Urban Energy Technical Note

09

University Curriculum Development

Main streaming Sustainable Building Design Principles for tropical climates into thecurriculum of universities and other learning institutions

The transition towards clean energy and sustainable use of resources calls upon all stakeholders across different sectors of society to make fundamental changes. While significant efforts need to be made to create awareness and build the capacity of existing practitioners in the building sector, future professionals in the sector should receive targeted training that will give them the skills and tools they need planning, designing and building sustainable human settlements.

The ideal approach is to incorporate the principles of integrated design, including energy and resource efficiency, into the existing curriculum rather than making it a separate course. However in cases where environmental design principles are completely lacking in the curriculum, a new course in Environmental Building Science should be introduced.

As the world moves towards a greener economy and sustainable development to address climate change, rapid urbanization and poverty, it is important that every professional graduating university understands the basic concepts of energy and resource efficiency, as well as all aspects of environmental design, from conceptualization to operation and maintenance.

The rationale

The majority of modern buildings in Sub Saharan Africa (mainly tropical climates) are replicas of buildings designed for the western world (cold and temperate climates) and do not take into consideration the differences in climate. As a result, buildings are heavily reliant on artificial means for indoor comfort, i.e. cooling, heating and lighting. Inefficient design, construction using materials produced with intensive input of energy, combined with poor understanding of thermal comfort, passive building principles and energy conscious behaviour, have led to tremendous energy wastage.

Any new building should be adapted to its climate and should not be “a copy and paste” process.

Few universities have made an active effort to include environmental science into their syllabus. Therefore a review is important in order to begin empowering the students at the very early stages of their training. Even with the growing interest from learning centres in this area, there is a lack of professionals in environmental design in the region.

In the two university syllabuses considered so far, some related courses introducing sustainable design have been integrated into the curriculum:

Jomo Kenyatta University of Agriculture & Technology (Kenya):

- 3rd Year: Sustainable design; Building environmental design (thermal); Building environmental design (lighting);
- 4th Year: Building environmental design (sound)

Ardhi University (Tanzania):

- 1st year: Environmental science 1;
- 2nd Year: Environmental science 2

However, these courses still need to be strengthened further to reflect the shift towards environmentally friendly and energy efficient architecture. In addition, the increased emphasis on sustainability needs to be integrated into other courses such as:

- Building construction studies
- Building physics
- Building services
- History and theory of architecture.
- Building material science
- Settlement development
- Urban design

Every concept learnt should be applicable to the design work undertaken in that given year to demonstrate understanding of the course work.

Below is a proposed structure stating areas that can be integrated into the curriculum:

Topic	Description	Year of Study
Introduction of climate and architecture	• An introduction to the recent changes in climate and population and the effects these changes have had on day to day life, especially on architecture.	**First year** At the end of the academic year, a student should be able to: 1. Differentiate between traditional design and integrated design. 2. Understand climatic parameters and how they affect design and energy balance in building performance 3. Understand the regional climate and differentiate between the climatic zones.
The Building Sector	• A look at global trends in the building sector and the resultant energy needed for urbanization.	
Integrated Design	• Introduction to integrated design: Phases of the design process that influence building energy performance and comfort. • Traditional Design Process vs. Integrated Design process	
Architecture in tropical climates	• Introduction to energy and buildings • Current trends in building design and energy consumption.	
Climatic Parameters	• The main climatic parameters affecting energy performance in buildings: • Solar Radiation: Solar geometry, designing with sun charts, parameters affecting local solar radiation, solar irradiance calculation. • Air temperature: Factors affecting air temperature (topography, location, surface factor) • Relative Humidity • Wind: Speed, direction and frequency • Aggregation of climatic data to calculate energy performance of buildings.	
Climate in the East African Communities	Description of climatic zones in the region and an introduction to creating comfortable living conditions: Zone 1: Hot-humid Zone 2: Hot arid Zone 3: Hot semi-arid/savannah Zone 4: Great lakes Zone 5: Uplands Zone 6: High uplands	
Passive Design	Introduction to passive design vs. active design	**Second Year** By the end of the year the students should be able to: 1. Distinguish between passive and active design. 2. Interpret and apply the bio-climatic chart. 3. Integrate passive design measures in their studio design in both planning of the site and the building. 4. Have an understanding of thermal, U-value and embedded energy properties of different building materials 5. Interpret and analyse a building design using the climatic zones learnt in their first year.
Bio climatic Charts	• Introduction of bio-climatic charts as a tool for analysing the climate of a particular place, indicating zones of human comfort based on ambient temperature and humidity, mean radiant temperature, wind speed radiation and evaporative cooling. • A step-by-step study and application of the Givoni Bioclimatic Chart to identify the 6 zones for passive design strategies: 1. Comfort zone 2. Natural ventilation zone 3. Evaporative cooling zone 4. High thermal mass 5. High thermal mass and night ventilation 6. Passive heating	
Site Planning	• Introduction to low energy urban design analysed by shape, orientation and distance between buildings. • Methodology for energy conscious urban design and recommended urban patterns. • Sustainable site planning	
Building Design	Factors affecting thermal and visual comfort and energy consumption in buildings: 1. Building Shape 2. Building orientation 3. Building fabric 4. Roof and wall design 5. Openings	
Natural ventilation	• Basic principles of natural ventilation. • Wind driven air motion: Sizing openings for cross ventilation, indoor air velocity, stack effect, room organization, induced ventilation. • Recommendations for the best exploitation of natural ventilation.	
Daylighting	Taking advantage of daylight levels and quality is essential for visual comfort, reduces the amount of conventional energy used and diminishes thermal gains indoor. • Window design and visual comfort • Systems to enhance natural lighting.	

Topic	Description	Year of Study
Shading	• Description of methods used to evaluate the shadows cast on a surface by projecting elements or surrounding obstructions: 1. Sundial 2. Shading masks • Overhang shading calculations • Shading devices: Fixed systems and movable systems.	
Natural Cooling	The use of natural technical solutions and how to measure effectiveness: • Evaporative cooling • Fans	
Building materials	• Introduction to conventional and sustainable construction materials. • Sustainably managed materials for: 1. Walls 2. Roofs 3. Insulation 4. Sustainable local/innovative building materials • Interlocking stabilized soil brick technology	
Design Guidelines according to East African Climates	Design guidelines for site planning, building design, natural ventilation, day lighting, shading and cooling according to each of the different climatic zones in the tropical climates for: • Residential buildings • Institutional buildings • Commercial buildings	
Lessons from the past	• How culture and tradition informed the design and construction of sustainable buildings in different climates. • Examples of colonial and pre-colonial architecture in East Africa	
The envelope	• Glazing: Glazing, climate and energy; solar radiation; thermal comfort and visual comfort; smart windows; glass architecture; sizing and design of openings. • Shading options.	**Third Year** By the end of the year, students should be able to: 1. Design and explain energy efficient building envelope including windows, wall and roof materials, ventilation systems, etc. 2. Distinguish between different energy intensive and energy efficient systems and apply them in design accordingly. 3. Have an understanding of energy performance certificates and rating systems around the world and how they are applied. 4. Simulate the energy balance of their designs on specified software.
Building Services	• HVAC types and features: Hydronic systems; air systems; air handling units; energy recovery ventilators; air terminal units; direct refrigerant systems; control systems; design, commissioning, operation and maintenance guidelines. • Centralised vs. decentralized systems • Efficient Energy Conversion Technologies: Refrigerating machine and heat pump; evaporative coolers; tri-generation systems; decentralized services. • Domestic hot water production • Artificial lighting: Types of lamps; lighting control systems; design of lighting systems; tips for artificial lighting	
Hybrid Ventilation	• Natural and mechanical ventilation • Fan-assisted natural ventilation • Stack and wind assisted mechanical ventilation	
Existing Building	• The energy consumption of existing buildings can be reduced by : 1. Envelope improvement. 2. HVAC systems improvement. 3. Operations and maintenance improvement. • Evaluation of energy saving potential during renovation.	
Simulation Tools	• Application of simulation tools that allow designers to calculate the energy consumption of their buildings.	



Topic	Description	Year of Study
Energy and urban metabolism	• Energy and the urban metabolism: • Designing a low energy development by: 1. Optimising energy efficiency of the urban structure 2. Minimising energy demand of buildings 3. Maximising the share of energy from renewable sources. • Urban mobility • Urban gardens	**Fourth Year/ Elective course** By the end of this course, a student should be able to: 1. Design and explain an energy efficient urban setting that uses relevant technologies, water management and solid waste management to improve the community
Water and sanitation	• Sources of water; water sources; water conservation; drainage; design strategies for reducing water consumption; rain water harvesting and water treatment technologies • Sludge to energy technology	
Solid waste management	• Composition of solid waste • Integrated management systems • Available and applicable technologies • Basic guidelines in waste management.	
Solar PV	• The uses of photovoltaic cells. • Architectural integration of photovoltaic systems.	**Fifth Year/ Elective Course** By the end of these year, the students should be able to: 1. Understand the application of renewable energies 2. Apply the energy efficient technology and renewable energy technologies applicable to each design.
Solar Thermal	• Introduction to solar thermal collectors • Type of solar collectors. • Determining collector efficiency. • Hot water production using solar collectors. • Solar cooling using solar thermal collectors	
Wind energy	• An overview of harnessing wind energy in the urban context.	
Hydropower	• Basics of hydropower energy • Types of turbines	
Biomass	• What is biomass? • Characteristics of biomass. • Biomass cook stoves: Improved cook stoves; kitchen stoves; fireplace heating systems; briquette heating stoves • Biomass to energy technologies.	
Net zero energy buildings	• Overview of the concepts of: Energy performance; zero energy buildings; net-zero site energy; net-zero source energy. • Zero Energy Buildings in the tropics: Early experiences	**Fifth Year / Elective course** The student should be able to: 1. Understand the net zero and the energy-plus concept in buildings and urban design. 2. Design a net zero concept based on the knowledge acquired over the five years.
Net Zero Energy Communities	• Understanding the concept of energy sufficient communities by combining technical and technological means available and appropriate for the local climate and resources.	
Energy Performance Certificates/ Green Building	• The role that these systems play in achieving energy and resource efficiency. • Overview of different systems and certificates around the world.	