Sustainable Architecture in Hot Regions:
The SURE-Africa Project

MANUEL CORREIA GUEDES¹, GUSTAVO CANTUÁRIA², KLAS BORGES³, ITALMA PEREIRA¹, JOANA ALEIXO³, LUIS ALVES¹

¹Instituto Superior Técnico, Lisbon, Portugal
²The Martin Centre for Architectural and Urban Studies, University of Cambridge, UK
³Department of Land Economy, University of Lund, Sweden

ABSTRACT: This paper summarizes the results achieved by the 3-year E.U. SURE-Africa project. The project aimed at strengthening knowledge and its application in practice, contributing to a sustainable development through the vital area of energy efficiency in buildings and cities, and, ultimately, to reduce poverty. Academic and professional expertise from three E.U. Universities - namely the Higher Technical Institute (IST, Coord., Portugal), the University of Cambridge (UK) and the University of Lund (Sweden) - was organised to set up a data-base of information, in cooperation with Academic Institutions in Portuguese-speaking African countries (Angola, Mozambique, Cape Verde and Guinea), with information about tools, case studies and teaching material in the field of sustainable, energy-efficient building and urban design. Seminars, workshops and conferences were carried out, and best-practice Manuals were published as a final outcome of the project.
Keywords: Sustainable Architecture, Hot Regions, Energy Efficiency in Buildings, Africa.

INTRODUCTION
The SURE-Africa project aimed at producing and strengthening knowledge on low-energy architecture for hot regions, contributing to a sustainable development through the vital area of energy efficiency in buildings and cities and, ultimately, to reduce poverty. The situation found in the participant countries was representative of many other countries in Africa, with developing economies often scarred by long-term armed conflicts. Building and urban renewal have an urgency that requires a different approach to the incorporation of renewable technologies from that in Europe. This is due to the scarcity of resources, the pressing demand for social housing and refurbished or new public buildings such as schools and hospitals, and the difficulties of implementing building and town planning regulations (often deficient or even non-existent).

It is important to consider energy conservation through passive building design as a proven equivalent to renewable energy power generation. The project adapted well-established knowledge in this area to the economic and climatic context. Emphasis will be on net demand reduction rather than generation; this approach making less downstream demands for maintenance and replacement, and being more compatible with traditional life-styles. In non-domestic buildings, a high priority was the avoidance of air-conditioning. In the case of housing, it is important that basic comfort performance criteria are met, since failure in this respect will prompt the occupants to purchase package air-conditioners if and when reduced costs and improved finances allow.

The project has also drawn from existing areas of expertise in post conflict reconstruction, trying to resolve inevitable conflicts between the short-term need, and the longer-term imperative of sustainability. It recognised, that in the area of housing in particular, there is much self-build, and it was acknowledged that the support materials must not only be accessible to the design professional but to the layman as well.

The overall objective is to create a network of practical and scientific knowledge between African and European Universities, in the field of energy-efficient building and urban design. Training workshops, Seminars and Conferences were held in each of the African countries involved (Cape Verde, Guiné-Bissau, Angola and Mozambique). Within this programme different target groups (local politicians, teachers, professionals, students, self-builders) were addressed at appropriate levels.

Academic and professional expertise from three E.U. Universities - namely the Higher Technical Institute (IST, Coord., Portugal), the University of Cambridge (UK) and the University of Lund (Sweden) - was organised to give the lectures at all training courses and workshops, and to contribute to documentary material. A database of information was set up, in cooperation with Academic Institutions in Africa, with information about tools, case study exemplars and teaching material in the field of sustainable, energy-efficient building and urban design. Best-practice manuals are also being published as a final outcome of the project. The basis for long term collaborative research on energy efficient and sustainable construction were developed during this 3-year E.U. COOPENER project.
PROJECT RESULTS
The main, long-term, objective of the project was to establish a network of practical and intellectual knowledge between African and European Universities in the field of sustainable, low-energy building design and construction. The project has enhanced the communication and information exchange between higher education institutions in the EU and Lusophone African countries in the field.

Several steps were taken for this purpose, following the initial workplan, mainly:

- Development of a website, which is updated regularly as a central resource for information and communication (http://www.sure-africa.org).
- Organisation of Project meetings and production of Reports.
- Planning, organisation and realization of Seminars and Workshops that took place in Cape Verde, Angola, Mozambique and Guinea-Bissau, with participation of the various institutions involved. The Seminars and Training Workshops were designed based on the identification of the specific needs and constraints existing in each of the African countries involved, and successfully delivered.
- Publication of the Best-Practice Manuals and teaching material. The Best-Practice Manuals are pioneer publications in this area (a reference not only for Portuguese-speaking countries but also for other African countries), and are one of the main outcomes of the project.

The Seminars and Training Workshops
Together with the publication of the Best-Practice manuals, the realization of the various Seminars, Training Workshops, and Conferences were one of the most important achievements of the project. Theses three types of events were distinct in nature. The Seminars consisted on series of presentations, with moments for queries between each presentation, and audiences involved a diversity of attendees, from Government and Local Authorities Representatives, to Professionals of the Building Sector (Architects, Engineers, Builders, Representatives of the Professional Orders and Associations), Academics and Students. In general, attendance was made by Invitation (from the Local Team Coordination). The Training Workshops were mostly directed to University Students and Professionals (mostly Architects and Engineers), and took place generally after the Seminars (where various presentations were made); in these, discussions were encouraged on various topics, questions (of a practical nature) were posed and answered, and case studies were analysed. The Conferences were opened to the general public, including a broader audience, and were generally opened and closed formally by important personalities (Government, Dean of the University).

In Angola the Seminars, Training Workshops and Conference took place in the premises of Faculty of Civil Engineering and Architecture of UAN. The seminars took place in the first days, to an audience of mostly students, academics and professionals. Informal workshops were realized after the end of each day, mostly with students, where a number of issues were debated. The final event was a conference, opened by the Minister of Environment and the University Dean, where a series of presentations were made, both by Local (e.g. Town Hall Architects and Engineers, University Staff) and EU experts.

In Cape Verde, two series of Seminars and Workshops were carried out, one in Praia Island (City of Praia, Capital of Cape Verde) and another in the Island of S. Vicente, at the M_EIA premises (City of Mindelo). Attendats were mostly professionals (Architects, Engineers), Academics, and representatives of local Government (Town Hall) and the Order of Architects and Engineers. A final conference was also realized in Mindelo (in collaboration with other institutions), at the Town Hall, opened to the general public.

In Guinea-Bissau, both the Seminars and the Conference (at the Franco-Guineese Institute’ Auditorium) had a high-profile attendance, including representatives of a number of Official and Private Institutions.

In Mozambique, the Seminars’ audience in Mozambique was about 90-100 people, mostly representing State Institutions, Academic Staff, and students. Some NGO’s were also present. A special presentation was made for students, at the Faculty.
Publications

A series of publications were produced by the project, being the most important ones the Best-Practice Manuals and Teaching Material (Brochures and Slides). A number of other publications were also produced, namely press releases and advertisements made during the Seminars in Cape Verde, Angola, Mozambique and Guinea-Bissau including TV and radio news and interviews, web postings, posters, flyers, etc. However, the bulk of the publications were the Best-Practice Manuals - a reference not only for Portuguese-speaking countries but also for other African countries, and are one of the main outcomes of the project.

One Manual – “Manual of Sustainable Architecture”- was produced for each country involved: Angola, Cape Verde, Guinea-Bissau and Mozambique, with approximately 200 pages each. They are destined to be used by professionals, academics, and general public. The Manuals include a general overview of the local context (social-economic, climatic, cultural, local resources and technology, etc) and present a set of design recommendations, applicable to most types of buildings – from self-construction to more complex buildings, such as offices or touristic infrastructures. They also include recommendations on other critical issues, such as urban planning, the use of water, and the use of renewable energy systems. A number of local case studies are presented.


**RESEARCH EXAMPLES**

*Case Study 1: Guinea-Bissau*

**Context**

Building in Guinea-Bissau involves facing particular climatic conditions and the urban problems common to tropical countries. The lack of urban identity, particularly in the capital, Bissau, together with unregulated construction projects, the degradation of urban buildings, a housing deficit combined with a massive influx of poor rural people, urban growth without planning, and low comfort levels inside buildings are the general problems [3].

Powerful climatic agents such as high levels of solar radiation and air humidity, and torrential rainfall, challenge builders and architects to create sustainable ways of providing security, comfort, and economic satisfaction for the final building users [4] [5]. Studies developed for tropical climates, presents the promotion of ventilation through openings and the prevention from climate agents as the key strategies [6]. In terms of town planning, regulations regarding regular road planning for the passage of breezes, and shade from trees, are considered crucial [7], not only protecting buildings from overheating, but also protecting roads from the consequences of rainfall.

**Purpose**

The aim of this research was to assess the characteristics of sustainable construction in Guinea-Bissau and, in doing so, to: i) study the main strategies for sustainable design in tropical warm and humid regions; ii) analyse energy and comfort performance of typical building types existing; iii) produce best-practice recommendations for sustainable design in Guinea-Bissau. The main question analysed was whether comfort is achievable solely by the use of passive design strategies, or if energy consuming mechanical systems are required. The aim is to reduce of both cooling and artificial lighting energy loads through passive design strategies, which can be complemented with active systems, powered by renewable energies, such as solar photovoltaic.

**Methodology**

In order to study building performance in the architecture of Guinea-Bissau, fieldwork was carried out in the country, when measurements of comfort levels in the interior of buildings were taken, and users’ comfort perceptions and opinions on their residences’ performance recorded through questionnaires, in addition to producing an extensive collection of photographs of the architectural range.

**Architectural Typologies**

Local architecture can be classified in terms of construction properties and by function type - public, private, cooperative, each focusing on a specific social and economic strata. The public sector serves families with no economic power, whilst the private sector promotes housing for economically stable and socially stratified wellbeing. In the middle, the cooperative sector meets the needs of the low middle class, organized by ministries or institutions, generally for their employees. Apart from these, spontaneous constructions are common in rural areas and suburban environments, powered by rural or the poorest people [3].

Considering the above, the architecture of Guinea-Bissau is characterized as follows:

I. Vernacular architecture - traditional housing with rammed earth or adobe walls and straw fibre roofs (6 - left), now with the straw roof being gradually replaced by zinc foil, especially in rectangular housing (6 - right), providing durability, light, waterproof properties and low maintenance requirements, but, on the other hand, poor thermal and acoustic insulation and requiring additional care in preventing corrosion. The best practice would be a double covering of zinc and straw, adapting the durability of the former to the better insulation properties of the latter, 7;

![Figure 6: Vernacular architecture (left). Replacing straw roof with zinc (right).](image)

II. Colonial architecture - colonial dwellings built with concrete blocks and a tile or cement panels cover, in the urban centres of the main cities (Cacheu, Bolama, Bissau, Gabú); Generally tall ceiling buildings, with a covered veranda at the front and overhangings above the openings (Figure), showing concerns with heat protection and dissipation;

![Figure 7: Double roof system, with aluzinc foil under a straw-covered roof.](image)

III. Contemporary trends - dwellings built with prime materials such as reinforced concrete for structure, bricks or concrete blocks on the walls, and clay tiles on the roof, in which concerns with ventilation and solar protection are sometimes present (9 - left); Ecotourism constructions are considered a contemporary trend as well, using natural raw materials such as earth, straw and timber; In the image below (9 - right), the elevated floor of the house prevents humidity and promotes ventilation from below;

![Figure 8: Colonial dwelling in Bissau city.](image)
Quelélé ort was from midday to 3 pm. Nevertheless, users revealed satisfaction with shading systems on their residences, as well as natural lighting, ventilation and security.

![Figure 9: Contemporary trends - modern dwelling (left), and ecotourism housing (right, picture from C. Schwarz).](image)

Nowadays it is also relevant to describe cooperative neighbourhood housing, characterized by dwellings built with reinforced cement, adobe and covered with zinc, in the periphery of urban zones (10 - left), or high-rise social housing consisting of 3 or 4 floors, built with the aid of international protocols (10 - right);

Figure 10: Cooperative housing in Bissau.

**Case study analysis**

The case study focuses on analysing the typologies of existing buildings, with regard to comfort, cost and reduction of the energy loads.

Three dwellings were analysed, in terms of humidity and temperature levels in specific urban zones: i) colonial dwelling - concrete blocks on walls and clay tiled roof (Chão-de-Papel zone); ii) cooperative dwelling - adobe walls and zinc roof (Plano - coastal zone); iii) contemporary dwelling - brick walls, and clay tiled roof (Quelélé zone).

The outside temperature results, Table 1, confirm that the worst outside temperature is in the Quelélé neighbourhood, which has a temperature range of 10°C, for which strategies such as night purge ventilation and thermal inertia are important prescriptions.

![Table 1: Outside temperature.](image)

<table>
<thead>
<tr>
<th></th>
<th>Plano (ºC)</th>
<th>Chão-de-Papel (ºC)</th>
<th>Quelélé (ºC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max.</td>
<td>29.8</td>
<td>31.8</td>
<td>32.1</td>
</tr>
<tr>
<td>Mean</td>
<td>26.4</td>
<td>26.9</td>
<td>26.6</td>
</tr>
<tr>
<td>Min.</td>
<td>23.6</td>
<td>23.5</td>
<td>22.3</td>
</tr>
</tbody>
</table>

Although it has a similar mean exterior temperature, the dwelling in the Plano zone shows higher comfort values for inside temperatures (Figure) because of the benefits of the coastal breezes. Even with clay tiled roofs and clay brick walls, better-known for their thermal insulation properties, the contemporary dwelling in Quelélé does not reveal the best thermal behaviour, due to its location, far from coastal zones.

With regard to comfort conditions, most of the inquired users experienced climate discomfort, generally caused by high temperature levels and humidity (Table 2), the latter mostly in the rainy season. The worst period mentioned for temperature discomfort was from midday to 6 pm in general, and more specifically from midday to 3 pm. Nevertheless, users revealed satisfaction with shading systems on their residences, as well as natural lighting, ventilation and security.

![Table 2: Users’ satisfaction perceptions, from very satisfied (VS) to Satisfied (S), Dissatisfied (D), and very Dissatisfied (VD).](image)

<table>
<thead>
<tr>
<th></th>
<th>VS (%)</th>
<th>S (%)</th>
<th>D (%)</th>
<th>VD (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>3</td>
<td>31</td>
<td>44</td>
<td>22</td>
</tr>
<tr>
<td>Humidity</td>
<td>5</td>
<td>52</td>
<td>29</td>
<td>14</td>
</tr>
<tr>
<td>Shading</td>
<td>13</td>
<td>76</td>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td>Natural lighting</td>
<td>14</td>
<td>66</td>
<td>16</td>
<td>4</td>
</tr>
<tr>
<td>Ventilation</td>
<td>16</td>
<td>55</td>
<td>18</td>
<td>11</td>
</tr>
<tr>
<td>Security</td>
<td>20</td>
<td>55</td>
<td>17</td>
<td>8</td>
</tr>
</tbody>
</table>

Users’ preferences also revealed that 64% preferred a concrete block wall and 83% preferred a tiled roof, based on perceptions of high resistance, durability, availability, aesthetic qualities, and thermal insulation, in opposition to adobe walls and zinc.

In the last part of this case study, a climate analysis and building simulation were carried out using Ecotect, an environmental building analysis software which allows the thermal response of a building, in terms of energy efficiency, or discomfort levels. The aim was to optimise the performance of a representative house, according to local climatic conditions, materials and available technologies, thus reflecting the economic viability of the chosen solution.

Annually temperature average ranges between 20 and 35°C. After a careful statistical analysis of the climate data, September 22 was defined as the typical day, with the temperature values shown below in Table 3 being the figures that occurred most frequently in an analysis of all 365 days of the year.

![Table 3: Temperature Values for September 22.](image)

<table>
<thead>
<tr>
<th></th>
<th>Min.</th>
<th>Mean</th>
<th>Max.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature (ºC)</td>
<td>23.3</td>
<td>28.5</td>
<td>34.3</td>
</tr>
</tbody>
</table>

Initially, three existing models were analysed, two vernacular buildings (Rammed earth 300 mm, Straw 150 mm; and Rammed earth 250 mm, Straw 150 mm); and one colonial model (Concrete block 250 mm, Fibre-Cement panels 8 mm). The results in terms of air...
temperature inside each (Table 4) show that the square vernacular house performed best.

Table 4: Air temperature in the rooms in each house and outside, on a typical day.

<table>
<thead>
<tr>
<th></th>
<th>Circular model</th>
<th>Square model</th>
<th>Colonial model</th>
<th>Outside</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean (ºC)</td>
<td>29.32</td>
<td>28.80</td>
<td>29.65</td>
<td>28.5</td>
</tr>
</tbody>
</table>

From the results obtained, a contemporary dwelling was designed, simulating the following parameters: orientation, glazing percentage, shading device systems, natural lighting, thermal inertia, insulation systems, and ventilation. The study was conducted in terms of reducing annual energy consumption and the best results for each of the simulated strategies are illustrated in Table 5. The solution initially tested had concrete blocks (200+50mm), tiled roof and no insulation system.

Table 5: Loads consumption for cooling.

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Best result</th>
<th>Loads (kWh/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orientation</td>
<td>E-W axis</td>
<td>-</td>
</tr>
<tr>
<td>Glazing</td>
<td>30-30-15-15 (%)</td>
<td>6.11</td>
</tr>
<tr>
<td>Lighting</td>
<td>Architectural optimisation</td>
<td>5.75</td>
</tr>
<tr>
<td>Shading</td>
<td>Veranda at front, overhangings around</td>
<td>4.39</td>
</tr>
<tr>
<td>Thermal inertia</td>
<td>Brick (200+50mm)</td>
<td>3.49</td>
</tr>
<tr>
<td></td>
<td>Concrete block (250+50mm)</td>
<td>3.98</td>
</tr>
<tr>
<td>Insulation on the covering</td>
<td>Sandwich panels (zinc+insulation)</td>
<td>4.44</td>
</tr>
<tr>
<td></td>
<td>Ceiling - Fibre glass</td>
<td>4.05</td>
</tr>
<tr>
<td>Insulation on the walls</td>
<td>Exterior insulation</td>
<td>3.37</td>
</tr>
<tr>
<td></td>
<td>Double brick plus cavity - insulation</td>
<td>3.35</td>
</tr>
<tr>
<td>Both walls and roof insulated</td>
<td>Sandwich panels + concrete block with exterior insulation</td>
<td>3.43</td>
</tr>
<tr>
<td>Ventilation</td>
<td>Mixed-mode system</td>
<td>0.83</td>
</tr>
</tbody>
</table>

Brick walls were simulated and this proved to be the best material (without insulation), however it is important to note that they are not produced or sold at present in Guinea-Bissau. Alternatively, when the thickness of the concrete blocks was increased (250+50mm) the results were also satisfactory.

For the purposes of this study we decided to proceed with default materials of the minimum legally prescribed thickness [8] (concrete block walls with 250mm), adding insulation systems (exterior insulation and sandwich panels) considering its economic benefits. The best result is achieved by ventilation promote, here simulated by the openings prescription, and a mixed-mode system, a combination of air-conditioning and natural ventilation where the HVAC system shuts down whenever outside conditions are within the defined thermostat range (20-28°C).

Case study 2: Southern Angola

Context

Angola has seen 30 years of armed conflict, resulting in great human and material damage. Today it is growing at a fast rhythm, with the creation of new urban centres, residential areas, business, shopping, etc. However, not always is the city planning or building construction appropriate to the local climate and, often, to the social environment: glass towers are raised in a tropical climate; the buildings have large glazing areas without any shading or natural ventilation. The result is an uncomfortable interior, requiring the use of air-conditioning and involving unnecessary spending of energy.

Angola is a country of contradictions - the lack of housing conditions and the unsustainable construction clashes strongly with the economic potential of the country. It is urgent to have an answer, a contribution so that the urban growth can be conducted in a sustainable manner, helping to reduce poverty levels and assigning sufficient housing conditions to everyone.

The study of traditional contexts concerns the search for constructive answers for examining the behaviour of vernacular housing models, given the geographic and climatic context in which they operate. This will be essential to understanding how those housing models perform, evaluating their best abilities and major weaknesses, thus proposing improved solutions.

In order to address this work to specific contexts, the case study focus on two sub-ethnic groups, the Kuanhama belonging to the group Ambó [9], and Kuvalé, belonging to the Herero [10], both of Bantu origin. The option comes from the particularity of both Kuanhama and Kuvalé being two sub-major groups within each group above (in number or influence). Both Kuanhama and Kuvalé locate in Southern Angola.


In addition good examples of solutions in other countries should be referenced, in response to the growing need to adapt the building to local contexts, reducing energy costs and minimizing the environmental impact, such as the ones of Baker, 1986 [16], Bay and
Ong, 2006 [5], Cougey and Oliva, 2006 [17], Dresser, 1996 [18], and Lauber, 2005 [4].

Purpose

The main objectives of this work are to: i) gather information about the vernacular housing model (12), its evolution and current framework in the urban space (13), of two southern Angola regions; ii) analyze the construction methods and environmental performance of these models and other models of existing housing within the urban space, comparing the results; iii) propose solutions for passive architecture construction development, including renewable technologies, with a view to its future implementation in dwellings at affordable rates.

Methodology

Starting from general to detail, it is vital to understand all the procedures in terms of legislation and its local applicability, at the current state of vernacular housing in both rural and urban areas and, finally, at the construction processes and economic implications. In this sense it will be made on site:
- Survey about how legislation and policies could be applied to promote housing, urban and territorial development in the study area;
- Survey of architectural typologies and design features;
- Monitoring and analysis of the environmental performance of buildings (involving the use of Data Loggers);
- Queries to the population (rural and urban), in order to understand the criteria and expectations.

Monitoring the environmental performance of buildings through the use of Data Loggers is essential since it allows the measurement of levels of comfort, namely, identifying and assessing existing environmental comfort problems. The results can then be used in comparisons to results of computer simulation, also vital.

Case study analysis

Computer simulations of the environmental performance of the building were developed:
Existing buildings computer models was carried out, using Ecotect software for the environmental performance simulation (Figs. 15 and 16).

Once analysed the energy consumption of the existing building model, the results showed very high levels of cooling needs. In order to minimize such results, several materials such as rammed earth, cement brick, insulation among others were tested in the model, as well as some glazing and shading devices variations on the facades.
The obtained results allowed the evaluation of the buildings behaviour, identifying key issues and pointing out some solutions to them. The main conclusions are summary presented below in the Conclusion section.

**Study’s conclusions**

The two presented case studies were set under the goal of understanding low cost building, fitted to specific geographic and social-economic environment, seeking to optimize their energy consumption, as well as their general performance.

By applying techniques of passive architecture not only the comfort within the building interior is optimised, but also, the energy demand during the building lifetime is reduced to minimum.

The main conclusions to be drawn from the Guinea-Bissau case-study are:
- Good practices start with orientation on E-W axis, minimum glazing distribution to East and West facades, and shadings prescriptions;
- The main concerns involve prevention of overheating, considering that the main loading requirements are for cooling systems;
- Natural ventilation is a relevant strategy, which acts on heat dissipation;
- The use of mechanical cooling systems may be necessary, however it is possible to reduce its requirement to minimum;
- The use of insulation systems like polystyrene, improves buildings thermal performance, without cost rise; Solutions like sandwich panels for roof can easily replace tiled roof, and concrete block walls exterior insulated, substitutes brick walls without compromising comfort levels. However, rammed earth walls on existent buildings have better performance than the usually used concrete block without insulation (on urban domains);
- The main conclusions to be drawn from the Southern Angola case-study are:
  - The optimum orientation for the building is also an E-W axis orientation;
  - Minimum glazing distribution to East and West facades, 15% to 30% maximum of glazing areas in South and North facades, horizontal and vertical shading devices on East and West facades and horizontal ones on South and North facades are passive strategies which improve the building behaviour;
  - Rammed earth walls on existent buildings also have better performance than the usually used concrete block without insulation;
  - Southern Angola regions have high temperature ranges between night and day, being useful to apply in the building some other passive cooling techniques such as daytime and night ventilation, thermal inertia, evaporative cooling and humidification, turning it more comfortable.

The improvement of the projects in terms of energy efficiency, reducing lighting and artificial cooling systems requirements, are important for both Angola and Guinea-Bissau. For those countries, local materials production and the renewable energy resource, should integrate the priorities of the local public administration.

It is important to state as a final note that one of the limitations of Ecotect 5.20 version is the fact that it does not provide system simulation; just cooling loads were here simulated.

Although the relevance of this study in determining the potentiality of passive design strategies, more investigation is required before taking any further conclusion.

The work done under the Sure Africa project represents a basis for further research on traditional and modern construction and architecture in Africa, one that is currently in development, under the PhD in Architecture at the Instituto Superior Técnico, on "Low cost housing in southern Angola", and another on “Sustainable construction and urban rehabilitation in western African countries with tropical climate - Case study Guinea-Bissau” to be developed under a PhD in the Instituto Superior Tecnico in collaboration with the Infrastructure Ministry of the Republic of Guinea-Bissau.

**FUTURE ACTIONS**

There is no doubt that the SURE-Africa project was the “embryo” for a long-lasting future collaboration. Various research and student exchange protocols are being formalised between E.U. and African Institutions as a direct result of SURE-Africa. A Network of Sustainable Architecture and Urban Design is also being created for Lusophone countries (including Brazil), which is now on the process of being extended to Universities existing in other countries.

The consortium is also considering candidacy for new joint projects in the line of SURE-Africa. The team is at the moment preparing another funding candidacy for a new project, a continuation of SURE-Africa for other Lusophone countries such as S. Tomé e Príncipe and Timor (local colleagues have already shown great interest in joining in). The existing team will also be dilated to include other universities.

The results of the Project are now going to be further disseminated, both in terms of the distribution of the manuals, the maintenance of the website, the participation in International meetings, and publication in peer-reviewed magazines.

**CONCLUSIONS**

The general opinion of all teams is that good work was made, with enduring impact. This project was the starting point for future projects, so necessary in the area. The most valuable deliverables were the Seminars, Training Workshops and Conferences, and very importantly the Best-Practice Manuals, which are a pioneer publication in this field of studies.

One is certain of the creation of future long-time links between the various teams of the SURE-Africa project.
The project is achieving one of its most important aims: being the embryo for a future extended network of information between EU and African Institutions.

ACKNOWLEDGEMENTS

This research was co-funded by the Community of Portuguese Speakers Countries (CPLP), the European Union, and the Foundation for Science and Technology.

REFERENCES