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BRIDGING THE HOUSING DEFICIT IN NIGERIA: ENERGY AND CO_2 EMISSIONS IMPLICATIONS

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Abstract

Affordable and decent housing constitute an important component of the urban infrastructure of any nation. In Nigeria, the housing deficit was estimated in the year 2012 to be about 17 million. Understandably, the huge financial and complex logistical implications of bridging the deficit appear to have dominated academic discussions on the subject matter. This paper attempts to address the energy and CO_2 emission implications of mitigating the huge housing deficit. Using a predominant urban social housing typology in the highly urbanized city of Lagos as a basis, the paper estimated the embodied energy and CO_2 emissions associated with providing the additional housing units needed to bridge the deficit. The life cycle energy analysis framework was adopted for the study with the Inventory of Carbon and Energy (ICE) as the main source of embodied energy and CO_2 coefficients. It was found that given a housing unit footprint of $120m^2$ and a building life span of 50 years, the embodied energy and CO_2 emissions intensities for the prototype were $7378MJ/m^2$ and $589kg/m^2$ respectively. For the additional housing units, the above intensities translated to about $15.x\ 10^{12}$ MJ of embodied energy and 1.2×10^{12}kg of CO_2. With respect to the building components, the largest contributors to the embodied energy and carbon profile were the substructure, frame and upper floors as well as internal and external walls and the key materials for the components were cement and steel reinforcement. In order to reduce the estimated embodied energy and carbon impact of providing the additional housing needs, the targets for mitigation should be the concrete, steel reinforcement and envelope/partition materials of the buildings.

Keywords: *Embodied carbon, Embodied energy, Life cycle assessment, Mass housing, Nigeria.*

Contact: **isidore.ezema@covenantuniversity.edu.ng**. The authors declare that they have no relevant or material financial interests that relate to the research described in this paper. Also, the authors declare that the submitted paper is their original work and that, upon publication, nothing contained in it will not constitute an infringement of any copyright. Paper received **17.04.2017**. Approved **30.05.2017.**

1. Introduction

Housing constitutes an important part of the infrastructural needs of society providing both a physical enclave and a social space. In spite of its importance, housing of the right quality and quantity has remained a major challenge especially in developing countries such as Nigeria. The quantitative deficit in housing in Nigeria has been estimated at about 17 million with annual housing production standing at about 100,000 units as against the expectation of about 700,000 units (Okonjo-Iweala, 2014). The magnitude of the housing deficit is such that government alone cannot cope with its mitigation. As a result, public-private partnerships are gaining ground as an important route for mitigating the housing deficit (Ibem and Aduwo, 2012).

Strategies to provide housing in Nigeria include direct provision by government and government agencies, private sector provision and public-private partnership arrangements. In all these scenarios and given the magnitude of the deficit, the mass housing approach is required. Mass housing connotes provision of large number of housing in multiple units on a continuous basis to meet the housing demand of both owner-occupiers and rental tenants. The purpose of mass housing is to provide decent housing units at affordable costs to households that cannot cope with the huge investments associated with land acquisition and direct construction of buildings. The major challenges of mass housing in Nigeria include land acquisition, finance, design-related issues, procurement methods including availability of good building materials and components as well as low adoption of innovative methods of mass housing construction.

Of increasing importance in mass housing is the environmental impact of its provision in terms of resource use, energy consumption and CO_2 emissions. This is against the background that buildings generally and residential buildings in particular are responsible for huge energy consumption and CO_2 emissions (UNEP, 2009). In addition, given the attention paid to emissions from the building sector at the 2015 UN Climate Change Conference (COP 21) and the subsequent emissions reduction targets agreed, more detailed examination of the energy and CO_2 emissions profiles of buildings is necessary. Incidentally the Intended Nationally Determined Contribution submitted to COP 21 by Nigeria indicated carbon reduction target of between 20% and 45% by the year 2030 (FGN, 2015). However, this aspect of mass housing has not been fully studied in the Nigerian context. With the huge material resources that would be needed to bridge the housing deficit, the current paper seeks to examine the energy and CO_2 emissions implication of the provision using the prevailing building materials and construction methods. In order to do this, a predominant public residential building typology in the highly urbanized city of Lagos, Nigeria was selected as case. Specifically, the energy and CO_2 emissions associated with the building materials/components and the construction processes are examined using mainly the Inventory of Carbon and Energy (ICE) database developed by Hammond and Jones (2011).

2. Literature review

The literature review coverage includes the concept of mass housing and the challenges of mass housing especially in the context of Nigeria. In addition, the environmental impact of mass housing was also considered. The section concludes with examples from several contexts of life cycle energy assessment of residential buildings

2.1 Concept of Mass Housing

Mass housing generally implies mass production of housing units in response to the needs of a particular context. In this respect, mass housing has its foundation in industrial production. Even though the concept often points to the physical attributes of a project in terms of size and construction methods, Kwofie, Fugar, Adinyira and Ahadzie (2014) in defining mass housing captured the non-physical attributes which includes organizational and operational features. Mass housing is essentially an urban phenomenon associated with urbanisation and the challenges associated with it (Musterd, Van Kempen and Rowlands, 2009). It has found expression in public housing, social housing, profit-oriented private-sector driven housing programmes and in public-private partnership arrangements.

2.2 Challenges of Mass Housing

The housing sector in Nigeria is confronted with a myriad of challenges which are further compounded by a rapidly growing population especially in the urban areas. With an estimated population growth in the range of about 2.5%, Hogarth, Haywood and Whitley (2015) estimated that 1.5 million new homes would be required annually between 2012 and 2025. The challenge is made worse by an existing housing deficit of about 17 million housing units as estimated in 2012.

Availability of land is fundamental to the provision of housing but land policy and implementation have been found to be debilitating to mass housing development in many African countries (UN-HABITAT, 2011). This was confirmed in a study by Makinde (2014) which found that cost of land and land access processes are limitations to mass housing in Nigeria. Also, Ugonabo and Emoh (2013) identified lack of secure access to land as a barrier to housing while Oloyede, Iroham and Ayedun (2011) attributed the continuous patronage of informal land markets by residential property developers in South West Nigeria to the failure of formal market.

Closely associated with land acquisition is the issue of housing finance. The housing finance situation was assessed by Okonjo-Iweala (2014) and it was found that total mortgage market is just about 0.5% of GDP and total commercial bank mortgage loans is less than 1% of banks total assets. The poor state of housing finance was responsible for poor implementation of mass housing schemes in Abuja, Nigeria's capital as identified by Ukoje and Kanu (2014).

Housing design issues are also paramount in mass housing especially with respect to flexibility and adaptability to a wide variety of dwellers (Narendran and Musau, 2014). Widespread housing transformations witnessed in mass housing is evidence of design inadequacies and residents dissatisfaction (Aduwo, Ibem and Opoko, 2013). Folaranmi (2012) and Okpoechi (2014) also emphasize the need to involve end users in design decisions while Jambol et al (2013) proposed a bottom-up approach to mass housing design.

Slow pace of innovation adoption has also been identified as a challenge to mass housing especially in the context of developing countries. Mehta and Bridwell (2006) consider innovative technologies for mass housing to entail production of housing in a cheaper, more efficient and more context-relevant manner. In Nigeria, mass housing construction projects are still characterized by in-situ construction processes (Ezema, 2014). The advantages of innovative construction methods such as offsite manufacturing (OSM) to the Nigerian mass housing sector has been emphasized by Kolo, Rahimian and Goulding (2014; 2015).

2.3 Environmental Impact of Mass Housing

Increasingly, emphasis is being placed on the building and construction sector in the drive towards a sustainable environment. It has been estimated that buildings alone account for about 30% of global greenhouse gas (GHG) emissions of which CO_2 is the most prominent (Gupta, 2014). This necessitated the prominence given to buildings in the deliberations of the 2015 COP 21. In mitigating carbon emissions from buildings especially in rapidly growing countries such as Nigeria, it is advised that emphasis should be placed on new buildings as they offer the best opportunities for mitigation (Jennings, Hirst and Gambhir, 2011).

Energy consumption and carbon emissions are often used to measure the environmental performance of buildings. In this respect, energy consumption and carbon emissions can be considered at two levels: the embodied phase and the operations phase. Embodied energy is the energy consumed in the process of bringing a building about and it includes the energy of building materials and components production as well as the energy of the building assembly or construction processes. In detail, the embodied aspect of a building covers the following: material embodied energy (cradle-to-gate), transportation energy, site construction energy, recurring energy (energy associated with maintenance) and demolition or end-of-life energy. Embodied carbon is the carbon associated with the embodied phase of a building. The energy of the operations phase which is outside the scope of current paper is the energy consumed in the process of using a building and it includes the energy used for household appliances, cooking, air conditioning and lighting. Conventionally, the embodied energy of buildings is estimated using the life cycle energy assessment framework which is a streamlined version of the internationally standardized life cycle assessment framework (ISO, 2006).

A number of methods are used in life cycle assessment and they include: input-output method, process method and hybrid method. The input-output method of life cycle assessment was developed by the Green Design Institute of Carnegie Mellon University based on the economic input-output model originally encapsulated by economist W. Leontiff. In process-based life cycle assessment, account is taken of direct and indirect upstream energy flows of a product or process and it was originally developed by SETAC (Society of Environmental Toxicology and Chemistry) and later adopted by the International Standards Organisation (ISO). The highly aggregated nature and low accuracy of the I-O method coupled with the enormous time required for the more accurate process method necessitated the hybrid method which overcomes the shortcomings of the earlier two methods (Weidmann, 2010).

Full life cycle assessment is conducted using standard soft-wares but the streamlined version highlighting for example, embodied energy and carbon dioxide emissions (Biswas, 2014) can be carried out using spreadsheet and embodied energy and carbon coefficients estimated previously from process life cycle assessment methodologies. In this respect the ICE database developed by Hammond and Jones (2011) comes to fore as it enables quick lifecycle energy and CO_2 emissions assessment for the purpose of determining hotspots in buildings.

2.4 Life Cycle Energy Assessment Examples

Using the energy input-output analysis and a predominant residential apartment typology of area 85m^2 in the Republic of Korea, Jeong, Lee and Huh (2012) estimated material embodied energy and embodied carbon to be 11.8TOE and 45.1Ton-CO_2 respectively which when converted translate to 494,042MJ of embodied energy and 45100kg of embodied CO_2 respectively. The resultant intensities were 5819MJ/m^2 and 531kgCO_2/m^2 respectively, with steel and concrete accounting for the bulk of the intensities. However, the intensities refer to initial material embodied aspect.

In an Indian study of a residential building of 2960m^{2}footprint, Ramesh, Prakash and Shukla (2013) using the process method estimated initial embodied energy intensity to be 7358MJ/m^2 while recurring embodied energy intensity was 716MJ/m^2 making a total embodied energy intensity of 8074MJ/m^2. The recurring component of the embodied intensity was approximately 10% of the initial embodied component. This could be attributed to the long life span of the major building components as assumed in the study.

Similarly in an Indonesian study (Surahman and Kubota, 2013), initial embodied energy of three housing types using input-output method were 36.3GJ, 130GJ and 367.7GJ respectively in the order of complexity of the buildings. With the footprints of the buildings at 57m^2, 127m^2 and 300m^2, the embodied intensities were estimated to be 637MJ/m^2, 1024MJ/m^2 and 1226MJ/m^2 respectively. Even though the intensities were dominated by the concrete and steel components, the relative low values of embodied energy point to increased use of materials sourced from the immediate environment.

Crawford (2008) demonstrated how the hybrid method can be used to improve the accuracy of traditional methods of embodied energy analysis of Australian buildings. In a residential case study with 109m^2 footprint and with basic materials made of concrete, timber, brick veneer and plasterboard, the hybrid method compared with the process and input-output method showed differences of between 41% and 59% respectively. Further modifications of the hybrid method have also been evolved. Acquaye (2010) described a stochastic model for embodied energy and carbon dioxide equivalent analysis of the Irish construction industry while Kibwami and Tutesigensi (2014) proposed a mathematical model for embodied carbon emissions reduction in building projects.

Of importance is the growing use of the ICE database in life cycle energy and carbon emissions analysis of buildings in the African continent. This may be due to the absence of good quality life cycle inventory data especially for embodied impact assessment. The economic input-output tables are over aggregated and energy intensity data are not available on a consistent basis. Hugo et al (2012) used the ICE database to assess the embodied energy and carbon footprint mitigation opportunities of BRT stations in South Africa. Hashemi et al (2015) also used the ICE database to comparatively evaluate the embodied energy of walling materials in low income housing in Uganda. Interestingly, the study found cement-based walling processes less energy intensive than traditional brick walling due to the inefficient brick firing processes. Abanda et al (2014) deployed the ICE database to compare the embodied energy and carbon emissions intensities of whole buildings using two construction alternatives in Cameroun. The study found embodied energy and carbon dioxide intensities to be $2008MJ/m^2$ and $228kgCO_2/m^2$ respectively for mud-brick house and $3066MJ/m^2$ and $397kgCO_2/m^2$ respectively for the cement-block house. All the intensities are however for the initial material embodied phase.

The foregoing review suggests that the mass housing delivery process in Nigeria need to be subjected to proper environmental assessment especially as efforts are being made to address the huge housing deficit. Also, the literature point to the central role materials use and construction methods play in the embodied energy and CO_2 intensity of residential buildings. However, the differences observed in the cited examples suggest that the context of the buildings has a role to play in their embodied energy and CO_2 profile.

3. Research methodology

The study area is Lagos, Nigeria and survey research design was used to obtain general primary data about the buildings. The research population was the public housing units established by Lagos State Government between 1981 and 2005 for low and medium income earners located in medium–rise multi-family residential blocks in residential estates managed by the Lagos State Development and Property Corporation (LSDPC). Nine estates were randomly selected and taking each estate as a stratum of the population, a sample size of 1,075 housing units was drawn systematically and used for questionnaire administration for the wider study which comprised of operational and embodied energy and carbon components. However, only the embodied component is reported in this paper.

In addition, building-specific inventory data for embodied energy estimation such as types and quantities of building materials and components as well as construction processes and inputs employed were obtained through observation, interviews and from secondary sources such as contract documents. A typical residential block typology was selected for the building-specific inventory (see Figure 1 and Figure 2). The block comprised of six apartments on three floors with gross floor area of 720m^2 (120m^2 per unit). The selected building was subjected to detailed embodied energy and CO_2 emissions analysis using the ICE database and international energy and emissions protocols.

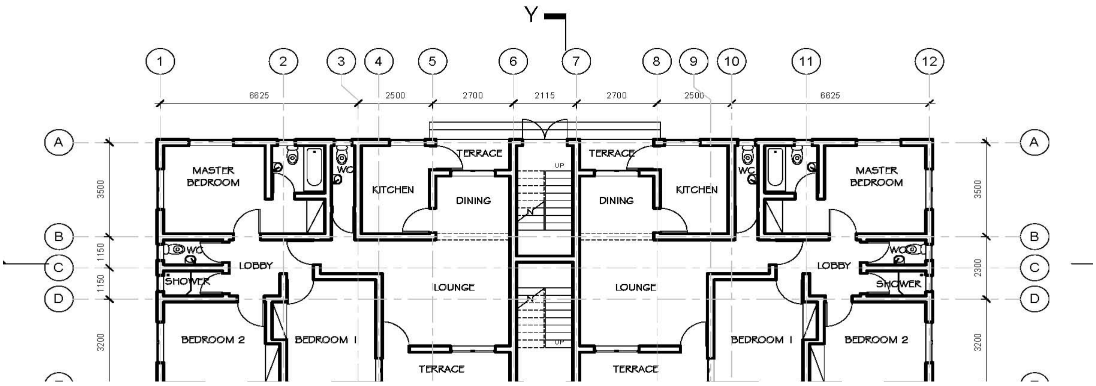

Figure 1: Typical Floor Plan of Building

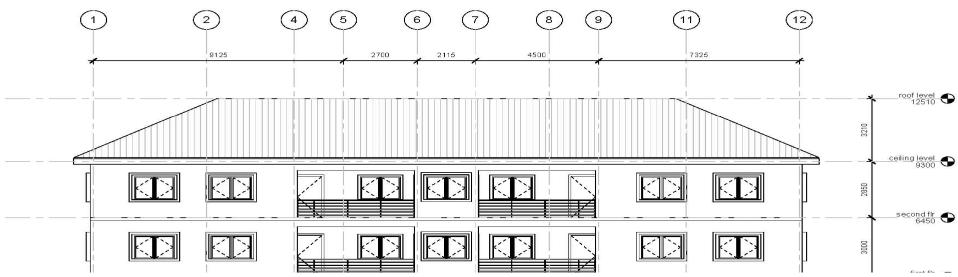

Figure 2: Front Elevation of Building

The results obtained from the survey and inventory stages were used in conjunction with relevant international embodied energy protocols, the Inventory of Carbon and Energy (ICE) database and some local inventory data to estimate energy consumption at the embodied phase of the selected residential building typology. The quantities of materials obtained from a standard bill of quantities were estimated either in mass (kg) or in volume (m^3) and later converted to mass (kg) in order to make the units of measure compatible with the ICE inventory. The quantities were also arranged according to construction milestones namely: substructure, frame and walls, suspended floors and staircases, roof structure and covering, finishes, fixtures and fittings as well as building services in order to indicate the relative materials and energy consumption of each milestone. The energy value arrived at represent the material embodied energy or cradle-to-gate embodied energy. In order to capture the full embodied energy, the energy of transporting the materials to site, energy of site construction operations and energy of building maintenance or recurring energy are also estimated as detailed in Ezema (2015). Recurring embodied energy is estimated using a 50 year life span for the building and building component life spans obtained from literature. Given the labour-intensive construction methods prevalent in the study area, manual energy was estimated using the manual energy coefficient for the tropical region as originally recommended by Odigboh (1997).Demolition in the study area is mostly carried out manually with the products of the demolition reused in other ways including construction. Hence, demolition energy was assumed to be negligible in the current study.

4. Findings and discussion

The findings of the study are presented under two sub-headings namely: embodied energy and embodied carbon.

4.1 Embodied Energy

The embodied energy profile of the selected building is as shown in Table 1. It is dominated by the initial material and recurring material components (97%). The total embodied intensity of 7378MJ/m2 is lower than that of the Indian study (8074MJ/m2). However, the recurring component of the Indian study is lower than that estimated in present study. The relatively high value of recurring embodied energy in present study may be ascribed to the low durability of building components used which necessitated frequent component replacement during the building life span. If the initial material embodied energy intensity in present study (3727MJ/m2) is compared with that of other studies, it would be observed that it is lower than the Korean study (5819MJ/m2) but higher than the studies in Indonesian and Cameroun. The differences may be explained by differences in primary energy sources as well as project status (formal or informal) and scale of the buildings.

Using the estimated embodied energy intensity of 7378MJ/m2 and a housing unit footprint of $120m^2$, the embodied energy content of 17 million housing units built with existing materials and employing existing construction methods will be $15x10^{12}$MJ. If the target is to totally offset the deficit in ten years at a constant rate, then the mass housing sector will be adding $1.5x10^{12}$MJ to the embodied energy content of the Nigerian built environment annually. This is equivalent to burning 42 billion litres of diesel annually or 115 million litres of diesel daily for the next ten years.

Table 1: Embodied Energy Profile

MEE (MJ)	TE (MJ)	SCE (MJ)	REE (MJ)	TEE(B) (MJ)	TEE(U) (MJ)	EEI (MJ/m^2)
2,683,461 (51%)	100,201 (2%)	60,138 (1%)	2,468,307 (46%)	5,312,107 (100%)	885,351	7,378

MEE = material embodied energy (cradle-to-gate), TE = transportation energy, SCE = site construction energy, REE = recurring embodied energy, TEE = total embodied energy, EEI = embodied energy intensity, B = residential block, U = residential unit.

The estimated embodied energy is mainly due to initial and recurring materials used in the buildings. Transportation and site construction energy are negligible. A sizeable percentage of the material embodied energy is traceable to the use of cement, cement-based materials and steel reinforcement. These materials were used as the main structural components of the building as well as for the internal walls and the external envelope (see Table 2). A major contributor to the recurring component of the embodied energy is painting as shown in Table 2 which had low contribution to the initial material embodied energy. This is mainly due to high churn rate for painting relative to other building components.

Table 2: Relative Contribution of Component to Embodied Energy

Building Component	MEE (%)	REE (%)
Substructure	13.6	0
Frame and Upper Floors	25.4	0
Walls (Internal and External)	11.7	0
Roof	7.8	8.5
Doors and Windows	6.0	6.5
Fixtures and Fittings	4.9	10.8
Wall Finishes	7.1	16.0
Floor Finishes	8.2	18.2
Ceiling Finishes	1.5	1.7
Plumbing Installations	4.2	4.5
Electrical Installations	2.6	2.8
Painting	7.1	31.0
Total	100	100

4.2 Embodied Carbon

The embodied carbon profile of the reference building is as shown in Table 3. The dominant components of the total embodied carbon are the initial and recurring materials components representing 97% of total carbon dioxide emissions. The total embodied intensity was also estimated at 589kgCO$_2$/m^2 while the initial material intensity came to 331kg/CO$_2$/m^2.
By adopting the estimated embodied carbon intensity of 589kgCO$_2$/m^2 for the 17 million housing units, the total carbon dioxide emissions from the embodied phase is estimated to be $1.2 x 10^{12}$kgCO$_2$. If the emissions are to be distributed over ten years, the annual addition of carbon dioxide will amount to $0.12 x 10^{12}$kgCO$_2$. The figure translates to 120 million tons of carbon dioxide annually released into the environment mainly from the use of building materials and components as the transportation and site construction components are rather negligible in comparison.

Table 3: Embodied Carbon Profile

MEC (kgCO$_2$)	TC (kgCO$_2$)	SCC (kgCO$_2$)	REC (kgCO$_2$)	TEC (B) (kgCO$_2$)	TEC (U) (kgCO$_2$)	ECI (kgCO$_2$/m^2)
238,589 (56%)	7527 (2%)	3105 (1%)	174862 (41%)	424083 (100%)	70681	589

MEC = material embodied carbon, TC = transportation carbon, SCC = site construction carbon, REC = recurring embodied carbon, TEC = total embodied carbon, ECI = embodied carbon intensity, B = residential block, U = residential unit.

5. Implications of the findings

The study identified building materials and components as the main contributors to both the embodied energy and embodied carbon profile of the buildings. In order to reduce the embodied energy intensity of mass housing, it is important that the flashpoints in their embodied energy and embodied carbon profile should be addressed. In this respect, the use of cement, cement-based products and steel reinforcement stand out. Incidentally, these are the most common construction materials in the study area. However, in line with energy and carbon reduction targets adopted at COP 21, there is the need to take appropriate measures to mitigate their impact. In this respect, the use of low carbon alternative building materials is advised. A number of these alternative materials are available in the study area and efforts should be made to popularize and improve their uptake.

At the level of policy, while recognizing the almost indispensable status of the aforementioned conventional building construction materials, it is important that best practices aimed at encouraging more energy efficient production processes be encouraged especially in the cement industry which is now fully indigenized. Interestingly, the main cement production company in Nigeria had in the third quarter of 2016 announced a switch from the use of natural gas and low pour fuel oil (LPFO) to coal as the main energy source for cement production. Even though the company cited high cost and irregular availability as main reasons for the switch, its effect on the energy and carbon profile of cement production needs further study. The adoption of energy and carbon efficient material production processes is an industry-wide issue and can be facilitated through legislation and institutionalized incentives.

At the research and development level, more research aimed at identifying alternative materials needs to be encouraged. A number of low-energy and low-carbon materials which potentially can facilitate gradual substitution of cement in building construction have been identified and need to be refined further for actual use. Also, low carbon composite materials that can replace cement-based walling materials should be explored. It should be observed that the huge advantage of cement stabilized earth bricks as walling material have not been fully exploited in mass housing in Nigeria in spite of their obvious environmental benefits.

In addition, the building construction processes need to be made more efficient. The preponderance of in-situ construction methods in the study area creates room for a lot of resource waste. Lean construction processes such as the use of OSM techniques should be encouraged as a more resource efficient construction method.

In professional practice, there is the need to work with appropriate regulatory institutions to standardize and certify alternative buildings materials to facilitate their specification by built environment practitioners. At the construction industry level, more efficient construction methods such as OSM can achieve substantial reduction in the quantity of high-energy materials that cannot be fully dispensed with in mass housing construction.

6. Conclusion

This paper examined the housing challenge in Nigeria generally and from the energy and CO_2 emissions perspective. It was observed that at the current state of material use and construction practice, the energy and CO_2 implications of bridging the Nigerian housing deficit would be enormous. The flashpoints to target for substantial reductions in energy use and CO_2emissions from housing construction were identified. Concerted efforts involving research and development, innovation adoption in housing design and construction as well as policy and appropriate legislation would be needed to curtail energy and CO_2emissions intensities associated with mass housing and by so doing contribute to achieving the energy and carbon reduction target of the United Nations Conference on Climate Change.

7. References

Abanda, F. H., Elambo, N. G., Tah, J. H. M., Ohandja, E. N. F. & Manjia, M. B. (2014). Embodied Energy and CO_2 Analysis of Mud-brick and Cement-block Houses, *AIM'S Energy*, 2(1), 18 – 40,

Acquaye, A. A. (2010). A Stochastic Hybrid Embodied Energy and CO2-eq Intensity Analysis of Building and Construction Processes in Ireland, Doctoral Thesis, Dublin Institute of Technology, Dublin, Ireland.

Aduwo, E. B., Ibem, E. B. & Opoko, A. P. (2013). Residents Transformation of Dwelling Units in Public Housing Estates of Lagos, Nigeria, *International Journal of Education and Research*, 1(4), 1 – 20,

Biswas, W. K. (2014). Carbon Footprint and Embodied Energy Consumption Assessment of Building Construction Works in Western Australia, *International Journal of Sustainable Built Environment*, 3:179 – 186.

Crawford, R. H. (2008). Validation of a Hybrid Life Cycle Inventory Analysis Method, *Journal of Environmental Management*, 88: 496 – 506.

Ezema, I. C. (2014). Innovation for sustainability in the design and construction of public housing: The case of Lagos Home Ownership and Mortgage Scheme, *Procs 8th CIDB Postgraduate Conference*, University of Witwatersrand, Johannesburg, South Africa, 357 – 370.

Ezema, I.C, (2015). Profiling the Environmental Sustainability of residential buildings in Lagos, Nigeria using life cycle assessment, PhD Dissertation, Covenant University, Ota.

FGN (2015), Nigeria's Intended Nationally Determined Contribution, www4.unfccc.int/Submissions/INDC/PublishedDocuments/Nigeria/1/ApprovedNigeria'Sindc_27115.pdf. accessed on 17/01/2016.

Folaranmi, A. O. (2012). Mass Housing in Nigeria, Customize the Brief: Provide a Desired House, *Civil and Environmental Research*, 2(4), 10 – 19.

Gupta, R. (2014). Towards Low Carbon Buildings: International Perspectives on Metrics, Policies and Practices, Public Lecture Series, University of Glasgow

Hammond, G. & Jones, C. (2011). Inventory of Carbon and Energy (ICE), Version 2.0, SERT, Department of Mechanical Engineering, University of Bath, UK.

Hashemi, A., Cruickshank, H. & Cheshmehzangi, A. (2015). Environmental Impacts and Embodied Energy of Construction Methods and Materials in Low-income Tropical Housing, *Sustainability*, 7: 7866 – 7883.

Hogarth, J. R., Haywood, C. &Whitley, S. (2015). Low Carbon Development in Sub-Saharan Africa: 20 Cross-Sector Transitions, Oversea DevelopmentInstitute, London.

Hugo, J., Stoffberg, H. & Barker, A. (2012). Mitigating climate change by minimizing the carbon footprint and embodied energy of construction materials: A compsrstiveanalysis of three South African Bus Rapid Transit (BRT) Stations, *Acta Structilia*, 19(2), 21 – 45.

Ibem, E. O & Aduwo, E. B. (2012). Public-Private Partnerships (PPPs) in Urban Housing in Nigeria: Evidence from Ogun State, *International Journal of Architecture and Urban Development,* 2(2), 5 – 14.

ISO (2006), Life Cycle Assessment (ISO 14040), ISO, Geneva, Switzerland.

Jambol, D. D., Molwus, J. J. & Daniel, M. M. (2013). Re-thinking the approaches to mass housing delivery in Nigeria, In: Smith, S. D. & Ahiaga-Dagbui, D. D. (Eds.), *Proceedings 29th Annual ARCOM Conference,* Reading, UK, ARCOM, 285 – 295.

Jennings, M., Hirst, N. & 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.

Jeong, Y., Lee, S. & Huh, J.(2012). Estimation of CO2 emissions of apartment buildings due to major construction materials in the Republic of Korea, *Energy and Buildings*, 49: 437 – 442, 2012.

Kibwami, N. & Tutesigensi, A. (2014). Mathematical Modelling of Embodied Carbon Emissions of Building Projects, In: Raiden, A. B. & Aboagye-Nimo, E. (Eds.), *Proceedings 30th Annual ARCOM Conference*, 1-3 September, 2014, Portsmouth, UK, Association of Researchers in Construction Management, 53 – 62.

Kolo, S. J., Rahimian, F. P. & Goulding, J. S. (2014). Offsite manufacturing construction: A big opportunity for housing delivery in Nigeria, Procedia Engineering, 85, 319 – 327.

Kolo, S. J., Rahimian, F. P. & Goulding, J. S. (2015). Housing stakeholders' perspective on offsite manufacturing in Nigeria, *Procs International Conference on innovative production and construction,* Perth, Western Australia, 179 – 182.

Kwofie, T. E., Fugar, F. Adinyira, E. & Ahadzie, D. K. (2014). Identification and Classification of the Unique Features of Mass Housing Projects, *Journal of Construction Engineering,* dx.doi.org/10.1155/2014/927652.

Makinde, O. O (2014). Housing delivery system, need and demand, *Environment, Development and Sustainability,* 16, 49 – 69.

Mehta, R & Bridwell, L. (2006). Innovative construction technology for affordable mass housing in Tanzania, East Africa, *Constuction Management and Econmics*, 23(1), 69 – 79.

Musterd, S., Van Kempen, R. & Rowlands, R. (2009), Mass Housing Estates on Different Tracks: An Introduction to the Book, In: Rowlands, R., Musterd, S. & Van Kempen, R. (Eds.), *Mass Housing in Europe: Multiple Faces of Development, Change and Response,* UK: Palgrave Macmillan, 1 – 16.

Narendran, A. & Musau, F. (2014). Flexible and Environment Responsive Housing in Bangalore, India, *Procs, 30th International PLEA Conference*, CEPT University, Ahmedabad, Pakistan, 16 – 18 December.

Odigboh, E.U. (1997). Machines for crop production, In: Stout, B. A. (Ed.), *CIGR Handbook of Agricultural Engineering,* American Society of Agricultural Engineering.

Okonjo-Iweala, N. (2014). Unleashing the Housing Sector in Nigeria and in Africa, Keynote Paper, 6th Global Housing Finance Conference, World Bank HQ, Washington DC, USA.

Okpoechi, C. U.(2014). Middle-Income Housing in Nigeria: Determining Important Functional Requirements for Mass Housing Design, *Architecture Research*, 4(1A), 9 – 14.

Oloyede, S. A., Iroham, E. O. & Ayedun, C. A.(2011). Informal Land Market: Alternative Apporach to mass residential housing provision in South-Western Nigeria, *Journal of Geography and Regional Planning*, 4(1), 598 – 603.

Ramesh, T., Prakash, R. & Shukla, K. K (2013). Life cycle energy analysis of a multifamily residential house: A case study in Indian context, *Open Journal of Energy Efficiency*, 2, 34 – 41.

Surahman, U. & Kubota, T. (2013). Life cycle energy and CO2 emissions of residential buildings in Bandung, Indonesia, *Advanced Materials Research*, 689: 54 – 59.

Ugonabo, S. A. & Emoh, F. I. (2013). The Major Challenges to Housing Development and Delivery in Anambra State of Nigeria, *Civil and Environmental Research*, 3(4), 1 – 19.

Ukoje, J. E. & Kanu, K. U.(2014). Implementation and the Challenges of the Mass Housig Scheme in Abuja, Nigeria, *American International Journal of Contemporary Research*, 4(4), 209 – 218.

UNEP (2009). Buildings and Climate Change: Summary for Decision-Makers, UNEP: Paris, France.

UN-HABITAT (2011), Affordable Land and Housing in Africa, UN-HABITAT, Nairobi, Kenya.

Weidmann, T. (2011). Frequently Asked Questions about Input-Output Analysis, Centre for Sustainability Accounting (CenSA), Special Report.

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