SOLAR SCHOOL PROGRAM IN REUNION ISLAND

Mathieu David, Laëtitia Adelard, *Industrial Engineering Laboratory, University of La Reunion, Saint-Pierre, 97410, Ile de La Reunion, France.*

Summary

Because of its particular geographic situation and relatively high altitude (3069 meters), Reunion Island is composed of a very large amount of micro-climates which have a direct impact on buildings' comfort, energy consumptions and renewable energy system efficiency.

In Réunion Island, the industrial engineering laboratory is involved in the regional solar school program. Its aim is to gather some local construction actors (city technical offices, architects, civil engineers, specialized university team research, meteorological services), for a better knowledge transfer, and a better environment understanding. The main objective is to rehabilitate primary school in a bioclimatic and low energy consumption way, taking into account climatic conditions.

Three primary schools corresponding to three particular micro-climates have been studied and simulated to evaluate main comfort targets (from a thermal, ventilation, humidity, lighting, and acoustic points of view). Architects then worked considering the technical prescriptions for renovation projects. An internal and external instrumentation was installed before and is planned to be reinforced after the renovation to validate these prescriptions.

This program illustrates precisely what has to be done in each building project:

- Meteorological data acquisition (hourly data for simulation software and for renewable energy options analysis and optimizations).
- Thermal comfort simulations taking into account natural ventilation, heating or cooling needs, condensation or other pathologies risks.
- And finally, an instrumentation campaign for all targets evaluation.

Keywords: bioclimatic, comfort, micro-climates, renewable energy.

INTRODUCTION

Reunion Island is situated near the tropic of Capricorn at a latitude of 21° south and a longitude of 55° east. The climate is humid tropical on the coast, and rather like temperate climate in high altitude. There is a wet season (November-April), mainly warm and rainy with risks of cyclones and a dry season (May-October), cool and drier, predominated by trade winds. There are a lot of different micro-climates due to the high altitude (3069m), specific relief, and geographic orientation.

In the insular context of fossil energy dependency, the local economy has to supply important needs in accommodation. Following the "Agenda 21", the local energy policy promotes energy reduction needs in buildings and initiates the "Solar school program". This action gathers local construction actors: city technical office, architects, civil engineers, specialized university team research and meteorological services.

The program consists of rehabilitating three primary schools (Espérance, Goyaviers and Platanes Sud) following bioclimatic prescriptions. Figure 1. presents steps that will be applied to design prescriptions in building construction or renovation according to micro-climates. We have illustrated the steps with the case of Platanes' school, with an altitude of 970 meters. Scientific publications already explained similar methodologies [1] [2] [3] [4]. A micro-climatic characterisation and numeric simulations of buildings behaviour, energy consumption and renewable energy systems production (photovoltaic, solar thermal water, wind turbine) give quantitative solutions and advice for architects and civil engineers. During the rehabilitation work, scientific instrumentation for comfort and energy system evaluation was installed.

MICRO-CLIMATIC ANALYSIS

Reunion Island overseas territory has the most dense meteorological net in France. It is composed of more than sixty [Meteo France] points of survey, including one for each primary school of the program. Automatics [Météo France] stations measure and store dry air temperature (°C), relative humidity (%), global irradiation (j/m²), wind speed (m/s), wind direction (°) and pluviometry every hour.

Treating a large range of climatic data needs computer support such as NewRuneole software based on climatic data bases analysis and generations using the typical weather sequences study [5]. It can provide pertinent files for buildings and energy systems simulation software. It is very powerful for climatic characterisation and climatic potentials or constraints evaluation.

NUMERIC SIMULATIONS

NewRuneole creates the implementation file for the building behaviour simulator CODYRUN. CODYRUN is a detailed building thermal simulation software regrouping design and research aspects. This software has already been covered in various publications [6]. Essentially, it involves multiple zone software including natural ventilation, humidity transfer and comfort estimation.

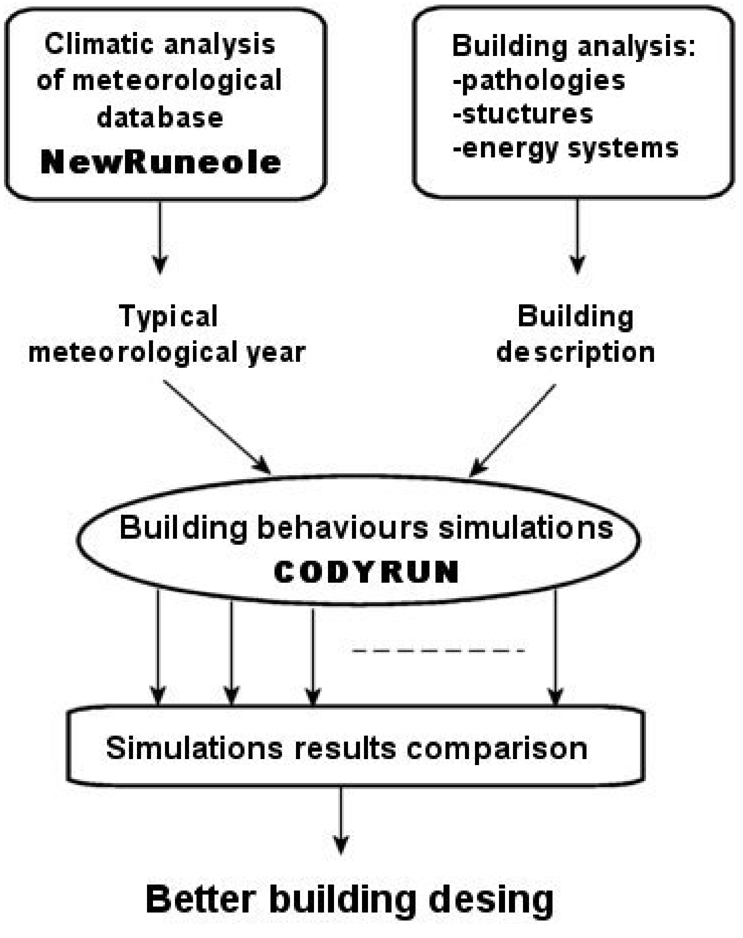

Figure 1. Applied methodology to support architectural design

First step: in situ observations permit a first approach to evaluating building pathology and configurations (table 1. and figure 6.). At the same time as collecting climatic data, we lead a measurement campaign about indoor comfort variables with “white boxes”. This small thermo-hygrometer datalogger stores hourly data during 40 days. Numeric simulations of the buildings before rehabilitation lead to comparison with in situ surveys during two sequences in the dry and wet season.

	Description			Pathologies	
Classrooms 1 to 4	Orientation of principal faces		North and south	Thermic	Heat sensation in wet season with uncomfortable ventilation
	Dimensions		7.87m long, 7.43m large and 3.5m high		Sensation of discomfort in dry season (due to low temperatures or high humidity rates)
	Structure		Reinforced concrete beams		Heating : 2 electric convectors
	Walls and roof		20cm concrete	Humidity	Infiltartions by ceiling
	Windows	North face	2 sliding window 183x138cm		Decollement of painting
		South face	3 french windows 176*138cm		Molds
			8 Nacos 70x80cm	Acoustic	None
	Doors	Extern	1 door 210*108cm	Lighting	use of artificial lighting
		Intern	1 door 210*108cm		Insufficient in natural lighting

Table 1. Platanes' school description and pathologies

In the figure 2., The "initial building" curve is the thermal numeric simulation during the dry season of the actual building configuration without using the electric convectors. The "measured data" curve corresponds to the in situ survey during the same days. The impossibility to model how users usually turn on the electric convectors explains the differences between the curves.

Figure 3. corresponds to simulated condensation risks, they are anormally high because of the humidity sensor overestimation. Rather than absolute observations, we will look at relative differences between simulations. Figures 2. and 3. are temperature and condensation risk means for each hour of the considered period (July 23 to September 2 - 2002).

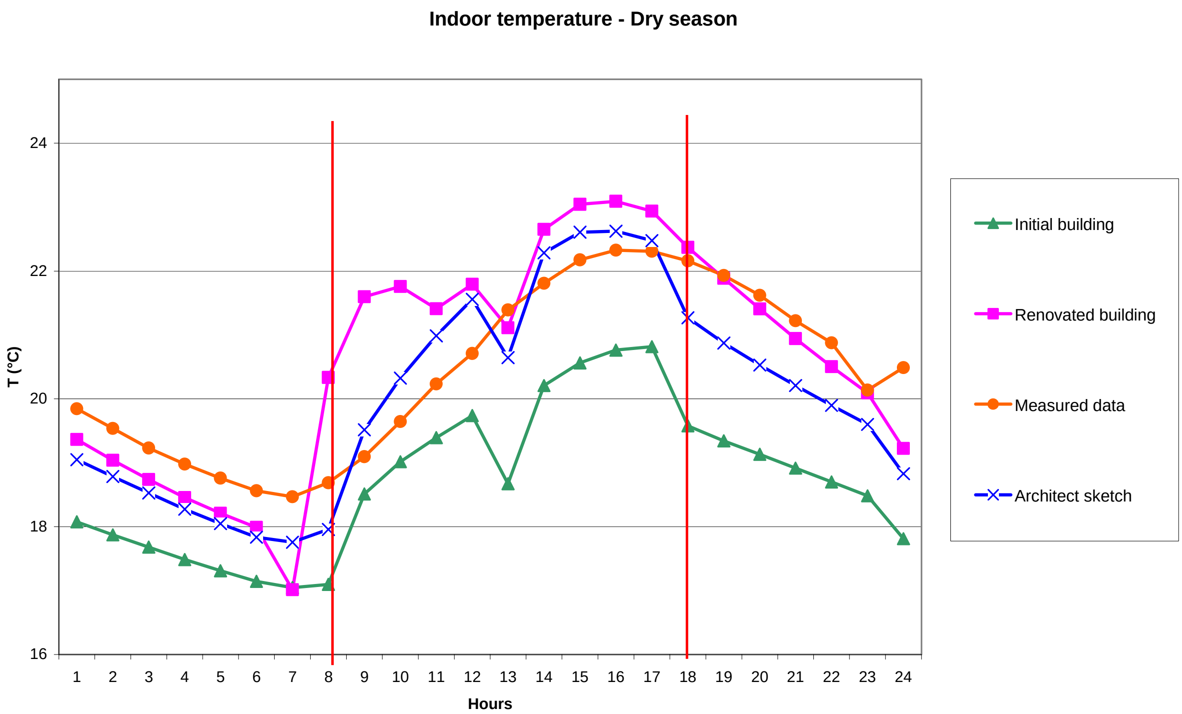

Figure 2. Comparison of measured and simulated mean day indoor air temperatures during the dry season

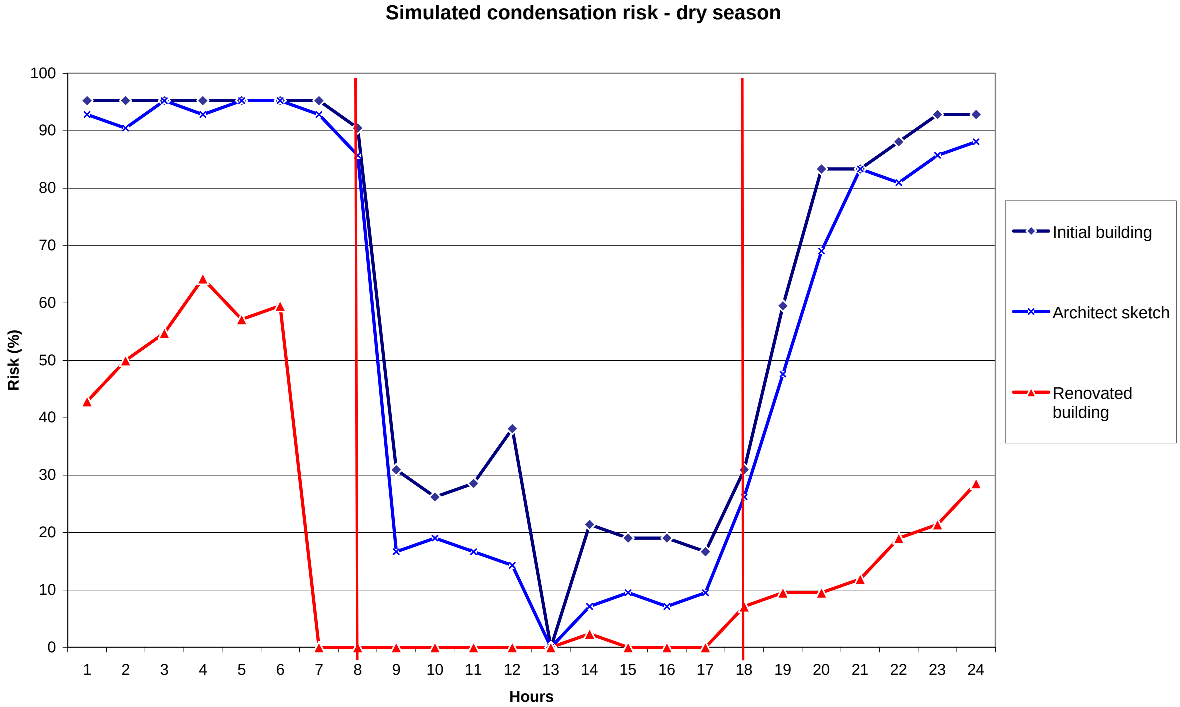

Figure 3. Comparison of simulated mean day condensation risk during the dry season

Second step: simulation of architectural sketch and test of different building configurations without significant architectural changes.

The major difference between living quarters and tertiary buildings is the schedules of activity. In school case, acceptable comfort conditions for buildings must be reached only between 8 o'clock in the morning and 6 o'clock in the afternoon (vertical red lines in Figures 2. to 5.). Rest of time, we only takes into account the damage risk.

We artificially tested basic architectural solutions and systems suitable for micro-climates. In the warmer part (littoral), use of well dimensioned solar protections and large open surfaces facing thermal winds (generally perpendicular to trade winds direction on coastal area) give good building behaviours [4]. In the colder part (high altitude), to limit heating needs during the dry season systems that collect solar energy in the morning are good solutions [2]. The most problematic zone is situated between the two last parts of the island. Up to 400 meters and under 800 meters, where the mean annual temperature is up to 21°C, high humidity rate produce a feeling of discomfort and rapid building damage. Numeric simulations are useful to reach the best compromise between solar collection and protection including good ventilation for both seasons.

In the Platanes' school case, two main problems have to be solved, high temperatures in the wet season due to bad natural ventilation. In the dry season the sensation of cold is intensified by the high humidity rate during the first hours of the morning (figure 2., "initial buildings" and "measured data") and there are problems of condensation (figure 3., "initial building"). The way to lower both building pathologies is with a good concordance between sun protections and ventilation.

In sketch, architect add on 7 m² of windows opening at the top of the north face. Translucent panels including an 80cm solar protection dark panel on the wall side substituate the concrete veranda (Figure 6.). In this building configuration, the new openings give good natural lighting in class, good natural ventilation in the wet season and a higher temperature in the dry season but the problem of discomfort persists during the first hours (figure 2., "architect sketch") and there is condensation risk (figure 3., "architect sketch").

Simulation shows that mechanical ventilation is necessary to limit the condensation risk in the dry season. To have a good inside air temperature during the first hours, two methods have been considered: trying to keep good level of inside air temperature with insulation or to heat the classroom early in the morning.

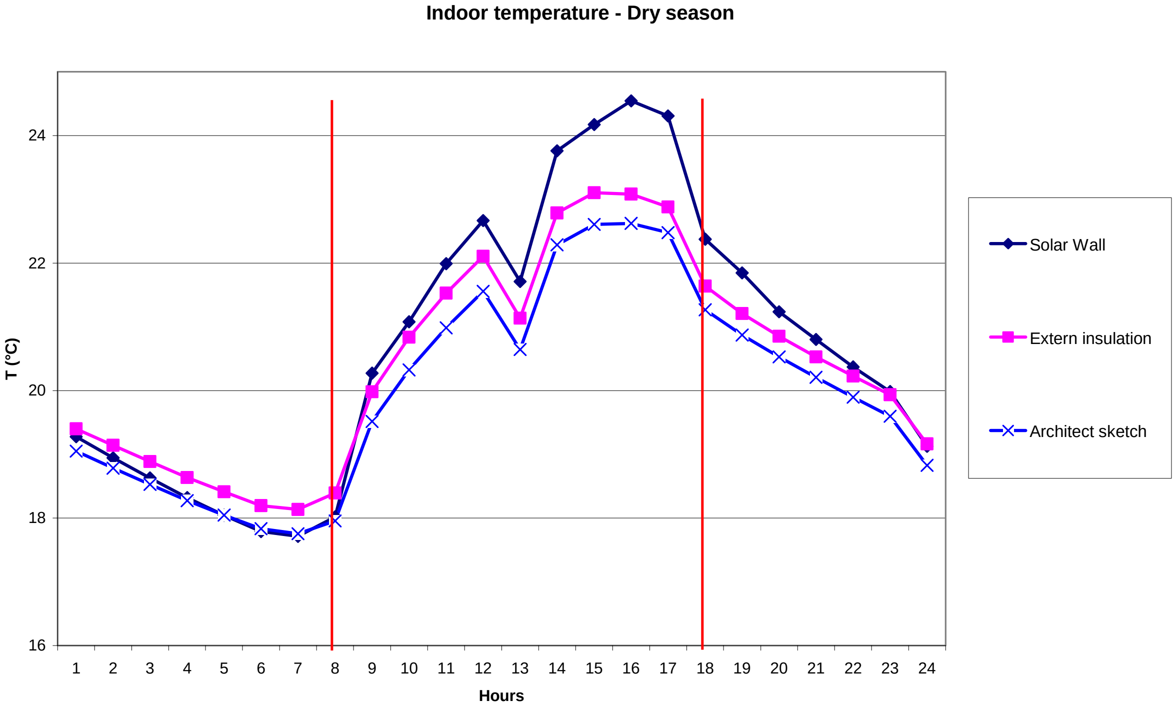

Figure 4. Comparison of measured and simulated mean day indoor air temperatures during the dry season

Passive insulation solution, for intern or extern faces of the walls, is not sufficient to keep a good level of temperature during the night (figure 4., "extern insulation"). To heat the classrooms, we tried solar walls [7] [8] on the north face of the building. Figure 4., the "solar wall" curve shows that the solar walls don't give enough heat supply during the first hours. Taking into account the solar walls and building thermal inertias, the effect on classroom heating begins after 11 o'clock in the morning. Passive solutions are not sufficient to reach morning temperature at a good level. So we test basic active solution, a heating electric resistor inside a mechanical ventilation system. This last solution seems to be the best. Turning on the resistance and ventilation system from 6 to 9 o'clock in the morning is possible to reach feeling of comfort from the first hour of school (figure 2., "renovated building") and to minimize condensation risk (figure 3., "renovated buiding"). The comfort index PMV [11] was calculated for each simulation (figure 5.).

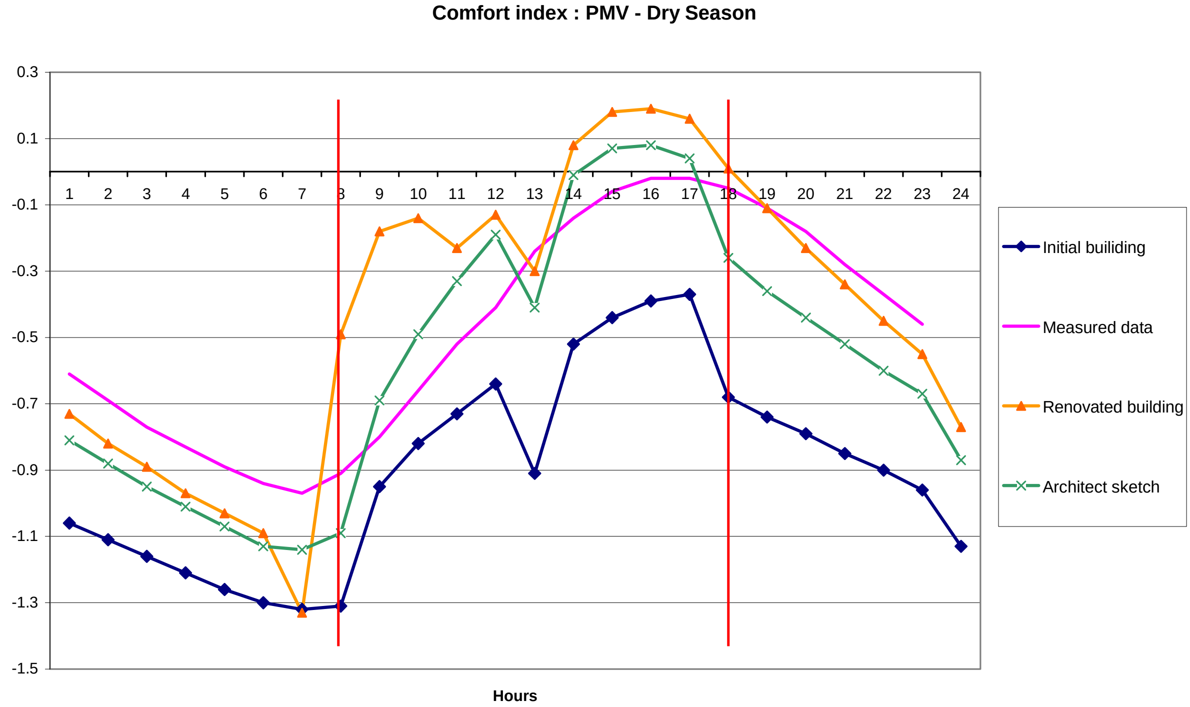

Figure 5. Comparison of measured and simulated mean day PMV during the dry season

To know which renewable energy system is pertinent to use [9], we evaluated the climatic resources (daily radiation, wind, rainwater) of each micro-climate. There is a good solar potential everywhere in Reunion Island. The daily mean radiation is up to 5kWh/m²/day for the coast and around 4.5kWh/m²/day for the rest (table 2.). Long term simulations show that photovoltaic panels, with normal sate subvention and electrical net connexion, takes less than 10 years to obtain return on investments. Likewise solar thermal water is really efficient. Wind turbines start to have good efficiency for a wind speed of up to 4m/s. So, to evaluate the wind potential, it is useful to know the wind speed statistical distribution (table 2.). The wind potential is probably the least known for the island, and the cyclonic risk can reduce the useful life expectancy of the wind turbines. In the Solar School Program, we only forecast low power wind turbines with fold down possibilities. It reduces the risk of noise disturbance and cyclonic destruction for schools and neighbours.

In the Platanes' school case, only 10 percent of the time, winds blow faster than 4m/s (table 2.), so it is not pertinent to forecast the installation of a wind turbine. But like everywhere in Réunion Island, solar potential can be fully used. So all hot water needs will be supplied by solar thermal water system. Near 60m² of photovoltaic cells will be installed on roofs.

	Platanes (670m)
Mean air temperature	21.5 °C
Mean hygrometry	%
Daily mean radiation	4576 Wh/m²/day
Wind speed < 2 m/s	77.5 %
Wind speed > 4 m/s	10 %
Annual pluviometry	1800 mm

Table 2. Climatic data for energy potentials evaluation

The final step of the numeric simulation campaign is the knowledge transfer to architects and civil engineers. They can take into account all the comfort and energy factors to design the better rehabilitation without forgetting social, financial and architectural constraints (figure 6.).

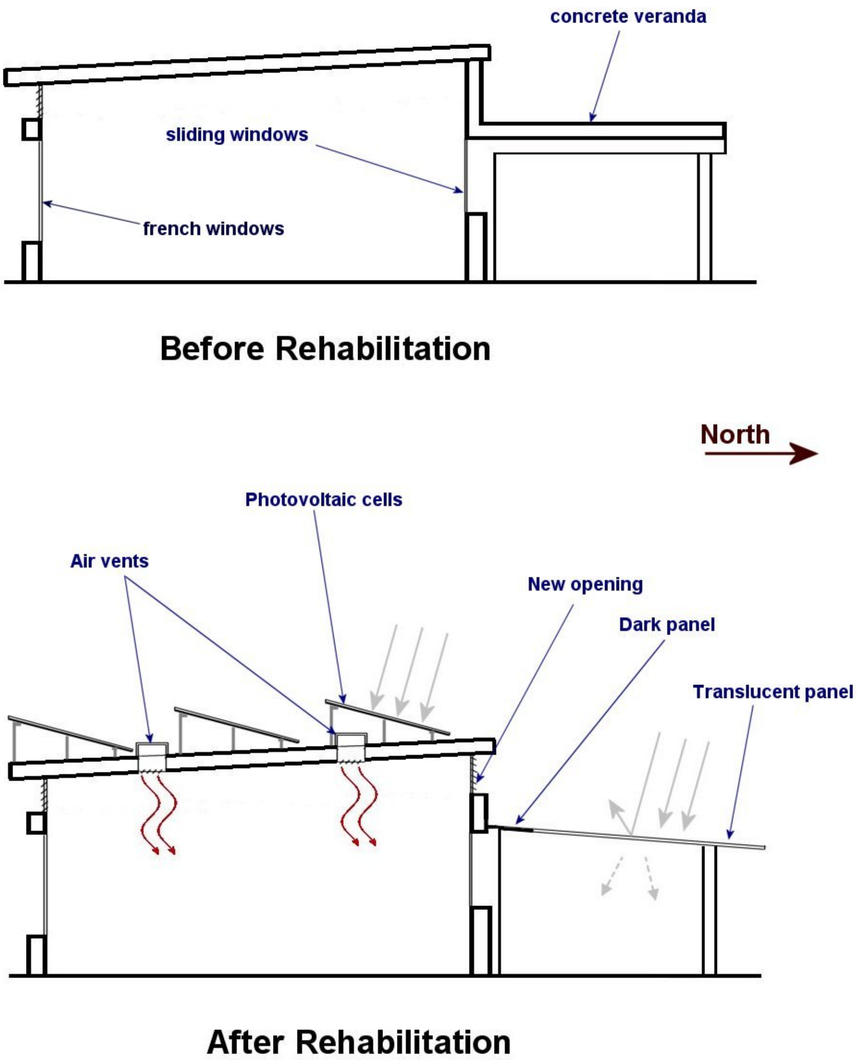

Figure 6. Platanes' primary school, before and after renovation works

RENOVATION AND SCIENTIFIC MONITORING

Rehabilitation forecast schedule: end of the year 2004 beginning of the work for a duration of 10 month.

The building rehabilitation will include a scientific internal instrumentation. One classroom per school will get a complete comfort acquisition chain. In humid tropical climates, human comfort in buildings depends on temperature, humidity, and inside wind velocity [10]. The latter is important for warm and wet weather; the first meter per second of wind speed reduces by 4 degrees thermal skin sensation[12]. This acquisition chain is made up of 4 comfort sensor modules with homogeneous space repartition, air quality and air renewal sensors (Fig 7.). Thermo-hygrometer, indoor air flow probe and long wave radiation sensor make up the 4 comfort sensor modules. The measurement campaign comes with questionnaires about users feeling. Finally the energy consumption and production will be measured and stored with electricity meters (one for each energy source).

All these data acquisitions will be gathered on the same computer inside the school. They will serve an educational purpose and could be transfered to our laboratory by internet to create a database about comfort and energy in primary schools, generally in the tertiary sector.

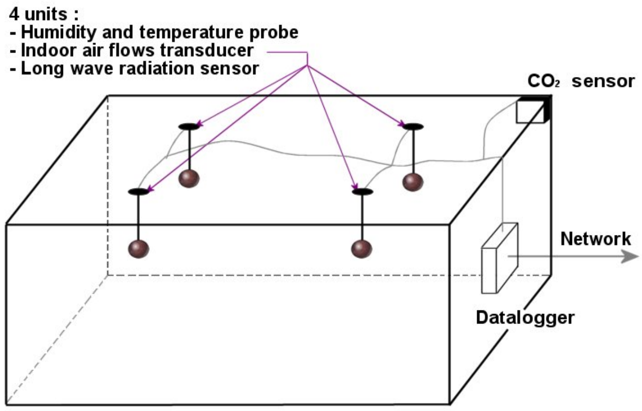

Figure 7. Internal comfort monitoring

This database will permit multiple validations:

- validation of the comfort index for insular tropical damp climates, taking into account the micro-climates differences,
- validation of architectural prescriptions for energy saving,
- validation of models of renewable energy systems under humid tropical climates.

CONCLUSION

Our approach is to study and create comfortable and low energy consumption schools using experimental steps of simulation, measurement and validation. It enables us to develop (NewRuneole) and validate (CODYRUN) tools inside a global methodology. The action criteria of this reasearch software could be extended to other sectors of building design.

This analysis showed a multi approach to buildings. It tries to estimate the impact on building comfort and energy behaviour for all possible technical solutions that can be applied to architectural design bases. Because of its high cost in simulation time, this methodology is not applicable to all renovation or construction projects. Like the "ECODOM label" elaboration [4], a knowledge database was created with the large number of simulations we carried out. The same analysis of different typical buildings for each micro-climatic zone will complete it.

In Reunion Island, this knowledge database will be the basis to building good comfortable and low energy consumption buildings, taking into account the micro-climates. The methodology and tools we illustrated during this paper will be applied fully in the thermic reglementation of French overseas territory elaboration.

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