Assessment of Regenerative Architecture Principles in Nigeria; A Case Study of Selected Research Institutes in Nigeria

Ukaegbu Chidinma¹ and Fulani Omoyeni¹

¹Department of Architecture, Covenant University, Ota, Ogun State, Nigeria
Corresponding Author; chidinma.ukaegbu@stu.cu.edu.ng

Abstract-
Buildings are an integral part of human existence, as shelter is one of the three basic needs of man. However, the design and construction of buildings, so far, has affected the natural environment negatively. The focus of research is, therefore, shifting towards buildings whose existence have minimum negative effects on the natural environment and even goes a step further to study buildings that positively influence the environment in which they are built. Nigeria, as a developing country, is also shifting towards these trends in building design and construction, however, more studies have to be carried out in order to fit these trends into our local context. This study, therefore, aims at identifying and analyzing the regenerative architecture principles adopted in the design of selected research institutes in Nigeria with a view to promote environmentally sustainable designs in Nigeria. Case studies of selected research institutes were assessed to determine the extent to which they comply with the principles and strategies of regenerative architecture, as proposed by Littman in 2009. Data was collected and analyzed using descriptive statistics and content analyses. The findings of this study suggest that the predominant strategies of regenerative architecture employed in Nigeria are those that promote and cater to energy efficiency, whilst other strategies of regenerative architecture were barely acknowledged. This paper concludes that as much as energy supply is a major issue in Nigeria, other strategies of regenerative architecture can also be employed in the design and construction of buildings to ensure a holistic net positive impact of the buildings on the environment.

Key words: Environmental sustainability, regenerative architecture, research institute

1. Introduction
As a result of human development and technological advancement, there has been an increased need for buildings to be provided to cater for numerous functions. The importance of buildings in human existence can, therefore, not be overemphasized [1], [2]. However, building design and construction has had numerous impacts on the natural environment such as pollution, resource depletion, climate change, waste production, energy consumption and environmental degradation, among others. Buildings, so far, have been known to have negative impacts on the environment or site on which they are constructed. For instance, an estimation by [3] shows that about 50% of the world’s total energy consumption and expenditure can be attributed to buildings whether directly throughout their lifecycle or indirectly. According to [4], buildings worldwide contribute 33% of carbon emissions. They also suggest that apart from the post-occupancy needs, buildings have additional requirements of resources to cater for their design, construction and, if applicable, demolition processes. Also, [5], suggest that construction and
demolition waste (CDW) represent between 25% and 30% of all generated waste, being the heaviest and bulkiest. Comparing the need for more construction of buildings with the effects buildings have had on the environment, so far, has posed a threat to the sustainability of the environment. One that should motivate and urge the government and professionals in the building industry towards finding a solution that allows more buildings to be constructed without the attributed negative effect on the environment. In an attempt to cater to this effect, [6], suggest that just as plants and vegetation adapt to their environment and are involved in the process of preserving the ecosystem, buildings should contribute and regenerate their environments rather than deplete it. This proposition is also in line with concepts such as environmental sustainability, green building design, autonomous buildings, living buildings, adaptive buildings, restoration and regeneration that are geared towards achieving environmental sustainability through building design and construction. Built environment professionals in developing countries like Nigeria thus face a tremendous challenge of creating buildings with similar attributes especially to stem the tide of degradation which buildings are unleashing on the environment.

Sustainability, as we know it, has been speculated to be a slow and ineffective solution to the challenges being faced by the environment and the current rate of deterioration [7]. According to [8], sustainability only focuses on the net-zero impact of buildings on the environment. This strategy, therefore, does not cater to the degradation that has already affected the natural environment. Research is thus leaning towards the concept of regenerative architecture, where buildings not only have reduced or no negative effect on the natural environment but strive towards positively influencing the environments and the site on which they are constructed. It also comprises of the concepts of a closed loop system of resource management and enhancing the environmental condition of the surrounding among others. Whereas the ultimate goal of sustainability is to meet the basic human needs of today without tampering with the ability and provisions required by future generations to meet their own needs, the highest goal of regenerative architecture is to create systems that co-exist and are able to provide more than is required to meet their needs thus having a net positive effect on the environment. Thus, regenerative architecture goes a step further in ensuring environmental preservation and advancement. It is against this background that this study aimed at analyzing the extent to which the various principles and strategies of regenerative architecture have been employed in the design and construction of selected institutional buildings in Nigeria. The main objectives were to identify the principles of regenerative architecture and place analysis criteria utilized in buildings and sites and to examine the compliance level of institutional buildings in Nigeria to principles of regenerative architecture. To realize these objectives the study sought to address two research questions. These are:

i. What are the principles of regenerative architecture and place analysis criteria utilized in buildings and sites; and

ii. To what extent do institutional buildings in Nigeria comply with principles of regenerative architecture?

This article reports findings from a research, conducted to investigate the compliance levels of institutional buildings in Nigeria with regenerative architecture principles. Three research institutes in Southwest Nigeria were analyzed based on the nine principles of regenerative architecture. The study suggests strategies of regenerative architecture that can be utilized in the Nigerian context in order to promote environmental sustainability. Also findings from this study
are expected to serve as a form of awareness to researchers and professionals in the built environment and general public alike.

1.1 Regenerative Architecture
Efforts have been made to monitor and control the effects on buildings on their environment, with a bid to minimize the negative impacts as much as possible. However, this process, according to [7], is inadequate and sluggish in contrast with the rate and amount of degradation in the environment. There is, therefore, a shift from sustainability to regeneration [9]. Regenerative architecture is a concept that was introduced to speed up and enhance the restoration and healing process. It is the “practice of engaging the natural world as the medium for, and generator of the architecture. It responds to and utilizes the living and natural systems that exist on a site that become the building blocks of architecture” [7]. This suggest that the architecture is informed by the site on which it is to be built which is simultaneous considering the site as an equal partner in the development [10], [11], [12], [13], [14]. This helps to cater for the natural as well as the built environment.

1.2 Principles of Regenerative Architecture
Jacob A. Littman, in 2009, developed a set of principles that focus on regeneration in terms of architecture. The principles are geared towards creating a fusion between the human and natural environment indefinitely and are derived from various inter related fields of study. There are a total of nine principles and each principle can be further broken down into guidelines that are geared towards regeneration in architecture. The principles are as follows.

1.2.1 Whole Systems Design Integration
The focus of this principle is on the understanding of the site as a system. The guidelines suggest that when designing the site or ‘place’ should be identified and studied as a system, with various elements and entities.

1.2.2 Integration into the Landscape
The focus of this principle is on the relevance of adequate analysis of the site. The guidelines suggest that a thorough study and analysis of the place, such that the introduction of the design is perceived as a continuation of the site and not as a separate entity.

1.2.3 Principle of Bold Ecology
The focus of this principle is on ecology and ecological systems, especially the organisms, species and their environment. The guidelines suggest that the system should be designed to produce more than it consumes, especially in term of energy.

1.2.4 Principle of Intelligent Limits
The focus of this principle is on the potential of the entities and the system as a whole. The guidelines suggest that each material and space that is to be introduced in the design must be created in such a way that it has the maximum positive contribution to the system.

1.2.5 Principle of Concentration
The focus of this principle is on space and spatial relationship between entities. The guidelines suggest that each space should be created in such a way that it has a relationship with neighbouring spaces and the system as a whole with maximizing the potential of the system.
1.2.6 Principle of Intelligent Construction
The focus of this principle is on construction and construction processes and materials. The guidelines suggest that the construction process merges both natural and artificial methods. It also suggests that the materials used should be carefully analysed to ensure durability and suitability to its expected use.

1.2.7 Principle of Community
The focus of this principle is on communities and their connectedness to one another and their environment. The guidelines suggest that every entity is categorised based on their relationship which other entities and not necessarily by size or proportion, creating interaction between the various elements in the community.

1.2.8 Experience of Place
The focus of this principle is on the uniqueness and specificity of the place. The guidelines suggest that the design should be intentional and driven by clear and pre-defined principles and strategies. The place should, therefore, be designed to create an image and experience that encourages and promotes the users of the community.

1.2.9 Principle of Culture
The focus of this principle is on the cultural identity of the place and elements within the site. The guidelines suggest that the experience of place is positive when it celebrates the social history of the system, created by the design.

1.3 Place Analysis Criteria
This is a form of site analysis employed to achieve a truly regenerative design. The focus of the set of strategies is ‘place’ or site [15], [16], [17], [18], [19]. These strategies were proposed by Jacob A. Littman, the prominent architect responsible for the nine principles of regenerative architecture, in 2009. According to [7], the place analysis criteria is carried out using the scale of permanence that is established in permaculture. The site systems to be analyzed include landforms, building and infrastructure, zones of use, microclimate, water, access and circulation, vegetation and wildlife as well as aesthetics and experience of place.

Landforms are a site system assessed based on the natural features on the surface of the site. The features of this system are slope, topographic position, geology and elevation. Buildings and infrastructure are assessed based on the structure to be erected on the site and the existing features. Zones of use are analyzed based on the zoning of the site and functional allocation. Microclimate is analyzed based on the climate conditions existing on the site. Water, on the other hand, is assessed based on water sources, storage and utilization on site, access and circulation are assessed based on patterns on movement within and around the site, vegetation and wildlife is assessed based on the existing species and their natural habitat while aesthetics and experience of place is assessed based on the appearance of the place and experience of the users.

2. Methodology
The main objectives of the study were to identify the principles of regenerative architecture and place analysis criteria utilized in buildings and sites and to examine the compliance level of institutional buildings in Nigeria to principles of regenerative architecture. To achieve this goal,
the study employed qualitative research approaches with the use of case study and semi-structured interviews.

The surveys were conducted between December 2018 and February 2019. For the case study, the study population is made up of all the institutional buildings in Nigeria. The sample frame, however, is made up of specific research institutes in Nigeria. As a result, the purposive sampling method was adopted. The research institutes that were studied were selected based on the possibility of the adoption of environmental sustainability strategies in their design.

The data described and analyzed in this study were obtained by carrying out a thorough assessment of the research institutes, using a carefully constructed observation guide. Research institutes sampled include: Nigerian Institute for Oceanography and Marine Research (NIOMR), Victoria Island, Lagos state, Federal Institute of Industrial Research (FIIRO), Oshodi, Lagos state, and Covenant University Centre for Research, Innovation and Discovery (CUCRID), Ota, Ogun state.

Two instruments of data collection were employed by the researchers to help gather data. The first was the observation guide. This instrument was used to record observations made with respect to the physical characteristics of the research institutes sampled, and it was designed to examine the institutional buildings based on the subject of study and its parameters. The observation guide, was used as a guide to carrying out the study on the research institutes. This was adopted from the Principles of Regenerative Architecture [5], as discussed previously. This guide was divided into 3 sections; A, B and C. Section A addresses the building information of the research institute, Section B addresses the performance analysis while Section C focuses on the principles and strategies of regenerative architecture that have been employed in the research institute.

The second instrument of data collection employed was the interview guide. Personal interviews were conducted to reinforce the findings of the case study. The interviews included the users or facility managers of the research institutes. A semi-structured interview guide was used to carry out the interviews. The interviews were carried out to obtain information about the research institute and facilities that are available within the institute. The interviews also focused on the strategies of regenerative architecture adopted in the research institutes.

3. Result and discussions

The case studies were carried out to examine the compliance level of selected institutional buildings in Nigeria to principles of regenerative architecture. The following buildings were therefore analysed based on the nine principles of regenerative architecture.

i. Nigerian Institute for Oceanography and Marine Research (NIOMR), VI.
ii. Federal Institute of Industrial Research (FIIRO), Oshodi.
iii. Covenant University Centre for Research, Innovation and Discovery (CUCRID), Ota.

3.1 Nigerian Institute for Oceanography and Marine Research (NIOMR), VI

The Nigerian Institute for Oceanography and Marine Research (NIOMR) is a multi-disciplinary research institute focused on all aspects of marine and allied sciences. It was established in 1975 by the Research Institutes’ Establishment Order with the vision to become a world-class Centre of Excellence in Marine Science. The research institute was analysed based on the principles of regenerative architecture, as discussed above and assessed on the extent to which these principles were adopted in the design.

3.1.1 Whole Systems Design Integration
The institute has a series of mutually supporting systems as is seen with the presence of a roof garden on most of the buildings. It also adopts the principle of multiplicity as is seen with the water recycling system.

3.1.2  Integration into the Landscape
Most of the greenery is made up of the native plant of the site with a few exotic plants for beautification. The design was also inspired by nature as the zoning was based on the location of the water bodies and other features of the site. However, the buildings are spread wide on the site with minimal provision for vertical development.

3.1.3  Principle of Intelligent Limits
Apart from the building footprint, the site was covered with permeable features such as interlocking pavers and natural vegetation. Some passive design strategies were employed such as the conscious integration of shading devices the building envelope and as well as use of trees as shading devices.

3.1.4  Principle of Concentration
The institute maximized the use of space as each space provided serves a unique purpose or set of purposes. There was also some level of flexibility adopted in the design of these spaces to cater for multiple functions. The zoning of the site also maximizes the functional relationship within and between each zone.

3.1.5  Principle of Intelligent Construction
The research institute was assessed based on the building material used for construction, durability and ability to be recycled. The material used for construction were not harmful or toxic however, they were not biodegradable as well. Most of the material used were durable although the paint was not suitable for the exterior walls due to its proximity to the water body.

3.1.6  Principle of Bold Ecology
Spaces in the institute maximize, to an extent, the use of daylighting and natural ventilation for thermal comfort within the spaces. However, the major source of energy for the institute is from the national grid with no alternative renewable energy source. The institute also encourages human-powered circulation with the presence of stairs and walkways, limiting distances between the buildings.

3.1.7  Principle of Community
The major species present in this design were the fishes and other marine animals. There was an exchange of experience between these elements as is seen with the presence of an exhibition space with aquariums that house these species.

3.1.8  Experience of Place
The building is also oriented to maximize the experience of users. This can be seen in the presence of courtyards at strategic locations to maximize connection with nature and improve the experience of place and interaction with the community. The research institute’s facade and interiors are visually appealing.

3.1.9  Principle of Culture
The design of the research institute introduced some elements of cultural expression. The major local elements adopted in the design was the vegetation and greenery. The institute, however, provided habitat for the local species such as the marine animals and the native vegetation used as lawns.

These regenerative principles have been summarised in Table 1, assessing the extent to which they have been adopted in the design, construction and utilization of the research institute.

| SN | Variable | Features                                      | Remarks |
|----|----------|-----------------------------------------------|---------|
|    |          | Principle 1: Whole Systems Design Integration |         |
| 1. | Accountability of Systems | All species are accounted for | ●       |
|    |                      | Mutually supportive relationships |         |
| 2. | Multiplicity of Systems | Elements with multiple functions | ●       |
|    |                      | Need met with multiple sources | ●       |
|    |          | Principle 2: Integration into the Landscape |         |
| 1. | Spread of Building on Site | Vertical development | ●       |
|    |                      | Extensive use of roof gardens | ●       |
| 2. | Working with Site Features | Integration of native landscape | ●       |
|    |                      | Letting nature inspire the design | ●       |
|    |                      | Preservation of site characteristics | ●       |
|    |                      | Treatment of landscapes as interdependent | ●       |
|    |                      | Use of forms inspired by nature | ●       |
|    |          | Principle 3: Principle of Intelligent Limits |         |
| 1. | Impact of Building Footprint | Minimal use of impervious site cover | ●       |
|    |                      | Minimal dependence on mechanical systems | ●       |
| 2. | Resource Utilization | Use onsite water storage and treatment | ●       |
|    |                      | Building elements that reflect local context | ●       |
|    |          | Principle 4: Principle of Concentration |         |
| 1. | Space Utilization | Positive building footprint impact | ●       |
|    |                      | Omission of useless/redundant spaces | ●       |
| 2. | Activity Zoning | Maximum impact on system's operation. | ●       |
|    |                      | Each module is individually optimized | ●       |
|    |          | Principle 5: Principle of Intelligent Construction |         |
| 1. | Building Materials | Non-harmful or non-toxic | ●       |
|    |                      | Biodegradable materials | ●       |
| 2. | Type of Materials | Locally sourced materials | ●       |
|    |                      | Durable materials | ●       |
|    |                      | Natural materials like rocks and water bodies | ●       |
| 3. | Recycling | Use of recycled materials | ●       |
|    |                      | Use of recyclable materials | ●       |
### Principle 6: Principle of Bold Ecology

| 1. Energy Use | Use of day-lighting | ●
|              | Use of natural ventilation | ●
|              | Passive design elements | ●
| 2. Source of Water | On site sources | ●
|              | Harvesting, processing and recycling | ●
| 3. Renewable Energy Sources | Solar panels, wind turbines and bio-gas. | ●
|              | Primary source of energy | ●
| 4. Energy Conservation | Dependence on natural systems | ●
|              | Use of human powered transportation | ●

### Principle 7: Principle of Community

| 1. Homogenous Entities | Connectedness of entities | ●
|                        | Independence of entities | ●
| 2. Heterogeneous Entities | Connectedness of entities | ●
|                        | Independence of entities | ●

### Principle 8: Experience of Place

| 1. Building Materials | Complementary landscape elements | ●
|                        | Resident building materials | ●
| 2. Mode of Construction | Building orientation to maximize experience | ●
|                         | Adequate site zoning | ●
| 3. Aesthetic Appearance | Visually appealing | ●
|                         | Interaction with community | ●

### Principle 9: Principle of Culture

| 1. Cultural Expression | Use of local elements | ●
|                        | Use of cultural elements | ●
| 2. Cultural Consideration | Provision of habitat for local species | ●
|                         | Positive impact on surrounding | ●

Note: H - High, M - Medium, L - Low, A - Absent

According to Table 1, the principles that were adopted the most in the Nigerian Institute for Oceanography and Marine Research (NIOMR) are principles of intelligent limits, bold ecology and experience of place. The least adopted principles are the principles of community and culture.

#### 3.2 Federal Institute of Industrial Research (FIIRO), Oshodi

The Federal Institute of Industrial Research (FIIRO), Oshodi is parastatal under the agency of the Federal Ministry of Science and Technology focused on coordinating industrial research activities in Nigeria. It was established in 1953 by the World Bank with a vision to be the foremost center for Science and Technology-based research and development for the industrialization and socio-economic advancement of the nation. The research institute was analysed based on the principles of regenerative architecture, as discussed above and assessed on the extent to which these principles were adopted in the design.
3.2.1 Whole Systems Design Integration
There are also a series of mutually supporting systems as seen in the allocation of resources between the different departments and workshops in the institute. Some systems in the institute serve multiple functions such as the cooling water system which also serves as a source of water for activities in the institute. However, each need within the system was met with only one source.

3.2.2 Integration into the Landscape
Native vegetation was used to beautify the environment with the inclusion of a few exotic plants. The site characteristics were also preserved by the design. However, the use of roof garden was not adopted to cater for the land occupied by the building footprint. The buildings were also spread across the site will minimal provision for vertical development.

3.2.3 Principle of Intelligent Limits
The complex is designed with permeable surfaces, such as interlocking pavers and vegetation, to prevent the disruption of the water cycle among other processes on the site. There’s a minimal dependence on mechanical systems as passive design strategies were adopted in the design.

3.2.4 Principle of Concentration
The research institute maximized the use of space as each space provided serves a unique purpose or set of purposes such as manufacturing, research, for carrying out experiments among others. The zoning of the site also maximizes the functional relationship within and between each zone. However, the footprint of buildings on the site was surplus as a result of the functions to be carried out on the site.

3.2.5 Principle of Intelligent Construction
The materials used were assessed based on mainly durability and recyclability. The material used for construction were not harmful or toxic however, they were not biodegradable as well. The materials used for construction such as concrete and glass were not recycled but have the ability to be recycled.

3.2.6 Principle of Bold Ecology
Most spaces within the institute maximize the use of natural lighting and ventilation to promote user comfort. The institute minimized its dependence on mechanical systems by adopting passive design strategies such as the use of shading devices and building orientation. Human-powered circulation was encouraged within the institute by making provision for walkways and stairs for vertical circulation.

3.2.7 Principle of Community
The connectedness and interdependence between homogenous entities and heterogeneous entities can be seen in the resource distribution and processes that occur within the research institute. This can be likened to industrial ecology.

3.2.8 Experience of Place
This principle was assessed based on certain criteria such as building materials, mode of construction and aesthetic appearance. The experience of users in the institute was average as
there was minimal interaction with the surrounding community. The aesthetic appearance of the buildings also does not encourage a positive experience as most of the buildings require maintenance and renovation.

3.2.9 Principle of Culture

The principle of culture employed in the research institute comprises of cultural expression and considerations. The institute did not adopt the use of local elements however used some cultural elements by making provision of habitat for natural vegetation and systems. The institute, therefore, has a minimal negative impact on the environment.

These regenerative principles have been summarised in Table 2, assessing the extent to which they have been adopted in the design, construction and utilization of the research institute.

Table 2: Assessment of Principles of Regenerative Architecture in FIIRO

| SN | Variable               | Features                                                                 | Remarks |
|----|------------------------|--------------------------------------------------------------------------|---------|
|    | Principle 1: Whole Systems Design Integration                             |                                                      |         |
|    | Accountability of Systems | All species are accounted for                                             |         |
|    |                         | Mutually supportive relationships                                         | ●       |
|    | Multiplicity of Systems  | Elements with multiple functions                                           | ●       |
|    |                         | Need met with multiple sources                                            | ●       |
|    | Principle 2: Integration into the Landscape                                |                                                      |         |
|    | Spread of Building on Site     | Vertical development                                                      | ●       |
|    |                         | Extensive use of roof gardens                                             | ●       |
|    | Working with Site Features   | Integration of native landscape                                           | ●       |
|    |                         | Letting nature inspire the design                                         | ●       |
|    |                         | Preservation of site characteristics                                      | ●       |
|    |                         | Treatment of landscapes as interdependent                                 | ●       |
|    |                         | Use of forms inspired by nature                                          | ●       |
|    | Principle 3: Principle of Intelligent Limits                              |                                                      |         |
|    | Impact of Building Footprint   | Minimal use of impervious site cover                                     | ●       |
|    |                         | Minimal dependence on mechanical systems                                  | ●       |
|    | Resource Utilization         | Use onsite water storage and treatment                                    | ●       |
|    |                         | Building elements that reflect local context                              | ●       |
|    | Principle 4: Principle of Concentration                                   |                                                      |         |
|    | Space Utilization           | Positive building footprint impact                                        | ●       |
|    |                         | Omission of useless/redundant spaces                                      | ●       |
|    | Activity Zoning            | Maximum impact on system’s operation.                                     | ●       |
|    |                         | Each module is individually optimized                                     | ●       |
|    | Principle 5: Principle of Intelligent Construction                        |                                                      |         |
|    | Building Materials          | Non-harmful or non-toxic                                                  | ●       |
|    |                         | Biodegradable materials                                                   | ●       |
|    | Type of Materials           | Locally sourced materials                                                 | ●       |
Durable materials
Natural materials like rocks and water bodies

3. Recycling
Use of recycled materials
Use of recyclable materials

| Principle 6: Principle of Bold Ecology |
|--------------------------------------|
| 1. Energy Use | Use of day-lighting |
| | Use of natural ventilation |
| | Passive design elements |
| 2. Source of Water | On site sources |
| | Harvesting, processing and recycling |
| 3. Renewable Energy Sources | Solar panels, wind turbines and bio-gas. |
| | Primary source of energy |
| 4. Energy Conservation | Dependence on natural systems |
| | Use of human powered transportation |

| Principle 7: Principle of Community |
|------------------------------------|
| 1. Homogenous Entities | Connectedness of entities |
| | Independence of entities |
| 2. Heterogeneous Entities | Connectedness of entities |
| | Independence of entities |

| Principle 8: Experience of Place |
|---------------------------------|
| 1. Building Materials | Complementary landscape elements |
| | Resident building materials |
| 2. Mode of Construction | Building orientation to maximize experience |
| | Adequate site zoning |
| 3. Aesthetic Appearance | Visually appealing |
| | Interaction with community |

| Principle 9: Principle of Culture |
|----------------------------------|
| 1. Cultural Expression | Use of local elements |
| | Use of cultural elements |
| 2. Cultural Consideration | Provision of habitat for local species |
| | Positive impact on surrounding |

Note: H - High, M - Medium, L - Low, A - Absent

According to Table 2, the principles that were adopted the most in the Federal Institute of Industrial Research (FIIRO), Oshodi are the principles of bold ecology and concentration. The least adopted principle is the principle of intelligent limits.

3.3 Covenant University Center for Research, Innovation and Discovery (CUCRID), Ota
The Covenant University Center for Research, Innovation and Discovery (CUCRID), Ota is an iconic structure, in the shape of an eagle (Plate 4.32). It was commissioned on the 24th June 2016 with a mandate to drive the university’s vision of being one of the top 10 universities in the world by the year 2022 from the research, innovation and discovery platform. The research institute was analysed based on the principles of regenerative architecture, as discussed above and assessed on the extent to which these principles were adopted in the design.

3.3.1 Whole Systems Design Integration
The building is made up of mutually supportive system as is seen with the spaces provided and their interdependence. Elements within the building also serve multiple functions for instance, the terraces at the end of the wings double as planters to mimic a green wall.

3.3.2 Integration into the Landscape
The building has about seven floors with a basement, therefore limiting the building footprint. Nature was an inspiration for the design as the orientation of the building was to maximize thermal comfort for the users. However, the site characteristics were not preserved as the surrounding of the building was developed to accommodate the number of car parks required.

3.3.3 Principle of Intelligent Limits
Apart from the built-up area that caters for the building footprint, the surrounding site is developed using interlocking pavers and vegetation which serve as permeable surfaces that do not disrupt the water cycle and other processes. The centre is also designed to limit its dependence on mechanical systems by adoptive some passive design strategies such as motion sensors and fenestrations for lighting.

3.3.4 Principle of Concentration
The research centre has maximized the use of spaces and each spaces provided is requires to serve a specific purpose. The spaces were designed and allocated based on the various departments and research focuses. The center is also adequately zoned to ensure that each module is self-sufficient without making provision for unnecessary or redundant spaces.

3.3.5 Principle of Intelligent Construction
The building has been richly finished with ceramic walling tiling units which has head absorption properties thereby making it a sustainable building in order to maintain energy efficiency and recycling. This way the building is less harmful to the environment as its carbon footprint is minimal.

3.3.6 Principle of Bold Ecology
Not only does this indigenous design incorporate numerous strategies to address sustainable issues, it also is characterized by relatively low overall energy consumption. Energy efficiency was given high priority in the design of the research center as is seen in the heating, ventilation and air conditioning (HVAC) systems used throughout the building.

3.3.7 Principle of Community
The principle of community was adopted minimally in the design of the research institute. The connectedness and interdependence between homogenous entities and heterogeneous entities can be seen in the resource distribution and processes that occur within the research institute. This can be likened to industrial ecology.

3.3.8 Experience of Place
This principle was adopted in the design of the research institute with the building materials used which are complementary to nature. The building is also oriented to maximize the experience of users. This can be seen in the presence of a basement to complement the topography of the site. The research institute also has a facade and interiors that are visually appealing.

3.3.9 Principle of Culture
The principle of culture employed in the research institute comprises of cultural expression and considerations. The institute did not adopt the use of local elements however used some cultural elements by making provision of habitat for natural vegetation and systems. The institute, therefore, has a minimal negative impact on the environment.

These regenerative principles have been summarised in Table 3, assessing the extent to which they have been adopted in the design, construction and utilization of the research institute.

Table 3: Assessment of Principles of Regenerative Architecture in CUCRID

| SN | Variable Features | Remarks |
|----|------------------|---------|
|    | PRINCIPLE 1: WHOLE SYSTEMS DESIGN INTEGRATION |
| 1. | Accountability of Systems | All species are accounted for | ● |
|    | Mutually supportive relationships | ● |
| 2. | Multiplicity of Systems | Elements with multiple functions | ● |
|    | Need met with multiple sources | ● |
|    | PRINCIPLE 2: INTEGRATION INTO THE LANDSCAPE |
| 1. | Spread of Building on Site | Vertical development | ● |
|    | Extensive use of roof gardens | ● |
| 2. | Working with Site Features | Integration of native landscape | ● |
|    | Letting nature inspire the design | ● |
|    | Preservation of site characteristics | ● |
|    | Treatment of landscapes as interdependent | ● |
|    | Use of forms inspired by nature | ● |
|    | PRINCIPLE 3: PRINCIPLE OF INTELLIGENT LIMITS |
| 1. | Impact of Building Footprint | Minimal use of impervious site cover | ● |
|    | Minimal dependence on mechanical systems | ● |
| 2. | Resource Utilization | Use onsite water storage and treatment | ● |
|    | Building elements that reflect local context | ● |
|    | PRINCIPLE 4: PRINCIPLE OF CONCENTRATION |
| 1. | Space Utilization | Positive building footprint impact | ● |
Omission of useless/redundant spaces

2. Activity Zoning
   - Maximum impact on system’s operation.
   - Each module is individually optimized

**Principle 5: Principle of Intelligent Construction**

| 1. Building Materials | Non-harmful or non-toxic |  ● |
|                       | Biodegradable materials |  ● |
| 2. Type of Materials  | Locally sourced materials |  ● |
|                       | Durable materials |  ● |
|                       | Natural materials like rocks and water bodies |  ● |
| 3. Recycling          | Use of recycled materials |  ● |
|                       | Use of recyclable materials |  ● |

**Principle 6: Principle of Bold Ecology**

| 1. Energy Use     | Use of day-lighting |  ● |
|                   | Use of natural ventilation |  ● |
|                   | Passive design elements |  ● |
| 2. Source of Water| On site sources |  ● |
|                   | Harvesting, processing and recycling |  ● |
| 3. Renewable Energy Sources | Solar panels, wind turbines and bio-gas. |  ● |
|                   | Primary source of energy |  ● |
| 4. Energy Conservation | Dependence on natural systems |  ● |
|                   | Use of human powered transportation |  ● |

**Principle 7: Principle of Community**

| 1. Homogenous Entities | Connectedness of entities |  ● |
|                       | Independence of entities |  ● |
| 2. Heterogeneous Entities | Connectedness of entities |  ● |
|                       | Independence of entities |  ● |

**Principle 8: Experience of Place**

| 1. Building Materials | Complementary landscape elements |  ● |
|                       | Resident building materials |  ● |
| 2. Mode of Construction | Building orientation to maximize experience |  ● |
|                       | Adequate site zoning |  ● |
| 3. Aesthetic Appearance | Visually appealing |  ● |
|                       | Interaction with community |  ● |

**Principle 9: Principle of Culture**

| 1. Cultural Expression | Use of local elements |  ● |
|                       | Use of cultural elements |  ● |
| 2. Cultural Consideration | Provision of habitat for local species |  ● |
|                       | Positive impact on surrounding |  ● |

Note: H - High, M - Medium, L - Low, A - Absent
According to Table 3, the principles that were adopted the most in the Covenant University Center for Research, Innovation and Discovery (CUCRID) are the principles of bold ecology and intelligent construction. The least adopted principle is the principle of community.

4. Conclusion
The findings suggest that institutional buildings in Nigeria minimally integrate principles of regenerative architecture into their design. However, focus is placed more on certain principles than others. For instance, the principle adopted the most was the principle of bold ecology which comprises of strategies such as energy sources, utilization and conservation. Other principles adopted include the principles of intelligent limit, intelligent construction and experience of place. On the other end of the spectrum, the principles least adopted in the cases studies are the principles of community and culture which focus on local species and cultural elements. This suggests that more focus is placed on strategies geared towards energy efficiency.

5. Recommendation
As much as energy supply is a major issue in Nigeria, other strategies of regenerative architecture can also be employed in the design and construction of buildings to ensure a holistic net positive impact of the buildings on the environment. There are various strategies of regenerative architecture that can be utilized in the Nigerian context in order to promote environmental sustainability as is noted from these case studies.

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Reference

[1] Alagbe, O. A. (2011). Enhancing Sustainable Housing Development in Nigeria using Compressed Stabilized Laterite Bricks. Journal of Sustainable Development and Environmental Protection, 1(3), 51-59.

[2] Ibem, E. O. & Amole O. O. (2010). Evaluation of Public Housing Programmes in Nigeria: A Theoretical and Conceptual Approach. The Built and Human Environment Review, 3, 88-117.

[3] Attia, S. (2016). Towards Regenerative and Positive Impact Architecture: A comparison of Two Net Zero Energy Buildings. Sustainable Cities and Society, 393-406.

[4] Wei, P., Kajjian, L., & Yue, T. (2018, July). Rethinking System Boundaries of the Life Cycle Carbon Emissions of Buildings. Renewable and Sustainable Energy Reviews, 90, 379-390.

[5] Domínguez, A., Domínguez, M., Ivanova, S., Centeno, M., & Odriozola, J. (2016, November). Recycling of Construction and Demolition Waste Generated by Building Infrastructure for the Production of Glassy Materials. Ceramics International, 42(14), 15217-15223.

[6] Naboni, E., & Garcia, D. (2017). Sensitive and Reactive Architectural Devices for Regenerative Design. Applications in Manaus Heat Islands and Surrounding Rain Forests. Procedia Environmental Sciences, 38, 658-665.

[7] Littman, J. A. (2009, February). Regenerative Architecture: A Pathway beyond
Sustainability. ScholarWorks@UMass Amherst. Amherst, Massachusetts, United States of America: University of Massachusetts Amherst. Retrieved from https://scholarworks.umass.edu/theses/303.

[8] Carbonnier, E., & Babtiwale, E. (2018, May 16). Sustainability is Dead: Regenerative Architecture is the New Green. Retrieved January 2019, from Building Design + Construction: https://www.bdcnetwork.com/blog/sustainability-dead-regenerative-architecture-new-green.

[9] Reed, B. (2007, November). Shifting from ‘Sustainability’ to Regeneration. Building Research and Information, 35(6), 674 — 680. doi:10.1080/09613210701475753.

[10] Kellert, S. R. (2005). Building for Life: Designing and Understanding the Human-Nature Connection. Washington: Island Press.

[11] Murphy, T., & Marvick, V. (1998, October). Policy Review. Environmental Policy and Governance, 8(5), 171-172.

[12] William McDonough & Partners. (2000). Design for Sustainability: The Hannover Principles. Hannover: William McDonough Architects.

[13] Van Der Ryn, S., & Cowan, S. (1996). Ecological Design. (10, Ed.) Washington DC, United States of America: Island Press.

[14] Todd, J., & Todd, N. J. (1994). From Eco-Cities to Living Machines: Principles of Ecological Design (Vol. 2). Berkeley, California, United States of America: North Atlantic Books.

[15] Lyle, J. T. (1994). Regenerative Design for Sustainable Development. New York City, New York, United Sates of America: John Wiley & Sons.

[16] Obioha, L. U. (2014). Exploring Regenerative Architecture Principles in the Design Of Oguta Blue Lake Resort Hotel, Imo. Ahmadu Bello University Zaria, Department of Architecture. Zaria: Ahmadu Bello University Zaria.

[17] Sumayyah, A. K. (2016). Exploring Principles of Regenerative Architecture in Eco-Resort Design of Falgore Game Reserve. Ahmadu Bello University, Zaria, Department of Architecture. Zaria: Ahmadu Bello University, Zaria.

[18] Vierra, S. (2016, September 12). Green Building Standards and Certification System. (Vierra Design & Education Services, LLC) Retrieved January 2019, from Whole Building Design Guide: https://www.wbdg.org/resources/green-building-standards-and-certification-systems.

[19] Wells, M. (1978). Gentle Architecture. McGraw-Hill Companies.