ENERGY AND THE CITY

ALIYU B. DAHIRU, SIRAJDIN ADESHINA & MOHAMMED K. HALIDU
Department of Computer Engineering, Federal Polytechnic Mubi, Adamawa State, Nigeria

ABSTRACT
By concept and analysis, cities are known to be the center stage for the consumption of energy. Their formations are directly related to the building arrangement and road networks, which are factors that are directly determined by the ministry of urban planning and development. This research work is designed to establish the relative magnitudes of energy consumption in buildings in comparison to transportation network, with a clear knowledge that points out the relationships between buildings and transportation in the context of climate change and social inclination in cities. The main objective of the paper is to examine the energy trends and implications of urbanization by making reference to building density and proffer strategic solutions.
Keywords: cities, buildings, transportation, urban planning, energy consumption, climate change, social inclination, density, city texture.

1 INTRODUCTION

Energy as an entity is one aspect of life that performs the most important role in the sustainability of economic growth, progress, development, poverty eradication, security and comfort of any nation. In an effort to meet the climatic and environmental policy goals in Nigeria, several measures are being analyzed. The processes of analyzing these objectives lead to key challenges relating to the planning of energy related urban infrastructures because planning encompasses the determination of locations for new power generating facilities [1]. Steady power supply is an important issue for all nations today. Similarly, the economic growth and future of any nation specifically depends on the availability of sources of energy that are available, reasonable, and environmentally friendly. Security, climate change, and public health are closely interrelated with energy [2].

The standard of living of a given country can be directly related to the per capita energy consumption and the per capita energy consumption is a measure of the per capita income as well as a measure of the wealth of a nation [3]. Research has also shown that the recent global energy crisis is as a result of the massive population growth and the increase in the living standard of societies as a whole [4]. The desire for people to strongly incline themselves to living in the cities gives rise to both positive and negative effects on energy consumption globally [5]. On one hand it causes the increase of cultural level, the creation of new job opportunities and improvement of economic conditions. On the other hand, concentration in cities increased traffic jam, carbon dioxide, greenhouse gases emissions and waste disposal which threaten health care conditions.

The size of a city drives energy consumption hence the need for territory redevelopment and obtainability of adequate infrastructures. In this development, the ideas of save the earth and people's health gives rise to the emergence of smart cities since smart cities are able to solve urban issues paying critical attention to climatic change. This is the reason why the idea of smart growth has begun to spread in the nineties. It involves a community-based reaction aimed at solving transportation issues, school overcrowding, carbon dioxide and greenhouse gas emission, lack of open space and the cost of skyrocketing public facilities [6]. The sustainability of urban development concepts give rise to the awareness, production and utilization of resources needed for industrial, residential, commercial, transportation, and

recreational processes [7]. Ecological urban development supports environmental awareness in the application of natural resources in the development of smart cities [8].

As a result, demand for energy in buildings and the transportation sector will rise as the growth of urbanization is expected to continue since urban areas are growing due to economic development and industrialization leading to more people attraction to live in the cities than ever before [9]. This rise in energy demand in both buildings and transport give rise to countless contribution of urban areas to greenhouse gas emissions that led to negative consequences such as climate change and air pollution outlined earlier [10]. To implement mitigation strategies, identifying energy consumption patterns in cities and other urban areas is of paramount importance. Buildings and transport are considered the key contributors to the urban energy demand therefore assessing their consumption is of immense importance [11].

The effective energy consumption of both buildings and transport is closely related as a result of urban layout influencing the building users, mobility and respective annual travel distances which affects the carbon footprint in the transportation sector [12]. Transport networks have an impact on the operational energy consumption of both buildings and transport by carrying individuals and goods between places. Studies of the energy usage of both buildings and transport are important to avoid unplanned result of unviable strategies by the ministry of urban planning and development [13]. Climatic change and energy problems in the world have necessitated constituted authorities and institutions at all levels to optimize energy systems in urban densely populated areas thereby improving the standard of living for its citizen [14].

Energy demands predictions for urban buildings are highly important to energy providers intending to boost the energy supplies and introduce renewable energy sources to the electricity mix considering the potential of buildings so as to contribute towards the reductions in carbon footprints globally [15]. Cities therefore consume approximately 70% of global energy and are projected to house approximately 60% of the global population by 2030 [16]. Nigeria's transportation system consists of road, rail, water, and air subsectors. Ninety percent of the total quantity of premium motor spirit consumed and 40% of the automotive gas oil consumed is attributed to road transportation. 24% of the dual-purpose kerosene consumed goes to aviation sector which is the sole fuel. 10% of the fuel oil consumed and 6% of the automotive gas oil consumed is attributed to water transportation [17].

Road transport is the most widely and commonly used means of transportation system in Nigeria today. This specifically depends on the mode of human settlements which account for more than 90% of the subsector's contribution to the gross domestic product. Road transport activities involve the conveyance of passengers in mass or small numbers, conveyance of livestock, farm products, merchandise and rendering of mobile services [18].

Energy consumption in buildings set a center stage in global discursion towards sustainable development and its broader interconnections with the entire environment. Research has shown that energy consumption of the built environment surpasses that of other sectors including transportation in many parts of the world [19]. In the United State, buildings consume as much as 48% and 60% of total energy and electricity respectively [20]. It has therefore become important to access energy consumption in the built environment in a developing world and follow sensible energy procedures in the short term. It is also vital to advocate for a clear policy as well as institutional contexts on the long term. This study examined energy consumption of office buildings and transportation in Abuja which is Nigeria's federal capital territory and its largest urban center. It also considered the fastest growing city in Africa. Abuja has been branded by the presence of significant government

and corporate bodies as well as rampant construction activities in an attempt to elicit the status, performance and the impacts of office buildings on energy in the city.

2 CURRENT ENERGY SITUATION AND DEMAND IN NIGERIA

Africa has been blessed with abundant energy sources such as coal, natural gas, petroleum, solar, hydro, geothermal, and nuclear which can be used to increase its current power production, yet Africa's power sector is predominantly weak. Since the inception of industrial revolution, energy has been the driving force for the development of a modern society. Sub-Saharan Africa's situation is the worst in the world from an electricity point of view and is true because this region has 13% of the world's population but 48% of the share of the global population lives without access to electricity.

More than 640 million people in Sub-Saharan Africa are presently living without access to electricity which represents 70% of the overall population. Moving on the present path will take until 2080 for there to be universal electricity access on the African continent. On the other hand Nigeria is estimated to require 12,800 MW of electricity for the year 2016 but the available capacity is only around 4,500 MW [21]. The importance of access to modern energy is now well understood by governments and significant efforts are being made to address energy access challenges.

The present state of Nigerian electricity reflects a situation of crisis between supply and demand where by industrial growth and socio-economic developmental processes operate below the potential of the economy [22]. It is believed that Nigeria is a custodian of abundant energy resources which is dominated by oil and gas. This availability makes it the mainstay of the country's economy accounting for over 85% of export earnings and government revenues. Nigeria is also the 9th largest exporter of crude oil in the world [23].

Table 1: Nigeria's energy reserve (captured December 2017).

Resource	Reserve	Reserves (Billion tonnes of oil equivalent)	Reserves ($x10^7$) TJ
Crude oil	36.2 Billion barrels	4.896	20.499
Natural gas	166 trillion standard cubic feet	4.465	18.694
Coal and lignite	2.7 billion tonnes	1.882	17.652
Tar sands	31 billion barrels of oil equivalent	4.216	17.652
Subtotal fossil		15.459	64.724
Hydropower, large scale	11,000 MW		0.0341/year
Hydropower, small scale	3,250 MW		0.0101/year
Fuel wood	13,071,464 ha		
Animal waste	61 million tonnes/year		
Crop residue	83 million tonnes/year		
Solar radiation	3.5 to 7.0 KWh/day		
Wind	2 to 4 m/s (annual average) at 10 m in height		

Source: Sunday Olayinka Oyedepo (2012). Energy and sustainable development in Nigeria: the way forward. Energy sustainability and society, a spring open journal.

With the availability or abundance of the afore mentioned energy resources, Nigeria is not in any way supposed to depend on the importation of energy to achieve a sustainable generating capacity adequate enough to target ever increasing economic growth and also have excess power generation to sell to neighboring countries [24]. Despite this abundance of energy resources, less than half of the population enjoy access to electricity and reside in the urban metropolis. Fuel wood precisely remains an important energy resource used mainly for cooking in rural and even parts of the urban areas there by aiding desertification [25]. The dominance of fuel wood over the prevalent sources of energy is eminent. This case scenario indicates the extent of competition in areas totally depending on electricity.

3 ENERGY CONSUMPTION PATTERN IN NIGERIA

African countries and in particular Nigeria are observed to have the lowest degree of energy consumption in the world. Although it is typical of any developing economy to suffer from inadequate supply of energy, Nigeria's case is alarming because of increasing demand on daily basis. Nigeria is rich in conventional energy resources which include oil, natural gas, lignite, and coal. It is also well endowed with renewable energy sources such as wood, solar, hydropower, and wind [26]. The pattern of energy usage in Nigeria's economy is divided into industrial, transport, commercial, agricultural, and household sectors. The household sector accounts for the largest energy usage in the country aiming at 65%. The low level of development in all the other sectors account for this percentage [27]. Table 2 below shows that Nigeria has been ranked the number 68 in terms energy consumption by the CIA world fact book 2017.

4 ENERGY CONSUMPTION IN BUILDING IN ABUJA

Abuja is the new capital city of Nigeria. The idea was conceived in the 1970s but the realization and subsequent relocation from Lagos took effect in 1991 by the then military ruler General Babangida. It is located within Latitude of 7° 25' N and 9° 20' North and Longitude of 5° 45' E and 7° 39' E of Greenwich Meridian placing the city exactly at the center of the country and almost at the same distance from anywhere to all its boundaries as shown in Fig. 1. Being at the center it has Kaduna state to the north, Nasarawa state to the east, Kogi state to the south-west and Niger state to the west. The map of Abuja indicating the first and second phases of its development is shown in Fig. 2.

Table 2: Consumption of electricity by the countries of the world.

Rank	Country	Total (Million KWh/year	Per capita (KWh/year)	Date
1	China	5,523,000	4,074	2014 est
2	USA	3,913,000	12,271	2014 est
3	Russia	1,065,000	7,475	2014 est
7	Canada	528,000	15,157	2014 est
8	Brazil	518,000	2,556	2014 est
68	Nigeria	24,000	135	2014 est
69	Hungary	21,550	2189	2014 est
70	Ecuador	21,000	1,341	2014 est

Source: CIA World fact book (2017/01/17). Available at world by map.org/electricity consumption.html.

Table 3: Nigerian energy.

Electricity access	Population without electricity: 95,5000,00
	Electrification – Total population: 45%
	Electrification – Urban Areas: 55%
	Electrification – Rural areas: 37%
Electricity production	29.83 Billion KWh (2015 est)
Electricity consumption	24.57 billion KWh (2015 est)
	Country comparison to the world: 68
Electricity exports	0KWh (2016 est)
	Country comparison to the world: 178
Electricity imports	0KWh (2016 est)
	Country comparison to the world: 181
Electricity – installed generating capacity	10.48 million KW (2015 est)
	Country comparison to the world: 59
Electricity from fossil fuel	80.3% of total installed capacity (2015 est)
	Country comparison to the world: 88
Electricity from nuclear fuels	0% of total installed capacity (2015 est)
	Country comparison to the world: 154
Electricity from hydroelectric plants	19.5% of total installed capacity (2015 est)
	Country comparison to the world: 90
Electricity from other renewable sources	0.2% of total installed capacity (2015 est)
	Country comparison to the world: 163
Refined petroleum products production	70,140 bbl/day (2015 est)
	Country comparison to the world: 72
Refined petroleum products consumption	316,000 bbl/day (2015 est)
	Country comparison to the world: 43
Natural gas production	45.15 billion cu m (2015 est)
	Country comparison to the world: 18
Natural gas consumption	26.86 billion cu m (2015)
	Country consumption to the world: 38
Carbon dioxide from consumption of energy	97 million Mt (2013 est)
	Country comparison to the world: 40

Source: CIA World fact book (2017/01/17). Available at world by map.org/electricity consumption.html.

Table 4: Nigerian transportation.

National air transport system	Number of registered air carriers: 16
	Inventory of registered aircraft operated by air carriers
	Annual passenger traffic on registered air carriers: 3,223,459
	Annual freight traffic on registered air carrier: 22,400,657 mt-kt (2015)
	Airports: 54 (2013)
	Country comparison to the world: 88
	Number of registered air carriers: 16
Railways	Total: 3798 km
	Standard gauge: 293 km 1.435-m gauge (2014)
	Country Comparison to the world: 51
Road ways	Total: 193,200 km
	Paved: 28,980 km
	Unpaved: 164,220 km (2004)
	Country comparison to the world: 29
Waterways	8,600 km (Niger and Benue Rivers and smaller rivers and creeks) (2011)
	Country comparison to the world: 15
Merchant marine	Total: 583
	General cargo: 14
	Oil tanker: 83
	Other; 486 (2017)
Ports and terminals	Major seaport(s): Bonny inshore terminal, Calabar, Lagos
	LNG terminals (export): Bonny Island

Source: CIA World fact book (2017/01/17). Available at world By map.org/electricity consumption.html.

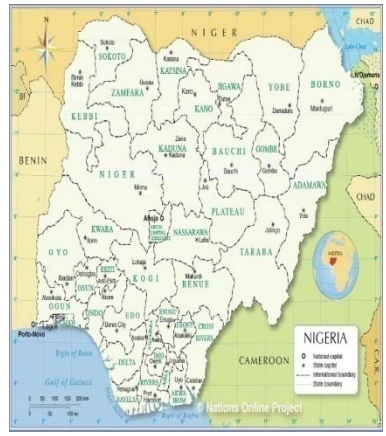

Figure 1: Geographical map of Nigeria.

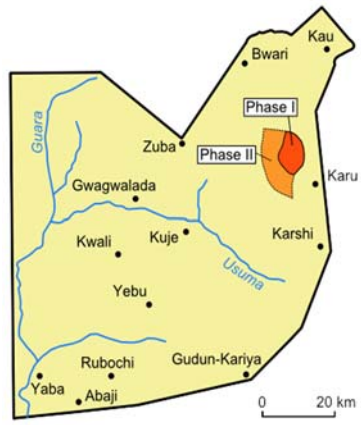

Figure 2: Map of Abuja.

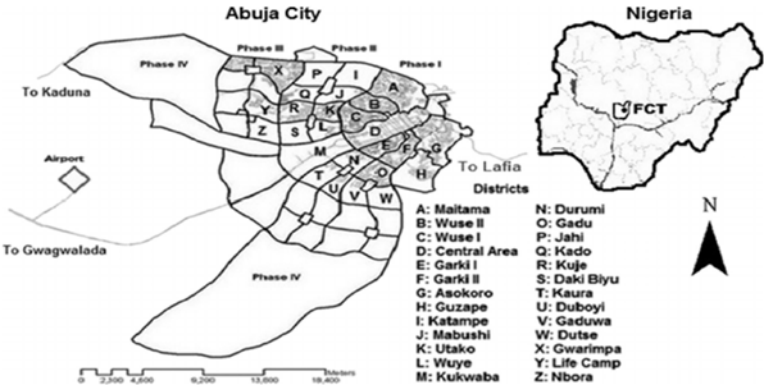

Figure 3: Map showing planned development of Abuja city.

The idea for the creation of the new capital city was prompted by two reasons. The first was the congestion and overcrowding environment in Lagos which was found unbefitting to the country's capital. The second idea was the need to site a capital city in a location that will be neutral to all parties amidst uncertainties propagated by lack of unity and security of the nation from frequent coup plots [28]. The Abuja project design was led by a group of town planners, engineers, foreign architects and also incorporates local architects. At the inception of the project, Abuja was tagged as the biggest project of the time [29]. The development of the main city was divided into four phases as shown in Fig. 3.

The city's land mass is not more than 1% of the total area covered by the country's total land mass with an area of 8,000km^2 and it is increasingly becoming an important urban settlement on the Nigerian landscape [30]. At the completion of Phase 1, the population of Abuja is estimated to be 250,000 from the inception and not more than 3.2 million at the completion of the remaining phases [31]. Contrary to the earlier estimate the population has risen from 400,000 to 1.4 million at the realization of the first phase from 1991 to 2006 showing more than 300% increase [32]. The figures given above are assessment from federal

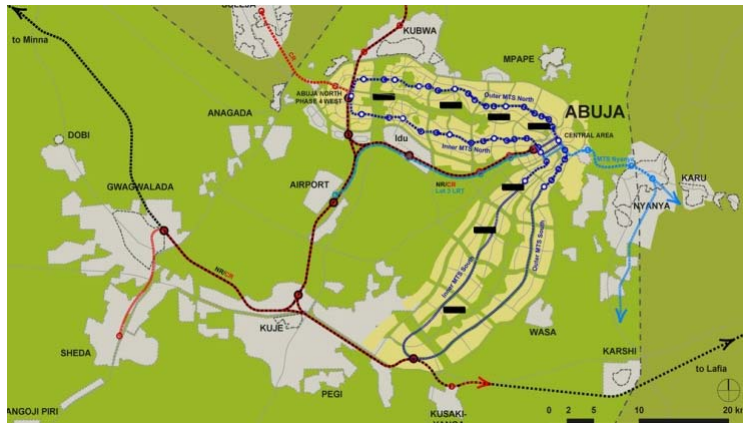

Figure 4: Public transport concept for Abuja.

population commission of Nigeria. The actual figure relates that the city's urban growth rate is said to be between 20–30% annually [33]. The sudden growth rates in Abuja municipal shows a significant effect in the developments on the infrastructure. Regarding energy supply, it was predicted that there was a supply shortage if the infrastructure base was not improved. This give rise to load shading of energy supply to neighboring location so as to give power to the capital [32]. The above sequence highlighted the fact that without significant improvement in the supply of energy dwellers of the city will experience power outages on the completion of the remaining phases. Diesel power generators which generate ample amount of carbon foot print are the only means of alternative source of power supply at the moment [34]. Daily consumption of fuel by generators is estimated to be 12–13 million liters on generators only for the purpose of supplementing power outages that affects all the sectors of the city [35].

5 CITY TEXTURE

Even though insights were gained from assessing urban density in terms of buildings and transport considerations, it is important to divert to the study of the practical or formal intricacy of a city. The study of urban design is a continuous concern at the Martin Centre for Architectural and Urban Studies for over 3 decades [36]. It has already been pointed out that the energy consumption of buildings and transportation is linked to the quality of the urban environment [37].

CONCLUSION

This study assesses the state of buildings and transport in Abuja whereas recognizing the availability of abundant energy resources in country. The study also looked at the energy demand particularly in the urban densely populated environment where electricity is the main source of power supply. Inhabitants are forced to use generators frequently to cover up the wide gap created by power outages. Analyses have shown that commercial and residential buildings account for 37% and 61% consumption of the energy supply respectively. This increase is less than the energy increase in changing from a naturally ventilated office to an air-conditioned office. However, this change is possible if the pollution and noise to the urban environment has been minimized to an appreciable and acceptable low level.

This gives rise to a proportion where the relationship between transport and building energy becomes apparent as cars are the major cause of urban environmental pollution which results in large carbon footprint. It is evident that the overall urban transportation system consumes less energy than the energy consumption of urban infrastructure. It is invariably necessary to note that the effects of reducing the use of private cars in favor of clean and efficient public transport can be significant for building energy use. This confirmed that commercial buildings have a significant impact on the energy supply of a city.

REFERENCES

[1] Kaden, R. & Kolbe, T.H., City-wide total energy demand estimation of buildings using semantic 3d city models and statistical data. *ISPRS Annals of the Photogrammetric, Remote Sensing and Spatial Information Sciences*, vol. II-2/W1, ISPRS 8th 3DGeoInfo Conference & WG II/2 Workshop, Turkey, 2013.

[2] Ramchandra, P. & Boucar, D., *Green Energy and Technology*, Springer: London and New York, 2011.

[3] Rai, G.D., *Non—Conventional Energy Sources*, Khanna Publishers: Deli, 2004.

[4] Sunday, O., *Energy and Sustainable Development in Nigeria: The Way Forward,* Springer open journal, 2012.

[5] Caragliu, A., Del Bo, C. & Nijkamp, P., Smart Cities in Europe, *Journal of Urban Technology,* **18**(2), pp. 65–82, 2011.

[6] Pardo, T. & Taewoo, N., Conceptualizing smart city with dimensions of technology, people, and institutions. *Proceedings of the Twelveth Annual International Conference on Digital Government Research,* New York, pp. 282–291, 2011.

[7] Yigitcanlar, T., Smart cities: An effective urban development and management model? *Australian Planner*, **52**(1), pp. 27–34, 2015. DOI: 10.1080/07293682.2015.1019752.

[8] Pietrosemoli, L. & Monroy, C.R., The impact of sustainable construction and knowledge management on sustainability goals. A review of the Venezuelan renewable energy sector. *Renewable and Sustainable Energy Reviews*, **27**, pp. 683–691. DOI: 10.1016/j.rser.2013.07.056.

[9] Goonetilleke, A., Yigitcanlar, T., Ayoko, G. & Egodawatta, P., *Sustainable urban water environment: Climate, pollution and adaptation,* Cheltenham: Edward Elgar, 2014.

[10] Reinhart, C.F. & Davila, C.C., Urban building energy modeling—A review of a nascent field. *Building and Environment,* **97**, pp. 196–202, 2016. DOI: 10.1016/j.buildenv.2015.12.001.

[11] Hickman, R. & Banister, D., *Transport, Climate Change and the City,* vol. 7, Routledge: London, 2014.

[12] Stephan, A., Crawford, R.H. & De Myttenaere, K., Towards a comprehensive life cycle energy analysis framework for residential buildings. *Energy and Buildings,* **55**, pp. 592–600, 2012. DOI: 10.1016/j.enbuild.2012.09.008.

[13] Barthelemy, M., Bordin, P., Berestycki, H. & Gribaudi, M., Self-organization versus top-down planning in the evolution of a city Nature. *Scientific Reports*, **3**(1), p. 2153, 2013. DOI: 10.1038/srep02153.

[14] Vanolo, A., Smart mentality: The smart city as disciplinary strategy. *Urban Studies,* **51**(5), pp. 883–898, 2013. DOI: 10.1177/0042098013494427.

[15] Pérez-Lombard, L., Ortiz, J. & Pout, C., A review on building energy consumption information. *Energy and Buildings,* **40**(3), pp. 394–398, 2008. DOI: 10.1016/j.enbuild.2007.03.007.

[16] Seto, K.C. & Dhakal, S., Human settlements, infrastructure, and spatial planning in climate change 2014: Mitigation of climate change. *Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. eds O. Edenhofer, R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, Cambridge University Press, Cambridge, UK, and New York, 2014.
[17] Oniwon, A., *Oil and Gas in Nigeria's National Development: An Assessment.* A presentation at the National Defence College: Abuja, 2011.
[18] Obih, H., *Fuel Distribution and Logistics.* Sub-regional conference on the phase-out of leaded gasoline in Nigeria and neighboring countries: Abuja, Nigeria, 2001.
[19] Brown, G., Architecture Industry; A hidden Culprit in Global Warming. Online. http://architecturalevangelist.com/green-architecture/the-architecture-industry-a-hidden-culprit-to-global-warming.html. 2010.
[20] Architecture2030, Total Energy Consumption in US (By Sector). Online. http://architecture2030.org/the_problem/buildings_problem_why. Accessed on: 18 Dec. 2010.
[21] Castellano, A., Kendall, A., Nikomarov, M. & TarrynSwemmer, T., *Brighter Africa: The growth potential of the sub-Saharan electricity sector.* McKensey & Company, 2015. Online. www.mckinsey.com/industries/electric-powerand-natural-gas/our insights/powering-africa, 2015.
[22] Adeyemi, A.O. & Ayomide, A., Electricity consumption and economic growth in Nigeria. *Journal of Business Management and Applied Economics,* **2**(4), pp. 1–14, 2013.
[23] OPEC, OPEC Bulletin, in Organization of the Petroleum Exporting Countries, 2011.
[24] Koledoye, O., Jumah, A. & Philips, A., The current and future challenges of electricity market in Nigeria in the face of deregulation process. Online. http://theses.covenantuniversity.edu.ng/bitstream/handle/123456789/166/The%20Current%20and%20Future%20Challenges%20of%20Electricity%20Market%20in%20Nigeria%20in%20the%20Face%20of%20Deregulatio n%20Process.pdf?sequence=1. Accessed on: 28 Feb. 2015.
[25] Bugaje, I., Renewable energy for sustainable development in Africa: A review. *Renewable and Sustainable Energy Reviews,* **10**(6), pp. 603–612, 2006. DOI: 10.1016/j.rser.2004.11.002.
[26] Okafor, E. & Joe, U., Challenges to development of renewable energy for electric power sector in Nigeria. *International Journal of Academic Research*, **2**(2), pp. 211–216, 2010.
[27] Energy Commission of Nigeria (ECN) National Energy Policy, Federal Republic of Nigeria: Abuja, 2003.
[28] Salau, A.T., A new capital for Nigeria: Planning, problems and prospects. *Africa Today*, **24**(4): pp. 11–22, 1977.
[29] Take, O., *Abuja, the New Capital of Nigeria, and the Urban Design of Its Central Area*, in *Continuity and Change: Design Strategies for Large-Scale Urban Development*, ed. M.B. Sevcenko, The Aga Khan Program for Islamic Architecture: Cambridge, Massachusetts, 1984.
[30] Mabogunje, A.L., *The Promise, Performance and Prospect in the Review of Abuja Master Plan*, Fountain Publications Ibadan: Abuja, 1999.
[31] Olomola, A.O., *Position Paper of the Nigerian Institute of Town Planners: On the Implementation of the Abuja Master Plan. In the Review of the Abuja Master Plan*, Fountain Publications Ibadan: Abuja, 1999.

[32] Galadima, E.I., *Power Supply and Improvement in the FCT. In the Review of Abuja Master Plan*, Fountain Publications Ltd, Ibadan: Abuja, 1999.
[33] World Bank, Nigeria Country Profile, World Development Indicators and Global Development Finance, World Bank 2011.
[34] Nwaobi, G.C. & Abuja, G., Solving the poverty crisis in Nigeria: An applied general equilibrium approach. *Computational Economics*, 2003.
[35] ECN (Energy Commission of Nigeria), Manufacturers spend N1.8bn weekly on diesel -MAN in Energy Commission of Nigeria. Online. www.energy.gov.ng/index.php?option=com_content&task=view&id=56&Itemid=58. Accessed on: 9 Sept. 2010.
[36] Martin, L. & March, L., *Urban Space and Structures*, Cambridge University Press: Cambridge, 1972.
[37] Steemers, K. & Ratti, C., Informing bioclimatic urban design. *Architecture and Engineering: The Teaching of Architecture for Multidisciplinary Practice,* ed. M. Voyatzaki, European Association for Architectural Education, 1999.