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Towards Net Zero Carbon Construction in Africa: A Systems Thinking

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Abstract
Climate Change remains a poignant challenge, significant and urgent threat to humankind. While effort is being made to counter the phenomena, carbon emissions from the construction industry remain high and counterproductive to climate action initiatives. This paper accentuates strategies towards achieving net zero carbon construction in Africa. It's the position of this paper, that in the fight against climate change, Africa has to be intentional, robust and dynamic in its approach on construction practices. The paper propounds five strategies that should operate indistinguishably for a Net Zero carbon construction in Africa by 2050. By elucidating the intricacies of carbon emissions, proposing viable pathways to achieve net zero, and advocating for a systems thinking perspective, this paper seeks to contribute to the advancement of sustainable construction practices in Africa aligned with international benchmarks and, ultimately, support climate action campaign. To this end, its recommended that Africa should enact appropriate environmental, Net Zero Carbon construction policies, regulations and progressively fortify them with enforcement measures.

Keywords: ***Carbon emission, Net Zero carbon construction, Systems thinking, Africa***

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1.0 Introduction

Admittedly, Greenhouse gases (GHGs) emitted by human activities are considered one of the biggest causes of climate change and one of the biggest threats of the 21st century when it comes to sustainability.[1] The greenhouse effect was first mentioned in a report called "Restoring the Quality of Our Environment"[2], by a group of scientists on the US President's Science Advisory Committee who proposed that increasing temperatures in the atmosphere was caused by a buildup of carbon dioxide but it wasn't until 1975 that the term "global warming" was coined by geoscientist Wallace Broecker[3] and it took years before the issue reached mainstream understanding. Meanwhile "climate change," which describes a long-term change in the Earth's climate, appeared a few years later in a 1979 National Academy of Science study on carbon dioxide[4]. Relatedly, extreme natural events such as extreme heat leading to wild fires and droughts necessitated numerous reports such as one presented by the United Nations' Intergovernmental Panel on Climate Change (IPCC)[5] which estimated that the global average land and sea surface temperature had increased by 0.6±0.2∞C since the mid-19th century, with most change occurring since 1976.This report was then used, arguably, as a reference point in several international climate negotiations.

[1] Mora, C., Spirandelli, D., Franklin, E.C., Lynham, J., Kantar, M.B., Miles, W., Smith, C.Z., Freel, K., Moy, J., Louis, L.V. and Barba, E.W., 'Broad Threat to Humanity from Cumulative Climate Hazards Intensified by Greenhouse Gas Emissions' (2018) 8 Nature Climate Change 1062

[2] Restoring the quality of our environment: Report of the Environmental pollution panel on president's science advisory committee 1965.

[3] Climatic Change: Are We on the Brink of a Pronounced Global Warming? By Wallace Broecker 1975

[4] Carbon dioxide and climate change: A scientific assessment 1979

[5] Climate change 2001: The scientific basis for the United Nations' Intergovernmental Panel on Climate Change (IPCC)

Undoubtedly, moving forward, numerous events occurring globally has highlighted the global imperative for achieving net-zero carbon emissions. Some of these catastrophic events include hurricane Ida whose damage was valued at a whooping seventy five billion dollars[6], flooding in China which recorded a year's worth of rainfall in twenty four hours[7] and a total of four hundred and thirty two catastrophic events were recorded in 2021 alone, which is considerably higher than the average of 357 annual catastrophic events for 2001-2020.[8] Consequently, according to the IPCC, its exquisitely observed, that to stabilize global temperatures and keep global warming to 1.5°C, the world must achieve net zero carbon emissions by 2050 and net zero GHG emissions at the latest by 2070, followed by negative emissions. It's the viewpoint of this paper, that the global construction industry is, preponderantly, at the center stage to achieving the above targets.

From the upshot, to limit climate change to 1.5°C, GHG emissions essentially need to peak immediately, and drop by nearly half (43%) by 2030[9]. A 2 °C target still requires a peak in emissions before 2025 and a 50% reduction by 2050, Importantly, the latest science also highlights that there is increased danger of passing critical biological and climatic tipping points that accelerate warming trends the longer we delay curbing emissions[10] . Interestingly, despite having contributed the least to global

[6] Comstock, O. (2021). Hurricane Ida caused at least 1.2 million electricity customers to Lose Power. In Homepage—U.S. Energy information administration (EIA).
[7] Extreme historical droughts and floods in the Hanjiang River Basin, China, since 1426 by Xiaodan Zhang et al 2022
[8] 2021 disasters in numbers Emergency Event Database (EM-DAT) (2022)
[9] IPCC. 2021a. Climate Change 2021: The Physical Science Basis. Working Group I contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Intergovernmental Panel on Climate Change.
[10] IPCC. 2021b. IPCC AR6 WGI: Summary for Policymakers. In Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth

warming and having the lowest emissions, Africa faces exponential collateral damage, posing systemic risks to its economies, infrastructure investments, water and food systems, public health, agriculture, and livelihoods, threatening to undo its modest development gains and slip into higher levels of extreme poverty. Worrisomely, massive infrastructural developments and investments in Africa, though spur economic growth, unwillingly catapult the continent to high carbon emissions[11]. To this end, it's not hyperbolic to surmise that time is not at large for African continent to embrace sustainable construction practices for its survival.

The above, necessitates drastic steps to reduce carbon emission in Africa which is largely attributed to development and especially the African construction industry. The construction industry is considered to be among the major sectors that contribute significantly toward the emission of GHGs in our environment, which have a major effect on the climate change, and is approximately responsible for about 19 percent of the overall GHG emission globally[12], rendering it a pollution hotspot requiring urgent mitigation measures. Recent research shows, explicably, that the building industry is responsible for about 40%[13] of the total

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Assessment Report of the Intergovernmental Panel on Climate Change. V. Masson-Delmotte, P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, & B. Zhou, Eds. Cambridge, UK: Cambridge University Press. 41.

[11] Awad, A.,& Warsame, M.H. (2017). Climate Changes in Africa: Does Economic Growth matter?. A semi-parametric approach. International Journal of Energy Economics and Policy, 7(1), 1-8

[12] The carbon footprint of construction industry: A review of direct and indirect emission Mathur Vivek et al (2021)

[13] Cao, X., Dai, X. & Liu, J., (2016). Building energy-consumption status worldwide and the stateof-the-art technologies for zero-energy buildings during the past decade. Energy and buildings,128, pp.198-213.

energy used globally and over one-third of GHG emissions in all developed or developing countries.[14] Accordingly, there exists a great opportunity in Africa's building industry to deliver long-term and sustainable GHG emission goals for the continent, the complex challenges notwithstanding. This is a great opportunity for the industry players to play a centerpiece role in addressing the unique challenges and opportunities in advancing sustainable construction practices across the continent.

2.0 Carbon emission: Construction Industry viewpoint

Evidentially, human activities are the primary contributors to all the greenhouse gas emissions[15] through the consumption of fossil fuels and desertification, which increases the amount of greenhouse gasses in the atmosphere at an immense rate.[16] Carbon dioxide (CO_2) is one of the dominant compound elements of the greenhouse gases and the principal causal factor of global warming[17]. It accounts for almost 82% of overall global warming, with the remainder coming from active greenhouse gases, methane, and nitrous oxide[18]. There have been numerous attempts

[14] Wen, T.J., Siong, H.C. & Noor, Z.Z., (2015). Assessment of embodied energy and global warming potential of building construction using life cycle analysis approach: Case studies of residential buildings in Iskandar Malaysia.Energy and Buildings,93, pp.295- 302

[15] David John Jackson,(2020). Addressing the challenges of reducing greenhouse gas emissions in the construction industry: a multi-perspective approach (Doctor of dissertation).

[16] Edeoja Joy Acheyini, Edeoja Alex Okibe,(2015). Carbon Emission Management in the Construction Industry – Case Studies Of Nigerian Construction Industry. American Journal of Engineering Re-search (AJER), 4 (7), 112-122.

[17] I. C. Ezema, A. P. Opoko, and A. A. Oluwatayo, (2016). De-carbonizing the Nigerian Housing Sector: The Role of Life Cycle CO2 Assessment. Inter-national journal of applied environmental science., 11(1), 325–349

[18] United nation environment programme, (2015). UN environment "walk the talk" on carbon neutrality

at defining carbon emission,[19] generally, it can be summarized as the release of carbon into the atmosphere through human activities in the construction industry such as combustion of fossil fuel and cement production where it is stored thereby increasing the concentration of greenhouse gas emission.

Proportionately, as a major sector with high development and pollution, the construction industry accounts for approximately 36% of global emissions[20]. In recent research, the industry has been named as one of the major drivers toward the persistent rise in temperature and global warming in general.[21] moreover, construction has particularly impacted the environment through the production of waste, Carbon dioxide emissions, change of land use, loss of biodiversity, depletion of wetlands and climate changes.[22] The "U.S. energy information and administration" reported that the Carbon dioxide emission globally will increase, by the year 2035, to 42.7% higher than that of 2007.

From the foregoing, there is a predicted increment of greenhouse gases in many countries[23]. Interestingly, almost 40% of the total amount of these

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[19] Mark Lallanilla (2019), Corinne Le Quéré et al., (2018), CP Ramesh et al., (2018), Makoto et al., (2015), J. Watkins, (2012), F. Ascui et al., (2012), M. Brander,(2012), T. Wiedmann, (2007), B. Mertz et al.,(2005),

[20] Yan, J., Zhao, T., Lin, T., Li, Y., 2017a. Investigating multi-regional cross-industrial linkage based on sustainability assessment and sensitivity analysis: a case of construction industry in China. J. Clean. Prod. 142, 2911–2924.

[21] M. Ö. Arıoğlu Akan, D. G. Dhavale, and J. Sarkis, (2017). Greenhouse gas emissions in the construction industry: an analysis and evaluation of a concrete supply chain. J. Clean. Prod., 167, 1195-207.

[22] Z. Alwan, P. Jones, and P. Holgate, (2016). Strategic sustainable development in the UK construction industry, through the framework for strategic sustainable development, using Building Information Modelling. J. Clean. Prod., 140, 349–358.

[23] Q. Shi, T. Yu, and J. Zuo,(2017). What leads to low-carbon buildings? A China study. Renew. Sustain. Energy Rev., 50, 726–73

emissions is from the construction sector[24].The "Sustainable Building and Construction Initiative (SCBI) of the United Nations Environment Program (UNEP)" reported that 30-40% of global energy demand is from the construction industry, which is expected to grow at an average of 1.5% to 3.4% rate in the next coming 20 years. In practical terms, the buildings contribute annually to the atmospheric emission with about 8.1 Gt of carbon dioxide[25]. Buildings account for 33 percent or 7.85 Gt of all the global Carbon Dioxide emissions related to energy, and the emissions are forecasted to rise by 2030 to about 11 Gt or even much higher value of 15.6 Gt[26].

Worrisomely, Africa is laboring under the weight of burgeoning numbers as these problems are exemplified in African developing countries. For

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[24] Tathagat D., and Dod R.D., (2015). Role of Green Buildings in Sustainable Construction- Need, Chal
lenges, and Scope in the Indian Scenario. Journal of Mechanical and Civil Engineering, 12 (2) Ver. II, 01-09.
A. Mastrucci, A. Marvuglia, E. Leopold, E. Benet-to, (2017). Life Cycle Assessment of building stocks from urban to transnational scales: a review. Re-new. Sustain. Energy Rev., 74, 316-332, 10.1016/j.rser.2017.02.060Article
Judit Nyári, (2015). Carbon footprint of construction products (a comparison of application of individual Environmental Product Declarations and Building Information Modeling software) (Bachelor Dissertation).
B. Lin, O. E. Omoju, and J. U. Okonkwo, (2015). Impact of industrialization on CO2 emissions in Ni-geria. Renew. Sustain. Energy Rev., 52, 1228–1239. DOI: 10.1016/j.rser.2015.07.164

[25] Jennings M., Hirst N., and Gambhir A., (2011). Reduction of Carbon Dioxide Emissions in the Global Building Sector to 2050. Report GR3, Grantham Institute for Climate Change, Imperial College London
I. C. Ezema, A. P. Opoko, and A. A. Oluwatayo, (2016). De-carbonizing the Nigerian Housing Sec-tor: The Role of Life Cycle CO2 Assessment. Inter-national journal of applied environmental science., 11(1), 325–349

[26] Tathagat D., and Dod R.D., (2015). Role of Green Buildings in Sustainable Construction- Need, Challenges, and Scope in the Indian Scenario. Journal of Mechanical and Civil Engineering, 12 (2) Ver. II, 01-09.

example, in Nigeria, the emission from the construction and manufacturing industries increased from 2557 to 23714 Gg of Carbon dioxide which is equivalent to the total emissions between 2000 and 2015 reflecting approximately 827% increase as observed which is exponentially above normal[27].In Kenya, increasing population has led to the creation of government development policy framework which was dubbed "Vision 2030" whose main focus of development was in the construction sector [28] . Research by the United Nations framework convention on climate change (UNFCCC) asserts that such developments, if not done sustainably, will quickly enhance the country's contribution of GHG emissions to unprecedented levels leading to advanced effects on climate change [29] . It is worth noting that Kenya continues to suffer immensely as a result of climate change caused by global warming. Frequent floods, droughts, and changing weather patterns associated with global warming have altered the country's economic and social fabric[30]

[27] BUR1 (2018). Federal Republic of Nigeria First Biennial Update Report (BUR1) of the Federal Republic of Nigeria under the United Nations Framework Convention on Climate Change (UNFCCC)

[28] Kenya Vision 2030 flagship programmes and projects progress reports(FY 2020/2021/0

[29] UNFCCC, (2021) United nations framework convention on climate change: Compendium on greenhouse gas baselines and monitoring, building and construction sector, UN COP26

[30] Lunga and Zwaan Do Kenya's climate change mitigation ambitions necessitate large-scale renewable energy deployment and dedicated low-carbon energy policy? (2017)

The main sources of Carbon Emission in the construction industry are energy consumption[31], on-site transportation[32], cement production[33], manufacturing of building materials[34] followed by burning of fossil fuel[35] and construction waste disposal[36]. Nevertheless, there are other factors leaking carbon in atmosphere such as mining[37], plant machineries[38], off-site transportation (transportation of workers)[39], construction works (maintenance and demolishing)[40], workers & staff activities[41] and on and off-site waste production and discharge[42].

Globally, prevalent practices contributing to the carbon footprint in the construction industry such as high energy consumption during building material production, transportation, and on-site construction activities are

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31 Nissen J. et al (2007), Upton B et al (2008), H. Yan et al (2010), Purnell (2012), C. Mao et al (2013), J. Hong et al (2012), T.J Wen et al (2015), X. Zhao et al (2015), B. Lin et al (2016), M. Sandana Yala et al (2018), Y.L. Li et al(2019)

32 Nissen J. et al (2007), Upton B. et al (2008), Hui Yan, Lein Zhang (2009), Hui Yan et al (2010), C. Mao et al (2013), J. Hong et al, (2015), T.J Wen et al (2015), X. Zhao et al (2015), M. Sandana Yala et al (2018), C.P Ramesh et al (2018), Y.L. Li et al(2019)

33 Hui Yan, Lein Zhang (2009), J. Hong et al (2015), T.J Wen et al (2015), X. Zhao et al (2015), B. Lin et al (2016), M. Sandana Yala et al (2018), Y.L. Li et al(2019)

34 Nissen J. et al (2007), Upton B. et al (2008), Hui Yan et al (2010), J. Hong et al (2015), M. Sandana Yala et al (2018), Y.L. Li et al(2019), C.P Ramesh et al (2018)

35 C. Mao et al (2013), J. Hong et al, (2015), B. Lin et al (2016), M. Sandana Yala et al (2018), Y.L. Li et
al(201

36 G. Gerilla et al (2008), Hui Yan et al (2010), C. Mao et al (2013), J. Hong et al, (2015), M. Sandana Yala et al (2018), Y.L. Li et al(2019), C.P Ramesh et al (2018)

37 Hui Yan et al (2010), Purnell (2012), Y.L. Li et al(2019)

38 J. Hong et al, (2015), T.J Wen et al (2015)

39 Hui Yan et al (2010), J. Hong et al, (2015), X. Zhao et al (2015)

40 G. Gerilla et al (2008), C.P Ramesh et al (2018)

41 J. Hong et al, (2015)

42 J. Hong et al, (2015), T.J Wen et al (2015)

a threat to the world's sustainability[43]. The Inter-National Energy Agency has obtained terrifying information on developments in energy consumption with estimates that show that urban areas, mainly due to buildings, consume more than 67% of global energy and release more than 70% of global Carbon emissions[44]. Carbon emissions from buildings are projected to grow faster than any other sector - 1.8% annually by 2030. Consequently, buildings last 50 to 100 years and consume energy continuously which then produces carbon emissions, affecting the climate and provoking global warming[45]. Widespread use of carbon-intensive materials, such as cement and steel, also significantly contributes to carbon emissions. In Africa, challenges include limited access to sustainable materials, reliance on traditional construction methods, and often insufficient regulations to promote eco-friendly practices[46]. This paper postulates that understanding these global and regional dynamics is crucial for formulating effective strategies toward net-zero carbon construction in Africa. Additionally, the impending doom of drought and flooding due to carbon emissions, which will affect over 80% of Africans who depend on low-yield rain fed agriculture for food and livelihood[47],

[43] David John Jackson, (2020). Addressing the chal-lenges of reducing greenhouse gas emissions in the construction industry: a multi-perspective approach (Doctor of dissertation).

[44] Shaojian Wang, Xiaoping Liu, Chunshan Zhou, Jincan Hu, Jinpei Ou, 2017. Examining the impacts of socioeconomic factors, urban form, and transportation networks on CO2 emissions in China's megacities

[45] Abergel, T.; Dean, B.; Dulac, J. Towards a Zero-Emission, Efficient, and Resilient Buildings and Construction Sector: Global Status Report 2017; UN Environment and International Energy Agency: Paris, France, 2017.

[46] Gao, T., Shen, L., Shen, M., Chen, F., Liu, L., Gao, L., 2015. Analysis on differences of carbon dioxide emission from cement production and their major determinants. J. Clean. Prod. 103, 160-170.

[47] Hermans, K.,& McLeman.R (2021).Climate Change, drought, land degradation and migration. Exploring the linkages. Current Opinion Environmental Sustainability, 50, 236-244

underscores the urgency of adopting sustainable approaches in construction activities.

3.0 Strategies to achieving net zero carbon construction in Africa

Cognizant of the impact the building industry has on carbon emissions; this paper delves into the strategies towards low Carbon Construction in Africa. These strategies are calls to move away from boilerplate arguments on climate action to an engaging anecdote about sustainability in construction hence Africa`s preparedness to achieve net zero carbon construction by 2050.

3.1 Sustainable Planning and Design

Literature is replete with evidence that the energy consumption and emissions of the construction sector are influenced by building type, type of structure, type of product and source of fuel[48]. This is proof of the pivotal role of sustainable design in mitigating carbon emissions. Sustainable design calls for the integration of environmentally conscious architectural practices which involves incorporating design strategies that prioritize sustainability and minimize the environmental impact of construction.

Sustainable design entails designing buildings to optimize natural light, ventilation, temperature regulation, reducing the reliance on artificial lighting and heating, ventilation and air conditioning (HVAC) systems[49]. This is because most emissions by buildings come from fossil fuel combustion to provide heating, cooling and lighting, as well as power &

[48] Peñaloza, D., Erlandsson, M., Berlin, J., Wålinder, M., Falk, A., 2018. Future scenarios for climate mitigation of new construction in Sweden: effects of different technologies

[49] GIZ,N (2014). Energy efficiency in Buildings (EEB) in selected sub-sectors of the Nigerian Building Sector.

electrical appliances. Research shows buildings account for 39% of carbon emission and consume 70% of electricity[50].

Moreover, planning construction projects to consider the site's natural features, optimizing solar exposure, wind patterns, and landscaping to enhance energy efficiency and reduce the need for additional resources is an essential part of sustainable design. Incorporating green spaces, planting native vegetation and creating habitats for local wildlife to enhance biodiversity within the built environment.[51]
Additionally, repurposing existing structures and materials to minimize waste and extend the lifespan of building components, contributing to a circular economy is also a feature of sustainable design. Conducting a lifecycle analysis of materials and building systems to evaluate their environmental impact from extraction to disposal, helping architects make informed decisions[52].

The sustainable design principles discussed above should be adapted to diverse environments to foster a resilient and ecologically sensitive approach to construction across the continent. Sustainable design should also entail context-specific design solutions tailored to Africa's unique climate, available resources and cultural aspects therefore addressing the practical aspects of Africa's climate and resources while respecting and celebrating the rich cultural diversity of the continent, fostering a harmonious integration of the built environment with its surroundings. The significance of context-specific design includes: climate adaptation,

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[50] Weihong Li (2011), Procedia Environmental Sciences 5 (2011), 173-177
[51] Dowd, R.M. and Mourshed, M, 2015. Low carbon buildings: Sensitivity of thermal properties of opaque envelope construction and glazing. Energy Procedia. 75, pp 1284-1289
[52] Chou, J.S , and Yeh, K.C, 2015, Life cycle Carbon dioxide emissions simulations and environmental cost analysis for building construction. Journal of cleaner production, 101, pp 137-147

resource efficiency, cultural relevance, social inclusivity, economic viability and environmental stewardship. From the foregoing, it's incumbent upon the design team to produce sustainable designs that promote low carbon construction.

3.2 Low Carbon Materials

Proportionately, the production of building materials contributes largely to Carbon emissions where nearly 2/3 of all emissions are produced by steel and concrete [53]. Cement is the basic and most commonly used building material in civil engineering, the quantity of which due to massive and rapid urbanization has increased drastically. One of the most widely carbon emitters is also the cement industry[54][55]. Construction sector is the world's largest user of materials, and buildings are the world's largest single energy consumption industry [56] hence the need for low carbon materials in construction.

Low carbon materials in the context of construction are those that have a significantly reduced carbon footprint throughout their life cycle, from raw material extraction to production, transportation, use and eventual disposal or recycling[57].Low carbon materials are known to minimize the amount of greenhouse gas emissions associated with their production.

[53] Hammond, G.P. and Jones, C.I., 2008. Embodied Energy and Carbon in Construction Materials. Proceedings of the Institution of Civil Engineers-Energy, 161 (2) pp 87-98

[55] Donald Huisingh, Zhihua Zhang, John C. Moore, QiQiao , Qi Li, 2015. Recent advances in carbon emissions reduction: policies, technologies, monitoring, assessment and modeling

[56] F Krausmann, S Gingrinch, N Eisenmenger, KarlHeinz Erb, Helmut Haberl and Marina FischerKowalski, 2009. Growth in global materials use, GDP and population during the 20th century

[57] Knoeri, C., Binder, C. R & Althaus, H.J (2011). Decisions on recycling: Construction Stakeholders decisions regarding recycled materials.

This involves selecting materials with lower embodied carbon content, such as recycled or rapidly renewable resources. In addition to this, materials made from recycled content help divert waste from landfills and reduce the demand for new raw materials. Examples include recycled steel, glass, or plastic. Utilizing materials derived from rapidly renewable resources, which have shorter growth cycles, helps reduce the environmental impact[58]. Examples of these materials include: bamboo and cork. It is also worth noting that materials sourced locally contribute to lower transportation-related emissions. Therefore, prioritizing local materials not only supports regional economies but reduces the carbon footprint associated with long-distance transportation.

Low carbon materials are also often produced using energy-efficient processes, minimizing energy consumption and associated emissions during manufacturing and have longer lifespans and greater durability contributing to reduced replacement needs and, consequently, lower overall carbon impact. A comprehensive life cycle assessment that considers the environmental impact of materials from cradle to grave is also often carried out[59]. Materials with lower overall carbon emissions, as determined by LCA, are considered more sustainable. Materials such as these usually have eco-labels or certifications, such as Cradle to Cradle, Forest Stewardship Council (FSC), or Leadership in Energy and Environmental Design (LEED).

Undoubtedly, Construction sector is the world's largest user of materials, and buildings are the world's largest single energy consumption industry [60] , therefore, prioritizing these characteristics in material

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58 Addis, B., 2012. Building with reclaimed components and materials: a design handbook foir reuse and recycling. New York: Routledge

59 Orsin, F; Masrom, P, (2019), Approaches for a low-carbon production of building materials: A review.J. Clean.Prod. 241,18380

60] F Krausmann, S Gingrinch, N Eisenmenger, KarlHeinz Erb, Helmut Haberl and Marina Fischer Kowalski, 2009. Growth in global materials use, GDP and

selection, construction projects can significantly contribute to the reduction of carbon emissions and promote a more sustainable and environmentally friendly built environment. On the same point, ways in which low carbon materials can be integrated into the construction industry include exploring the use of traditional building materials that are abundant and have a low environmental impact. Indigenous materials such as bio waste and anthill soil can be sourced sustainably as alternatives to conventional concrete. Other ways of incorporating low carbon materials are: recycled and upcycled materials, carbon friendly alternatives for materials, incorporating life cycle assessments for materials and ensuring that materials are locally sourced[61]. It's clear from the foregoing, that the choice of construction materials is at the center of things hence, a deal breaker in the pursuit of Net Zero carbon construction in Africa, its, therefore, a call for the built industry players to be deliberate in this score.

3.3 Energy Efficient Technologies

The third strategy focuses on the use of energy efficient technologies. The rapidly increasing worldwide use of energy has already raised concerns about difficulties in production, exhaustion of energy resources and severe environmental impacts such as depletion of ozone layers, global warming, and climate change.[62] There is an urgent need for energy-efficient technologies in buildings which encompass a range of innovations aimed at reducing energy consumption and promoting sustainability.

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population during the 20th century

[61] Chan, M.; Masrom, M.A.N, Yasin, S.S (2022). Selection of Low-Carbon Building Materials in Construction Projects: Construction Professionals Perspective: Buildings 2022, 12, 486.

[62] L Pérez-Lombard, J Ortiz, C Pout, 2008. A review on buildings energy consumption information

Accordingly, several examples are possible in this regard. Light-Emitting Diode (LED) lighting is more energy-efficient and longer-lasting than traditional incandescent bulbs, contributing to reduced electricity consumption in buildings and is one of the energy efficient technologies that can be used for net zero carbon building[63]. Furthermore, automated lighting systems that adjust based on occupancy, natural light levels, and time of day, optimizing energy usage and minimizing unnecessary lighting is an important adoption in the building industry.
In addition to this, High-efficiency heating, ventilation, and air conditioning (HVAC) systems use advanced technologies to regulate temperature, airflow, and humidity while consuming less energy hence reducing overall building's carbon emission[64]. Integration of Building Automation Systems (BAS) allows for centralized control and monitoring of various building systems, optimizing energy use, and identifying areas for improvement also ensures energy efficiency[65].

Moreover, harnessing solar energy through Solar Photovoltaic (PV) panels to generate electricity also ensures reduction on dependence on conventional power sources and lowering carbon emissions[66]. Other technologies include: smart thermostats, occupancy sensors, building-integrated renewable energy systems like wind turbines or geothermal systems, energy management Software. Implementing a combination of

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[63] Vishwakarma, S.K., Upadhyaya,P.,Kumari., B & Mishra, A.K (2019). Smart Energy Efficient home automation System using iot. IEEE

[64] Belyaev V S 2014: Energy saving when choosing translucent external fences. Housing Construction 8 PP 6-11

[65] Komkov V A, Timakhova N, S., 2014: Energy Saving in the housing and utilities sector 2nd ed (M.INFRA-M) 204p

[66] Lin, G.T. (2011): The promotion and development of Solar photovoltaic industry: Discussion of its Key factors. Distribution Generation & Alternative Energy Journal, 26 (4), 57-80

these technologies not only enhances energy efficiency in buildings but also contributes to a more sustainable and environmentally friendly built environment.

3.4 Smart, Innovative Construction Practices

Smart and innovative construction practices are cardinal for achieving net zero carbon construction, hence addressing the environmental impact of the building industry[67]. In the context of sustainability and net-zero carbon goals, innovative construction practices refer to forward-thinking methodologies, technologies, and approaches that aim to revolutionize the construction industry towards minimizing environmental impact and achieving carbon neutrality[68]. These practices prioritize resource efficiency, reduce carbon emissions, and enhance the overall sustainability of construction projects. For example, Prefabrication and Modular Construction promises benefits that are supportive of carbon neutrality. Including reducing on-site waste, accelerating project timelines, and enhancing overall construction efficiency[69].

Secondly, 3D printing for construction has the potential to revolutionize the use of sustainable materials while reducing material waste[70]. Furthermore, digital fabrication technologies contribute to precision and resource optimization. This makes it an essential feature of innovative construction practices. Furthermore, the incorporation of nature-based

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[67] Wang Dongfeng (2021): The development and application of intelligent materials in civil engineering. Construction Technology Development

[68] Hong, W.Y.,2022. A techno-economic reviewon carbon capture, utilization and storage systems for achieving a net-zero CO2 emissions future. Carbon Capt. Sci.Tech., 100044.

[69] McGraw Hill Construction Report (2009): Prefabrication & Modularization, Increasing Productivity in the construction industry.

[70] Zhang,,J.,Wang., J., Dong.,S, Yu, X., Han, B 2019. A review of the current progress and application of 3D Printed Concrete. Compos. Appl. Sci. Manuf, 125, 105533.

solutions, such as green roofs, vertical gardens and permeable surfaces, to enhance sustainability and promote biodiversity would lead to increased sustainability of the built environment both in urban and rural areas[71]. Preferably, technologies and methods for capturing and storing carbon emissions generated during construction processes such as pre and post combustion capture can also be used to mitigate the impact of fossil fuel use on climate change by preventing carbon emissions from entering the atmosphere.

Thirdly, the integration of smart sensors, building management systems, and Internet of Things (IoT) devices to optimize resource usage and enhance energy efficiency should be explored[72]. equally, data analytics are important in improving building performance. This paper posits that the use of Drone Technology, Robotics and automation in construction processes, from site preparation to assembly has the potential to reduce labor-intensive tasks and improving construction precision and should be encouraged. The principles of a circular economy in construction, which emphasizes the reuse, recycling, and repurposing of materials is an innovative way of reducing carbon emission in the African construction industry[73].

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[71] Qaidi, S.M., Dinkha, Y.Z., Haido, J.H, Ali, M.H., Tayeh, B.A., 2021. Engineering properties of sustainable green concrete incorporating eco-friendly aggregate of crumb rubber; a review.J.Clean.Prod. 324,129251

[72] Oke, A.E. Arowoiya, V.A., 2021. Evaluation of Internet of things (IoT) application areas for sustainable construction. Smart Sustain. Built Environment. 10 (3) 387-402

[73] Ogunmakinde, O.E., Egbelakin, T., Sher, W., 2022. Contributions of the circular economy to the UN Sustainable development goals through sustainable construction. Resource conservation. Recycl, 178, 106023.

3.5 Policy and Regulation Frameworks

Policy and regulation as a strategy play a crucial role in steering the construction industry towards sustainable and low-carbon practices[74]. It's the argument in this paper, that appropriate policy and regulatory frameworks in support of low carbon construction will, nevertheless, anchor the building industry in Africa on a growth trajectory towards Net Zero Carbon Construction by 2050. Though effort has been done to this end, its insufficient, low starter on implementation and weak enforcement mechanisms. Using Kenya as exemplifying case, the National Climate Change Action Plan of 2013 (NCCAP)[75] provides a perfect blue-print towards climate action, generally. The NCCAP is a plan started in 2013 to ensure Kenya's development goals are anchored firmly in law geared towards low carbon emissions and sustainability and is revised every five years with a potential of reducing GHG emissions by 40% but is yet to show results because it lacks precise policy instruments that can be relied upon by the industry's stakeholders to align with the country's climate change and sustainable development goals. Therefore, it is evident that policies and regulations are needed in aligning the African construction industry's behavior with net-zero carbon objectives.

To ensure that effective policies and regulations are put in place, the industry should ensure that some practices are incorporated. For example, the existing national policies related to climate change and energy transition in African countries should be examined because they set the tone for sustainable construction practices and contribute to net-zero goals. Furthermore, effective building codes and standards that promote energy efficiency and environmentally friendly construction

[74] Aldieri et al.,2021: Evaluation of energy resilience and adaptation policies: An energy efficiency analysis.

[75] Government of Kenya (2018). National Climate Change Action Plan (Kenya): 2018-2022. Nairobi: Ministry of Environment and Forestry

should be implemented. The existing codes and standards should also undergo updates or revisions needed to align with net-zero carbon targets. Importantly, Policies that incentivize the integration of renewable energy sources in construction projects should also be created and government initiatives that support the use of solar, wind, or other renewable technologies made a priority. To supplement this, government incentives and subsidies that encourage the adoption of sustainable construction practices to encourage reduced carbon emissions can be implemented. Features such as financial or tax benefits for using low-carbon materials or energy-efficient technologies can also be explored.

On a similar wavelength, Carbon pricing mechanisms should be implemented, such as carbon taxes or cap-and-trade systems, to incentivize carbon reduction in construction[76]. Suffice to say, policies play an important role in fostering public awareness and stakeholder engagement in sustainable construction practices. Critical to the foregoing, is the monitoring and enforcement mechanisms that ensure compliance with sustainability regulations. This being a weak link, should be explored including penalties or incentives in driving adherence to net-zero carbon construction standards. Regulations related to construction waste management, encouraging recycling, and minimizing landfill contributions should be created using successful waste reduction strategies implemented in other regions as blueprint.

As part-strategies on environmental stewardship, Environmental Impact Assessments (EIAs) that play a crucial role in ensuring that construction

[76] Augustine S.K.K., Xiaohua.J, Robert Osei-Kyei, and Srinath Perera (2022) : A Conceptual Framework for Carbon Trading in the construction industry. 45th Australiasian Universities Building Education Association Conference, 23-25 Nov, 2022, Western Sydney University.

projects consider and mitigate potential environmental impacts can be made mandatory towards net zero carbon building[77].

4.0 The Concept of Systems Thinking

The economic boom and industrial development after World War II led to the necessity of "Systems Thinking" and "Systems Approach"[78]. The new technologies that were being developed involved interaction between heterogeneous technologies such as mechanical, electrical, chemical and physical. The systems approach contrasts with the analytical method, whereby an entity is examined primarily from the viewpoint of its constituent elements or components. All the same, the systems thinking supplements rather than replaces the analytical thinking[79]. A systems view of construction activity can therefore be coupled with the analytical (un-systems-like) views that have hitherto been embraced.

Viewing an entity as a system assists in solving problems within that entity, from a broader perspective; the problem solving adopts a broad look at the organization rather than an overly obsessive scrutiny of the particular problem in question. This holistic view is considered to be most realistic for the solution of present-day problems because of their increasing complexity [80] .Systems thinking considers the interaction among people, materials, processes and the environment and provides a perspective that is crucial for addressing multifaceted aspects of sustainability which makes it extremely relevant in addressing complex challenges such as achieving net zero carbon construction. Key principles

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[77] Kukah, A.S.K.,Blay Jnr, A.V. and Opoku, A. (2022): Strategies to reduce the impact of resource consumption in the Ghanaian construction industry. International Journal of Real Estate Studies, 16(1),51-59

[78] Thomas and Agatha Hughes, (2000) Thinking Systematically: Systems, Experts, and Computers

[79] Russell L Ackoff and Jamshid Gharajedaghi (2003) On the mismatch between systems and their models

[80] Naudé Scribante, Leon Pretorius (2020) Establishing a Reference Model for Requirements Elicitation Behavior

of Systems Thinking that will steer the race towards net zero carbon construction include the recognition of the interdependence of different elements in the construction sector, including design, materials, energy use, and waste management and emphasizes the need to consider the entire lifecycle of construction projects.

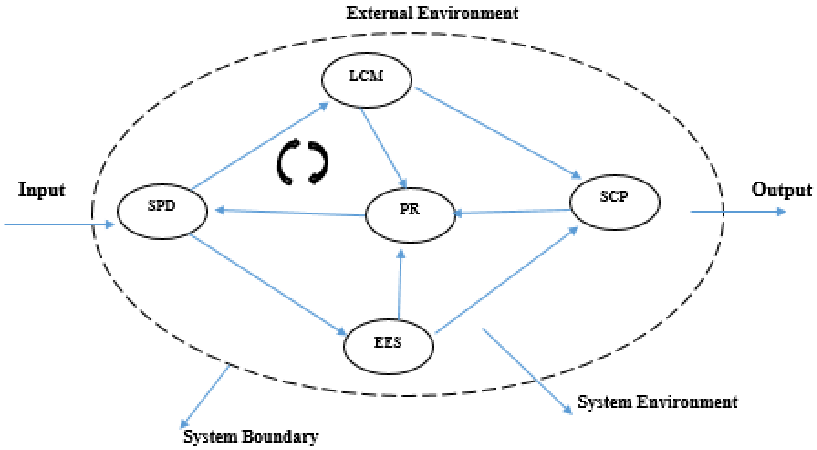

Figure 4.1: Net Zero Carbon Construction System:

Source: Author`s formulation. 2024.

Key:

Element, Relationship ----Boundary feedback loop

SDP--- Sustainable Planning & Design, **LCM**--- Low Carbon Materials, **SCP**—Smart Construction Practices, **EES**—Efficient Energy Systems, **PR**—Policy and Regulations

This paper conceptualized Net Zero Carbon Construction as a system consisting of five elements (SDP, LCM, SCP, EES, and PR) which should operate as a whole. The concept of feedback loops and dynamic complexity in this system suggests that changes in one element can impact the entire system and understanding these dynamics is essential for effective decision-making on carbon construction. It's imperative that the planners and designers of construction projects set the tone from the onset with regards implementing net zero carbon principles, this informs materials selection, construction practices as well as the need for energy efficient systems within a development. Importantly, the Net Zero Carbon

Construction should be anchored on appropriate policies, regulations and enforcement measures framework.

From the above, considering Net Zero Carbon Construction as a system, helps identify leverage points where policy interventions can have the most significant positive impact. Examples of leverage points in the construction industry are: materials selection and specification, energy efficient design standards, lifecycle assessment integration, green building certification, construction waste management policies, decentralized renewable energy mandates, training and certification programs and adaptive reuse and historic preservation incentives among others. To this end, Systems thinking facilitates the integration of sustainability principles across these dimensions.

In sum, viewing net zero carbon construction as a system, allows for the recognition of emergent patterns and behaviors in the construction industry and identifying these patterns can inform strategies for achieving net-zero carbon goals. Equally, there is need for transdisciplinary collaboration within the construction sector, which can be facilitated by systems thinking as collaboration across disciplines enhances the effectiveness of sustainability efforts.

5.0 Global Best Practices

Globally, effort has been made, albeit, on a case basis, to develop Net Zero Carbon projects where exemplary approaches, strategies and methodologies have been used to demonstrate outstanding success in promoting environmental responsibility, social equity and economic viability within the construction industry. These practices are recognized at an international level and are considered benchmarks for achieving sustainable development in the built environment.

Firstly, In Sydney, Australia, One Central Park is an iconic development that has incorporated sustainable features like green walls and roofs, along with on-site renewable energy generation. Consequently, it achieved a 5-star Green Star rating and is an excellent example of integrating nature into urban spaces while minimizing carbon footprint[81]. Secondly, The Masdar City, Abu Dhabi, UAE is designed to be a carbon neutral and zero waste city. The City utilizes renewable energy sources, smart grid technologies and sustainable building practices. It aims to be a model for future urban developments in terms of energy efficiency and environmental responsibility [82]. On Similar score, The Edge, in Amsterdam, Netherlands is a development renowned for its innovative design, one of the greenest and most energy-efficient developments globally. It utilizes advanced technologies like smart sensors, rain water harvesting, and efficient heating/cooling systems, achieving both LEED Platnum and BREEAM outstanding certifications for sustainability [83]. From the foregoing, its testament that there exists diverse approaches to achieving net zero carbon construction globally which Africa can benchmark.

From the Case studies, it can be deduced, that Environmental Stewardship is one of the global best practices proving fruitful for the race towards net-zero carbon emissions therefore; integration of these practices can minimize the environmental impact of construction activities. This can be done through adoption of resource-efficient processes, waste reduction measures, and the use of renewable materials

[81] Jean Nouvel, Ateliers Jean, Bertram Beissel, and Ateliers Jean, (2014): Case Study: One Central Park Sydney. International Journal on Tall Builidngs and Urban Habitat.
[82] Venkatanarayan Sankaran and Ashok Chopra (2020): Creating global sustainable Smart Cities (A case of Masdar City)
[83] World Green Business Council (2013): The Business Case of Green Buildings, a review of costs, benefits for developers. Toronto, WGBC

to enhance environmental stewardship. Significantly, the practice of integration of renewable energy sources, such as solar or wind power, to promote a shift towards low-carbon and sustainable energy solutions can be effective to reduce carbon emission. Additionally, embracing a circular economy approach by prioritizing material reuse, recycling, and minimizing waste generation throughout the construction lifecycle has the potential to reduce the demand for new resources.

Notably, adherence to globally recognized green building certification systems, such as LEED (Leadership in Energy and Environmental Design) or BREEAM (Building Research Establishment Environmental Assessment Method), underscores compliance with rigorous sustainability standards hence best practice that should be implemented globally. To this end, implementation of integrated design processes that involve collaboration among architects, engineers, contractors, and stakeholders from the early stages of project planning is a practice that has shown great results in specific parts of the world. This calls for holistic decision-making that considers environmental, social, and economic aspects throughout the construction project. Active engagement with local communities to understand their needs, priorities, and cultural considerations has also shown great result in the reduction of carbon emission. This involves the integration of social responsibility practices that prioritize the well-being and inclusivity of local communities affected by construction projects.

To supplement the above best practices, adoption of innovative technologies, such as Building Information Modeling (BIM), 3D printing, and advanced construction materials, to enhance efficiency and sustainability in construction processes has been adopted in a few areas in the world and remarkably increased energy efficiency[84]. Utilization of smart infrastructure and IoT technologies to optimize resource management, enhance energy efficiency, and improve overall performance of constructed assets has also been used. Another innovation is the implementation of lifecycle assessment methodologies to evaluate the environmental impact of construction materials and processes and ensure that sustainability goals are maintained throughout the operational phase.

6.0 Conclusion

The sum total of this paper is a call for Net Zero Carbon construction in Africa. The paper posits that in the fight against climate change, Africa has to be intentional, robust and dynamic in its approach on construction practices. By elucidating the intricacies of carbon emissions, proposing viable pathways to achieve net zero, advocating for a systems thinking perspective, and drawing insights from global best practices, this paper has established a roadmap for fostering environmentally responsible construction in Africa and anchor it on growth trajectory towards achieving Net Zero Carbon goals by 2050. To this end, its recommended that Africa should enact appropriate environmental, Net Zero Carbon construction policies and regulations and progressively fortify them with enforcement measures. It is imperative that stakeholders collaborate, integrating these principles into local policies and practices, to pave the way for a resilient and ecologically mindful construction landscape on the continent.

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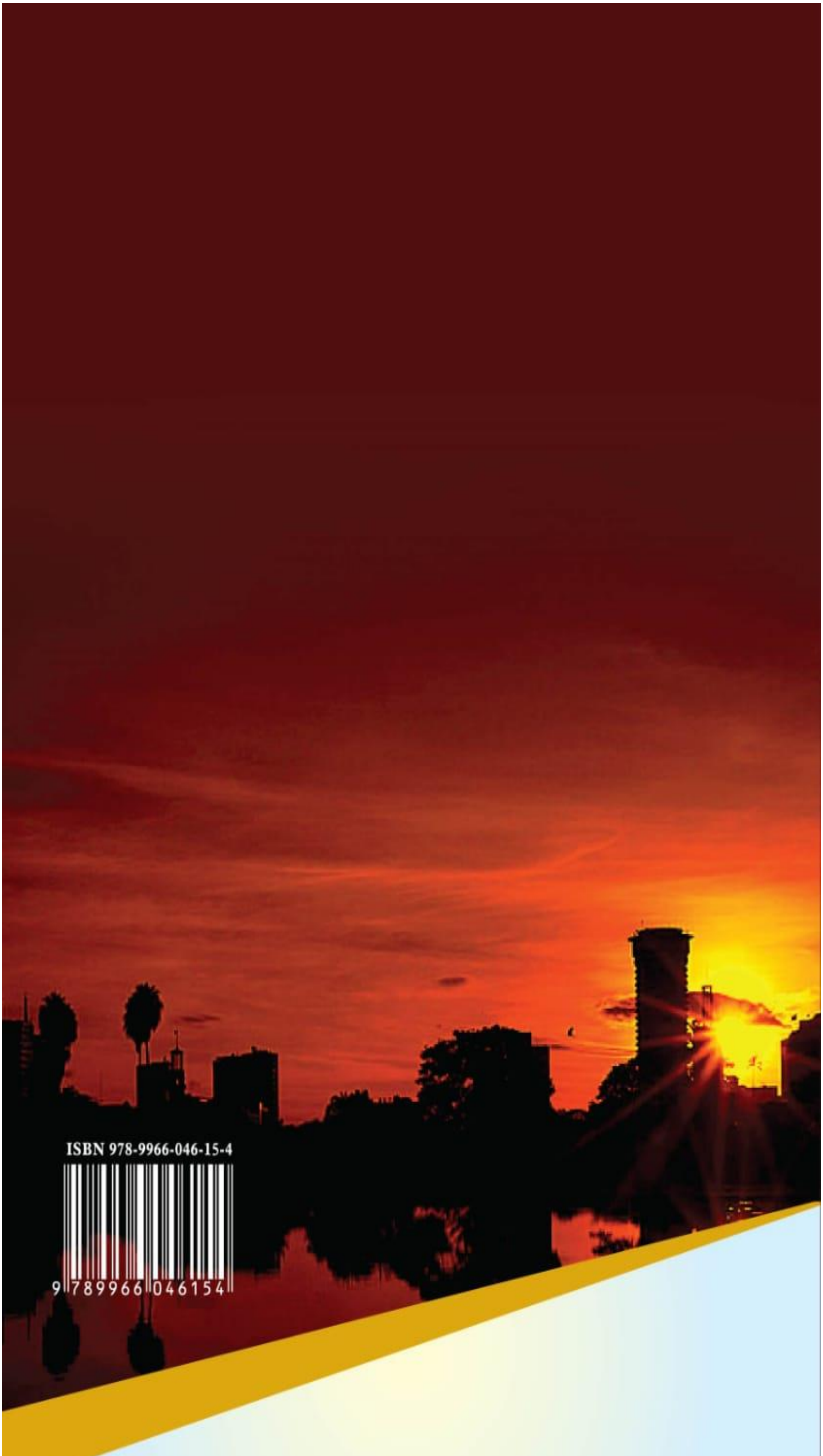

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