CiCoSA - Handbook

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1. Executive Summary

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1. Introduction

1.1 Urbanization, Housing and Waste in Sub-Saharan Africa

Africa is the world's second largest continent after Eurasia, with a total surface area of 30,365,000 km^2, including several islands. It stretches approximately from 37 degrees latitude north to 35 degrees latitude south and has 54 sovereign nations (48 mainland and 6 Island States) [1]. 49 of these 54 nations belong to Sub-Saharan Africa, these are the countries that lie partly or fully south of the Sahara.

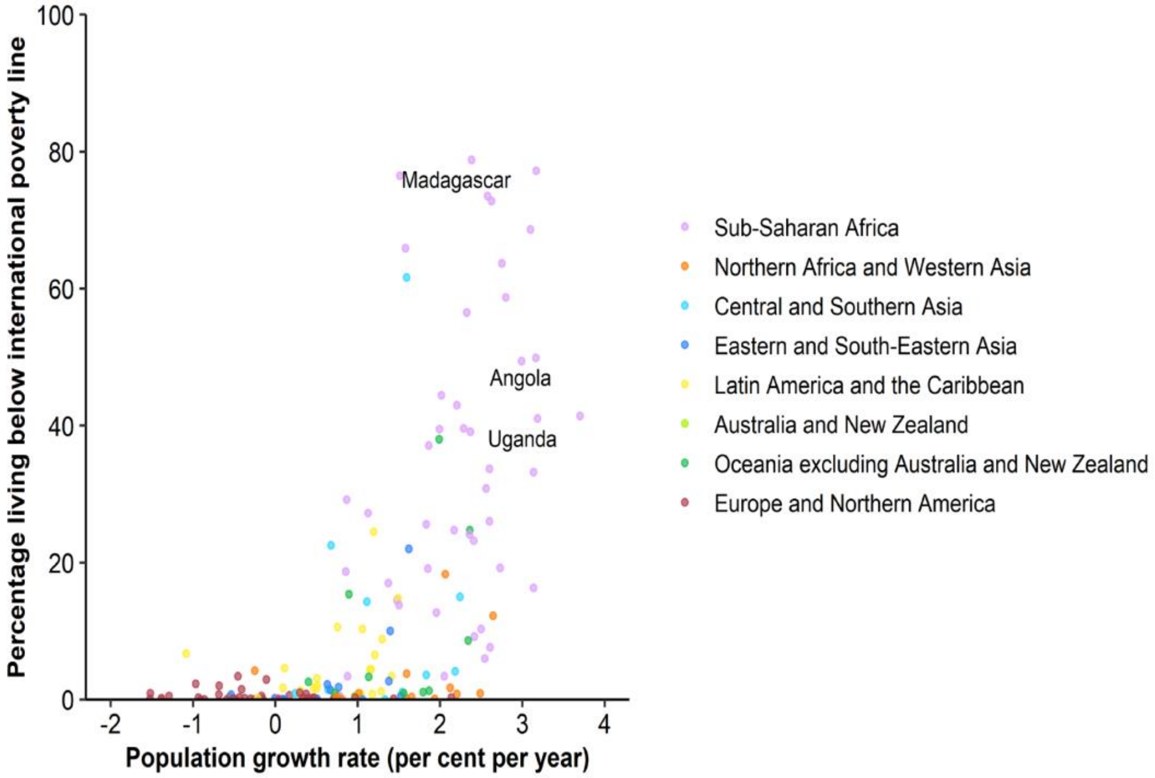
The populations of countries in the Sub-Saharan African region are expected to continue growing through 2100 [2]. Between 2022 and 2050, the population of this region is expected to almost double, surpassing 2 billion inhabitants by the late 2040s. With average fertility levels of 4.6 births per woman in 2021 which will be remaining close to 3 births per woman in 2050, Sub-Saharan Africa is projected to account for more than half of the growth of the world's population between 2022 and 2050 [2]. In 2022, the size of the population in this region was growing at an annual rate of 2.5 per cent, this is more than three times the global average of 0.8 per cent per year [2].

More than half of the projected increase in the global population between 2022 and 2050 is expected to be concentrated in just eight countries: the Democratic Republic of the Congo, Egypt, Ethiopia, India, Nigeria, Pakistan, the Philippines and the United Republic of Tanzania [2], 5 of which are African countries, 4 belonging to the Sub-Saharan Africa region.

While population in Africa used to be mainly rural (40 % as of 2014 [3]) Africa is urbanizing faster than other regions. The urban growth in Africa is at around 3.55 % per year with the urbanization rate expected to reach 59% by 2050 [3]. The growth of the number of Cities with more than 5 million inhabitants will grow fastest in Sub-Saharan Africa between the years 2020 and 2070 [4]. At the same time, the region is also struggling to provide adequate housing to its population, represented by the proportion of urban population living in slum-households which is still above 50% in the Sub-Sharan African region (2020: 50.2 % [4]). On the other hand, waste generation in the region is also expected to triple by 2050.

According to the Sustainable Development Goals Report 2022 [5] in 2020 one in four urban dwellers lived in a slum or an informal settlement. This amounts to more than 1 billion people worldwide, 230 million of which are from Sub-Saharan Africa. According to that report a one per cent increase in urban population growth will increase the incidence of slums by 2.3 per cent in Africa [5]. The World Cities Report 2022 [4] states that based on data from an UNDP and Oxford Poverty and Human Development Initiative (2020) the urban population of multidimensionally poor in Sub-Saharan Africa amounts to 92.3 million people. In that context the issue of affordability of housing becomes especially relevant for Africa.

Figure 1-1 shows the correlation between population growth rate and the percentage of population living below the international poverty line. It is clearly distinguishable that the Sub-Saharan region is unprivileged with regard to the poverty. Most of the Sub-Saharan African countries show a comparable high annual growth rate of the population and a comparably high percentage of people living below the international poverty line.



Source: Based on the most recent data available for the period 2003-2021, SDG Indicators Database, available at https://unstats.un.org/sdgs/dataportal/database/. Accessed on 2 June 2022.

Note: SDG indicator 1.1.1 is the proportion of the population living below the international poverty line, which the World Bank has defined as a per capita income of U.S. dollars 1.90 per day in terms of purchasing power parity (PPP).

Figure 1-1: Population growth rate, 2015-2020, by the proportion of the population living below the international poverty line, 2003-2021 [2]

Although per-capita waste generation is currently lower in Africa than in the developed world, Sub-Saharan Africa is forecast to become the dominant region globally in terms of total waste generation if current generation trends persist [1]. 125 million tonnes of municipal solid waste (MSW) were generated in Africa in 2012, 81 million tonnes of which were from Sub-Saharan Africa, these numbers are expected to double by 2025 [1].

Waste collection services in most African countries are inadequate. The average MSW collection rate in 2012 in Africa was only 55% and in Sub-Saharan Africa it was on an average as low as 44% [1]. The actual collection rate varies very much between individual cities and can be as low as 20% or as high a 90%. The average collection rate of waste in Africa is expected to increase by almost 40% and should therefore be as high as 69% by 2025 [1]. It must also be born in mind that between 50 and 100% of the waste collection services in place is provided by informal waste pickers a majority of whom is living in slums [4].

Open dumping and open burning are still the main prevailing forms of waste treatment at a share of 47 % resp. 9 % with respect to end-of-life MSW [1]. 19 of the world's 50 biggest dumpsites are located in Sub-Saharan Africa [1].

All the above-mentioned aspects result in high pressures on waste management systems in urban areas in the African region on one hand and high demands for establishing adequate housing in the urban centres on the other hand. This pressure is likely to get higher as urbanization rate and per capital waste generation are increasing.

1.2 Circular Construction in Sub-Saharan Africa (CiCoSA) adding to a Sustainable Urbanization Strategy in the Region

Considering the region’s world fastest urbanization rate, the need for new construction works including housing and urban infrastructure will grow rapidly in the decades to come. Buildings and the construction sector are the single largest source of GHG emissions both at the time of production as well as during the use-phase. With the current baseline of most of the waste being neither collected nor managed in an environmentally sound manner the dimension of this challenge becomes clear. Applying circular economy and low-carbon principles in the sustainable building and construction (SBC) sector especially looking at the housing sector could provide some breakthrough solutions for the challenges imposed by rapid urbanization in the region.

There are many publications dealing with decarbonization and circularity in the building and construction sector such as for example the Global Status Report for Buildings and Construction [6], Circular Built Environment – Highlights from Africa [7] or Circularity and Sustainability in the Construction Value Chain [8] focus on the design of buildings and the use of sustainable materials, however, the utilization of waste as a secondary resource in the building and construction sector is not discussed in depth.

The CiCoSA Handbook examines benefits and risks of circular economy approaches to a sustainable building and construction (SBC) sector from the waste management perspective, providing practical case studies that could be scaled up in the region as part of a sustainable urbanization strategy. It also provides policy recommendations and implementation guidelines building on the current legislative landscape in the region, taking the example of Kenya and Namibia.

2. Waste Management and Circular Economy

Concepts and principles of "waste management" and "circular economy" share similar values and objectives. However, it can be said that seeking circularity while neglecting basic waste management principles could pose risks to human health as well as to nature in the long term. This section will deep dive into the two similar yet different concepts by highlighting key complementarities towards safe and circular economy with a special focus on the construction sector.

Circular economy is a concept of production and consumption, which involves sharing, leasing, reusing, repairing, refurbishing and recycling existing materials and products as long as possible [9]. In this way, the life cycle of products and materials is extended and natural resource extraction should thereby be reduced as much as possible. As per the UNEP concept of circularity there is the guiding principle of reduce by design accompanied by eight value retention loops (8Rs) that allow for achieving the establishment of a circular economy [10] as shown in Figure 2-1.

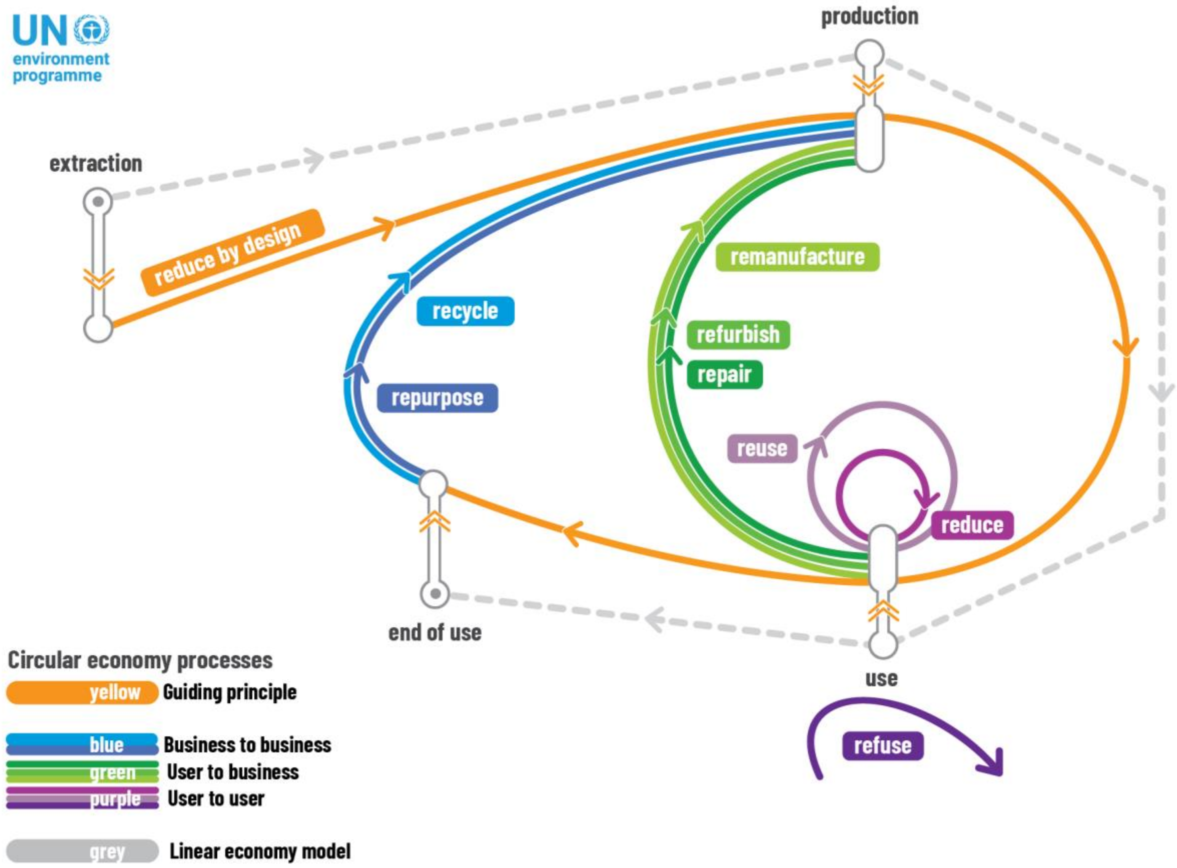


Figure 2-1: UNEP Circularity concept

While "circular economy" is a concept of production and consumption, "waste management" focuses on the downstream solutions for managing end-of-life products and materials minimizing environmental pollution and protecting public health. Although waste management focuses on downstream solutions, the concept of "waste management hierarchy" [11] recommends "prevention", "minimization" and "re-use" to avoid "waste" generation as much as possible. These overlaps with reduce by design, refuse, reduce, re-use, repair, refurbish and remanufacture under the concept of circular economy. "Recycle" under the waste management hierarchy overlaps with repurpose and recycle. However, the concept of “recovery including energy recovery”, “landfill” and “controlled disposal” in the waste management hierarchy are not covered under the concept of circular economy. Those elements of the waste hierarchy are important since they are relevant for materials that must not be kept in the anthroposphere but need to be treated and disposed of in order to protect humans and the environment. While it is important to close material loops and thereby allow for the establishment of a circular economy, it must be acknowledged that only products or materials that will not pose any risks to human and public health should be reused or recycled. It is important to acknowledge that a clean and safe circular economy should not create pollutant cycles and cause accumulation of pollutants in products in the market.

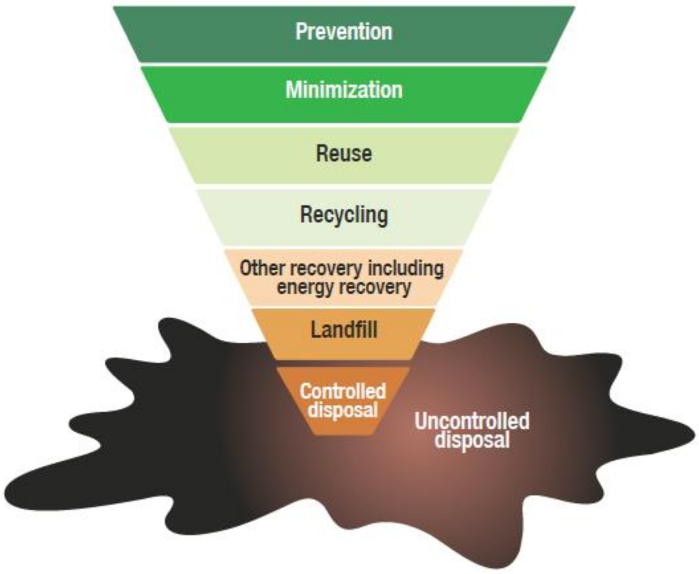


Figure 2-2: Waste Management Hierarchy [11]

In addition, it is also important that “recyclability” of the products and materials are affected by the product design, the product use as well as the development of a secondary resource market. The latter very much depends on environmental legislation as well as its enforcement in a specific region. For example, globally only 9% of the over-all plastic waste is recycled [12]. Low recycling rates of plastics are largely due to the lack of market for specific types of secondary plastics, for which a sustainable operation of recycling is not economically viable.

The same applies to other products and materials. Recycling loops can only be economically viable when there is a market for the specific recycled products and materials. This means different geographical locations have different recyclability. This results in a large portion of products and materials to be mismanaged (open dumping, open burning) or managed according to a different – economically more attractive – waste management route such as utilization as Refuse Derived Fuel (RDF), incineration for energy recovery or disposal at landfill sites.

Products and materials that cannot be recycled or recovered or contain pollutants which pose human health risks need to be managed accordingly. Especially products containing pollutants should not be fed into a recycling loop leading to accumulation and must be managed in an environmentally sound way. This for example could be the incineration for organic pollutants or a safe and sound sanitary landfill for inorganic compounds.

This essential element of sinks is missing in **Error! Reference source not found.**. The concept of "sinks" in order to avoid accumulation of pollutants is largely acknowledged by several international conventions, such as the Stockholm Convention for Persistent Organic Pollutants (POPs) [13] and the Montreal Protocol for Ozone Depleting Substances [14] [15] that prevents specific substances from the economic cycle, to treat and destroy them or retain them in a safe manner. This element of preventing inappropriate substances to go circular is one of the important aspects when discussing circular construction materials.

The need for preventing pollutants to re-enter the economic cycle is especially relevant wherever long-lived products are involved. This is particularly valid in the building and construction sector where the product lifetime even for plastic-based products usually is more than 20 years and sometimes up to 50 years and more (see Figure2-3). Due to these long lag-times from production to end-of-life of a product there is a great risk that products are contaminated with legacy substances once they become waste. This is especially true with regard to any demolition and refurbishing activities resulting in waste arisings of such "old" products.

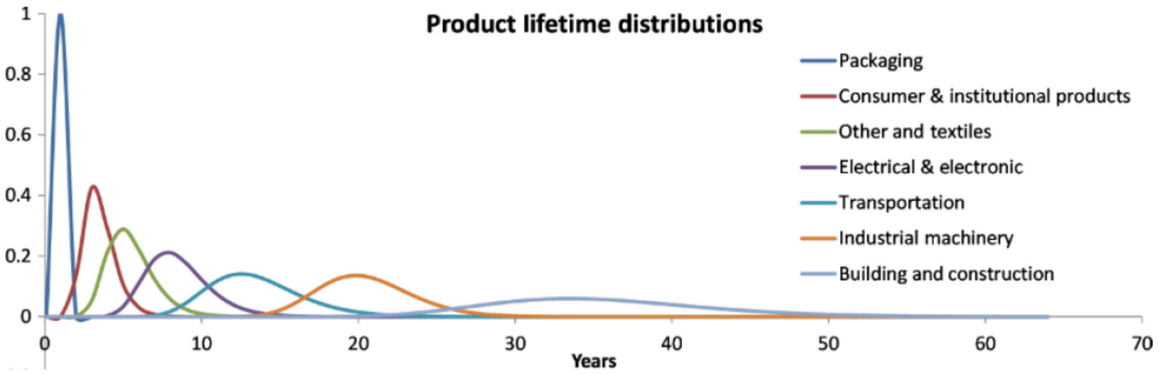


Figure2-3: Product lifetime distribution [16]

The risk of accumulation of toxic contaminants in products through inappropriate recycling is preventative when there is a strong institutional framework with the appropriate infrastructure and its controlled management with the environmental regulation enforcement in place to ensure sound waste management. However, when this is lacking there is a high risk that circular economy retains toxic products and materials in use, possibly affecting human health. This pose concerns particularly in building and construction sector where products have a longer lifetime when for example compared to packaging.

The Circularity Gap Report (2022) [17] presented only 9.1% of global economy is circular and suggested 21 circular solutions for a 1.5-degree pathway, which include circular construction materials. The report suggested 1.14 GT emission and 3.55 GT material use can be saved through the promotion of this solution where construction materials with recycled content, diversion of construction and demolition waste are promoted.

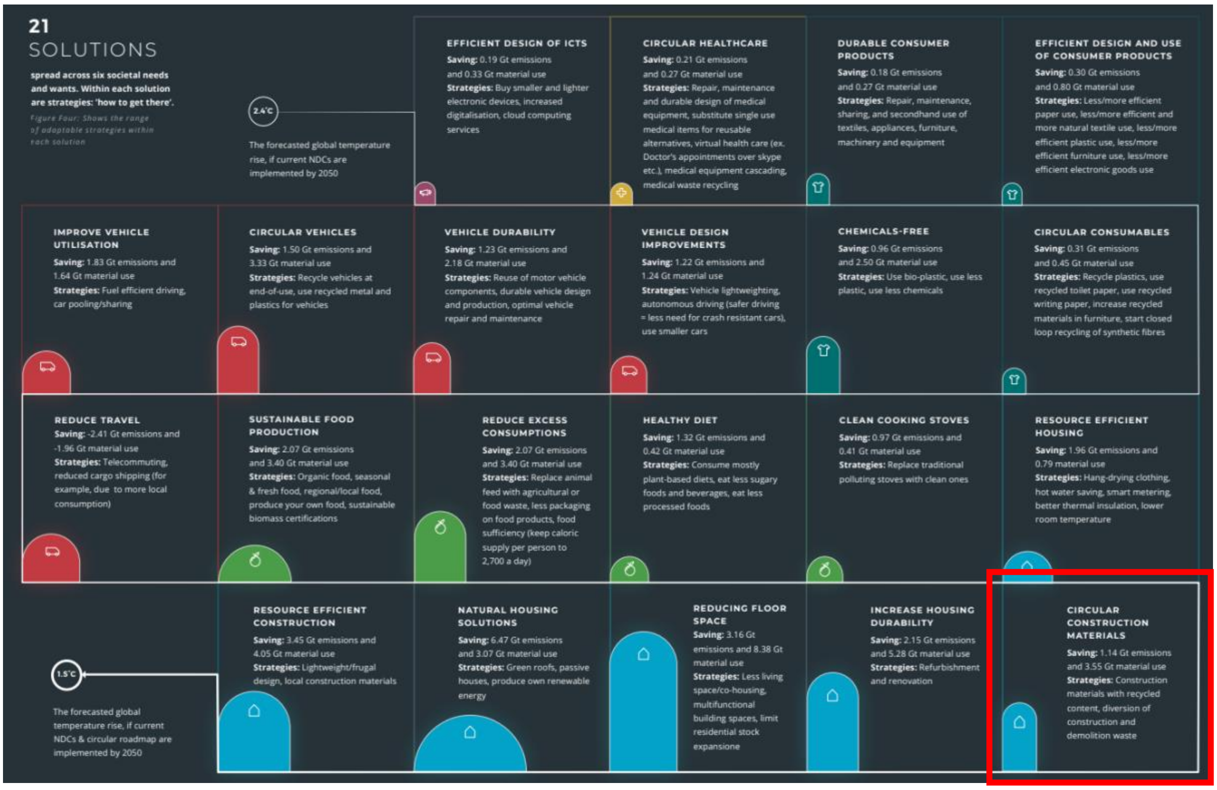


Figure Four: Shows the range of adoptable strategies within each solution

CiCoSA Handbook aims to delve into possible circular construction material options that is applicable in the Sub-Saharan African context, paying a careful attention to remove the toxic products and materials, with waste management perspective.

3. Circular Construction Cases According to Different Waste Streams

This chapter should give a brief overview about the current status of generation as well as management of specific waste streams. Based on their relevance for the circular construction both in terms of quantities generated as well as the potential of (partial) recovery following waste streams are looked at in detail:

- Municipal Solid Waste (MSW)
- Construction and Demolition Waste (CDW) as well as
- Agricultural Waste

Apart from a few publications addressing MSW and providing some overview there is very little systematically recorded data on waste generation and waste disposal. Therefore, only a brief overview based on available data and case studies can be provided.

1.3 Municipal Solid Waste (MSW)

1.3.1 What is Municipal Solid Waste?

Municipal solid waste (MSW) is also commonly known as trash or garbage in the United States and rubbish in Britain. It is a waste type consisting of everyday items that are discarded by the citizens. The quantity as well as the quality and composition of MSW very much depends on the consumption habits of the citizens as well as the collection system in place. In principle all different kinds of material such as plastics, paper, textiles, food waste, glass and metal among others are to be found in MSW. Besides the every-day waste discarded by citizens the MSW also comprises of waste from school, offices and commercial waste as long as it is similar in nature and composition to household waste [18].

According to the World Bank [19], organic, i.e. biodegradable, waste constitutes 57 % of the total MSW generated in Sub-Saharan Africa as illustrated in **Error! Reference source not found.**, considerably higher than its proportion when compared to the total global MSW (relative to the other waste components). Plastic as a percentage of MSW for Sub-Saharan Africa is also higher than the global average, at 13 %. These two aspects are of special importance as 1) the proportion of biodegradable waste poses a high potential and risk for the formation of methane when there is no adequate collection, treatment and disposal for MSW in place and 2) the proportion of plastics becomes especially important when the waste is not collected or treated in an adequate manner due to clogging of sewers and/or release of plastics to the environment.

According to The Global Waste Management Outlook 2024 which poses the most recent publication on this subject matter around 68% of the MSW in Sub-Saharan Africa is comprised of food and garden waste, around 6 – 7 are represented by paper and cardboard respectively plastic and 2 % are glass [20].

Comparing these two numbers it becomes clear that available data show different numbers this is a common draw-back and shows that reliable and consistent data still need to be collected.

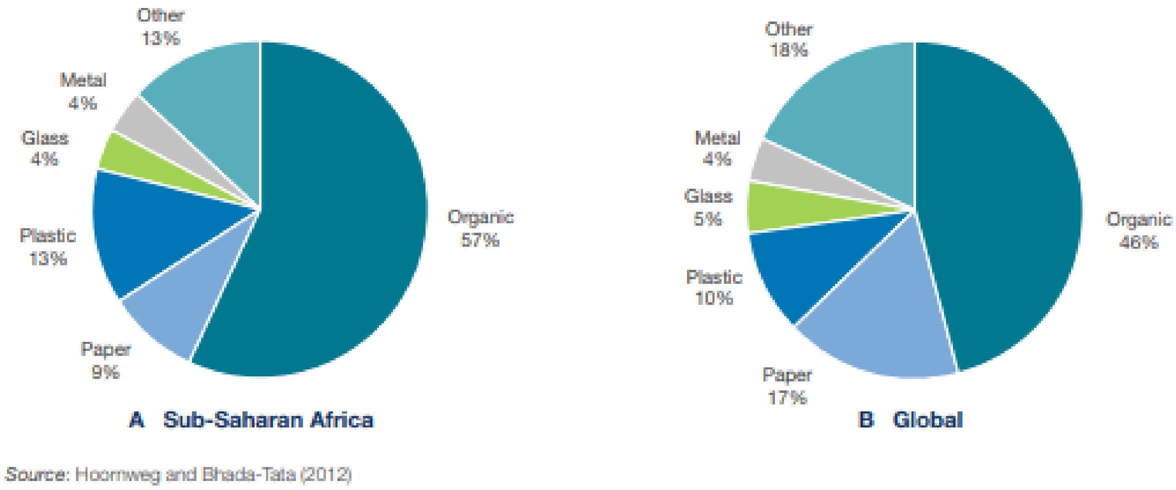


Figure 3-1: MSW composition, Sub-Sahara and global [1] based on [19]

1.3.2 Estimated MSW generation in Sub-Saharan Africa

With regard to Municipal Solid Waste (MSW) the first and foremost truth that becomes obvious researching qualitative and quantitative data for the Sub-Sahara Africa region is that there is a lack of solid and reliable data. The most recent and reliable information available is the African Waste Management Outlook issued by UNEP in 2018 [1].

The data presented in Figure 3-2 is based on the best available comprehensive data for Africa. The spatial distribution of MSW generation in African countries was mapped based on data drawn from the World Bank [19] and Scarlat et al. [21].

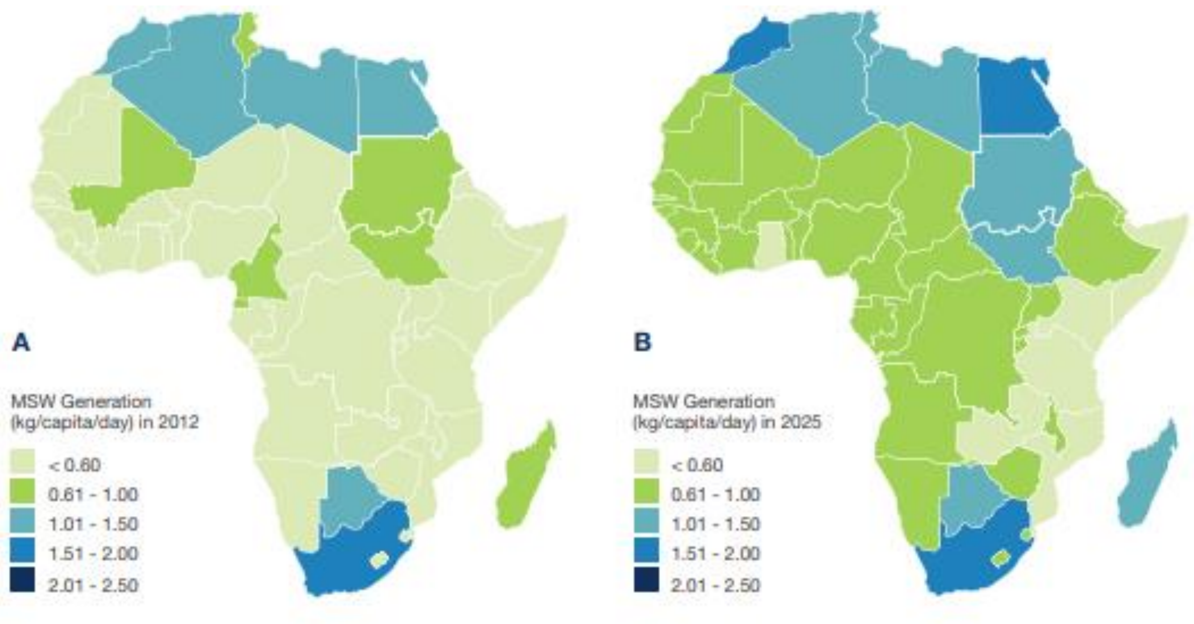


Figure 3-2: Daily per capita waste generation in African countries in 2012 (A) and 2025 (B) [1] based on [19]

The estimations focus on solid waste generation in urban areas in Africa, as data for rural waste generation and management in Africa is almost non-existent. It is generally assumed that per capita waste generation in rural areas is lower than in urban areas owing, for example, to lower purchasing power, higher rates of waste reuse, and lower household consumption patterns.

The total MSW generated in Africa (in 2012) was estimated to be 125.0 million tonnes a year, of which 81.0 million tonnes was from Sub-Saharan Africa [21]. North African countries have a relatively higher per capita waste generation than Sub-Saharan countries (compare Figure 3-2). Recently published data show a little more than 200 million tonnes of MSW in Sub-Saharan Africa 90% of which is uncontrolled [20]. Unless urgent action is taken the figures for Sub-Saharan Africa will increase to almost 500 million tonnes be 2050, still more than 80% uncontrolled [20].

Collection rate refers to the total waste collected to total waste generated. The collection rate of African countries in 2012 ranges from as low as 18 % to over 80 % as illustrated in Figure3-3.

The average collection rate for the African continent is projected to increase to 69 % by 2025 [21]. Given the likely increase in MSW generation, however, the quantity of uncollected MSW is not expected to decrease, even with this improvement in collection rate.

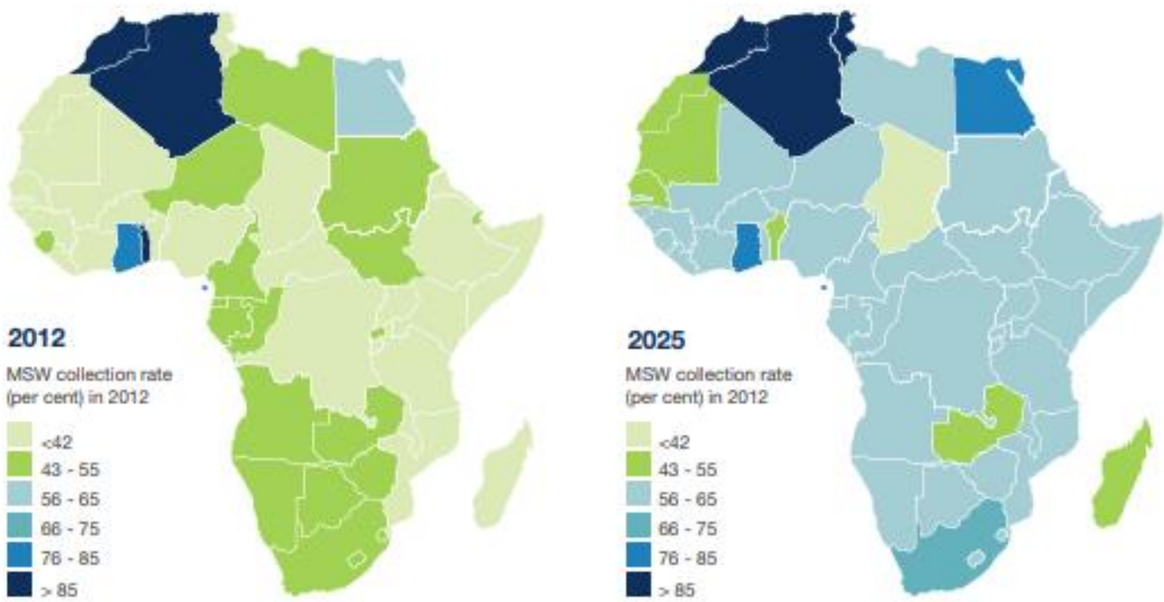


Figure3-3: MSW collection rate (per cent) in 2012 and in 2025 [1]

The average collection rate for MSW in Sub-Sahara Africa lies at 49% in 2023 and is therefore the lowest globally [22]. In addition to that also the share of MSW managed in controlled facilities is the lowest globally at 15% (compare Figure3-4) [22].

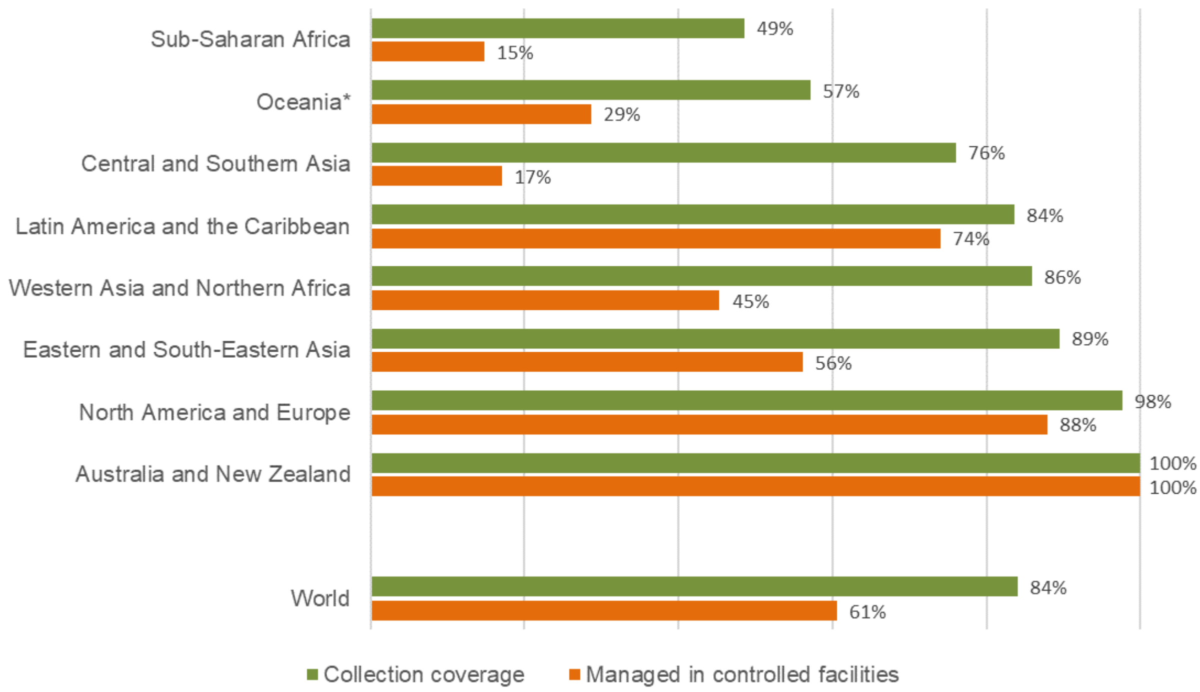


Figure3-4: MSW collection rate and percentage of treatment in controlled facilities in 2023 [22].

A household-based survey conducted by UN-Habitat in the cities of Nairobi, Kenya, and Kampala, Uganda, revealed that the population with access to the basic waste collection service differs from 10% in the slum areas to 70% in the non-slum areas [22]. It is especially in underserviced areas where the informal sector plays an important role for resource recovery from waste.

Open burning and open dumping are the most prevalent "management" options of MSW in Sub-Saharan African countries. This leads to a high emission of short-lived climate pollutants (SLCP) such as methane and carbon black as well as the emission of plastics and microplastics to the natural environment. Both, collection, and environmentally sound downstream management of MSW entails a huge potential for improvement.

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1.3.3 Toxic and Hazardous Substances in MSW

1.3.4 Cases for the Utilization of MSW for Construction Materials

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1.3.5 Benefits of using MSW for Circular Construction

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1.3.6 Stakeholder Mapping for the Increased and Safe Use of MSW for Construction Materials

1.4 Construction and Demolition Waste (CDW)

1.4.1 What is Construction and Demolition Waste?

Construction and Demolition Waste (CDW) is generated during the construction phase of buildings, during refurbishments and at the end-of-life phase.

Typical CDW are timber, metal, concrete, glass, gypsum, asphalt, clay bricks, tiles, as well as asbestos-containing and other potential pollutant bearing building materials. CDW is one of the major waste streams in terms of weight and volume. Studies have shown that in some countries the CDW is representing up to 50% of the total volume of waste landfilled [23]. For example concrete is globally the second most consumed material after water along with the urbanisation at the global scale.

Studies on South Africa about CDW quantities showed that CDW is significantly underreported. Reasons for this include lack of reporting by municipalities and public statistics about proper waste characterization. The use of CDW for informal constructions of residential buildings and informal recycling also makes it difficult to understand the scale of CDW reuse and recycle on the ground. Most of the CDW nevertheless is in the best case landfilled, in many cases however dumped into illegal dumpsites or dumped into riverbeds, and therefore forever withdrawn from reuse and recovery of the material resources.

Most of the materials in CDW stream are long lived products, which are hardly bio-degradable and most of the time not burnable. As the products are long lived there is a high potential of legacy substances to be part of the demolition waste (compare Figure2-3). This poses a major challenge to environmentally sound practices for a circular construction sector.

Quantitative understanding of CDW generation is essential to plan and establish an effective waste management system where CDW is used as resource to substitute new construction materials [24].

Volume of demolition waste in general is much higher than construction waste. Globally it is estimated that up to 75% of the waste generated by the construction industry has a residual value and currently is not reused or recycled [25]. To improve data availability about the CDW generation and composition as well as to identify construction components containing pollutants and legacy substances, waste audits before the demolition of buildings started, would improve the data availability significantly and this data could be used for a meaningful deconstruction strategy that also ensures that construction parts containing legacy substances and pollutants are not reused or recycled and reusable and recyclable constructions components are used as secondary resources to the highest possible degree [26].

Figure3-5 gives an overview about the typical CDW types and the embedded resources which could be recovered. The actual quantity of CDW is also dependent on the legislation as well as its actual implementation and enforcement in respective countries. For example, excavation soil is not always seen as a waste in legal terms.

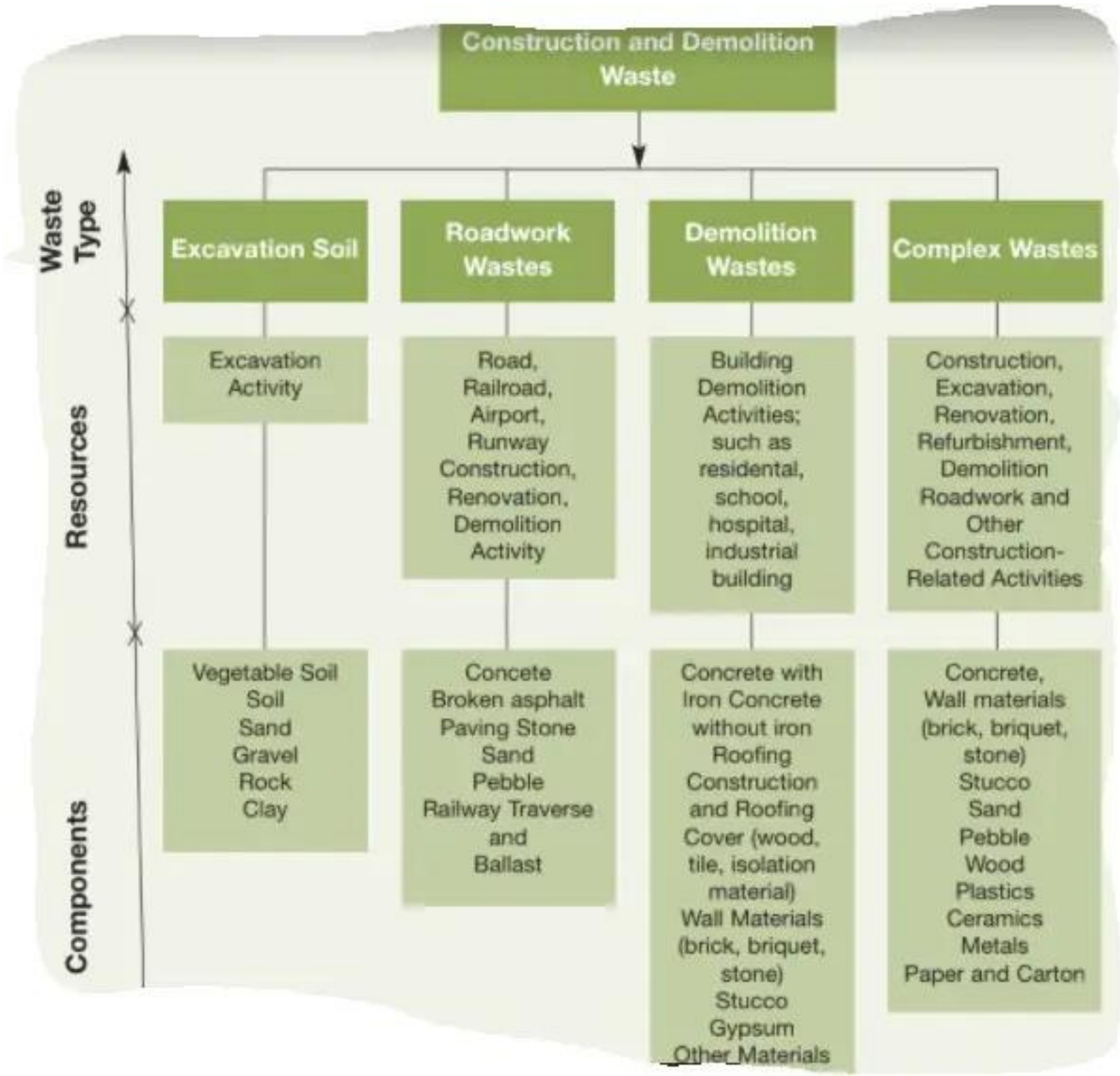

Figure3-5: Various types of CDW [27]

While it can be assumed that CDW generation per capita in Sub-Saharan Africa is still lower than other regions, the current rapid urbanization would lead to an increase of this waste stream in the near future. Additionally, reuse and recovering CDW has a positive climate impact due to the high embodied energy and thereby ecological footprint.

CDW provoke a series of environmental problems in places where they are not managed in an environmentally sound manner. The most urgent issues related to CDW are the following [28]:

- CDW very often is illegally disposed of and is provoking routinely the clogging of open water drains and water channels and leading to flooding.
- The fine fraction of open dumped CDW contributes to particle matter pollution.
- Dumping of CDW place provoke serious health risk and risk of injury for residents.

- Hazardous substances in CDW are contaminating the ground water and air if not properly landfilled.
- The mixing of CDW with other waste streams, like MSW, makes the recovery of recyclable fractions technically more challenging.
- The dumping of CDW in wetlands or riverbeds are a serious threat to these sensitive ecosystems.
- CDW, due to its bulky shape, consumes in landfills a lot of volume and results in the need for more landfills.

1.4.2 Barriers for circularity of CDW

There are some key reasons why CDW are not properly used as a resource for building materials in the construction sector [29].

- **Lack of suitable policy, governance, and enforcement**

The lack of policy related incentives to recycle CDW back into the construction sector as well as missing monitoring and enforced rules on proper disposal respectively missing enforced penalties on improper CDW management are one of the principal barriers to promote such alternative and sustainable uses.

- **Lack of quality and performance**

The proper quality of CDW is key in order to return these material stream back to become high quality resources for the construction industry again. This requires efforts prior and during the construction or demolition activity as well as skilled man-power for the orderly separation of the different waste fractions and the timely detection of contaminated materials, like with chemicals treated wood, etc.

- **Lack of Information, know-how and technology**

A lack of knowledge and information in the construction industry about the benefits and the potential of recycled CDW materials are a main factor which is limiting the exploitation of that resource.

- **Lack of competitiveness**

Where improper dumping practices are not criminalized and where no adequate landfill levy is collected open dumping or landfilling will turn out to be cheaper than recycling the materials. This is limiting the acceptance of such type of materials for reuse and recycling.

- **Lack of acceptance**

In the construction sector many times the perception about waste as a worthless material is limiting the acceptance by users to use these materials for construction purposes.

- **Permits and specifications**

Lack of material specifications and laws which are not granting permits for the use of such recycled materials are a major limitation for its increased use. Furthermore, contractual arrangements between principals and construction companies as well as applicable standards constituting fundamentals for the contractual arrangements are sometimes an obstacle for reuse and recycling.

The following illustration summarizes these barriers and shows the enablers, which can support the use of CDW as resource in the construction industry. In addition, this illustration shows very clearly that there are many stakeholders involved in the realization of buildings. All of them in different roles and with different boundary conditions such as contractual arrangements, standards, guidelines, and laws to respect; so circular construction therefore also encompasses very often a redesign of prevailing processes and interfaces in the construction sector in order to actually allow for a broader implementation.

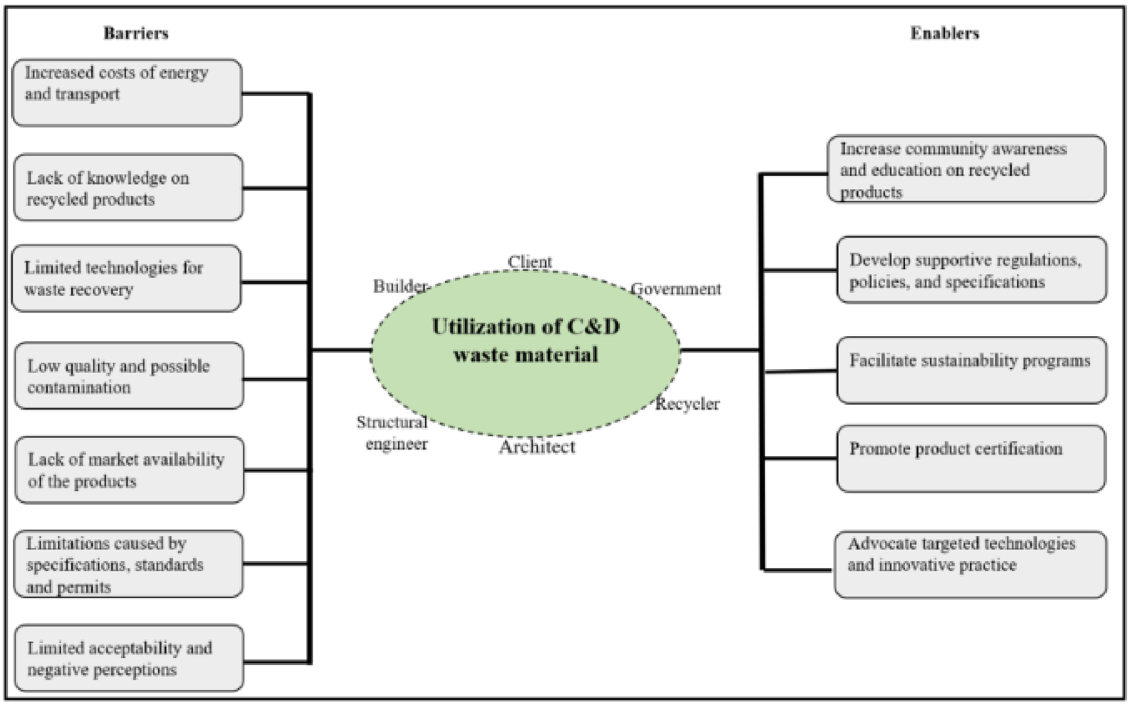

Figure3-6: Barriers and enablers of CDW as building material [30]

1.4.3 Benefits of using CDW for Circular Construction

Because of the large quantities of natural resources which are consumed by the construction sector the application of the concept of circularity for CDW has a couple of benefits which are highlighted in this chapter.

- Environmental benefits
  The landfilling of CDW provokes a series of environmental problems which can be reduced if more of this waste stream can be diverted and used again for the construction of buildings. Organic materials, like timber, result potentially in high methane emissions and therefore contributes to climate change. Additional to that, CDW contributes due to the high quantities to an accelerated filling up of scare landfill space. The diversion of CDW towards a circularity-orientated use, reduces these harmful effects at landfills and contributes to avoided environmental contamination due to heavy load traffic.

- Economic benefits
  The recycling of CDW in Sub-Saharan Africa could contribute to the development of many new employment and entrepreneurship opportunities. The processing of such waste streams to process them to useful materials for the construction industries can contribute to the formation of new companies to offer these types of services. Such companies will create many new formal job opportunities for qualified and un-qualified labour opportunities and can therefore contribute significantly to the improvement of economic conditions in Sub-Saharan Africa.

  Additional to that the avoidance of landfilling of CDW can reduce the financial burden due to waste levies, if applicable under the specific context.

- Social benefits
  Most of landfills in Sub-Saharan Africa are still unmanaged dumpsites significantly deteriorating the living conditions of many communities living nearby. These impacts range from contaminated water and air quality up to the devaluation of the value of agricultural and building land at and nearby of dumpsites. The reduction of landfilling CDW can contribute significantly to lower these negative social impacts on adjacent communities.

1.4.4 Toxic and Hazardous Substances in CDW

Critical in the CDW composition is the use of environmentally questionable substances, which can be legacy substances and make deconstruction and proper treatment or recycling of CDW very challenging. In the second half of the 20th century the replacement of traditional building materials by new and synthetic alternatives has been seen as important part of economic development in order to improve diverse material properties like durability, insulating properties, weight reduction or the reduction of costs. Not always these new materials have been undergone a detailed examination regarding its impact on health during the use period or the environmental risk related to their final disposal. The use of some of these substances already has been prohibited based on international law (i.e. Stockholm Convention for Persistent Organic Pollutants (POP`s) [13] and the Montreal Protocol for Ozone Depleting Substances [14]) but, some are still being used. In any case these materials are part of the existing building stock and thereby become relevant once buildings are deconstructed. These materials and contaminations still pose a danger for human health as part of the continuously generated CDW in the long term.

We would like to point out some of the major pollutants that are prevalent in (historically) used building products. This is Asbestos, flame retardants such as Hexabromocyclododecane (HBCD), ozone depleting substances such as Hydro-Chlorofluorocarbons (HFC`s/CFC`s) as well as plasticizers such as Poly-Chlorinated Biphenyl (PCB) [31]. These are only some examples as there is many more relevant contaminants to be considered and taken care of (for instance also wood preservatives such as for example Pentachlorophenols). With regard to the mentioned applications the focus will be laid solely on application relevant to the Sub-Saharan African region.

- **Asbestos**

Most known is probably the use of Asbestos, which has been used worldwide in the 20th century as cheap material for thermal insulation, and roof covering. In addition to that Asbestos was also used for fire-protection purposes for instance spray-coating and in flooring, pipes, and ducts as well as paints and so on. Its putting on the market and its use is in industrialized countries already banned since the last century due to the related health dangers, but in some Sub-Saharan African countries its utilization is still common today (compare Figure3-7) [32].

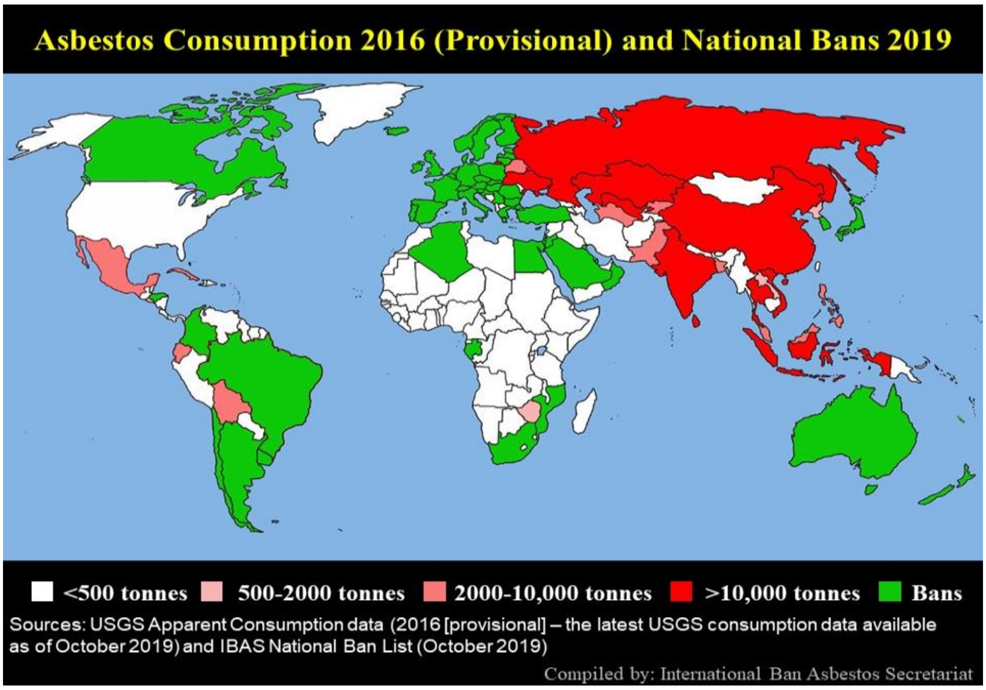

Figure3-7: Asbestos Consumption 2016 (provisional and national bans 2019 [33]

Due to its durability Asbestos products are still widely spread in our existing building stock even though they sometimes have been banned decades ago (compare Figure3-7). Asbestos is listed in the Rotterdam Convention (Amphibole Asbestos) or recommended for inclusion in Annex III of the Rotterdam Convention [34]. Figure3-8 shows an application example of Asbestos containing corrugated sheets.

<<add a photo of corrugated asbestos sheets in a slum or on a building in the SSA context>>

Figure3-8: Corrugated Asbestos Sheets in use [XX]

- **Flame retardants such as Hexabromocyclododecane (HBCD)**

Especially in polymer products such as expanded polystyrene (EPS) and extruded polystyrene (XPS) as well as textiles Hexabromocyclododecane has been and still is used as a flame retardant. In a recent comprehensive risk assessment, the US EPA has concluded HBCD in XPS/EPS insulation foam to pose unreasonable risks to the environment at all life cycle stages (i.e. manufacture, use, disposal and recycling) [35]. Figure3-9 shows an application example of HBCD containing insulation material.

<<add a photo of EPS / XPS in use in a slum or on a building in the SSA context>>

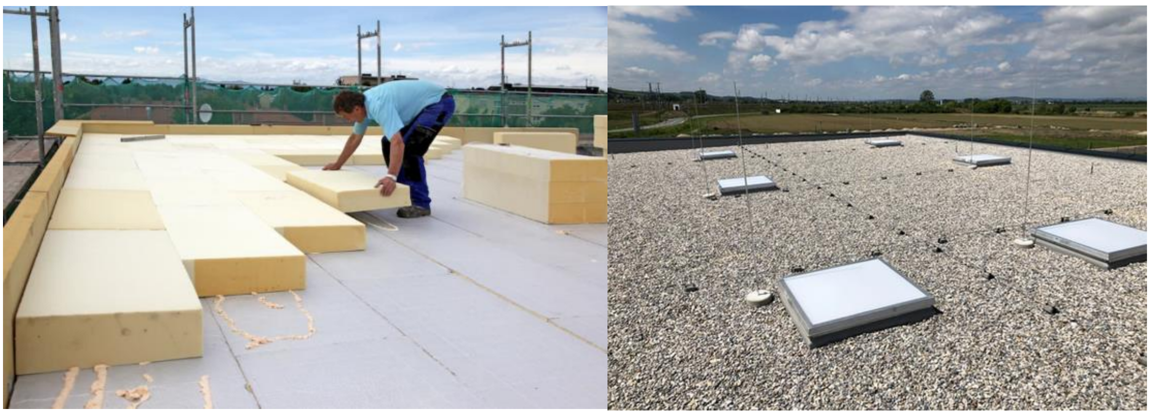

Figure3-9: EPS / XPS sheets in use [XX]

One of the main paths of exposure for this kind of contaminant is through plastics release to the environment and microplastics entering the food-chain and subsequently being taken up by human beings. Figure3-10 gives information about human exposure of micro- and nano plastic particles. Figure3-11 explains the effect of flame retardants and plasticizers that have been and are used as additives for plastic products on the human body.

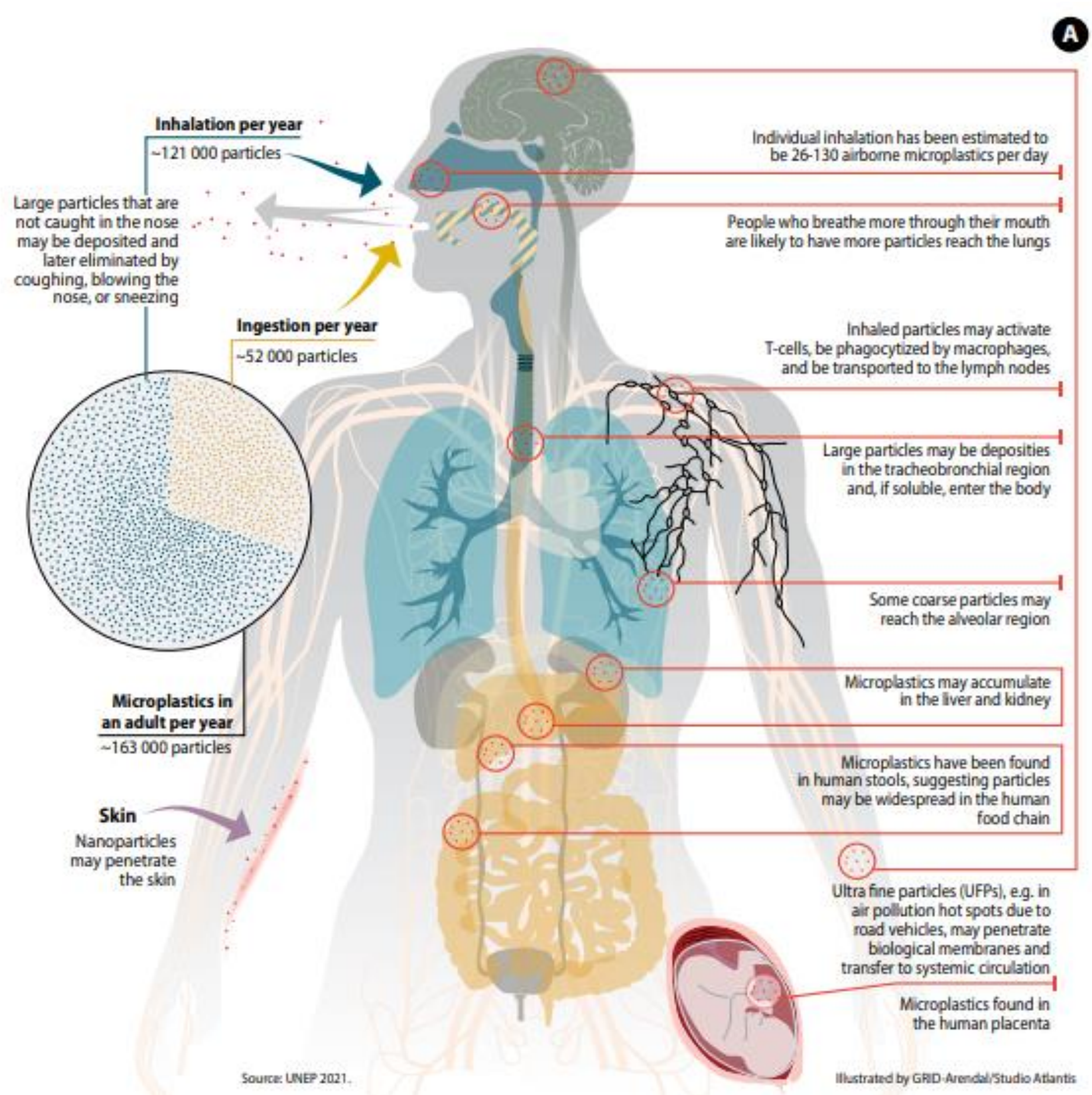

Figure3-10: Human exposure to micro- and nano-plastic particles [36]

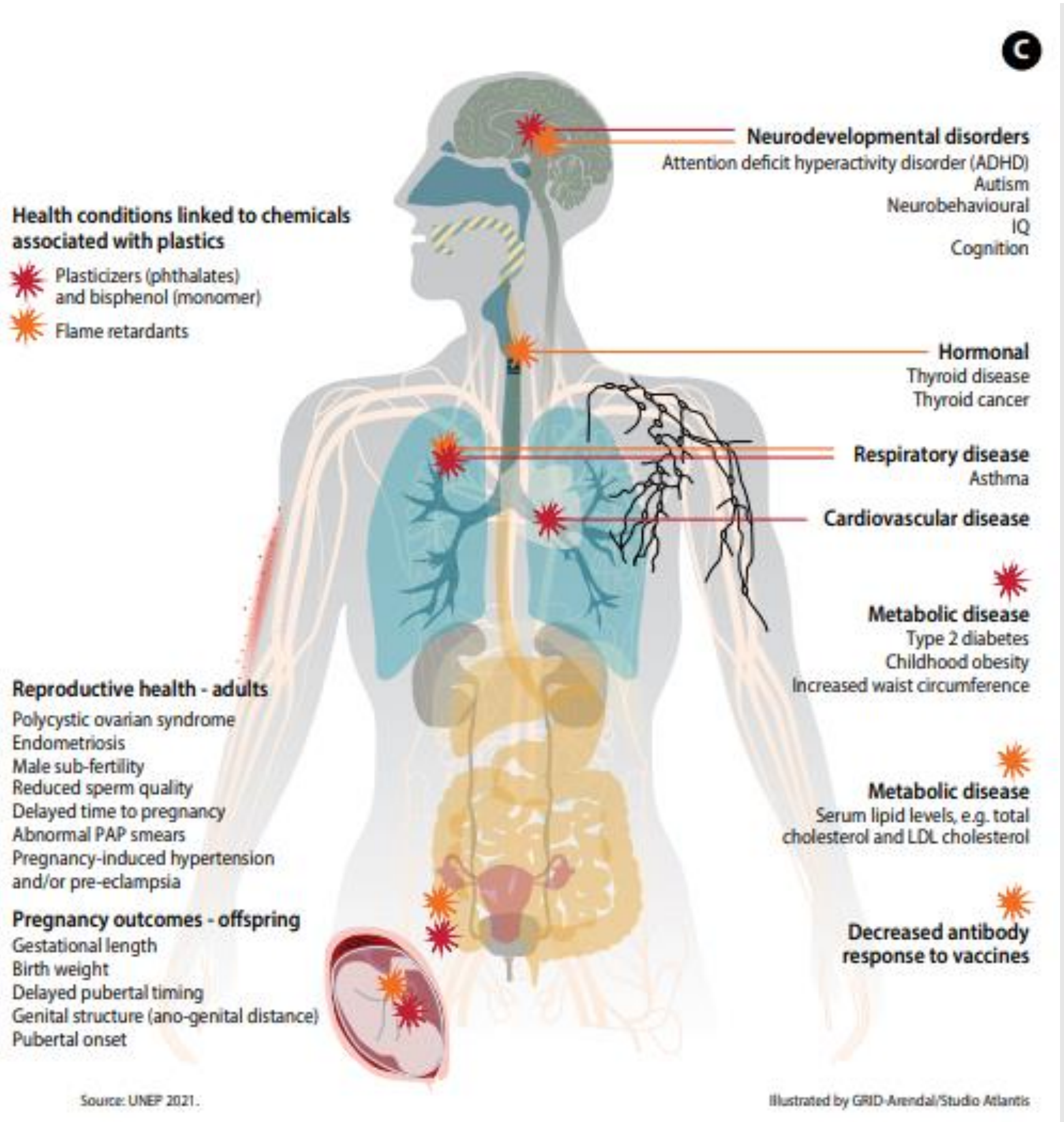

Figure3-11: The effect of plasticizers and flame retardants on the human body [36]

- **Ozone depleting substances (ODS) such as (Hydro-)Chlorofluorocarbons (HFC`s/CFC`s)**

Amongst other applications HFC´s have been widely used as blowing agents for foam products. Most relevant in the building and construction sector is XPS and PU panels used for insulation or as a composite sandwich component for construction purposes itself. These foaming agents have been banned from use in Europe in 2005 and cannot be brought to market in Europe anymore since 2009. However, when we keep in mind the lifecycle of such products, we have to acknowledge that such substances are widely in use in our building stock. If demolition is not done thoroughly these ozone depleting substances are set free during the demolition process. Figure3-12 shows an application example of ODS containing sandwich panels.

<<add a photo of XPS/PU sandwich panels in use in a slum or on a building in the SSA context>>

Figure3-12: Sandwich elements in use [XX]

- **Plasticizer**

This category of additives has been used for plastic products such as PVC-flooring or for expansion joints at building facades. The effects of plasticizers is explained in Figure3-11. Figure3-13 shows an application example of plasticizer containing expansion joints.

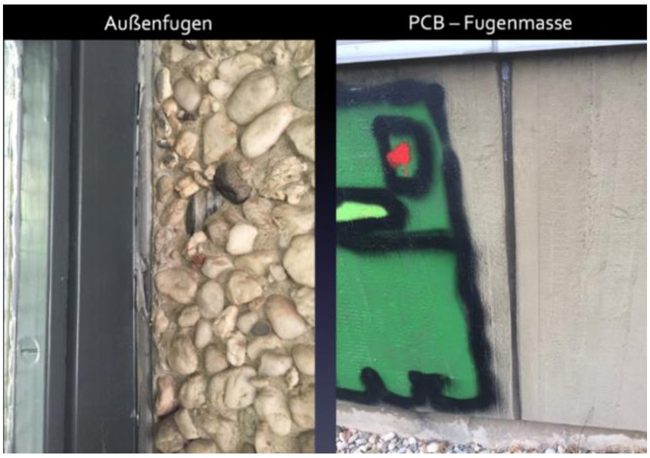

Figure3-13: Expansions joints in use [XX]

To avoid any negative health and environmental risks it is very important that hazardous substances are detected as early as possible in the CDW stream and diverted in order to avoid that such substances contaminate other fractions, which are suitable as resource for the construction industry. Pre-demolition audits, selective demolition practices as well as separate collection of different materials at source are therefore, vital elements for circular construction practices.

1.4.5 Cases for the Utilization of CDW for Construction Materials

As CDW streams are composed of a multitude of different materials the suitability of its use as input material in the construction industry is very much dependent on the actual separation of different materials at source. Quality assurance on a case-by-case basis is also a vital element for enabling circularity.

Below an overview about typical use cases for circular use of CDW is provided.

- Aggregate replacement for concrete production

  The use of typical aggregates in concrete, like sand and gravel, is becoming a huge environmental problem, due to its over extraction in many places and the loss of complete ecosystems depending on them, like beaches, riverbanks, etc. This global problem is growing fast in Sub-Saharan Africa due to the booming construction industry and the demand for sand and gravel for large buildings and infrastructure constructions [37] [38]. The replacement of sand and gravel by inert fractions of CDW is an ideal way to alleviate the pressure on these non-renewable resources. For that purpose waste fractions which typically are composed of bricks, concrete, ceramics, etc. are processed in dedicated CDW processing plants in order to recycle these materials and generate usable material fractions. In the academic literature many different materials are discussed as alternative aggregates in concrete. These range from the use of glass, ceramics, clay bricks, concrete waste, fly ash, agricultural waste up to fractions of the MSW like PET or rubber. Such usages have to be evaluated on a case-by-case basis in order to make sure that the environment benefits exceed potential negative effects. Important is the consideration of the waste hierarchy and to make sure that the use as aggregate substitute is done just for materials, where no higher value-added use case exists. The other important aspect, which has to be considered is the avoidance of future legacies, like microplastic generation, emissions of pollutants or the impossibility of future recycling of the concrete. Therefore, the use of inert and stable fractions as concrete aggregate, like glass, tiles, clay bricks or ceramic might be an interesting use case for such materials.

- Use for road surfacing

  Another interesting use option for CDW is the utilization as input material for paving roads and replace traditional aggregates like sand. The same preventive measures should be applied as for aggregate replacement in concrete. No material should be used which could lead to an environmental legacy in the future.

- Use of wood waste for scaffolding and formwork at construction sites

  Suitable wood fractions from CDW, like boards, beams or poles can be used directly at construction sites for formworks and scaffolding. Such use allows the replacement of natural wood and helps to reduce the use of natural resources from forests.

- Reuse of windows and doors

  Still suitable windows and doors from demolition sites can be salvaged for donation or for alternative uses, like for example for greenhouses

- Use as filling material

Bricks or concrete can be processed onside in order to use them as filling material for the new building or to stabilize the driveway bedding.

For all the proposed examples it must be stated clearly that there are quality criteria that need to be met according to the respective application. In addition, there might be standards, legislation regulations as well as contractual arrangements that have to be complied with.

Table

1.4.6 Stakeholder Mapping for the Increased and Safe Use of CDW for Construction Materials

To increase the utilization rate of CDW to recover embedded resources as construction material all involved stakeholders have to be addressed in order to improve the waste management of this type of waste.

The following illustration shows the main stakeholders, which have to be involved in such an improved waste management strategy for CDW.

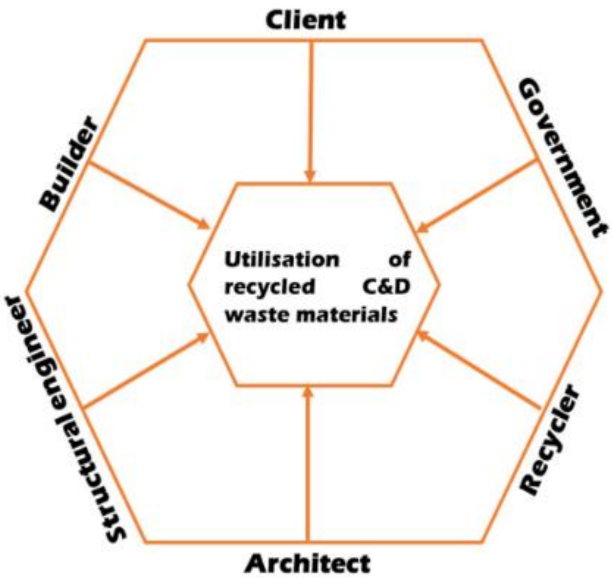

Figure3-14: Stakeholders for increasing the use of CDW as construction material [30]

1.4.7 4.2.8 Processing of CDW to building materials

For the processing of CDW it is important that all the easily removable and reusable materials are removed before the remaining waste enters a CDW processing line, where all the inert materials like stones, bricks, cement, ceramics, etc. are crushed and screened in order to produce aggregates of different sizes, which can be used as building materials. The following illustrations shows a typical process and material flow at a CDW processing plant (compare Figure3-15) as well as a waste concrete recycling plant (compare Figure3-16).

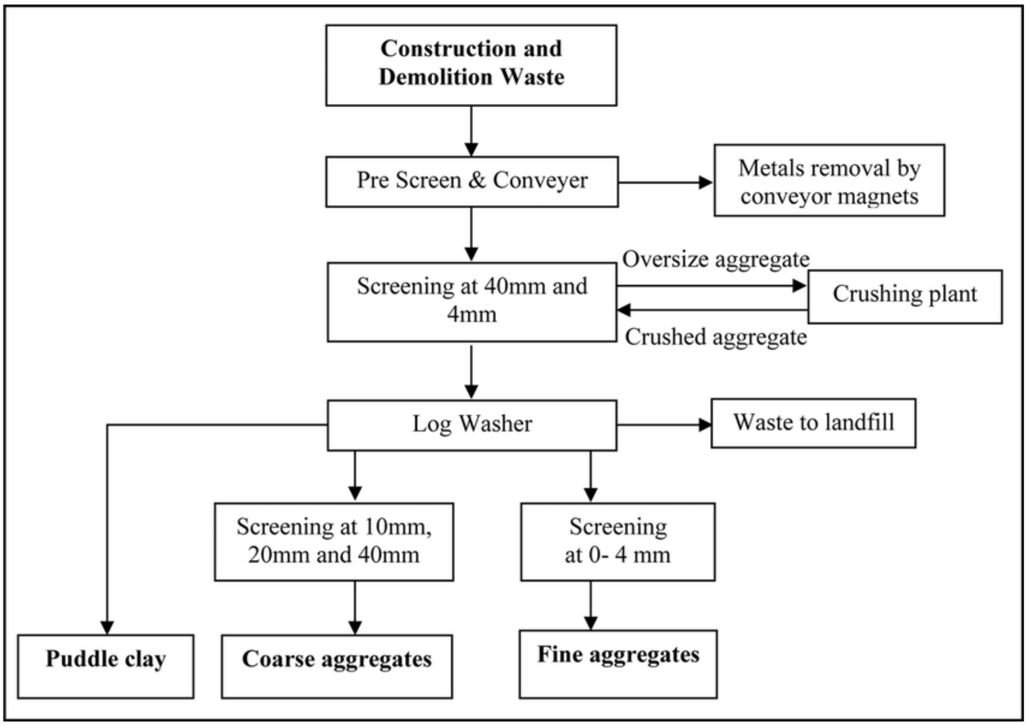

Figure3-15: Process flow for the processing of CDW to extract building materials [39]

The following illustration shows the process flow of waste concrete recycling.

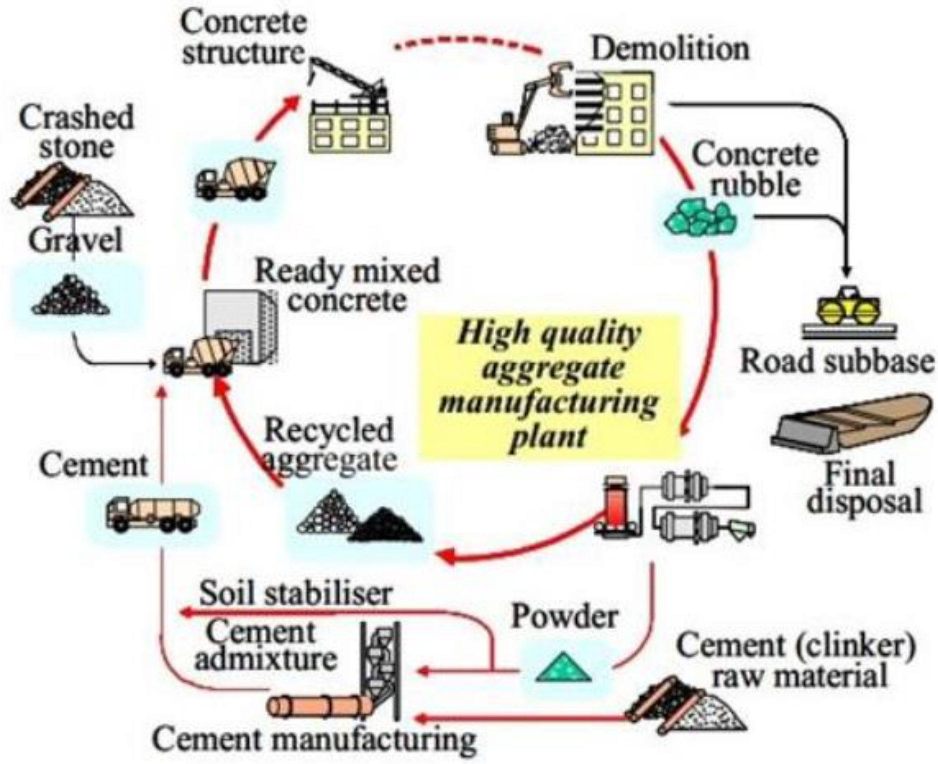

Figure3-16: Process flow for waste concrete recycling [40]

1.5 Agricultural Waste

In contrast to waste from construction and demolition (CDW) agricultural waste streams are always biodegradable and their occurrence is predominantly concentrated on the country-side, where agricultural production is happening. Agricultural wastes are very divers in their composition because these types of residues are coming from many different crops and in each climate zone other plants are cultivated and processed. In Sub-Saharan Africa typical agricultural residues are corn cobs, sugarcane bagasse, rice straw, rice husks, coconut shells, peanut husks, cacao pods and many others.

These types of waste pose several environmental challenges if not treated properly due to their biodegradability. Landfilling or open burning provoke a series of environmental problems, like air and ground water contamination or GHG formation (methane from landfills), that´s why the use of agricultural waste as input material in the construction sector can be seen as a beneficial opportunity to increase circularity by replacing unsustainable building materials.

The benefits of using agricultural residues in construction many times are not limited to the reduction of negative environmental impacts. Often the use of such type of materials can improve the quality of living by improving the air quality in buildings, support the natural management of moisture levels or reduce allergic reactions. Additional to that, the valorisation of agricultural residues can contribute to improve the economic viability of agricultural production, which contributes to improving the living conditions in rural areas. [41]

1.5.1 4.3.2 Utilization of agricultural waste as input material in the construction industry

As there are almost countless different types of agricultural wastes, its availability and potential to use as construction material differs widely. This section gives a short overview about common practice and opportunities to use specific agricultural waste as building material.

- Use as aggregate or cement substitute in concrete mixtures and cement blocks

Agricultural waste can be used as aggregate in concrete mixtures or cement blocks in order to achieve different material properties, like weight reduction or altered thermal properties and binding carbon in a sink at the same time. Many agricultural residues, like sugarcane bagasse, hemp fibres or jute fibres, have a high fibre content and can be used for this purpose. If and up to what amount such mixing is feasible, has to be evaluated on a case-by-case basis and is highly dependent on the actual use case and the prevailing static load.

Other agricultural wastes can be used to replace non-renewable materials like gravel and sand in concrete mixtures and cement blocks. This for example is the case for coconut shells, walnut shells, etc.

For certain types of agricultural waste, e.g. rice husk, its transformation to inert ash is done, before the ash is used as aggregate in concrete mixtures [41] [42]. The resulting ash from rice husk has a very high silica concentration, which has beneficial effects on the properties of concrete and allows to replace a fraction of cement in the concrete mix, with additional benefits in terms of GHG emission reduction based on the cement replacement [43]. As there is a risk of reduced strength of the concrete which contains agricultural waste particles, the use of this type of material seems to be more suitable for non-load bearing structures or low-story buildings [44].

The transformation of agricultural waste via pyrolysis to biochar is another promising solution for its use as input material in the construction sector. Biochar is produced from organic wastes, like agricultural waste, in a pyrolysis process, a thermal transformation process under oxygen-free process conditions. This allows to transform the organic waste in a type of stable organic carbon. Biochar can be mixed in concrete and so replace GHG intense cement, up to a certain amount without affecting negatively static properties [45]. This use case has a series of advantages. On one hand the thermal property of the concrete improves and results in a better quality of living in concrete buildings, and on the other hand the biochar is stable and allows a long-term sequestration of carbon, which otherwise would have been emitted to the atmosphere. This makes it to an interesting instrument for carbon sequestration and climate mitigation. The maximum amount of biochar which can be added depends on the occurring static load and has to be assessed on a case-by-case basis. However, it must be said that the operation of a pyrolysis unit and the production of a high-quality biochar that may be used in the construction sector demands a lot of infrastructure and also know-how.

- <u>Production of panels, composites and other structural elements</u>

Some agricultural wastes can be used as raw material for the fabrication of building materials, like panels, cover plates, cladding, particle boards and similar structural elements. For example, in Sub-Saharan Africa large quantities of sugar cane bagasse are currently not used and are a suitable material for the production of particle boards, which could reduce the pressure on natural resources, like wood, which currently is used for this purpose [46].

Another interesting raw material for particle boards are peanut shells, which are very resistant to biodegradation, what makes them ideal for the use as building material.

Agricultural wastes can also be used for the production of biobased composites, where processed agricultural waste is mixed with other materials, like resins or tannin-based adhesive, in order to produce solid composites, which can be used as boards for cladding of walls and other building materials. Figure3-17 shows such type of boards.

Figure3-17: Composite panel produced with organic waste [47]

- <u>Insulation materials</u>

The use of agricultural waste as thermal and noise insulating materials is also an interesting application in the construction industry. Some agricultural wastes have excellent low thermal conductivity properties, which makes them ideal as insulating material. This for example is the case for corn cobs, which has a low-density foam-like structure and makes it to an ideal material for insulation. [48] The biodegradability and inhomogeneity of agricultural waste requires nevertheless proper processing and treatment of the waste for such applications in order to make sure that the material can fulfil without limitations its function as building material.

- <u>Direct use as building material</u>

Agricultural waste can be used also directly for building purposes, without further processing and change of their physical or chemical properties. The use of straw bales for structural elements like walls for example is a viable alternative for single-floor buildings. Buildings made from straw bales have excellent thermal, structural and acoustic properties. To use straw bales for structural buildings it is important that the bales are produced with a high density, which increases their static properties significantly [49]. Important for such use is also that the roof is completely watertight and that the foundations are well carried out in order to keep the straw bales always dry.

Traditionally agricultural waste has been used also for roof covering. For that purpose, for example straw, palm fronds, or reed still is used in rural Sub-Saharan African regions.

- <u>Hempcrete</u>

Agricultural by-products, like hemp fibres, can be used for the production of hempcrete, which is an interesting application in order to replace concrete bricks. For that purpose, the hemp fibres are mixed with lime and sand and formed to blocks, which are air-dried. The material properties are very excellent because hempcrete provided high vapour permeability and contributes to a positive living quality in buildings. It is considered as a carbon negative material due to the carbon which is sequestered in the hemp fibres. Figure3-18 below shows a sample of hempcrete bricks.

Figure3-18: Hempcrete blocks [50]

1.5.2 4.3.3 Benefits of using agricultural residues as building material

Because of the high climate protection effect of diverting agricultural waste from decomposition under non favourable conditions and using it as a resource in the construction sector and thereby many times (except when ash is used and prior thermal decomposition happens) binding carbon in a sink the application of the concept of circularity for agricultural waste has a couple of benefits which are highlighted in this chapter.

- <u>Environmental benefits</u>

  Agricultural wastes can provoke a series of environmental problems, if not properly treated. Dependent on the current practises, if agricultural wastes are landfilled, they contribute to an accelerated filling up of landfills and result due to anaerobic conditions to high methane emissions for many years.

A common practise for agricultural waste is also the open burning in order to reduce to clear space. This practise is done in many countries with straw or bagasse and contributes to local air pollution, but contributes also to climate change. The use of this waste streams as building material would contribute to reduce these harmful practices.

- Economic benefits

  To give residues an economic value is one of the key instruments to support circularity. The valorisation of agricultural residues to use them as building materials can make a meaningful contribution to peasants on the countryside and improve their living conditions by generating an additional income. It also contributes to generate new job opportunities by the development of a new value chain for such residues and its transformation to building materials.

- Social benefits

  The dumping of agricultural waste has also many negative social effects for communities living nearby. The development of bad odour, the propagation of flies and the spreading of infectious disease are very common in regions with high generation of untreated agricultural wastes. Its valorisation as construction material could play a role to reduce these negative impacts on communities nearby.

The following Figure3-19 is summarizing the benefits related to the use of agricultural waste as building material.

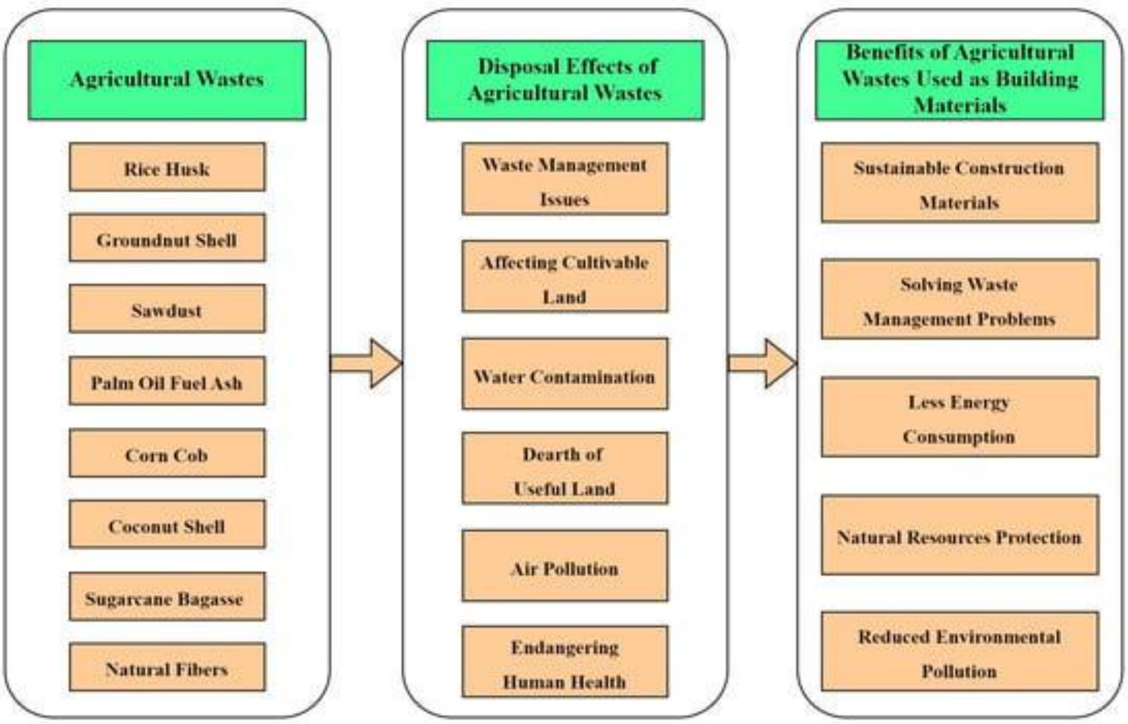

Figure3-19: Disposal effects and benefits of agricultural wastes as building material [51]

4. Policy and Infrastructure Gaps

In Sub-Saharan Africa, quite a number of policies and legislative instruments on Solid Waste Management exist [XX], [XX] although they are not particularly related to the management of Construction & Demolition as well as Agricultural wastes. Most relevant Sub-Saharan African legislation focusses on health, hazardous material control and environmentally sound waste management in general. However, in Namibian waste legislation Construction and Demolition Waste is for example explicitly mentioned.

Even where the general provisions of sound waste management are already included in the legislation the broad implementation as well as enforcement is still lacking.

Apart from the waste related legislation mentioned in **Error! Reference source not found.** there are no relevant provisions promoting the reuse or recycling of waste in the construction sector nor there are provisions that pose an obstacle to reuse or recycling in line with the waste legislation. Below is a comparison of some examples of legislation that touch on construction waste in the three mentioned countries.

Table 4-1: Relevant Policy and Legislation in a few Sub-Saharan African countries ([K] … Kenya; [N] … Namibia, [SA] … South Africa).

Policy and Legislation	**Impacts on the construction sector**		
	KENYA	**NAMIBIA**	**SOUTH AFRICA**
[K] Constitution of Kenya 2010 [N] The Namibian Constitution [SA] South African Constitution Act (No 108 of 1996)	[K] Article 42 – states that every person in Kenya is entitled to a clean and healthy environment and has a duty to safeguard and enhance the Environment. -[K] Articles 69 and 70: articulates the obligations of the state to the Environment and inclusive public participation in environmental protection and conservation [K] Fourth Schedule: Role of the county Governments in the waste management services	[N] Does not provide for an environmental clause directly relevant to pollution. However, the provisions are generally relevant for environ-mental protection, namely, Article 91(c)	[SA] Right to an environment that is not harmful to health or well-being, and to protection of the environment

Policy and Legislation	Impacts on the construction sector		
	KENYA	**NAMIBIA**	**SOUTH AFRICA**
[K] The Environmental Management and Coordination Act (EMCA), 1999 [N] The Environmental Management Act (No. 7 of 2007) EMA 2007 [SA] Environment Conservation Act (No 73 of 1989)	[K] Every person shall cooperate with the authorities to protect and conserve the environment and to ensure the ecological sustainable development and use of natural resources The delivery of this has been reinforced through various regulations to operationalise the law.	[N] Acknowledges responsibility to protect and maintain its own environmental and natural resources. The 2012 regulations guide the implementation of EMA 2007.	[SA] Provides for the protection of the environment, control of environmental pollution, and control of activities which may have a detrimental effect on the environment
[K] Solid Waste Management of 2022 [N] Solid Waste Management Policy [SA] The National Environmental Management Act (No 107 of 1998) & National Environmental Management Act: Waste Act 2008, (No 59 of 2008)	[K] Identifies sustainable waste management promotion; improving the health of all Kenyans by ensuring a clean and healthy environment; ensuring the delivery of waste service	[N] Waste is closely related to pollution but not identical. Framework to enforce, promote and support the principles within the Solid Waste Management Policy. The regulations provide for storage, collection, transportation, treatment and disposal of various kinds of wastes, including household hazardous waste; construction and demolition waste; & recyclable waste;	[SA] Provides for co-operative environmental governance and for the enforcement of environmental management laws. Adopts a waste hierarchy, promotes cleaner production, waste minimisation, re-use, recycling and waste treatment, with disposal seen as a last resort
[K] The Public Health Act [Cap. 242] [N] Public and Environmental Health Act, 2015 (No. 1 of 2015) [SA] National Health Act, 2003 (Act No. 61 of 2003)	[K] for controlling the construction of buildings, and the materials to be used in the construction of buildings;	[N] Promotes public health and wellbeing; prevent injuries, protect individuals and communities from public health risks; encourage community participation in order to create a healthy environment	[SA] Encourage individuals and communities to plan for, create and maintain a healthy environment. Provide for the prevention or early detection of diseases and other public health risks
[K] The Occupational Safety and Health Act, 2007 [N] The Occupational Safety and Health Act [SA] Occupational Health and Safety Act (No 85 of 1993)	[K] Emphasizes on the safety of all workers and safeguards the safety of all employees	[N] Employers, by law, must provide employees with a safe and healthy working environment. Occupational Health and Safety in Namibia is governed by the Labour Act Nr 11 of 2007	[SA] Provides for the health and safety of persons at work and the health and safety of persons in connection with the activities of persons at work

Policy and Legislation	Impacts on the construction sector		
	KENYA	**NAMIBIA**	**SOUTH AFRICA**
[K] National Waste Management Strategy 2015 [K] Kenya Vision 2030	The strategy specifically recognises construction and demolition waste noting the waste is classified as non-hazardous though mixed that will require seperation for re-use and recycling while the vision encourages the development of material recovery facilities in major urban areas and municipalities		

Legislation is in place, but poor monitoring and enforcement is a challenge. A study on waste management in the three northern Namibian towns of Oshakati, Ongwediva and Ondangwa concluded that the general waste management practice in these towns is not in line with international solid waste management standards neither with the national laws of waste management. Waste is being treated as waste and there is lack of awareness of the benefits related to the proper waste management.

In Kenya, although Sustainable Waste Management Act (2022) has been established, the implementation of the law is a challenge. UN-Habitat's SDG indicator 11.6.1 monitoring using Waste Wise Cities Tool survey showed that the percentage of municipal solid waste collected and managed in controlled facilities in Nairobi, Mombasa and Kiambu is 15%, 5% and 3% respectively[1]. The percentage of municipal solid waste collected in those cities are 65%, 56% and 52%. Main reasons for this are attributed to the insufficient financial resources flowing into the entire system to provide full coverage of waste collection service and environmentally sound management of municipal solid waste.

If circular construction is to be discussed it becomes also very relevant that most countries in Sub-Saharan Africa lack respective provisions in the building codes that enable a sustainable circular construction. Based on the current context of often times unreliable infrastructure and public services decentralized solutions will be of high importance in the short run.

5. Policy Recommendations

1.5.3 Instruments to Increase the Use of MSW as resource in the construction sector

1.5.4 Instruments to increase the use of CDW as resource in the construction sector

There are simple instruments that enable an increase of the share of CDW for its use as a resource in the construction sector. Important would be to make sure to remove pollutant

[1] https://unh.rwm.global/Map

bearing building components prior to the demolition itself. This asks for identification of these construction elements for instance in a pre-demolition waste audit (compare Table) followed by the removal of relevant construction elements prior to demolition. In addition, mixing of different forms of CDW must be avoided as much as possible by the means of separation at source.

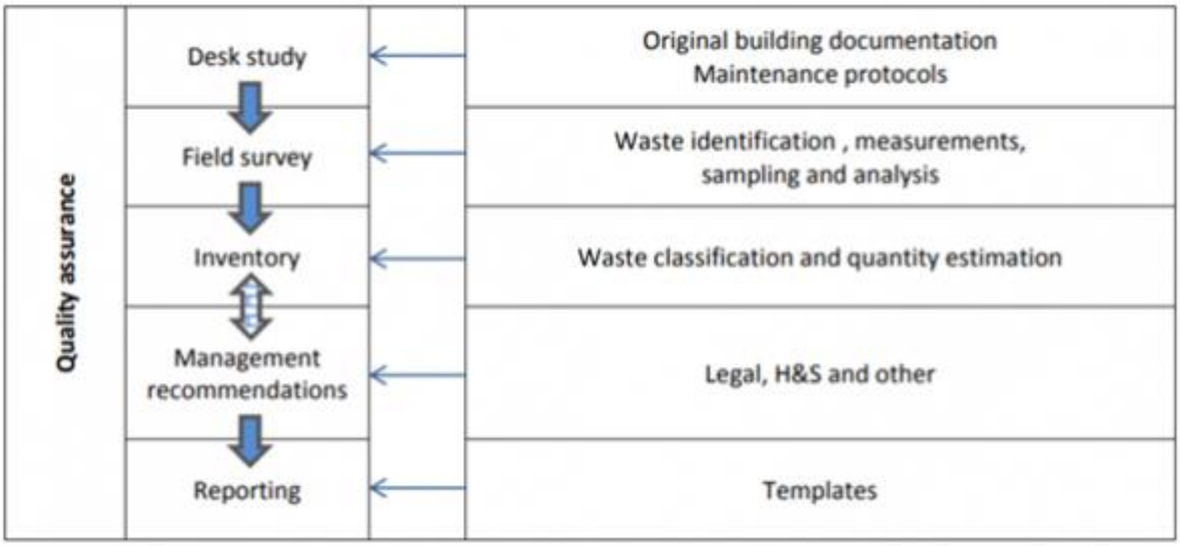

Figure5-1: Process diagram of a pre-demolition waste audit [26]

Increased taxation of landfilling of CDW is also a good way to incentivize its utilization as a resource wherever open dumping is not an alternative based on such legal stipulations and their effective enforcement. Wherever no legal stipulations exist yet and where CDW is still openly dumped such legal provisions must be put in place.

Tax exemptions for recycled materials as well as stipulations for mandatory use of recycled material could be also a good way to incentivize the processing of CDW to building materials.

Enhanced monitoring and enforcement of identified CDW issues established during the Environmental Impact Assessment/Audit for construction projects will inject impetus for sustainable Circular construction.

1.5.5 Instruments to increase the use of Agricultural waste as resource in the construction sector

To increase the use of agricultural waste as a building material several measures should be implemented. First of all, a proper waste audit about agricultural waste would be important in order to assess the type and quantity of available agricultural waste. Similar to the CDW, data availability for agricultural waste is very poor because most of this waste is not recorded and many times disposed of in an informal way, without allowing to gather statistical data.

Agricultural wastes are biodegradable and therefore are prone to spoiling quickly if they are not processed soon after their production. Proper storage and conservation actions can help to avoid the degradation of these waste streams in order to make them easier accessible as resource for construction materials.

Despite the fact that agricultural waste in many locations in Sub-Saharan Africa is a traditional building material for huts and houses, the perception about its suitability as building material is low, especially in construction companies, which often prefer to use modern building materials. Therefore, capacity building for the possibilities to use agricultural waste as a full-fledged building material would be required in order to increase awareness in the construction industry about the versatile opportunities which exists.

Important would be also the promotion of R&D in close cooperation with local universities and research partners in order to develop prototypes of locally produced building material using agricultural waste. These R&D efforts might act as the starting point to develop an entrepreneurial ecosystem of companies producing locally building materials for the construction industry and generating many job opportunities.

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