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STATUS OF LIFE CYCLE ASSESSMENT (LCA) OF SOLAR SYSTEMS IN NIGERIA

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ABSTRACT:
Life Cycle Assessment (LCA), as a tool for analysing the environmental impacts of products and services has been receiving increased attention from various researchers for over 20 years. Globally, over 25,000 articles linked to LCA were published in scientific journal databases such as the Google scholar and Scopus; yet, the perception of LCA is comparatively underdevelopment in most African countries particularly Nigeria, where the number of links has been emphasised to be less when compared to other Africa's top economies. This article reviewed the life cycle assessments that were carried out in Nigeria between the years 2010 to 2020, with the aim of establishing the existing research gap in the conduct of LCA of solar systems in Nigeria. A total of 16 LCA articles were traced for the country; this number is lower than that of other top economies like South Africa and Egypt with 41 and37 articles respectively. Energy and Agricultural sectors have high number of articles (4 each), followed by Electricity and Waste (3each), transport, and other sectors (1 article each); with no single article on Photovoltaics Plant (PV Solar system). Most of these researches were conducted in the southwestern Nigeria. Creating awareness on the importance of LCA of products, establishment of a specific Life Cycle Inventory (LCI) database for Nigeria are some of the steps identified to boost the number of LCA research articles to take care of Solar photovoltaics.

Keywords: Review, Life cycle assessment,Environmental Impact; Nigeria, Solar System,

1. INTRODUCTION

The world population and that of Africa are predicted to reach 9.8 billion in 2050, 11.2 billion in 2100; and 2.53 billion in 2050, 4.47 billion in 2100 respectively. Consequently, Nigeria is projected to become the third most populous country in the world shortly before 2050 . This rapid increase in population and the resultant energy related problems in Nigerian is putting an absurd strain on the environment due to emission of pollutants and the consumption of non-renewable resources. The common method for evaluating environmental impacts is the Life Cycle Assessment (LCA). Life cycle assessment (also known as life cycle analysis, Eco balance, and cradle-to-grave analysis) is a technique to assess environmental impacts associated with all the stages of a product's life from raw material extraction through materials processing, manufacture, distribution, and use . The core LCA principles to be considered in developing the LCA model are the goal and scope definition, inventory analysis, impact assessment, and improvement assessment.
According to , Solar energy is considered one of the main ways for Nigeria to reach its

electrification targets and increasingly adopted across the country by households to power small appliances, in the shape of mini grids powering entire markets or (rural) communities, and by corporate entities who seek to reduce their reliance on expensive diesel generators. However, Informational publications for decision-makers in the European Community (European Commission, 2003) and Australian Coal Industry Association Research Program (ACARP), 2004 indicated that photovoltaics have relatively high environmental impacts compared with other renewable energy technologies . Hence the need for policy makers and financial institutions, who will be involve in making decisions on providing the support for the use of solar systems to have the required knowledge of LCA of these systems in order to make an informed decision. Consequently, the conduct of LCA studies in African countries such as Nigeria is surprisingly on the lower side . This article aimed to determine the availability and status of LCA studies of Solar systems in Nigeria.

1.1 BRIEF DECRIPTION OF SOLAR PHOTOVOLTAIC TECHNOLOGY

The devices responsible for conversion of sunlight into direct current (DC) electricity are termed as Photovoltaics (PV) or semiconductors. PV cells are constructed and arranged into modules and arrays, called solar panels to charge batteries, and to power any number of electrical loads, operate electrical motors or charge batteries, etc., PV systems can produce alternating current (AC) when connected to the suitable power conversion equipment for operation of any conventional appliances,and can operate in parallel with, and interconnected to, the electricity grid. The aim of continuous development of PV technology is to raise the performances of the cells, toreduce the market price of the modules, and to optimize the speed and cost of manufacturing processes..

1.2 LIFE CYCLE ASSESSMENT OF SOLAR SYSTEMS

assessed the environmental performance of sc-Si and mc-Si panels with power conditioning system (PCS) and BOS, in Korea. Pre-manufacturing, manufacturing, use and disposal stages were used to define the system boundaries. The results related to GWP showed that the increase of irradiation allowed a GWP reduction of 26% and 22% for base case, and a reduction of 22% and 24% for best case (for sc-Si and mc-Si, respectively).

evaluates the energy and environmental profile of Photovoltaics (thin-film and crystalline) and solar thermal collectors (flat plate and vacuum tube) technologies. The environmental burdens were analysed using a detailed cradle to grave life cycle assessment (LCA). The results of the study showed that the cumulative CO2-eq emissions over the whole life cycle of the solar systems are quite close, in the range of 2.22 × 10- 2 and 2.38 × 10- 2 kg CO2-eq/kWh·m2. Also, the economic viability of both systems is proven as the simple payback period is 2.6 and 3.8 years for the flat plate and the vacuum tube system, respectively.

2.0 MATERIALS AND METHODS

The data collected for the study was sought using intensive literature search of articles published between 2010 and 2020 through Google Scholar and other academic journal databases such as ScienceDirect and Springer. The Keywords used for the search were “Life Cycle Assessment”, Environmental impacts”, and “Nigeria”. The study was only concerned with environmental impacts related LCA studies, other types of life cycle assessments that included life cycle costing (LCC) or social life cycle assessment (SCLA) were not considered. Also, the study did not take researches that were not peer-reviewed into consideration in order to allow for neutrality of the review. Data obtained from the reviewed studies were not compared because they are mainly obtained fromlife cycle inventory databases based on situations in developed countries such as the European Reference Life Cycle and Eco-invent Databases.

4.0 RESULTS ANDDISCUSSIONS

About 244 LCA studies were found. Out of which, a total of 16 articles on LCA and environmental impacts in Nigeria were traced from the search engines and databases (Google Scholar, Elsevier, and Springer). This limitednumber of articles might be due to the fact that the concept of LCAis not yet considered valuable in some countries like Nigeria. A description of the number of articles studied between 2010 and 2020 is shown in Tables 1. The main details of each article such as year of publication, Life cycle inventory (LCI) database, product is also provided.

Out of these studies no information found regarding environmental impact assessment using life cycle (LCA)on solar photovoltaics in Nigeria within the period under review.

There is an increase in number of studies published from one article in 2010 to three articles in 2015, indicating that the idea of LCA has gained more attention; however, the lack of studies in year 2012 and the decline in the number of articles between 2016 and 2019 suggests that the concept might still be new in Nigeria.Hence, the idea or concept to carry out Life cycle and environmental impact assessmentof products and services in Nigeria is still low. Eleven of the studies traced were conducted in specific locations across Nigeria such as; Lagos, Ogbomoso, Ibadan, and Ilorin (2 articles each) while Zaria, Shelleng, and Minna (1 article each).

With regards to the types of product/services on which the LCA studies have been mostly carried out, the sectors that was considered to have more attention were Energy and Agriculture with four (4) articles each. This could be due to much dependant on the agricultural sector as a source of revenue in most parts of Nigeria; and also pollution problems as a result of consumption of solid and fossil fuels in households and industries respectively . It was noted that there was no specific LCI database available for Nigeria whenbrowsed thedifferent LCA software such as GaBi,SimaPro and the associated databases,e.g., Eco invent v3.0.

Table 1. Summary of available Life Cycle Assessment (LCA) studies conducted in Nigeria (2010 -2020).

S/N	Year	Product	LCI Database	Reference
1	2010	Electricity	Primary data/Existing literature/GEMIS 4.3/SimaPro	Gujba*et al.* (2010)
2	2011	Brewery	Primary data/Existing literature/ABREW Software.	(Adewumi et al., 2011)
3	2013	Passenger Transport	Existing literature/GEMIS4.3	(Gujba et al., 2013)
4	2013	Biodiesel	Primary data/Existing literature	(S.O. Jekayinfa & Sasanya, 2013)
5	2014	Biodigesters	N/A	(Bartlett et al., 2014)
6	2015	Municipal solid waste management	Primary data/Ecoinvent	(Ogundipe & Jimoh, 2015)
7	2015	Residential building	Primary data	(Ezema et al., 2015)
8	2015	Jatropha biofuel	Literature review/ Agrifootprint/Ecoinvent	(Lorenzo, 2015)
9	2016	Shear Butter	Primary data/Ecoinvent	(Ewemoje & Oluwaniyi, 2016)
10	2017	Municipal solid waste management	Literature review/Ecoinvent	(Ayodele et al., 2017)
11	2018	Municipal solid waste management	Primary data/Existing literature	(Ayodele et al., 2018)
12	2019	Electricity	Existing literature/Gabi	(Jumare & Bhandari, 2019)
13	2020	Sweet Oranges	Primary data	(Ogunlade et al., 2020)
14	2020	Cowpeas	Primary data/Gabi 8.7	(Ogunjirin, O C; Jekayinfa, S O; Olaniran, J A; Ogunjirin, 2020)

15	2020	Electricity	Primary data/Ecoinvent	(Yuguda et al., 2020)
16	2020	Cassava	Primary data/Existing literature	Olaniran (2020)

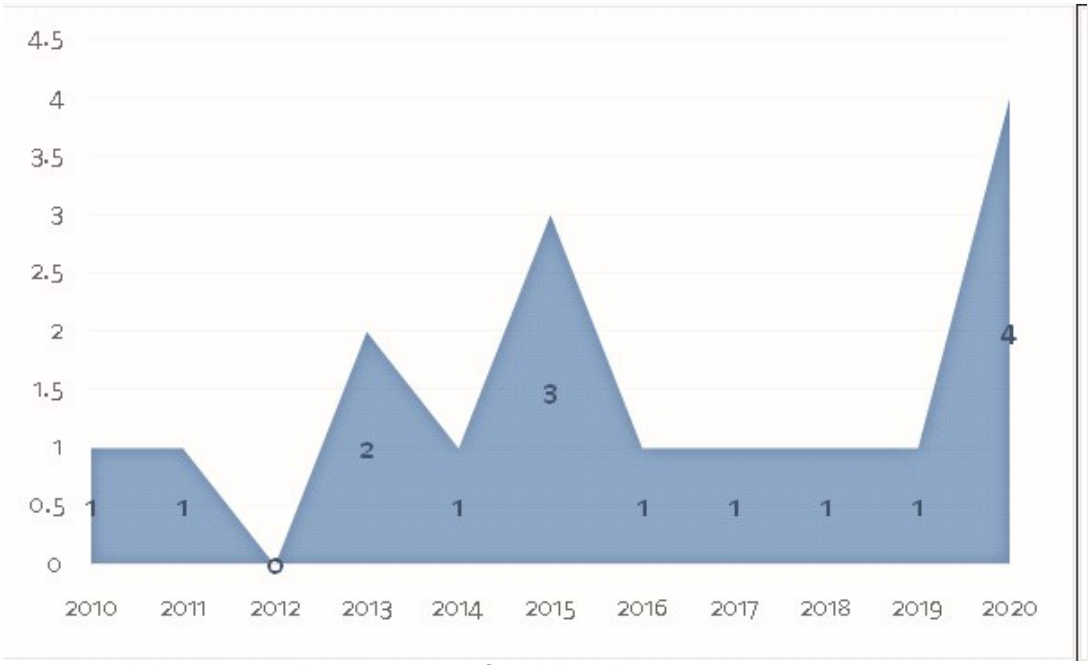

Figure 1. Articles according to year of publication.

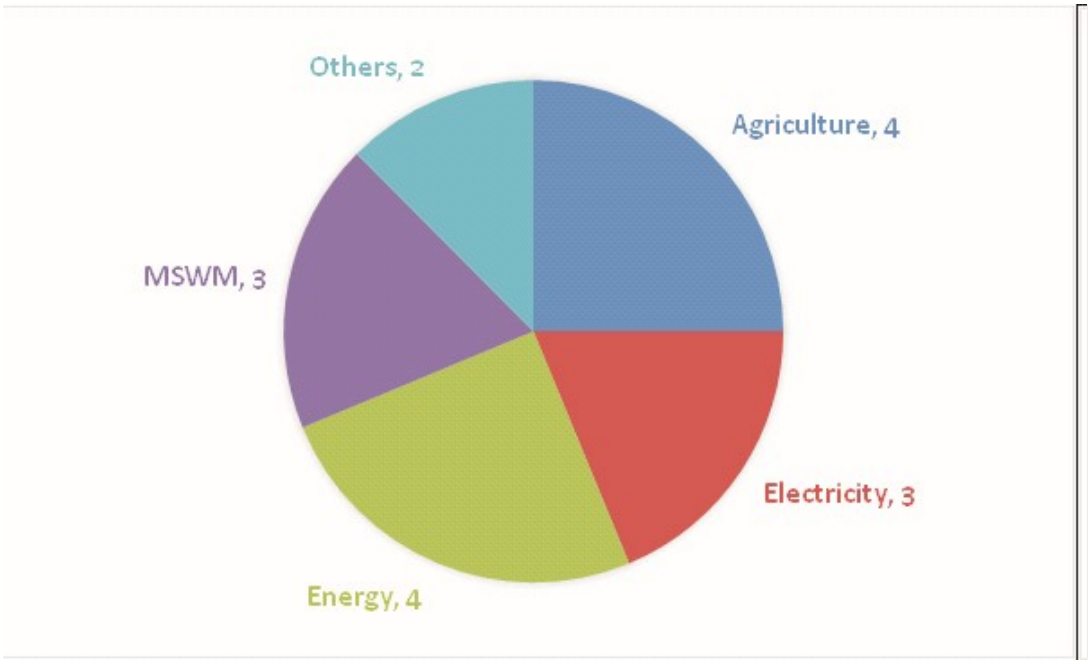

Figure 2. Articles published according to type of product.

4.0 CONCLUSION

The study found sixteen (16) peer reviewed LCA and Environmental impacts articles for Nigeria. The number of LCA researches in Nigeria is still limited, and therefore the need creating awareness through education and training of life cycle thinking. Most of the studies in the south west paying more attention to agricultural products and energy. However, considering the contribution of Solar energy in Nigeria's energy sector, it was not encouraging for not having a single LCA study of solar system. From table 1, it was noted that the studies were conducted with LCI databases that are not specific to Nigeria.

5.0 RECOMMENDATIONS

An LCIdatabase that is specific to African sub Saharan region like Nigeria be developed for data access.Manufacturersof solar systems products and other stakeholders need to help identify environmental and socialopportunities prior to large Research and Development (R&D) investments.

References

Adewumi, I. K., Oyebode, O. J., Igbokwe, K. C, & Aluko, O. G. (2011). Water F ootprints in F our S elected B reweries in Nigeria. *Towards Life Cycle Sustainability Management,* 1 7 1 - 1 8 1 . https://doi.org/10.1007/978-94-007-1899-9

Ayodele, T. R., Ogunjuyigbe, A. S. O., & Alao, M. A. (2017). Life cycle assessment of waste-to-energy (WtE) technologies for electricity generation using municipal solid waste in Nigeria. *Applied Energy, 2 0 1 ,* 2 0 0 - 2 1 8 . https://doi.Org/10.1016/j.apenergy.2017.05.097

Ayodele, T. R., Ogunjuyigbe, A. S. O., & Alao, M. A. (2018). Economic and Environmental Assessment of Electricity Generation using Biogas from Organic Fraction of Municipal Solid Waste for the City of Ibadan, Nigeria. *Journal of Cleaner Production.* https://doi.Org/1 0.1016/j jclepro.2018.08.282

Bartlett, Z., Olivares, A., Yang, L., & Rosentrater, K. A. (2014). *Economic and Environmental Analysis of Farm-Scale Biodigesters to Produce Energy for Kitchen Stove Use. 7004,* 1-21.

Ewemoje, T. A., & Oluwaniyi, O. O. (2016). *Mechanised shea butter production in south-western Nigeria using Life Cycle Assessments (LCA) approach from gate-to-gate. 18(2),* 230-242.

Ezema, 1. C, Olotuah, A. O., & Fagbenle, O. I. (2015). *Estimating Embodied Energy in Residential Buildings in a Nigerian Context. November.*

Fthenakis, V. M., & Kim, H. C. (2011). PhotovoltaicsG: Life-cycle analyses. *Solar Energy, 85(S),* 1609-1628. https://doi.Org/10.1016/j.solener.2009.10.002

GaBi Database & Modelling Principles Principles Principles (Issue January). (2017).

Gujba, H., Mulugetta, Y., & Azapagic, A. (2013). *Passenger transport in NigeriaU: Environmental and economic analysis with policy recommendations. 55,* 2012-2014.

J A Olaniranl, S. O. J. and T. A. A. (2020). Energy consumption and environmental burden analysis of cassava tuber production in Ogbomoso southwest Nigeria Energy consumption and environmental burden analysis of cassava tuber production in Ogbomoso southwest Nigeria. *IOP Conference Series: Earth and*

Environmental Science, https://doi.org/10.1088/1755-1315/445/1 /012062

Jumare, I. A., & Bhandari, R. (2019). *Environmental Life Cycle Assessment of Grid-Integrated Hybrid Renewable Energy Systems in Northern Nigeria.*

Karkour, S., Rachid, S., Maaoui, M., & Lin, C. (2021). *Status of Life Cycle Assessment (LCA) in Africa.*

Kim, B., Lee, J., Kim, K., & Hur, T. (2014). ScienceDirect Evaluation of the environmental perfonnance of sc-Si and mc-Si PV systems in Korea. *SOLAR ENERGY, 99,* 100-114. https://doi.Org/10.1016/j.solener.2013.10.038

Lorenzo, G. Di. (2015). *Energy Efficiency and Environmental Life Cycle Assessment ofJatrophafor Energy in NigeriaU: A " Well-to-Wheel " Perspective. June.* https://doi.org/10.1115/ES2015-49654

Maepa, M., Bodunrin, M. O., Burman, N. W., Croft, J., Engelbrecht, S., Ladenika, A. O., & Macgregor, O. S. (2017). *Review* I: *life cycle assessments in Nigeria , Ghana , and Ivory Coast,* https://doi.org/10.1007/sl 1367-017-1292-0

Milousi, M., Souliotis, M., Arampatzis, G., & Papaefthimiou, S. (2019). *Evaluatingt he Environmental Performance of Solar Energy Systems Through a Combined Life Cycle Assessment and Cost Analysis.*

Muralikrishna, I. V., & Manickam, V. (2017). Environmental Management Life Cycle Assessment. *Environmental Management,* 57-75. https://doi.org/10.1016/B978-0-12-811989-1.00005-1

Muteri, V., Cellura, M., Curto, D., Franzitta, V., Longo, S., Mistretta, M., & Parisi, M. L. (2020). *Review on Life Cycle Assessment of Solar Photovoltaic Panels.*

Ogundipe, F. O., & Jimoh, O. D. (2015). *Life Cycle Assessment of Municipal Solid Waste Management in Minna , Niger State , Nigeria. 9(A),* 1305-1314.

Ogunjirin, O C; Jekayinfa, S O; Olaniran, J A; Ogunjirin, O. A. (2020). Environmental life cycle assessment of cowpea production , storage and disposal in Ilorin , Kwara Environmental life cycle assessment of cowpea production, storage and disposal in Ilorin , Kwara State , Nigeria. *IOP Conf. Series: Earth and Environmental Science.* https://doi.Org/l 0.1088/1755-1315/445/1/012040

Ogunlade, C. A., Jekayinfa, S. O., Olaniran, J. A., & Adebayo, A. O. (2020). *Energy life-cycle assessment and economic analysis of sweet orange production in Nigeria.* 22(2), 123-132.

S.O. Jekayinfa, J. A. O., & Sasanya, and B. F. (2013). *Life cycle assessment of soybeans production and processing system into soy oil using solvent extraction process.* (5(4), 311-321. *Solar Report Nigeria.* (2021). U. (2017). *World Population Prospects: The 2017 Revision, Key Findings and Advance Table.*

Yuguda, T. K., Li, Y., Xiong, W., & Zhang, W. (2020). *Life cycle assessment of options for retrofitting an existing dam to generate hydro-electricity. 2017.*

Zaman, A. U. (2013). *Life Cycle Environmental Assessment of*

Municipal Solid Waste to Energy Technologies. October 2013. https://doi.org/10.1007/sl3762-013-0230-3

Adewumi, I. K., Oyebode, O. J., Igbokwe, K. C, & Aluko, O. G. (2011). Water F ootprints in F our S elected B reweries in Nigeria. *Towards Life Cycle Sustainability Management,* 171-181. https://doi.org/10.1007/978-94-007-1899-9

Ayodele, T. R., Ogunjuyigbe, A. S. O., & Alao, M. A. (2017). Life cycle assessment of waste-to-energy (WtE) technologies for electricity generation using municipal solid waste in Nigeria. *Applied Energy, 201,* 200-218. https://doi.Org/10.1016/j.apenergy.2017.05.097

Ayodele, T. R., Ogunjuyigbe, A. S. O., & Alao, M. A. (2018). Economic and Environmental Assessment of Electricity Generation using Biogas from Organic Fraction of Municipal Solid Waste for the City of Ibadan, Nigeria. *Journal of Cleaner Production,* https://doi.org/10.1016/jjclepro.2018.08.282

Bartlett, Z., Olivares, A., Yang, L., & Rosentrater, K. A. (2014). *Economic and Environmental Analysis of Farm-Scale Biodigesters to Produce Energy for Kitchen Stove Use. 7004,* 1-21.

Ewemoje, T. A., & Oluwaniyi, O. O. (2016). *Mechanised shea butter production in south-western Nigeria using Life Cycle Assessments (LCA) approach from gate-to-gate. 18(2),* 230-242.

Ezema, I. C, Olotuah, A. O., & Fagbenle, O. I. (2015). *Estimating Embodied Energy in Residential Buildings in a Nigerian Context. November.*

Fthenakis, V. M, & Kim, H. C. (2011). PhotovoltaicsL : Life-cycle analyses. *Solar Energy, 85(S),* 1609-1628. https://doi.Org/10.1016/j.solener.2009.10.002 *GaBi Database & Modelling Principles Principles Principles* (Issue January). (2017).

Gujba, H., Mulugetta, Y., & Azapagic, A. (2013). *Passenger transport in Nigeria^: Environmental and economic analysis with policy recommendations. 55,* 2012-2014.

J A Olaniranl, S. O. J. and T. A. A. (2020). Energy consumption and environmental burden analysis of cassava tuber production in Ogbomoso southwest Nigeria Energy consumption and environmental burden analysis of cassava tuber production in Ogbomoso southwest Nigeria. *IOP Conference Series: Earth and Environmental Science.* https://doi.Org/l 0.1088/1755-1315/445/1/012062

Jumare, I. A., & Bhandari, R. (2019). *Environmental Life Cycle Assessment of Grid-Integrated Hybrid Renewable Energy Systems in Northern Nigeria.*

Karkour, S., Rachid, S., Maaoui, M., & Lin, C. (2021). *Status of Life Cycle Assessment (LCA) in Africa.*

Kim, B., Lee, J., Kim, K., & Hur, T. (2014). ScienceDirect Evaluation of the environmental performance of sc-Si and mc-Si PV systems in Korea. *SOLAR ENERGY, 99,* 100-114. https://doi.Org/10.1016/j.solener.2013.10.038

Lorenzo, G. Di. (2015). *Energy Efficiency and Environmental Life Cycle Assessment ofJatrophafor Energy in Nigeria^: A " Well-to-Wheel "*

Perspective. June. https://doi.Org/10.l 115/ES2015-49654

Maepa, M., Bodunrin, M. O., Bunnan, N. W., Croft, J., Engelbrecht, S., Ladenika, A. O., & Macgregor, O. S. (2017). *ReviewD: life cycle assessments in Nigeria, Ghana , and Ivory Coast,* https://doi.org/10.1007/sl 1367-017-1292-0

Milousi, M., Souliotis, M., Arampatzis, G., & Papaefthimiou, S. (2019). *Evaluating the Environmental Performance of Solar Energy Systems TJrrough a Combined Life Cycle Assessment and Cost Analysis.*

Muralikrishna, I. V., & Manickam, V. (2017). Environmental Management Life Cycle Assessment. *Environmental Management,* 57-75. https://doi.org/10.1016/B978-0-12-811989-1.00005-1

Muteri, V., Cellura, M., Curto, D., Franzitta, V., Longo, S., Mistretta, M., & Parisi, M. L. (2020). *Review on Life Cycle Assessment of Solar Photovoltaic Panels.*

Ogundipe, F. O., & Jimoh, O. D. (2015). *Life Cycle Assessment of Municipal Solid Waste Management in Minna , Niger State , Nigeria.* 9(4), 1305-1314.

Ogunjirin, O C; Jekayinfa, S O; Olaniran, J A; Ogunjirin, O. A. (2020). Environmental life cycle assessment of cowpea production , storage and disposal in Ilorin , Kwara Environmental life cycle assessment of cowpea production , storage and disposal in Ilorin , Kwara State , Nigeria. *IOP Conf. Series: Earth and Environmental Science,* https://doi.org/10.1088/1755-1315/445/1/012040

Ogunlade, C. A., Jekayinfa, S. O., Olaniran, J. A., & Adebayo, A. O. (2020). *Energy-life-cycle assessment and economic analysis of sweet orange production in Nigeria.* 22(2), 123-132.

S.O. Jekayinfa, J. A. O., & Sasanya, and B. F. (2013). *Life cycle assessment of soybeans production and processing system into soy oil using solvent extraction process.* 6(4), 311-321. *Solar Report Nigeria.* (2021). U. (2017). *World Population Prospects: The 2017 Revision, Key Findings and Advance Table.*

Yuguda, T. K., Li, Y., Xiong, W., & Zhang, W. (2020). *Life cycle assessment of options for retrofitting an existing dam to generate hydro-electricity. 2017.*

Zaman, A. U. (2013). *Life Cycle Environmental Assessment of Municipal Solid Waste to Energy Technologies. October 2013.* https://doi.org/10.1007/sl3762-013-0230-3