An Innovative Technical Platform for Sustainable Buildings, Resilience, and Smart Grids in Tropical Climates

Pr Ted SOUBDHAN

University of Antilles, Laboratory LARGE, 97159 Pointe à Pitre Cédex
Ted.soubdhan@univ-antilles.fr

Abstract

The tropical climate, characterized by high humidity, elevated temperatures, and increased exposure to extreme weather events, presents specific challenges for the building sector and the development of smart energy grids. This paper introduces BEPSODOM (Bâtiment a Énergie Positive, Durable et Optimisé pour les Milieux Tropicaux – Positive Energy, Sustainable and Optimized Building for Tropical Environments), a multidisciplinary technical platform to address these issues. BEPSODOM aims to catalyze innovation, applied research, and the validation of solutions tailored to the specificities of the tropical climate, focusing on sustainability, resilience, and smart grid integration. The paper details the platform's design, its main components, the services offered, and its expected role in accelerating the ecological and energy transition in tropical regions, with a particular focus on Guadeloupe and the Caribbean region. To do so we will first examine the theoretical and empirical basis for defining bioclimatic building design in tropical climates, focusing on strategies that enhance thermal comfort and energy performance.

Keywords: Sustainable building, resilience, smart grids, tropical climate, technical platform, innovation, applied research, Guadeloupe, Caribbean.

1. Introduction

Humid tropical regions, such as Guadeloupe and the Caribbean, face unique challenges in terms of sustainable development and energy management. The building sector, responsible for 49% of energy consumption and greenhouse gas emissions, must adapt to specific constraints related to high humidity, elevated temperatures, cyclone risks, and local biodiversity (IPCC AR6, 2023). Simultaneously, the transition towards cleaner and more resilient energy systems necessitates the development of smart grids capable of effectively integrating intermittent renewable energy sources and meeting the specific needs of non-interconnected island territories (Lombardi, P., & Giordano, R. (2012). Innovation and applied research are essential to identify and validate technical, architectural, and energy management solutions adapted to this particular context (Bansal et al 1994). It's also relevant to identify the most effective passive design measures, quantifies their performance outcomes, and discusses methodological frameworks for adaptation in diverse tropical regions.

2. Defining Bioclimatic Building Design in Tropical Climates

The built environment in tropical climates faces significant challenges due to persistent high temperatures, intense solar radiation, and high relative humidity. Conventional building models developed for temperate regions often fail to achieve adequate thermal comfort in these contexts, leading to increased reliance on mechanical cooling systems and subsequent energy demand (Garde et al., 2012). In response, bioclimatic design has emerged as a critical framework for creating energy-efficient, comfortable, and contextually adapted buildings. The term ‘bioclimatic architecture’ refers to the integration of local climatic conditions into the design process to minimize energy consumption and optimize comfort (Taing et al., 2025). In this section we expose the methodological basis for defining bioclimatic buildings in tropical climates, synthesizing quantitative evidence from global case studies**.**

2.1 key elements to be considered in tropical climates

Bioclimatic design in tropical regions requires a systematic understanding of the interaction between climate parameters and building form. The methodological framework applied in this review follows a threefold approach:

- climatic characterization using psychrometric and solar path analyses,
- assessment of passive strategies for heat gain reduction and ventilation enhancement,
- performance evaluation through empirical data.

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Figure 1 presents the key elements that's needs to be considered in tropical climate:

- Solar protection and insulation
- Ventilation,
- Natural lighting,
- Air conditioning
- Renewable Energy and Energy management

In hot-humid climates, the emphasis lies on shading, cross-ventilation, and material reflectivity, whereas in hot-dry tropical regions, thermal mass and evaporative cooling are prioritised (Bulbaai & Halman, 2021). Psychrometric charts and bioclimatic zoning diagrams (e.g., Olgyay, 1963) are key analytical tools used to define comfort zones and guide design interventions.

Figure 2 shows how ventilation can increase the comfort zone under tropical climate: a wind speed of 1m/s can extend the comfort zone from 26°C and 80% humidity rate to 30°C and 80% humidity rate, including then about 80% of couple's temperature/humidity recorded over one year with one hour step.

The red dots outside the shaded area are out of the comfort zone, ventilation is not sufficient, it is then necessary to use air conditioning in order to reach comfort conditions. According to this, we can assume that air conditioning and cooling will be necessary only on about 20% of the year, which can lead to significant energy savings in buildings.

Figure 1: Strategies in tropical Climate: solar protection, daylight, ventilation, shades.

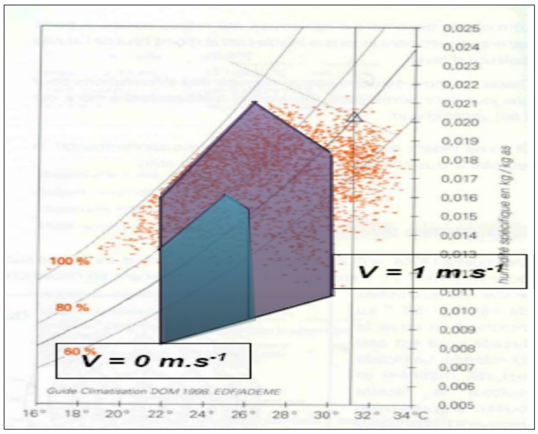

Figure 2: Psychrometric diagram for le Raizet, Guadeloupe.

Table 1 presents a summary of empirical data from bioclimatic building performance studies across tropical regions. The findings consistently demonstrate that passive strategies, when properly integrated, significantly enhance indoor thermal comfort while reducing reliance on active cooling systems.

Table 1: summary of empirical data from bioclimatic building performance studies across tropical regions

Study Location	Passive Strategy	Temperature Reduction (°C)	Energy Savings (%)
Cambodia (Taing et al., 2025)	Natural ventilation + shading	3.5	32
Malaysia (Ismail & Lokman, 2007)	Bioclimatic façade + daylighting	2.8	28
Côte d'Ivoire (Tanoe et al., 2018)	Thermal mass + reflective roofing	4.0	35
Curaçao (Bulbaai & Halman, 2021)	Cross-ventilation + vegetation	3.2	30

As shown in Table 1, the implementation of combined passive strategies yields synergistic effects, achieving notable temperature reductions and energy savings. These outcomes are particularly relevant for high-density urban contexts, where mechanical cooling loads can represent over 60% of total building energy consumption (Ismail & Lokman, 2007).

3. Necessity for a Specialized Technical Platform: BEPSODOM

Given the lack of experimental and validation infrastructure specifically designed for tropical climates, the development of the BEPSODOM technical platform emerges as a strategic necessity. BEPSODOM aims to fill this gap by providing an environment dedicated to experimentation, performance characterization, and validation of innovative solutions in the fields of sustainable building, structural resilience, and smart grid integration. (Sovacool et al 2018). This technical platform aspires to become a regional center of excellence for research, training, and the transfer of technologies adapted to the specificities of the humid tropical climate.

3.1. Design and Components of BEPSODOM

BEPSODOM is designed as a multidisciplinary infrastructure comprising several key zones and equipment:

- **On site Testing Zones:** Instrumented building modules allowing for the evaluation of the thermal and hygrometric performance of different materials and construction systems in tropical climates. These zones will also enable the study of resistance to weathering and cyclone risks.
- **Analysis and Characterization Laboratories:** Equipped spaces for analyzing material properties (thermal conductivity, air and moisture permeability, mechanical resistance), characterizing the performance of energy systems (photovoltaic panels, storage systems, ventilation systems), and assessing indoor air quality.
- **Smart Grid Platform:** An experimental microgrid enabling the testing of renewable energy source integration (solar, wind, biomass), storage systems (batteries, hydrogen), demand-side management devices, and energy flow optimization solutions.
- **Simulation and Modeling Center:** Advanced software tools for building energy modeling, smart grid performance simulation, and environmental impact assessment of proposed solutions.
- **Training and Collaboration Spaces:** Meeting rooms, shared workspaces, and videoconferencing equipment to facilitate exchanges between researchers, companies, local authorities, and training providers.

Figure 3: An overview of the BEPOSDOM Technical platform

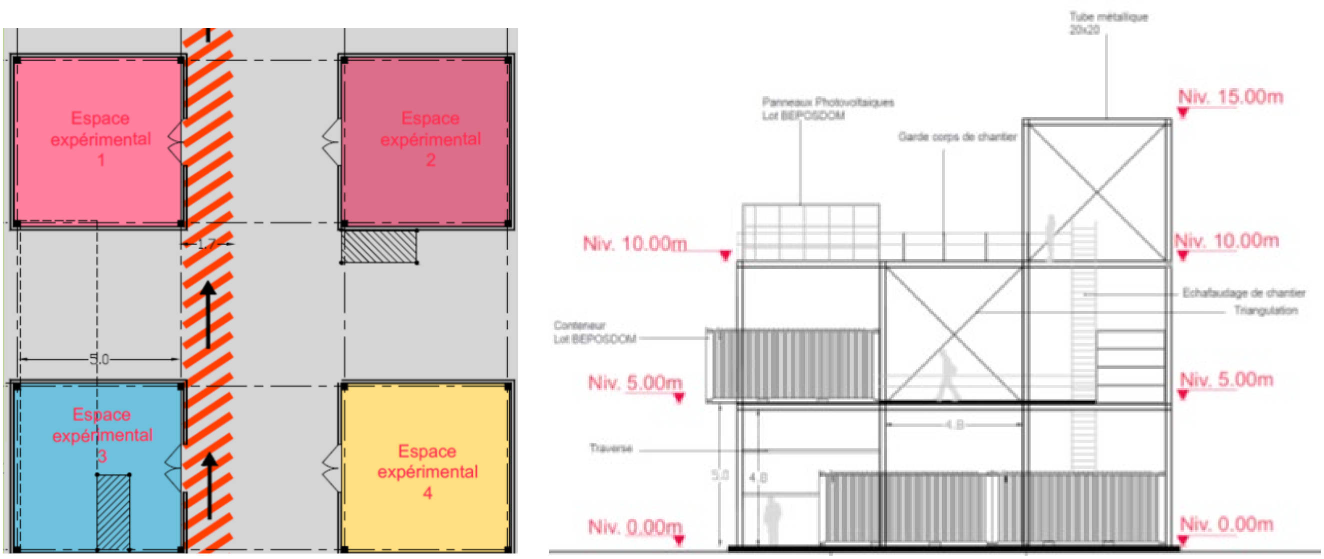

Figure 4: The 4 experimental spaces for building experiments and material testing and three level for different experiments including solar panels

3.2. Services and Activities Offered by BEPSODOM

BEPSODOM will offer a range of services to support innovation and development in the targeted sectors:

- **Collaborative Research and Development**: Provision of infrastructure and expertise for joint research projects between academic institutions, companies, and research centers.
- **Technology Testing and Validation**: Performance, durability, and resilience testing of materials, construction systems, and energy solutions under real and simulated tropical climate conditions.
- **Training and Skills Transfer**: Organization of technical training courses, workshops, and seminars for building professionals, installers, engineering firms, and local authorities.
- **Support for Innovation and Business Creation**: Assistance to promoters of innovative projects in the fields of sustainable building and smart grids.
- **Knowledge Dissemination and Awareness:** Organization of conferences, open days, and publication of research results to inform and raise awareness among the public and policymakers.

4. The first studies: Bio-Based Materials in Decarbonizing Tropical Buildings

The construction sector is a major contributor to global carbon emissions, accounting for approximately 38% of total CO2 emissions when considering both operational and embodied energy (World Green Building Council, 2019). In tropical climates, high energy demand for cooling exacerbates the sector's carbon footprint. Consequently, the adoption of bio-based materials—derived from renewable resources such as timber, bamboo, coconut coir, and palm fiber—represents a viable strategy for decarbonizing buildings. These materials offer not only lower embodied carbon but also beneficial thermal and hygrothermal properties suitable for tropical climates (Lawrence et al., 2021).

We have then decided to lead our first studies to investigate the thermal performance of plant-based bio-sourced materials used as insulation in buildings under humid tropical climates. The main objective is to identify local, renewable, and cost-effective solutions to improve thermal comfort while reducing energy consumption in tropical dwellings. The methodology combines experimental measurements of thermal conductivity (Flash and Hot Box/Hot Plate methods) and dynamic simulations of representative building cells (metallic, concrete, concrete with openings). Materials examined include banana leaves, latanier leaves, vetiver fibers, palm kernel, sargassum, coconut leaves, wood sawdust, and sugarcane leaves. Both experimental and simulations where conducted;

4.1 Heat and mass transfer modelisation in a building envelop

Our first objectives were to develop a heat and mass transfer model that represents well the physical transfert in a bio sourced material. In order to show the system of equations balance through a porous wall, it is considered to be composed of homogeneous and isotropic biosourced insulating materials, with a thickness “e” negligible compared to its length L (L >> e) represented in the figure 6:

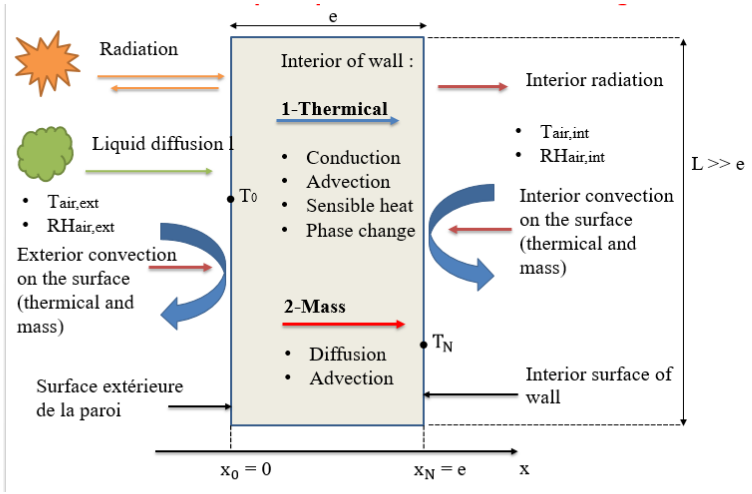

Figure 5: Schematization phenomena of thermal and mass transfer through homogeneous wall of building envelop.

Other hypothesis considered are air velocity is constant and air flow is laminar. The system of equations for the balance of coupled moisture and temperature transfers can be approximated in one dimension (1D). In this the other Cartesian components in the directions (y and z) are negligible. The system can be written as follows [8,15]:

$$\psi_T \frac{\partial T}{\partial t} + \psi_b \frac{\partial b}{\partial t} = \nabla\left[\delta_{p,mat} \nabla\left(bp_{v,sat}\right)\right] - \rho_a \cdot 0{,}622 \frac{v_a}{p_0} \cdot \nabla\left[bp_{v,sat}\right] + \nabla\left[D_l^b \nabla b\right] + \nabla\left[D_l^T \nabla T\right] \qquad (1)$$

$$\begin{aligned} &\left[\rho_0 C_{p,0} + C_{p,l}\left(T\psi_T + w - T_{ref}\psi_T\right)\right] \cdot \frac{\partial T}{\partial t} + C_{p,l}\psi_b \cdot \left(T - T_{ref}\right) \cdot \frac{\partial b}{\partial t} = \nabla\left[\lambda \nabla T\right] - C_{p,a}\rho_a v_a \nabla T \\ &+ \rho_a \cdot 0{,}622 \frac{v_a}{p_0}\left(C_{p,v}T_{ref} - L_v\right) \cdot \nabla\left(bp_{v,sat}\right) - C_{p,v}\rho_a v_a \cdot \frac{0{,}622}{p_0} \nabla\left(bp_{v,sat}T\right) + \left(L_v - C_{p,v}T_{ref}\right) \cdot \nabla\left[\delta_{p,mat} \nabla\left(bp_{v,sat}\right)\right] \\ &+ C_{p,v} \nabla\left[T\delta_{p,mat} \nabla\left(bp_{v,sat}\right)\right] + C_{p,l} \nabla\left[TD_l^b \nabla b\right] + C_{p,l} \nabla\left[TD_l^T \nabla T\right] - C_{p,l}T_{ref} \nabla\left[D_l^b \nabla b\right] - C_{p,l}T_{ref} \nabla\left[D_l^T \nabla T\right] \end{aligned} \qquad (2)$$

This system of equations is strongly coupled and also strongly non-linear. In order to solve this system numerically, it must first be linearized. To simplify, we have first fixed the coefficients of these equations at a temperature T_0 = 303K corresponding to a relative humidity of the air circulating within the material b_0 = 70%. Since in overseas departments, humid tropical regions, the Temperature-Relative Humidity coupling retained by professionals for the dimensioning of air conditioning systems is overestimated at 32°C and 75% [16]. It should be noted that Abahri et al., 2011 [9] have already made this hypothesis to study analytically and then numerically the temperature and humidity profiles through a wooden building wall as a function of its thickness and time. Indeed, the studied material is considered as homogeneous and its thermophysical properties are assumed to be constant. Moreover, the initial distribution of moisture content and temperature in the wall is uniform. Moisture content is the potential that governs the transfer of humidity through the material.

In a second step, we discretized and applied the Euler's semi-explicit resolution method followed by the splitting method or fractional pitch. The following diagrams represent the numerical scheme of discretization in space and in time (Figure 2) as well as the resolution methods adopted (Figure 3).

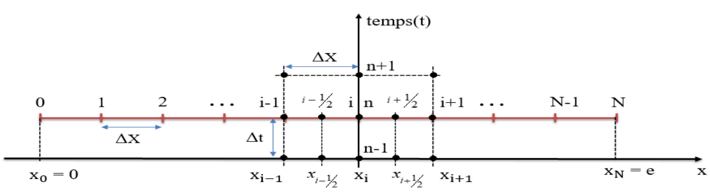

Figure 6: Representation of numerical schema in space (x) and time (t).

The discretization of the system of heat and moisture transfer equations using the semi-explicit Euler method gives for the moisture transfer balance equation [17] :

$$\psi_T \cdot \left(\frac{T_i^{n+1}-T_i^n}{\Delta t}\right)+\psi_b \cdot \left(\frac{b_i^{n+1}-b_i^n}{\Delta t}\right)=\frac{\left(\delta_{p,mat_0}\cdot p_{v,sat}+D_{l0}^b\right)}{\Delta x^2}\cdot\left(b_{i+1}^n-2b_i^n+b_{i-1}^n\right)$$
$$-R_1\cdot p_{v,sat}\cdot\left(\frac{b_{i+1}^n-b_{i-1}^n}{2\Delta x}\right)+D_{l0}^T\cdot\frac{\left(T_{i+1}^n-2T_i^n+T_{i-1}^n\right)}{\Delta x^2} \quad (3)$$

And for the heat transfer balance equation, we have [17] :

$$C_{mT0}\cdot\left(\frac{T_i^{n+1}-T_i^n}{\Delta t}\right)+C_{mb0}\cdot\left(\frac{b_i^{n+1}-b_i^n}{\Delta t}\right)=\lambda_{01}\cdot\left(\frac{T_{i+1}^n-2T_i^n+T_{i-1}^n}{\Delta x^2}\right)-C_{p,a}\rho_a v_a\cdot\left(\frac{T_{i+1}^n-T_{i-1}^n}{2\Delta x}\right)$$
$$+R_2 p_{v,sat}\cdot\left(\frac{b_{i+1}^n-b_{i-1}^n}{2\Delta x}\right)+R_3\cdot\left(\frac{b_{i+1}^n-2b_i^n+b_{i-1}^n}{\Delta x^2}\right)+R_4\cdot\left(\frac{b_{i+1}^n\cdot T_{i+1}^n-b_{i-1}^n\cdot T_{i-1}^n}{2\Delta x}\right) \quad (4)$$

By following the semi-explicit Euler method with the splitting method, the two equations become respectively :

$$\psi_T \cdot \left(\frac{T_i^{n}-T_i^{n-1}}{\Delta t}\right)+\psi_b \cdot \left(\frac{b_i^{n+1}-b_i^n}{\Delta t}\right)=\frac{\left(\delta_{p,mat_0}\cdot p_{v,sat}+D_{l0}^b\right)}{\Delta x^2}\cdot\left(b_{i+1}^n-2b_i^n+b_{i-1}^n\right)$$
$$-R_1\cdot p_{v,sat}\cdot\left(\frac{b_{i+1}^n-b_{i-1}^n}{2\Delta x}\right)+D_{l0}^T\cdot\frac{\left(T_{i+1}^n-2T_i^n+T_{i-1}^n\right)}{\Delta x^2} \quad (5)$$

$$\boldsymbol{C_{mT0}\cdot\left(\frac{T_i^{n+1}-T_i^n}{\Delta t}\right)+C_{mb0}\cdot\left(\frac{b_i^{n+1}-b_i^n}{\Delta t}\right)=\lambda_{01}\cdot\left(\frac{T_{i+1}^n-2T_i^n+T_{i-1}^n}{\Delta x^2}\right)-C_{p,a}\rho_a v_a\cdot\left(\frac{T_{i+1}^n-T_{i-1}^n}{2\Delta x}\right)}$$
$$\boldsymbol{+R_2 p_{v,sat}\cdot\left(\frac{b_{i+1}^{n+1}-b_{i-1}^{n+1}}{2\Delta x}\right)+R_3\cdot\left(\frac{b_{i+1}^{n+1}-2b_i^n+b_{i-1}^{n+1}}{\Delta x^2}\right)+R_4\cdot\left(\frac{b_{i+1}^{n+1}\cdot T_{i+1}^n-b_{i-1}^{n+1}\cdot T_{i-1}^n}{2\Delta x}\right)} \quad (6)$$

The latter is programmed on the PYTHON software as follows:

$$\begin{cases} b^{n+1}=b^n+dt\cdot F^n\left(b^n,T^n,T^{n-1}\right) \\ T^{n+1}=T^n+dt\cdot G^n\left(b^{n+1},b^n,T^n\right) \end{cases} \quad (7)$$

With F^n and G^n are square matrices.

Boundary conditions are applied to the outer and inner surfaces of the insulation material. On the one hand, the Dirichlet boundary conditions consist in imposing at the initial moment on the external surface of the material, a temperature T_{ini} = 330K corresponding to a relative humidity b_{ini} = 20% of the air circulating within the material. On the other hand, the Neumann boundary conditions consist in considering that the derivatives of the temperature and relative humidity flows are null on the inner surface of the material according to the order of arrival of the heat flow.

Different hygrothermal parameters are required before using the numerical model on materials produced locally in the humid tropical climate (raw banana and coconut leaves). These parameters are summarized in the following table:

Table 2: model parameters

Input parameter of the model	**symbols**	**Units**
Thermal conductivity of material	λ	$W.m^{-1}.K^{-1}$
Specific heat (air, material, water vapor, water liquid)	$C_{p,a}$; $C_{p,0}$; $C_{p,v}$; $C_{p,l}$	$J.kg^{-1}.K^{-1}$
Coefficient of resistance to vapor diffusion	μ_0 et $\mu(b)$	-

Permeability of material at the vapor	$\delta_{p,mat}$	$kg.m^{-1}.Pa^{-1}.s^{-1}$
Volume mass (air and material)	ρ_a et ρ_0	$kg.m^{-3}$
Latent heat of vaporization	L_v	$J.kg^{-1}$
Atmospheric pressure	P_0	Pa
Molar mass (water and air)	M_l et M_a	$kg.mol^{-1}$
Water content	w	$kg.m^{-3}$
Permeability of air	$\delta_{p,a}$	$kg.m^{-1}.Pa^{-1}.s^{-1}$
Pressure of saturation	$P_{v,sat}$	Pa

Different hygrothermal parameter necessaries before using straw banana or coco are summarized in the following table :

Table 3:Different hygrothermal parameter necessaries before using straw banana and coco

Hygrothermal parameter	**symbols**	**Method of determination**
Permeability banana straw on air	$\delta_{p,mat}$	Cup method
Coefficient of resistance of banana straw to water vapor diffusion in dry state (low humidity)	μ_0	Dry cup method
Coefficient of resistance of banana straw to water vapor diffusion in wet state (high humidity)	$\mu(b)$	Humid cup method
Specific heat of banana straw	$C_{p,0}$	Formulas
Water content of banana straw	w	Formulas
Hydraulic conductivity	K_l	Darcy's law
Pressure exercised on two faces of banana straw sample	P_1 and P_2	Sensors of pressure

We have carried out numerical simulation tests on materials whose properties are known in the literature. The results of the tests presented in this paragraph concern wood and cork with the hygrothermal properties mentioned in this paper (see tables 3 and 4).

- Profile for the temperature and relative humidity in the cork of 10cm of thickness

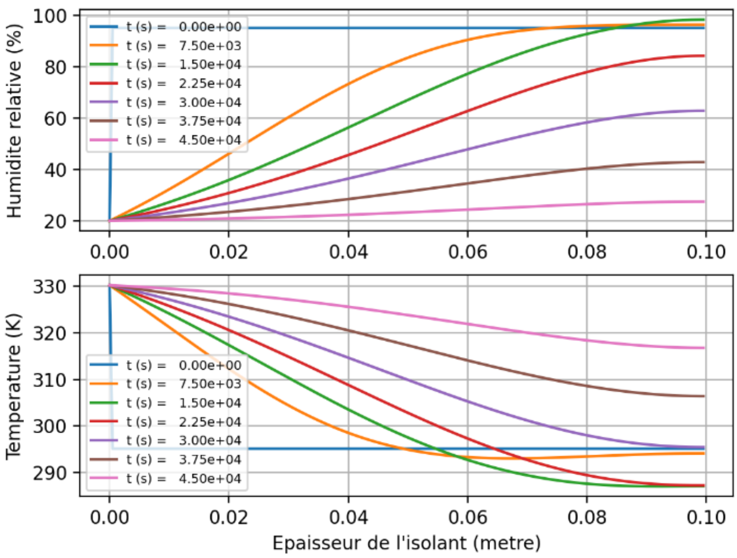

Figure 7.space (x) and time (t) numerical simulation of system balance equation applied to cork..

We present the profiles of temperature and relative humidity as a function of time and thickness of the material. We present different curves at different times of the simulation for t = 0 to 45000 s. For example: In the case of cork, the blue curves are curves corresponding to the instant t = 0 and x = 0, those of color correspond to 7500s, those of green color to 15000s, those of red color to 22500s and the last ones of magenta color correspond to 45000s. We can notice that as the iteration time increases, the relative humidity profile shows a tendency to decrease while the temperature tends to increase. This is a normal behavior since the temperature increases when the humidity decreases. We can say that the numerical model reacts well for this material.

The relative humidity profiles show that the temperature profiles increase at Dirichlet-Neumann boundary conditions as a function of time and thickness.

The profiles observed in the tested material are consistent with those in the literature [9,12].

- Profile for the temperature and relative humidity in the wood of 10 cm of thickness

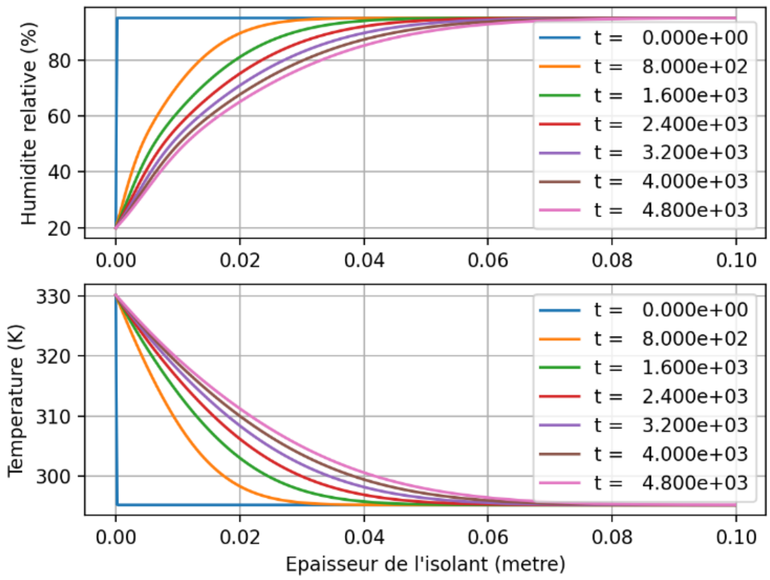

Figure 5. Graphic obtained in space (x) and time (t) for numerical simulation of system balance equation in using the data's wood.

Identically in cork, the different ones have the same colors in wood. Only the simulation times are much smaller. Temperature and humidity progress less and less within the material as they travel through the thickness as a function of time.

Moisture and temperature profiles converge and are consistent with the literature [9,12]

4.2 Experimental characterisation of bio sourced material

Another part of this work was devoted to the measurement of the thermo-physical properties of bio-based material with the guarded hot plate and flash method.

In stationary regime the Hot Plate Method (MPH) is very widely used by authors to evaluate the thermal conductivity of insulating materials in buildings. Among these works consulted in the literature are [22]-[26].

Saleh and Al-Ajlan measured the thermal properties of insulation materials including thermal conductivity and thermal diffusivity using the kept MPH. They also explained in their literature review that Abdelrahman et al. and Al-Hammad et al. proceeded in the same way in Saudi Arabia [14].

In the most influential work, the operating principle of MPH is based on the establishment of a temperature gradient over a known thickness of a sample in order to control the heat flow from one side to the other [14]. The sample is placed between a cold plate and a hot plate whose experimental setup is shown in Fig. 1, in the stationary state the static calculations assume the use of Fourrier's law (1). The MPH has been developed for the measurement of low thermal conductivity. This method requires a long handling time and the variation of humidity over time also leads to erroneous results. Errors can be related to the fact that the temperature gradient must be large and the duration of the experiment must be long, not to mention the contact resistance between the thermocouples and the sample [13], [14].

$$\lambda = \frac{e\phi_0}{S(T_{C(t)} - T_{e(t)})} \quad (3)$$

$\frac{\phi_0}{S}$ −Flow density conducted by the sample in (Wm^{-2}); $T_{C(t)} - T_{e(t)}$ −Temperature difference between the two faces of the sample in Celsius. e - Thickness of the sample in meters.

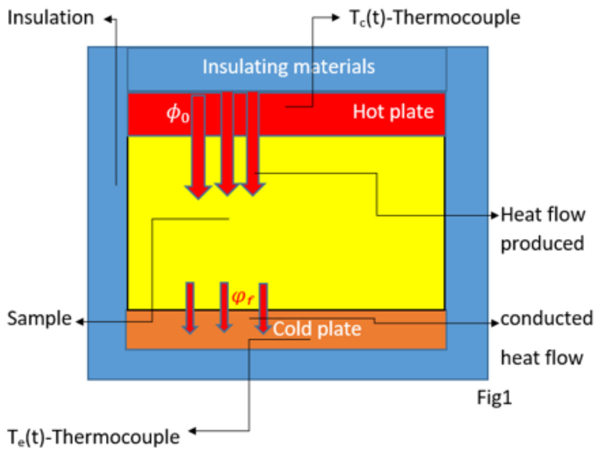

Figure 8: Diagram of the MPH, Te(t)-temperature of the cold plate, TC(t)-temperature of the hot plate

In the literature, the Flash method (FM) is widely discussed, it has been proposed by Parker et al. and can be considered among the best known and most widely used to measure the thermal conductivity of insulating materials [13]. Among the works that have highlighted this method are [13], [12], [25], and [26].

The FM [31] in its principle of operation consists in subjecting a system to a short thermal perturbation and observing the temperature response. The system studied can be a sample with a parallel face subjected to a thermal pulse on one of these faces, the temperature evolution being recorded on the opposite face. It can be added that this is a unidirectional method which consists in subjecting or making one face of the sample absorb a pulsed heat flow of short duration and to record the evolution of the temperature during this same time interval at one or more points on the opposite face of the sample [18], [13]. The schematic diagram of the experimental set-up is shown in Fig. 8.

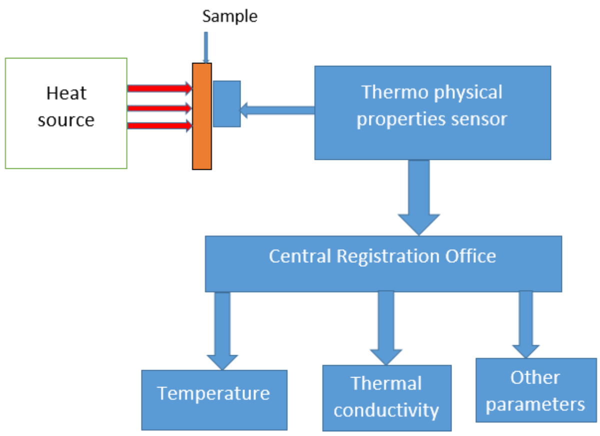

Figure 9: Diagram of the FM

The Experimental results shows that these materials have low thermal conductivity (0.031–0.050 W·m^{-1}·K^{-1} depending on material and method) and good thermal inertia, with moisture content and air pockets significantly affecting properties. Simulations indicate that combined roof + wall insulation of 10 cm bio-sourced material can reduce cooling load up to 91.2 % for a metallic cell, 71.45 % for a concrete cell, and 45.44 % for a concrete cell with openings. Thermal comfort analysis demonstrates an increase in the percentage of hours within the comfort zone from 64.1 % to 88.5 % for the metallic cell. Optimal thicknesses are around 15 cm for the roof.

Table 4:Thermal conductivity of bio-sourced materials

Material	λ (Flash method) [W/m·K]	λ (Hot Plate) [W/m·K]	Mean λ [W/m·K]
Banana leaves	[0.032; 0.042]	[0.034;0.041]	0.038
Coconut leaves	[0.036;0.043]	[0.037;0.042]	0.040
Sargassum	[0.031;0.041]	[0.030;0.042]	0.038
Latanier leaves	[0.036;0.044]	[0.036;0.045]	0.042
Palm kernel	[0.031;0.039]	[0.030;0.040]	0.036
Vetiver fibers	[0.038;0.043]	[0.036;0.044]	0.041
Sugarcane leaves	[0.033;0.041]	[0.031;0.042]	0.038
Wood sawdust	[0.031;0.047]	[0.031;0.050]	0.045

Table 5: Measured thermal heat flux and temperature

	Hot plate	**Cold plate**	**Hot plate**	**Cold plate**
Sample	**Thermal flux Measuring range: (W/m²)**		**Temperature Measuring range**	
Banana Leaf	[1032;1701]	[6,96;90,10]	[40;151]	[28,61;35,70]
Coconut Leaf	[1552;2533]	[0,29;25,98]	[37;110]	[30,00;34,22]
Sargassum	[1122;2533]	[0,29;39,19]	[35;119]	[31,34;33,43]
Latan Leaf	[1185;2412]	[0,29;28,37]	[37;114,8]	[32,00;36,52]
Palm kernel stain	[628;2335]	[0,59;49,57]	[36;108,7]	[31,77;37,15]
Vetiver Fiber	[1244;2288]	[2,28;39,72]	[48;115,5]	[30,00;36,26]
Sugar Cane Leaf	[1226;2264]	[0,29;34,64]	[46;119,6]	[30,71;35,23]
Sawdust	[1244;2252]	[0,29;51,96]	[36;117,4]	[29,84;35,10]

The study highlights the potential of bio-sourced materials for sustainable, economical insulation strategies adapted to humid tropical climates. Results support their integration into simple or low-cost housing while emphasizing the need for further research on durability, biodegradation, and standardization.
The second part of the study will be held on the BEPSDOM technical platform at real scale. The following issues will be tested:

4.1 Embodied Carbon Reduction

Bio-based materials significantly reduce embodied carbon in construction. For example, using bamboo structural elements instead of reinforced concrete can decrease carbon emissions by over 50% per cubic meter. Similarly, natural insulation materials such as coconut coir replace petrochemical-based insulation products while sequestering carbon during their growth phase [26]. The cumulative impact of substituting conventional materials with bio-based alternatives is especially significant in tropical regions, where rapid urban expansion and high-rise residential development are prevalent.

4.2 Thermal and Comfort Benefits

In tropical climates, controlling heat gain and maintaining indoor comfort are critical. Bio-based materials generally have lower thermal conductivity and higher specific heat capacity, contributing to reduced indoor temperature fluctuations and enhanced comfort [26].Timber and bamboo elements in walls and roofs act as natural insulators, while lightweight bio-based insulation materials limit heat transfer, reducing the need for mechanical cooling and associated energy use.

4.3. Lifecycle Assessment and Sustainability

The lifecycle assessment (LCA) of bio-based materials highlights their potential for achieving net carbon reductions. During their growth phase, plants sequester CO2, partially offsetting the carbon emissions from processing and construction. At the end-of-life stage, many bio-based materials are biodegradable or can be reused in new construction, further limiting environmental impact [26]. Integrating bio-based materials into tropical building codes and green certification schemes can accelerate decarbonisation and support sustainable urban development.

5. Conclusion and Perspectives

Defining bioclimatic buildings in tropical climates requires a multi-dimensional approach that integrates climate analysis, passive design strategies, and performance evaluation. Empirical evidence confirms that context-specific bioclimatic design can substantially reduce energy use and improve occupant comfort. Future research should focus on adaptive design frameworks, digital simulation integration, and standardization efforts to support climate-responsive architecture in the tropics.

The development of the BEPSODOM technical platform represents a strategic initiative to address the specific challenges of the tropical climate in terms of sustainable building, resilience, and smart grids. By offering a unique platform for research, validation, and training, BEPSODOM has the potential to catalyze innovation and accelerate the ecological and energy transition in Guadeloupe and the wider Caribbean region. Future steps will include finalizing the detailed design of the platform, securing the necessary funding, and establishing strategic partnerships to ensure its long-term success and impact.

In a first step, we focused on Bio-based materials who represent a key strategy for decarbonizing tropical buildings by reducing embodied carbon, improving thermal performance, and enhancing sustainability throughout the building lifecycle. Thermal characterization of local raw material and thermal simulations of building substituting conventional materials with local raw material, has shown a significant increase in indoor comfort and energy reduction in hot and humid climates. A next step is to use material such as Banana leaves, Coconut leaves, Sargassum, Latanier leaves, Palm kernel, Vetiver fibers, Sugarcane leaves, Wood sawdust in real conditions as components of a building envelope, whether in horizontal or vertical walls.

Future research should focus on optimizing material selection, durability, and integration with passive design strategies to fully leverage the decarbonization potential of bio-based materials in tropical regions.

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