEB depend on the quality of the raw materials (soil, additive) and the expertise of the manufacturer (preparation, mixing, compression, cure). ABNORM (The Burkinabé Agency for Standardization, Metrology and Quality) established eight standardization codes for the manufacturing of compressed earth blocks to define the standards for manufacture and technical specifications of CEB and facilitate the widespread adoption of these as a building material.

ABNORM partnered local universities and businesses to develop the standards for CEB. These standards enabled local manufacturers to achieve a minimum performance standard for the CEB and to qualify for use in formal building projects.

Impacts

The standardization of the compressed earth blocks facilitated the quality assurance of locally manufactured compressed earth blocks. Construction companies are able to obtain a construction permit for formal building projects using CEB.

The standardization of CEB enhanced the innovation of compressed earth blocks manufacturing processes and promoted the use of CEB as an ecological construction material. The standardization of CEB also contributed to the creation of green jobs.

Replicability, scalability

This policy approach can be replicated in many other countries where local materials are not recognized in the building specifications due to lack of standardization. The introduction of production and design guidelines supports manufacturers in processing the local materials to meet standard specifications and formalizes the use of the materials, reducing reliance on imported, and often more processed, materials.

Main challenges

Many people prefer using cement bricks for the construction of their homes because of the conception that CEB is a material for poor people. The lack of demonstration projects further exacerbates this, as most government construction projects use concrete bricks rather than CEB.

Local manufacturers have difficulty securing funding for capital costs for the equipment to scale their manufacturing processes.

Main success factors

The standardization of CEB involved the inputs of partners from the building industry and universities. Inputs from researchers, manufacturers, builders, designers and developers enabled the government agency to develop a set of guidelines that was relevant for the Burkinabe context.



Figure 11: Zero waste interlocking CEB in construction

Credit: DSF Africa

Hotel Azalai, Burkina Faso, 2021-

Project type

Building (renovation)



Impacts

Environmental impact (waste reduction, material use efficiency, energy use), capital costs



Related SDGs

SDG7, SDG9, SDG11



Life Cycle Phase(s)



Keywords

Repair and reuse, heritage buildings, knowledge transfer, repair not demolish

Contact information

<https://www.croix-rouge.mc/wp-content/uploads/2018/05/croixrouge.pdf>

<https://www.croix-rouge.mc/en/inauguration-of-the-future-training-centre-in-loumbila-burkina-faso/>



Figure 12: Newly refurbished Hotel Azalai

Credit: GGGI

Overview

Hotel Azalai was constructed in Ouagadougou in 1960 and is regarded as an icon in the city. A significant part of the building was set on fire during the civil uprisings in 2014. After the uprising, it was deemed cheaper to repair and reuse the building, rather than rebuilding the hotel. Hotel Azalai is undergoing its second major refurbishment since its construction. This current renovation consists of 45% of refurbishment and 55% of reinforcement of the existing building. The entire complex has been reinforced with an additional structure to support the new floor slab.

The renovation works are led by a foreign and a local architectural firm, with a focus to maximize thermal comfort of the occupants and reduce the energy consumption. Foreign expertise had to be engaged as major repairs and refurbishments are not common in Burkina Faso.

Impacts

- Life span of the building extended through major refurbishment.
- Demolition and construction process fully complied with regulatory requirements, setting an example for other projects.
- Minimization of energy demand due to cooling because of the thermal insulation.

Replicability, scalability

Technical capacity is needed to manage repairs and refurbishment projects and to obtain the required refurbishment permit. Such expertise does not currently exist in Burkina Faso but can be built up over time. Trained professionals are also needed to assess the structural adequacy of damaged structures and suitability for repairs and refurbishment. Replicating this approach will extend the useful lives of buildings.

Main challenges

- Lack of local expertise for structural assessment – The project had to engage help from overseas to assess the adequacy of the existing structure to support the loading from the extension.
- Higher construction costs due to material and equipment taxes that had not been anticipated. These taxes were further increased during the (Covid-19) pandemic. While Hotel Azalai is eligible for tax exemption on certain materials, the administrative process is time-consuming.

Main success factors

- Government support in the project facilitated access to finance for the construction works.
- Engagement of foreign companies to work with local companies to provide technical guidance and capacity transfer.
- Careful selection of companies carrying out the refurbishment project (responsive companies allows us to avoid a lot of site issues by preventing them, there is a weekly meeting with the different companies working on this project).



Figure 13: Fire damage to building interior

Credit: Azalai Hotel



Figure 14: Vandalism and fire damage to courtyard

Credits: Azalai Hotel

EcoKiln, Malawi, 2015-

Project type

Material

Impacts

Operation costs, environmental impacts (material use efficiency, energy use, CO2 emissions, biodiversity), social impacts (women's empowerment), green jobs and skills

Related SDGs

SDG7, SDG9, SDG11



Life Cycle Phase(s)



Keywords

Energy efficient production, local resources, low carbon material, local jobs, good quality bricks, skills, technology transfer

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<http://www.cleantechmalawi.com/EcoKilnTechnology.aspx>

<https://www.tara.in/malawi.aspx>



Figure 15: EcoKiln constructed in Malawi.

Credit: Dr. Soumen Maity (Development Alternatives, TARA).

Overview

Many homes in Malawi are constructed with local bricks. These bricks are often irregular in shape and have poor strength. Constructing with poorly shaped bricks requires a significant volume of mortar and therefore a high consumption of cement. Poor quality bricks result in weak and unsafe structures with shorter life spans. Bricks in Malawi are produced in traditional clamps. The only fuel used to fire the bricks are fuelwood leading to deforestation in Malawi.

EcoKiln technology features an extremely energy efficient kiln fuelled by industrial waste such as waste biomass, tobacco dust and low-grade coal. The kiln produces minimal air pollution despite the use of coal. This reduces the pressure on forests that are the main source of wood fuel for producing bricks in Malawi. The presence of a roof on the kiln ensures production throughout the year. EcoKiln produces bricks that are standardized in shape and of high strength. Construction using EcoKiln bricks requires substantially less mortar as bricks are regular and smooth. Buildings are also faster to construct and more robust than using traditional bricks.

Impacts

- 1 demonstration kiln was constructed and presently operated by local communities.
- 3 commercial EcoKilns are being constructed and local communities are being trained in construction technologies and brick making.
- Through shifting the fuel of kilns to low quality coal and tobacco dust, the demand on forest timber to fire kilns is substantially reduced, with 270 tonnes of firewood saved through the project.
- The training of local labor, which made deliberate effort to engage women, has demonstrated the capacity and interest of women to be trained and engaged in income generating activities, including brickmaking. 145 people, including 50 women, were trained and employed.

Replicability

Organizations in Zambia, Kenya and Uganda have expressed interest to pilot EcoKiln. A feasibility for brick production in Uganda has been conducted by the TARA team. Within Malawi, there are 3 commercially-funded projects to construct EcoKilns. These investors are civil contractors, needing standardized brick sizes for construction. Any surplus bricks produced by the kilns will be sold. TARA will support the training of operators and masons for the new kilns.

Scalability

There is a GCF concept note in development phase to facilitate finance for EcoKiln scale up within Malawi. TARA is working with the government of Malawi to develop a policy for all new public construction to use energy efficient bricks.

The project aims to construct at least 8 EcoKilns in Malawi by 2022.

Main challenges

- SMEs face significant difficulties in accessing finance for capital costs to construct EcoKilns as they lack the collaterals required by banks.
- There is a low level of consistency and quality in construction in Malawi, making it difficult to find good masons and engineers to construct with EcoKiln bricks.
- Absence of standardized testing laboratories or anchor institutions for promotion of the technology in Malawi.
- Very low level of technical competence and understanding of scientific process of brick firing within the industry, hence trainings for setting up of EcoKilns need to start from the basics.

Main success factors

Technical solution (EcoKiln) addressed numerous challenges in Malawi – deforestation due to timber felling for kilns, poor quality of bricks and the need for employment creation. This enabled stakeholders advocating for the different issues to come together in support of this project.



Figure 16: Women and men trained in brickmaking in the EcoKiln demonstration project

Credit: Dr. Soumen Maity (Development Alternatives, TARA)

Casamémoire and Les Abattoirs, Morocco, 2009

Project type

Building repurpose



Impacts

Social impacts (wellbeing), new businesses, green jobs and skills, environmental impacts (waste reduction)



Related SDGs

SDG10, SDG11, SDG17



Life Cycle Phase(s)



Keywords

Heritage building, repurpose, urban renewal, partnerships, urban planning, urban space, cultural space.

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Figure 17: Les Abattoirs re-opened as a cultural space.

Overview

Casamémoire is a non-profit organization with the goal to safeguard the 20th century heritage in Casablanca, Morocco. As part of the mission of safeguarding and preserving the architectural heritage, the association works by sensitizing the general public and public institutions to the architectural heritage of Casablanca.

Les Abattoirs was constructed in 1922 and was one of the first reinforced concrete structures in Morocco. It operated as an abattoir for the city until approximately 2002 and was left unused since. The building was put up for redevelopment as it is located near a train station at the outskirts of Casablanca. Casamémoire advocated for the building to be registered as a national heritage, to prevent it from being demolished. It was necessary to reopen the building for usage to achieve the heritage listing. Casamémoire represented a collective of cultural actors to administer the cultural factory. The space is dedicated to urban arts and offers Casablancans a space for creativity and leisure. Cultural events include concerts, dances, theater, fashion shows, shootings, exhibitions, conferences, circus and workshops. These events drew tens of thousands of visitors to the area. Les Abattoirs was eventually listed as a national heritage building, safeguarding the building from demolition. The city government of Casablanca is currently preparing for the repair and retrofit of the building to extend its functional life as a cultural space.

Impacts

The building is located at the outskirts of the city and was disused for many years. The area around the building became neglected and marginalized. Reopening the building with dynamic cultural programmes attracted people back to the public space, bringing increased dynamism and economic activities to the neighbourhood. It also provided a space for performing artists of the city to perform and interact.

Replicability, scalability

This approach of retrofit and reuse for buildings is replicated by various organizations globally. The introduction of cultural and heritage perspectives in this project brings a more human dimension to the urban renewal project, beyond the usual technical approach.

Another aspect in this project that is replicable is the collaboration between multiple stakeholders. Casamémoire worked with performing artists, architects and city governments to effectively influence the urban development decision for the building.

Main challenges

Real estate developers disagreed with the proposal to conserve and reuse the building for cultural activities. They had plans for construction of residential blocks that were anticipated to raise the land value of the area.

The Ministry of National Territory Planning, Land Planning, Housing and City Policy did not initially support the proposal to recognise Les Abattoirs as a heritage building. Support from other entities such as the Order of Architects to advocate with the powerful ministry was sought. Due to lack of technical and financial resources and expertise it was difficult for Casamémoire to implement the rehabilitation of the building. The city of Casablanca is collaborating with the organization to mobilize financial and technical support to realize the rehabilitation of the building.

Main success factors

Casamémoire worked through the networks where they had influence, they advocated with the Ministry of Culture for the listing of the building as a heritage building, while they obtained the support of the Order of Architects to lobby with the Ministry of National Territory Planning, Land Planning, Housing and City Policy to change the urban development plans.

The collaboration with other entities in culture and performing arts and the positive reaction from the citizens and visitors provided momentum to change the development plans for the building.



Figure 18-19 (up & down, left): Images of Les Abattoirs in the past.

Figure 20 (up, right): Les Abattoirs re-opened as a cultural space.

Primetech Office Building, Nigeria, 2014

Project type

Building



Impacts

Operation costs, environmental impacts (material use efficiency, energy use, water use, waste reduction), social impacts (wellbeing)



Related SDGs

SDG6, SDG9, SDG11



Life Cycle Phase(s)



Keywords

Building certification, recycled content, local materials, resource efficiency, private sector leadership, green building, renewable energy

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Figure 21: Primetech office building

Credit: PrimeTech Design and Engineering Nigeria Ltd

Overview

PrimeTech Design and Engineering Nigeria Ltd. (PrimeTech) is part of the Julius Berger Group and the new office building is focused on principles of sustainability and efficiency. The office is situated in a brownfield industrial site in Nigeria. LEEDv4 requirements were followed during the design and construction phases for the project. Passive aspects such as building orientation, sun shading, foam glass insulation in walls and roofs were included in the design to reduce heat gain. In addition, a Building Management System (BMS) was incorporated to control and monitor the building's electrical systems. Motion sensors control lighting to optimize energy usage, while the solar panels on the roof provide 20% of the total energy used. High efficiency water fixtures used in the building reduce usage of portable water by over 60%. Minimum imported materials were used, while recycled content and local materials were prioritized.

During construction, the generated waste was separated into bins to facilitate recycling and reuse. The fine aggregates were covered up on the site to prevent dust pollution.

Material circularity strategies include:

- Utilizing recyclable materials (such as gypsum plaster board where available).
- Exploiting on-site runoff drainage to reduce water flowing into district sewage lines and replenishing ground water.
- Segregating construction waste to retain the value of the materials and facilitate reuse/recycling.
- Designing in grids aligned to material stock dimensions.

Impacts

Through the combination of active and passive means, 75% energy savings (measured from BMS) was achieved over the baseline for the operation of the office building.

This project demonstrates that renewable energy is economical in Nigeria. As the cost of public energy has increased over time, the payback period of the photovoltaic system has been reduced from 17years (2031) to 10yrs (2024).

Designing to minimize or eliminate construction waste became a core value for the firm on subsequent projects. Lessons on waste minimization from this project inform other projects in the company.

Replicability, scalability

Replication of the project and construction approach requires commitment from the project owners, starting from the design process. Primetech has integrated the lessons for construction waste minimization in subsequent projects,

Main challenges

Recycling is still developing in Nigeria, there are few registered recyclers. Construction waste ends up at authority-designated dump sites but high value waste such as steel and timber are quickly salvaged and reused or recycled.

Lack of QA for recycle and product certification incorporating recycle composites was a challenge to using locally recycled content for building certification.

Main success factors

The project was successfully completed due to the commitment of the company to develop the office building as a showpiece in sustainability. The Nigerian team of engineers also had access to technical support from overseas to complement the local skills and complement in analytical gaps.



Figure 22: Fine aggregates are covered to prevent air pollution

Credit: PrimeTech Design and Engineering Nigeria Ltd.



Figure 23: Sorting of construction waste on site

Credit: PrimeTech Design and Engineering Nigeria Ltd.

Modern Bricks, Rwanda, 2012-

Project type

Material

Impacts

Capital costs, operation costs, environmental impacts (CO2 emissions, waste reduction), new businesses, green jobs and skills

Related SDGs

SDG7, SDG8, SDG9, SDG11, SDG12



Life Cycle Phase(s)



Keywords

Low carbon materials, high quality bricks, circular material, energy efficiency, biowaste fuel, affordable buildings, cost savings

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Figure 24: Modern brick demand anticipation with in-situ brick production

Credit: SKAT Rwanda

Overview

The PROECCO Programme, implemented by SKAT Consulting funded by the Swiss Cooperation Agency, focused its attention in supporting the value chain of the Modern Brick. Modern Bricks are fabricated using various types of low carbon and energy-efficient technologies and biowaste for firing the kilns. The fuel is derived from local agricultural bi-products (sawdust, coffee husk, maize cobs among others) and is carbon neutral. The energy efficient kilns reduce energy requirement from 6MJ/KG from traditional firing to 1.2MJ/kg in modern kilns for brick production. At the end of the production units' life cycle the kiln can be dismantled and the material re-used. The clay extraction zone is rehabilitated and restored to previous conditions. Modern Bricks can be also re-used at the end of building life for new construction.

Walls from Modern bricks can be up to 40% lower in cost than the current traditional bricks and cement-based walls, when used in tandem with the Rowlock Bond (RLB) construction system promoted by SKAT/PROECCO. This system includes Rowlock bond/Cavity brick walls, low-cost maxspan™ slabs, and simple floor plans. Construction with Modern Bricks requires less mortar-cement and sand and minimal plastering. These add up to savings in labor and material costs and facilitates deconstruction and material reuse.

Impacts

6 Policies modified or adopted following inputs from PROECCO;

Since 2013, 44 entrepreneurs have invested in Modern Brick production and are now producing or are at the design stage, while 24 are producing independently of actual supply contracts. 22 new producers are at the planning stage.

58 real estate investors received support and guidance on the construction of Modern Brick construction systems. Additionally, 22 private real estate developers are committed to build 5390 dwelling units using Modern Brick's affordable housing system.

3 new urbanization projects in Rwanda are committed to plan and construct new neighborhoods using the technologies promoted by PROECCO;

Number of people trained: 21 in finance, administration and planning of modern brick and tile yards, 550 in brick making, 36 in management, 515 in masonry and 27 in machine operation, site management, kiln operation and quality control in the brickyard.

11.2 million/year additional Modern Bricks produced based on by PROECCO technologies

Constructed a 12-unit pilot building in partnership with City of Kigali using Modern Bricks.

Established 3 Infopoints across Rwanda in partnership with Rwanda Housing Authority to promote awareness on Modern Bricks. 27 residential units are currently under construction to pilot participatory re-housing schemes.

Replicability, scalability

All the expertise and know-how generated by the programme is fully open-source and it is designed to be replicated by limiting complexity of the design as much as possible.

Main challenges

Local manufacturers lack access to start-up capital to upgrade from traditional and more pollutive brickmaking facility to the semi-industrial kilns promoted by the Programme. Brick manufacturing is perceived as risky business by financial institutions as clay extraction window is limited to a few months each year.

Limited incentives provided to medium-level companies and extremely limited scale of traditional brickmakers which prevents scaling-up and improving their operations.

Lack of awareness and skills in the market to fully benefit from the construction technology in large scale real-estate project.

Main success factors

Substantial effort put in formalizing the value chain from the production to the construction, passing through the financial aspects, dramatically improved working conditions, product quality and effectiveness of the chain itself.

Continued training and capacity building activity ensured that both investors and workers had the appropriate skills to run the production processes while limiting risks and improving working conditions and business profitability.



Figure 25 & 26 (up & down, left):
Community driven informal settlement upgrade using modern bricks

Credits: SKAT Rwanda

Figure 27 (up, right): Semi-mechanized modern bricks

Credit: SKAT Rwanda

Norrskan Kigali House, Rwanda, 2018-

Project type

New project



Impacts

Operation costs, environmental impacts (energy use, water use, waste reduction), new businesses, green jobs and skills



Related SDGs

SDG7, SDG9, SDG11, SDG12



Life Cycle Phase(s)



Keywords

Deconstruction, material reuse, landscape conservation, multifunctional spaces, renewable energy, passive cooling.

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<https://massdesigngroup.org/work/design/norrskan-kigali-house>

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Figure 28: Renovated building installed with rooftop solar PV panels

Credit: Mass Design

Overview

Norrskén Kigali House is the largest innovation and entrepreneurship in East Africa, built on the old premises of the Ecole Belge in downtown Kigali. It is the first project in Rwanda to demonstrate such extensive materials and building reuse. Instead of demolishing the old classes built in 1938, their structure and reinforcing walls were maintained to extend the life span of the building. For the areas that had to be demolished, almost all the materials that were salvaged such as pavers, bricks, steel, etc, were either reintegrated into the design of the building or used in the landscape. The existing landscape was maintained, with buildings designed around trees.

New structures were designed in accordance with the principles of modularity and assembled as a bolted system to facilitate dismantling and repurpose at the end of life. 100% roof space is covered with solar PV panels and rainwater harvesting systems were incorporated. A passive cooling system leveraging the level difference between existing buildings and the street was implemented in the design to reduce need for mechanical cooling.

Impacts

- The project managed to re-use most of the materials from the old buildings
- The landscapes were maintained - existing trees were carefully removed and replanted where needed.
- The project sourced for key project materials within Rwanda and provided opportunities for training and job creation.

Replicability, scalability

The project can be replicated in Rwanda, though technical guidance would be required for local designers and builders to complete such a project.

Main challenges

Insufficient supply of FSC certified timber in Rwanda, leading to the importation of half of the required quantity of timber from Tanzania. The source in Tanzania was not FSC certified but they practiced sustainable forest management.

Difficulty in dismantling brick walls due to the cement-based mortar holding the bricks together. Cement (or other) stabilisers also prevent the direct reintegration of material into the ground. Designing with reused materials is challenging due to uncertainty whether the material will be salvaged well.

Seismic retrofitting is not a typical practice in Rwanda. The technology exists to do it but it has not been applied in this manner before.

The application of circular economy principles promotes standardization and modularity, however the building needs to meet the users' unique requirements.

Main success factors

Mass Design is a design and construction firm with extensive technical and sustainability expertise from local and foreign professionals. This mix of skills and exposure enabled the company to embark on this ambitious project, which is groundbreaking in numerous ways. As the first seismic retrofitting of a building in Rwanda, assumptions of the quality of the existing building were made based on selective investigations during design phase.



Figure 29: Old columns and structure maintained and strengthened

Credit: Mass Design



Figure 30: New Structures constructed around existing landscape

Credit: Mass Design.

Strawtec wall panels, Rwanda, 2015-

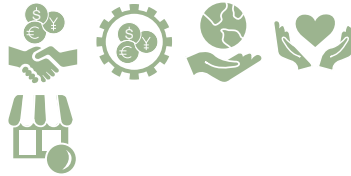
Project type

Material



Impacts

Capital costs, operation costs, environmental impacts (waste reduction), social impacts (wellbeing), new businesses



Related SDGs

SDG9, SDG11, SDG12



Life Cycle Phase(s)



Keywords

Low carbon material, biowaste, local industry, faster construction, affordable buildings

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<https://constructionreviewonline.com/products/strawtec-offers-alternative-common-cement-construction-market/>



Figure 31: Manufacturing process for straw panels

Credit: Strawtec Building Solutions

Overview

The Strawtec panels are manufactured by compressing rice and wheat straw, without chemical additives. After thermal combustion, they are wrapped in special recycled paper. The raw materials, as well as the production process produce nearly zero carbon emission, giving the straw panels very low carbon footprint. Building using straw panels is fast due to easy assembly leading to reduced construction time and costs. The houses are also cheaper than conventional building and thermally insulate the indoor space from the high tropical temperatures.

Impacts

- About 2000 people are directly or indirectly involved in the project through services like collection of straw, logistics and storage, ground handling etc.
- More than 15 big and medium scale projects have been completed using 120 000 m² of manufactured panels in the last 3 years.

Replicability, scalability

By expanding production facilities and installing other production line /-s, produced volume can be increased, limited only by the market offtake and total machinery capacity.

Main challenges

- Market (customer) perception of the use of modern natural construction materials
- Insufficient offtake amount reduces operational efficiency, hence increasing the cost of final products
- Low market capacity in development of green projects either by the state or investors (price prevails over environment concerns)

Main success factors

- This project prevents the burning of the biowaste, and rather use it to produce strawboard that contributes for a positive cause
- It creates jobs and additional increase to farmers through procurement and sourcing of locally available straw for production of panels
- The manufactured straw panels are a great substitution for imported goods, hence fostering economic development.



Figure 32: Rice straw bales collected from farmers

Credit: Strawtec Building Solutions



Figure 33: Strawtec panels ready for installation

Credit: Strawtec Building Solutions

Rwanda Green Building Minimum Compliance System Rwanda, 2019

Project type

Policy



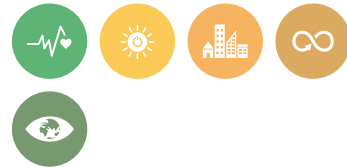
Impacts

Environmental impacts (energy use, water use, waste reduction), social impacts (wellbeing)



Related SDGs

SDG3, SDG7, SDG11, SDG12, SDG13



Life Cycle Phase(s)



Keywords

Green building, energy efficiency, water reuse, resource efficiency, passive design, low carbon materials, recycled content

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<https://gggi.org/report/rwanda-green-building-minimum-compliance-system/>

https://www.rha.gov.rw/fileadmin/user_upload/documents/General_documents/Laws_of_construction/Green_Building_Minimum_Compliance_System-Official_Gazette.pdf



Figure 34: Capacity building session for engineers on the Rwanda Green Building Minimum Compliance System

Credit: GGGI



Figure 35: RGBMCS Training for City of Kigali officials

Credit: GGGI

Overview

The Rwanda Green Building Minimum Compliance System (GBMCS) is developed as a holistic system with a set of green building indicators to guide building designers and practitioners to integrate energy & water efficiency, environmental protection, better indoor environmental quality and green innovation in new buildings during the design, construction and operational stage.

This policy emphasizes circular principles such as wastewater recycling and use of recycled content in the building materials. Compliance with GBMCS is mandatory and applies to new Category 4 & 5 buildings and major refurbishments as per Ministerial Order Determining Urban Planning and Building Regulations. The GBMCS is an Annex-3 to the Rwanda Building Code 2019.

Impacts

- Several new category 4 and 5 buildings across Rwanda are applying GBMCS during the design and construction phase
- Capacity building programmes have been organized to disseminate GBMCS among the professionals and numerous awareness initiatives such as animation videos and TV advertisements have been implemented for the public.

Replicability, scalability

The GBMCS can be developed to suit different country contexts and can be scaled-up to be applicable for all building categories.

Main challenges

- Need for a continuous capacity building programme to successfully enforce GBMCS
- Lack of financing within the lead institution-the Rwanda Housing Authority, to implement the system
- Low awareness among the public
- Perceived high cost of green buildings
- Low availability of green building products and technologies

Main success factors

- Strong commitment from the Rwanda Housing Authority and good collaboration with the Rwanda Green Building Council.
- Several new buildings by reputable architectural practices in Kigali are applying GBMCS in their projects. A few projects are going beyond GBMCS and applying for international green building certifications.
- GBMCS is seen as a key tool to reduce emissions from the buildings sector in Rwanda. Rwanda NDC and GGCRS refer to the GBMCS standard.
- GBMCS has been acknowledged by the 2019 Global Status Report for Buildings and Construction as one of the examples of building energy codes and the 2020 GlobalABC Regional Roadmap for Buildings and Construction in Africa as one the regional examples of policy action on new buildings

Standardization of adobe blocks (Rukarakara) Rwanda, 2019-2021

Project type

Material, policy



Impacts

Capital costs, operation costs, environmental impacts (CO2 emissions, waste reduction), new businesses



Related SDGs

SDG10, SDG11, SDG12, SDG17



Life Cycle Phase(s)



Keywords

Local materials, building with clay, low carbon materials, formalizing traditional methods, circular materials, standardization, affordable buildings, quality control

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Figure 36: Adobe block production process

Credit: Mass Designs

Overview

The Government of Rwanda has a strategy to transform housing in Rwanda to be safe, durable and affordable through standardizing construction with Adobe Blocks (Rukarakara), a common building material in Rwanda. Adobe bricks are made of a mix of soil and water and sometimes with a mix of grasses depending on the type of soil. They are affordable, locally available and environmentally sustainable. While these structures can be structurally stable and durable, many are poorly built and require a lot of maintenance. Without standardization and guidelines, it was challenging to gauge the adequacy of buildings using the traditional material. Adobe blocks do not require chemical stabilizers and can be reintegrated to the soil after use.

The Rwanda Housing Authority established the Local Building Materials Think Tank, bringing together stakeholders with complementary expertise to review ways to standardize construction with adobe blocks, also known as Rukarakara in Rwanda. Rigorous soil testing and brick making methods were trialed by the group. The Think Tank eventually published the Rwanda Standard for Adobe Blocks and Technical Guidelines on Adobe Block Construction in Rwanda. Together, these standards provide quality guidance for the brickmaking and construction processes.

The standard is under review by RSB who are targeting the release at the end of 2021, and dissemination of the Technical Guidelines will also start before the end of 2021.

Impacts

Publication of the two standards provide useful guidance for self-builders and informal builders to demonstrate structural adequacy using the local material they are familiar with. The publications also provide guidance on ways to improve the strength and durability of adobe blocks, enabling home builders to build stronger houses.

Replication

Earth blocks are widely researched and much of this guidance is based on global literature and transferrable to other contexts. Soil types vary by region within Rwanda and outside of Rwanda so a certain amount of testing will always be required – instructions for field tests are included in the guidance. However, before replicating elsewhere, it is always important to first review existing practices.

Scalability

Key to scaling up the application of guidance in the publications is to disseminate the content through hands-on training across Rwanda. The dissemination process aims to raise awareness among the general population (especially local leaders and construction industry stakeholders), organise masons into cooperatives who will be certified to build with rukarakara, incorporate guidelines for rukarakara into curricula at masonry TVETs country-wide, and most importantly certify masons across the country by providing practical training on the guidelines. Pilot houses will also be constructed across the country.

Main challenges

Soil quality varies in different regions of Rwanda, so the documents try to account for this variety through field testing. The document also provides guidance on methods to improve soils that do not meet quality requirements, to enable builders in different regions to build with adobe blocks.

Most informal and self-builder do not have access to testing facilities to verify the strength of the bricks. The guidelines had to develop soil and block testing strategies that could be administered in the field. Testing procedures are illustrated in simple diagrams and videos to facilitate learning.

Rwanda is moderately seismic and adobe homes are vulnerable to collapse. Balancing engineering methods to resist earthquakes and the cost of implementation was challenging especially when failure of buildings could lead to fatalities.

Main success factors

The leadership provided by the Rwandan Housing Authority enabled different stakeholders from industry, civil society and universities to collaborate effectively on producing the technical documents.

The collaboration of stakeholders with different areas of technical expertise and experience of local construction practices ensured that the guidelines developed have universal applicability across the country.

Dangote Cement Production, Senegal, 2014-

Project type

Business, material



Impacts

Environmental impacts
(energy use, CO2 emissions)



Related SDGs

SDG8, SDG9, SDG11,
SDG12, SDG13



Life Cycle Phase(s)



Keywords

Energy efficiency, alternative fuels, decarbonization

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<https://dangotecement.com/wp-content/uploads/2021/05/Dangote-Cement-PlcAnnual-Report-and-Accounts-2020-interactive.pdf>

<https://dangotecement.com/social/>

Overview

Dangote Cement Plc is a leading cement manufacturing company in Sub-Saharan Africa's, with a production capacity of 48.6 million tonnes per year across ten countries including Senegal. Dangote cement plants are mostly designed to be energy efficient using cutting edge technology in cement production by adopting the 7 Sustainability Pillars – institutional, social, economic, financial, environmental, operational, and cultural sustainability.

Dangote uses large, modern rotary kilns equipped with 'preheaters' that use exhaust gases from the kiln to heat raw materials as they pass down the preheater tower to the kiln. Through using waste heat, the raw material is heated to about 900oC before it enters the kiln, thus reducing its time in the kiln itself and the amount of fuel needed to convert it into a clinker. This reduces costs and carbon emissions from the production process. The company is exploring the use of alternative fuels in kilns, using construction and demolition waste produced on site, including old tires and packaging materials.

Impacts

- 456 employees engaged in learning and development initiatives in Senegal
- 1,210 jobs created in Senegal
- Constructed and donated a fully equipped school to Galane community, Keur Moussa
- Invested nearly one billion FCFA (approximately US\$2 million), to improve infrastructure and social amenities in Galane.

Replicability, scalability

The use of alternative energy in the cement production, began with the Nigerian operations, and by the end of the first year of pilot, it was already being replicated across other African operations such as Senegal through co-processing of wastes. Engineering of a modular concept for both short (pneumatic) and long-term (multi-fuel) alternative fuel feeding systems can also be replicated across kilns in all plant operations.

Main challenges

One challenge is the limitations in sourcing of specific goods and services locally. When these are not available in Senegal, the company has to import the materials and equipment. This has led to delays in the commissioning of various industrial equipment coming through the port of Dakar.

Another challenge is in keeping the energy and water consumption, as well as CO₂ emissions down while increasing cement production every year to meet demand.

Main success factors

Company commitment to the SDGs and adoption of the sustainability pillars in business operations. The company further developed an Alternative Fuel (AF) Project Charter detailing the roadmap and milestones for the AF Strategy. As part of the AF Strategy, Dangote developed in-house co-processing systems and equipment to enable the use of alternative fuels in cement production.

Allô Gravats, Senegal, 2020-

Project type

Government programme



Impacts

Environmental impacts (waste reduction), social impacts (wellbeing), green jobs and skills, new businesses



Related SDGs

SDG8, SDG9, SDG11, SDG12, SDG13



Life Cycle Phase(s)



Keywords

Construction demolition waste, recycled materials, road construction

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https://www.ucg.gouv.sn/docsucg/detail_actu_ucg.php

https://www.ucg.gouv.sn/img/JOURNAL_ELECTRONIQUE_V6.pdf



Figure 37: Paving stones from recycled material at Santenaire, Dakar

Credit: GGGI

Overview

Allô Gravats is a construction and demolition waste removal initiative initiated by the Senegalese government. Companies, communities and individuals can access the digital customer service platform and make a request for debris removal. Allô Gravats removes the waste for a fee and transports it to a recycling facility where the waste is sorted and recycled. The facility uses construction and demolition waste and sand from desilting for road infilling and the manufacture of pavement blocks.

The removal of rubble from urban spaces prevents the accumulation of vectors and spreading of diseases while improving the urban environment. Allô Gravats also results in reduced pressure on waste disposal facilities as building waste is diverted from landfills, hence extending their operational life spans. These waste gravel and stones are crushed and used as road fillers or mixed with sand and stabilizers to form paver blocks. Through recycling and reusing of construction waste, Allô Gravats introduces an environmentally sustainable way of managing construction and demolition waste materials. In the process, it improves the conditions of driveways and pedestrian walkways, as well as contributes to an increase in economic activities in recycling industries.

Impacts

Since June 2020, the initiative has progressively removed construction and demolition waste from the public areas of Dakar, improving the urban environment.

- Public sensitization - 43 clean-up stations dedicated to raising awareness of safety measures when processing construction and demolition waste for reuse.
- 492 regulatory garbage cans have been distributed across the country.
- Allô Gravats responded to calls for building waste removal across Dakar, renewing public spaces and improving health and safety conditions in the streets.
- Substantial volume of solid waste was diverted from the landfills, extending their operational life spans.
- Salvaged materials were reused for road infill and paver block manufacture. As the cost of maintenance for concrete roads is high, the project contributes to the maintenance of such roads, extending the durability of the infrastructure.
- 4.5 km of landfill driveway redeveloped using recycled material collected by Allô Gravats, reducing the average truck dwell time at the landfill from 45 to 30 minutes.
- The paving stones manufactured with recycled gravel are durable and strong, easy to maintain, and environmentally friendly. The company has installed paving stones in 3 neighborhoods in Dakar that are prone to flooding improving mobility for the local communities.
- 3 550 people are currently employed with Allô Gravats, including those working at the recycling facility.

Replicability, scalability

This government-led initiative is already being replicated in other regions in Senegal. However, in regions outside the capital city, it will take longer to introduce Allô Gravats as a paid service as income levels are much lower.

Main challenges

One of the main challenges was the lack investment in procuring suitable machinery for efficiently crushing C+D waste into paving stones. Only low powered crushers were available, resulting in longer time needed for processing the waste before reuse.

Some companies find it expensive to pay for Allô Gravats and choose to engage other waste disposal companies at lower cost. However, such companies may not always dispose of the waste responsibly. Very often, waste removal companies salvage reusable materials from the construction and demolition waste picked up and dump the remaining materials at unregulated sites.

Main success factors

Government-led programme with alignment to wider urban development policies ensure coherence in public messaging and resources for expansion to other cities. Through this programme, the Government of Senegal also plans to establish a legal entity focused on waste management to mainstream circular economy across the country. The entity will develop and implement a country strategy for integrated sustainable solid waste management, including to nurturing an industry focused on waste treatment and resource recovery.

Elementerre, Senegal, 2010-

Project type

Business



Impacts

Operation costs, environmental impacts (CO2 emissions, energy use, water use), social impacts (wellbeing), new business, green jobs and skills



Related SDGs

SDG8, SDG12, SDG13



Life Cycle Phase(s)



Keywords

Low carbon materials, circular materials, local resources, affordable buildings

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<https://www.construction21.org/france/articles/h/construction-terre-crue-au-senegal.html>



Figure 38: Hotel Djoloj in Dakar

Credit: GGGI



Figure 39: Earth-typha ecopavilion of Diamniadio

Credit: GGGI

Overview

Elementerre is a Senegalese company designing and constructing earth buildings using locally abundant types of clays and fibers to optimize the performance of the buildings. The company adapts traditional construction techniques and improves them using materials such as BTC (compressed earth brick) and insulation blocks made of typha. Constructions from Elementerre are well adapted to the local climate and provide thermal comfort to the occupants without reliance on air conditioning. Over time, Elementerre aims to develop, democratize, the sector of eco-construction in Africa by producing ecological building materials “ready to use” at commercial scale, including raw earth bricks, insulating panels in Typha and breeze blocks in typha.

Impacts

Elementerre trains workers to manufacture building materials with local raw materials. Further employment opportunities are created in the construction process of buildings ranging from individual villas to buildings such as school facilities and health structures.

The company uses less energy and water during the material production and building construction processes, compared with buildings constructed of concrete, iron and steel.

The earth used in construction can be reused after demolition unless it is mixed with cement. In this way, Elementerre contributes to environmental protection, but also to job creation, by training workers in ecological construction techniques.

Replicability, scalability

Elementerre has been conducting design and material production trainings for companies in Guinea, where a similar approach to bioclimatic buildings is applicable.

Main challenges

The use of local materials for construction is not yet well developed in Senegal. For example, the supply chain does not yet exist to ensure a steady supply of typha and clay. This makes the production process challenging and time consuming.

Main success factors

Elementerre builds on traditional construction techniques and local resources to create buildings that are attractive, cost effective and comfortable. While these methods and materials are not new to Senegal, the integration of ecological design principles provide a modern twist to the buildings, making them more attractive to buyers.

Digiyard, South Africa, 2018-

Project type

Phone-based application



Impacts

Capital costs, environmental impacts (waste reduction), social impacts (wellbeing), new businesses, green jobs and skills



Related SDGs

SDG1, SDG11, SDG17



Life Cycle Phase(s)



Keywords

Digital technology, informal networks, material circularity, community empowerment, affordable housing, waste reduction

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Figure 40: Informal builder with truckload of timber

Credit: Arup Digiyard team

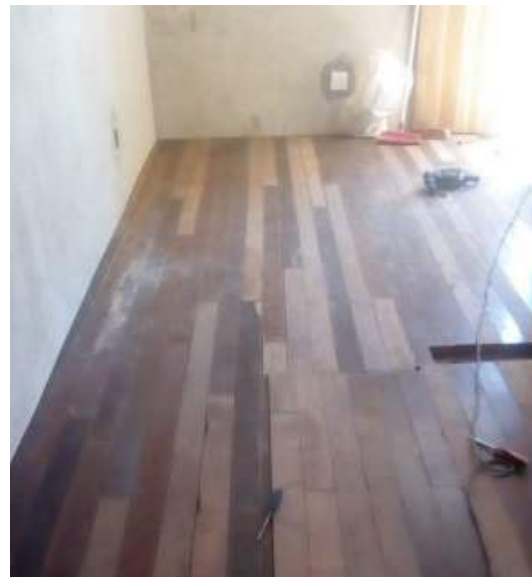


Figure 41: Timber installed with support from in-app instructions

Credit: Arup Digiyard team

Overview

DigiYard is a phone-based platform that links small scale, and often informal, builders with surplus building materials from construction sites. The application enables builders in South African townships to obtain good quality building materials at low-cost and to access trainings on safe construction methods and proper installation of building components. It also prevents the construction waste from larger sites from being sent to landfills. The application is free to use and is currently in pilot and development phase.

For construction managers, it provides a quick and cost-effective outlet for surplus construction materials. These are often sent to landfill and incur transport and landfill costs. These materials are unused, of good quality and often under some form of manufacturer warranty.

For informal builders, Digiyard enables them to secure building materials at affordable prices. The application further provides guidance on construction methods and proper use of materials, to improve skills and ensure that homes are well-constructed. The enhanced access to affordable and quality materials promotes construction activities among lower-income households and creates jobs.

For the city, the application has the potential to generate jobs in new areas such as material delivery, warehouse management and logistics. Improved quality of self-built housing reduces fire risk and other safety hazards in townships. The diversion of construction waste materials from landfill sites reduces pressure on the sites, extending their life spans.

Impacts

Business case validation: Project confirmed that construction firms are willing and keen to donate unused construction materials and that informal builders are able and willing to pay a small amount for the materials.

Communities mobilized to support the transport of materials and construction of houses in townships. Well-built houses improve the safety of townships and create jobs within the local community.

Phone based training resources: Capacity development for informal builders delivered through training modules on the platform and other printed guidelines on construction methods.

Replicability, scalability

The application can be replicated across cities and countries, especially where there are large pockets of disadvantaged communities, in need of affordable good quality building materials. The project is scalable to an extent, however there are logistical gaps that need to be addressed to enable larger numbers of users to donate and access materials through the platform. Notably, the pilot demonstrated the need to provide storage and transportation services to enable flexibility between the time and volume of material donation and collection.

Main challenges

Logistics gaps – short term storage space. Companies need the rapid removal of large volumes of donated materials from construction sites but recipients need time to get the site ready for the materials. Sometimes, donations are in quantities too large for a single recipient.

Logistics gaps – transportation. Informal builders do not always have access to transportation to move materials. The project

Skills and knowledge gaps in informal builders to correctly install or apply some of the donated materials. This needed to be addressed to ensure perverse outcomes such as unsafe installations or illegal disposal of donated materials do not arise.

Main success factors

The pilot project was successful due to successful partnership between Arup (the project owner), the city official and local organizations.

Upcycle Africa, Uganda, 2015-

Project type

Organisation



Impacts

Capital costs, environmental impacts (waste reduction, biodiversity), new business, green jobs and skills



Related SDGs

SDG1, SDG9, SDG12, SDG13, SDG17



Life Cycle Phase(s)



Keywords

Construction and demolition waste management, adaptability, flexibility and refurbishment of buildings and neighbourhoods, use of reused or recycled content in new products and buildings, reconstruction

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<https://upcycleafrica.org/>



Figure 42: Residential flat from compacted bottles

Credit:GGGI



Figure 43: House with reused tyres for roofing

Credit:GGGI

Overview

Upcycle is an organization that is building affordable housing from soil compacted plastic bottles. Marginalized youth and women are trained and employed to collect empty bottles, compact soil into them and construct the houses. The houses are low cost, seismic resistant, durable, and heat-insulating. The compacted bottles are an alternative to burnt bricks whose production process leads to deforestation and emits enormous carbon during heating. The project also has a waste picking programme where plastics are collected and either repurposed or sold to recyclers.

Impacts

- Over 3,000,000 bottles have been recovered
- Over 100 tonnes of plastic have been repurposed
- 117 eco houses have been built
- Over 2 million people have been sensitized on the dangers of plastics and alternative solutions. This is done through social media platforms, radios, brochures and local meetings.

Replicability, scalability

Plastic bottles are found abundantly in the waste stream in Uganda. It is estimated that Uganda consumes 600 tonnes of plastic a day (majority of which is plastic bottles) yet only 6% of this is collected, hence this creates a huge potential for replicability.

Main challenges

Changing people's mindset towards appreciating the use of compacted bottles for walls. Currently, 90% of the operations are in remote areas that have limited access to waste plastic bottles and other building materials which makes it expensive to transport them from the towns.

Main success factors

Support from international agencies such as IKEA foundation and AUDI the SDG 2030 Agenda. Media publicity which has helped to advertise the work to both the local and international scene. These media houses include both on the local (NTV, Urban, Bukedde, Spark) and the international scene (Aljazeera, DW)

Nsambya Youth Sharing Hall, Uganda, 1977-

Project type

Business / facility



Impacts

Operational cost, environmental impact, social impact



Related SDGs

SDG4, SDG8, SDG12, SDG13



Life Cycle Phase(s)



Keywords

Multi-use space, community space, community empowerment

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Figure 44: Hall being used for learning. The court lines for sports can be seen

Credit: GGGI



Figure 45: Nsambya Youth Sharing Hall

Credit: GGGI

Overview

Nsambya Sharing Youth Centre is a facility designed for multi-use of spaces, comprising three major buildings (main hall, conference hall and the library). It is the only public hall facility serving the 300,000 residents in the slum of Nsambya. The open space design of the main building and conference hall allows the facility to be used for several purposes. These include wedding receptions, graduation ceremonies, training workshops, spiritual seminars, public lectures, political rallies, music concerts and launches, indoor games among others with the sitting capacity of 800-1000 people depending on the sitting arrangement at an affordable fee.

Impacts

- USD 350 monthly savings on water and electricity.
- Provision of a space to engage the youth in sports.

Replicability, scalability

Other facilities in Kampala such as the UMA multi-purpose hall and the Lugogo indoor stadium were constructed based on the model of Nsambya Youth Sharing Hall. A new branch of the youth sharing hall is to be constructed in Arua district.

Main challenges

- The Ministry of Education policy requires that for such a facility to qualify as an institution of learning, there should be a required number of separated classrooms for different subjects, therefore limiting the use of the same space for learning.
- Cultural challenges especially with spiritual denominations that are not comfortable using the same space as other faiths.

Main success factors

The affordable fees, as well as the proximity of the facility to the city with good transport access makes it a desirable venue for different functions.

Hima cement, Uganda, 1999-

Project type

Material



Impacts

Environmental impacts (waste reduction, CO2 emissions, energy use), green jobs and skills, new businesses



Related SDGs

SDG1, SDG7, SDG8, SDG9, SDG12, SDG13, SDG17



Life Cycle Phase(s)



Keywords

Alternative fuels, renewable energy, biowaste fuel, waste to resource

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<https://www.cemnet.com/News/story/149544/uganda-hima-cement-turns-to-husks-to-power-kilns.html>



Figure 46: Artificial gypsum

Credit: Hima Cement

Overview

Hima cement is one of the leading cement manufacturers in Uganda with a total production capacity of 1.7 million tonnes. The company has a 65% thermal energy substitution rate with renewable energy (55% from biomass and 10% is from waste recycled fuels), making it the largest users in Middle East Africa of renewable energy in the production line. The biomass comprises coffee husks, rice husks, ground nut husks, palm kernels and saw dust while sources for waste recycled fuels include: waste car tyres, waste or used automotive oils. At

the same time, Hima cement is reusing artificial gypsum, which is a waste product from some industries (such as kitchen ware, toilet & bathroom etc.) to supplement the imported gypsum for the cement production process. The kilns of factory are integrated to enable co-processing of waste materials, such as glass, plastic, paper, filtering aid, filtering cake and waste paint to make clinker.

Impacts

- Reduction of the carbon footprint. 70,000 tonnes of carbon are reduced annually.
- Creation of employment for farmers, millers and trade agents, in the bio economy
- Approximately USD 32 million was earned by farmers from the Hima Coffee Project. This project was created to increase sourcing for coffee husks for the kilns.

Replicability, scalability

Hima cement has introduced a similar production approach for its new plant. However, the proportion of energy generated through biomass is lower than the original plant while local supply chains for fuels are being established.

Main challenges

The supply of coffee husks is seasonal. High supply is during the harvesting season. During the low-supply season, biomass has to be sourced from Tanzania and DRC.

Main success factors

Good supply of coffee husks from the Hima Coffee Project. Hima distributed 16.7 million coffee seedlings to 45,000 farmers in the Rwenzori region so as to increase their sourcing for biomass.

Dedicated staff made up of 90% Ugandans.

Partnerships with Uganda Coffee Development Authority, Geocycle, Vivo Energy and Total Energy that supply waste.



Figure 47: Coffee husks in the warehouse

Credit: Hima Cement

Stone Roofing, Uganda, 2008-

Project type

Material

Impacts

Capital costs, environmental impacts (CO2 emissions), new businesses, green jobs and skills

Related SDGs

SDG8, SDG9, SDG12, SDG13



Life Cycle Phase(s)



Keywords

Local resource, low carbon materials, job creation

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https://www.youtube.com/watch?v=sssZQscpizY&ab_channel=UrbanTVUganda

<https://www.newvision.co.ug/articledetails/112338>



Figure 48: Bungalow with stone roofing

Credit: Stone Roofing Ltd

Overview

Stone roofing Uganda is a construction company which specializes in durable roofing for houses using pers-stone of 10 mm thickness. The roof is lighter and cheaper than clay tiles, and can easily be cleaned. The excavation and preparation of the stone roofing material does not require machinery hence reducing the carbon footprint. The stones are also water and fire resistant in addition to being self-regulating (warm during cold weather and cool during hot days). At the end of the building's life cycle, the stones can be salvaged and reused in new projects.

Impacts

Establishment of the Stone Roofing International Perfection Institute where 200 youth have been trained at various levels of the production lines such as excavation, transportation, preparation and accessories.

20% savings in roofing costs in comparison to clay tiles

Replicability, scalability

The roofing technology is simple without any special equipment making it easily replicable, however, it depends on the presence of suitable raw materials.

Main challenges

High costs of loading and transporting stones from the quarries due to poor transport infrastructure.

Reluctance of the market to adopt new alternative roofing. People prefer to use the conventional iron sheets and clay tiles.

No clear policy to support innovations especially through training like incubators, leading to challenges in accessing funding for business development.

Main success factors

The abundant rocky areas in the region provide a low cost and abundant supply of raw material for the roofing.

7. Findings from case studies and SDG survey

The building lifecycle consists of the following key phases: *manufacture (of materials), design, construction, use/operation, maintenance and deconstruction/end of life*. Through this research, there are several recurring themes on the barriers and facilitators of circularity. It comes through in the analysis below that working with industry stakeholders influence the lifecycle phases before and after occupancy. During the building operation phase, the engagement would have to extend to building managers and occupants.

7.1 Barriers to increased circularity

7.1.1 Building product manufacturing and design phases

I: Poor control of building standards and processes

In many African countries, the building permitting processes are only adhered to in urban areas, and even then, not comprehensively. This typically results in buildings with poor designs and substandard materials and construction. Where adequate regulations and codes exist, the enforcement of these are patchy at best. The limitation in development and enforcement of building standards and regulations is in turn related with other barriers discussed below, including technical capacity of public and private sector professionals. A direct consequence of a poor regulatory environment is that buildings are often unsafe and inadequate for the occupants. The absence of regulations on energy management in buildings represents a first barrier to the promotion of energy efficiency in building construction.

Poorly designed and constructed buildings require regular repairs and maintenance, which is often neglected. This results in shorter useful lives for buildings and a widening infrastructure gap for many countries in Africa. This challenge with the quality of buildings is exacerbated by the high level of informality in the building activities in many African countries, even in urban areas. Many people construct their own homes, with or without prior training. The building materials for self-built homes are also difficult to regulate and can sometimes be of very low quality as builders seek out the lowest cost. While improving the regulation and standardization of the building stock provides an entry-point for enhancing the adequacy of the building stock in Africa, support needs is needed to ensure the transition does not deprive poorer households of adequate shelter.

II: Lack of testing and certification laboratories

A lack of testing and organizations that are capable of certifying building quality is a common barrier for developing countries hoping to move away from conventional building materials such as concrete, steel and bricks. With increasing green building certifications and environmental performance certification requirements, this lack of test data for local materials becomes even more pronounced. The lack of testing and certification facilities to provide performance assurance for local and recycled materials cause such materials to be prohibited by authorities. This gap also prevents further valorisation and reuse of local material resources, compelling developers to import materials that have been tested and certified overseas. In at least two of the Case Studies in this report, project teams were compelled to import materials rather than use local sources due to the lack of certification for products. Without testing and certification of reused or recycled materials, the performance of such components cannot be verified and safely included in building projects. This limitation also applies to innovative building materials integrating materials from the waste stream.

III: Low technical capacity within the building sector

There is a shortage of certified and trained professionals in the building industry in many countries, though there are also informal means of training and skills transfer, such as apprenticeships. Consistently across the different countries where stakeholders were interviewed, the lack of skills was a major issue cited by interviewees. Some problems arising from this lack of capacity included the poor quality of locally produced building materials, lack of energy and material efficiency in manufacturing process and challenges in implementing analyses for building repairs.

Among the building and construction professionals interviewed for this report, the understanding of circularity varied significantly. As a basis, most acknowledged the massive volumes of construction and demolition waste was a problem that needed to be addressed by the industry. For most industry stakeholders, including those interviewed for this study, the extent of circularity in the building sector was limited to the recycling of construction and demolition waste. Apart from metallic waste, other material waste is often crushed and used for road infill or recast to form pavers. There is limited appreciation for circularity in other resources such as water and energy. This is further exacerbated by the lack of a clear and universal metric for measuring circularity in the built environment. There is also limited exploration of value retention for materials in repeated cycles of reuse.

IV: Limited awareness of circularity among building owners and developers

Project architects interviewed discussed their efforts to introduce green building principles into their designs, including the minimization of waste and use of recycled content. However, the lack of interest from clients and the higher costs of pursuing circular strategies mean that such initiatives are often dropped at conceptual stages of projects. The increased documentation and sensitization of the general public to the benefits from increased circularity can change mindsets and industry practices. Architects could be a promising entry point as almost half the architects interviewed in the study have proposed circularity aspects to their clients.

7.1.2 Operations, Maintenance/Repairs, Renovation

V: Lack of repair/reuse/maintenance regime

Several project stakeholders spoke about the lack of maintenance or repair culture for buildings. When buildings are old or damaged, the typical practice (in some African countries) is to abandon the building or demolish it for taller and more profitable developments. The two building restoration projects in the Case Studies both involved culturally significant buildings. This provided the basis on which project owners mobilized political support to protect the buildings from destruction and to access financing for repairs. These precedents could provide useful learnings for expanding the repair and reuse of buildings across Africa. Buildings with adequate structural integrity, not only those with cultural value, can be assessed, retrofitted and reused. Governments can promote the optimization of building useful lifespan by banning the abandonment of disused buildings and providing incentives for repairs, retrofit and reuse.

7.1.3 Construction, Renovation and deconstruction

VI: Poor regulation of waste management

In all the countries covered in this study, the management of construction and demolition waste remains a challenge. At best, contractor firms deliver the mixed waste to a designated landfill site where informal waste pickers salvage components with resale value. At worst, the waste

is dumped on any vacant site in the vicinity. While stepping up the enforcement of proper waste disposal for construction and demolition projects, the Government of Senegal has also introduced an initiative to remove building rubble dumped illegally in Dakar. Regulations on waste management is a potential instrument to stimulate increased effort to reduce construction and demolition waste materials.

VII: Time and cost of deconstruction

Most existing structures in Africa (and globally) were not constructed with deconstruction in mind. Bricks and building components are held together with plaster, making it extremely time consuming to remove individual building component and to preserve these for reuse. This translates to additional costs for construction companies, who must pay for labor costs and storage space. Additionally, the risk of material damage during deconstruction causes significant uncertainty over the quality and quantity of materials available for construction. Where materials retrieved from deconstruction of buildings require additional processing prior to reuse, this would further add on to the cost of materials, which may not be competitive with new materials in the market.

IX: Access to financing to promote circularity

In many countries, the policy environment for promoting circularity is still in its initial stages, including for the building sector. Building developers and material manufacturers face difficulties in accessing finance to fund innovations for increased circularity. In this study, several projects discussed challenges in securing financing, included financing for energy efficient brick kilns and for building repairs and renovations. This is in part due to the small market for building renovations in many African countries, with owners preferring to abandon or demolish old and damaged buildings.

7.2 Facilitators of increased circularity

I. Informal networks of material circularity

All across Africa, the resale of used building components occurs at varying scales. Reusable building materials are typically salvaged from demolition sites or designated landfill by informal workers. Several construction companies interviewed also included the distribution of excess materials or construction waste materials to staff and local communities as a form of waste management practice. The example in South Africa seeks to formalize and upscale this informal exchange of materials and provides many useful lessons for a similar transition towards formality in material exchange in other countries.

In theory, this network of material exchange could be facilitated during building demolition or deconstruction phase as well. However, in most African countries, there is no formal demolition process. Buildings are left derelict and demolished when the land is required for redevelopment. This will gradually change as African cities mature in the coming decades and see an increasing proportion of their building stock undergo renewal and reconstruction.

II. Development organizations and private sector facilitating knowledge transfer and pilot projects

The opportunity for introducing greater circularity across the entire building life cycle is constrained by the lack of technical capacity among the building sector practitioners. In many of the case studies covered, companies and organizations enlisted foreign expertise to fill these technical gaps. Support was brought in for scanning damaged buildings for structural

adequacy, designing for waste minimization, construction management for deconstruction and transitioning to new ways and equipment for brick making. These new technologies and knowledge from other countries helped build up technical capacity not just within the project but has wider benefits of serving as demonstration projects for the whole industry.

III. Abundance of local material resources

In each of the focus countries, there are multiple local companies experimenting with local raw materials and materials from the waste stream to create new and circular building materials. These materials are low in embodied carbon, suited to local climatic conditions and more affordable than imported materials of similar quality. Supporting the development of local building materials that are durable, reusable or recyclable reduces the dependence on imported products, creates new jobs and value chains and improves access to quality materials at affordable prices. Where waste materials are removed from the waste stream and reused in the manufacture of building materials, there is the added benefit of reducing the burden on landfills or pollution of the environment.

7.3 SDG and Indicators – Measuring circularity

Circularity is not a standalone Sustainable Development Goal, but it is embedded within numerous goals. The One Planet Network launched a survey to collect viewpoints from building sector stakeholders across the world. As responses from industry stakeholders show, there is reasonably strong consistency in opinions on which goals and indicators are most closely related with the circularity transition for the buildings industry. Respondents were asked to rate the SDGs on a scale from 0 to 9 (in steps of 0, 1, 3, 5, 9), in terms of relevance to circularity. Figure 7 shows the relative relevance of the SDGs from the survey. Respondents from Africa and the global response have selected two main groups of SDGs in relation to circularity. The primary cluster (very relevant) consists of **SDGs 11, 12 and 13**. The secondary cluster (quite relevant) of SDGs include SDGs 6, 7, 9 and potentially SDG 8. Responses for the primary cluster were unanimous, with little spread in the ratings. However, the survey results for the secondary cluster were more spread across the rating scores. *From the survey, there is no significant difference in the SDGs identified by 35 African and 36 global respondents.*

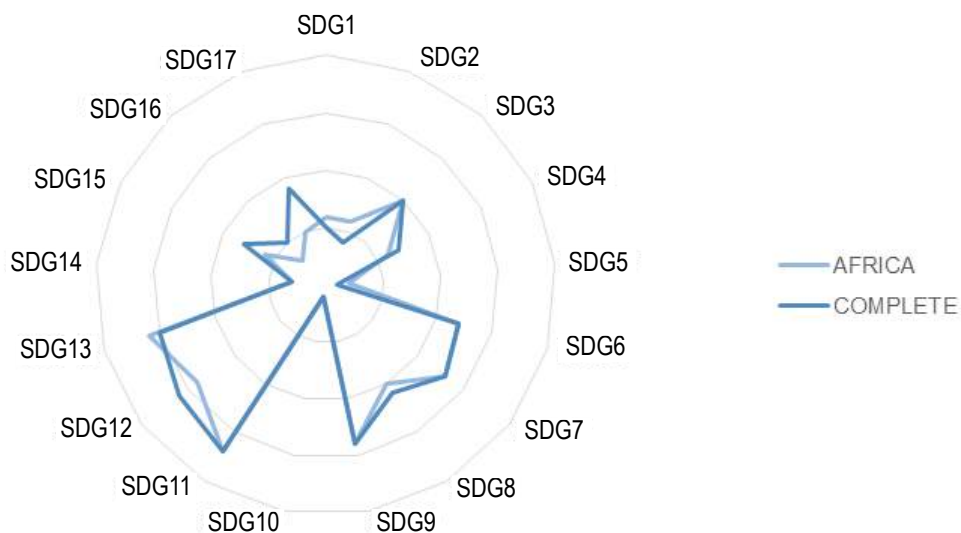


Figure 49: Prioritization of SDG relevance to circularity by survey respondents

Nineteen Case Studies are presented in this study, provided by stakeholders leading the projects. Each of these cases were mapped against relevant SDGs by the research team, as shown in Table 5. The shaded columns show the primary (green) and secondary (dark blue) SDGs in relation to circularity. The mapping from the Case Studies shows little difference in the scores for primary and secondary clusters of SDGs, with SDGs 8, 9, 11, 12 and 13 being reflected in many case studies. Among the Case Studies covered, very few touched on SDG 6, which had been identified in the survey as quite important for circularity. To a large extent, the mapping of Case Studies confirmed the survey results on the main SDGs linked to circularity to be **SDGs 8, 9, 11, 12 and 13**.

Table 5: Case studies mapped to SDGs

	SDGs																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1. BF			X			X	X	X				X					
2. BF								X				X	X				
3. BF							X		X		X						
4. MW					X			X	X		X	X					
5. MO										X	X						X
6. NG						X			X		X						
7. RW							X	X	X		X	X					
8. RW							X		X		X	X					
9. RW									X		X	X					
10. RW			X			X	X				X	X	X				
11. RW										X	X	X					X
12. SN								X	X		X	X	X				
13. SN								X	X		X	X	X				
14. SN								X				X	X				
15. ZA	X										X						X
16. UG	X								X			X	X				X
17. UG				X				X				X	X				
18. UG	X						X	X	X			X	X				X
19. UG								X	X			X	X				
	3	-	2	1	1	3	6	10	11	2	12	15	9	-	-	-	4

Beyond looking at the most relevant SDGs for circularity, the survey also sought inputs on specific indicators across all SDGs that could be relevant for measuring circularity in the built environment. From the responses from Africa, the top 10 scoring indicators are as displayed in Figure 50, the indicators are listed in Table 6. Consistent with the earlier SDG mapping, most of these indicators correspond to the relevant SDGs identified in the case studies.

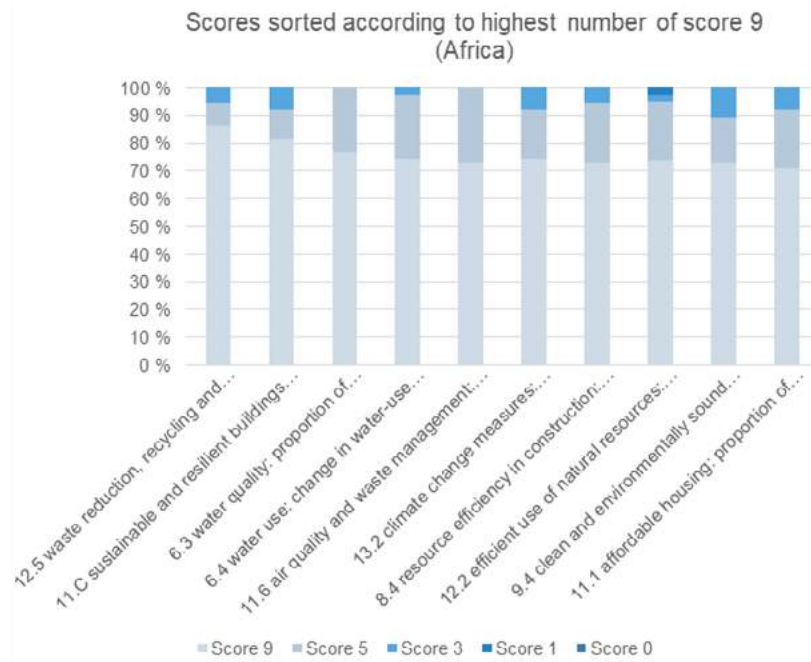


Figure 50: Top 10 indicators identified by African respondents

Indicator 8.4.1 is *Domestic material consumption, domestic material consumption per capita, and domestic material consumption per GDP*, which is the same as Indicator 12.2.1. These are scored 6th and 7th by respondents in Africa. Although respondents rated indicators on water management quite highly, in practice, few circular projects and products include sustainable water management.

Table 6: Top 10 indicators identified by African respondents

Indicator	Aggregated score ¹
12.5 waste reduction, recycling and reuse: national recycling rate	8.35
12.2.2 sustainable and resilient buildings utilizing local materials: financial support	8.11
6.3.1 water quality: proportion of wastewater safely treated	8.08
6.4.1 water use: change in water-use efficiency	7.92
13.2.1 climate change measures: countries with an integrated policy/strategy/plan	7.82
12.2.1 efficient use of natural resources: material footprint	7.79
8.4.1 resource efficiency in construction: material footprint	7.81
11.6.1 air quality and waste management: proportion of urban solid waste regularly collected	7.92
9.4.1 clean and environmentally sound technologies: CO2 emission per unit of value added	7.70
11.1.1 affordable housing: proportion of urban population living in inadequate housing	7.68

¹ Aggregated score computed as mean score rated by respondents in Africa (Total score divided by number of respondents.)

Comparing the indicators identified by the African respondents with respondents from all regions, as illustrated in Figure 9, the same 9 indicators were rated with top scores, with some difference in scoring while the 10th indicator differs. Indicator 11.1.1 *Proportion of urban population living in inadequate housing* is challenging to measure due to definitions around inadequate housing. The prioritization of this indicator by respondents in Africa is reflective of the high level of informality in the housing stock in Africa, particularly in urban areas. Quite likely, this indicator will increase in rating should the survey be extended to industry stakeholders who do not use the internet. When different perspectives are included in the survey responses, it is anticipated that the top scored indicators will shift in their order, but most likely not change. The blue shaded cells in Table 6 are the top 5 Global indicators from the survey.

During interviews and stakeholder discussions, there was unanimous agreement that material recycling (ranked first) and prioritizing local materials in construction (ranked second) are key outcomes of the circularity transition. Indicators ranked third and fourth by respondents in Africa involve wastewater treatment and water use efficiency. Related interventions were adopted in a few building project Case Studies and can be promoted wider, given the support for these indicated in the survey. While there was no objection to the indicators during survey validation, the limited adoption suggests a knowledge gap among industry practitioners for implementing such initiatives.

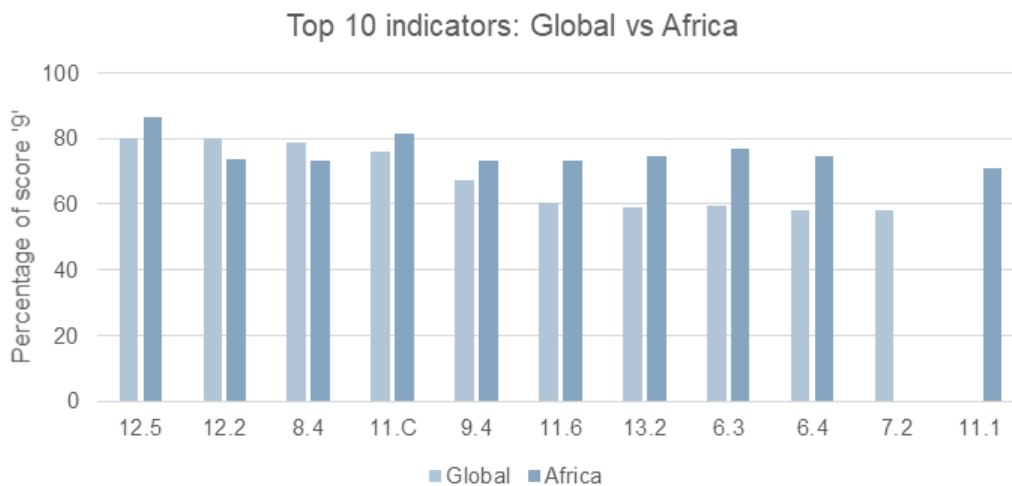


Figure 51: Top 10 indicators identified by African respondents (dark blue) and all respondents (light blue).

8. Conclusion and recommendations

8.1 Conclusions

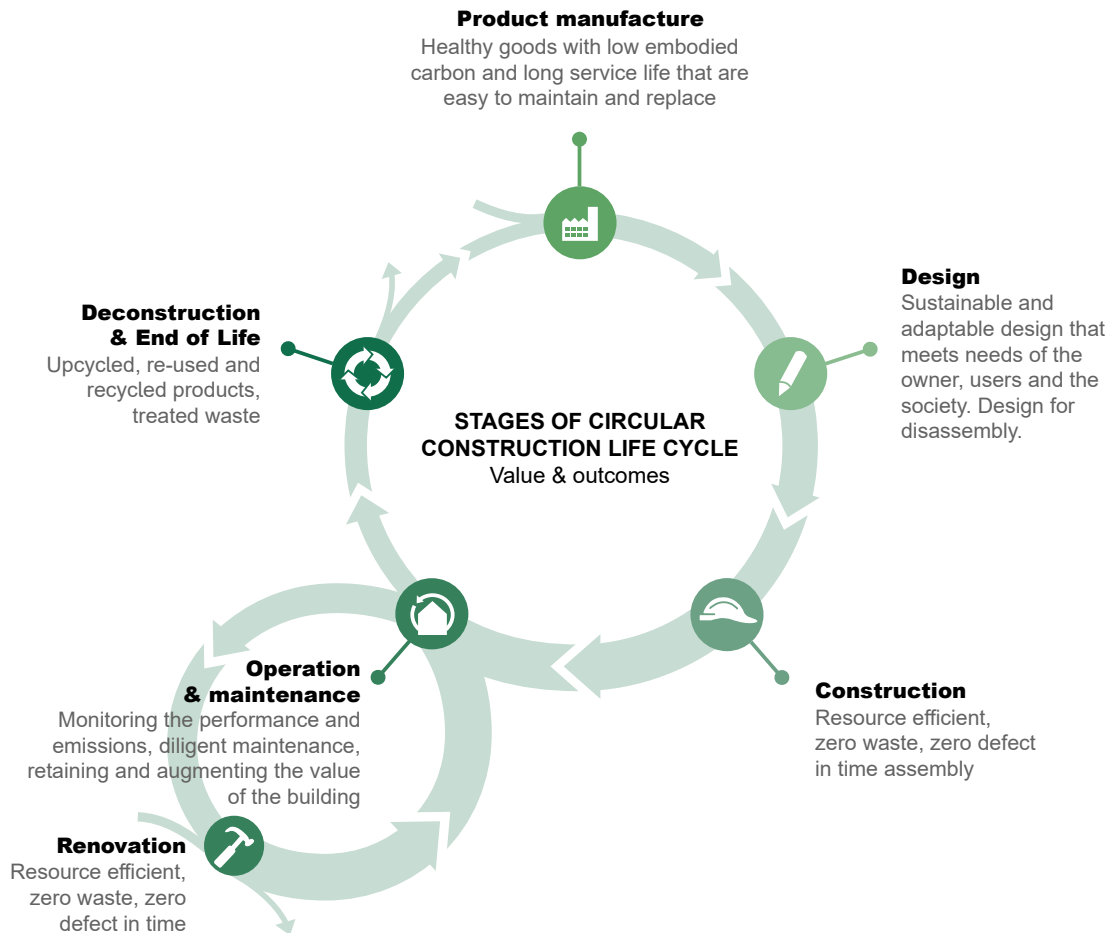


Figure 52: Stages of circular construction life cycle - value & outcomes

Credit: Ninni Westerholm. Developed from UNEP (2021)

This study consisted of extensive conversations with public, private and informal building sector stakeholders from Burkina Faso, Rwanda, Senegal, Uganda and other countries in Africa, supported by literature review. The policy environment indicates that governments are increasingly considering material circularity, both from the climate perspective and more obviously, from the perspective of waste management. Increasing volumes of solid waste, including construction and demolition waste, threaten to overwhelm landfill sites and vacant spaces in cities where waste accumulates. Circularity also brings about secondary benefits such as job creation, supporting local businesses and reducing energy demand, all critical considerations for many governments in the African region.

The nineteen Case Studies in this report provide a snapshot to the efforts on the ground, sometimes supported by governments, but more often initiated from the ground up. The cases often mention informal dynamics of circularity, from the salvage of reusable materials for resale and reuse to systematic distribution of construction waste to employees, etc. In the building projects covered, the decision to pursue water, material and energy circularity were not

compelled by local regulations. Project owners voluntarily chose to construct exemplary projects for demonstration of circularity principles. The cases also found a high level of innovation taking place in the sphere of material production using local resources.

The low level of technical capacity of the workforce and weak regulatory environment in many countries in Africa are barriers for enhanced circularity in the building sector, further hindered by the limited facilities for standardizing and certifying building materials. However, the informal networks for material reuse and knowledge transfer from development and business partners create new opportunities for circularity.

An observation made during the course of data collection and stakeholder interviews is the extent of activities that are not documented on the internet. Many stakeholders did not regularly access emails nor did their projects or companies have a web presence. For the organizations that did run websites, these were often lacking in updated information and project details. This observation has wider implications on future research on practices in the building sector in Africa. It also confirms that the respondents to the web-based SDG survey represent only a very small proportion of the industry in Africa. To capture more representative perspectives, an offline survey could be rolled out, though manual computation of the results would be challenging.

The absence of a systematic monitoring of manufacturing or construction processes and results from circular initiatives create a data void in quantifying the extent of circularity and the benefits from these initiatives. For most of the Case Studies, quantitative information on volume of materials reused, greenhouse gas avoided and other benefits could not be obtained. These could be useful to record for demonstrating the case for shifting from linear to more circular buildings systems.

The study found **SDGs 8 (Decent work and economic growth), 9 (Industry, innovation and infrastructure), 11 (Sustainable cities and communities), 12 (Responsible consumption and production) and 13 (Climate action)** to be focal in the approach to circularity in the built environment.

8.2 Recommendations

The Case Studies presented in this report are clear illustrations of circularity at play in every phase of the building life cycle. However, substantial obstacles exist that hinder the wider adoption of resource circularity as practiced in the Case Studies. Some recommendations are made for leveraging the current facilitators and overcoming the barriers identified in the report.

8.2.1 Prioritize access to skills and training in the building industry

In the context of Africa, opportunities for training do not always require formal institutions and programmes. However, while optimizing informal networks for skills transfer, care needs to be taken to ensure the quality of training is maintained. Without formal certification, this could take the form of endorsement by a group of recognized experts or other forms of community recognition of achievement. With the young and relatively untrained work force in Africa, there is opportunity to generate significant momentum for circular building material production, improved building design and construction methods and even repairs and deconstruction by mobilizing their skills and energies towards skills and training programmes.

While promoting informal networks of traditional expertise, support must also be provided to training and education institutions to integrate sustainable resource management into the training courses on building and construction. Through improving the skills of building industry stakeholders, the quality of building materials and subsequent constructions are improved. This has implications for building safety, occupant comfort, and structural durability.

8.2.2 Invest in regional standardization and certification facilities

With the development of national guidelines for construction with earth and adobe, governments featured in the Case Studies have created an official pathway for traditional materials and construction methods to be recognized in quality and adequacy. These manuals are essential for bridging traditional methods with modern science and regulations. Regulating construction with local and traditional materials keep buildings affordable for the majority of the population, while these manuals ensure such construction meet measurable performance specifications. Much more is needed in the aspect of certification and standardization.

Apart from local materials such as earth and adobe, companies and organizations are experimenting with biowaste, plastic waste and construction and demolition waste materials to manufacture building products. Certification standards are required to guide the development of such materials and endorse the quality of the process and products for commercial distribution in local, and potentially export, markets. Without an easily accessible certification facility, building professionals in Africa will continue to have to source overseas for certified recycled content while local producers struggle to establish demand.

8.2.3 Improve regulatory and policy environment and implementation

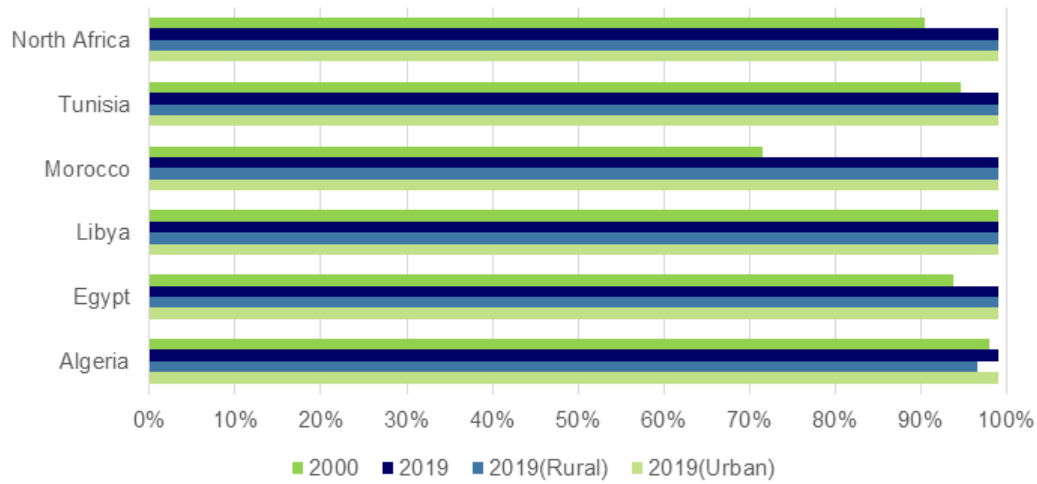
Government policies and regulations provide the framework within which the formal building stock is designed, constructed and managed. Through providing clear guidance on avenues to promote circular strategies, decarbonize energy use and reduce waste generation, government documents can guide industry towards the improved sustainability. The development of technical guidelines for constructing with earth, as described in the Case Studies (from Burkina Faso and Rwanda), demonstrate the need for a multi-stakeholder, consultative approach to the development of such documents. Additionally, government regulations need to reflect local realities and resources. By formalizing and supporting house construction with an affordable local resource, these technical manuals are invaluable in enhancing the quality and access to adequate housing for local populations.

8.2.4 Promote collaborations for knowledge transfer and stimulate innovations

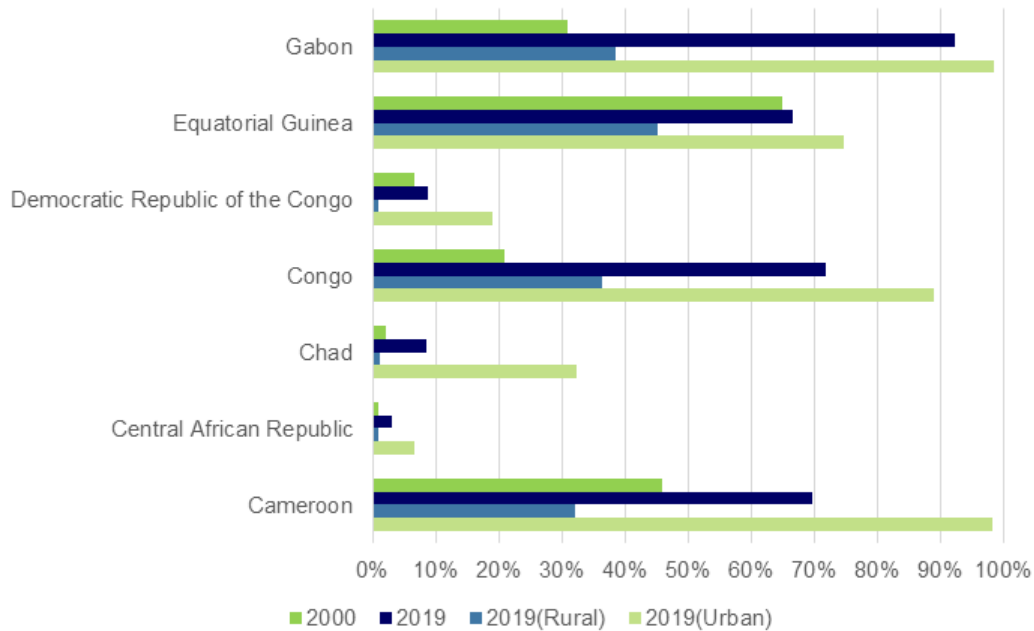
In the Case Studies presented, it is often seen that knowledge and technology gaps faced by African companies and project teams were supplemented by external resources. This capacity transfer is strategic for building up the knowledge base within African countries, from which local innovations and refinements can take place. One challenge in organizing such capacity transfer collaborations on a national scale would be in matching the needs to the skills on offer. Much of the construction and product manufacturing activities are not reflected on the internet, hence matching with capacity partners requires a dedicated institution.

ANNEX 1 ELECTRICITY ACCESS IN COUNTRIES ACROSS AFRICA (DATA FROM IEA)

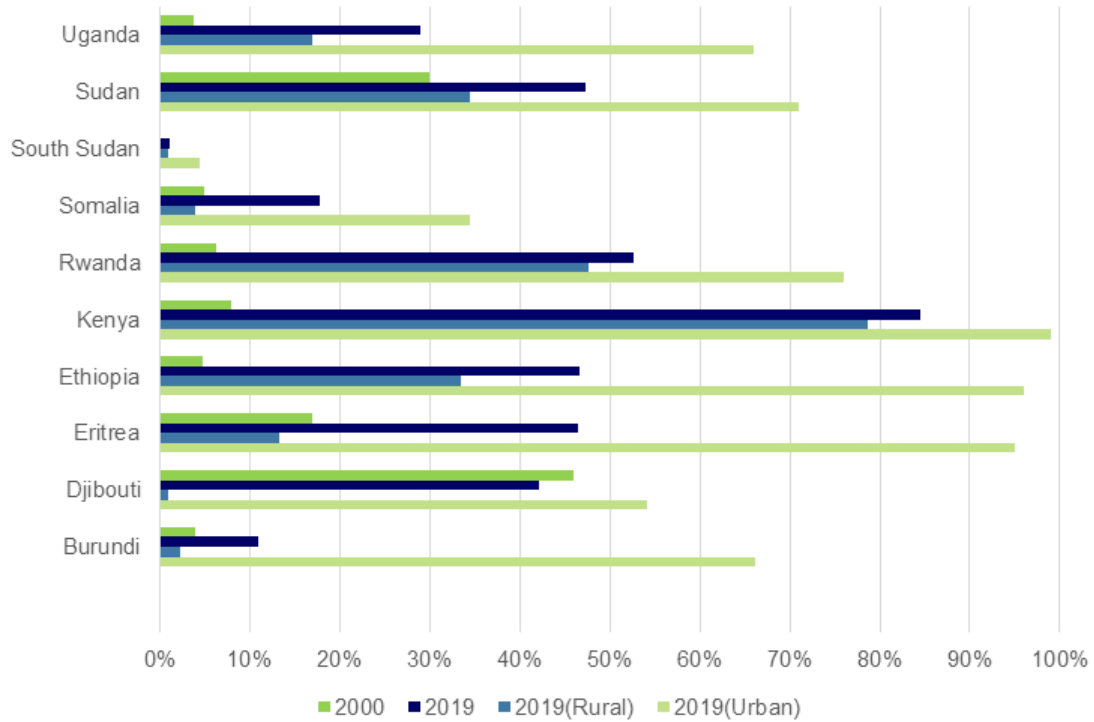
Electricity Access in North Africa



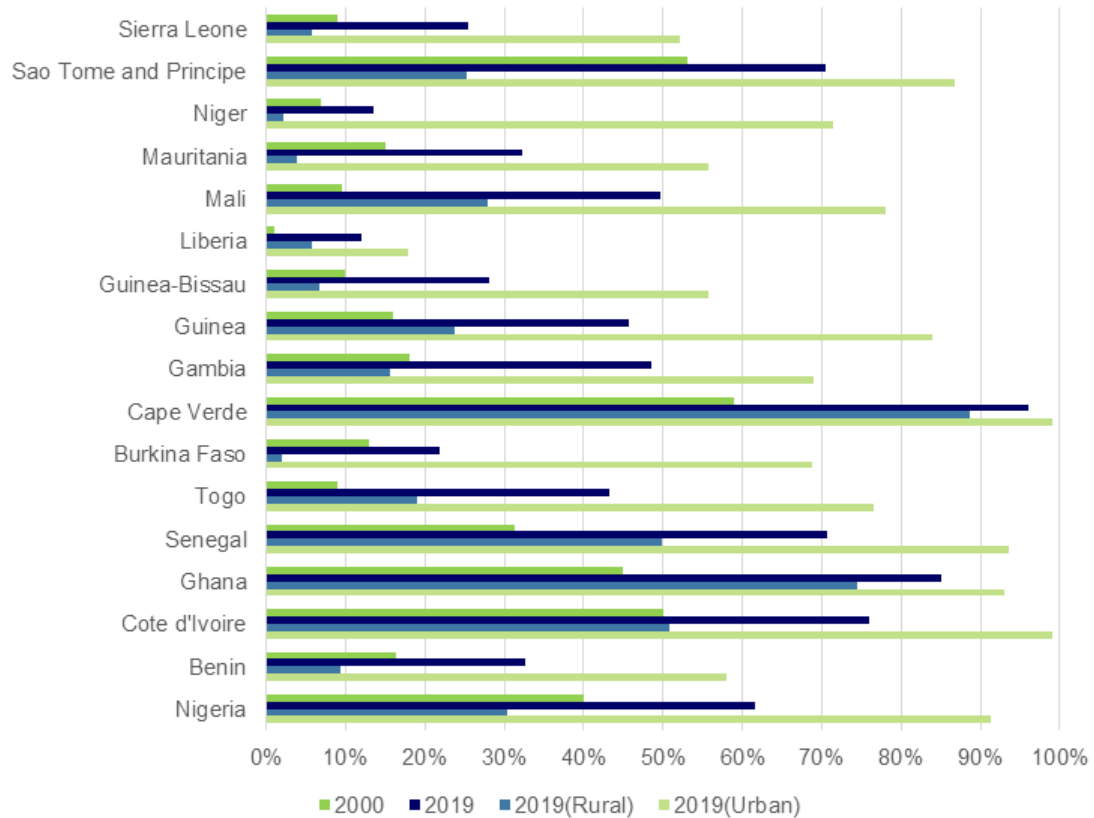
Electricity Access in Central Africa



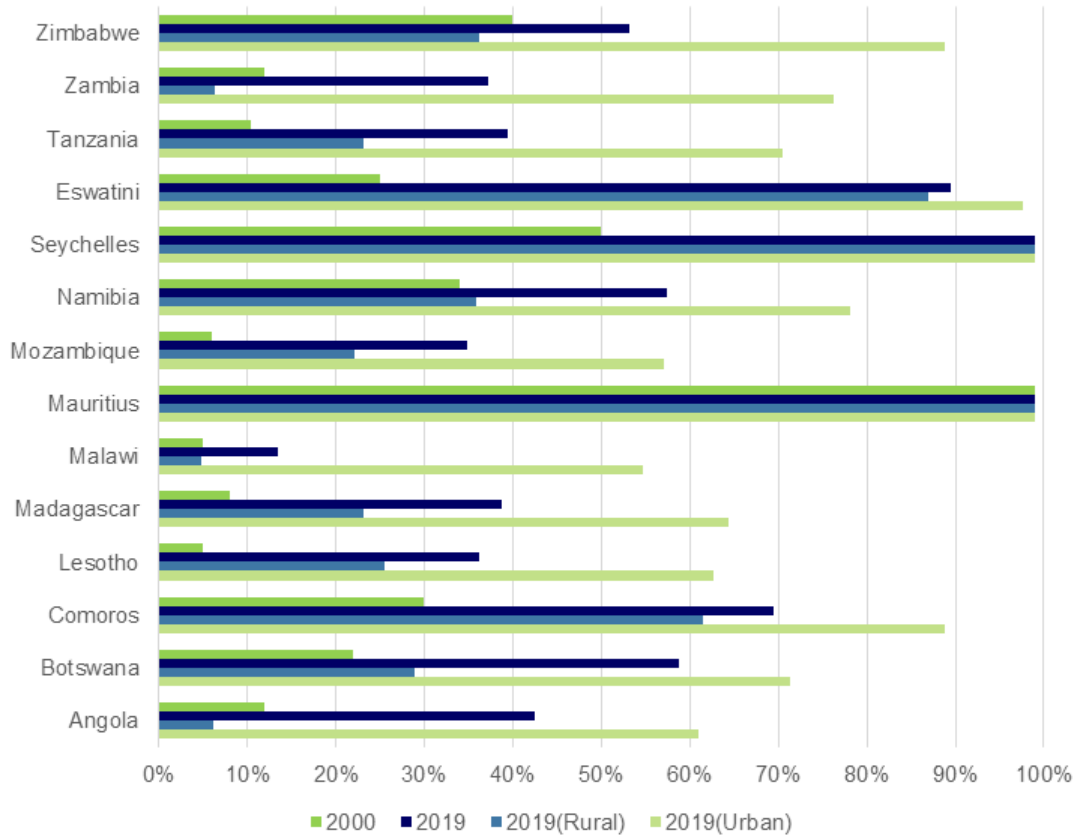
Electricity Access in East Africa



Electricity Access in West Africa



Electricity Access in Southern Africa



References

- ABNORM, 2019. Compressed Earth Blocks.
- Adegun, O.B. and Adedeji, Y.M.D., 2017. Review of economic and environmental benefits of earthen materials for housing in Africa. *Frontiers of Architectural Research*, 6(4), pp.519-528. Accessed 01 October 2021
<https://www.sciencedirect.com/science/article/pii/S2095263517300547>
- AfDB, OECD and UNEP, 2016. *The African Economic Outlook 2016*, OECD Publishing, Accessed 01 October 2021
https://www.afdb.org/fileadmin/uploads/afdb/Documents/Publications/AEO_2016_Report_Full_English.pdf
- African cement market–environmental issues, regulative framework, and quality infrastructure requirements. In *MATEC Web of Conferences* (Vol. 149, p. 01014). EDP Sciences. Accessed 01 October 2021
<https://doi.org/10.1051/mateconf/201814901014>
- Aquastat, 2017. Data from Aquastat. Website of Food and Agriculture Organisation of the United Nations, Accessed 01 October 2021
<http://www.fao.org/aquastat/statistics/query/index.html?lang=en>
- Arcadis, Circular Economy, WBCSD, 2018. *Scaling the Circular Built Environment: Pathways for Businesses and Government*. World Business Council for Sustainable Development, Circular Economy, Accessed 01 October 2021
https://docs.wbcsd.org/2018/12/Scaling_the_Circular_Built_Environment-pathways_for_business_and_government.pdf
- Biteye M, 2016. 70% of Africans make a living through agriculture, and technology could transform their world, website of World Economic Forum, Accessed 01 October 2021
<https://www.weforum.org/agenda/2016/05/70-of-africans-make-a-living-through-agriculture-and-technology-could-transform-their-world/>
- Bosman, G. and Van der Westhuizen, D., 2014. The effects of climatic conditions on attitudinal changes towards earth construction in South Africa. *Acta Structilia: Journal for the Physical and Development Sciences*, 21(1), pp.117-141, Accessed 01 October 2021
<https://journals.co.za/doi/abs/10.10520/EJC160907>
- Chatham House, 2020. *Policies*, website of Circular Economy Earth, Accessed 01 October 2021
<https://circulareconomy.earth/>
- Circular Economy and Shifting Paradigms, 2021, *Circularity Gap Report 2021*, Circular Economy, Accessed 01 October 2021
<https://www.circle-economy.com/resources/circularity-gap-report-2021>
- Clay Brick Association, Accessed 01 October 2021
<https://www.claybrick.org/>
- Clay Brick Association, undated. *The Environmental And Socio-Economic Impact Of Clay Bricks In South Africa*, Accessed 01 October 2021
https://www.claybrick.org.za/sites/default/files/downloads/CBA%20LCA_technical%20brochure_WEB.pdf

- Construction Review, 2021. Cement production in Africa and pricing and trends, Construction Review, Accessed 01 October 2021
<https://constructionreviewonline.com/concrete/cement-production-in-africa-and-pricing-and-trends/>
- Deloitte, 2020. Africa Construction Trends, Deloitte, Accessed 01 October 2021
<https://www2.deloitte.com/za/en/pages/energy-and-resources/articles/africa-construction-trends-2020.html>
- EC, undated. Global Greenhouse Gas Emissions, European Commission. Accessed 01 October 2021
https://edgar.jrc.ec.europa.eu/dataset_ghg60#p3
- Etim, M.A., Babaremu, K., Lazarus, J. and Omole, D., 2021. Health Risk and Environmental Assessment of Cement Production in Nigeria. Atmosphere, 12(9), p.1111. Accessed 01 October 2021
<http://dx.doi.org/10.3390/atmos12091111>
- European Commission(EC) 2020, Circular Economy – Principles for Building Design, European Commission, Accessed 01 October 2021
<https://ec.europa.eu/docsroom/documents/39984>
- Fuyane, B.F., Athlopheng, J.R. and Mulale, K., 2013. Impact Analysis of Informal Brick production on the Environment: Gaborone Dam Area, Botswana. International Journal of Scientific and Technology Research, 2(9), pp.73-78, Accessed 01 October 2021
<https://www.ijstr.org/final-print/sep2013/Impact-Analysis-Of-Informal-Brick-Production-On-The-Environment-Gaborone-Dam-Area-Botswana.pdf>
- Geissdoerfer M, Savaget P, Bocken NM, Hultink EJ, 2017. The Circular Economy–A new sustainability paradigm?, Journal of cleaner production. Feb 1;143:757-68, Accessed 01 October 2021, https://www.researchgate.net/publication/311776801_The_Circular_Economy_-_A_new_sustainability_paradigm
- GGGI 2018. GGGI and the Government of Senegal held the Technical Validation Workshop on the National Green Growth Strategy, GGGI, Accessed 22 October 2021, <https://gggi.org/gggi-and-the-government-of-senegal-held-the-technical-validation-workshop-on-the-national-green-growth-strategy/>
- GGGI, 2019. National Launching Workshop of the Development of Green City Guidelines for Burkina Faso, GGGI, Accessed 22 October 2021. <https://gggi.org/national-launching-workshop-of-the-development-of-green-city-guidelines-for-burkina-faso/>
- GGGI, 2019. Project Reference Profiles – Senegal(SN09) Senegal Green building readiness programme, GGGI. Accessed 22 October 2021, <https://gggi.org/project/project-reference-profiles-senegalsn09-senegal-green-building-readiness-program/>
- GGGI, 2019. Project Reference Profiles – Senegal(SN2) Green Secondary Cities Wastewater, Plastic Waste and WEEE Management: Innovative Business Model, GGGI. Accessed 22 October 2021. <https://gggi.org/project/project-reference-profiles-senegalsn2-green-secondary-cities-wastewater-plastic-waste-and-weee-management-innovative-business-model/>
- Government of Burkina Faso, 2013. National Policy of Sustainable Development in Burkina Faso. UN Partnership for Action on Growth Economy (UN PAGE). Accessed 22 October 2021. https://www.un-page.org/files/public/pndd_burkina_fao.pdf

- Government of Burkina Faso, 2021. Nationally Determined Contributions of Burkina Faso 2021-2025, United Nations Framework Convention on Climate Change (UNFCCC) Accessed 22 October 2021, https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Burkina%20Faso%20First/Rapport%20CDN_BKFA.pdf
- Government of Senegal, 2001. Law 2001-01 of 15 January 2001 on the Environment Code , Climate Change Laws of the World, Accessed 22 October 2021, <https://www.climate-laws.org/geographies/senegal/laws/environment-code-law-2001-01>
- Government of Senegal, 2008. Law n° 2008-43 of 20 August 2008 on the Urban Planning Code. The National Office for the Fight against Fraud and Corruption. Accessed 22 October 2021, <https://www.ofnac.sn/resources/pdf/Lois/LOI%20N%C2%B0%202008-43%20portant%20code%20d%20l'urbanisme.pdf>
- Government of Senegal, 2009. Law No. 2009-23 of 8 July 2009 on the Building Code. Droit-Afrique. Accessed 22 October 2021. <http://www.droit-afrique.com/upload/doc/senegal/Senegal-Code-2009-de-la-Construction-Partie-legislative.pdf>
- Government of Senegal, 2013. Ministerial Decree No. 9317 establishing the organization and functioning of the National Greenhouse Gas Reduction Programme through energy efficiency in the building sector and related regulation, Climate Change Laws of the World, Accessed 22 October 2021, <https://www.climate-laws.org/geographies/senegal/policies/ministerial-decree-no-9317-establishing-the-organization-and-functioning-of-the-national-greenhouse-gas-reduction-programme-through-energy-efficiency-in-the-building-sector-and-related-regulation>
- Institution of Rwanda Engineers 2017. Perspective of Solid Waste Collection in the City of Kigali, Internal reports, Report on Kigali Landfills.
- International Energy Agency (IEA), 2019. Africa Energy Outlook 2019, International Energy Agency, Accessed 01 October 2021 https://iea.blob.core.windows.net/assets/2f7b6170-d616-4dd7-a7ca-a65a3a332fc1/Africa_Energy_Outlook_2019.pdf
- International Labour Organisation (ILO) 2020, Global Employment Trends for Youth 2020: Africa, International Labour Organisation, Accessed 01 October 2021 https://www.ilo.org/wcmsp5/groups/public/---dgreports/---dcomm/documents/briefingnote/wcms_737670.pdf
- International Renewable Energy Agency (IRENA), 2018. Irena Country Profiles, IRENA, Accessed 01 October 2021 <https://www.irena.org/Statistics/View-Data-by-Topic/Renewable-Energy-Balances/Country-Profiles>
- Kusena, W., Shoko, N. and Marambanyika, T., 2012. Socio-economic impacts of cement production at Sino-Zimbabwe on Hozheri community, Gweru, Zimbabwe. Journal of Sustainable Development in Africa, 14(8), pp.94-103. Accessed 01 October 2021 https://www.researchgate.net/publication/290431296_Socio-economic_impacts_of_cement_production_at_Sino-Zimbabwe_on_Hozheri_community_Gweru_Zimbabwe
- Mason N, Nalamalapu D and Corfee-Morlot J, 2019. Climate Change Is Hurting Africa's Water Sector, but Investing in Water Can Pay Off, website of World Resources Institute. Accessed 01 October 2021 <https://www.wri.org/insights/climate-change-hurting-africas-water-sector-investing-water-can-pay>

- Ministry of Economy, Planning and Cooperation (MECP), 2014. Plan for an Emerging Senegal, website of Ministry of Economy, Planning and Cooperation, Accessed 01 October 2021. <https://www.economie.gouv.sn/en/dossiers-publications/publications/pse>
- Ministry of Environment of Rwanda, 2019. National Environment and Climate Change Policy, Ministry of Environment of Rwanda, Accessed 22 October 2021, https://www.environment.gov.rw/fileadmin/user_upload/Moe/Publications/Policies/Rwanda_National_Environment_and_Climate_Change_Policy.pdf
- Ministry of Infrastructure of Rwanda, 2015. National Housing Policy, Rwanda Housing Authority. Accessed 21 October 2021, https://www.rha.gov.rw/fileadmin/user_upload/documents/General_documents/Housing_regulations_and_standards/Policies/National_Housing_Policy.pdf
- Ministry of Infrastructure of Rwanda, 2016. National Sanitation Policy Implementation Strategy. Rwanda Utilities Regulatory Board, Accessed 22 October 2021, https://www.rura.rw/fileadmin/Documents/Water/Laws/NATIONAL_SANITATION_POLICY_IMPLEMENTATION_STRATEGY_DECEMBER_2016.pdf
- Ministry of Lands, Housing and Urban Development (MLHUD), 2016. The Uganda National Housing Policy. Website of Ministry of Lands, Housing and Urban Development, Accessed 01 October 2021 <https://mlhud.go.ug/wp-content/uploads/2015/10/National-Housing-Policy-May-2016.pdf>
- Ministry of Water and Environment, 2015. Uganda National Climate Change Policy, Ministry of Water and Environment, Accessed 11 October 2021. <https://www.mwe.go.ug/sites/default/files/library/National%20Climate%20Change%20Policy%20April%202015%20final.pdf>
- National Assembly, 2013. Law no. 006-2013 (on the Code for the Environment). Climate Change Laws of the World, Accessed 22 October 2021, <https://www.climate-laws.org/geographies/burkina-faso/laws/law-no-006-2013-on-the-code-for-the-environment>
- National Planning Authority (NPA), 2018. Developing the Iron and Steel Industry in Uganda- Harnessing the Low Hanging Fruits, National Planning Authority, Accessed 22 October 2021, <http://npa.go.ug/wp-content/uploads/2018/07/Iron-and-Steel-Industry-in-Uganda.pdf>
- National Planning Authority, 2017. Uganda Green Growth Development Strategy (UGGDS), Global Green Growth Institute, Accessed 11 October 2021. <https://gggi.org/site/assets/uploads/2019/03/Uganda-Green-Growth-Development-Strategy-20171204.pdf>
- National Planning Authority, 2018. Developing The Iron And Steel Industry In Uganda – Harnessing The Low Hanging Fruits, National Planning Authority, Accessed 01 October 2021, <http://npa.go.ug/wp-content/uploads/2018/07/Iron-and-Steel-Industry-in-Uganda.pdf>
- Ngounou B, 2019. SENEGAL: Bandio baobab reserve threatened by cement company extension Afrik21, Accessed 22 October 2021, <https://www.afrik21.africa/en/senegal-bandio-baobab-reserve-threatened-by-cement-company-extension/>
- Nko'o B.C, 2006. Prospective Studies For The Development Of A Quality Habitat In Adobe Akoudougou, Burkina Faso. Craterre Organization. Accessed 22 October 2021. http://craterre.org/terre.grenoble.archi.fr/documentation/downloads/DSA_Christian_Belinga.pdf

- Ogedengbe, K. and Oke, A.O., 2011. Pollution impact of cement production on air, soil and water in a production location in Nigeria. *Journal of Science and Technology (Ghana)*, 31(2). Accessed 01 October 2021
<http://dx.doi.org/10.4314/just.v31i2.69393>
- Our World in Data, 2020. Share of electricity production from renewables, 2020. Website of Our World in Data. Accessed 01 October 2021
<https://ourworldindata.org/grapher/share-electricity-renewables?region=Africa>
- Rajasheker, A., Bowers, A. and Gatoni, A.S., 2019. Assessing waste management services in Kigali. International Growth Centre, International Growth Centre, Accessed 22 October 2021, <https://www.theigc.org/wp-content/uploads/2019/11/Rajashekar-et-al-2019-paper.pdf>
- ReportLinker 2020. Africa Construction Market-Growth, Trends, and Forecast (2020-2025), ReportLinker, Accessed 01 October 2021
https://www.reportlinker.com/p06001589/Africa-Construction-Market-Growth-Trends-and-Forecast.html?utm_source=GNW
- Republic of Rwanda, 2011. Green Growth and Climate Resilience; National Strategy for Climate Change and Low Carbon Development, *Climate Change Laws of the World*, Accessed 22 October 2021, <https://www.climate-laws.org/geographies/rwanda/policies/green-growth-and-climate-resilience-national-strategy-on-climate-change-and-low-carbon-development>
- Republic of Rwanda, 2019. Rwanda Building Code, Rwanda Housing Authority, https://www.rha.gov.rw/fileadmin/user_upload/documents/General_documents/Laws_of_construction/Rwanda_Building_Code_2019.pdf
- Rupiny D, 2021. Uganda has Huge Investment Potential Opportunities in Iron and Steel Sector, Uganda Revenue Authority, Accessed 22 October 2021, <https://www.ugandainvest.go.ug/uganda-has-huge-investment-opportunities-in-iron-and-steel-sector/>
- Rwanda Environment Management Authority (REMA), 2010. Practical Tools on Solid Waste Management of Imidugudu, Small Towns and Cities : Landfill and Composting Facilities, REMA, Accessed 22 October 2021, https://rema.gov.rw/fileadmin/templates/Documents/rema_doc/Environmental%20Management%20Practical%20Tools/11.1-%20Practical%20Tools%20on%20Solid%20Waste%20Management%20of%20Imidugudu%20Towns%20and%20Cities%20%202017-07-2010.pdf
- Rwanda Environment Management Authority (REMA), 2017. Rwanda State of Environment and Outlook, REMA, Accessed 22 October 2021, <https://www.rema.gov.rw/soe/summary.pdf>
- Saka, L. and Busari, D., 2020. State, Industries and Regulation in Nigeria: Ife Iron and Steel Company and Environmental Pollution. *Journal of Management and Social Sciences*, 9(1), pp.750-768. Accessed 01 October 2021
<https://fountainjournals.com/index.php/fujmas/article/view/272>
- Schmidt, W., Ngassam, I.L.T., Breitschaft, G. and Virchow, S., 2018. Challenges of the growing

- Senfuka, C., Kirabira, J.B. and Byaruhanga, J.K., 2011, January. Options for Improvement of the Ugandan Iron and Steel Industry. In Proceedings of the Second International Conference on Advances in Engineering and Technology, Entebbe, Uganda, Jan (Vol. 31). Accessed 01 October 2021
<https://www.mak.ac.ug/documents/Makfiles/aet2011/Senfuka.pdf>
- The Centre for the Development of Industry (CDI) and CRATerra EAG Basin, 1998. Compressed Earth Blocks Standards, The New Zealand Digital Library, Accessed 11 October 2021
<http://www.nzdl.org/cgi-bin/library?e=d-00000-00---off-0cdl--00-0----0-10-0---0---0direct-10---4-----0-1--11-en-50---20-about---00-0-1-00-0-0-11---0-0-&a=d&c=cdl&cl=CL2.3&d=HASH01979938ef89e979ddfb736b.1>
- The Low Hanging Fruits, National Planning Authority, Accessed 01 October 2021
<http://npa.go.ug/wp-content/uploads/2018/07/Iron-and-Steel-Industry-in-Uganda.pdf>
- Toesland F, 2019. Africa's megacities a magnet for investors, Africa Renewal
<https://www.un.org/africarenewal/magazine/april-2019-july-2019/africa%E2%80%99s-megacities-magnet-investors>
- UN-Habitat, 2017. New Urban Agenda, UN-HABITAT III, Accessed 01 October 2021, <https://uploads.habitat3.org/hb3/NUA-English.pdf>
- UN-Habitat, undated. Sustainable Urban Development And Agenda 2030: Un-Habitat's Programme Framework, UN Habitat. Accessed 01 October 2021
https://unhabitat.org/sites/default/files/download-manager-files/Sustainable%20Urban%20Development_3.pdf
- UN, 2019. World Population Prospects, United Nations, Accessed 01 October 2021
<https://population.un.org/wpp/>
- UNDP, 2020. Human Development Reports, UNDP, Accessed 01 October 2021
<http://hdr.undp.org/en/content/human-development-index-hdi>
- UNEP, 2010. Africa Water Atlas, UNEP, Accessed 01 October 2021
<https://wedocs.unep.org/handle/20.500.11822/7919>
- UNEP, International Environmental Technology Centre (IETC), Council for Scientific and Industrial Research (CSIR), Africa Waste Management Outlook, Undated. UNEP, Accessed 01 October 2021
https://wedocs.unep.org/bitstream/handle/20.500.11822/25515/Africa_WMO_Summary.pdf?sequence=1&isAllowed=y
- UNEP, 2021. Global Status Report for Buildings and Construction: Towards a Zero-emission, Efficient and Resilient Buildings and Construction Sector, UNEP, Accessed 01 October 2021
https://globalabc.org/sites/default/files/inline-files/2020%20Buildings%20GSR_FULL%20REPORT.pdf
- UNSTATS, 2021. The Sustainable Development Goals Report 2021, UNSTATS, Accessed 01 October 2021
<https://unstats.un.org/sdgs/report/2021/goal-07/>
- Vicat, undated. Working close to the community, website of Vicat, Accessed 01 October 2021
<https://www.vicat.com/commitments/working-close-to-the-community>
- World Bank, 2013. Harnessing Urbanisation to end Poverty and boost prosperity in Africa. The World Bank, Accessed 01 October 2021

<https://documents1.worldbank.org/curated/en/710431468191672231/pdf/815460WP0Afric00Box379851B00PUBLIC0.pdf>

World Steel, 2020. Steel Statistical Yearbook 2020 concise version, World Steel Association,
Accessed 01 October 2021

<https://www.worldsteel.org/en/dam/jcr:5001dac8-0083-46f3-aadd-35aa357acbcc/>