PRELIMINARY SECTOR STUDY OF ADAPTATION TO CLIMATE CHANGE IN AFRICA

CONSTRUCTION AND BUILDING

CLIMATE NEGOTIATIONS FOR ALL AFRICA SUCCESSFUL (NECTAR)

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PRODUCED BY:

GRET – GROUPE DE RECHERCHE ET D’ÉCHANGES TECHNOLOGIQUES
# PLAN

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LISTE OF ACRONYMS

• COP: Conference Of the Parties
• CFC: ChloroFluoroCarbon gas
• GEF: Global Environment Facility
• GHG: Green House Gas
• LDC: Least Developed Country
• LED: Light-Emitting Diode
• LPG: Liquefied Petroleum Gas
• HFC: HydroFluoroCarbon
• HEP: High Energy Performance
• HEQ: High Environmental Quality
• CDM: Clean Development Mechanism
• JI: Joint Implementation
• NAMA: Nationally Appropriate Mitigation Action
• NAPA: National Adaptation Program of Action
• HP: Heat Pump
• GDP: Gross Domestic Product
• PPP: Public-Private Partnership
• PoA: Program of Activities
• REDD+: Reduced Emissions from Deforestation and Degradation
• SHW: Sanitary Hot Water
• TNA: Technology Needs Assessment on climate change
• UNITAR: United Nations Institute For Training and Research
• CER: Certified Emission Reduction
• MCV: Mechanically Controlled Ventilation
• R&D: Research and Development
• UNDP: United Nations’ Development Program
• UNFCCC: United Nations Convention on Climate Change
• UNITAR: United Nations for Training and Research
Introduction

Throughout the study, the terms “building sector” and “construction sector” will cover on one hand, residential and tertiary buildings, including household activities; and on the other hand, the chain of actors, techniques, tools, materials and activities involved in the tertiary and residential construction sector.

The study will focus on the following aspects:

- Construction and renovation;
- Thermal variations related to heating, cooling and ventilation in buildings (residential and tertiary);
- The activities involving energy consumption and GHG emissions: mainly lighting, electricity, and production of Sanitary Hot Water (SHW);
- Cooking as it currently represents 50% of energy consumption in Africa;
- And upstream activities, such as the industrial and small-scale local activities involved in building construction: the manufacturing of materials and installations and other construction site activities.

In addition, in order to estimate the GHG emissions of households, GHG emissions related to domestic waste disposal should be taken into account.

However, the questions of town-planning, means of transport, and land-planning will not be analyzed in this study.

The residential and tertiary building sector has three contrasting characteristics when it comes to climate change:

- The sector represents 4/5 of energy consumption and GHG emissions in Africa, including biomass for cooking purposes;
- Yet, there has been very little financial support for projects via the CDM or the Adaptation Fund in this sector;
- Furthermore, there are very few analyses on a quality of construction that would improve the life conditions and the level of comfort within a low-carbon development perspective;
- The new mechanisms discussed within the climate negotiation arena - mainly NAMAs and REDD+ - bring new hope for the post-Kyoto agreement because they can frame multiple small and large-scale projects.

This last point is crucial. However, at this stage, there are many uncertainties as to the outcome of the Copenhagen conference (December 2009), and as to the instruments chosen for the post-2012 agreement: what financial capacity? What governance? What fields of action?

This report is structured into 4 chapters:

- **Chapter 1** describes the African building sector’s current situation; how it is affected by and how it affects climate change;
- **Chapter 2** analyzes the possible technical and technological improvements on two aspects:
a) What is quality of construction required to achieve, on the longer term, a positive energy building adapted to climate and cultural specificities?

b) How can biomass consumption for cooking purposes be reduced?

- **Chapter 3** makes an inventory of the financial instruments available for development and climate policies;
- **Chapter 4** recommends the financial means that could be
  a) Used to support various types of projects,
  b) Build up sustainable activities in the construction and renovation sector.

However, this study should serve as a basis for further analysis by 2010: on one hand, a more in-depth analysis of the recommendations for the post-Kyoto agreement; and on the other hand, detailed technology, GHG emission and cost analyses.

## 1 – Inventory of the building and construction sector in Africa

### 1.1 – Buildings in Africa

#### The sector’s history

Historically, the African building sector has two energy-related specificities:
- Before the colonial period, town-planning did not exist outside of North African countries. Shelters were built in local materials available in the rural zones: wood, clay, vegetal/animal fibers.
- These buildings had no energy requirements other than the firewood needed for cooking purposes. They were designed to protect inhabitants from overheating and direct sun exposure. In mountainous regions, firewood was used for heating needs.

#### Recent constructions and designs did not take into account energy-related questions

In the past 50 years, energy was not considered a crucial stake when designing and constructing buildings because “energy” was understood to cover heating needs only. However, with the increasing need for electricity in the past decades, this perception is no longer justified.

Indeed, the residential and tertiary sectors are responsible for 72% of Africa’s final energy consumption, 2/3 of which for cooking purposes. This high figure is also due to unusually low energy consumption in other sectors (i.e. industry, transportation, agriculture).

Furthermore, most of the energy-consuming activities in the residential and tertiary sectors are low-yielding and performed in inadequate conditions.

**Traditional constructions**

Traditional shelters were adapted to the weather conditions and local specificities. African architects used very simple techniques to avoid overheating:
- Shapes that reduce the direct impact of sunrays;
- High thermal inertia in the walls;
- Vegetal surroundings for shade and humidity;
- Roofs made of low heat-transfer materials (mainly, vegetal fibers in sub-Saharan Africa);
- Strong natural ventilation, particularly in highly humid zones.

**Recent constructions**

As cities started to develop and demand for housing increased quickly, traditional constructions techniques were slow replaced by industrial processes and materials manufactured rapidly.

The new and « modern » buildings were conceived with techniques suited to the North temperate climate of the industrialized countries. This design was “easy” because the materials were mass-manufactured. This mass construction was able to respond to the yearly 3% growth in housing demand (compared to 1% in industrialized countries). However, it soon proved unsuited to the climatic conditions on the African continent:

- Lack of protective shutters,
- South-oriented windows,
- Non-oriented and non-insulated,
- Low thermal inertia,
- Concrete constructions.

These inadequate construction techniques and choices affected life conditions in the warmer seasons, further worsened by climate change impacts. This consequently induced the development of air-conditioning, particularly in the tertiary sector and in the public administration, to make life in the office more bearable.

The impacts of climate change have induced the need to question this obsolete conception of construction and comfort requirements.

**Informal settlements**

The issue of informal settlements should also be addressed in a new light. 50 to 75% of constructed areas in sub-Saharan Africa are considered as informal settlements. Informal settlements grew as cities developed and attracted more and more people (phenomenon further intensified by strong demographic growth and rural exodus). It shows that the construction sector cannot industrially, logistically or financially face the mass housing demand.

These informal constructions have generic characteristics: lacking access to water and electricity, dependence on firewood for cooking purposes, use of easily found construction materials (wood, concrete, and sheet metal). Unfortunately, corrugated iron (roof), and concrete breeze blocks (walls) are materials that conduct heat more than traditional materials (clay and fibers).

**Energy efficiency in buildings**

There are forerunning countries in Africa in the field of energy efficiency in buildings. For example, Tunisia has had an energy efficiency policy for over 20 years. The country set up an institutional and regulatory framework; and launched a national program promoting the rational use of energy and renewable energy resources.

Other countries, Algeria for example, have already constructed « High Energy Performance » (HEP) and “High Environmental Quality” (HEQ) buildings.
New expectations

This historical evolution is now facing new social demands induced by the development process.

New energy-related needs

Evolutions in life conditions and expectations, demographic growth, the availability of new electric appliances to make housekeeping life easier and the growing scarcity of wood resources have generated new energetic demands and needs. In particular:

- Electricity for lighting, refrigeration, housekeeping appliances, audiovisual appliances, telephones…;
- Sanitary Hot Water (SHW);
- The need to replace firewood or coal for cooking purposes, to avoid the overexploitation of the forest cover, to reduce indoor air pollution, and to adapt to urban lifestyles.

Constructions that were designed without taking into consideration the energy needs and climatic conditions are now facing an increasing energy demand for the most basic needs (that are also increasing). Satisfying these needs depends on each country's capacity to electrify peri-urban and rural areas.

The abovementioned needs do not directly question the architectural choices and construction techniques. However, they require access to public utilities, i.e. a connection to the drinking water, sanitation and electricity networks.

Communities are progressively increasing their comfort expectations

Aside from the abovementioned basic yet vital needs, individual and community expectations - in terms of thermal comfort - are evolving. Ventilation and air-conditioning are more and more considered as “vital”. This demand for “cooling” is even more so increased by global warming as it affects life conditions during heat waves. Cities are selling, buying and using more and more air-conditioning appliances which emit a fluorinated gas that is partially responsible for global warming. The development of air-conditioning is an issue because the available appliances are of mediocre quality and have leakage issues.

Adaptation in buildings represents a vital challenge for Africa: on one hand, it will be the continent most affected by climate change and by the increasing prices of fossil fuels; on the other, it will face an increasing demand for housing, comfort and higher lifestyle expectations.

Furthermore, based on the recent evolutions of climate change, it appears that the extreme climatic events (i.e. droughts, floods) will become both more extensive and intensive, making it necessary to adapt existing and future buildings to these phenomena.

In addition, modern and inadequate architectural designs have increased cooling needs and air-conditioning consumption in African cities and towns. The electricity powering air-conditioning appliances is generally produced in decrepit low-yielding plants reliant on fossil fuel, and conveyed through a decrepit electricity network. In these conditions, low quality air-conditioning becomes a major GHG emitting activity. The growing demand for air-conditioning generates more peaks in electricity production during the day. The electricity sector is often unable to meet this demand and this slows down the electrification process in rural zones.

The increasing demand for cooling appliances has induced the need for an in-depth review of architectural and constructive processes.
In the context of climate change, the next housing stock must reconcile economic growth, social development and curb the increase in GHG emissions and in non-renewable energy consumption.

The share of buildings in energy consumption and GHG emissions

According to the World Bank, buildings (including cooking and water-heating activities) currently consume:
- 30 to 40% of the world’s primary energy produced;
- 4/5 of the energy consumed in developing countries.
These trends were also observed in African countries.

<table>
<thead>
<tr>
<th>Final energy consumption for each source of energy, in the building sector:</th>
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<tr>
<td>• Electricity: 4%,</td>
</tr>
<tr>
<td>• Petroleum products: 20%,</td>
</tr>
<tr>
<td>• Biomass: 76% (mainly, firewood, coal, farm residues)</td>
</tr>
</tbody>
</table>


The building and construction sector: a high stake in developing countries

Five considerations arise from the previous analysis:

The building and construction sector is becoming the main GHG-emitting sector in the world

According to a « business-as-usual » CO2 emission scenario, the building/construction sector could emit up to 7Gt in developing countries. Residential and tertiary activities could consume up to 2/3 of the electricity available. However, this growing emitting sector also has great energy saving and mitigation potential, using technologies within reach.

It is a crucial sector because buildings have a long life span

What is built today will last until the end of the century. It doesn’t matter that for the time beign, Africa only emits 4% of the world’s GHG emissions, today’s choices in terms of construction quality and energy efficiency will play a decisive role in this century’s emission trends.

The quality of construction is a crucial stake in Africa, for existing buildings too. Indeed, renovating old buildings will progressively become a challenge, namely the big buildings in the public tertiary sector, and the social housing sector with mediocre thermal comfort, built in the last decades.

The building and construction sector is strongly interlinked with the electricity production sector

GHG emissions cannot be curbed in the electricity production sector; unless a high level of energy efficiency is achieved in building and construction activities. The African continent
has the most fossil fuel-dependent electricity production sector (i.e. coal in South Africa, oil and natural gas elsewhere). In fact, a minimal share of African electricity is produced with renewable energy (correlated to the obsolescence of hydroelectric plants).

**The building and construction sector has decisive impacts on the life of communities.**

Offering access to very energy efficient, sustainable, high quality and low-carbon homes would improve wellbeing in African rural and urban communities and help tackle climate change.

**Firewood consumption for cooking purposes is crucial in rural areas**

Although the situation varies greatly from one country to another, excessive firewood consumption is the main cause for deforestation, degradation and desertification processes. These often have negative and irreversible consequences on agriculture and water resources. Firewood consumption is also responsible for indoor pollution.

### 1.2 – High quality construction for new buildings

The question of quality construction is directly correlated with the questions of GHG emissions and energy consumption. It is now necessary to review the design of buildings, using both traditional and recent bioclimatic designs. Energy-efficient building designs, along with reduced firewood consumption, can curb energy consumption and GHG emission trends in Africa.

**The concepts of passive and energy-positive buildings**

In the past 30 years, research studies and analyses reflected on how to face high energy prices, reduce energy dependence, reduce indoor pollution, and curb GHG emissions. In industrialized countries, bioclimatic concepts evolved, experimental projects were implemented, and finally, large-scale bioclimatic construction programs were launched. These concepts need to be applied in Africa.

**Designing a bioclimatic building**

Bioclimatic design is defined by:

- Site specificities;
- The volume and shape of the building;
- The location of the building on the site, according to sunshine, shade and dominant winds (force and direction);
- The orientation of the building, to benefit from sun exposure;
- The judicious organization of spaces and functions;
- The size and location of the openings;
- Choice of insulation for the wall envelope to ensure appropriate thermal inertia;
- A preference for local materials;
- The use of vegetation as a natural curtain (local species);
- Fixed and mobile solar protections.

When launched in the 1980s, bioclimatic design did not involve quantified energy efficiency goals or rely on renewable energy.
**The passive building ("passivhaus")**

A building that is said to be passive is made of insulating materials and conceived in a way that minimizes and optimizes energy input whilst addressing thermal and lighting needs. The concept of the passive building was researched and developed in countries that experienced a strong demand for heating, mainly Germany and Scandinavian countries. This type of design is particularly adapted to cold climates with high heating needs, as it has the following characteristics: reinforced insulation, limited temperature losses, airtight walls, high performance appliances, reduced energy consumption... Similar concepts were developed in other parts of the world (Japan, United States).

**The positive energy building**

A positive energy building has a negative energy footprint: the building is energy efficient to the point that its energy consumption is inferior to the energy produced by the building’s environment (solar and wind power, geothermal or biomass energy).

A positive energy building is a passive building (as it consumes very little energy), which also relies on renewable power-producing appliances. This design is appropriate in hot and sun-exposed countries.

**Designing a low energy-consuming and low GHG-emitting building in Africa**

This study aims to identify the building designs that:

- Are appropriate and feasible in African countries (climate and socioeconomic conditions);
- Are low energy-consuming and low-GHG emitting;
- Address people’s household and comfort needs.

It is useful to analyze concepts developed in industrialized countries. However, African countries need to address opposite issues: thermal discomfort during heatwaves and excessive air-conditioning consumption. Nonetheless, some of the construction techniques to address cold and hot weather conditions are similar (i.e. insulation, ventilation, etc).

With regard to other energy needs, the appliances used are often the same (water-heating, lighting, household appliances, etc.).

The questions of quality in new constructions and quality in renovation of old buildings must be dealt with separately. Renovation will also entail conforming to norms, improving thermal comfort during heat peaks, reducing the air-conditioning bill, adapting new technologies to the building.

**Long term prospects**

Economically and technically efficient measures targeting energy management can lead to a 10 to 30% reduction in energy consumption. According to the International Energy Agency (IEA), based on a scenario of worldwide construction programs of positive energy buildings adapted to climate constraints, the building sector could represent up to 40% of the world’s energy savings in 2030 and 68% of electricity savings (with efficient air-conditioning devices).

**The construction/building sector has the biggest GHG mitigation potential.**

**Policies mitigating and adapting to climate change**

In the sector for new constructions, there is no point separating adaptation and mitigation since most of the actions to adapt buildings to climate change also reduce emissions (less air-conditioning and firewood consumption). Furthermore, building a new housing stock...
with positive energy buildings and improved cooking hearths will increase people’s wellbeing. This way, the latter will more easily adapt their lifestyle to the new climate condition.

2 – Policies relative to the quality of construction needed to achieve low GHG-emitting buildings

2.1 The characteristics of the two major climate conditions in Africa

Climatic map of Africa (UNDP)

<table>
<thead>
<tr>
<th>Mediterranean zone</th>
<th>Desertic zone</th>
<th>Sahelian zone</th>
<th>Dry tropical zone</th>
<th>Humid tropical zone</th>
<th>Equatorial zone</th>
<th>High altitude</th>
</tr>
</thead>
</table>

There are six climate zones in Africa but these come down to two major climate types: the “dry and hot” climate (roughly the Mediterranean and tropical zones) and the “hot and humid” climate (roughly the equatorial zones).

✓ The dry and hot weather
This climate is characterized by:

- Long sunny periods;
- High temperatures;
- Notable difference between day and night temperatures;
- Low rainfall.

In hot and dry weather zones, buildings should offer a comfortable microclimate, colder than the outdoor temperatures. This requires enormous inertia, solar protections (smaller
openings), large sun-radiated surfaces (example: dome-shaped roof) and optimized night ventilation to make the most of cool night temperatures. The question of air flows is crucial. The high temperature variation between day and night implies the need to a) reduced heatpeaks during the day and b) strongly ventilate at night.

✓ **The hot and humid climate**

This climate is characterized by:
- Long sunny periods;
- A constant daylight span;
- High temperatures with little variation from daytime to nighttime, and from one season to another;
- High hygrometry.

In hot and humid weather, buildings should offer the same thermal comfort indoors and outdoors: i.e. the pleasant temperature experienced by an individual, in the shade, with a light breeze. This requires solar protections, and permanent ventilation. Strong ventilation lessens the humidity caused by regular rainfall.

✓ **Climate in mountainous regions**

The climatic conditions in the mountainous regions (mainly in the North, East and South of Africa) are very different from the abovementioned weather conditions. The mountain climate is close to a temperate climate: pleasant average temperatures in the warmer season; cold winters which require heating.

### 2.2 – Implementing policies in the three construction markets in Africa

There are three distinct construction sectors in Africa. They are very different in terms of access to technology, skill availability, training needs and capacities. They do not have the same relation to construction regulation and financial management. They do not target the same populations. Consequently, recommendations on how to improve energy efficiency in buildings and how to reduce GHG emissions must be specific to each construction sector.

- **The industrialized construction sector, based on industrialized country standards**

This sector is dominated by multinational companies and focuses on the construction of public buildings, offices, infrastructures and hotels for tourism.

✓ **Small-scale construction sector**

This sector targets the construction of individual houses, or small buildings.

✓ **Informal settlement sector**

This sector defines settlements built by the inhabitants themselves with cheap and readily available materials.

### 2.3 – The possible technical solutions with regard to new constructions

✓ **General conception of buildings**

The location, climate conditions and functions should be defined before designing the building. The following aspects should be taken into account:

- The location and choice of the site;
- The building’s orientation;
- The vicinity: it should be nearby in hot and dry regions, and far in hot and humid regions;
- Volume and shape;
- Interior designing: central patio, shaded terrace;
- Passive solar potential;
- Vegetation for shade.

- **In hot and humid climate zones**

In hot and humid weather, the buildings should be exposed to the dominating winds. Houses should be distinctly separated from each other to allow the air to circulate in between buildings and thus, favor natural ventilation. Shaded patios and vegetation bordering the buildings will help cool the building and its surroundings. Choosing to make the buildings more compact will reduce the construction cost and increase energy savings. Heat transfers (both inputs and calories losses) depend on the wall surface in contact with the ground or the outside air: for the same volume or surface, a more compact building will require less energy to cool down or warm up. The design should reach a compromise between volume and surface to limit the heat input, increase heat evacuation and globally reduce energy consumption. The design should also protect the openings, as they bring in heat as much as they do light.

- **In hot and dry climate zones**

In hot and dry weather, the buildings should be close together in order to reduce the wall surface that is exposed to the sun, and help cool down both indoors and outdoors. The houses are organized around a central patio which helps the air circulate. The issues of shade, compact volumes and solar protections are similar in both types of weather. Vegetation is good for humidity as well as shade.

The table below contains an action that can help achieve the high quality low-carbon construction objective (cf. annexed synthetic table). It also specifies which of the three construction sectors are relevant to implement the action.

<table>
<thead>
<tr>
<th>Actions</th>
<th>Description</th>
<th>Industrialized construction</th>
<th>Small-scale construction</th>
<th>Informal construction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Train the chain of required actors (Architects, engineers, technicians, etc.)</td>
<td>The concept of positive energy buildings is new. Consequently, it requires the creation of a chain of skilled agents, trained to use new techniques</td>
<td></td>
<td></td>
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</tbody>
</table>

The following chapters will analyze each of the main components of new constructions and make technical recommendations.

- **Choosing the appropriate envelope for the building**

It requires selecting a construction material for the envelope itself, as well as insulating material.
The question of materials and of their industrial production

The choice of materials will depend on the part of the building (wall, roof), of the manufacturing process and the cost. Construction materials can be divided into two categories: materials that are industrially manufactured (cement, corrugated iron, glass, etc.) and improved local materials (wood, stabilized clay, stone). Local materials are often defined as opposed to the industrial materials that are conventionally used in the African standardized construction sector. Local materials are natural raw materials used according to traditional techniques, possibly modified for increased efficiency.

**Industrial materials** are used by most African people and perceived as efficient and sustainable. These materials are very popular because they are the only materials readily available, unlike local materials which lack organized diffusion channels. Industrial materials are popular because they are “easy”. They are nonetheless scarcely available in isolated zones, and costly. In addition, their application is complicated and inappropriate for countries with hot weather conditions. Industrial materials also have a high environmental cost.

**Improved local materials** (for example, raw clay bricks mixed with cement) are adapted to hot countries and can contribute to both acoustic and thermal comfort. Their insulating properties reduce the need for air-conditioning and for industrial insulating material. Local materials can be improved using very simple techniques and with little logistical organization. Building with improved local materials is an opportunity for the development of small rural companies and can help create new jobs. It requires the use of small-scale, manual and low-cost equipment.

For the time being, very few professionals are trained to use these techniques, thus increasing the price of resorting to local materials.

There are no programs or specialized trainings that could contribute to building up a real economic sector for locally-made constructions. Without local expertise, local craftsmen cannot be trained to use local materials and the associated construction techniques. Promoting local and adapted materials entails fund availability. They are not yet competitive and often more costly to produce than industrial materials, and nevertheless depend on imported machines and tools. Clearly, without political will, developing the “local material” industrial branch will prove difficult.

The construction sector plays a major part in most national economies, as it covers construction of individual houses, bigger buildings, and renovation. Construction activities can be structured according to three types of construction: housing, non-residential buildings, civil engineering projects.

Construction companies range from independent workers to multinational companies. In general, most companies cover a delimited location and accomplish specific tasks. Construction materials, parts and equipments are generally bought or hired from other companies. The design and the engineering services are often provided by other companies. The construction sector relies on a very mobile workforce since materials are often manufactured or assembled on the site.

Below is non-exhaustive table listing different construction materials and their composition.
<table>
<thead>
<tr>
<th>Material</th>
<th>Technique</th>
<th>Description of the technique</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clay</td>
<td><em>Adobe</em></td>
<td>The adobe technique consists in molding bricks with clay (without compacting it), and letting them dry in the sun. This technique is also known as the &quot;raw clay brick&quot; or &quot;banco&quot;. Sand or organic material (dung, straw) can be added to the clay.</td>
</tr>
<tr>
<td></td>
<td><em>Banco</em></td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>Raw clay</em></td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>Compressed clay brick</em></td>
<td>The clay is compacted using a molding press. Once the bricks are dry, they will be used similarly to adobe bricks, baked bricks or bricks mixed with cement.</td>
</tr>
<tr>
<td></td>
<td><em>Pisé (rammed earth)</em></td>
<td>Pisé is a construction technique that uses raw clay and branches.</td>
</tr>
<tr>
<td></td>
<td><em>Geopolymer brick</em></td>
<td>This brick is made of laterite clay, with a binding geopolymer agent. Geopolymer bricks can be made in small brick works, with little equipment and a low financial investment. These bricks are cheap and appropriate for hot weather conditions.</td>
</tr>
<tr>
<td>Vegetal</td>
<td><em>Wood</em></td>
<td>Wood has a much lower density than concrete or clay. It is therefore more adequate in humid and hot regions. It is a natural material, and – to a certain extent – renewable.</td>
</tr>
<tr>
<td></td>
<td><em>Thatch</em></td>
<td>Thatch usually includes straw residues collected after a harvest or ligneous branches. It contributes to an efficient thermal insulation. It is however very vulnerable to fire. Recently, R&amp;D looked into fireproof thatch material.</td>
</tr>
<tr>
<td></td>
<td><em>Cob</em></td>
<td>Cob works similarly to <em>pisé</em>: a wooden panel structure is filled with dry and raw clay. The house is built with a number of these wood-clay panels. Traditionally, the main structure is composed of wooden beams and smaller more supple reels (wood, bamboo, reed, and rush). The reels are wrapped in a mixture of clay and animal/vegetal fibers.</td>
</tr>
<tr>
<td>Concrete</td>
<td>«Concrete»</td>
<td>«Concrete» is the generic term used to design a construction material composed of granules (sand, pebble stones) aggregated with a binder. Concrete is a very popular material because it lasts in time, is water and fire resistant, malleable, and low cost.</td>
</tr>
<tr>
<td></td>
<td><em>Cement</em></td>
<td>Cement is often used as a binder</td>
</tr>
<tr>
<td></td>
<td><em>Clay</em></td>
<td>In this case, the binding element can be silt or clay. Concrete floors are interesting if there are ready available materials (laterite clay, clay sand, pebble stones). The mechanic resistance of concrete floors can be increased by adding stabilizing elements (cement, lime, straw).</td>
</tr>
</tbody>
</table>
**Insulation**

A building can be insulated either from the inside or the outside. The insulating material can also be used as a construction material.

In hot weather, the building should not be completely insulated: only the very exposed surfaces are insulated. In hot and humid weather, only the roof should be insulated. It should also be strongly ventilated to let the heat escape. Outside insulation is preferable to evacuate the heat. In hot and dry weather, both the walls and the roof need to be insulated. It is best to insulate the outside walls to avoid a night transfer of the day’s heat inside the building.

Clay can be used both as construction and insulating material.

Below are the selection criteria for thermal insulation material:
- Thermal conductivity ($\lambda$),
- Inertia with respect to the material’s density, particularly in hot weather conditions,
- The type of material (permeability).

Insulating materials can be:
- Synthetic material: polystyrene, polyurethanes, urea-formaldehyde insulating foam, polyesters;
- Mineral materials: mineral wools, cellular glass, perlite and vermiculite, expanded clay;
- Thin reflective insulating material (also known as a radiant barrier);
- Vegetal insulation material: wood fiber felt, *fibragglos*, wood granules, cellulose wool, expanded cork, hemp, linen, coco fiber felt, cotton, reeds;
- Animal insulation material: sheep wool, duck feathers;
- Local insulating materials (not manufactured): shavings, residues from the wood industry, various farm residues, “green polystyrene”, any potential fibers.

It is preferable to use local insulating materials, both vegetal and animal, to curb the importation of industrialized countries.

With regard to the composition of « natural » insulating materials, products are sometimes used to make the fibers more resistant to humidity, fire, insects, and mushrooms. On the other hand, these organic materials are very easy to recycle.

The table below contains a selection of actions that can help achieve the high quality low-carbon construction objective (cf. annexed synthetic table). It also specifies which of the three construction sectors are relevant to implement the action.
### Actions

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Implement a regulatory framework on a temperature regime will reduce energy consumption in buildings. Due to the fact that it is a complex regulation to implement, it will apply only to State and touristic buildings.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>It is crucial to promote the use of local materials in the construction sectors. Training, tools and appliances must be provided.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>For a greater comfort in hot weather, exposed surfaces (rooftops in particular) of the building should be properly insulated to ensure they do not overheat.</td>
<td></td>
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</tr>
<tr>
<td>The use of local materials reduces the need to import materials and contributes to develop the local economy.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hot weather-inadequate materials, such as corrugated iron, leads to overheating the building. It is crucial to develop alternative materials to decrease the use of corrugated iron.</td>
<td></td>
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</tr>
</tbody>
</table>

### Solar protections

Solar protections protect the building or the house from direct sunlight. Architectural “masks” or solar protections are integrated into the building and project shadows on other parts of the building (generally, windows). The shadow created by a “mask” depends on the following parameters:

- Hour of the day,
- Season,
- Size and shape of the window,
- Size and shape of the “mask”,
- The mask’s position with regard to the window in need of shade,

Protecting the outdoor walls is used to stop, hinder or reflect sunrays. Various devices are available:

- Retreating façade and protruding roof eaves on the North and South façades;
- Horizontal and vertical solar protection for the East and West façades; vertical overhangs are used to protect from the low sun (rising and setting sun);
- Reflective materials and coatings;
- Insulating materials;
- Double skin panel systems
· **Fixed protections and architectural masks**

Most often, these fixed protections are embedded in the building structure, and located around the windows that need shading. They are built in right from the beginning, and therefore do not induce a significant extra cost.

There are various types of fixed protections

- The « **weatherboard** » effect: eaves on the roof, porch, running balcony, wall installations in horizontal direction, etc.
- The « **flank** » effect: protruding façade, cleaved ledge, wall installations in vertical direction, etc.
- The « **loggia** » effect: loggia, portico, window lintels, wall installations in both vertical and horizontal directions, etc.
- The « **patio** » effect: inside court, patio, light wells, cleaved ledge, full railing, etc.
- The « **vis-à-vis** » effect: fence, a rail, double-skin panel protection.

· **Mobile protections**

Mobile protections are defined as auxiliary protections, added when necessary. This category includes:

- Shutters,
- Venetian blinds,
- Slats.

Closing systems (such as shutters) often cumulate other functions:

- Thermal insulation in winter;
- Nocturnal ventilation;
- Protection against intrusion.

The table below contains a selection of actions that can help achieve the high quality low-carbon construction objective (cf. annexed synthetic table). It also specifies which of the three construction sectors are relevant to implement the action.

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<tbody>
<tr>
<td>Add fixed or mobile protections for the openings</td>
<td>It is essential to protect the openings of buildings using fixed (e.g. weatherboard) or mobile (e.g. shutters) solar protections to avoid heat peaks.</td>
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<tr>
<td>Organize transitional spaces (galleries, covered terraces)</td>
<td>In each region, these spaces are designed and named differently. In humid weather zones, these transitional spaces are called “covered terraces” and in dry weather regions, “galleries”.</td>
<td></td>
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</tr>
<tr>
<td>Add vegetal protection</td>
<td>In the « greener » regions, vegetation is used as protection against sunlight. Deciduous trees are interesting species: the tree shades the house during the hot season; its leaves fall during the winter season thus letting the sunlight through.</td>
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</tbody>
</table>
**Ventilation**

In hot countries, ventilation is a crucial comfort factor as it can significantly impact a building’s thermal comfort.

It is a decisive question because lifestyles are very different in hot and temperate countries:

- In temperate countries, people protect themselves from the outside air temperature to prevent feeling cold.
- In the Mediterranean, tropical and equatorial regions, habits are very different. People tend to live outdoors as much as indoors. It is difficult to manage the air’s circulation and temperature although it is a crucial condition for thermal comfort under hot and dry weather.

Bioclimatic designs strongly rely on an optimal use of the wind forces to promote natural ventilation and thus, reduce energy consumption. The air propellers activate the circulation of fluids and allow physiological cooling to take place. Their auxiliary use should be complementary to the natural ventilation system. The use of a Mechanically Controlled Ventilation (MCV) appliance with an air-to-air heat exchanger is used to cool the air circulating in a building. This solution is costly but could be adapted to a major building complex. Indeed, the air coming into the building is cooled with the air exiting the building, using a heat exchanger system.

Natural ventilation is generated by a difference in temperature or pressure between façades of the building. Natural ventilation evacuates the internal and solar heat stored in the building.

The following devices are used to optimize natural ventilation:

- Prior assessment of the site’s ventilation potential;
- Façade exposure to the dominating winds during the hottest period;
- Keep the building far from obstacles to the wind’s circulation;
- Protect the building’s surrounding and envelope from sunlight;
- Carefully define the size of the openings and air circulation devices to optimize natural ventilation;
- Organize the rooms within the building so that air circulation is channeled and optimized.

The table below contains a selection of actions that can help achieve the high quality low-carbon construction objective (cf. annexed synthetic table). It also specifies which of the three construction sectors are relevant to implement the action:

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<tr>
<td>Promote natural ventilation</td>
<td>Natural ventilation evacuates the calories accumulated during with the heat without consuming energy.</td>
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</tr>
<tr>
<td>Study the possibility of using a MCV air-to-air heat exchanger</td>
<td>The MCV system is used to cool the air entering the building. This type of system is expensive and takes up space (large diameter pipes are required).</td>
<td></td>
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</tbody>
</table>
Cooling systems

A cooling system does not involve a refrigerating appliance with guaranteed power thresholds. In fact, using a cooling system implies that:

- It will prove difficult to maintain a specific temperature;
- The indoor temperature will depend on the weather condition outdoors.

Cooling down a building is a two-step process:

- First, protections are used to avoid heat peaks, and contribute to reducing the indoor temperature;
- Secondly, if the first step is not enough, the building can resort to an air-conditioning appliance.

The need to cool the building must be reduced. The following techniques and devices can be used:

- Use of fixed and mobile solar (screens, blinds with mobile slats), vegetal (deciduous trees) protections;
- Use of insulation and inertia to prevent the building from overheating;
- Use of ventilation to evacuate or cool hot air;
- Simple openings, with no glazed windows;
- Use of low solar factor\(^1\) blinds;
- Use of a good night ventilation system to evacuate from the building the heat stored during the day;
- Reduce the use of heat-producing appliances: energy-saving lighting, computers and refrigerators;
- Best possible use of passive techniques.

- The Canadian or “Provencal” well

The Provencal well is composed of a series of pipes (or possibly, a single pipe), horizontally buried under the building, and connected to the ventilation system. The Provencal well lessens the outdoor temperature variations by using the ground’s thermal inertia: that is, it absorbs the ground’s coolness during the hot season, and the ground’s heat during the colder months. This solution is adequate in both the residential and tertiary sector.

It is called a “Provencal well” when used for cooling purposes and a “Canadian well” when used for heating purposes. In hot weather, the Provencal well can bring the building’s temperature down by 5 to 8°C. This installation is not linked to an air-conditioning appliance. It is a very simple device blowing cooled air up through the ground. There is however a risk of condensation in the pipes, that could lead to the presence of mosquitoes, particularly in the humid regions.

The table below contains a selection of actions that can help achieve the high quality low-carbon construction objective (cf. annexed synthetic table). It also specifies which of the three construction sectors are relevant to implement the action:

\(^1\) The « solar factor » is the ratio of solar energy flux entering the building through the glass to the flux outside the window.
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</tr>
</thead>
<tbody>
<tr>
<td><strong>Limit the resort to air-conditioning by using appropriate thermal inertia</strong></td>
<td>Informal settlements cannot resort to air-conditioning. Buildings must therefore be designed to a satisfying level of naturally-regulated thermal comfort.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Develop “Provencal wells”</strong></td>
<td>A “Provencal well” is easier to build in during the construction process. The system is costly and can only be implemented by the industrial construction sector.</td>
<td></td>
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</tr>
</tbody>
</table>

**Air-conditioning**

In contrast with a cooling system, an air-conditioning system:

- Will always refrigerate at a set temperature (only if the air-conditioning appliance has an adequate size for the volume that needs refrigerating);

- **“Active air-conditioning”**

The use of active air-conditioning generates GHG emissions due to:

- the fossil fuel-powered electricity consumption,
- energy inefficient appliances,
- insufficiently airtight circuits for the GHG-emitting refrigerating gases (their global warming potential is 10 000 times higher than CO₂),
- installation and maintenance of the appliances by non-professionals,
- Absence of recycling for obsolete appliances.

The power supply is inefficient and often unable to meet the demand because of irregular and unpredictable peaks in the power demand (households tend to use their air-conditioning appliances during the hottest hours).

The **vapor-compression refrigeration** system is the most well-known and widespread refrigerating system used to air-condition buildings. In general, the compressor is electricity-powered. Vapor-compression systems have become very efficient appliances because manufacturers massively invested in R & D, optimized the exchangers and the variable speed engines. Also, the system contains a refrigerating gas.

Caution: the use of an active air-conditioning system requires good insulation. Unfortunately, buildings are rarely insulated properly and air-conditioning is often used with windows and doors open. The appliance needs to work intensively to refrigerate the extra heat.

- **Evaporative air-conditioning**

Evaporative air-conditioning relies on a natural phenomenon: water’s changes in state. Water evaporation requires a quantity of water proportional to its latent heat. When evaporation takes place, the heat absorbed from the air leads to cool the air temperature, “in exchange” for an increase in the humidity rate. This process is why one feels cold after coming out of the shower: the body’s temperature decreases when the water drops evaporate from the body.
However, in arid zones, water is a scarce resource and used for more vital needs. Therefore, this type of air-conditioning system is inappropriate.

- **Heat pumps**
  A heat pump transfers calories into the building or vice-versa, depending on the indoor temperature. Heat pumps work like air-conditioners because they contribute to refrigerate the building by evacuating calories out of the building.
  There are two main types of Heat Pumps (HPs):
  - Geothermal HPs that absorb the calories from the ground or from a water table, using sensors or drill holes.
  - Aero thermal HPs that take calories from the air outside the building.
  There are various sorts of HPs: *air/air, air/water, ground/ground, ground/water, and water/water* or *glycolated water/water systems*. The first word refers to the source of absorption of calories and the second word indicates the calorie distribution mode. However, there is one exception: the glycolated water/water HP absorbs calories from the ground, using buried sensors that contain glycolated water.
  HPs that absorb calories from outside should not be used in Africa because during the day, the air outside is hotter than the air inside of the building. The geothermal HPs are more appropriate.

- **Solar air-conditioning**
  Solar air-conditioning includes different systems by which heat is used to refrigerate. Solar heat is produced using the solar sensing panels. However, solar cooling requires more performing solar panels than water heating for example, because the temperature needs to be much higher.
  There are two main types of refrigeration systems, using a heat source: the desiccant cooling system and the sorption systems (adsorption or absorption)
  **Description of these systems:**
  - **Absorption**
    Absorption is a sorption phenomenon used to bind a molecule absorbed to another molecule, and thereby induce its disappearance by transformation or chemical modification. An absorption system uses the properties of coupled liquid/gas: the liquid is the “avid” absorber of gas (the “absorbed”). The gas is the refrigerating fluid, absorbed by the liquid when temperature and pressure are low, and desorbed when temperature and pressure are high.
  - **Adsorption**
    Adsorption is a surface phenomenon by which gas or liquid molecules fix themselves to the solid surface of the adsorbers. In the case of a simple adsorption, the adsorbed molecule is not deteriorated and keeps its primary shape, but is no longer suspended in the solvent. An adsorption system relies on a solid’s property to a) adsorb (trap at the surface) a gas at a low temperature (20-30°C), and b) desorb the gas at a higher temperature (50-80°C).
  - **The desiccant cooling system**
    It de-humidifies the air (outside the building) in order to refrigerate it by allowing the air to evaporate: the air is channeled through a honeycombed wheel filled with a desiccant (substance that eliminates water) that adsorbs the vapor, and consequently, heats the air. The outside air is then cooled in a heat exchanger by the air already in the building, (previously cooled using a humidifying process). The outside air is then further cooled
using a liquid water humidifier. To be regenerated, the desiccant wheel needs to be heated, in order for it to evacuate the adsorbed water. In the case of solar air-conditioning, solar energy can be used to regenerate the desiccant wheel. The de-humidifying process can be either liquid or solid. The most common technology uses silica gel or lithium chloride as its desiccating substance.

- **Refrigerating appliances reliant on sorption and solar energy:**

Absorbing solar-powered machines follow the absorption cycle. This cycle works like a compression cycle. Only the mechanic compressor is replaced by a thermo-chemical compressor. The latter is composed of a refrigerating fluid and a solvent (which strongly interacts with the refrigerating fluid) such as a lithium bromide solution. The heat produced using the solar sensors replaces the mechanic compression. Using a “generator”, the heat allows the refrigerating fluid to evaporate. Cooling the condenser usually requires a humid cooling tower.

Adsorbing solar-powered machines use a solid adsorbing material. The machine contains two compartments- an evaporator and a condenser- filled with adsorbing fluid. The fluid allows water to evaporate at a low pressure. Solar heat regenerates the solar adsorber. The appliances available on the market use water as a refrigerating fluid and silica gel as an adsorber.

- **Radiative cooling**

Natural radiative cooling systems rely on the specific color/texture coating on the outside walls of the building. This very sophisticated coating material further radiates the sun’s energy (infrareds) back into the atmosphere to avoid overheating. The cooling process can be hindered only by convective heat exchanges with the air (i.e. the wind).
The table below contains a selection of actions that can help achieve the high quality low-carbon construction objective (cf. annexed synthetic table). It also specifies which of the three construction sectors are relevant to implement the action:

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</thead>
<tbody>
<tr>
<td><strong>Limit the use of active air-conditioning</strong></td>
<td>The use of active air-conditioning increases energy consumption and GHG emissions. Alternative cooling systems must be used.</td>
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</tr>
<tr>
<td><strong>Develop the use of heat pumps</strong></td>
<td>In Africa, geothermal heat pumps appear more appropriate. These systems are costly and require underground water tables. They can only be developed in the industrial construction sector. More simple heat pump systems can be used in small-scale constructions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Develop the use of low energy-consuming air-conditioning</strong></td>
<td>This type of air-conditioning appliance should be promoted by developing disseminating programmes and by raising awareness among the users on how to adapt the appliance to their needs. This action could be easily implemented by the industrial sector.</td>
<td></td>
<td></td>
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</tr>
<tr>
<td><strong>Develop the use of solar air-conditioning</strong></td>
<td>Solar air-conditioning is complex and expensive but relies on renewable energy</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Develop the use of radiative cooling</strong></td>
<td>Some radiative systems can be easily implemented. However, the coating is expensive.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Develop the use of evaporative air-conditioning</strong></td>
<td>In hot and dry weather, the use of evaporative air-conditioning can cool and moisten the air. This system, however, requires sufficient water availability.</td>
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</tr>
</tbody>
</table>

**Various household needs and lighting**

**Sanitary Hot Water**

Sanitary Hot Water (SHW) can be produced in a centralized manner (for a number of households) or individually. SHW can be heating using combustible material (oil, gas, coal, biomass, etc.), electric power, or solar energy. Solar thermal energy transforms solar radiation in thermal energy. The energy produced can be directly used (to heat a building for example) or indirectly (further transformed into electricity using water vapor). The intensity of the sun’s radiation is irregular. It is best to keep a hot water storage tank as well as auxiliary energy systems:

- A tank to store the energy and use it when needed (over a set period of time);
- A complementary energy resource to supply additional heating needs, when the energy tank is empty or when solar energy is insufficient.

However, in the hottest countries characterized by scarce season variations, simplified solar sensor systems provide a good intermediate SHW system, at a minimal cost.

The table below contains an action that can help achieve the high quality low-carbon construction objective (cf. annexed synthetic table). It also specifies which of the three construction sectors are relevant to implement the action:

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<tbody>
<tr>
<td>Promote solar water-heaters</td>
<td>Solar water-heaters rely on a renewable source of energy</td>
<td></td>
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</tbody>
</table>

**Glazed windows and openings**

A building’s openings have various functions:
- Let the light in;
- Capture the sun’s energy;
- Ventilate the spaces;
- Ventilate the heat;
- The ability to see outwards and inwards;
- Give the façade its specificities;
- Be in touch with the outdoor surroundings.

But also:
- Avoid glare;
- Protect from too much sunshine;
- Protect from the dust;
- Protect from insects;
- Noise insulation;
- Protect from the cold and the heat;
- Protect from the bad weather;
- Protect from burglary.

The size of the openings and the presence (or absence) of glazed windows play an important role in terms of light inflow, and in terms of heat peak management. In temperate countries, an efficient glazing retains the heat in the building, whereas in tropical countries, it avoids heat peaks.

- **In hot and humid weather**

Glazed windows on the openings are not always required. Indeed, without a glazed window, the air circulates more easily and improves the ventilation capacity. However, a glazed window can protect the inside of the building from bad weather, insects and burglaries. In hot and humid weather, a single-panel glazed window should be enough.

- **In hot and dry weather**

In hot and dry weather, depending on the region, single or double glazed windows will be required. Glazed windows are needed to protect the building from the heat and from (mainly sand) storms.
The table below contains a selection of actions that can help achieve the high quality low-carbon construction objective (cf. annexed synthetic table). It also specifies which of the three construction sectors are relevant to implement the action:

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</thead>
<tbody>
<tr>
<td>Pay attention to the size and location of openings</td>
<td>The openings are necessary for natural lighting and ventilation but they also let the heat in. They must be adequately sized and located on the building to reduce the heat inflow.</td>
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<td></td>
</tr>
<tr>
<td>Develop absorbing glazed windows, photochromes and electrochromes</td>
<td>These glazed windows limit the inflow of sun radiation in the building. However, these materials are hardly developed and still expensive.</td>
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</tbody>
</table>

**Energy production**

Africa’s most available and cost-effective energy is solar energy, and in particular photovoltaic solar energy for electricity production.

- **Photovoltaic solar energy**
  Industrially-wise and technologically-wise, producing electricity by converting sunlight (with silicon Cristal solar cells) into power is the most advanced option. Indeed, silicon is one of the most abundant elements on earth, perfectly stable as well as not toxic. However, there are also modules made with other elements.

  For positive energy buildings, the photovoltaic panels would be set up on the roof. It is less expensive to cover the roof in photovoltaic modules than to integrate the panels in the roof shingles, which requires much more complex technology. However, the simple covering system calls for a security and mechanical check because the panels add a significant weight on the roof compared to the integrated systems. Another option is to set up modules on the ground close to the buildings. This option only works in rural areas because it requires space.

  Another criterion is the size of the installation: small-scale installations (one or two modules) are easy to fix it on the roof, particularly in terms of electricity fitting. For large-scale modules, a ground installation is safer.

  Electricity production using photovoltaic panels has the following characteristics:
  - The high cost of photovoltaic technology hinders its dissemination in Africa and calls for international financial aid;
  - The photovoltaic technology is the only existing technology that can produce electricity without being connected to the electricity network;
  - Photovoltaic panels can be connected to the network and serve as an auxiliary - using an inverter – in the countries where electricity consumption peaks in the middle of the day or late afternoon.
  - Photovoltaic technology has great potential for improvement.
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<tr>
<td>Promote the use photovoltaic modules</td>
<td>Decentralized renewable energy production is interesting to develop even if the photovoltaic modules are costly.</td>
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</tbody>
</table>

**Artificial lighting**

Low energy lamps are characterized by luminous efficacy (lumens per watt lm/W) which expresses the ratio of visible light waves to the electricity consumed.

Fluocompact lamps are the main kind of low energy lamps. They belong to the category of “low pressure” discharge lamps, along with the fluorescent tubes. These lamps contain a thin coiled-up tube, and integrated electronic ballast. These tubes have a life span 2 to 4 greater than the conventional fluorescent tubes. Although the luminous efficacy of fluocompact lamps is slightly inferior to that of conventional fluorescent tubes, they consume 4 to 5 time less energy than incandescent lamps.

There are more and more development programs aiming for the dissemination of low energy lamps in Africa, because they can contribute to improve people’s comfort. State subsidies are necessary in order for the people to benefit from these technologies and to disseminating the lamps in rural areas. So far, the lamps have contributed to reduce electricity consumption (and minimize electricity bills) of communities in some regions. The concept of Luminescent Diodes (LED) is another emerging technology.

The table below contains a selection of actions that can help achieve the high quality low-carbon construction objective (cf. annexed synthetic table). It also specifies which of the three construction sectors are relevant to implement the action:

<table>
<thead>
<tr>
<th>Actions</th>
<th>Description</th>
<th>Industrialized construction</th>
<th>Small-scale construction</th>
<th>Informal construction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disseminate low-energy lamps</td>
<td>The dissemination of low energy lamps can help reduce the energy bill.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test DELs in various weather conditions</td>
<td>The Luminescent Diodes have long life spans and are bound for a widespread development. It is however necessary to analyze the impact of LEDs in hot climate conditions, before investing in diffusion programs.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Household appliances

- Refrigeration

In Africa, only middle and high income households have access to electricity and consequently, the possibility to own a refrigerator. Most of the refrigerators in Africa are second-hand and represent 50% to 60% of a household’s total electricity consumption.

- Low-energy refrigerators are less energy consuming but more expensive than low-range refrigerators.
- Gas or oil-fueled refrigerators are convenient where access to electricity is not available. These refrigerators are CO₂ emitters and the room must be cautiously ventilated at all times, to ensure the evacuation of the fumes.
- Solar refrigerators work like conventional compressor refrigerators; except that the compressor’s engine relies on a Rankine system (i.e. a source of warmth, heated by a helio-thermal sensor, increases the gas’ temperature until it reaches the state of vapor, consequently increasing the pressure within the circuit). The gas will then condense when passing through a source of cold (air, fresh water). Between the hot and cold, the expansion gear is a paddle engine, powered by the variations in pressure. The paddle engine powers the refrigerator’s compressor. Other solar refrigerators rely on adsorption systems (using 100% solar heat), which directly convert the sun’s caloric power into ice to preserve perishable goods.

The table below contains an action that can help achieve the high quality low-carbon construction objective (cf. annexed synthetic table). It also specifies which of the three construction sectors are relevant to implement the action:

<table>
<thead>
<tr>
<th>Actions</th>
<th>Description</th>
<th>Industrialized construction</th>
<th>Small-scale construction</th>
<th>Informal construction</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Diffuse low-energy appliances</strong></td>
<td>The dissemination of low energy appliances contributes to reduce energy consumption and the electricity bill.</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

- Cooking

In Africa, cooking generally relies on firewood or coal. The use of electric or gas stoves is marginal.

- The question of firewood

Cooking is the main source of energy consumption and GHG emissions of African households. Firewood and coal represent up to 57% of the energy consumed in Africa, and up to 90% of the energy consumed in rural areas of sub-Saharan Africa. Firewood is mainly used for cooking (2/3) or water heating purposes. Households tend to consume:

- Firewood and other kinds of biomass in rural areas;
- Wood coal in towns.

The cooking installations vary also: traditional hearths are predominant in rural zones, and metal hearths are used most in urban areas. These installations provide very low heat
yield: 10 to 15% for firewood-fueled cooking hearths and 20 to 25% for coal-fueled hearths.

Trends in energy consumption strongly vary in Africa, depending on the level of income, the geographic location and the supply conditions.

Wood coal is produced using a traditional process (small-scale carbonization of the wood by partial combustion, directly on the ground or in a humid clay clamp). Its energy yield is also very low, around 15%. Tree felling activities for small-scale cooking purposes is the major cause of deforestation - and consequently, land degradation - in Africa, particularly around the big cities.

Collecting wood takes up a significant amount of time: in sub-Saharan Africa, women carry around 20 kg of firewood every day, for 5 kilometers on average. In rural areas, 90% of the people collect firewood, as opposed to 20% in urban zones (which mostly rely on wood coal). Wood coal has a number of advantages: a more efficient logistic organization, better energy yields and less pollution. However, the supply chain is globally more inefficient.

Firewood combustion generates pollution in confined spaces (poorer households often lack ventilation systems), leading to increasing health problems (i.e. respiratory and eye-related diseases).

The nutritional intake of African households is strongly correlated to the availability and cost of firewood. In some parts of the Sahel, firewood can represent up to 50% of a household’s income.

The question of firewood management is crucial because it is at the junction of a number of issues: the question of access to energy, deforestation, poverty, social and gender issues (discrimination, traditions). Improved management of firewood resources and uses is a major step on the path to sustainable economic, social and environmental development.

- **Possible solutions**

  - Increased energy efficiency: simple improvements on the wood processing and on the cooking recipient can reduce wood consumption by 70%. Open hearths can be closed to concentrate the heat and avoid unnecessary heat losses. New carbonizing ovens achieve betters yields that traditional ovens to manufacture wood coal.
  - Alternative energy resources: butane gas, kerosene, solar ovens, etc…
  - Sustainable management of forest resources: well-managed woodlands and reforestation policies to address increasing urban density.
The table below contains a selection of actions that can help achieve the high quality low-carbon construction objective (cf. annexed synthetic table). It also specifies which of the three construction sectors are relevant to implement the action:

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<tr>
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<th>Informal construction</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Promote alternative energy resources, like LPG</strong></td>
<td>Replacing firewood with other energy resources, such as LPG for cooking purposes, can contribute to reduce GHG emissions.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Launch a program for sustainable management of forestry resources</strong></td>
<td>Managing forest resources can contribute to tackle deforestation induced by firewood and wood coal consumption</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Disseminate improved hearths/cookers</strong></td>
<td>Disseminating improved cooking materials among households will improve cooking efficiency and reduce firewood consumption.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

✓ **Lifestyles and behaviors in low GHG-emitting buildings and households**
Individual behaviors impact the efficiency of appliances and equipments. Raising households' awareness on energy savings is decisive.

**An example: air-conditioning**
The way in which an individual will use its active air-conditioning appliance will influence its lifespan and rate of energy consumption. Indeed, the appliances are designed to cool a specific volume, in specific conditions. Otherwise, the appliance will become less energy efficient and effective. For example, there is no point in using an air-conditioner if the window is open. The number of rooms to cool and the hours of cooling wanted should also be taken into account. Air-conditioning is more effective if turned on early at night to cool the building down and evacuate the heat stored during the day. There is no point air-conditioning an empty room. Also, professional maintenance is crucial to ensure a stable output.

The table below contains an action that can help achieve the high quality low-carbon construction objective (cf. annexed synthetic table). It also specifies which of the three construction sectors are relevant to implement the action:

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<th>Small-scale construction</th>
<th>Informal construction</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Awareness-raising campaign</strong></td>
<td>Awareness-raising on energy efficiency and savings is crucial both for construction companies, craftsmen and the building’s residents</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Difficulties encountered in various countries with regard to new constructions

Institutional barriers
The first barrier is often institutional. Political will and institutional involvement are crucial when it comes to promoting energy-saving buildings and making the decisions. The relevant administrative bodies should be supported by subsidiary bodies and by a financial, political and institutional framework. Once the decisions are made, their application will need to be closely monitored.

Technical barriers
The fact that technologies and professional know-how and practices evolve rapidly in the construction sector can become an issue. Evolutions imply the need to constantly train the architects, engineers, workers and craftsmen to adapt to new designing, construction and renovation, exploitation and maintenance techniques. Energy-saving buildings will require capacity-building and training of stakeholders in the construction sector and in the relevant administrative bodies.

Methodology-related barriers
Capacity-building activities in a country or a region will only partially contribute to adapting the construction sectors, unless they are integrated in a coherent and more global methodological framework. Firstly, a “baseline” containing the current construction practices and techniques should be established. Secondly, a team of experts should research the country’s climate conditions; and characterize coherent climate zones (for example, based on the degrees-days of heating/cooling per year). Engineers and economists should analyze the market potential, compare the technical and economical factors according to the extra costs – as well as the financial and energy savings - they incur on the short and long term.

These different phases should be reinforced with a new construction and renovation code on energy efficiency. This can be done based on existing construction codes in countries with similar climate specificities and socioeconomic needs.

Financial barriers
Implementing a program on positive energy buildings incurs very high costs that most countries - developing countries in particular- cannot afford. Even if the country is institutionally organized, the program also involves financial incentives to promote the implementation of new regulatory measures on the market. In addition, constructing a positive energy building entails a large investment at the start. Indeed, it is only on the long term that energy savings will contribute to lower the building’s global cost (i.e. construction and consumption) compared to that of a conventional building.

Low awareness barrier
In some countries, this kind of program will be hindered by the absence of information and lack of awareness-raising and communication tools that could convince the stakeholders: administrative bodies, research institutes, academics, electricity companies, industrials, trade-unions, and trade guilds.
This barrier can be overcome by conferring with local citizens; raising awareness on energy savings among the communities; informing and training stakeholders and guilds on existing construction techniques.

Social and cultural barriers
Social and cultural barriers are specific to each country, and must be rapidly identified. Consulting and debating with the local communities can help overcome these barriers.
2.4 – The technical options to improve renovation

In developing countries experiencing strong demographic growth, the stakes are high in both the renovation sector and the new construction sector. Renovation is particularly crucial in State buildings. A renovating program will aim to adapt existing buildings to new norms, improve thermal comfort in case of heat peaks, and limit the resort to air-conditioning with natural ventilation systems. Also, the program will try to adapt recent technologies to old buildings. The technical options available are often the same in the renovation and construction sectors, but more difficult to use and less efficient in renovation projects.

The table below contains a selection of actions that can help achieve the high quality low-carbon construction objective (cf. annexed synthetic table). It also specifies which of the three construction sectors are relevant to implement the action:

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<th>Small-scale construction</th>
<th>Informal construction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimize air-conditioning in buildings</td>
<td>Old appliances should be replaced and people informed on how to use them appropriately</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reinforce insulation</td>
<td>Reinforcing insulation can improve the thermal comfort inside the building</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Add solar protections</td>
<td>Solar protections will protect the building from overheating</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Set up solar water-heaters</td>
<td>Solar water heaters can help improve daily life conditions for those who did not have hot water, and reduce the energy bill for those who relied on electric water-heaters</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Promote improved cooking systems</td>
<td>Cf. options in the chapter on new constructions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Raise awareness</td>
<td>It is crucial to raise the people’s awareness on energy savings.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3 – How can international mechanisms and development aid contribute to mitigate GHG emissions in Africa’s building (construction and renovation) sector?

This chapter will focus on the following aspects:

- The sector’s specificities with regard to financial arrangements for international aid projects;
- Building-related projects for developing countries in the international climate change negotiations and mechanisms (namely, the Clean Development Mechanism);
- The role of other development aid and investment mechanisms in developing countries.

3.1 – The building sector has specificities that need to be taken into account by international aid and investment mechanisms

International aid mechanisms must take Africa’s building sector’s specificities into account:

- Construction projects in Africa tend to be small-scaled, rely on a low financial capacity, and involve a large number of stakeholders. This subtle “granulation” of each construction project becomes a disadvantage when requesting international aid. Development aid agencies and international bodies usually fund a few large-scale projects, to reduce the administrative cost.
- There need to be multiple channels for financial resources: local savings, State subsidies, international funds (to leverage private investment and secure the loans).
- Technologies in building sectors worldwide can be easily mass-manufactured, allow economies of scale and consequently, be rapidly disseminated in other countries without incurring prohibitive extra costs.

Based on these specificities, two types of project can be supported:

- Project type 1: international aid mechanisms must financially support national programs that contain multiple and diversified small-scale projects. This type project could involve, for example, the diffusion of energy efficient appliances such as low-energy consuming lamps, solar sensors for water-heating, improved cookers. Emission reductions can be calculated by multiplying the energy saving potential of one appliance per the number of appliances disseminated.
- Project type 2: a very complete construction program (for example, a housing construction program or tertiary building program) which would design one type of building/house and then mass produce it. To assess the global cost of the program and the expected emission reductions, data on the technologies and techniques used, their costs should be provided to the potential financers.

3.2 – The conventional actions by international public aid and investment in developing countries

A number of sleeping partners could contribute to projects and programs in the building sector, depending on their profitability: multilateral funds (the World Bank, the Global Environmental Facility…), bilateral development aid agencies (German GTZ, French AFD,
European Investment Bank, Nordic Development Fund, etc.). Funding opportunities can also be found in Africa: for example, the Development Banks of Western and Southern Africa, African Development Bank, State budgets, public and private banks, etc. International funds should be used to support African financial initiatives for development.

Unfortunately, these international aid and investment funds never benefit the African building sector (housing programs in particular). Projects are mostly funded by African States and national public and private banks. The few existing projects financially supported by international sleeping partners target major infrastructures (hospitals, airports…).

Surprisingly, bilateral and multilateral sleeping partners have invested very little in the African energy production sector. In fact, access to energy is not one of the Millennium Development Goals. Energy issues are rarely taken into account in internationally-funded projects.

**Development Aid**

Development banks (regional development banks, national development banks (for example, AFD, GTZ, Europe Aid, etc.) are the major industrialized sleeping partners. Aid can be donated or loaned to a developing State. For the time being, development aid amounts to 0.3% of each industrialized State’s GDP. By 2015, it should amount to 0.7%. This financial aid is not directly correlated to the mechanisms created by the negotiation process on climate change; however, most of the multilateral and bilateral development aid bodies tend to favor projects with GHG mitigation potential.

Development aid for African countries could be used to develop and improve skills, techniques and practices in the housing construction sector and to study trends in urban development.

**North-South decentralized cooperation between towns and regions**

Actions in the building and construction sector are generally implemented at the local level. Many decentralized cooperation activities between local communities in the North and in the South target the promotion of improved cookers, State constructions, land-planning, renewable energy, or the environment. Tackling climate change has also become a major question in horizontal cooperation.

**Public-Private Partnerships (PPP)**

PPPs are a good option in the construction sector because they can attract the required investment flows. Until now, these partnerships were used to fund massive public construction programs for social housing or touristic purposes. These programs relied on partnerships between major banks, further supported by national or local public money. They rarely call upon international funding, mainly because these national programs do not target energy efficiency or GHG mitigation. This financial instrument is not commonly used on the African continent. However, the PPP could be used as an intermediary to channel complementary funds.

**Energy Services Companies (ESCO)**

Creating ESCOs could contribute to develop a national program on energy efficiency. ESCOs invest in energy efficiency and renewable energy projects, and recover the money saved on the energy bills. Until now, ESCOs were used to fund basic projects: distribution of low-energy lamps, solar sensors for SHW, etc. These companies could however fund more ambitious projects.
3.3 – The instruments adopted in climate Change international agreements (the Rio Convention and the Kyoto Protocol) and how they apply to the building sector.

The Kyoto Protocol established three « flexibility mechanisms »:
- The “cap and trade” system (i.e. the international emission trading systems);
- Two project-based mechanisms:
  - Joint Implementation (JI),
  - Clean Development Mechanism (CDM).

The two project-based mechanisms allow industrialized countries with GHG reduction targets to firstly, invest in clean energy projects in non-annex I countries and secondly, use the achieved emission reductions as a means to reach their national mandatory mitigation target. The emission reductions translate into Certified Emission Reductions (CERs), also known as carbon credits. The JI was specifically designed to support projects in countries with economies in transition.

The CDM, officially created in 2001 (Marrakech agreements), was designed to specifically benefit developing countries, in a North-South perspective. It aimed to promote investment in developing countries on GHG-mitigating projects. However, the mechanism has experienced many difficulties:
- Slow and heavy procedures,
- Very few successful projects,
- Unable to handle complex projects.

**Clean Development Mechanism**

**The CDM’s objectives**

The CDM was designed to:
- Reduce the cost of mandatory mitigation in industrialized countries by funding or achieving GHG-mitigating projects, cheaper in developing countries;
- Launch projects that would contribute to a more sustainable development in developing countries and facilitate technology transfers.

The CDM was designed to be a “win-win” mechanism for all participants: on one hand, the investor earned CERs that he could either sell on the carbon market to a company or a State; on the other, the host developing country benefited from a new technology and more sustainable activities.

**The concept**

A State or a company invests in a GHG-mitigating project in a developing country. In exchange for the achieved emission reduction, the investor receives an equivalent volume of CERs. The investor can trade these units on the carbon market (de facto, the European Emission Trading Scheme), deducts the units from its international mitigation obligation (annex I parties) or adds it to its quota of emission allowance (major companies). The project’s emission reduction is calculated according to the emissions that would have been induced without the additional CDM investment (additionality principle).

**Terms and conditions**

There are four conditions of eligibility:
- Both States (investor and host) have ratified the Kyoto Protocol;
- The project must contribute to sustainable development in the host country;
The project must be first approved by the host country.
The project must be “additional” (financially and environmentally-speaking): it must lead to emission reductions that would not be achieved otherwise.

**CDM-eligible sectors and projects**

Sectors eligible for CDM projects are energy, waste management, industries, residential and tertiary activities, transports, agriculture and forests. Projects in these fields can target energy savings, alternative energy resources, renewable energy, and development of “carbon sinks” (in the forest sector).

**CDM restrictions:**
- It cannot be used to promote nuclear energy-related projects;
- Only afforestation and reforestation activities are eligible in the forest sector;
- A CER limit was established for afforestation and reforestation CDM projects: certified emission reductions cannot amount, per year, to more than 1% of the 1990 GHG emission ceiling in the industrialized country party.

**Very few CDM projects in Africa**

De facto, the countries which most needed the CDM did not benefit from it. In four years, only 28 (2%) of the 1596 projects registered by the CDM board were located on the African continent. Indeed, 84% of the CDM CERs were generated in China (more than half), Brazil, Korea and Mexico.

Furthermore, the 28 projects were implemented in only 8 African countries: Kenya, Morocco, South Africa, Uganda and Tanzania. And 15 of the 28 projects were registered by South Africa.

This significant imbalance is due to:
- The CDM’s administrative and registration complexity;
- The CDM was unvoluntarily designed for large-scale projects, with a rapid return on investment;
- The transaction costs for these projects are very high, making the mechanism prohibitive unless it targets major industrial projects;
- The lack of capacities and know-how to design projects and follow the complex procedure;
- The lack of institutional stability;
- The weak regulatory framework in developing countries.

**CDM Program of Activities**

The CDM’s scope was broadened end of 2007. At the COP in Bali, parties agreed on the possibility to register and implement “programs” of CDM project activities: Programs of Activities (PoA). PoAs were designed to reduce the marginal transaction costs and directly reach small companies and households. The CDM has become more effective because PoAs can work on more than one type of activity at a time, and act upon a whole sector, region or country.

However, the term “program of activities” is not well-defined yet. Should a PoA be characterized by its large scale, its single objective, its single technology, or by the number of projects it contains? Decision 4/CMP.1 does not elaborate on the eligibility criteria; however the procedure is very similar for project activities and project programs (in fact, a PoA can even be registered as a single project activity). The same GHG accounting methodology applies also. Unlike “bundles”, which entail pre-defined and very separate
projects, PoA is a single entity with undefined components. Its internal structure can thus change during the implementation process.

The UNFCCC gives the following examples of PoAs in the energy sector:

- Subsidy program for the replacement of old and inefficient appliances (heat pumps, engines) and for the renovation of old buildings;
- A program to promote more efficient appliances on the market: reduce the price of the more efficient options available, new regulatory framework on energy efficiency (construction code, inspections, labels);
- A low-rate loan to invest in renewable energy (for example, the acquisition of a solar water-heater by a household);
- A labeling program to promote energy efficiency of electric appliances.

In India for example, the CDM board registered and validated a PoA to accelerate the replacing of CFC refrigerating fluids with HFC fluids. Because CFCs are regulated by the Montreal Convention, only CO$_2$ emission reductions will be certified.

**Very few CDM projects in the construction/building sector**

The cost of reducing CO$_2$ emissions varies from one sector to another. CDM projects targeted sectors with rapidly profitable mitigation potential (for example, industrial plants, waste management, fluorescent gas-producing factory), to the detriment of projects relative to energy efficiency or renewable energy (in the case of the construction sector) because they generate less CERs and require more investment.
Figure 1. Sectoral distribution of CDM activities

<table>
<thead>
<tr>
<th>Sectoral Scope*</th>
<th>Registered Projects</th>
</tr>
</thead>
<tbody>
<tr>
<td>(01) Energy industries (renewable - / non-renewable sources)</td>
<td>1245</td>
</tr>
<tr>
<td>(02) Energy distribution</td>
<td>0</td>
</tr>
<tr>
<td>(03) Energy demand</td>
<td>20</td>
</tr>
<tr>
<td>(04) Manufacturing industries</td>
<td>100</td>
</tr>
<tr>
<td>(05) Chemical industries</td>
<td>58</td>
</tr>
<tr>
<td>(06) Construction</td>
<td>0</td>
</tr>
</tbody>
</table>

2 Graph can be found at: [http://cdm.unfccc.int/Statistics/Registration/RegisteredProjByScopePieChart.html](http://cdm.unfccc.int/Statistics/Registration/RegisteredProjByScopePieChart.html)
<table>
<thead>
<tr>
<th>Activity</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>(07) Transport</td>
<td>2</td>
</tr>
<tr>
<td>(08) Mining/mineral production</td>
<td>22</td>
</tr>
<tr>
<td>(09) Metal production</td>
<td>5</td>
</tr>
<tr>
<td>(10) Fugitive emissions from fuels (solid, oil and gas)</td>
<td>130</td>
</tr>
<tr>
<td>(11) Fugitive emissions from production and consumption of halocarbons and sulphur hexafluoride</td>
<td>21</td>
</tr>
<tr>
<td>(12) Solvent use</td>
<td>0</td>
</tr>
<tr>
<td>(13) Waste handling and disposal</td>
<td>359</td>
</tr>
<tr>
<td>(14) Afforestation and reforestation</td>
<td>6</td>
</tr>
<tr>
<td>(15) Agriculture</td>
<td>120</td>
</tr>
</tbody>
</table>

* Note that a project activity can be linked to more than one sectoral scope

In Africa, a single project was relevant to the building and construction sector. The project was implemented in South Africa and targeted energy efficiency in households (with environmental and socio-economical benefits):
- Insulation of the ceiling to reduce temperature variations, and reduce the need for air-conditioning (coal-powered);
- Solar sensors to heat the water and reduce the electricity bill (compared to the electric water-heater);
- The use of low-energy consuming lighting.

Worldwide, very few projects involved the building/construction sector: only China was able to register CDM projects in this field. Clearly, an international aid mechanism founded on a single-project approach is not adequate for the construction sector as it requires multiple and diffuse actions.

**Therefore, the CDM must cover global construction programmes, and not only single project activities.**

To launch programs on positive energy buildings, African States will require enough financial aid to cover the whole construction sector, or even the whole country. Programs for energy efficient buildings should be promoted, namely because:
- They do not entail technological difficulties,
- The extra costs are quantifiable and constant,
- They can be implemented by local companies if trained.

A CDM Program of Activities in the construction sector could target:
- Reduced and improved used of firewood,
- Construction of energy efficient buildings;
- Renovation of old buildings: reduce the need for air-conditioning; adapt to energy efficiency norms, etc…
- Dissemination of energy-efficient appliances and lighting.

**Waste management**

In Africa, household and municipal waste is dumped and accumulated in inadequate urban fields. These informal landfills are the main cause of water pollution and a health hazard for the neighboring communities. About 1/5th of CDM projects address waste management issues, namely by capturing methane (emitted by fermenting waste in landfills) to produce electricity in urban areas with no access to the utility network. A number of these projects were implemented in Africa: Côte d’Ivoire, Egypt, South Africa, Tunisia, etc.

<table>
<thead>
<tr>
<th>CDM projects related to waste management in Africa:</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Abidjan municipal solid waste to energy project</td>
</tr>
<tr>
<td>- Waste gas-based cogeneration project at Alexandria</td>
</tr>
<tr>
<td>- Onyx Alexandria landfill gas capture and flaming project</td>
</tr>
<tr>
<td>- Omnia fertilizer limited nitrous oxide reduce project (South Africa)</td>
</tr>
<tr>
<td>- Durban landfill gas-to-electricity project</td>
</tr>
<tr>
<td>- Landfill gas recovery and flaming for 9 bundled landfills in Tunisia</td>
</tr>
</tbody>
</table>

**NAPAs (National Adaptation Programmes of Action) and the Adaptation Fund**

NAPAs were established by the Kyoto Protocol to identify vulnerabilities and priority adaptation needs in developing countries. The recommended actions were to be financially supported by the Adaptation Fund, created in 2001 to help vulnerable countries mitigate and anticipate the impacts of climate change.

Industrialized countries requested that the Fund be governed by the Global Environmental Facility (de facto ruled by industrialized countries) whereas developing countries wanted to govern the new fund. In 2007, it was agreed that developing countries should play a predominant role on the Adaptation Fund board. The Fund is financed by the share of proceeds on CDM project activities (2% of CERs) and through voluntary contributions by annex I countries.

For the time being, only Least Developed Countries (LDCs) are obligated to draw up a NAPA. Recently however, countries recommended that all countries draw up NAPAs to better identify their needs in terms of adaptation, and to act in a coordinated manner.

**NAPAs but no investments to implement the actions**

Most LDCs have drawn up their NAPA, with UNITAR’s (United Nations Institute for Training and Research) technical support and the GEF’s financial support. However, hardly any concrete actions were implemented. This is due to delays in activating the Fund, and due to lack of voluntary contributions by industrialized countries. No adaptation project relative to the building/construction sector has yet received financial support from the Adaptation Fund.

Financial support for adaptation projects in the building sector target namely: land-planning, capacity-building for local councils, protecting buildings against rising sea-levels
in coastal towns, protecting buildings from flooding, managing thermal comfort during heat waves and their correlated peaks in electricity demand.

The issue with NAPAs is significantly different from the difficulties experienced with the CDM. The main problem with NAPAs was the lack of voluntary contributions in the Adaptation Fund, and the administrative delays.

**TNAs (Technology Needs Assessment on climate change)**

TNAs were established (at the Marrakech Conference in 2001) to identify and assess priority needs in terms of technology for adaptation and mitigation in developing countries. The TNAs served as the starting point for negotiations on technology transfers, one of the major questions to be discussed at the Copenhagen Conference in December 2009.

### 3.4 – Considering new mechanisms for the post-2012 agreement

**The REDD+ mechanism (Reducing Emissions from Deforestation and Forest Degradation and developing carbon sinks)**

In the international negotiations on climate change, parties agree on the importance of the deforestation issue, responsible for about 20% of world CO₂ emissions. At the Montreal conference in 2005, Papua New Guinea recommended the creation of a specific mechanism to tackle deforestation in the post-2012 agreement. Since then, the “REDD” proposal is an official component of the negotiation process.

The REDD concept consists in financially supporting countries that protect their forests and tackle deforestation and forest degradation. Initially, REDD’s only objective was the reduction of emissions induced by deforestation (RED). It then included forest degradation. Recently, some countries have insisted on a REDD+ mechanism which would include sustainable forest management, and the development of carbon sinks.

Deforestation has four main causes:

- Forest exploitation, namely exotic timber for export purposes;
- Tree-felling for local construction needs;
- Land clearing for cultivation needs in regions lacking farmland;
- Wood collecting for cooking purposes.

The REDD+ mechanism should work closely with poverty alleviating mechanisms to tackle the last two causes of deforestation.

**Firewood**

Actions to reduce GHG emissions induced by households’ firewood consumption could be supported by the REDD mechanism since actions to reduce firewood consumption also reduce deforestation. Programs promoting improved cookers would prove particularly useful in this context.

**NAMAs (Nationally Appropriate Mitigation Actions)**

In April 2009, the Chair of the Ad-Hoc Working Group on Long Term Cooperation Action under the UNFCCC formally adopted the concept of NAMAs as a possible new instrument of support to developing countries.

The concept is a new mechanism based on the following principles:
Voluntary participation of developing countries;
Allow developing countries to design small and large-scale generic actions (that could potentially be implemented again and elsewhere);
Provide international funds to totally or partially fund these actions;
Take into account each country’s specificities and in particularly, their individual level of development;
Acknowledge the efforts achieved by developing countries as an effective contribution to climate change mitigation.

The concept is convenient because it:
- Involves all non annex I countries (from emerging countries to LDCs);
- Is flexible and can be adapted to each country;
- Includes both specific actions and National Plans to tackle climate change
- Can fund each action step by step.

NAMAs would provide industrialized countries with:
- A concrete framework to financially support developing countries, based on carefully prepared actions or programs with estimated GHG emission reductions.
- A dynamic process that could, in the long term, lead to worldwide sectoral programs and facilitate technology transfers with collective benefits (cost reductions).

Founding the post-2012 agreement on the NAMA concept would be a decisive step forward: indeed, acknowledging voluntary mitigation actions by developing countries would contribute to curb their GHG emission trends (particularly in the more advanced developing countries).

However, at this stage of the negotiation process (July 2009), the concept is still unclear and countries tend to appraise the content, perimeter, nature, stakeholders involved, sources and types of funds, governance and framework of NAMAs in very different manners.

**A promising mechanism for the construction/building sector**

In the building/construction sector, NAMAs could be used to launch programs on the following:
- Improved quality of construction and renovation techniques and practices;
- Improved industrial processes, namely in the extractive industry and raw material processing industries;
- Construction programs to build hundreds or thousands buildings, based on a sample energy efficient building (avoided emissions x the number of buildings);
- Programmes to disseminate an energy efficient appliance: improved cookers, low energy-consuming lamps, efficient household appliances, etc…;
- Programs to design and manufacture improved local materials (adobe, clay+cement);
- Capacity-building programs for architects, engineers, technicians;
- Awareness-raising programs on energy efficiency and energy savings;
- Waste management to tackle methane emissions;
- Programs tackling deforestation and forest degradation.
4. Recommending projects, programs and relevant mechanisms

This chapter will make recommendations on programs, both needed and feasible, in the building sector. These recommendations target a number of sub-sectors and rely on various financial mechanisms (namely the mechanisms founding the agreements on climate change).

In coherence with the sectoral approach structuring this study, chapter 4 makes recommendations per purpose and in technical terms.

The study shows that the building sector (construction, renovation, households and household activities…) benefited very little for the Clean Development Mechanism. Generally-speaking, programs proposed for this sector are shut out from the mechanisms used in the international arena on climate change. Using the NAMA mechanism to fund programs could be the key to a more sustainable and energy efficient construction and building sector.

4.1 – New construction

Improving quality of construction techniques and practices is a complex process. A number of different actions will need to be implemented, using different funding mechanisms.

- **Direct support to single activity projects (CDM-like)**

  This type of approach is often inadequate for the construction sector. The only feasible action using a CDM-type mechanism would be:
  - **Construction of exemplary large-scale buildings**

    These energy-efficient sample buildings would help assess the global cost and emission reductions of such constructions.

- **Investment in CDM-like programs for which emission reductions and extra costs are easy to appraise**

  - **Household appliances, cookers, solar sensors**

    There are a number of options to support the diffusion of mass-manufactured efficient appliances.
  
    - **Efficient cooling and air-conditioning appliances**

    This type of program is only relevant and effective if first, the building’s design (in terms of thermal comfort) improved.

- **Designing in the new construction sector**

  Designing and building capacities are the two crucial steps towards improving quality in the new construction sector. The State should resort to development aid since the existing mechanisms in the climate change arena were not designed to take these steps. Development-aid supported programs could target:
  
    - **Architectural design**

    In most countries, there is currently no R&D on the most adequate architectural conception with regard to climate conditions, impacts of, mitigation and adaptation to climate change, and energy uses. Architectural conception should also take into account local material availability, national or regional traditions in terms of both design and lifestyle. Research
on architectural design should be supported mainly by development aid, R&D cooperation programs.

- **Drafting the legal and regulatory framework (construction code, regulation on thermal and electric power)**

These climate-adapted and energy efficient architectural designs will be founding elements for the new national construction policy and its regulatory framework. The process will be very gradual since the policy must cover three distinct markets: the industrial, small-scale and informal markets. Each market will be regulated differently: for example, stricter regulation will apply to public tertiary buildings, large-scale tertiary buildings and malls, and big hotels. On the other hand, the social housing and public construction sector will require more flexible regulation.

Regulation should include norms on the State equipment-manufacturing sector and on imported construction materials.

Furthermore, the regulatory framework should rely on international cooperation for funding as well as institutional and legal capacity building. Tunisia, for example, relied on a European partnership when drawing up its regulatory framework on thermal power.

- **Funding exemplary actions**

The draft legal and regulatory framework’s technical relevance and cost efficiency should be tested through pilot actions, and modified accordingly.

These pilot actions can be funded using multilateral or bilateral development aid, carbon funds, foundations or banks, PPP or NAMAs.

- **Training programs for architects, contractors, builders, financers**

This type of action contributes to adapt the professionals involved in the construction business and plays a crucial role in the diffusion of improved practices to all professional corporations

- **Industrial projects targeting factories manufacturing materials and appliances**

Investments that could be filed as CDM projects are, for example, projects to make factories (brick works, cement works) more energy efficient or to provide them with cleaner energy.

- **R&D programs to create sustainable economic channels for local materials and equipments.**

It is crucial to launch experimental projects to test the development of a local industry to manufacture and design adapted materials and equipments. Indeed, local industries will be the key to a mass dissemination of competitive materials and equipments.

Such R&D programs can be financially supported by development aid and become PPPs during the phase launching the mass dissemination process.

- **Pilot actions in a number of sub-sectors (social housing, public tertiary buildings, sanitary infrastructures, hotels...)**

In this phase, the number of pilot actions will be increased to promote the best techniques available in each sector, and on the territory. Pilot actions tend to be expensive at this stage because they require uncommon expertise and are one-shot projects. Development aid could be invested in these pilot projects. Or the projects could be integrated into large-scale programs (NAMAs for example) supported by the banking sector and industrial stakeholders.
✓ **Major investment programs**

Once the pilot projects have been achieved and validated, the large-scale construction programs can be launched. There are two major types of construction programs:

- **Mass construction of one type of building or one component**

  A State program to build a large series of identical collective or individual buildings could be filed as a CDM PoA. The CDM investment will be indexed on the emission reductions per building unit per the number of units constructed.

  There could also be State wide programs on specific components of a building both in renovated and newly constructed buildings: roof insulation, solar screens…

- **Mass construction programs for various types of buildings**

  More diversified programs could involve integrating a global program for improved quality in new constructions in the national climate change policy. The current procedures for the PoA CDM are not adequately designed to fund such programs because their impact is difficult to assess and translate into CERs. NAMA or sectoral programs would offer a more appropriate setting for complex programs, particularly because they would involve multiples sources of funding: contributions by industrialized countries, investments by the banking sector, carbon funds…

  In addition, mass construction programs could also receive funding from the Adaptation Fund to optimize thermal comfort during the more frequent heat waves and hereby adapt to one of the major impacts of climate change.

✓ **To fit up households with electricity-generating photovoltaic modules**

  The photovoltaic market is strongly supported by international development aid because it contributes to improving life conditions of communities with no access to electricity. Programs to disseminate photovoltaic modules are too expensive to attract CDM investors but could be included in NAMA programs.

### 4.2 – Cooking

Programs to reduce firewood consumption in cooking activities are financially supported by bilateral cooperations (particularly the German GTZ). However, although this issue is an African priority with regard to both energy resources and environmental protection, programs on firewood consumption suffer from insufficient and irregular support for a number of reasons. Alternative cooking means don’t always respect cultural and nutritional habits. Also, the programs lacked the logistic organization needed to massively disseminate the appliances. Furthermore, rural issues are not considered a priority concern for urban elites and policy-makers. Yet, such programs are the easiest and less costly option to reduce emissions and improve social wellbeing.

Programs could support initiatives to massively diffuse improved cookers in rural zones to increase the energy yield; and butane gas stoves in urban zones. Solar cookers could also be widely diffused. In addition, these programs should be tied to awareness-raising campaigns, particularly directed toward women.

Cooking-focused programs could be registered as:

- Projects within a PoA CDM;
- REDD+ projects;
- NAMAS (as part as a deforestation policy).
4.3 – Sanitary Hot Water

Solar sensors are definitely the most optimal technical option. Their broad diffusion would give access to SHW to all African communities.
A number of programs are currently being funded in Africa, through bilateral and multilateral cooperation programs. Some projects even involve locally produced sensors. Single projects are too small to be registered as CDM project activities. However, large-scale CDM PoAs could contribute to the mass diffusion of solar sensors for SHW.

4.4 – Lighting and household appliances

Energy efficient household appliances could be disseminated via projects in a CDM PoA. This program approach could be used to diffuse:
- Low energy-consuming lamps and LEDs;
- Various household appliances (refrigerators, etc.).

4.5 – Household waste management

Reducing methane emissions in landfills of household waste (particularly in hot and humid zones) has two main objectives: a) reduce water pollution and the correlated health hazards and b) produce an auxiliary electricity resource in cities.
Africa-wide, household waste should be managed and processed on environmentally-safe sites, in which the methane emitted can by captured and combusted in small power plants that will then sell the electricity to the utility network.
A number of the existing projects are filed as CDM project activities. At a larger scale, waste management projects could become PPPs with two components: on one hand, waste methanization and on the other, local services for household waste collection.

4.6 – Further considerations

This report highlights the funding needed by African countries to achieve a low-carbon sustainable construction sector.
A number of remarks to consider:
- This study chose to base its recommendations on existing financial means and mechanisms for project funding rather than anticipate future ones (NAMAs for example).
- Some of the projects could benefit from various sources of funding. This study recommends orientating projects towards sources of funding indexed on the project’s mitigation potential.
- The NAMA concept has yet to be discussed and adopted. In any case, its content and financial structure will not be finalized before COP 15 (December 2009) or COP 16 (December 2010).

The study clearly demonstrated:
- The inadequacy of the project-funding mechanisms used under the Rio Convention and the Kyoto Protocol.
- The need for a tool which would assemble multiple projects into one global program; and promote the development of national sub-sectors within the construction sector.
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- CDM Projects of activities: http://cdm.unfccc.int/Projects/index.html
Examples of successful projects

_building secco roofs in Mali^4_

’Sacco (also known as the « elephant herb ») grows abundantly in Mali, and close to reed. It is used to weave roofs: 4 cm diameter bunches of sacco branches are interwoven to make panels that are 4 cm thick, and tied together with plastic string. Two of these panels are then threaded together to form an 8 cm thick lining, and separated by a plastic sheet. The double panels are then attached to the wooden structure of the house, and threaded/tied together.

_building a community health centre in Djibouti^5_

The building is made of highly condensed raw clay, using a manual (or hydraulic, however more costly) press. The bricks contain a mix of 15 shovels of clay and one of cement, with a little water.

The newly-made bricks are covered with empty bags of cement, on sandy ground. They need to be dampered regularly during 3 weeks to slow down the drying process and ensure the clay does not crackle. The walls are built using the same method as cement breeze blocks. Each layer of bricks should be dampered first, and then covered with a 1 cm thick mortar coat. There will be no external coating but the inside part of the wall is coated with cement mortar.

This construction technique was 28% less expensive than a breeze block brickwork (one could save up to 47% if the land was cheap, and there was no press rental/acquisition). Globally, it allowed for a 6% decrease in the cost of the construction work.

Cement-stabilized clay brick construction on the Comoros Island^6_

In 1976, International Labor Organization (ILO) and the United Nations’ Development Program (UNDP) launched a program to manufacture clay bricks, stabilized with a cement blend, using a “Cinva-Ram” press.

Acquiring the technique and the press are very useful when building low-income housing. The test bricks gave satisfying results. An office and a shop were satisfactorily designed and built by the program’s participants.

At this point, the government decided to build new local administrative buildings (“moudirias”) with condensed bricks. The administration provided the communities with the needed materials and appliances, and trained the people. Local professional training centers organized continuing training programs in construction. The brick’s manufacturing cost was estimated at 16.07 KMF, and the manufacturing cost of a square meter of wall was estimated at 578.50 KMF, 36% of a cement breeze block.

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^6^ « Opérations expérimentales de l’habitat aux Comores », [http://baticom.org/projets.html](http://baticom.org/projets.html)
**Project supporting the promotion and the popularization of terracotta and micro-concrete roofing in Benin**

Importing construction materials is expensive. It is often more cost-effective to use local materials. The project “promotion and popularization of terracotta and micro-concrete roofing in Benin aims to give Potemat (Technology Pole for the Promotion of Local Materials) the institutional and financial support that it needs to build up expertise on how to produce and use local construction materials in Benin and in the surrounding region.

Since its creation in 1997, POTEMAT’s activities have focused on training roof-slaters on building sample houses (with a prototype TMB tiled roof), on conducting research studies on the molecular structure of micro-concrete, on the development of production equipment.

**Project on « vegetal roof tiles » in Côte d’Ivoire**

Like in most neighboring countries, roof raw materials are imported at a high cost in Côte d’Ivoire: they make up about 30% of the construction cost of an average home and also require the outflow of precious foreign currencies. These materials, said to be “modern” and efficient and sustainable, are however not adapted to the local environment and often increase problems like corrosion, temperature variations and acoustic nuisance. In urban zones, roofs are often made with corrugated iron, reinforced concrete or terracotta tiles. In rural areas, the traditional roof is made with straw, palm leaves and other plentiful, cheap and comfortable, local materials. However, these materials also have a very short life span and can catch on fire very easily.

Two types of tiles can be used in this case:

- Fiber-reinforced mortar tiles: sand, cement, sisal (natural fiber) which are all imported products. A) Sisal was replaced with local raw materials like coconut or rice fiber, or even couch-grass. B) Cement consumption was reduced and improved by using a mix of kaolin and silica-enriched vegetal ashes. C) Equipments and appliances were improved and made more cost-efficient.

- Micro-concrete tiles: cement, water, sand (this material is a perfect environmental and economic solution with regard to the country’s natural constraints, evermore since the country is full of sand quarries).

**Pilot-project for the construction of sustainable housing in Africa (December 2008)**

A new type of sample house was presented in Villeneuve-la-Guyard (Yonne–Bourgogne). It will be sent to Pô, a town in Burkina Faso that was partially destroyed by heavy rains during the summer of 2007. It will be assembled by the local community. The project is supported by the UNEP/SBCI (United Nations Environnement Programme/The

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7 Laboratoire d’Etude et de Recherche en Techniques Industrielles à L’Université Nationale du Bénin, Pôle technologique de promotion des matériaux locaux (POTEMAT), « document de projet d’appui à la promotion et à la vulgarisation de tuiles en micro-béton et en argile culte », http://www.bj.refer.org/benin_ct/rec/potemat/DOCUMENT%20DE%20PROJET%20PROMOTION%20POTEMAT.htm


Sustainable Buildings and Construction Initiative) and aims to build sanitary, sustainable and cost-effective homes for low-income communities.

The pilot-project has a number of objectives:
- Promote the construction in West Africa of sustainable houses, with a strong structure, high thermal comfort, use of local materials and renewable energies,
- Reduce the cost of construction and maintenance of the building,
- Allow a family to build its home without outside help,
- Improve existing construction techniques,
- Promote the local architectural heritage.

The project is a Plastbau construction system, promoted by an Italian company Plastedil. It was recently imported in France by a company called Neopano. For the past 30 years, the Plastbau system has allowed the quick and simple construction of solid buildings, with high energy performance. Two shuttering blocks in expanded polystyrene, connected by a metal structure, are assembled to form the structure of the building. In the case of the project in Burkina Faso, laterite (abundant local clay in tropical zones) will be poured in between the panels to keep them together and fill the holes. The outside walls of the building will then be painted according to the architectural traditions of the Kassena ethnic community. These construction techniques prevent the community from resorting to expensive construction materials (the price of a bag of cement increased from 10€ to 16€ and up to 29€ in other African countries). Furthermore, cement is often irregularly supplied and available.

The structure of the house will now be sent to Burkina Faso. Once the prototype is achieved, the project’s next steps will be to collect funds from international organizations and private foundations to invest in the creation of a Plastbau factory (2.5 M€ investment needed). This way, the panels can be locally manufactured for the local communities, and the neighboring countries if needed. The factory could also train and support the local communities during the construction to develop sustainable construction practices.

Health center of Barkoundouba in Burkina Faso (bioclimatic construction)¹⁰

The national development project for Burkina Faso aims to launch a development plan for the rural health centers in order to grant the local communities access to health care. Bioclimatic architecture appears to be the right response to this challenge as it offers sanitary and comfortable conditions, and uses local materials, workforce, and techniques. This reduces the costs of conception and development.

The project aims to reduce the use of imported materials and thus promotes the use of condensed and pressed clay bricks (30 cm thick). This solution is convenient because it offers:
- Excellent mechanical resistance,
- Good regulation of humidity level in the air,
- Very good inertia,
- Clay is available and pressed manually on the construction site,
- Reduces the importation of material and the cost of construction.

In this type of climate, optimizing both thermal and visual comfort is crucial yet difficult to achieve. The architect must think of the orientation (East-West axis) but also about protecting the windows: i.e. placing a window roof on the east façade and a screen wall on the west façade; and letting the roof overhang over the northern and southern walls. Walls with windows/openings allow the air to circulate as well as protection from the sun.

The rooftop is the construction component most affected by solar energy: its design should reduce the risks of overheating by evacuating at night the heat stored during the day. There is a large space between the rooftop and the thick ceiling that insulates the building. This space allows for natural and continuous ventilation; and the rooftop completely shades the ceiling.

Since the site does not have access to the electricity network, the buildings cannot rely on conventional air-conditioning. Due to the bioclimatic design, using the abovementioned techniques (i.e. solar protections, rooftop design, thermal inertia), there is no need for air-conditioning. However, it is crucial to train the staff on how the buildings work: during the day, all the windows must be closed and protected. During the night, all the natural ventilation installations are used, in order to evacuate the heat stored during the day (due to the inertia) through the various openings.

The project was launched in 1998 and 100% funded by the French and Burkinabe Barkoundouba association. The bioclimatic design appeared as the most adapted construction design in the regions with poor access to energy, and where the climatic constraints make it difficult to achieve thermal comfort. Barkoundouba entrusted the French NGO GERES with the bioclimatic construction.

The technical success achieved by the project is difficult to quantify since there is no energy consumption. However, the project achieved its aim: thermal comfort within the house without resorting to MCV or air-conditioning.

Each square meter cost 150€/m², leading to a total expenditure of 64 200€. The extra cost induced by the resort to a bioclimatic design was estimated at 15%. The results were very satisfying and the project was launched a second time in another rural zone of Burkina Faso.

The project allowed Burkinabes to acquire experience in bioclimatic design, but also in construction project developments.

Examples of projects funded by the French Agency for Development Aid (AFD)

A number of projects were funded by the AFD in Africa, in both the construction/infrastructure sector and the firewood/deforestation sector.

**Infrastructures:**

- Project promoting access to electricity for the poor rural communities of Benin;
- Project to reinforce the electric utility network in urban and peri-urban zones of Kenya;
- Project to extend the electric utility network in the rural areas in Mauritania;
- Program supporting the reduction of the number of households lacking sanitation in Morocco;
- Program promoting the renovation of poor and/or ancient districts in Tunisia;
- Urban environmental project in Lomé (mainly domestic waste management) in Togo.

**Forest management:**
• Support to the « forest & environment » sectoral program in Cameroun;
• Reforestation and concerted management of natural resources in Kenya;
• Environmental project in Tunisia: creation of an interbank credit flow designed to support environmentally-friendly investments (depollution, renewable energies, waste management and recycling, energy savings).

**Improved cooking hearths**

**The concept**

Improved cooking hearths are ovens (made of clay, bricks or metal sheets) inside which branches, firewood, or coal slowly burn. They are very energy efficient compared to the traditional cooking methods with no wind protection. Improved hearths can save up to 75% of the energy traditionally required to cook a meal.

**Various types of hearths**

1. **Traditional hearth**: composed of three stones forming a triangle to hold the pan or the pot or the pan.
2. **Other hearths**:
   - Made of stone, clay mixed with straw and dung. Eg. the traditional bread oven: “tabouna” ou “albarka” au Niger et du Rwanda. It uses firewood and farm residues as fuel.
   - Made of terracotta: “Filli” hearth in Chad.
   - Made of sand and clay, it uses wood as fuel. Eg. « Maendeleo » in Kenya.
   - Made of bricks with a metal grate. It has a ventilation valve as well as a chimney. Eg. “Chingwa”, in Zimbabwe, uses firewood as fuel.
   - Made of metal sheets and vermiculite (natural insulating material). Eg. The “Tso Tso” in Zimbabwe, which uses small pieces of wood and brick waste as fuel.
   - Made of recycled metal sheets. Eg. The “Katindé Nyandi” in Cameroun, which uses firewood as fuel.
   - The « Ganoune » hearth uses coal and is made of metal wire. Its average price is 2.29€.

**Different uses depending on the location**

1. **Rural households**: their hearths rely on firewood, cow dung, farm residues. The fuel is not bought but collected by the women and children. It is their daily chore and hardship. Families which can afford to will buy firewood.
2. **Urban households**: their hearths rely on firewood and coal (bought).
3. **State-owned** hospitals, schools, restaurants and little hotels buy firewood.

**The pros of improved cooking hearths**

- Keeps the flames alive during windy weather;
- Efficient control of the fire;
- The consumer is not exposed to the heat and the smoke;
- Réduction des risques d’incendie et de maladies;
- Protection of forest resources (70% decrease of firewood consumption with respect
More job creation than with traditional hearths;

- More job creation than with traditional hearths.

**Realization (2001 is the reference date for the prices)**

- **Improved hearths in metal sheets** (30% saving with respect to the tradition Ganoune hearth; price around 4€); local production; one or two year lifespan.
- **Success:**
  - Coal and firewood-fueled hearths (« Nafacaman » in Mali).
- **Improved hearths made in metal sheets and terracotta, coal-fueled.** The combustion room is in terracotta, but covered in a metal sheet, using cement. It is distributed in Kenya, in Senegal, in Burkina Faso, in Mali and Benin. It allows a 40% saving on firewood and coal. “High range” hearth which is quite difficult to build. Price in the range of 6-7.5€.
- **Metal hearth with one hole, but no chimney:** It is built in recycled metal sheets by traditional craftsmen. More than 25000 hearths had been sold in Niger by 2001.
- **Improved firewood-fueled terracotta hearths:** it was inspired by the traditional “filli” hearth.
- **Improved hearth « Roquet »** has a very efficient combustion room. The air comes in through the bottom, and is heated under a metal plate. The wood is entirely consumed without the flames licking the pot, preventing smoke. The combustion room is made of insulating materials (mix of clay, wood residues and chamotte) compacted into thick bricks. This way, there is no lost heat.
- **Improved hearths “Roumdé”**
- **The “rondereza” technique:** construction of a brick oven in which firewood and coal burn on adobe plaques. This maximizes the energy yield and conserves the heat. It costs 40 euros but can save up to 2/3 of firewood/coal consumption.

**Dissemination under constraints**

There are a number of obstacles to the dissemination of improved hearths and other equipments in rural zones.

Financial and income-related obstacles:

- The targeted communities have a very low purchasing power, and cannot buy the installations for the market price. Without the subsidies, the communities stopped buying the improved hearths.

The obstacles related to information and awareness-raising:

- Restricted population targets (urban centres only),
- Insufficient information of target populations on the use of certain equipments,
- Insuffisance d’information des populations cibles sur l’utilisation de certains appareils (in the case of gas stoves).

Technical obstacles:

- Difficulty to buy the raw materials required to build the installations (furnaces and improved hearths);
- Technical conception of installations that are not adapted to the local context (example of pressurized-burner stove);
- Difficulty to find the spare parts.

Sociological obstacles:
- Craftsmen travel during the winter season, inducing a breakdown in production;
- Appliances not adapted to cooking habits.

**R&D-related obstacles:**
- Insufficient involvement by research entities;
- Lack of investment in these research entities.

**The new technologies**
Gas and oil-fueled stoves and furnaces are being increasingly used in urban zones. However, gas and oil are more expensive than the good quality firewood or coal used to fuel improved hearth.

**The solar cooker**
Solar energy is often used to:
- Heat the water and sterilize the medical material in maternity hospitals, free clinics, health centers and even hospitals with no continuous access to electric energy;
- Cook some meals.

**The pros of the solar cooker**
- Carbon-neutral cooking;
- No use of firewood;
- No health hazards;
- Adapted to African sunshine.

**The cons of the solar cooker**
- The cooking is outside;
- The cooking time is longer;
- The solar cooker cannot be used at night time, and women who work in the fields usually cook at night;
- The fire is a means to warm the village during the night, in the colder regions;
- Repairs and spare parts are often needed;
- Comparatively costly: more than 50€ (plus the cost of the spare parts).

**Various sorts of improved cooking hearths**

The traditional Ganoune provides a powerful fire, thanks to its efficient ventilation system. It does not require constant attention. However, this hearth is not very stable.

The “mixt and round” hearth works well with a medium-sized pan. However, if the pan is too big, it may put out the fire. Its base is narrow and unstable. It is more efficient than other and consumes 31% less coal, with respect to the Ganoune.

The Sewa furnace can contain a very limited amount of coal, but the combustion room maintains a strong flame during the entire cooking process. It is the only hearth that does not need to be replenished in the course of the cooking process. It is extremely stable, and allows a 34% coal saving.

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The “Chateau” hearth has a very large combustion room, which means that the pan floats in the furnace and the fire tends to die out. It nonetheless allows a 32% coal saving.

The “Abéché” hearth is supported by 3 legs. However, the combustion room is also very large and the fire tends to die out. It allows a 28% coal saving.

Description and making

This hearth is distributed in Senegal, under the name « Sakkanal », and in Mali under the name “Daamu”. It is made of recycled metal sheets, folded and riveted. A small shutter closes the air out during low-flame cooking.

The furnace's base must be large enough to ensure stability. The grill can be removed and replaced.

**Foyer à charbon de bois tôle/terre cuite**

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### Description and making

This hearth is a simplified version of the Jiko Kenyan. It was successfully implemented in Madagascar. The clay bowl is molded by the potter around wooden molds. The recommended composition for the terracotta is: 30% silty clay; 35% of grey clay, 30% of chamotte\(^{14}\). The clay bowl is covered in a thin metal sheet cylinder (10/10\(^{mm}\)), using cement.

\(^{13}\) AEDE, Rapport de mission de P.LAURA « Mise au point d’une gamme de foyers améliorés et réchauds et préparation de la diffusion », 2001.

\(^{14}\) « Chamotte » is clay powder with lumpy deposits
**Description and making**

This traditional hearth, made of terracotta, is a widened cylinder with a slit on the side, for the firewood. It is made by the local potters around Ndjaména in Chad. The top part of the hearth widens and can be used with pans of various sizes.
Type of furnace: metal hearth. It uses coal and firewood. It can contain more than one pan.

Origin: it was created during a workshop by the UNDP on “appropriate technologies” in 1991. A few hundred models were distributed by the national gas programme in 1997.

Construction materials: new metal sheets welded together;

Description: basis of the cylindrical hearth; single air opening; three-legged support.

Comments: imperfect finish (low quality welding).

Test: making of “la boule”\(^\text{15}\) for 4 days. 31% energy saving but cooking time increased by 9%.

\(^{15}\) “La boule” is a traditional African meal.
### Summary of the actions that can be implemented in each type of construction sector

- **Options for adaptation and their implementation**

<table>
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<tr>
<th>Activities</th>
<th>Arguments</th>
<th>Concrete Project/Road Map</th>
<th>Financial Mechanisms, Sources of Funds</th>
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</table>
| Cooking             | • Abusive use of wood fire and charcoal has negative impacts in terms of deforestation  
• Improvements of women domestic work conditions, relating to water and wood duty, with distribution of improved fireplaces and other cooking methods | • Reducing wood consumption as combustible (replacing with butane, improved fireplaces...)  
• Economic incentives for the use of LPG in the context of climate policies with international support | • State  
• Programmatic CDM  
• Private investors  
• PDA |
| New constructions   | • Research                                                                | • Develop research on local construction materials and their implementation  
• Technology transfer  
• Research programs specific to African countries | • PDA  
• GEF |
|                     | • Integration of energy efficiency standards in law                        | • Implementation of a progressive construction quality standardization with respect of obligatory standards in public markets  
• Integration, in construction standards, of aspect and insulation recommendations  
• Encourage property developers and project managers to integrate climate change issues in construction  
• Encourage respect of regulations | • State  
• PDA  
• GEF |
|                     | • Pilot projects                                                           | • Pilot operations  
• Development of local jobs and industries of materials instead of imported products  
• Development and implementation of solutions that avoid conditioning | • State  
• Public-private partnership  
• PDA  
• GEF  
• Regional banks |
<table>
<thead>
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<th><strong>Urbanism</strong></th>
<th><strong>Rehabilitation of existing housing</strong></th>
<th><strong>Behaviour</strong></th>
<th><strong>Domestic and tertiary equipments</strong></th>
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</table>
| Climate adapted housing promotion  
Thermal comfort improvement, particularly with efficient conditioning techniques  
Large scale distribution | In warm and dry regions, because of demographic pressure, development of collective housing  
Informal district restructuration issue | The ignorance of equipment running costs | Reduce energy related expenses  
Reduce power cuts  
Develop sanitary hot water without greenhouse gas emissions |
| Develop of cheap, low energy consumption and high quality new construction  
General promotion of sustainable development | Restructuration of old and peri-urban districts | Improvement of behaviours | Distribution of low energy consumption light bulbs, efficient electrical appliances, solar panels, office equipments  
Availability and accessibility of high-performance equipments  
Implementation of standards on importations and product design  
Development of energy efficiency in every equipments |
| Programmatic CDM  
NAMAs  
Private developers  
Banks  
Carbon funds,  
GEF | | | State  
PDA  
NGOs |
| State  
PDA  
NAMAs | | State  
Media  
NGOs  
Unesco | State  
Programmatic CDM  
NAMAs  
PDA  
GEF  
Banks |
## Industrialized construction

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<th>Means, partnerships, actions</th>
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<td>Capacity-building, development aid</td>
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<th>Creation of local channels for the production of material</th>
<th>CDM, development aid, PPP</th>
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<td>Roof insulation</td>
<td>CDM program of activities, NAMA</td>
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<tr>
<td>Thermal regulation</td>
<td>Thermal regulation</td>
<td>Development aid</td>
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### Thermal installations

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<th>Cooling</th>
<th>Develop the « provençal wells »</th>
<th>CDM program of activities, NAMA</th>
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<td>Reduce the use of air-conditioning</td>
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<td>Develop heat pumps</td>
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<td>Develop low-energy air-conditioning</td>
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<td>Develop solar air-conditioning</td>
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<tr>
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<td>Develop radiative air-conditioning</td>
<td>CDM program of activities, NAMA</td>
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<tr>
<td></td>
<td>Develop evaporative air-conditioning</td>
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<td>Solar protections</td>
<td>Mobile or fixed protections for the openings</td>
<td>CDM program of activities, NAMA</td>
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<td>Create transitional spaces</td>
<td>CDM program of activities, NAMA</td>
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<tr>
<td></td>
<td>Vegetal protection</td>
<td>CDM program of activities, NAMA</td>
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<tr>
<td>Ventilation</td>
<td>Promote natural ventilation</td>
<td>CDM program of activities, NAMA</td>
</tr>
<tr>
<td></td>
<td>Study the potential use of a Controlled Mechanical Ventilation, with an air-to-air heat exchanger</td>
<td>CDM program of activities, NAMA</td>
</tr>
</tbody>
</table>

### Other equipments

| Sanitary hot water | Promote solar water-heaters | CDM program of activities, multilateral and bilateral cooperation |
| Glazing/opening | Size and location of openings | CDM program of activities, NAMA |
| | Development of absorbing glazing, photochromes & electrochromes | CDM program of activities, NAMA |
| Energy production | Photovoltaic modules | NAMA, development aid |
| Artificial lighting | Dissemination of low-energy light bulbs | CDM program of activities, NAMA |
| | Test the use of LED | CDM program of activities, NAMA |
| Domestic appliances | Dissemination of low-energy appliances | CDM program of activities, NAMA |
| Cooking | Promotion of substitution energy resources (LPG) | CDM program of activities, NAMA |
| | Programme of sustainable management of forest resources | REDD+, NAMA |
| Behaviors | Awareness-raising campaigns | CDM, NAMA |
| Renovation | Renovation programme | PPP et CDM program of activities |
| Domestic waste management | Electricity production with waste-produced methane | CDM, PPP |
## Construction by local small-scale companies

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<th>General conception/architecture</th>
<th>Actions to be implemented</th>
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<td>Building up the chain of actors involved</td>
<td>Capacity-building, development aid</td>
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<th>Envelope</th>
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</thead>
<tbody>
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<td>Materials</td>
<td>Mise en place d’une filière de fabrication de matériaux locaux</td>
<td>CDM, development aid, PPP</td>
</tr>
<tr>
<td>Insulation</td>
<td>Roof insulation</td>
<td>CDM, NAMA</td>
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<th>Thermal installations</th>
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<tr>
<td>Cooling</td>
<td>Study the potential development of « provençal well »</td>
<td>CDM program of activities, NAMA</td>
</tr>
<tr>
<td></td>
<td>Reduce the use of air-conditioning</td>
<td>CDM program of activities, NAMA</td>
</tr>
<tr>
<td>Air-conditioning</td>
<td>Development of heat pumps,</td>
<td>CDM program of activities, NAMA</td>
</tr>
<tr>
<td></td>
<td>Develop low-energy air-conditioning</td>
<td>CDM program of activities, NAMA</td>
</tr>
<tr>
<td></td>
<td>Develop solar air-conditioning (using solar panels)</td>
<td>CDM program of activities, NAMA</td>
</tr>
<tr>
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<td>Develop radiative air-conditioning</td>
<td>CDM program of activities, NAMA</td>
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<tr>
<td></td>
<td>Develop evaporative air-conditioning</td>
<td>CDM program of activities, NAMA</td>
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<tr>
<td>Solar protection</td>
<td>Fixed or mobile protections for openings</td>
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<td>Create transitional spaces</td>
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<td></td>
<td>Vegetal protection</td>
<td>CDM program of activities, NAMA</td>
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<tr>
<td>Ventilation</td>
<td>Promote natural ventilation</td>
<td>CDM program of activities, NAMA</td>
</tr>
</tbody>
</table>

| Other equipments              |                           |                             |
| Sanitary hot water            | Promote the solar water-heaters | CDM program of activities, bilateral and multilateral cooperation |
| Glazing/openings              | Dimensions and location of openings | CDM program of activities, NAMA |
| Energy production             | Photovoltaic modules      | NAMA, development aid       |
| Artificial lighting           | Dissemination of low-energy light bulbs | CDM program of activities, NAMA |
| Domestic appliances            | Dissemination of low-energy light bulbs | CDM program of activities, NAMA |
| Cooking                       | Dissemination of improved cooking hearths | CDM program of activities, NAMA |
|                               | Dissemination of other energy resources (LPG) | CDM program of activities, NAMA |
|                               | Programme of sustainable management of forest resources | REDD+, NAMA |

| Behaviors                     |                           |                             |
| Awareness-raising campaigns   | CDM program of activities, NAMA |
| Renovation                    | Renovation programme      | PPP & CDM program of activities |
## Informal construction sector

<table>
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<th>Means, partnerships, actions</th>
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</thead>
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<td>Materials</td>
<td>Reduce the use of corrugated iron</td>
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</tr>
<tr>
<td></td>
<td>Promote the use of local materials</td>
<td>CDM programme of activities, development aid, PPP</td>
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<tr>
<td>Insulation</td>
<td>Roof insulation</td>
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<tr>
<td>Thermal installations</td>
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<tr>
<td>Cooling</td>
<td>Reduce the use of cooling systems adapted through thermal inertia</td>
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<td>Solar protection</td>
<td>Fixed or mobile solar protection</td>
<td>CDM programme of activities, NAMAs</td>
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<tr>
<td></td>
<td>Create thermal transition spaces (corridors, galleries)</td>
<td>CDM programme of activities, NAMAs</td>
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<td></td>
<td>Vegetal protection</td>
<td>CDM programme of activities, NAMAs</td>
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<td>Ventilation</td>
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<td>Other installations</td>
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<tr>
<td>Glazing/windows</td>
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<tr>
<td>Artificial lighting</td>
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<tr>
<td>Cooking</td>
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<td></td>
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<td>Programme of sustainable management of forest resources</td>
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<tr>
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<td>Awareness-raising campaigns</td>
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<tr>
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<td>Renovation programme</td>
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