Sustainable building strategies to combat climate change in Africa

In response to climate change, we often resort to energy-intensive heating and cooling systems to maintain thermal comfort within buildings. However, passive solar systems (which harness solar radiation) and smart building designs (that create optimal indoor conditions) are now being adopted across Africa to reduce energy consumption. Building on previous investigations into passive solar systems and design, Michael Santos and João Lanzinha (University of Beira Interior, Portugal) and Ana Vaz Ferreira (Polytechnic Institute of Castelo Branco, Portugal) undertook a review of bioclimatic architectural systems. They offer energy-saving strategies that improve thermal comfort in the face of climate change. The researchers also reviewed case studies of rainwater harvesting for conserving water resources with the aim of promoting sustainable construction techniques.

Around the world, energy use, pollution, and economic growth are fuelling climate change. Our actions impact the planet, which in turn impacts us. In a recent review article, Michael Santos and João Lanzinha (University of Beira Interior, Portugal) and Ana Vaz Ferreira (Polytechnic Institute of Castelo Branco, Portugal) share that the residential sector contributes 40% to global energy consumption as people strive for thermal comfort (that is, achieving an ideal indoor environment through heating or cooling) in their homes and business buildings. These processes require significant energy inputs, contributing more than 30% to the world's carbon dioxide emissions. However, there could be a way to harness sustainable development designs to reduce energy consumption.

MONITORING THERMAL COMFORT

But first, how can thermal comfort of users be assessed? Models compiled data on air and radiant temperature, relative humidity, air velocity, metabolic rate, and clotting factor (a measure of blood's ability to clot) to understand how humans respond to uncomfortable environments. We adapt our behaviour or physical state to achieve thermal comfort – we might shiver or put on extra clothes when we (and our environment) are cold but sweat or move closer to open windows when conditions are warm. Ideally, human bodies are comfortable between 21 and 26°C, with a relative humidity between 20 and 70%. However, studies show that building designs themselves can also be adapted to make indoor environments more comfortable.

PASSIVE TEMPERATURE CONTROL

The researchers reviewed literature to identify passive solar systems (which harness solar radiation to control a building's temperature) in African countries that are experiencing severe environmental and socio-economic effects because of above-average temperate rises associated with climate change. Passive solar systems include solar heating, humidification, conventional heating, solar protection, cooling through a high thermal mass, evaporative cooling, air conditioning, cooling through natural and mechanical ventilation, and conventional dehumidification. However, not all of these solutions are currently used throughout Africa.

Simulations can help to assess the effectiveness of such bioclimatic architectural systems with regards to improving a building's energy efficiency using active or passive designs while maximising the user's thermal comfort. Computer programs such as Design-Builder and EnergyPlus can help urban planners to design energy-efficient buildings by ensuring structures are comfortable for the user, meet construction requirements, minimise investment and energy costs, plus limit carbon emissions. However, African countries often have limited financial resources to adopt bioclimatic building designs. This means that, even though these countries have a low contribution to climate change, they often suffer the effects the most. Rehabilitation of buildings across Africa is paramount to improving building energy efficiency, so despite the challenges in developing sustainable buildings, passive solar systems are being adopted in countries across Africa. In fact, numerous African countries (including Nigeria, Algeria, Morocco, Egypt, and South Africa) have building legislation which includes minimum energy efficiency requirements to ensure that developers are planning buildings with thermal comfort in mind.

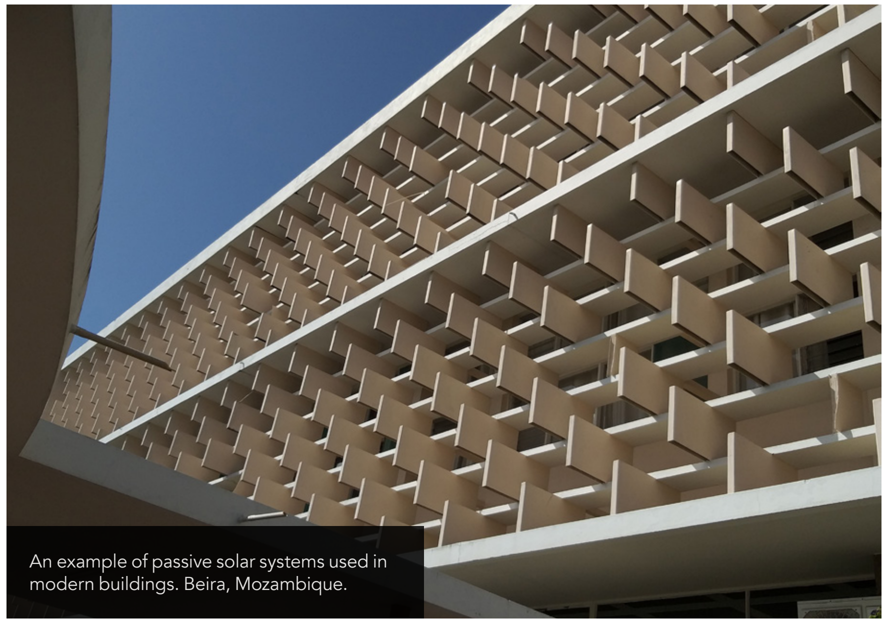
Thatched roofing with extended eaves to provide shade for the openings. Dondo, Mozambique.

The residential sector contributes 40% to global energy consumption as people strive for thermal comfort.

SUSTAINABLE SOLAR SYSTEMS

In passive and active solar heating, buildings capture solar energy in the floor, walls, roof, and through glass windows. In the northern hemisphere, this helps to passively moderate indoor temperatures during different seasons. If buildings are designed with energy efficiency in mind, then new constructions can be orientated to avoid more solar radiation during the summer and conversely capture more heat in the winter. To do this, longer walls should be orientated towards the sun during winter when solar radiation is weaker as the sun sits at a lower altitude in the sky. If a longer wall faces the sun, it increases the surface area over which solar radiation can be absorbed by the building. Conversely, shorter walls should be orientated towards the sun in the summer (when the sun sits higher in the sky) to reduce the amount of insolation the building receives. This design helps to reduce temperature fluctuations within the building, improving energy efficiency and maintaining a comfortable environment for the occupants.

Simulations of Egyptian coastal cities also showed that changing the size, shape, and orientation of urban buildings impacted the air temperature, wind speed, and relative humidity experienced by the structures, and if designed strategically, buildings could improve thermal comfort. Furthermore, energy from passive solar heating of a building can also be captured by solar panels to generate electricity to power conventional heating and cooling systems (for example, radiators and air conditioning units), adding to the sustainability of smart building designs.



An example of passive solar systems used in modern buildings. Beira, Mozambique.

Above 20°C, bioclimatic architectural systems that create shade help to avoid heat gain by buildings. Natural solutions, such as trees or pergolas with vegetation can be placed near to buildings (particularly near openings such as doors and windows) to reduce the amount of insolation these areas receive. Perennial plants will provide shading all year round while deciduous plants shed their leaves in winter, providing seasonal shading. During building design, consideration should be made to orientate windows away from the sun during the hottest parts of the day, with shade provided by, for example, protruding balconies, canopies, or blinds to reduce the amount of solar radiation entering a building and so decreasing the greenhouse effect. Such architectural designs have proven effective in Uganda, where more than 50% of extreme overheating cases during the hottest months of the year have been prevented by shading on or in buildings.

Natural ventilation harnesses the power of the wind and the temperature gradient between external and indoor environments to maintain thermal comfort for building users. However, this process can be supplemented by mechanical processes, such as ceiling fans which reduce the pressure gradient between inside and outside of buildings, reducing the amount of warm air that enters. Other bioclimatic architectural systems include insulating the roof and providing warm air vents on upper floors to allow rising warm air to escape. This latter technique is termed ventilation through the chimney effect and has been used effectively in Mozambique.

Exterior building elements promote shading. Ponte Gêa, Mozambique.

The CUCA cultural center, Beira, Mozambique is an example of African modernist architecture.

COOLING THE AIR

In dry and arid climates (between 20 and 40.5°C) evaporative cooling decreases the temperature while increasing humidity. Green roofs present an ideal solution in urban environments as water evaporates from plants while they draw in carbon dioxide through photosynthesis. A review of green roofs as a thermal comfort strategy indicates that this architectural method can reduce summer heat gain by 70 to 90% and winter heat loss by 10 to 30%. Additionally, Santos, Ferreira, and Lanzinha share their findings that indoor air quality is also affected by humidity. The addition of air channels in buildings helps to create pressure differentials that move air between indoor and outdoor environments. When vegetation is planted near windows, the moisture released through photosynthesis can move into buildings via these air channels, helping to increase indoor humidity and prevent respiratory conditions caused by dry air.

As temperatures rise with climate change, people across African countries are using air conditioning to moderate the temperature of their buildings. Refrigeration and air conditioning units consume approximately 15% of the world's electricity. If this electricity does not come from renewable sources, then people should take measures to reduce energy consumption by turning air conditioning off when they leave the building and not setting the thermostat too cold. Furthermore, powering heating and cooling systems with electricity produced by solar panels makes these buildings self-sufficient and is an ideal energy source for countries across Africa which receive large amounts of solar radiation year-round.

As urbanisation and climate change continue, more cities around the world will experience the urban heat-island affect, where buildings store large amounts of heat during the day and expel it at night. If passive solar systems can instead be used to transfer that solar radiation into buildings for heating or solar panels to generate electricity, then the currently problematic urban heat-island effect can be harnessed to achieve thermal comfort instead. Climate change will continue to shape our landscapes. Africa currently has three climate types: arid, tropical, and temperate. By 2100, projections suggest arid and tropical climates will dominate the continent. Adopting bioclimatic architectural systems across Africa will help people to obtain thermal comfort in their homes and businesses as their environment changes and will reduce energy consumption within the residential sector.

Despite African countries having a low contribution to climate change, they often suffer the effects the most.

Shaded areas around structures is effective for reducing direct sunlight inside buildings.

Behind the Research

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Detail

Bio

Michael Mendes Santos is a civil engineer, Master in sustainable construction from University Zambeze, Mozambique, Master building structures at the Polytechnic University of Madrid, and a PhD student in civil engineering at the University of Beira Interior, Portugal. His research interests cover the areas of sustainable construction and building materials. He currently develops research in the energy and water efficiency of buildings in Mozambique and the recovery of waste for new construction materials.

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Personal Response

Are there any passive solar systems that should be used in African countries that have not yet been tested?

" Passive solar systems are being integrated into buildings in African countries, employing strategies like false facades or solar devices to prevent solar incidence. These elements, with their distinct shapes, materials, and designs, are examples of some solutions construction.

Although numerous passive solar systems have been tested in Africa, there is always potential for innovation and adaptation. Unexplored techniques, such as building-integrated photovoltaic-thermal systems (BIPV-T), warrant further research to determine their effectiveness in African climates. Implementing and testing region-specific designs that take into account local materials and cultural practices can optimise the efficiency of passive solar systems, making them more accessible and suitable for diverse communities across the continent. "