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Public School Buildings in Lagos, Nigeria: Renovations, Renewable Energy Retrofits and Implications for Technology- based Education

Isidore C. Ezema*, Oladunni Izobo-Martins, Abraham O. Owoseni
Department of Architecture, Covenant University, Ota, Nigeria
E-mail of corresponding author: isidore.ezema@covenantuniversity.edu.ng

Abstract
Renovation of existing building stock across several building types has continued to generate interest in built environment research. It is a way of restoring aging building stock to good condition thereby reducing the need for new buildings and ultimately contributing to sustainability through resource efficiency. Residential and non-residential buildings have been found to be high energy consumers and by implication, carbon emitters. School buildings which form part of the non-residential building stock account for a significant share of energy consumption and carbon emissions of the building sector. As a result of the relatively large stock of buildings erected prior to the enactment of energy efficiency regulations in many jurisdictions, renovation is often seen as an opportunity to improve the energy performance and efficiency of old buildings. Given the conditions of public secondary school buildings in Lagos State, Nigeria and bearing in mind the poor access to energy prevalent in the study area, this paper examines ongoing school buildings renovation programmes with a view to ascertaining the extent to which the renovation efforts contribute to sustainability practices especially through the promotion of renewable energy retrofits. The study employed qualitative research methods to identify school buildings renovated between 2010 and 2020 within the six education zones of the study area. Archival studies, interviews and observation methods provided the data for the study. Content analysis was deployed in the analysis of data collected. The result of the study showed that huge opportunities for the installation of renewable photovoltaic retrofits abound in the buildings studied as exemplified in the huge roof footprints and relative heights of the buildings. The study also found that emphasis was more on making the school buildings durable, functional and secure. Even though opportunities for renewable energy retrofits exist in the renovated buildings, very few school buildings considered had such installations. Hence, most school buildings still relied on the national grid for electricity supply. Given the epileptic supply from the grid, most of the schools resorted to fossil fuel fired generators for electricity supply with dire implications for sustainability. The findings point to the need to make school building renovations more holistic by incorporating the energy efficiency component of building renovation.
Keywords: energy retrofits, Lagos, renewable energy, renovation, school buildings
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1. Introduction

Lagos State, according to official national population figures, is the second most populous state in Nigeria (NPC, 2007) with a 2016 projected population of about 12.6 million (NBS, 2017). The state also doubles as the commercial capital of Nigeria. It is not surprising that there is net influx of other Nigerians especially those of productive age to Lagos State given the attraction that the commercial life presents. As a result, overall population and that of school age children are high. This is evident in the school enrolment figures for secondary schools which indicate that Lagos State has the highest school enrolment figures in Nigeria. For example, as at 2016, Lagos State accounted for about 8% of secondary school enrolment in the whole country (Federal Ministry of Education, 2017). Even though provision of educational facilities for the secondary school age population by private entities is substantial in the study area (Harma, 2011), public schools still accounted for 67% of enrolment in 2016 (Federal Ministry of Education, 2017). This is an indication that provision of public school buildings and associated facilities is central to the attainment of the objectives of the Lagos State Government in the area of education in general and secondary education in particular.

As at 2017, there were 349 junior secondary schools and 322 senior secondary schools in Lagos State (Adeola, 2018). Most of the schools were conceived and substantially built between 1979 and 1983 during the administration of Lateef Jakande as governor of Lagos State. The social orientation of the administration made it to focus on public infrastructural development such as schools and mass housing. Even though the quality of the buildings delivered during that period was later adjudged not to be the best (Ilesanmi, 2009; 2012), they nevertheless constitute the bulk of public school buildings and mass housing to date. Most of the units under the housing programmes were allocated to individuals and organisations who took up their regular maintenance even if only at rudimentary level. The same cannot be said of the school buildings. As a result, it was not long before the school building assumed varying degrees of dilapidations. In addition, the school buildings antedated the building energy awareness that is gradually unfolding in Nigeria. Hence they were not built with energy efficiency in mind.

In response, school renovation programme was adopted with the advent of democratic governance in Nigeria's Third Republic which commenced in 1999. However, the renovation effort acquired a massive boost from about 2009 when it became a priority programme of government and has continued even with new school buildings added. Incidentally, most of the school buildings were constructed without adequate provision for modern school facilities. School buildings have changed both in character and usage over time. From mere centres of fact memorization, school buildings have become interactive environments where critical thinking and problem solving skills are inculcated. One aspect of the modern school building is the increasing use of information and communication technology (ICT) resources.The deployment of these resources and technologies is dependent on the availability of energy. The most useful form of energy in this regard is electricity which can be generated from both renewable and non-renewable sources.

The electrical energy supply situation in Nigeria is largely inadequate and inefficient. Electricity access in Nigeria grew from 40% in 2015 to 60% in 2018 (IEA, 2019). Even at that, great disparity exists between access in urban areas (86%) and access in rural areas (34%) according to IEA (2019). Installed generation capacity is over 12000MW but total generation hovers between 3800MW (Advisory Power Team, 2015) and a little above 4000MW (USAID, 2019) which gives a per capita energy consumption of about 126Kwh (Advisory Power Team, 2015). This is one of the lowest in the world given that in the corresponding period Ghana had a per capita consumption of 361Kwh while South Africa had a per capita consumption of 3926Kwh (Advisory Power Team, 2015). Given the difficulty in providing needed electricity from the national grid using conventional means in the short term, experts are recommending off grid renewable energy sources especially for Nigerian schools. It has become a good practice in the renovation of old school buildings to include energy efficiency retrofits.

Energy retrofits have over time provided opportunity for improving energy efficiency of older buildings. Energy efficiency retrofits take different forms. However, emphasis of this paper is on renewable energy retrofits. This is because off-grid renewable energy in the form of solar photovoltaic installations is well suited for schools where grid electricity supply is either inadequate or erratic. Given the poor energy access in the study area, it is important to examine the school renovation programmes adopted for Lagos State public secondary school buildings with a view to ascertaining the components of the renovation and determining the extent to which the renovations incorporated improved energy access and efficiency. The study also examined the opportunities that the renovations provide for renewable energy retrofits. The specific objectives of the study are:

i. to determine the various components of the renovation programmes
ii. to ascertain the energy supply situations in the identified schools
iii. to examine to which extent renewable energy has been incorporated in the renovated school buildings
iv. to identify opportunities for installing renewable energy retrofits in the renovated buildings

2. Literature Review

2.1 Preamble

The Nigerian National Policy on Education gives priority to science and technological education (FGN, 2013). This policy is further reinforced by the National Policy on Science and Technology (Garuba, Agwada & Abumere, 2012). In addition, the National Policy on Science, Technology and Innovation (STI) has a component that deals with promotion of technology-based education through curriculum and other interventions such as provision of physical facilities (Federal Republic of Nigeria, 2011). However, poor implementation, inadequate funding and inadequate teaching aids have combined to make the goal of technological advancement through education largely unachieved at the moment (Ekanem & Samuel, 2010).

In order to realize the educational objectives of the Nigerian government, the operational education system is the 6-3-3-4 system which means six years of primary education, three years of junior secondary education, three years of senior secondary education and a minimum of four years of university or other tertiary education (Uwaifo &Uddin, 2009). However, with the advent of the Universal Basic Education (UBE) programme, the first two tiers were merged which gave rise to the 9-3-4 system where basic education takes nine years while secondary and tertiary education take three and four years respectively. In reality, however, the two-tier secondary education structure is most prevalent in Nigeria. Hence, the schools under consideration in this study belong to the secondary category. As a result, the study will cover both junior and senior secondary schools. In most cases, both schools are domiciled in one school premises. Also, very often, a number of schools may be clustered in one large school premises especially within the urban areas. This is attributable to the limitations in land acquisition for new schools in the study area given the small land mass available relative to the high population (National Population Commission, 2006).

2.2 School as Learning Environment

School buildings and surrounding environments are places for learning. As a result, they should inspire creativity and evoke curiosity in the learners. At the rudimentary level, school buildings must be safe, durable and responsive to the environment. The physical, human and financial resources invested in a school influence the education provided to the learners as well as to teachers and their teaching (OECD, 2009). The learning environment is therefore very critical to learning.

Using the stimulation, individualism and naturalness framework, Barrett, Davies, Zhang & Barrett (2014) showed that the measurable aspects of the physical environment interact with other factors to influence both learning and learning outcomes such as academic progress of pupils. Naturalness refers to the environmental parameters that promote physical comfort such as light, sound, temperature, air quality and links to the environment. Individualism on the hand refers to how the learning environment addresses the special needs of groups of leaners using such parameters as ownership, flexibility and connection. Stimulation refers to how exciting the learning environment is and it can be assessed using complexity and colour. While exploring further the impact of the physical environment on learning, Okafor, Maina, Stephen and Ohambele (2016) asserted that adequate and conducive facilities such as classrooms and related facilities tend to guarantee improved academic performance. Similarly, Akomolafe and Adesua (2016) posited that the availability and conditions of physical facilities in schools affect students' motivation and academic performance.

The school environment also extends to the immediate external context of the buildings such as the surrounding environment. In this respect, security is important. School fencing is an important security measure. Good and proper school fencing should achieve a number of objectives: (i) delineating the school premises, (ii) enables surveillance of the premises, (iii) limits access to areas that are not highly visible, and (iv) controls both entry and exit points (Hanover Research, 2013). The rise in the use of fence for school delineation is associated with the theory of defensible space as it helped in the prevention of crimes in urban areas (Huang, 2012).

From the forgoing, good physical facilities are necessary conditions for both the motivation to perform and actual performance of students. In order for the school physical facilities to perform the stated role, they must be in good conditions. However, the facilities in public schools in the study area are not usually topnotch. For example, Izobo-Martins, Dare-Abel and Ayo-Vaughan (2014) in a study of public secondary schools found that most of the academic buildings were in a state of disrepair with some basic facilities out-rightly not available. This was attributed to poor management of the school infrastructure facilities occasioned by absence or poor maintenance culture (Izobo-Martins, Olotuah, Adeyemi, Ayo-Vaughan and Odetunmbi, 2018). The building components found to be in different states of disrepair include walls, doors, windows and water/drainage pipes. Hence, regular maintenance is advised but renovation is needed to restore the buildings before routine maintenance can be deployed to keep them in good condition.

2.3 Building Renovation

Building renovation can be distinguished from building maintenance even though the terms are often used in the same sense. Maintenance refers to routine activities to keep a building in good condition while retaining the original value of the building while renovation connotes returning a building to a good state of repair after it has fallen into disrepair thus improving the value of the building. Building renovation is often adopted to prolong the life span of a building. Decision to renovate is often taken when it would be more expensive to build a new facility. In addition to prolonged life and adding value, building renovation also improves the performance of a building (Kakkinen et al., 2012). Very importantly, from the building sustainability perspective, renovation improves the energy performance of buildings at both the embodied and the operational phases. At the embodied phase, renovation promotes resource efficiency as materials that would have been expended on new buildings are conserved (Artola et al, 2016). At the operational phase, renovation also often leads to improved energy efficiency. This is especially so in locations where building energy regulations are in full operation. For example, the European Union recognizes the value of building renovation as a critical element in attaining long-term energy and emissions goals of the overall building sector (Atanasiu & Kouloumpi, 2013).

Only a small proportion of building stock is made up of new buildings. In the EU, annual new building constructions account for only 1% of building stock (Artola, et al, 2016). Also, 40% of EU building stock were built before 1960 while while the figure goes up to 90% if the reference year is 1990 (Artola, et al, 2016). The bulk of buildings especially in developed societies are old buildings many of which were built several years before sustainability became the guiding principle. It is also more sustainable to renovate than to build new from the life cycle perspective. It encourages embodied impact mitigation of the buildings. It is not therefore unexpected if the target of building renovation is directed at improving building performance especially building energy performance. In Europe, for example, building renovation is directed at achieving improved energy efficiency (BPIE, 2015).

In Nigeria, given the level of development, the stock of new buildings is on the ascendance. The real estate sector is 6th largest sector in the economy, growing at a rate of 8.7% and propelled largely by rapid urbanization and a growing middle class (PWC, 2015) In addition, there is the need to keep the stock of old buildings especially public buildings in a good state of repair to reduce demand pressure on such facilities. Quality concerns have been raised with respect to some public infrastructure such as schools and housing. This is underscored by the incessant events of building collapse especially in the study area (Ezema & Olatunji, 2018). In addition, maintenance practice for such public infrastructure has been found to be inadequate and sometimes completely unavailable (Izobo-Martins, et. al., 2018). Building components that often benefit from renovation include the building envelope such as walls, doors, windows, roof/ceiling and building services such as water/drainage, electricity supply, solid waste disposal, among others (Izobo-Martin, et al. 2014).

2.4 School Energy Requirement and Sustainability

A building is incomplete without associated services such energy supply. This is especially so given that most modern building gadgets function only when there is energy supply. The most usable form of energy in buildings is electricity. Hence, access to electricity is a necessity for any modern building including school buildings. In Nigeria, however, access to electricity is not only limited but the service is often unreliable even where access exists. According to a World Bank report, Nigeria with an electricity access deficit of 75 million people is only second to India (World Bank, 2017). With an estimated population of 180 million people, it implies that over 40% are without electricity access. The trend is replicated in many countries especially in sub-Saharan Africa where electricity access during the period 2000 – 2014 grew by only 11% compared with South Asia where access grew by about 23% (World Bank, 2017).

The National Policy on Education in Nigeria promotes technological education. Energy especially in the most usable form – electricity - is required for technology-based education. However, it has been observed that about 65% of public schools in Nigeria do not have access to grid electricity, which greatly impairs the capacity for technology-based education (Why Electricity Matters, 2017). A number of educational benefits can be derived from electricity access. According to UNDESA (2014), there are five major benefits which include (i) longer hours of study by students; (ii) facilitation of ICT education and training; (iii) higher level of students' retention in schools;

(iv) improved school performance and (v) extension of the benefits to the surrounding community. An agency UNESCO estimates in a report that in sub-Sahara Africa, majority of the schools are without electricity supply (UNESCO Institute for Statistics, 2014). The same report found that in more than 50% of the countries surveyed, 80% of primary schools have no electricity (UNESCO Institute for Statistics, 2014). In Nigeria, electricity access for schools is low. It has been estimated that 65% of primary and secondary schools in Nigeria have no access to electricity (Why Electricity Matters, 2017).

Even more challenging than improving electricity access is the fact that it should be done with sustainability in mind in line with the Paris Accord on reduction of GHG emissions by the building sector. Current electricity mix in Nigeria is lopsided in favour of non-renewable sources. Hence, in order to meet the energy access targets while at the same time, promoting low carbon sources, there must be recourse to clean energy sources such as renewable energy (Corfee-Morlot, et al, 2019).

The Nigeria Renewable Energy Master Plan (Federal Republic of Nigeria, 2005), Renewable Energy and Energy Efficiency Policy (Federal Republic of Nigeria, 2015) and the Renewable Energy Action Plan (Federal Republic of Nigeria, 2016) target the installation of 500MW of solar electricity by the year 2025. Main objective is to increase renewable electricity mix from 13% in 2015 to 23% in 2025 and 36% in 2030. In this respect, renewable sources such as solar energy can be harnessed to advantage. The targets cannot be achieved without some regulatory and other changes such as building energy regulation. Building energy regulation is a new phenomenon in Nigeria. In fact, energy benchmarks for buildings are yet to come into full effect. Hence majority of existing building which include school buildings predate building energy regulation. Moreover, building energy regulation for the moment is restricted to new buildings (Federal Ministry of Power Works & Housing, 2016).

Given that the bulk of school buildings predate the building energy regulation, it implies that energy efficiency is foreclosed for old and existing buildings. However, the opportunity of incorporating renewable energy retrofits into existing school buildings may be the way to go. Incidentally, Lagos State government in Nigeria is implementing an ongoing school renovation programme. The program through its various components which includes building envelope modifications offer good opportunity for renewable energy retrofits. Incidentally building energy regulation was recently introduced in Nigeria (Federal Ministry of Power Works & Housing, 2016; Geissler, Osterreicher & Macharm, 2018).

2.5 Energy Retrofit Principles

In the life cycle of a building, renovation is often required to increase the service life of the building. Often, renovation affords property owners the opportunity to introduce into the building certain features or elements that will make for better use. Usually renovations do not tamper with the main structural support of the building which then limits it to envelope materials, partition components and very importantly, building services. Hence in many developing countries, building renovation efforts focus more on the envelope especially the aesthetic aspects of the building (El-Darwish & Gomma, 2017). However, the experience of more technologically advanced societies, in the area of building services indicate that the energy supply system is particularly important.

Energy retrofit activities can be conducted at two levels: (i) reduction of overall energy consumption of the building and (ii) introduction of clean energy options in the form of renewables. The building envelope is regarded as the most important building component in the promotion of energy efficiency. Building envelope improvements for energy efficiency through retrofitting can be achieved through wall and roof insulation (Reiss, 2014; Kamel & Memari, 2016). Insulation of existing external walls can be achieved through the use of a second building shell (Basarir, Diri & Diri, 2012). The use of some passive design elements can also come in handy in the retrofit effort. Use of passive cooling, green roof and solar shading devices have been known to be useful (El-Darwish & Gomma, 2017; Basarir et al., 2012). In this respect, adjustable shading devices are particularly effective. Effective window design is also well documented as a retrofit strategy. Windows admit light but are also good avenues for heat loss and heat gain. Double glazing, triple glazing or some coatings on glass improve their U-values and thereby contribute to energy use efficiency (Reiss, 2014; El-Darwish & Gomma, 2017). Retrofit strategies also take the form of smart technologies such as automated adjustable envelope components, automated building services management (Reiss, 2014; Li, et al., 2017). Hence, the first category of retrofit involves improved envelope design strategies such as: thermal insulation, double or triple glazing, shading devices (manual /automatic) as well as use of low impact appliances such as low energy lighting fittings, low impact ventilation equipment and use of smart technologies. Retrofit strategies also involve the incorporation of materials re-use and recycling into the renovation process (Abdullah, 2016).

The second category involves use of clean energy sources such as renewables in the form of solar photovoltaic panels, wind and biomass as well as use of low energy equipment such as LED lighting fittings and low impact ventilation equipment. Renewable energy sources include solar energy, wind energy and energy from biomass. In urban areas, the solar powered electricity system is most prevalent. The solar powered photovoltaic panels are particularly suited for retrofit procedures whether as roof mounted members or as building integrated systems (Hayter & Kandt, 2011).

2.6 School Renovation in Lagos State, Nigeria

Renovation of public schools in Lagos has been an ongoing activity and has attracted varying interests from the Lagos State Government over the years. The school renovations became more defined from about 2009 (Lagos State Government, 2010) when up to 42% of Lagos State public schools were in need of major renovation. This has dropped to about 18% in 2019 (Lagos State Government, 2019), indicating some progress in the renovation efforts. The expenditure profile on education by Lagos State Government has been impressive. In 2021, the total budget for education was 12.63% of the entire budget (Lagos State Government, 2021). Within the same budget, 24 new school buildings were to be built while 134 existing school buildings were earmarked for renovation. With effect from 2019, the construction and renovation of public school buildings in Lagos is handled by the Special Committee for Rehabilitation of Public Schools (SCRPS), under the State Ministry of Education. The agency handles both renovation of existing buildings and the construction of new school buildings in existing school premises. In order to ensure that the newly constructed and renovated school buildings are kept in good state of repair, the renovated buildings are handed over to the Lagos State Infrastructure Asset Management Agency (LASIAMA) to keep in a state of repair. LASIAMA appoints Facilities Managers to take care of the entire asset stock of the schools. The energy supply aspect of the school infrastructure improvement scheme is facilitated by the Lagos Solar Power project under the Lagos State Electricity Board (LSEB).

3.0 Research Methods

A qualitative approach was adopted for the study in order to understand in-depth the dimensions of the renovation and its implications for energy efficiency. The data for the study was obtained mainly from secondary sources such as vendor specifications and documents, school records and publications from the relevant government ministries and ministerial departments. Additional information was obtained through the use of observation schedules and interview guides. Lagos State has a decentralized structure for managing secondary schools based on the school management reforms introduced in 2005 (Lagos State Government, 2005). Hence there are six education districts (District I – District VI), details of which are provided in Table 1. Two school buildings from the newly renovated buildings were selected from each of the six education districts to determine the components of the renovation. The selected buildings were renovated or reconstructed between 2010 and 2020. Secondary data were obtained from the relevant agencies involved in the management of the schools and the provision of required facilities for the schools. The agencies include SCRPS, LASIAMA and LSEB. Observation of the buildings renovated also provided valuable data in the study with the aid of an observation schedule. Afterwards, the end users of the renovated buildings represented by the heads of the schools were interviewed for an in-depth understanding of the renovation efforts using interview guide. The components of the buildings and that of the building environment were considered. Furniture items were excluded. Some very basic building measurements were undertaken to ascertain the building footprint and other associated building parameters.

Table 1: Education Districts and Local Government Coverage

SN	Districts	Local Governments	Headquarters
1	District I	Agege, Alimosho, Ifako/Ijaiye	Dairy Farms Primary Schools Complex Agege
2	District II	Ikorodu, Kosofe, Shomolu	Maryland Schools Complex, Maryland
3	District III	Epe, Eti-Osa, Ibeju-Lekki, Lagos Island	St Gregorys Primary School. 123 Awolowo Road Ikoyi
4	District IV	Apapa, Surulere, Lagos Mainland	Domestic Science Centre. 8 McEwen Road, Sabo-Yaba
5	District V	Ajeromi-Ifelodun, Amuwo-Odofin, Badagry, Ojo	Agboju Schools Complex, Agboju
6	District VI	Ikeja, Mushin, Oshodi-Isolo	Schools Complex, Ewenla Street Charity Oshodi

Source: Adapted from Lagos State Government (2005).

4.0 Findings and Discussions

4.1 Descriptions of the Buildings

The school buildings investigated were mostly blocks of between two and four floors. However, most of the school blocks are three floors high. The typology is that of single banked corridors with classrooms and staircases accessed directly from the corridors. This typology facilitates effective lighting and ventilation of the classrooms. They range from one block school building to multiple blocks within one school site. In multiple block schools, the blocks are arranged to create a quadrangle which functions as the recreation area or the school sports field depending on the space available. More than one school can exist in one school premises as students' population would be overwhelming for one school management. In general, junior high schools are administratively separated from senior high schools but both can exist in one school premises. Some very large school premises can accommodate up to six schools. The average footprint of a school block is within the range of 500m2 to 600m2. The existing buildings are reinforced concrete framed structures with sand-cement blocks in-fill. The walls are rendered with sand cement mortar and painted with emulsion paint. The school compounds are fenced and clearly delineated.

4.2 Components of the building renovations

The renovation efforts of the government with respect to school facilities have focused on all aspects such as the buildings, the school environment, school furniture and teaching aids. However, the study focused mainly on the school buildings and surrounding environment. In this respect, the building envelope best describe the extent of renovation undertaken. The building envelope components in this regard are the roof, doors, windows and walls as presented in Table 2.

4.2.1 The Roof Component

The roof structure of the earlier school buildings was made of timber while the roof covering was asbestos-cement roofing sheets. However, with time, the timber suffered either from pest attack or decay while the roofing sheets got broken. In the renovation, long-span aluminium roofing sheets were used to replace cement-fiber roofing sheets. The roof structure is hardwood timber treated with anti-termite chemicals. Metal based roofing sheets last longer than the cement-fibre sheets. However, metal based roofing sheets admit more heat to the interior. However, most of the renovated roofs retained their timber structural framework. Structural steel roof structure was deployed in the new build modular school blocks that are being built at the moment. It was also observed that no roof insulation was introduced in spite of the increased heat transmission from the metal based roofing sheets to the building interior. The buildings rely mostly on the vented airspace between the roof covering and the ceiling for insulation function.

Table 2: Components of the Building Envelope

SN	Component	Prior State	Renovated State
1	Wall	Sandcrete Blocks	Sandcrete Blocks
2	Wall Finish	Rendering/Painting	Rendering/Painting/Brick Facing
3	Windows	Wooden shutters, Glass louvres	Steel casement windows/aluminium & glass casement/sliding windows
4	Doors	Wooden Panel/flush doors	Steel Door, Wood panel doors
5	Roof Structure	Timber	Timber, Structural Steel
6	Roof Covering	Asbestos-cement sheets, zinc-coated sheets	Long-span aluminium
7	Ceiling	Asbestos-cement sheets	PVC ceiling

4.2.2 Doors and Windows

Prior to the on-going renovations, the windows were mostly made up of glass louvre blades on galvanized steel louvre carriers which in turn were screwed to timber window frames. A number of them had timber window shutters while another fraction was built without windows. According to some respondents, the windows were easily vandalized and soon got dilapidated. Hence, in the renovation, steel casement windows were used to replace glass louver windows and wooden shuttered windows, especially on the ground floor of the school buildings. Office areas and common spaces had aluminium framed glass sliding or casement windows. Steel doors were also used to replace wooden doors.

4.2.3 Walls

The predominant walling material in the study area is sandcrete solid or hollow blocks. The hollow blocks are most prevalent because of ease of use and its insulation properties. Hence, both external and internal walls were built with sandcrete masonry work which were rendered and painted. However, brick facing is increasingly being introduced as wall finishing material to reduce the frequency of repainting external wall surfaces. The use of brick facing is shown in Figure 1.

Figure 1: Brick Facing on a School Building (Nwannekanma, 2021)

4.3 Other Components

Another prominent feature of the school upgrade programme is the erection of perimeter fence walls for the school premises. Prior to this, most school premises were not properly delineated. As a result, the schools were often not secure and a number of serious security breaches have been witnessed. The fence walls were fitted with watchtowers, floodlights and panic bells to make the schools more secure. The fence walls were also finished with brick facing in order to minimize the frequency of maintenance. From the foregoing, it may be inferred that the school upgrade programme was mainly to create a conducive and secure school internal and external environment which will facilitate sustainable inputs into the school system. The ICT infrastructure needed to drive improved learning can only be possible in a secure and conducive school environment.

4.4 New Builds

There are some new blocks of classrooms and other facilities that were newly built by the relevant government agency. Most of the new builds are reinforced concrete framed structures with sandcrete block infill as building envelope. The roof covering is corrugated long-span aluminium roofing sheets fixed to timber roof structure. The external walls are finished with brick tiles to reduce the frequency of repainting the walls. As a way of procuring the new school buildings very rapidly, the government has commenced the use of shipping containers as modular units for the construction of school buildings (Figure 2). The containers are placed on an in-situ concrete pedestal and roofed with structural steel frame which receive long-span aluminium roofing sheets such that the airspace between the roof covering and the shipping container acts as insulation for the shipping container. The walls are also properly insulated for improved comfort internally.

Figure 2: Ongoing Modular 12 classroom block (Nwannekanma 2022)

4.5 Energy Supply to the Schools

The schools are all connected to electricity from the national grid. However, the electricity supply is epileptic and inefficient. As an immediate alternative, the schools have standby electricity generators which are powered by carbon intensive premium motor spirit (PMS). Many of the schools visited have at least two generators. Some schools use the generators as main source of electricity as grid source comes on mostly after school hours due to the load shedding adopted by the grid electricity distribution companies. For schools that rely on generators for daily activities, a minimum of 50 litres of PMS is used every week. In monetary terms, purchase of PMS consumes about 16% of the monthly running cost of the schools. As a result, the usage of generators is highly controlled and this has some effect on the time devoted to ICT related sessions.

The schools are desirous of having clean energy source such as solar energy as a necessary follow-up to the renovation projects. The installation of solar energy in schools has proceeded gradually from about 2015 when the government launched a programme to install solar electricity in 172 schools especially rural schools and schools in riverine areas where access to electricity is low (Oyedade, 2015). The project has been ongoing even though it has witnessed delayed deliveries (Adebutu, 2020). This programme is executed under the Lagos State Solar Power project, under the Lagos State Electricity Board. However, the current target of the project can only cover about 25% of the public schools in Lagos. So far the Lagos Solar project is limited to the provision of stand-alone off-grid systems.

4.6 Opportunities for Renewable Energy Installations

Most of the school sites are good for installation of renewable energy equipment especially solar photovoltaic (PV) panels. The rural schools have good exposure to solar radiation. Even though urban schools are located within built-up urban areas, the relative area of the school premises in comparison to adjoining residential premises allows for installation of renewable energy especially solar installations without obstructing shadow from adjoining buildings. Similarly, the average height of the school buildings is three floors (about 12 metres) which make them stand out within the predominantly residential neighbourhoods where the schools are located.

In specific terms, education census figures from Lagos State Government indicate that there are about 18875 classrooms in the public school system (Lagos State Government, 2019). With an average classroom area of about 56m^2, the Lagos State public schools have a combined gross floor area of 1,057,000m^2 for the academic areas of schools. Assuming an average of three floors for the academic buildings, this translates to about 352,000m^2 of roof footprint available for solar PV installations. However, roof mounted solar PV systems which were not factored into the original design of the roofs may pose some structural problems. Hence, it is advisable in subsequent renovations to replace timber roof structure with structural steel roof structure for public schools given that steel is more durable. Subsequent renovations may adopt structural steel roofs which can withstand the extra load imposed by the solar PV panels.

The new builds, especially the modular units provide more opportunities for building integrated PV systems (BIPVs). Hence, building integrated PV panels where the panels form the roof covering of the building will be more advantageous. The structural frame of the roof can be made independent of the walls of the building which offers more flexibility in the design. Given that the solar PV panels are also in modular units. It will fit into the framework of the modular container units. So, the modular classroom units and other new build typologies offer a good opportunity to incorporate solar PV panels on a continuous basis in school buildings within the study area.

5. Conclusion

From the foregoing, it is evident that the renovation programmes focused more on durability, functionality and security of the buildings and the school properties within the buildings. The long-span aluminium roofing sheets were selected as roof covering for the renovated buildings because of their durability and ease of installation. Even though the absence of insulation under the roof covering may have increased heat gain through the roof, the ventilated ceiling helped to dissipate the heat gain and prevent full transmission to the interior of the buildings. Also, the steel doors and windows were installed in place of louvre windows and wooden shutters because they were more durable and could provide better security for the school properties within the buildings. Of particular importance is the introduction of brick facing tiles as external wall finishing material in most of the renovated buildings. The brick facing reduces the frequency of repainting the walls which is a common maintenance requirement in most schools. The reduction in frequency of painting makes the buildings more resource efficient.

The security requirement played key role in the renovation efforts. The school fences and gates were given priority so as to secure lives and properties in the school. This is understandable given the few security breaches that have recently affected schools in Nigeria. The school fence walls were often finished in durable maintenance free materials such as brick facing tiles.

It can be inferred from the findings that the school renovation programme was intended to be holistic and multi-sectoral, involving different sections of government. However, stages of implementation across the different sectors differ. While good progress has been made on the building renovation proper, the maintenance management aspect has been slow in taking off. Similarly, renewable energy retrofitting and improved energy access has recorded marginal progress.

The renovation proper which focused mainly on the building envelope has not incorporated any renewable or clean energy initiatives but has nevertheless provided a framework for the installation of clean energy systems in the public schools. Opportunities for installation of more solar PV panels and accessories abound in Lagos State public schools. With the average height of about 12 metres and relatively large roof footprint, the prospects for roof mounted solar PV panels are high. However, the preference for standalone off grid systems may be less efficient in the long run. The promotion of mini grids for the school and surrounding community may be a more sustainable and cost effective option due to the derivable economies of scale. Given the fact that several schools are located in one large area, the mini grid option has good prospects. Very importantly, the modular school construction programme provides a good opportunity for incorporation of building integrated photovoltaic panels (BIPVs) as permanent roof covering for the modular school blocks. This will dispense with the requirement for conventional roofing systems.

Given the poor energy access in the study context, clean energy in the form of solar electricity can be used to mitigate the digital divide by proving affordable energy to drive technology based education for sustainable human development. This is achieved with the additional advantage of curtailing GHG emissions associated with conventional and alternative electricity generation in the study area. Given the positive role education plays in the adoption of sustainability principles, clean energy adoption in schools will help in inculcating sustainability principles in young people thereby building capacity for tackling future climate change related issues. Most importantly, the incorporation of clean energy in the school renovation programme will provide uninterrupted energy that is necessary for the much desired technology based education.

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About the Authors

Isidore C. Ezema (PhD): Architect and Senior Lecturer, Department of Architecture, Covenant University, Ota, Nigeria
Oladunni Izobo-Martins (PhD): Architect and Senior Lecturer, Department of Architecture, Covenant University, Ota, Nigeria
Abraham O. Owoseni (PhD): Architect and Lecturer, Department of Architecture, Covenant University, Ota, Nigeria