Management and assessment of performance risks for bioclimatic buildings

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A B S T R A C T

Given high energy demands of buildings, developing countries need to be sensitive to the critical rote of building energy efficiency in the fight against climate change. Especially in tropical countries where the thermal flow is strong and the lack of electricity distribution networks is a sad reality. The consolidation of this energy efficiency requires the preservation of nature through a harmony between the building and its environment on one hand and an effective evaluation of energy performance on the other hand. Faced with these challenges, the bioclimatic concept is one of the best alternatives to weave this harmony between the building and its environment. Furthermore a meaningful energy performance assessment of buildings based on the knowledge of capitalization with the experience feedback processes can be used to structure the different phases of implementation of the buildings. Firstly, this article presents the general concept of bioclimatic buildings with emphasis on thermal notions that influence thermal comfort inside a building. Secondly, the effort focuses on identifying non-qualities and factors of discomfort whose resolution helps to improve the energy and environmental performance of buildings. This approach supported by land surveys to interview the building actors and users to collect data favourable or not favourable to energy-performance. These data are then processed for the generation of graphical representations used by methods developed on the basis of knowledge and strategies of bioclimatic concepts. After the capitalized knowledge from experience feedback processes allows us to offer corrective solutions and share best practices to address the identified performance problems.

Keywords:
Meteorological data
Information
Knowledge
Sustainable design
Energy efficiency
Thermal comfort

1. Introduction

The building sector is responsible for about 4/5 of the Africa's total energy consumption with more than 2/3 of electricity (Sophie et al., 2012), so there are enormous emissions of greenhouse gases without counting the indirect emissions of obtaining different construction materials process. These indirect emissions are the consequences of the use of energy (grey energy) in the production, recycling, transportation, and storage of the building materials. Generally this energy is not considered in the environmental degradation of observations.

Currently, the rote that buildings energy efficiency plays in the reduction of global warming makes unanimity in ail countries. Consequently, there is a need for new sustainable construction techniques and if possible with some building local materials against imported or industrial materials commonly used in many countries. For example, the use of straw, baked earth and techniques of solar gains or natural ventilation in tropical buildings climates areas can be valued.

Also the use of various renewable energy sources could encourage under-investment in energy efficiency and exploitation of renewable systems. In fact, renewable energies whose potential elements are naturally available must play a more important role in areas with tropical climates.

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Tropical areas climate is a type of climate that we meet between the tropics, up from 15to 25° latitude, north and south. lndeed, the length of daily illumination varies little during the year and is approximately 10-12 h. Solar rays are mostly very close to the vertical, thus they provide a strong warming.

ln scorching periods, during part of the day, the outdoor temperature exceeds comfortable values (27 °C-30 °C). lt is therefore not possible to use natural ventilation to remove heat generated by the sun (even if it is reduced due to sunscreens) or that generated by the occupants without overheating the premises (Haddam, 2015).

However, diurnal and annual temperature differences are more important than under the equatorial climate.

There are two types of tropical climates:

> Hot and humid areas characterised by abundant sunshine, full power of day, high temperatures with little differences between the day and the night, little seasonal variations and a hygrometry always very high;
> Warm and dry areas characterised by abundant sunshine, high temperatures, a low hygrometry and a difference of temperatures between the day and the night is relatively large (Sophie et al., 2012).

The very high temperature causes an enormous need for cooling of buildings (air conditioning and ventilation), that explains the energy expenses and enormous impacts on the environment. ln these tropical climates areas, building occupants will increasingly need energy resources for the improvement of thermal comfort guidelines achievement, and this is a potential source of significant energy consumptions. Modern buildings in many of these tropical countries, especially in sub-Saharan Africa, are unsuitable for heat, because in the absence of regulations on the energy section (lwaro and Mwasha, 2010), the design is based on technologies and standards sourced from other sociological and climatic contexts.

lt is therefore necessary that the construction techniques of these countries should take into account climatic realities and research results. For example, it is notable that the natural illumination levels inside the buildings in the tropical areas are generally lower than those commonly achieved in European and North American buildings (Edmonds and Greenup, 2002). Generally, these areas face problems such as Jack of electricity (Jack of energy source, low capacity of production and distribution electricity networks ...). In these areas, the potential for natural lighting should be used while adjusting the building openings to deliver the goods of thermal and visual comfort in size and positioning.

In Italia, it is showed that contrai solar gains through the openings are more effective in warmer clirnates (Bellia et al., 2013). In Hong Kong, it is significant that heat gains through the windows of a high rise apartment building represent 45% of the required energy needed for the cooling (Lam, 2000). In addition to the openings, the adequate configuration (orientation, geometry and roof) of the building with the site realities promotes ventilation and natural lighting; so this properly reduces the building's consumption. ln Japan, the studies of comparisons were made between a roof having a cavity subjected to natural ventilation and a single roof (Susanti et al., 2011). The results show that this type of ventilation reduces the operative temperature of about 4.4 °c and hence irnproves the life of the air conditioning system.

There are several passive strategies to reduce the roof contribution to the heat gain within the building.The classification of passive techniques is enabling the actors to progress on the perception of the roofs thermal performance in architectural and non-architectural methods (Sanjai and Chand, 2008). The nature of the building envelope is also important on the opaque walls of the building temperature, because it causes a reduction or an elevation of the heat flow to the indoor environment synonymous of energy savings or wastes in air conditioned buildings and thermal stress level in buildings (Synnefa et al., 2007; Hernandez-Perez et al., 2014). Thus, the buildings must be harmonized with their environment (passive or bioclimatic concepts) in order to be adjusted to consume less energy, to worry about pollution and atmospheric emissions, materials used by sustainable practices (Lombera and Roja, 2010) and many other related issues. ln the same vein, the bioclimatic architecture ensures durability through an improved environment, an economically prosperous society (Shen et al., 2010).

The study of this article is carried out in the architectural bioclimatic context. The state of the art covers the thermal of the building for energy efficiency of buildings and the adopted methodology is based on the assessment of ail risk factors of energy performance in buildings. The proposed approach is based on the experience feedback experience processes with continuous learning principles for analysis (Kamsu and Tiako, 2017; Camara et al., 2016; Kamsu-Foguem, 2016; Kamsu-Foguem et al., 2015; Kamsu-Foguem and Abanda, 2015; Kamsu-Foguem and Mathieu, 2014; Kamsu-Foguem and Noyes, 2013; jabrouni et al., 2013; Potes Ruiz et al., 2013; Kamsu-Foguem et al., 2013; Potes Ruiz et al., 2014; jabrouni et al., 2011; Kamsu-Foguem et al., 2008) and performance evaluation. This takes into account the risks in construction of bioclimatic buildings in the tropical areas by integrating field players' experiences for better decision-making in future construction projects (Rapport octobre 2014, Grenelle de !'Environnement).

2. State of the art: thermal and bioclimatic concept of building

2.1. Bioclimatic concept

The bioclimatic concept is to preserve the nature through a harmony between accommodation and its environment (local climate, vegetation, local materials) for thermal comfort of occupants in the rooms (see Fig. 1). It restores architecture in its relation to man and climate while drawing makes the most of solar radiation and natural ventilation to reduce energy requirements , maintain comfortable temperatures, contrai humidity and promote natural lighting. The bioclimatic concept is based on three basic concepts: passive heating, passive cooling and natural lighting.

The bioclimatic architecture exists only in the objective of trying to meet comfort requirements. lt therefore cares about the parameters that determine the well-being of the inhabitants. The climate is the decisive element in the bioclimatic concept namely sunshine, ternperatures, wind patterns and precipitations which contribute to determine a physical environment to which the architect refers.

For use in the tropical and subtropical climates, bioclimatic concept is going to be the passive cooling techniques and natural lighting. ln summer comfort meets the cold strategy:

- Protection of someone from solar radiation and heat gain,
- Minimisation of excess solar gain,
- Dissipation of excess heat and cooling naturally.

ln order to prove this, the perfect knowledge of the following aspects is capital (Watson and Labs, 1983).

> **Incident solar radiation** to adequate application of insulations to facades especially the roof is directly under solar radiation, because solar energy intercepted by an isolated opaque surface (walls and roofs) does not really enter in the building, but is mostly rebroadcasting outward.

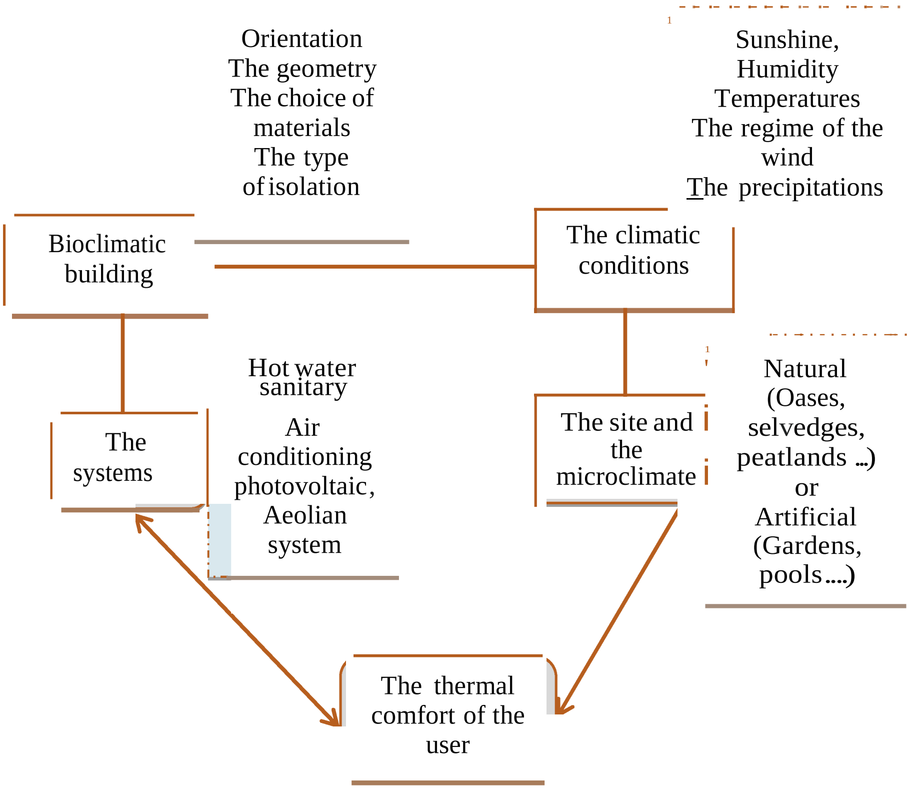

Fig. 1. Schematic illustration of bioclimatic concept.

> Implantation of the building to take into account the turmoil, urban planning, solar neighbour masks and the surrounding vegetation.

> Orientation and building Opening

- The orientation of the windward should not deviate from the wind over 45° to receive the prevailing winds, heat dissipation (internai and solar gains) and fresh air in the room (natural ventilation);
- lt must be along East/West longitudinal axis to reduce exposure to sun in hot climates except desert or Mediterranean climate where solar gains are useful during the cold season (live by the glass) or night (out of step with inertia);
- The windows' size, as part of capture, must match the availability of the sun (site, orientation and tilt) and the heat demand (building tosses: transmission and air exchange).

> Shape and building geometry

- lt is compact in general to limit tosses to surface or exhibits a major solar illumination,
- To create the greatest shade possible (a fully open courtyard is desirable in desert climate).

2.2. *Thermal building*

Physically, the building is a mass and a volume. The mass (opaque and transparent walls) is the link between the internai microclimate and fluctuations of climate solicitations. The morphology, orientation, and organization of spaces in the bioclimatic concept characterize the modalities of interactions and energy transfers between the inside and outside.

Thermal exchanges by conduction operate in opaque and transparent walls. The thermo-physical properties (thermal conductivity, density and heat capacity) intervene in this heat exchange mode. In the context of tropical dimates, the need for comfort is based on the premises of buildings cooling. Bioclimatic buildings should ensure the reduction of heat transmission to the interior of the premises. To do this, it acts both on the inertia and conduction (thermal diffusion). Thermal diffusion in a material is determined from the physical parameters whose expressions are below:

$$D = \frac{3}{pC} \quad E = pCV'D$$

Diffusivity D and thermal effusivity E give important information about the transmission of heat to the scale of a material. The effusivity (W.s½)/(m²K)) is the ability of a material to absorb energy and return while the thermal diffusivity (m²/s) describes the speed of heat removal through a material mass. With: p: density; λ: thermal conductivity; C: specific heat.

If effusivity is not taken into account in a heat balance, it therefore remains an important parameter of thermal comfort:

- A high effusivity material quickly absorbs a large amount of energy without heat up significantly;
- Ifhis effusivity is low, the material heats up the surface in a short time. lt is this effusivity that gives cold wall sensation in winter, thermal discomfort synonymous.

Diffusivity allows scaling a solar wall thickness which captures calories in the day and returns them a few hours later to a nightlife room.

These settings facilitate the judicious use of materials in the building envelope (materials of better heat storage capacity). This helps to improve thermal comfort in the buildings and improve buildings energy efficiency (Herde and Liebard, 2004).

The diffusivity coefficients of some building materials are given in the following table (see Table 1):

Table 1
Diffusivity Coefficient of different building materials (Herde and Liebard, 2004).

Materials	Concrete	Terracotta	Sheet metal	Bricl<Wall	Wood	Hollow building black	Pressed earth	Glass wool
D.10^7 m^2/s	4,81	7,10	112	3,79	3,33	6,09	7,10	5,7

2.2.1. *Thermal inertia*

The building envelope inertia represents its ability to oppose the passage of heat by storing it in the form of sensible heat. lnertia is a function of the body mass and its specific heat. The term pC above is inertia per volume unit. To fully characterize the inertia of the building envelope, one must know its specific heat C and its density p (Li and Xu, 2006).

The inertia of a building is the sum of the inertia of its parts. In practice, we most often characterize the building by its mass per area unit using the coefficient *a*. measuring the mass per area unit covered by the building.

$a < 75$ l<gm^{-2} *light buildings*

75 l<gm^{-2} $< a <$ 300 l<gm^{-2} *means buildings*

$a >$ 300 l<gm^{-2} *heavy buildings*

The coefficient of surface exchange combining radiative and convective phenomena as well as the exchange surface of the thermal mass determines the rate of heat transfer between the thermal mass of the element and the air (Li and Xu, 2006). Light-weight structures such as wooden ventilated facades can lower the thermal load of the building compared to traditional plaster facades. Differences in temperature and humidity profiles can have a great influence on the performance of buildings. Therefore, the moisture buffers materials are needed to prevent high moisture absorption and increase the sustainability as well as energy efficiency in houses (Mlakar and Strancar, 2013). The dug slight bricks with compound systems of complex internai cavities can be used to replace dug ordinary bricks having only large cavities (Koei et al., 2014).

Local brick soi! mixed with plant sludge is used in some areas in Africa. These types of clay bricks are used in South Africa. The clay has improved properties of bricks by reducing the thermal conductivity and water absorption. The thermo-physical properties, extemal climatic conditions, indoor thermal comfort, saving energy and cost effects were assessed by numerous studies (Kong et al., 2014), (A. Chan, 2011).

2.2.2. *The isolation of the building envelope*

The building envelope is the seat of multiple thermal stresses bath outside and inside. These thermal stresses are among others the temperature of the outer atmosphere, the solar flux, the heat supplied by the occupants and appliances inside the habitat. For heat exchange between the inner and outer atmospheres of habitat, the envelope plays a key role through its thermal performance. Thermal performances due partly to the insulation of the envelope allow a significant reduction of energy consumption due to heating and/or cooling.

The thermal insulation and the thermal inertia form the two parameters which define the thermal diffusivity. According to the insulation or thermal conductivity of the body, the heat is transmitted more or less quickly, or in large quantity. Thermal insulation is the low or high resistance of materials to oppose the transfer of heat. For example, brick lets heat more easily than wood, which itself is more conductive than glass wool. The thermal insulation of the composite wall Trombe helps achieve savings of 46% in winter and 80% in summer compared to a regular building, in which the storage capacity of the Trombe wall only contributed 20.7% (Al-Obaidi et al., 2014). ln a tropical building, the roof can contribute as much as 70% of total heat gain (Hadavand et al., 2008), sothat the use of radiating and insulating materials is considered as effective methods to reduce heat gain and create a comfortable indoor environment. In tropical countries, vaulted roofs are more common than flat roofs. Indeed, in hot and humid climates, the vaults promote air stratification (Hadavand et al., 2008).

The bioclimatic concept encourages Jess dark coloured roofs that absorb less heat to a significant reduction in building energy consumption. This measurement is generally adopted for buildings located in warmer regions (Hadavand et al., 2008). The insulation of the passive houses walls has reduced both the cooling and heating loads while slightly increasing the average air temperature in winter and decreasing soi! temperatures in summer (Benhamou and Bennouna, 2013).

A comparative simulation study between conventional roofing materials delivers interesting results, which have shown that insulated roofs with reflective materials can reduce cooling energy consumption by 26-49% compared to other materials (Muselli, 2010). The insulation of a building involves treating the walls' lasses and that of thermal bridges which correspond to ruptures of the surface insuiation, because thermal bridges can represent up to 25% of heat loss of a house (S. Bekkouche et al., 2013). An uninsulated building represents low lasses (<20%) at the thermal bridges level, but heavy losses at the walls Ievel (on the order of >1 W/m²K). However, since the walls are heavily insulated, the lasses increase at the thermal bridges level, the percentage becomes significant (>30%), but the overall losses are very low (less than 0.3 W/m²K) (S. Bekkouche et al., 2013). For energy efficiency and comfort of buildings, these results are important indicators for the insulation of buildings in tropical zones.

2.2.3. *Walls and indoor environment of the building facing the heat exchange*

The wall exchanges with its environment following three basic exchanges modes, by conduction inside the wall, by convection with the surrounding air and by radiation to the adjacent walls. In the transparent materials case, the transmitted flux share follows its course to the building's interior walls. The visible part of that transmitted flux provides natural light into the building while the share infrared is absorbed by the inner walls.

ln the African climate context, interior environments of many buildings are uncomfortable and this weighs on the occupants health and productivity. They will increasingly need energy resources for the guidelines achievement of thermal comfort, which is potential source of significant energy consumption. Recent buildings (described as modem) of many of these countries are inadequate to the heat because in the lack of regulation on the energy section (Janda and Busch, 1994) (Iwaro and Mwasha, 2010), because the conception is based on technologies and standards from other sociological and climatic contexts (e.g. European context). It is essential nowadays to try to adapt the building sector to the bioclimatic context. A context that encourages the efficiency of energy use and promotes the use of sustainable solutions while ensuring measures to protect the environment.

2.3. *Opening and windows placem ent*

Configurations of the various windows openings in a building have a significant impact on natural ventilation, so on energy efficiency. Natural ventilation is an important technique for passive cooling. In general, indoor environments ventilation is also necessary to maintain the required levels of quality air in a space. ln hot environments, the overheating dissipation can be achieved through natural ventilation, by exploiting the temperature gradients. lts effectiveness depends on the outside air temperature. ln fact, the night ventilation can reduce energy consumption for cooling close to 20% (Geetha and Velraj, 2012). ln areas with high solar radiation, the building structures ventilation reduces necessary energy for cooling during the overheating period (Ciampi et al., 2003), (Dimoudi et al., 2006), (Hadavand et al., 2008).

The window position, the door position and the orientation are three parameters identified with possible influences on the natural ventilation. The combination of the three was studied and the simultaneous changes of two parameters have proved to be more efficient than the change of ail three of them due to the effects between the neutralization parameters . The fixed breeze sun is able to reduce the peak Joad cooling, at the expense of daylight access and heat harvesting in winter. The adjustable shade, therefore controlled by daylight or climate controller, is an attractive way to maximize natural light and provide passive heating in winter (Pacheco et al., 2012).

In tropical and subtropical regions, because of the intensity of sunlight, the main objective of the windows conception is to improve summer thermal comfort (Freewan et al., 2008), (Edmonds and Greenup, 2002).Particular attention should be given to impacts on natural lighting. Previous studies have revealed that regions with warm climates where the illumination is high throughout the natural lighting is not sufficiently operates in comparison to regions with temperate climates (Ochoa and Capeluto, 2006).

2.4. *Infiltration and sealing*

The infiltration, the airtightness of the windows and the openings are essential to contrai the rate of airtightness required air in bioclimatic house construction. Condensates on the wall surfaces cause biological contamination and compromise the quality of the indoor air. The effective way to alleviate uncontrolled infiltration is to improve the building seal.

The airtightness is measured by the building pressurisation up to 50 Pa and air change rate per hour is obtained through a blower door test (Badescu and Sicre, 2003). For a defined building as a passive designed house, this rate should normally be Jess than 0.6 (Mahdavi and Doppelbauer, 2010) (Allard et al., 2013). In a passive house in Germany, the air change rate per hour at a pressure of 50 Pa was measured at 0.27 only from the internai volume as a result of good air tightness. However, such a tightness test may not be applicable to large buildings in the area, in this case, a mode! field or thermal image is feasible.

The infiltration Joad calculation was divided into sensible and latent charges using a linear function connecting the outside temperature charges (Wang et al., 2014). Recent studies have checked in the sensitivity analysis that infiltration is the third highest contributor to the heating Joad after the transmission coefficient window U and the heating temperatures (Tian et al., 2014).

2.5. *Climate influence*

The required climatic conditions for proper use of buildings are influenced by the geographical characteristics of the considered regions or countries. The maximum temperature for which the strategy storage by inertia is still possible depends on the upper limit of thermal comfort in a building without air conditioning (Baruch, 1994). This limit is dependent on the ambient vapour pressure and on the speed of the air inside the building. The limit varies from 25 °C to semi-humid climates (with a vapour pressure of 18 mm Hg-20 mm Hg) to 28 °C for an arid climate (with a vapour pressure less than 15 mm Hg). For the satisfied condition of the temperature variation between day and night, this must be more than 10 °C. Indeed, for a night cooling strategy, an external temperature variation should be sufficiently important with a temperature and an average humidity included in the comfort zone, thus avoiding air infiltration during the day (Baruch, 1994).

3. Adopted methodology and approach

ln order to provide an objective basis for the experience feedback and to help the determination of causes and risk factors affecting the bioclimatic buildings performance in the tropic areas, we formulated an assessment approach based on the capitalisation and extraction of information.

The detailed graphie illustration of the adopted methodology is given below (see Fig. 2):

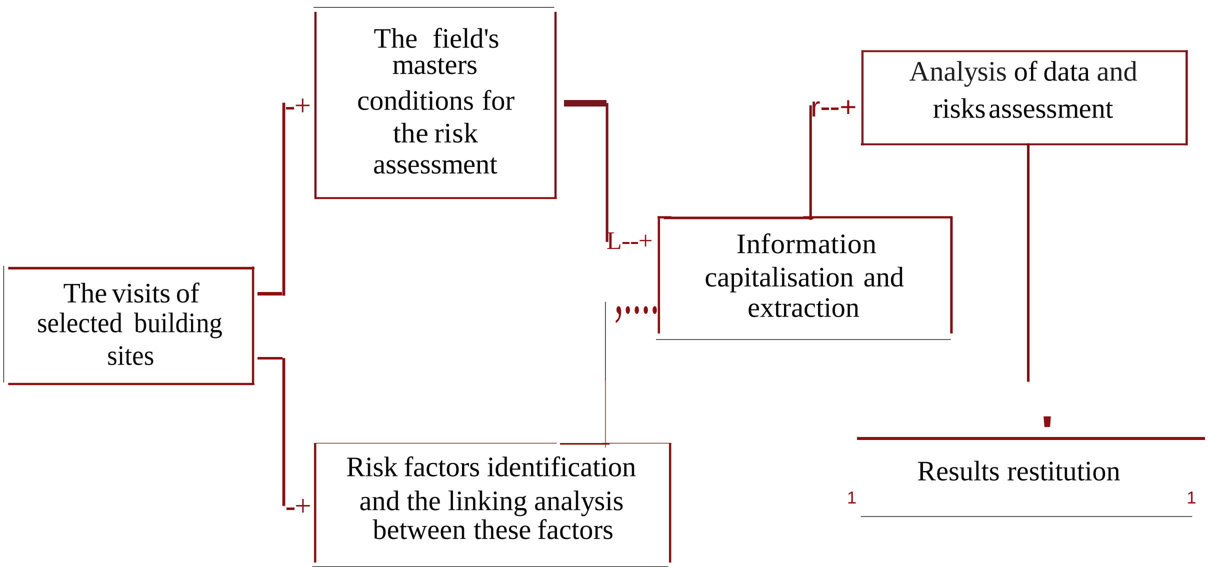

Fig. 2. Graphie illustration of the adopted methodology.

3.1. *Visits of selected building sites*

The selection of sites can concern ail types of buildings (bioclimatic or ordinary buildings) in tropical climates areas. Ordinary buildings being majority can be studied for experience feedback in their bioclimatic renovation.

Visits of different phases (conception, construction and use of buildings) are organized to identify information and data on bioclimatic elements through observations, photos taken, interviews with the different actors (the project manager. the construction manager, the client or the user).

These different visits ways allow us to:

./ Collect the constraints, the stakeholders needs;
./ Know the construction techniques and materials used;
./ Observe the user's behaviour;
./ Observe and identify the non-qualities;
./ Have images for information illustration and consolidation.

3.2. *Risk factors identification and linking analysis between these factors*

3.2.1. *Risk factors identification*

Given the high amplitude of temperature due to sunlight in the tropic areas. thermal discomfort is a ubiquitous problem in buildings. The need for thermal comfort requires much cooling (ventilation and air conditioning) in the buildings.

The components that participate in the thermal behaviour are:

./ A perfect airtightness and air infiltration;
./ An insulation of the building shell (walls, thermal bridge);
./ Adequate materials inertia to the local climate;
./ Better orientation of buildings (natural ventilation and solar gain).

3.2.2. *Linking analysis between these factors*

The building insulation is not a recent practice, but it is not always easy to implement, because it has to be chosen in the best possible level. Reasonable energy consumption depends on good insulation. The insulation can offer both a high level of comfort in winter and in summer. The insulation technique must ensure the renewal of air in quality and quantity.

Priority should be given to the roof and thermal bridges (discontinuity between materials and walls). The roof is the part of the building that is the most heat Joss in winter because it receives the most sunlight in summer and represents the easiest part of an insulated protective system. To avoid disturbance of the air flow inside by leakages through various components walls and junctions, a good airtightness of the walls is necessary.

ln addition to these factors. the bioclimatic concept relies on natural ventilation and solar gain opportunity for occupants' comfort, so there is a need for coherence between the orientation, the building geometry and the types of climates construction site.

3.3. *The fie ld 's masters conditions f or the risk assessment*

During the phases of buildings realization process, the mastery of the field is verified with the building construction sector actors through the below criteria elements (Flage and Aven, 2009):

- Are the data or information reliable and available?
- Are the assumptions made by the actors reasonable?
- Are proposed models consensual between the various actors?
- ls knowledge of the actors or the mastery of the field is high?

3.4. *Information capitalisation and extraction*

Data collection allows us to fill the criticality matrix that is a visual representation of non-performing situations along with their probabilities and severities. The critical matrix provides an opportunity to identify inefficient modes and at the same time encourage more sustainable construction methods and building configurations. So, it contains a certain amount of elements relating to information capitalized and the management of the extracted evidence.

Once it is filled, the criticality matrix evaluates risks and classifies them according to risks scoring. The risks scoring is divided into nine different levels of descriptions (three levels of probability as one axis and three levels of severity as second axis).

> Three levels of probability occurrence: minor (if the occurrence concerns one risk factor for energy performance), medium (if the occurrence concerns two or three risk factors for energy performance). major (if occurrence concerns more than three risk factors for energy performance).
> The severity rates depend on the geographical area of the building between the two tropics and risk factors of energy performance.

For example, for two different climates of tropical areas, the requirements on a thermal component or the used practice for thermal comfort can be different. For instance, suitable materials and shapes of buildings for the Sahelian climate are not necessarily the same for the Sudano-Guinean climate.

Three risk judgment levels are defined (Low/Medium/Strong) respectively noted (Fa/Mo/Fo) and associated to three colour code (green, orange and red).

The colour code allows:

- To carry out a comparative risks ranking;
- To prioritize improvement actions.

The results of the risk assessment are formalized in a summary table with a structured format and a specific notation. The buildings characteristics as well as information collected on the disorders are indicated in this table.

3.5. *Data analysis and risk assessment*

The risk assessment is dependent on the observations and collected information related to the occurrence level and the severity level of the disorders. ln this study, the criteria chosen for the occurrence is related to the probability of the occurrence of each identified risk factor. The risk assessment (ISO, 2009) covers the intersection of occurrence estimations and severity evaluations within the risk matrix having severity as vertical axis and occurrence as the horizontal axis (see Table 2). This serves as an analysis element for many reasoning related to potential risk treatments (e.g. avoidance and reduction). The calculation of the risk is given in the following classical formula:

$R = O * G$, with O : occurrence of the observation, G : severity of the observation.

Table 2
Criticality matrix.

	Minor	Medium	Major
Minor	Fa	Fa	M
Medium	Fa	M	Fo
Major	M	Fo	Fo

This formula can be quantitatively determined by a product of uncertainty measurement occurrence of the observation and by the measurement severity of the observation (Aven and Bodil, 2014).

The definition of risk level is not only based on an effective risk-scoring but also on a subjective risk assessment. However, the occurrence was sometimes modulated by estimating the potential development of the disorder.

The performance of a building being a function of several factors, the risk performance is thus the sum of risks linked to factors in question. It may include insulation, sealing, infiltration, natural ventilation, or building orientation. So, the risk performance is defined as the sum of the key elementary risk factors:

$$R = \sum_{i=1}^{n} R_i$$

with *"Ri"* the risk performance factor and *n* the number of risk performance factors.

For example, if the risk is related to the insulation and the bad orientation of the building, in this case we have three risk factors (n = 3), and i varies from 1 to 3 (insulation, ventilation and solar gain).

$$R = R_1 + R_2 + R_3$$

R_1: the related risk to insulation (gain or heat Joss), R_2: the risk related to ventilation (the need for air conditioning or cooling) and R3: the risk related to solar gain (heat gain and natural lighting inside requirements).

The risk assessment has the purpose to estimate the factors of the performance reinforcement or deterioration. The exercise is to fill the criticality matrix database. ln this matrix, the observation levels and those of occurrence probability are respectively assigned horizontally and vertically. The intersection of observation and occurrence determines the risk level.

For each of the observations, the risk assessment conclusionsare given.

The different types of bioclimatic buildings are noted in the table below (see Table 3):

Table 3
Building nomenclature.

IB	lndividual Building
CB	Common Building
TB	Tertiary Building
AB	Airport Building

Finally, corrective or preventive solutions as well as best practices are presented for each case. Sorne of these quality improvement opportunities have been observed in the field, others are issued from the experiences of specialists.

3.6. Results restitution

Evaluation results capitalize experience feedback of the different actors of buildings.

Different discomfort factors identified are presented as well as remediation techniques and best practices.

Therefore, experience feedback of users and experts can contribute the improvement of energy performance and environmental quality.

4. Case study: bioclimatic housing type F3 study in Mali

4.1. Presentation of the case study

The social housing construction project is a property program launched in 2004 by the Malian government throughout the national territory. Different categories of housing *(F3A, F3B, F4, and F5)* are built under this program. Malian and foreign construction companies are funded by the Malian government to build those social housings. According to the incarne of the household, these types of housing are assigned to the people living in the interior or the exterior of the country with a contractual engagement and a subsequent reimbursement period from 20 to 25 years.The use of the first buildings began in 2006.

The housing type F3 was selected for the case study of bioclimatic buildings (Fig. 3). F3 housing have dimensions 10 m x 20 m,

Fig.3. Distant *view* of a construction site of these social housing in Mali.

in other terms 200 m^2 and have two bedrooms, a living room, a kitchen, a terrace and a toilet. There are two categories of housing type F3 namely F3A and F3B. The differences between the two types are the configuration settings for toilets. For F3A the toilet is inside the house while in F3B it is outside the house. However, F3B the better equipped with additional space for the storage of various abjects.

4.2. *justification of the case study*

ln Mali and many African countries, building social housing projects are underway. These social housing have a social connotation, because they are intended for people with middle incarnes. lt is therefore preferable that these houses are in line with performant buildings.

Given the climate in the tropics zones (a long period of sunny days in the year where the temperature in the shade exceeds 32 °C during this period); the bioclimatic concept is an alternative for better energy savings (energy efficiency) in the long-term interests of the recipients and the environment preservation. For this, a risk and analysis assessment study is crucial. This study allows us to identify the performance risks factors and causes in order to review the construction projects and encourage sustainable buildings while enhancing the thermal comfort of the occupants of social housing.

The results of this study are intended to capitalize experience feedback from stakeholders through good practices proposais and to support national stakeholders in enhancing energy efficient-based developments for renovations or new constructions of houses.

4.3. *Analysis of the case study*

In the case study, we use the practical knowledge gained from this construction project as the basis for the analysis of the energy efficiency in the delivered buildings. The used methodology is based on the principle of experience feedback to evaluate risks for design and assessment of energy and environmental performance of buildings. The social housing types F3 are analysed to estimate the risks performance in the context of bioclimatic buildings.

The analysis and risk assessment are intended to propose a ranking of disorders associated to the identified aspects concerning the most non-quality observations. The intersection of occurrence and severity observation within the matrix translated in the formula below serves as a basis for the analysis and risk assessment of buildings environmental and energy performance.

The matrix formula is:

R = O*G, with **O** : occurrence of the observation, G : severity of the observation.

An example of the energy performance and associated risk assessment are illustrated in the case of a housing type F3 belonging to the collective building (C).

4.3.1. *Risks case related ta parcels' size*

This first case allows us to bring to light the risk related to the plots dimensions in bioclimatic conception. The housing type F3 has dimensions 10 m x 20 m in other terms (200 m^2). The facades alignments, the garage reservation and the place to plant trees on such a small land (<300 m^2) were not too easy to allow a quality bioclimatic building.

The building integration in its environment obviously could not be done if a reasonable dimensioning of plots (at least 400 m^2) was planned by the team in charge of the segmentation. The small size of the plots should be a consensus from the initial phases of the project construction where the found discomfort risk (excessive heat in summer period) was estimated insignificant.

Considering these reasons, we use the risks description for this scenario of small plots in the bioclimatic construction. The average level of occurrence probability and the average level of observation severity determine the positioning of this risk in the matrix as follow (see Table 4):

For a realistic assessment of the risk linked to this dimensioning aspect, it is necessary to use one of the two evaluating methods of the background knowledge reflecting the apprehension of the context presented by (Aven, 2013). This knowledge level covers inter alia assumptions and beliefs, historical system performance information and knowledge about the situation considered (Flage and Aven, 2009). Even compared to the contrai of working conditions for risk assessment, the sizing studies are irrelevant, thus the apprehension of the context is considered low and reduces the confidence in the sizing phase.

Therefore, for effective risk assessment of energy and environmental performance, it is necessary to adjust the risk level related to this parcels of dimensioning aspect. The risk estimated by the criticality matrix was medium (yellow code), so it will be deemed major (red code). Indeed, the small size plots pose enormous problems to designers for the suitable application of the bioclimatic concept. High risks on energy and environmental performan ce can cause thermal discomfort (excessive heat in summer period) with a strong need of cooling (air conditioning or ventil ation).

The shortfall due to the high cost of the electricity bill can be important.

Consequently, the risk matrix is considered as follow (see Table 5):

The proposed solutions are:

Table 4
Medium-medium risk.

	Minor	Medium	Major
Minor			
Medium		Mo	
Major			

Table s
Medium-major risk.

	Minor	Medium	Major
Minor			
Medium			**Fo**
Major			

- Taking into account the energy and environmental performance factors during fragmentation phases and project definition;
- Straw hangars construction to the front of the house;
- Solar panels settling to the need for ventilation.

4.3.2. Risks case on the insulation of the building envelope

In this second case, reflection focuses on the risks caused by the building facades covered only with a thin layer of cernent (cernent brick walls and cernent concrete roofs) and the Jack of mechanical ventilation in the rooms.

Despite the concrete inertia, given the high intensity of heat flow in summer and lack of mechanical ventilation, thus the thermal discomfort risk due to the lack of the envelope insulation should not be overlooked. The concrete inertia and the simple plastering of facades can surely not be the argument of the designer to overlook the risk related to the lack of insulation in the building envelope. The insulation of the building envelope was omitted or overlooked by the project funding.

We consider the two explanations and we use the description of risks for this scenario with the Jack of the insulation envelope and the building ventilation: the major occurrence probability level and the major observation severity level are considered. This leads to the following risk matrix (see Table 6):

ln this case, the mastery of the field is low (very low advanced hypothesis or disagreement between the expert opinions), thus the risks related to absence of insulation and ventilation remain strong (risk of thermal discomfort and dilatation level of thermal bridges due to climatic stresses). These risks respectively Iead to a cooling need (air conditioning or ventilation), and cracks on the facades (building degradation).

In Mali, the hot and dry climate is spread over a long period of the year. it is important to emphasize that cernent brick inertia is not enough, so the recomm ended solutions are:

> The outside insulation which increases the thermal inertia inside by storing energy during the hottest hours of the day in order to restore them during the night when extemal temperature is lower;
> The airtightness of the walls for good contrai of ventilation flows in both volume and circuit so that the air which cools the house flows wherever we wish it, as well as the desired amount.
> The achievement of effective sun protection systems in summer to avoid overheating by the structures in charge of the mass.

Nocturnal ventilation devices must also be settled to:

> Evacuate overnight calories stored during the day;
> Cool the incoming air during the hottest hours of the day.

For the incoming air cooling, the Canadian well is well indicated.

4.3.3. Risk case about the kinds of openings' windows

In this third case, the focus is on the risk related to unwanted infiltration due to the use of fixed metal strips and not airtight (unglazed) in housing doors and windows.

Unwanted air infiltration risk and dangerous insects at certain times of the year are present; hence there are the mosquitos' proliferation in winter and the dust-laden winds in summer (caused by the dry and dusty north-easterly trade wind activity). The use of such opening windows and doors can-not obviously happen unless the lack of recognition of the issues impacting the infiltration risks. This can be explained by:

> A misunderstanding of the plot by the construction manager (climatic conditions);
> Commercial reasons (investment savings);
> Controllers Ievel requirement default;
> The fact that the risk was considered negligible by ail the stakeholders.

We consider that this latter case was the main explanation and we use the risks description for this scenario of unwanted infiltrations from the site experts as follows: minor level probability

Table 6
Major-major risk.

	Minor	Medium	Major
Minor			
Medium			
Major			**Fo**

Table 7
minor-minor risk.

	Minor	Medium	Major
Minor	**Fa**		
Medium			
Major			

Table 8
Medium-medium risk.

	Minor	Medium	Major
Minor			
Medium		Mo	
Major			

of occurrence and minor level of severity. This leads to the following risk matrix (see Table 7):

Given the low level of advanced hypotheses and the proposed models about the infiltration aspect, we believe that the mastery of the field remains to be desired in order to improve the background knowledge of the main stakeholders (Flage and Aven, 2009). It is therefore important to adjust the level of risk associated with this infiltration aspect through suitable doors and windows used in the building.

The estimated risk by the criticality matrix was low (green code), so it will be judged medium (yellow code). Indeed, the use in housing of fixed and not airtight metallic strips for doors and windows can cause the risk of poor performance regarding air quality (a high rate of renewal air, dust inside) and health protection (e.g. problems caused by insect bites and stings).

Consequently, the risk matrix is determined as follows (see Table 8):

We recommend using as solutions windows and doors made of aluminium or wood with solar glass or adhesive films for the windows (to limit solar gains both in winter and summer), and also with the association of the following elements:

- Mosquito nets with fine wire mesh for windows and door frames that we want to leave open in summer or in warm climates to prevent mosquitoes and other flying insects from entering into homes or premises open to the public;
- Bioclimatic sun shades as sun protection that could be open in summer and closed in case of bad weather or at Jess mild temperatures, thanks to the closure process of landing strips.

4.3.4. *The influence of climate data on the thermal comfort of the buildings*

Thermal comfort is a subjective notion depending on various parameters that are imposed by the influencing factors (metabolic rate, clothing insulation, air temperature, mean radiant temperature, air speed, relative humidity and natural ventilation) with some specificity and sensitivity (individual differences, biological gender differences, regional differences and medical environments). A pragmatic approach of the comfort study consists in taking into account only the most important ones of these parameters. In the following analysis, we focus on the combined effects of dry weather (outdoor temperature measured in the shade) and relative humidity.

Table 9 and Fig. 4 illustrate the normal climatic averages including temperature, sunshine and relative humidity for the twelve months of the year in the considered geographical area (i.e. Bamako city).

Table 9
Meteorological data for Bamako city.

Month		F	M	A	M			A	S	O	N	D	Annual average
Tmax (°C)	32	36.2	37.3	39.9	38.8	35.5	32.4	30.8	31.9	33.6	34.4	313	34.5
Tmin (°C)	15.6	19.9	22.6	24.5	25.6	23.8	22.3	21.9	21.8	22.1	17.2	15.5	21.5
Insol (h)	267	281.7	265	237.3	240.7	217.8	243.7	211.4	217.7	263.6	286.1	237.2	247.4
Hmax (%)	36	40	33	52	73	89	97	98	98	98	83	51	70.7
Hmin (%)	12	14	11	14	28	43	57	64	61	53	23	15	32.9

Tmax (◦C): maximum monthly mean temperatures, Tmin (◦C): minimum monthly average temperatures, Inso (h): Average monthly sunshine Hmax (°C): Maximum monthly average humidity, Hmin (°C): Minimum average monthly humidity.
Source Bamako-Senou National Weather Station in 2015

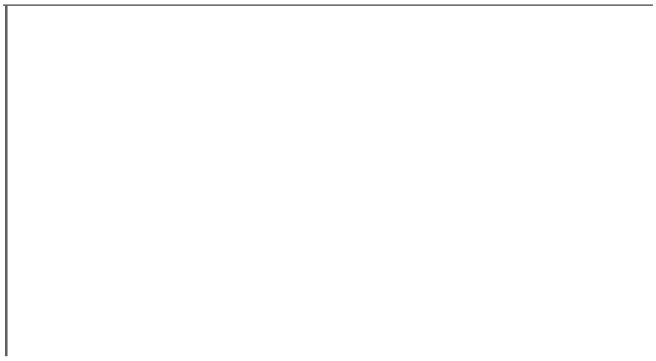

Fig. 4. Graph showing the monthly max and min temperatures in Bamako city in 2015.

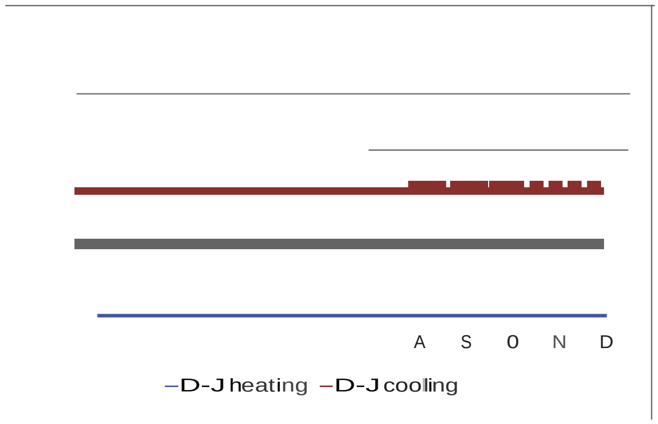

Fig. 5. Graphical representation of D-J heating and D-J cooling in Bamako city.

The temperature data in Table 9 give us the following graph:

Data analysis in Table 9 shows that the average length sunshine of Bamako city is 247 h a month. The temperature mean values are included between 21.5 °C and 34.5 °C, with absolute maxima which can sometimes reach 39.9 °C (see Fig. 4).

The warmest period extends from February to June where the maximum temperature exceeds 35 °C. We observed over a period of 5 months (December-April) in the year the Iowest relative humidity values vary between 11% and 15% while the strongest values occur between May and November with a value superior to 98% in August during the winter (see Table 9).

These meteorological data lead to other climatic data namely the heating degree-days and the cooling degree days (see Table 10)

They allow us to have an idea on the demand for energy needed to heat a building in cold periods and similarly the consumption of energy used to cool (e.g. using air conditioning) a building in hot periods.

The data in Table 10 give us the graph of Fig. 5 shown below:

4.3.5. *Thermal comfort study relative to the heating and* cooling *of buildings*

Fig. 5 shows that throughout the year, Bamako city buildings do not need heating while their air conditioning is a necessity. The graphical representation informs us that there is a strong need for air conditioning or cooling during the months of March, April and May compared to the other months of the year.

According to these climatic data, we can estimate the comfort temperature inside a building by the adaptive approach developed in (ASHRAE55, 2004).The adaptive comfort of Standard ASHRAE55 recommends using the suggested method only for buildings with natural ventilation (building in a free evolution scheme). **In** the context of energy saving, many buildings in Mali as in the other developing countries are free evolution buildings. This approach is based on field surveys using in situ experimental studies results to define comfort conditions based on meteorological data.

Thus, the comfort optimum temperature in buildings with natural ventilation was a function of the outside temperature and could be predicted by linear equations of the following form (Nicol and Raja, 1995):

$$Tc = aTmext + b$$

with, Tc: the comfort temperature; Tmexr: the average monthly outside temperature (meteorological data of the nearest site station).

The determination of the terms *a* and *b* is proposed by the following equation (de Dear and Brager, 2002):

$$Tc = 0.31Tmext + 17.8$$

So, it is possible to calculate the comfort temperature Tc in buildings subjected to natural ventilation according to the average monthly outside temperature Tmext. This comfort temperature is the operating temperature **in** the building which takes into account the walls radiation as well as the air speed. The standard (ASHRAE55, 2004), defines an error band with an error margin of plus or minus 2.5 °C whose width is around the comfort temperature for 90% acceptability.

The calculation from the formula and the previous Table 10 of temperatures give us the following value table:

By applying the uncertainties of error margin of the Standard ASHRAE55 to the values in Table 12, we compare the temperatures obtained with the limit values of the comfort zone proposed by (Olgyay, 1963). Olgyay proposed a diagram called the bioclimatic diagram which places the comfort zone in the range of values within 21 °C and 27,8 °C for a relative humidity included between 17% and 77%.

For the uncertainty of -2,5 °C of the margin of error, the values of the comfort temperatures Tc are generally in the comfort zone of the Olgyay bioclimatic diagram (See Table 12 and Fig. 6).

The data in Table 12 give us the graph of Fig. 6 shown below.

For an uncertainty with a margin of error equal to 2,5 °C, the maximum values of the comfort temperatures Tmax are outside in the comfort zone of the Olgyay bioclimatic diagram (See Table 13 and Fig. 7).

The data in Table 13 give us the graph of Fig. 7 shown below.

The effects of these observations on thermal comfort in the

Table 10
Heating and cooling data degree-days of Bamako city.

Month		F	M	A	M			A	S	0	N	D
D-J heating ('C.d)	0	0	0	0	0	0	0	0	0	0	0	0
D-J cooling ('C.d)	459	501	648	675	663	558	505	487	483	536	507	462

D-J heating: Heating degree-days 18'C.
D-J cooling: Cooling degree day days 10 'C.
Source RETScren Expert

Table 11
Comfort temperatures according to the maximum monthly average temperatures of Bamako city.

Month		F	M	A	M			A	S	O	N	D
Temin (°C)	22,6	23,9	24,8	25,4	25,7	25,2	24,7	24,6	24,5	24,6	23,1	22,6
Tcmax (°C)	27,7	29,0	29,4	29,8	28,8	28,8	27,8	27,3	27,7	28.2	28,5	27,5

Table 12
The temperatures described according to the values in Table 11 with an uncertainty for a margin of error equal to 2,5 °C.

Month		F	M	A	M			A	S	O	N	D
Tlsup-0 (°C)	27,8	27,8	27,8	27,8	27,8	27,8	27,8	27,8	27,8	27,8	27,8	27,8
Tmax (°C)	20,1	21,4	22,3	22,9	23,2	22,7	22,2	22,1	19,5	22,1	20,6	20,1
Tlinf-0 (°C)	21,0	21,0	21,0	21,0	21,0	21,0	21,0	21,0	21,0	21,0	21,0	21,0
Tmin(°C)	25,2	26,5	26,9	27,3	26,3	26,3	25,3	24,8	25,2	25,7	26,0	25,0

Tlinf-0 = 21 (°C): the lower limit of the comfort zone (Olgyay bioclimatic diagram).
Tlsup-0 = 27.8 (°C): the upper limit of the comfort zone (Olgyay bioclimatic diagram).
Tmin = Temin (°C) - 2.5 °C; Tmax (°C) = Tcmax (°C) - 2.5 °C.

building may be remedied by renovation works. "The experimental building is a housing of type F3B built with hard materials (e.g. cernent, concrete, and hollow-brick)". lts roofis of concrete slab, the walls are of classic hollow bricks and plastered in layer of 1.5 cm of cernent (no insulation). Doors and windows include lamella substructures of metallic materials but are not waterproof (no glazing at ail).

Considering this study results, a renovation of the building is necessary in order to improve the energy performance and the thermal comfort inside the building. The renovation works may be one or the following applications:

- Action on the mean radiant temperature by insulating the inside of the concrete roof (part which acts like a real radiator in hot period),
- Use (at certain hours of the day) of artificial cooling systems powered by renewable energy sources,
- Installation of a night ventilation system to evacuate during the night the calories stored during the day.
- Protection of the building from solar radiation either by deciduous trees, awnings, curtains, or various masks. In an environment of adverse weather conditions where the trend should be to energy savings, the main concepts of sustainable (or bioclimatic) building design are becoming increasingly essential in renovations of existing buildings or new construction projects.

5. Discussions

Faced with global warming and the need to reduce energy consumption for renovation and construction of buildings, ail countries of the world began to be more sensitive to the role of programmes to support actions improving energy efficiency in buildings. The assessment and analysis of the performance of ail the relevant elements causing energy inefficiencies are included in a large part of the risk management effort in this sector.The insights gained will help in future to encourage every attempt to facilitate the improvement of energy efficiency in buildings, from the side of both users and home builders or renovators.

Risks to the energy inefficiency of buildings can corne from Jack of efficacy or from improper practices or questionable usages that impact energy and environmental performances of buildings construction and renovation projects. Nowadays , several recent methods of risk assessment and views on the risks have been developed to allow sufficient emphasis on background knowledge needed to support an adequate understanding of the target context (Aven, 2012) (Henning and Aven, 2015). In ail continents of the world (from warmer to colder regions), there is growing interest in research and development of new energy solutions and technologies for the analysis of building energy performance and various means (e.g. international policy practice for energy performance) to support the transition towards more energy efficient buildings (Henning and Aven, 2015).

This article is in line with the development of approaches on background knowledge and their uncertainties for energy analysis of residential buildings with a new angle that can bring new relevant contribution to existing methods. For instance, there is often a Jack of consideration on background knowledge and their uncertainties.The observations of these knowledge elements require ways of adapting that will reduce the risks of misinterpretations on the energy performance of buildings. There are many situations where the uncertainties are related to home builders or renovators and are influenced by collected data and information.

These uncertainties are related to the evaluator knowledge, and are influenced by collected data, synthesized information and background knowledge. At a point in time, signais and warnings to a root cause of energy inefficiency or a risk factor may become available, and the challenge is to integrate them into the measurements in a way that makes assessments reliable to support decision making. The background knowledge necessitates consideration of the cognitive concems (e.g. prudence, reflection and concentration) and the ergonomie activity aspects that are essential to avoid unwanted inefficiency performances and the procurement of desirable outcomes (Henning and Aven, 2015).

The formalization of concepts related to energy performance for buildings can contribute to capitalize the acquisition of experience due to the best practices. Over time with observations and

Table 13
The temperatures according to the values in Table 11 with uncertainty for a margin of error equal to 2,5 •C.

Month		F	M	A	M			A	S	O	N	D
Tlsup-0 ('C)	27,8	27,8	27,8	27,8	27,8	27,8	27,8	27,8	27,8	27,8	27,8	27,8
T'max ('C)	30.2	31,5	31,9	32,3	31,1	31,1	30,3	29,8	30,2	30.7	31,0	30,0
Tlinf-0 ('C)	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0
T'min ('C)	25,1	26.4	27,3	27,9	28,2	27,7	27,2	27,1	27,0	27,1	25,6	25,1

Tlinf-0) = 21('C): the lower limit of the comfort zone (Olgyay bioclimatic diagram).
Tlsup-0 = 27.8 ('C): the upper limit of the comfort zone (Olgyay bioclimatic diagram).
T'min ('C) = Temin ('C) + 2.5 •C: T'max ('C) = Tcmax ('C) + 2.5 •C.

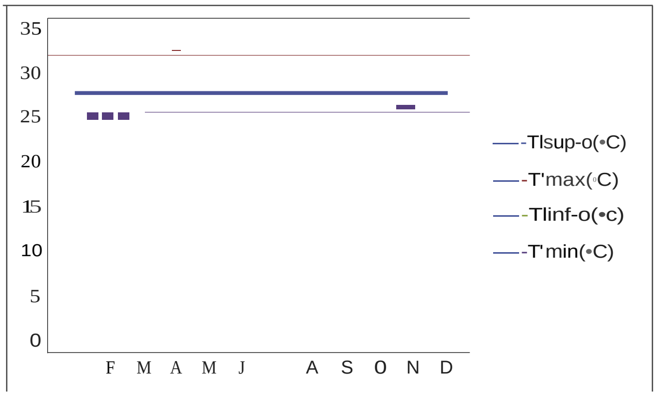

Fig.7. Graph of data in Table 13.

repetitions of different scenarios carried out, the reflex and the anticipation ability of risk events can be very critical for the performance assessments. ln ail cases, the collected data and information may influence the uncertainties related to these knowledge, because these data are often obtained through evaluator's knowledge (observations and practices). For example, the construction sites understanding and the used techniques (insulation and materials choice) may allow the evaluator to review the performance assessment, so to confirm data collected or to facilitate the reasoning for more energy efficient buildings.

The practice and the domain experience allow consolidating the background knowledge, so to facilitate this signais and warnings with uncertainty nature of energy assessment performance and risks identification. The consideration of uncertainties and background knowledge is integrated in the methodology described in this article. In principle, it is important to consider ail this aspects as much as possible to better assess the risks performance in bioclimatic buildings (theory and practice).

The proposed evaluation method of energy performance and associated risks is based on field visits through interviews with users and construction sector participants of buildings. These site visits allow us to identify the different practices used in the field and to identify factors related to thermal discomfort, energy performance and environmental quality and their risks in the target buildings. These collected data are entered into the database allowing extracting the knowledge in order to evaluate energy and environmental performance with their risks. Finally, the issued results from this study allow us to elaborate the experience feedback from the various actors for a best basis of future construction projects and buildings renovation in warmer regions.

6. Conclusion

While many countries in the southern hemisphere have inherited some ancestral sustainable building traditions, there are still the requirements to move towards more energy efficient in the building sector. The main focus in this paper is on the energy performance of buildings in warm regions (e.g. tropical zones) that are faced the challenges of energy transition. The proposed methodology aims to improve the assessment of building energy performance by integrating the experience feedback approach from field studies and background knowledge. These field studies are conducted through interviews of stakeholders working in the building sector, observations and photos taken to collect information and relevant understanding on bioclimatic construction techniques.

The study case focused on the housing type F3 in Mali. Itallowed us firstly to highlight the indicative information on the risk factors of energy performance namely risks linked to the parce! size, the risks associated with building openings, the building envelope insulation risks and also to identify the difficulties the actors can face during the implementation of construction projects and bioclimatic renovations in tropical areas. To highlight the risks impacting the energy performance factors, we used the site's climate data to determine the building's internai temperature in order to provide additional information on the comfort Ievel in the building. Adequate responses to these challenges of energy efficiency, the identified risks are prioritized and proposed for the development of effective actions and services for sustainable buildings. As a result, for a better energy performance analysis of buildings, a better risk management integrating the experience feedback processes helps concretely to provide relevant knowledge in relation with socio-economical, technological and energy realities of the considered construction area. This analysis provides a Ieverage action for continuous improvement processes through knowledge sharing and best practices diffusion that can be fed into policy formulation.

After this study, we showed that causes influencing energy performance assessment in the building may enable to identify risk factors, to analyse the relationships between these factors and to assess the background knowledge on which the judgements by the analysts are conditioned. However, the setting up of specific strategies for ecological standards and performance measures are continually required. To improve the energy analysis of buildings, a further work on the building thermal simulation is necessary, which will consolidate the results of energy performance assessment and provide the building sector with a qualitative database on the construction material properties. The recommendations of these studies could be used to suggest new ideas and promote new knowledge for a contribution to the measurements and evaluation on the energy performance of buildings.

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