PEEB Cool Funding Proposal

Annex 18b: Assessment of level of results by project

PEEB's support projects can be separated into two categories:

I. PEEB "lighthouse" projects receiving multi-level support combining technical assistance, institutional support and financing with an ambition to achieve national sector-wide transformation.
II. Projects receiving technical assistance from PEEB with an ambition to lead by example in their respective country or region.

This annex provides an overview of the level of achieved or estimated results for each ongoing or completed support project in comparison to PEEB's initial support objectives. The relevance of additional financing in combination with provided technical and/or institutional assistance is discussed for each case.

Part III. presents a qualitative case study of what PEEB support provided to a project in the education sector in Comoros.

I. PEEB "lighthouse" projects receiving multi-level support combining technical assistance, institutional support and financing with an ambition to achieve national sector-wide transformation.

Project: ***Energy Efficient Hotel Chain,*** **Mexico**

PEEB Support Objectives:

Mexico is experiencing rapid growth in the building sector. Energy efficiency standards and regulations already exist. The country has committed to reducing GHG emissions by 36% by 2030 with international support. Its NDC put the focus on energy efficiency measures in residential and commercial buildings. Private firms, however, need more capacity and incentives. PEEB supports this through active engagement with the private sector, including investors, developers and financiers, as well as public institutions responsible for large public works and energy efficiency standards.

PEEB Support Activities:

- Investment support:
    - Technical Assistance:

- Advice to the Ministry of Environment on incorporating more ambitious energy performance standards into the existing building regulation for hotels
- Technical guide on energy efficiency in hotels
- Technical support on energy efficiency concepts for Mexican hotel chain Grupo Misión

- Institutional Support:

- Advice to the Ministry of Finance on financing criteria in tenders for school and hospital projects.
- Private sector mobilisation through recommendations on financial and non-financial incentives and trainings on financing.

Level of Results:

Expected results:

- 20 new Grupo Mision hotels will integrate energy efficiency measures.
- The average mitigation potential of these hotels is 37%, reducing emissions on average from around 138 kg CO_2 / m^2 a to around 86 kg CO_2 / m^2 a.
- According to a data survey (National Energy Efficiency Commission CONUEE, BASE and Transenergie, 2008), on average beach hotels consume 466 kWh/m^2 per year and city hotels 303 kWh/m^2 per year. With a projection where 10% of the hotels in Mexico would consider reducing their energy consumption by 30%, the CO_2 mitigation potential that could be achieved would be 287,000 t CO_2 per year.

Additionality of PEEB Cool in the country:

The work carried out by PEEB has paved the way for future private investments in the hotel sector in the implementation of energy efficiency hotel guide and the proposal for concrete measures for one hotel chain.

In the public sector, AFD is engaging into energy efficiency in housing that offers possible investment perspectives and institutional support in Mexico while providing complementary support to what was provided with PEEB.

Project: ***Climate Financing for Energy Efficiency in Affordable Public Housing*, Morocco**

PEEB Support Objectives:

Morocco already has a comprehensive building energy code (RTCM). However, compliance is lagging behind, while 192,000 new housing units are needed every year to face demographic growth until 2030. PEEB and the Moroccan Ministry of Housing identified that proper enforcement, technical capacities and financial incentives are missing for the building sector to achieve the objectives set out in the countries NDCs in terms of energy consumption and GHG emissions reductions. PEEB works with the Moroccan Government on an integrated multi-level set of measures aiming to shift the building sector towards 19% reduction in energy demand until 2030.

PEEB Support Activities:

- Investment Support:

    - Technical Assistance:

- Technical study for the identification of energy performance improvement measures adapted to the Moroccan residential sector.
- Technical study for the development of a national grant mechanism to support energy-efficient housing improvements and the purchase of energy-efficient appliances.

    - Financing:

- Identification of an investment opportunity with the public housing developer, Al Omrane, for energy efficient buildings and appliances.

- Institutional Support:

- Enforcement of the building code through support for the Ministry of Housing and training of 100 government officials
- Regional roundtable of a Regional Roundtable of the GlobalABC gathering 100 representatives from 12 countries.
- Strengthening of the Moroccan Alliance for Buildings and Climate (AMBC)
- Support to practitioners and private sector through trainings on financing energy efficiency measures in large building projects targeting architects, engineers, project developers and decision-makers, and the identification of energy-efficient projects of private developers.

Level of Results:

An MRV system is in preparation to monitor following objectives over 5 years after implementation start:

- 7,000 households (32,000 Moroccans) benefiting from improved energy-efficient affordable housing.
- 35,000 households (115,000 Moroccans) benefiting from improved energy-efficient equipement.
- 20% increase in household satisfaction.
- Direct energy savings of 134 GWh-electric and 188 GWh-thermal.
- Direct emission reductions of 163,161 tCO2e.
- 25,000-30,000 underperforming fridges replaced and recycled (fridges being the highest energy consumer in an average Moroccan household)
- At least two key regulations are adopted and/or enforced (RTCM, MEPs, EEEs, …)
- At least one long-lasting financial instrument addressing appliance recycling is put in place.

Relevance of combining institutional support with investment support to transform the building sector:

The additional cost of implementing recommended energy efficiency improvements would represent 7-10% of the purchase price of a social housing unit. That is DH 17,500-25,000 depending on climate zones, while the median monthly income for Moroccan households is estimated at DH 3,500. The overall payback time for these energy efficiency measures (building and equipment combined) lies between 7 and 17 years.

Additionality of PEEB Cool in the country:

PEEB has allowed the identification of an investment opportunity with Al Omrane that could be financed under PEEB Cool. PEEB has contributed to raise public awareness on energy efficiency in housings matters. PEEB Cool could provide in Morocco the necessary financial support to move forward with the institutional support initiated by PEEB and the need for concessional loan to kick start a green housing programme with Al Omrane. It is expected that the concessional loans provided by GCF will foster the uptake by the market of the incremental cost of bioclimatic buildings and change in paradigm in the enforcement of the national building code in Morocco.

Project: ***Energy Efficient Health Facilities,*** **Tunisia**

PEEB Support Objectives:

Tunisia's building sector is expected to grow by 25% in the next 15 years. The country's NDC stipulates a reduction in carbon intensity of 41% by 2030. A regulatory framework and incentive mechanisms for energy efficient buildings are already in place. To support the Tunisian government in reaching its ambitious NDC targets, compliance with existing building regulations is essential. PEEB focuses on awareness raising among public and private actors, the identification of social housing projects and the improvement of two regional hospitals.

PEEB Support Activities:

- Investment Support:

    - Technical Assistance:

- Guide for health facilities and awareness raising within the Ministry of Health
- Mapping of current and future building stock and energy demand to demonstrate the need for action
- Technical assistance to achieve HQE certification on two regional hospitals

    - Financing:

- EUR 158 million committed for the construction and renovation of two upgraded, energy efficient regional hospitals.
- Additional EUR 2 million from the EU.

- Institutional Support:

- Enforcement of building codes through trainings for municipal employees and a legal review of enforcement mechanisms
- Training of policy makers, architects and engineers on financing for energy efficiency in buildings
- Assistance to the Ministry of Housing in identifying an appropriate large scale, energy-efficient social housing project.

Level of Results:

Expected results:

- Both hospitals will outperform energy regulations for hospital buildings by 20%.
- Combined, the two hospitals will save 171 700 tCO2e in 25 years compared to their baseline scenario.
- The hospitals are prepared for a +3°C increase scenario by 2050, with a steady or slightly reduced (-2/3%) energy consumption.

Relevance of combining institutional support with investment support to transform the building sector:

To transform the hospital sector, the development of a guide for energy-efficient hospitals is backed by investment support to two regional hospitals projects out of the 13 planned by the Tunisian government until 2030. These two projects will be aligned with the new guidelines and exemplify the feasibility of their implementation and their effectiveness in terms of well-being and long-term energy savings. The two hospitals will gather best practice experiences to help remaining 11 hospital projects align with the guide.

Additionality of PEEB Cool in the country:

AFD in Tunisia, is particularly involved in financing of construction and/or refurbishement of hospitals and urban public facilities. Discussions with the NDA in the frame of PEEB Cool have shown a need for investments in housings, especially individual homes and social housing. PEEB Cool will provide a support that is complementary to PEEB by targeting urban public facilities in addition to health facilities.

II. Projects receiving technical assistance from PEEB with an ambition to lead by example in their respective country or region.

Project	PEEB Support Objectives	PEEB Technical Assistance	Level of Results	Additionality of PEEB in the country
Hospital, **Uganda**	>Support to the construction of a hospital in Uganda > PEEB intervene while the project management was preparing the detailed design of the building	> Proposal of EE measures > Scoring study[1] > Support to the preparation of procurement documents	>PEEB has shown that an HQE Very Good certificated could be obtained by updating the existing design with a list of measures that would lead to a 2% incremental construction cost. > the Project is on hold because of the pandemic but the target of HQE Very Good Certification had been accepted by the client.	> The proposal includes partial financing of the incremental costs incurred by the certification which facilitated the adoption of bioclimatic measures.
School renovations and extensions, **Ecuador**	> Address the urgency of climate mitigation and building resilience in a country with numerous climate zones prone to climate and seismic risks. > Support to Ministry of Education (MINEDUC) in a project of refurbishment and construction of schools >The list of schools to be refurbished under preparation and project management (in charge of engineering and works monitoring) not yet recruited	>Proposal of EE measures >Support to the preparation of procurement documents >Development of guidelines for the development of an energy and environmental high-performance construction guide covering the different types of schools concerned by the project.	>PEEB support allowed to provide recommendations with costing and impact on thermal comfort improvement for 2 climate. In hot and humid climate, the recommendations allowed an improvement of the thermal comfort by 80% by implementing measures increasing construction costs by 3%. In the Sierra area, 50% improvement in thermal comfort could be achieved at a more important investment cost (10-20% incremental cost). >The infrastructure component of the project was canceled.	> The project was canceled. This project shows the uncertainty of project finance. By enabling a programmatic approach allowing for more flexibility among projects and ensuring a longer term view, PEEB Cool mitigates this risk by diversifying projects.
Social housing construction, **Ecuador**	> Address the urgency of climate mitigation and building resilience in a country with numerous climate zones prone to climate and seismic risks. > Support to the Ministry of Housing (MIDUVI) and to "Casa Para Todos" in a social housing project > MIDUVI has prepared technical specifications and is about to launch calls for tender	>Analysis and review of sample plans >Analysis and review of technical specification for the construction of housings >Proposal of EE measures and costing	> PEEB Consultants reviewed the plans of multi-family and single-family dwellings in 2 climates. In the Costa Guayaquil climate, the adoption of bioclimatic measures (incremental cost of 6-8%) could allow an increase of thermal comfort by 22-29%. >The measures could not be implemented because of the incremental cost that could not be borne by Ecuador.	>It was impossible for the project owner to bear the incremental investment cost of bioclimatic design, even if it leads to reduced operation costs of the buildings. This shows the financial barriers that PEEB Cool is addressing through GCF concessional loans (output 1.2).
Construction of 100 Secondary Schools, **Ivory Coast**	>Support to Ministry of Education (MENETFP) in the construction of 100 secondary schools >The program management unit has recruited architects to elaborate sample plans and is recruiting technicians in charge of monitoring the construction works	>Analysis and review of sample plans >Proposal of EE measures and costing >Cost-benefit analysis of the investments related to the proposed measures >Support to the preparation of technical specification of construction companies	>3 types of secondary schools were analyzed. Up to 36% improvement of thermal comfort could be reached by applying measure leading to a maximum of 3,6% over cost. >The project owner is reviewing PEEB's recommendation before including them in the concept and detailed design	> 500 kEUR grant are considered to cover part of the incremental costs due to the bioclimatic design.
Ouagadougou Sustainable	>Support to Ouagadougou city hall in construction and refurbishment of public	>Economic and financial analysis of PV investment on Ouagadougou bus terminal	>PEEB consultants analyzed two types of schools and proposed measures with (decrease by 4 to 18% the need for	> Size of the PV power plant was limited in surface by the current energy regulations.

[1] A Scoring study shows the level of certification that can be reached by a building and identify measures that allows to reach an upper level of certification

Development Programme, **Burkina Faso**	buildings >The bus station is under construction. The project design of the two buildings is to be done.	>Proposal of EE measures for 2 buildings to be constructed or refurbished >Review of sample plans of the 2 buildings >Thermal dynamic simulation of the buildings >Support to the preparation of the project management tender documents	cooling) and without (11%-14% improvement of thermal comfort) air conditioning. The analysis of PV investment shows a return on investment of 15 years of an installation of 120 kWc. >The project owner applied PEEB's recommendations for solar PV. For the schools, it is planned to integrate PEEB's recommendations in the technical specifications.	PEEB Cool could enable institutional support to update current energy policies in order to promote decentralized energy production by allowing for larger rooftop PV power plants.
Education development programme, **Senegal**	>Support to Ministry of Education (MEN) in the construction of more cost effective schools >The financing is a global budget support and is not directed to specific construction programmes. PEEB support contributes to the objective of optimizing long term expenses on schools constructions and is focused on revising sample plans of the MEN.	>Analysis and review of sample plans >Thermal dynamic simulation >Economic and financial analysis of investments related to proposed measures	>Two sample plans have been reviewed (high school and administrative building) under 5 climatic zones of Senegal. For the school, incremental cost lies between 9.6 to 14% and leads to a decrease in uncomfortable hours by 4.8 to 28.7%. For the administrative building, incremental cost lies between 9.5 to 12.1% and leads to a decrease in uncomfortable hours by 14.1 to 48.1%. >The next step is to identify construction projects that could apply those measures.	>We can see that when technical assistance is not backed by an investment project, the impacts are not guaranteed. Here, even though PEEB support shows the value added of bioclimatic design, the results cannot be measured because the measures have not yet been implemented in a project. PEEB Cool eligibility criteria filter those case in order to only apply technical assistance support to investment projects.
National Programme for affordable low-carbon housing, **Vietnam**	Until 2040, 374,000 new housing units are needed in Vietnamese cities each year. The country has set reduction targets for greenhouse gas emissions in its NDC and seeks to promote low-carbon construction. PEEB supports the Vietnamese government in setting up a national programme for affordable low-carbon housing (Green Housing Programme) and strengthening its NDC in the building sector. The new programme will introduce basic standards for energy efficiency and offer green credits for both private housing developers and low- to mid-income households.	>Advisory to the Ministry of Construction on a technical guide for green housing. >Technical feasibility study for the development of the Green Housing Programme with concessional loans to housing developers and credits to apartment buyers for highly efficient appliances. >Preparation of a national credit line for affordable energy-efficient housing. >Support for the development of an NDC Buildings Mitigation Platform and a buildings and construction sector roadmap for faster NDC implementation. >Trainings on financing for policy makers and practitioners as well as investment recommendations for green buildings.	Estimated results 15 years after project start: - 3 400 affordable housing units financed - 192 ktCO2e emissions avoided as compared to baseline scenario (direct impact).	PEEB paved the way of green housing paradigm shift in Vietnam. However, since green housing is still in its early stages of development in Vietnam, a support programme is necessary to strengthen the capacity of participating banks to develop an appropriate security product offering. The main themes are: identification of housing projects meeting eligibility criteria, verification and reporting of E&S and climate impacts and the preparation of individual loan files for households. It is expected that since NAMA facility plays the role of kick starter of market uptake, need for concessional loans will be reduced.
Energy Efficient Social Infrastructure – focus on Education and Health, **Senegal**	The building code does not limit the energy consumption of buildings. PEEB supports the Senegalese government in developing a thermal regulation to limit the consumption of new buildings. At the same time, work with the Ministries of Education and Health promotes energy efficiency and sustainable building materials. Three rural health centers are supported with technical and financial support to integrate energy efficiency.	>Revision of standard plans for the construction and renovation of three health centers >Thermal dynamic simulation of the reference design of school buildings to identify realistic measures for the AFD-funded program supporting education development. >Technical study on building sector growth and energy consumption (country study) >Market study on sustainable building materials and construction in Senegal - Institutional Support:	>60 members of ministry staff trained on energy efficiency measures in buildings >45 private and public actors trained on financing for energy efficiency in buildings >Estimated results of recommended energy efficiency measures for the three health centers: Overall improved work and health conditions for staff and patients - Reduced average periods of discomfort throughout the day from 85% to 5% - EUR 20,000 energy cost savings per year for every health center	The adoption of a thermal regulation for Senegal would be a step change and send strong market signals. Nevertheless, given the low capacities to enforce regulation, regulation alone would not be sufficient. Boosting this through financial instruments such as green credit lines sends the necessary price signals in a very dynamic market environment. This could be combined with the development of labels for green buildings for financial support. Collaboration with the Ministries of Health and Education could be reinforced through financial collaboration to scale-up the

		>Roadmap for the development of a thermal regulation for new buildings. >Support to integrate the regional directives for energy-efficient buildings into national law >Private sector trainings on financing for energy efficiency in buildings >Capacity building in the Ministries of Health and Education for staff in charge of construction projects.		replication of measures in several buildings projects. Work with the private sector would ensure the supply of materials and services to satisfy the demand.

III. Case study of PEEB support in the education sector in Comoros

1. Presentation of the PAES Project

a) Description of the project

The Union of the Comoros is a small island state facing high poverty with 42.3% of the population living below the national poverty line. Comoros is particularly exposed to the effects of climate change and natural disasters (cyclones, coastal erosion, floods, etc.). The major risks are the increase in the frequency and intensity of cyclones, earthquakes, sea level rise, drought and flooding. In recent years, heavy rains and cyclones (most recently Kenneth in April 2019) have caused deaths, property damage and significant displacement of people. In the field of education, many challenges remain to ensure quality education for all students. Enrolment is rising sharply at all levels of education, particularly at general secondary level. Thus, the increase in enrolment over the past few years has led to a deterioration in the conditions in which pupils are received and taught, which has a direct impact on the quality of education. In general, school structures are very degraded and were heavily impacted by Cyclone Kenneth, considerably reducing the capacity of the school.

AFD provided initial support to the Comorian education sector in September 2019 through the Comoros Education Performance and Governance (PGEC) project, called "Bundo la malezi", which aims to achieve equity, learning support and good school management in primary, secondary and high schools.

In July 2019, France and the Union of the Comoros signed a France-Comoros Development Plan (PDFC) which includes the education sector as a priority.

The PDFC is implemented through two projects:

- A project to improve the school environment by renovating and extending approximately 45 primary, middle and high schools on the three islands and developing physical education and sports in primary schools.
- A project for the integrated development of knowledge, skills and attitudes, through the improvement of initial learning at primary level, the reinforcement of professional training from high school to bachelor level and the development of physical and sports activities at different levels.

As part of the PDFC's infrastructure component, a feasibility study has been launched to address the renovation and extension of school infrastructure. The PDFC is part of the ongoing PGEC, which includes an infrastructure component (€1.2M) for the rehabilitation of around thirty schools.

b) Operating procedure

Component 1. Comprehensive rehabilitation of public school infrastructure

The activities are implemented by the Ministry of National Education, Teaching and Research (MEN), on behalf of the Union of Comoros. The management of the project is entrusted to the project management unit "Bundo la Malezi" attached to the MEN. An international expert supports the installation of an "infrastructure" department at the MEN and provides advisory support to the management unit. This support aims to alleviate the environmental constraints to better learning for students through comprehensive rehabilitation of the infrastructure of the target public primary, middle and high schools. In a sustainable development approach, these interventions concern the rehabilitation of buildings, the construction of missing premises, the upgrading of access to water,

sanitation, waste management and the development of outdoor spaces. These interventions are contextualised and adapted according to the site and the level (primary, secondary, high school).

Component 1 objectives:

i) Strengthen the reception and improve the image of the establishments
ii) Creating a stimulating school environment adapted to learning
iii) Create the conditions for the sustainability of the investment and the quality of the heritage
    a. Simple designs and solutions in terms of materials and implementation, requiring minimal maintenance
    b. The use of durable materials, preferably of local origin
    c. Premises strictly adapted to the need and taking into account this maintenance criterion
    d. Bioclimatic renovation of premises as part of a sustainable development approach
    e. Integrated furniture, wherever possible
    f. A closed and secure storage room for maintenance equipment

Component 2: Development of physical activity and sport in primary schools

The implementation of the Kids Athletics programme is ensured by the Mauritius-based Africa Athletics Development Centre, an association with which AFD will sign a financing agreement.

Costs and funding

Component 1	19 400 000 €
Component 2	100 000 €

Expected implementation time: 4 years

c) Stakeholder, operating mode and project management

Component 1:

Project owner

The project owner is entrusted to the MEN. This project accompanies the creation of a permanent "school infrastructure" unit within the MEN. The project foresees an extension of the project management unit (PMU) of the "Bundo la malezi" project, existing since October 2020, to accommodate this project.

Project manager - Company in charge of the implementation of the project (MOE)

Local project managers do not have sufficient skills to deliver technical and architectural design studies that meet the requirements in terms of quality, bioclimatic approach and consideration of local climatic risks.

Moreover, international project manager do not have sufficient knowledge of the local context. Finally, community ownership of projects is a key condition for the success and sustainability of the project.

Thus, it was retained that:

- The recruitment, through an **international call for tenders, of a team of co-contractors called "MOE Coordinator/Community"**, associating an international firm and a technical consultancy or an NGO specialising in the community approach, making it possible to pool the thoughts on the construction strategy for all the targeted establishments, to harmonise the technical and architectural interventions, to guarantee the implementation of construction solutions that comply with the requirements in terms of quality, bioclimatic approach, and taking into account local climatic risks, and to ensure that the projects are taken on board by the local communities and school boards.

- The **recruitment of 3 to 6 local projects managers (MOE) through a national call for tenders** to ensure an implementation adapted to the local context.

Component 2:

The Kids Athletics program will be implemented through a grant from AFD to the WA African Athletics Development Centre.

2. Intervention of the PEEB

As the Comoros Islands are located in a hot and humid tropical climate, it is essential to design bioclimatic infrastructures to obtain satisfactory thermal comfort without active cooling solutions (air conditioners). The search for hydrothermal comfort is one of the most characteristic environmental targets of bioclimatic design.

The PEEB was requested in January 2019 to support the Comorian Ministry of Education and its services, regional education directorates and schools in the renovation and extension of schools.

a) Presentation of the intervention

The required services are as follows:

- Analysis of sample plans
- Dynamic thermal simulation
- Proposal of energy efficiency measures (envelope, system, management, ENR, etc.) and costing
- Carbon footprint and climate accounting
- Support for the elaboration of specifications for the selection of the project management teams

The Terao consultancy was recruited by the PEEB Secretariat to carry out these services. Terao intervened in the pre-programming phase and thus provided support on the aspects of improving the energy and environmental performance of buildings. The purpose of this support is to contribute to the transformation of the way things are done in the country, the region or the sector in terms of building construction or renovation.

b) TERAO deliverable/report

The TERAO deliverable presents the following studies:

- A national context study
- A study of current and 2050 climate data,
- Analysis of the typical layout of the different classroom modules,
- The definition of the reference model,
- The Energy Efficiency Strategy Study,
- Adaptation of the reference model according to the feedback from the mission,
- The study of suitable combinations according to the case of rehabilitation or new construction and their costing,
- The analysis of a preferred combination applied for the 3 classroom organisation configurations in the 2020 climate,
- Analysis of a preferred combination on the single classroom module with climate 2050,
- Recommendations related to the integration of Compressed Clay Brick (CCB),
- Climate benefit analysis for the new and renovation cases,
- Recommendations for outdoor spaces,
- Recommendations for support in the development of specifications for the selection of EPC teams.

The elements presented in the rest of the report are the structuring elements of the bioclimatic design of the project: 1) Analysis of the reference plans, 2) Estimation of the hydrothermal parameters of the rooms on the basis of these plans, 3) Proposals for improvement measures, 4) costing of these measures, 5) and 6) Proposals for measures surrounding the buildings.

1. Analysis of typical classroom layouts

Terao analysed plans of current typical classrooms in the Comoros in order to take a reference case and then be able to simulate this reference case and propose energy improvements.

The analysis of the plans leads to the following conclusions:

- The building is rectangular in shape and is not attached to any other building. This will allow heat gain and loss through the building materials in all directions.
- The ratio of glazed area seems reasonable.
- The building appears to have sufficient windows. These will allow natural light to enter the space and provide adequate daylight for the users.
- The window head levels are high. This will allow natural light to reach interior areas away from the windows.
- The main façade (with windows) of the building is currently oriented in the west direction. This can lead to significant heat gain and glare for the occupants.
- The roof of the building is made of sheet metal, which is unfavourable. The tin roof will absorb a lot of heat which will be immediately transmitted into the room. This will directly increase the temperature of the indoor air. In addition, the roof will function as a radiant panel, resulting in a high thermal discomfort condition.

2. *Dynamic thermal simulation of the reference case*

In order to analyse the thermal behaviour of buildings in the Comoros climate, Terao has carried out Thermal Dynamic Simulations (TDS). The TDS is a software tool that allows to have an overview of the thermal behaviour of the building analysed in a precise way in time (at an hourly time step) and space (3D model representing each room of the buildings). The software used in this study is Design Builder, which uses the Energy Plus calculation engine.

The following table lists all the characteristics of the reference building:

Building envelope	
Description	**Building materials**
Exterior wall	Mortar + hollow block + grey mortar
Paving	Sand bed + slab + screed + tiles
Roofing	Sheet metal
Opening	1 door and 2 openings and 3 windows on the south side
Infiltration rate	Normal sealing
Orientation	North/South
Number of floors modelled	1 (DRC)
Opening area ratio	5%
Total surface area of the building	63 m²
Overhang/Solar protection	No roof overhang/No sun protection
Internal inputs	
Lighting	None
Occupation	40 occupants

Summary table of the characteristics of the reference building (typical classroom)

Once the simulation has been carried out, a heat balance analysis is carried out for the hottest week to find out the heat losses and gains through the building elements of the reference case. The main points retained from this simulation are the following:

- The main heat gain is from the roof and windows because of the tin roof.
- Secondly, there are inputs related to lighting and occupancy.
- The low floor allows cooling thanks to the inertia of the floor.
- An East/West orientation is not suitable, it increases the number of hours of discomfort and thermal comfort of the users.

3. *Optimisation studies - Proposal of energy efficiency measures*

The thermal simulation of the reference building therefore allowed a number of improvement hypotheses to be established. Terao simulated several types of optimisations on the envelope, and on the type of fan in order to determine the number of hours of discomfort and the operating temperature during the hours of occupation. In addition, in order to model a typical school, 3 ways of grouping classrooms were modelled and simulated (adjoining rooms, individual rooms and stacked classrooms).

The results of the optimisation studies have made it possible to select the most effective strategies.

Thus, the improvement strategies are as follows:

- A North/South orientation
- A roof overhang with a largely ventilated space between roof and false ceiling,

- Large roof overhangs,
- Clear finishes,
    - Painting walls and roofs in light colours reflects direct radiation and reduces the heat effect.
- Facade to facade openings,
- 50% openwork shutters or grilles allowing natural ventilation at night and a secure space at night,
    - The solar protection of the openings is also fundamental, representing 15 to 30% of the heat gain through the walls. Several types of opening treatment have been listed: free opening with a welded mesh grille, glass window with reflective glazing, metal blinds, glass blinds, wooden shutters, solid metal or wooden shutters.
- The use of CCB where possible.
    - The adobe or compressed earth brick walls regulate the humidity in the classroom and reduce the temperature.

Studies have shown that these provisions allow the **maximum operating temperature to be reduced from 48°C to less than 35°C**, and that a very reasonable improvement in thermal comfort can be achieved, provided that air flow is ensured.

In addition, the study of the 3 configurations of the classroom module confirmed that the ideal case corresponds to the adjoining modules because it takes advantage of the inertia of the floor.

Cases	Improvement in thermal comfort compared to the reference case
Module only	-48%
Stacked modules	-39%
Attached modules	**-49%**

Summary table of thermal comfort improvement according to classroom layout

Furthermore, the TDSs and the theoretical climate data of Comoros 2050 allow to estimate that **the discomfort for the case of the improved new module will be reduced by -27% to 42%** depending on the air speed.

4. Costing of energy efficiency measures

Terao has calculated the estimated overall cost to be taken into consideration for a case of heavy rehabilitation and a case of new construction.

In the case of the renovated module, the estimated cost of the renovation work to improve the bioclimatic design is approximately €13,400, which corresponds to 66% of the total cost of the work. The costed measures in this case are as follows:

In the case of the new module, the estimated cost of the work related to bioclimatic design is €16,325, representing 51% of the total cost of the work.

In both cases, the quantified measures are as follows:

- Clear finish on new or renovated walls
- Roof finish
- Installation of a false ceiling in wood plywood
- A roof (in the case of new buildings only)
- A ventilated surtory in the case of rehabilitation

- 50% openwork shutters
- Naco louvre window and protective grille
- Integration of screens in the rehabilitated case
- BTC walls (only in the case of new construction)
- 2m corridor to the north
- Cap 0.6m to the south
- Small gable overhang to protect the false ceiling
- 2m perimeter corridor for new buildings

The percentage ratios are the ratios applied in the project and include the improvements made to the project. They are not additional costs.

Note on CCB cost

Concerning CCB, according to the studies and missions on site, the material is less expensive than cinder block. However, as a precautionary measure, given that the technique is not widely used, Terao, with the help of an economist, estimated the cost of CCB to be equivalent to that of cinder block.

5. *Recommendations related to revegetation*

TERAO has provided recommendations for a landscaped area. The landscaping will contribute to the indoor and outdoor comfort of the school by providing shaded areas for the residents, thus improving their comfort during hot weather. It will also help to educate and train students, and create a place for biodiversity development.

6. *Recommendations for the use of raw soil*

TERAO lists all the advantages and disadvantages of building with earth. It is a natural and abundant material and therefore economical, producing little CO_2 and generating little waste during the construction phase. Earth has a high density and its thermal conductivity gives it thermal inertia qualities. It is a good sound insulator and resists wear and tear well. However, raw earth is vulnerable to moisture, has low resistance to earthquakes and has a long installation time which requires more labour than in conventional construction.

TERAO recommends the use of CCB for the project.

c) C. Support for the elaboration of specifications for the selection of project management teams

1. *Strengthening the project owner team*

TERAO recommends that an assistance to the project owner be commissioned to support future local design teams in addressing the challenges of sustainable project design.

According to the main infrastructure manager of the PAES project, they an international project management team is being recruited and will be able to produce 4 standard models of schools and will be able to train local project managers.

2. *Guide to renovating and building sustainable schools in the Comoros*

The TERAO report states that it is essential that future project management teams take advantage of all the studies conducted during the PEEB mission. TERAO recommends the creation of a Guide "Renovating and building sustainable schools in Comoros".

This guide will be produced by the international project management team.

3. *Technical specifications*

A technical specification has been drawn up by the project owner. These specifications are intended for use by the contractors who will be working on the project and are intended to set out the project guidelines and technical specifications as well as to define the expected level of quality.

All TERAO's recommendations for the implementation of hydrothermal comfort improvement devices have been taken into account in the specifications.

However, the specifications do not present the CCB but recommend the use of the SCB (Stabilised Clay Brick). This brick is made of clay, pozzolanic sand, little cement and water. It is a locally produced material, there is an abundance of good quality clay on the islands of Anjouan and Moheli. SCB has a better carbon footprint than concrete block masonry.

The Terms of Reference detail all the advantages and disadvantages of the SCB:

Advantages:

- The hygrothermal comfort properties of earth are relevant for hot climates
- SCB can be produced locally, creating local employment
- Very good acoustic properties

Disadvantages:

- The SCB is vulnerable to earthquakes and water, which implies that constructive measures must be put in place for each construction site to guarantee the durability of the structure.
- There is a lack of political will to further develop the local SCB pathway
- Lack of awareness among the population
- Longer installation time than cinder blocks

3. Conclusion

The overall support from PEEB is considered very satisfactory. The energy efficiency recommendations made by the TERAO consultancy were fully taken into account in the technical specifications of the PAES project, with the exception of the installation of the CCB. The project is under implementation.