Universitat de Lleida

Passive systems for energy savings of buildings in tropical climate

Institut Teknologi Bandung

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1. Introduction and objectives

- Passive systems and bioclimatic architecture principles applied to modern architecture are able to reduce the energy demand of the building sector, and to meet the Nearly Zero-Energy Building goals.
- The aim of this research is to reduce the discomfort time of buildings located in tropical climate, by using passive systems taken from vernacular architecture and bioclimatic modern buildings.

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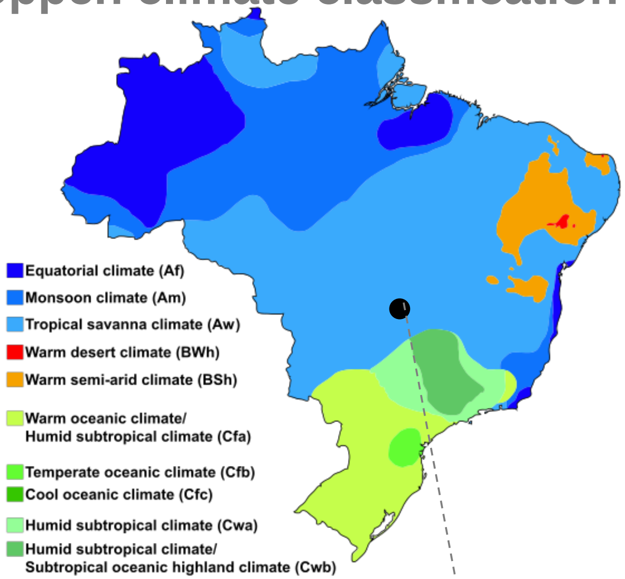
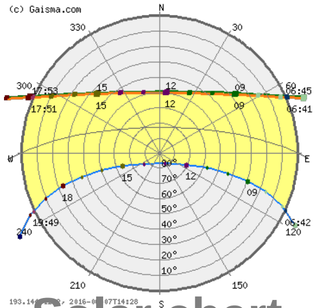
2. Goiânia (Brazil): tropical savanna climate

Brazil
Köppen climate classification

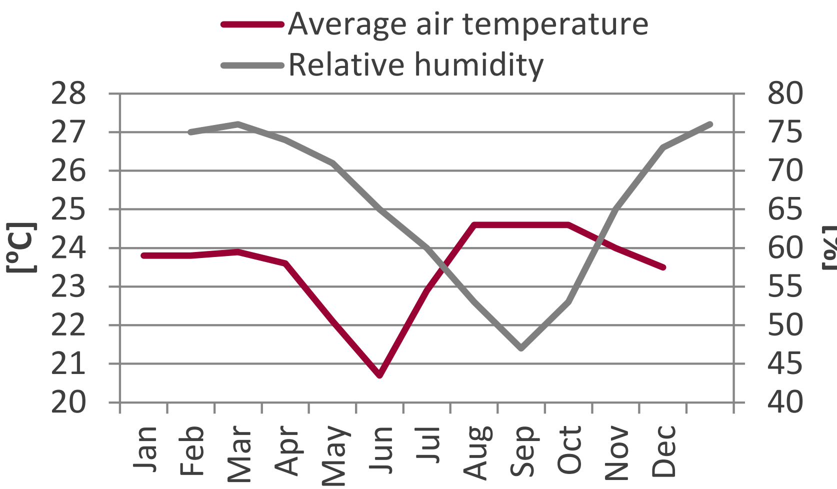




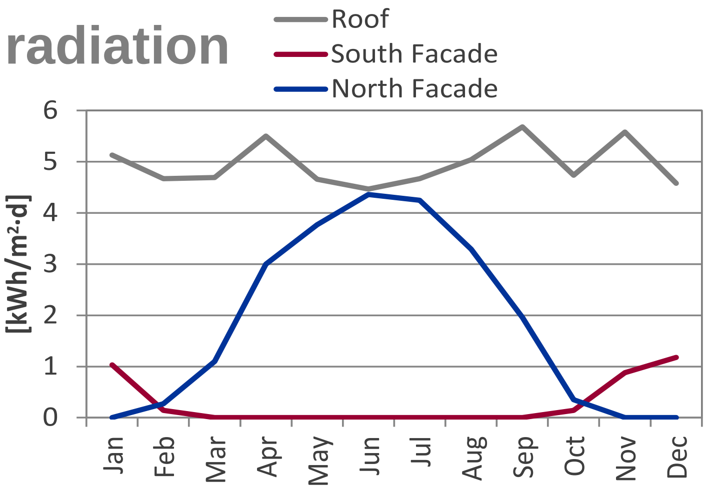
Solar chart

- Latitude -16.7º
- Longitude -49.3
- Elevation 741 m

Temperature and humidity



Daily solar radiation



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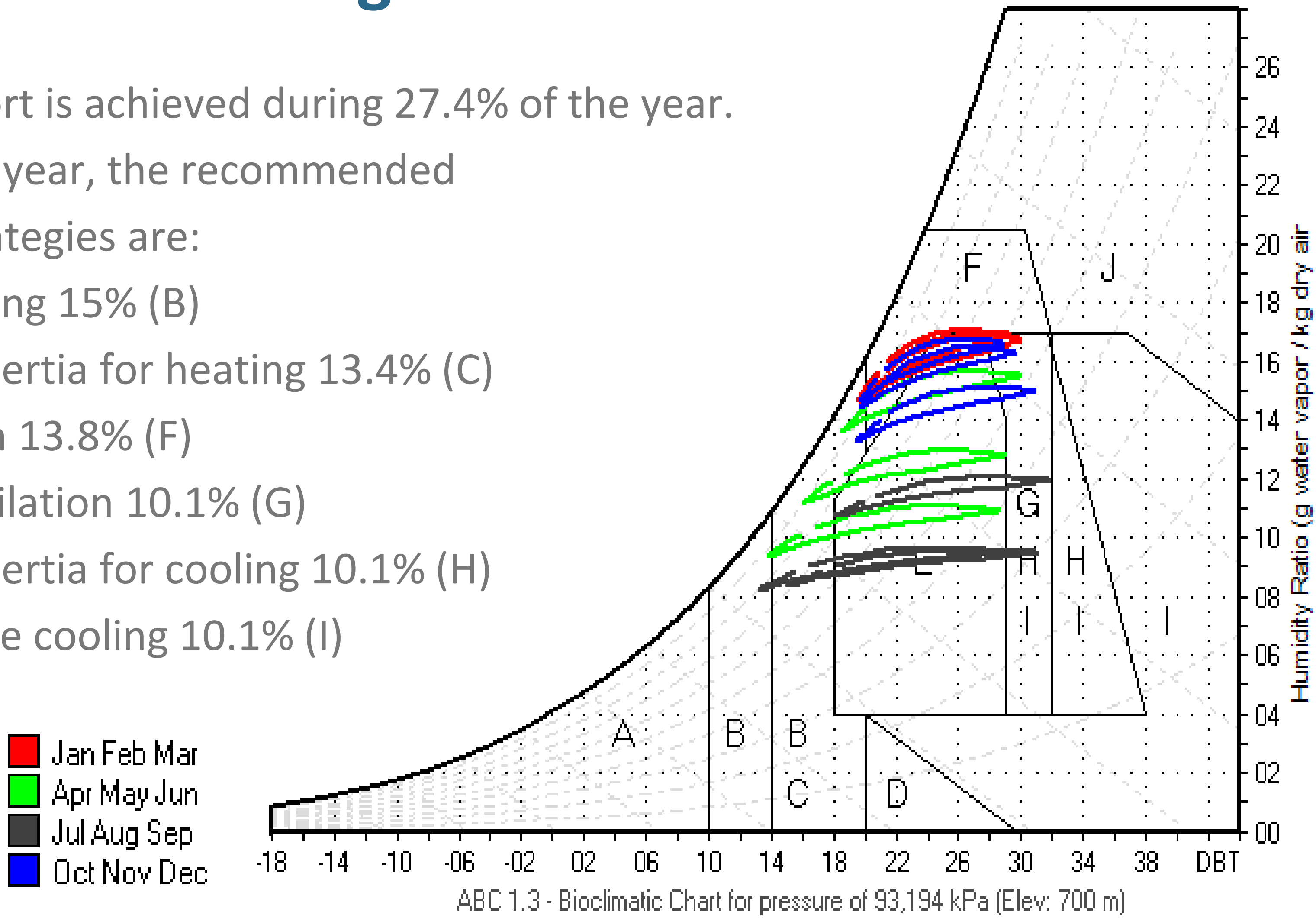
Bioclimatic strategies

Thermal comfort is achieved during 27.4% of the year.

The rest of the year, the recommended bioclimatic strategies are:

- Solar heating 15% (B)
- Thermal inertia for heating 13.4% (C)
- Ventilation 13.8% (F)
- Night ventilation 10.1% (G)
- Thermal inertia for cooling 10.1% (H)
- Evaporative cooling 10.1% (I)



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3. Building design of the “Model House”

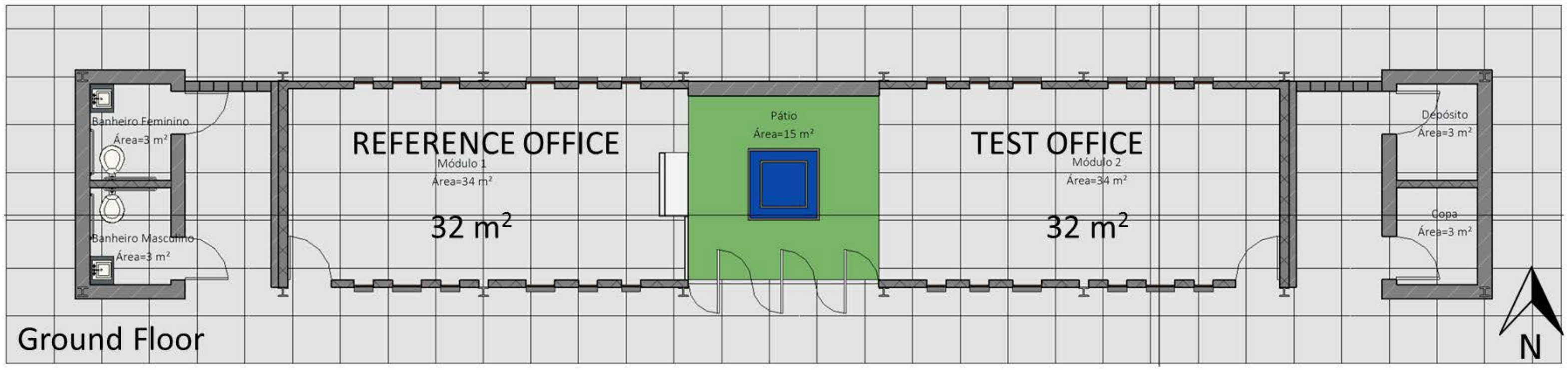
Office building designed meeting the tropical climate requirements and the NZEB concept to realize experimental researches about thermal comfort and energy efficiency in the Campus of Pontifícia Universidade Católica de Goiás, Brazil.


Exterior view.


North facade.


Interior view.


Courtyard.



Occupancy: 2 people per office, 8-12 AM and 1-7 PM. No cooling or heating device.

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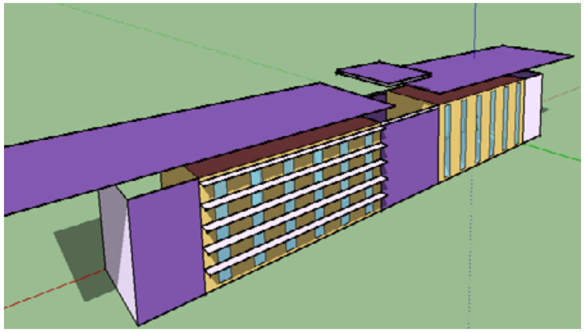
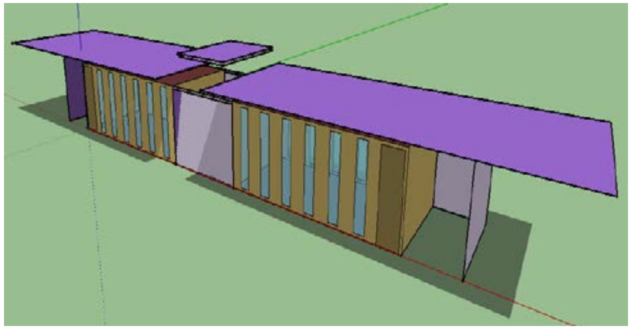
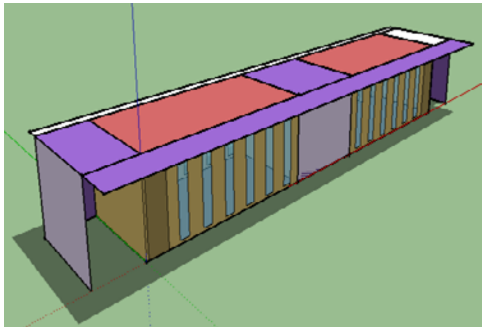
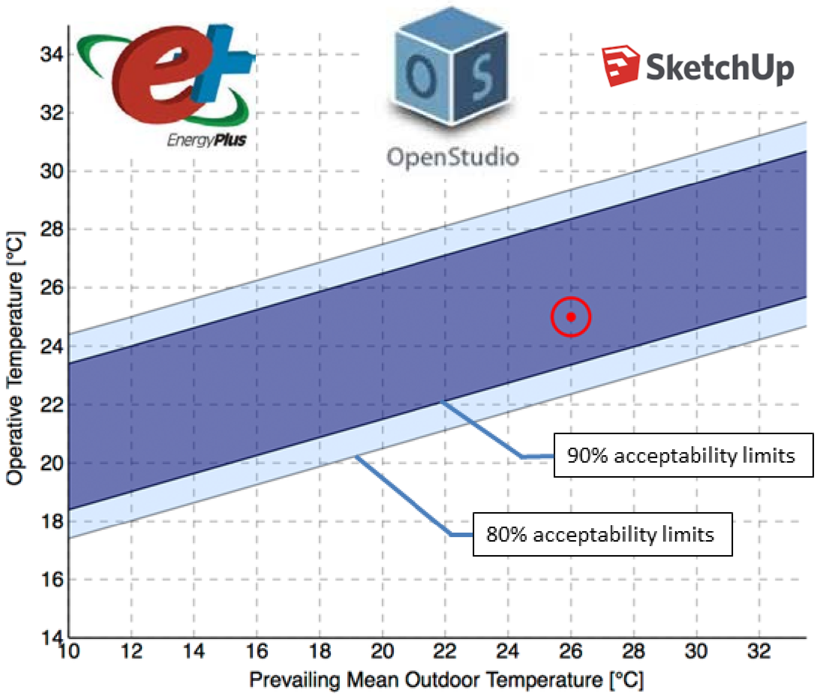
4. Energy simulation experiments

- Energy simulation *(EnergyPlus software)* has been done to compare the thermal behavior and thermal comfort conditions of the building-
- The thermal behavior of is evaluated by using the number of hours of discomfort, based on the ASHRAE Standard 55 Adaptive Comfort model, within the 80% acceptability limits, and the Fanger's Comfort model for the dehumidification case.



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4. Energy simulation experiments

Experimentation cases and timing.

Bioclimatic strategy to be tested	Reference Case A	Evaluated Case B	Period of time of the experiment
1. Solar protection in the north facade	No solar protection	Brise-soleils	14th – 28th June
2. Cooling through a high thermal mass	Ceramic brick	Concrete facade	14th – 28th June
3. Cooling by high thermal mass with nocturnal renovation	No nocturnal ventilation	Nocturnal ventilation	14th – 28th June
4. Cooling through natural ventilation **4.1. Dry season** **4.2. Wet season**	No Ventilation	All day ventilation	• Dry season: 1st-15th September. • Wet season: 14th – 28th December
5. Conventional dehumidification	No dehumidification	HVAC Dehumidifier	14th – 28th December
6. Thermal insulation in the roof **6.1. Solstice in June** **6.2. Solstice in December** **6.3. Equinox in September**	No insulation	Insulation	14th – 28th June 14th – 28th December 14th – 28th September

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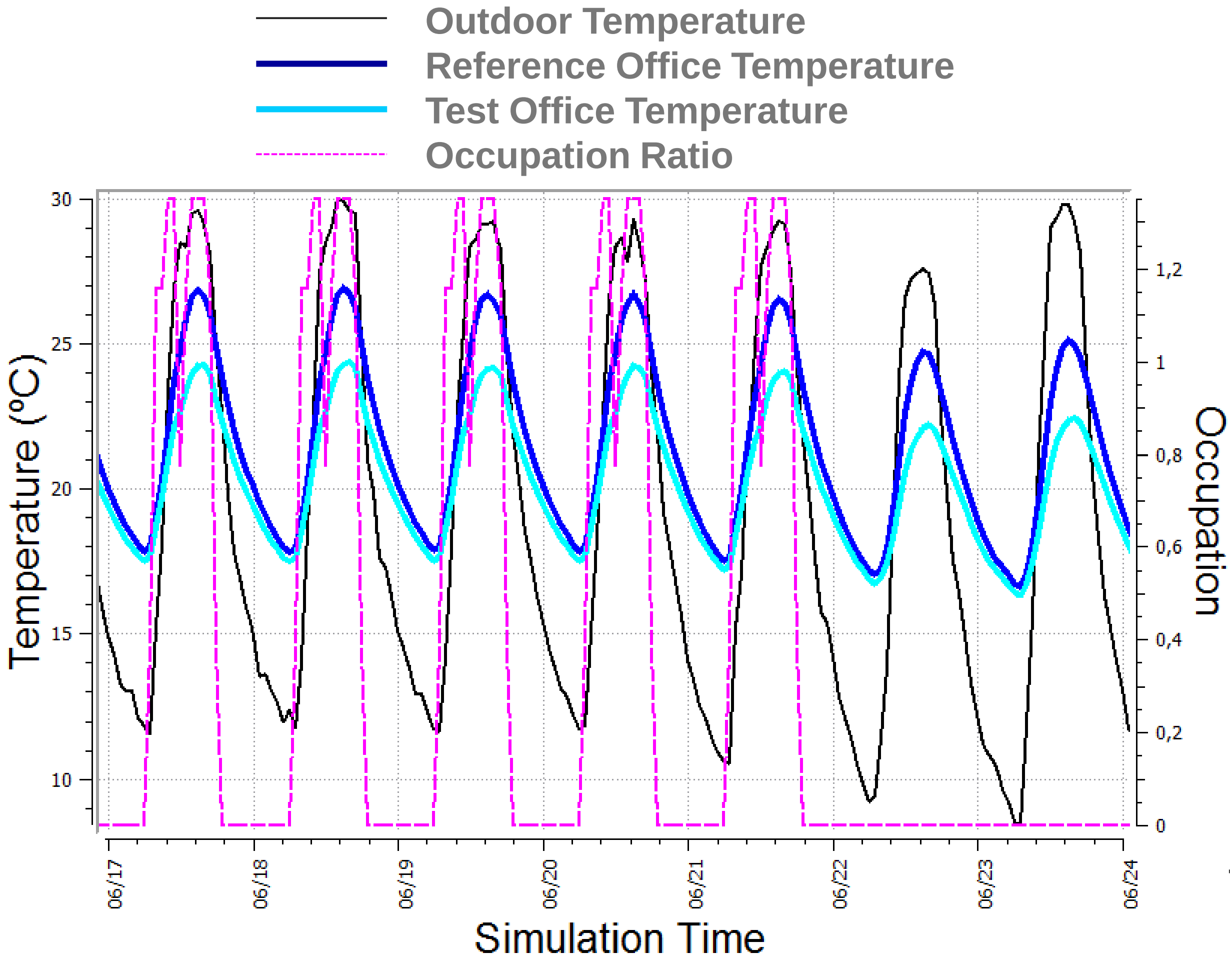
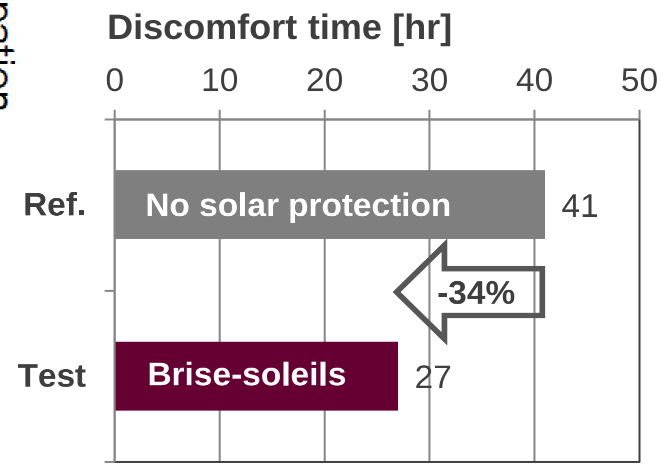
Solar protection north facade





June 14th-28th

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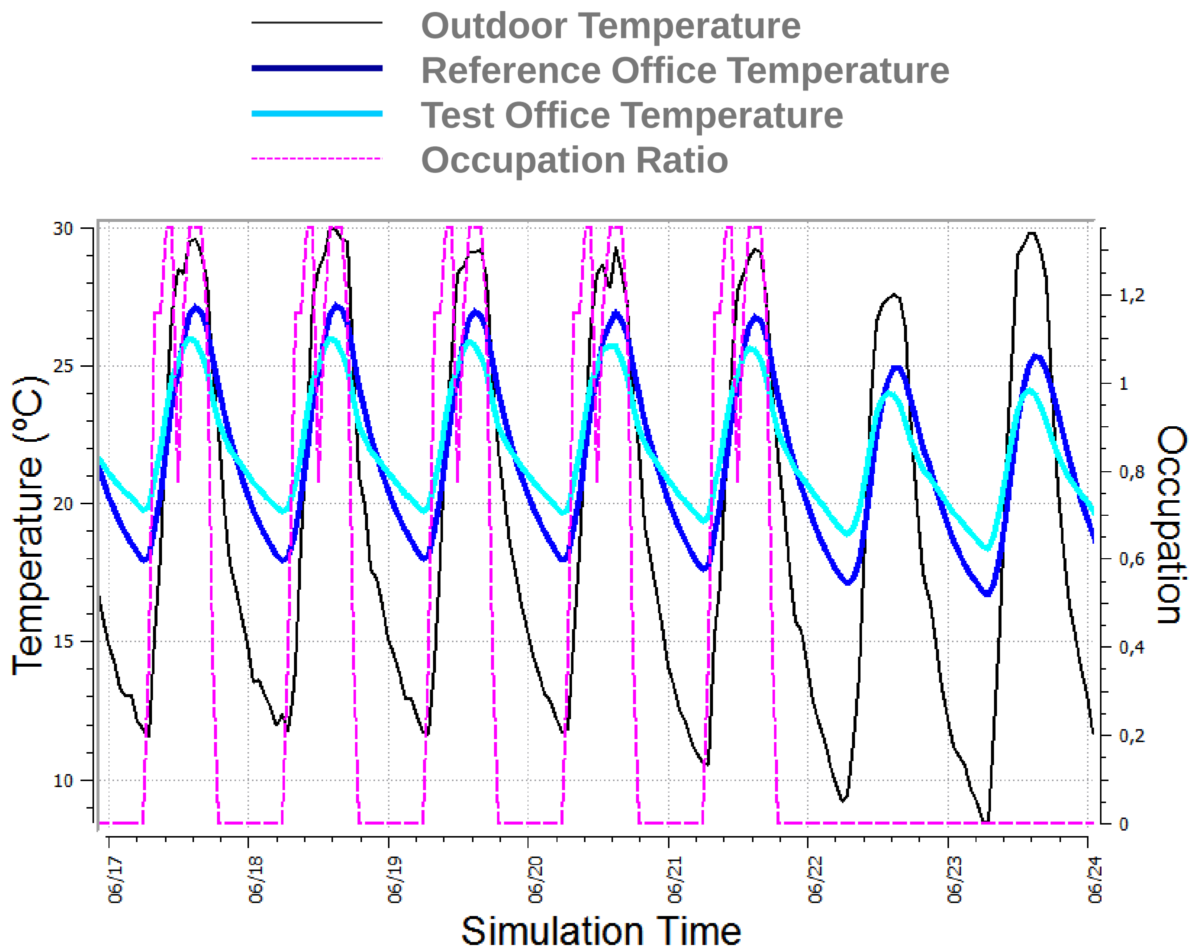
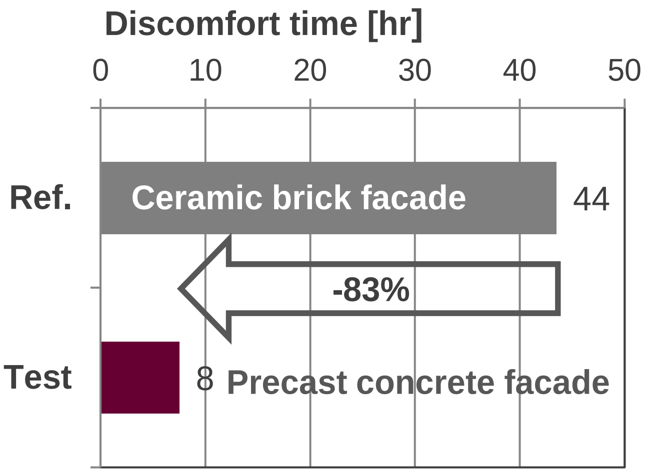
Cooling by high thermal mass





June 14th-28th

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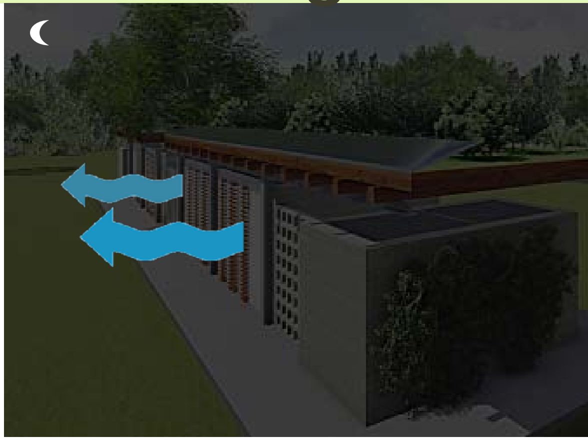
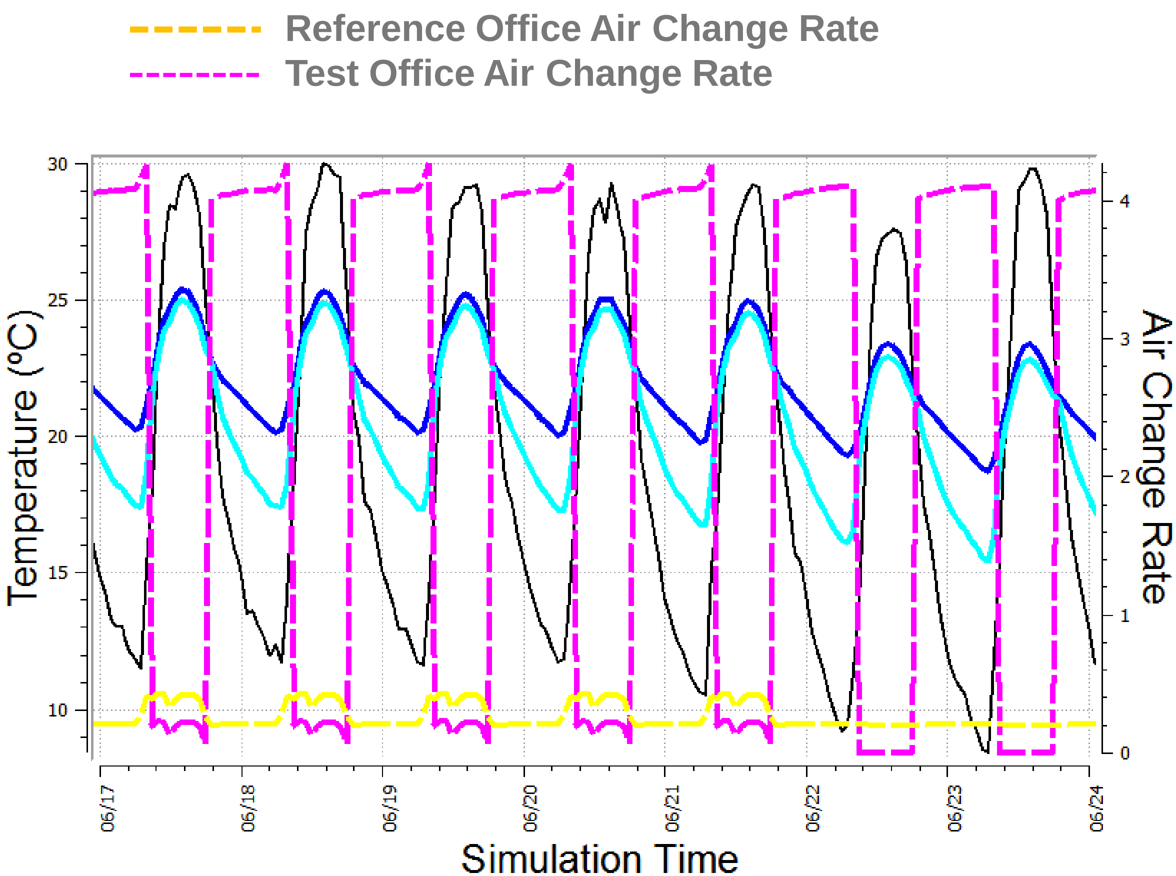
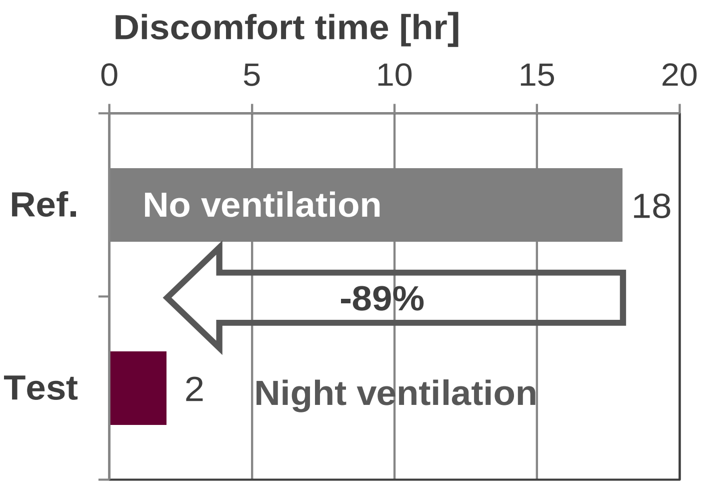
Cooling by high thermal mass with night ventilation







June 14th-28th

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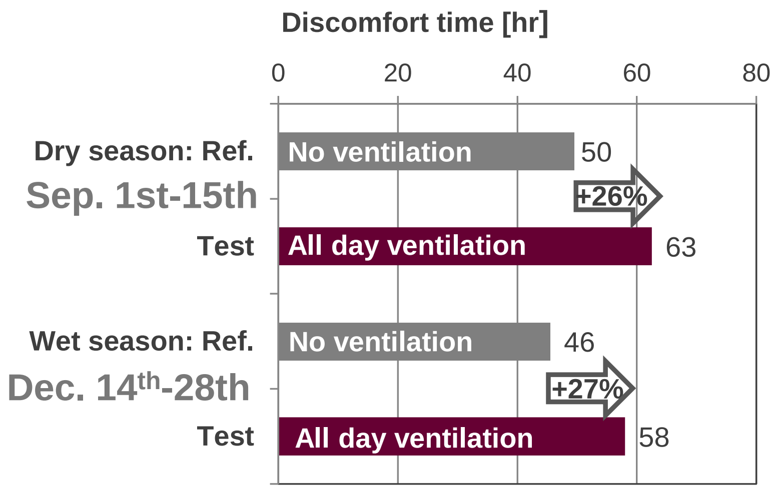
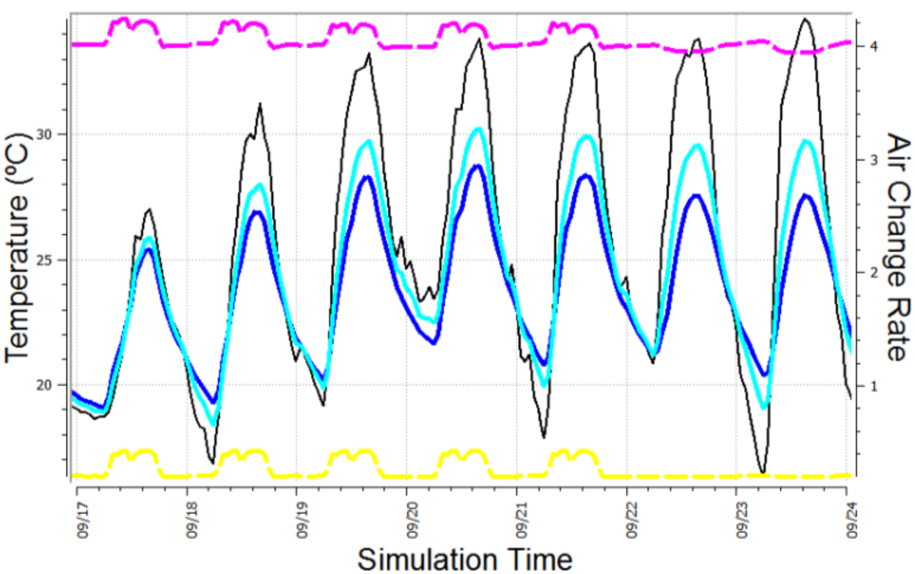
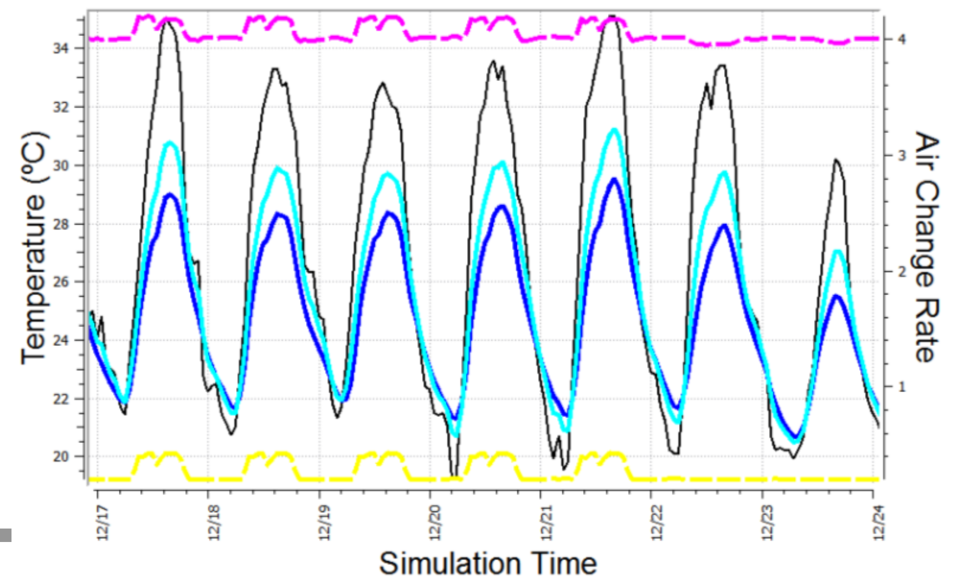
Cooling by all day natural ventilation



DRY SEASON



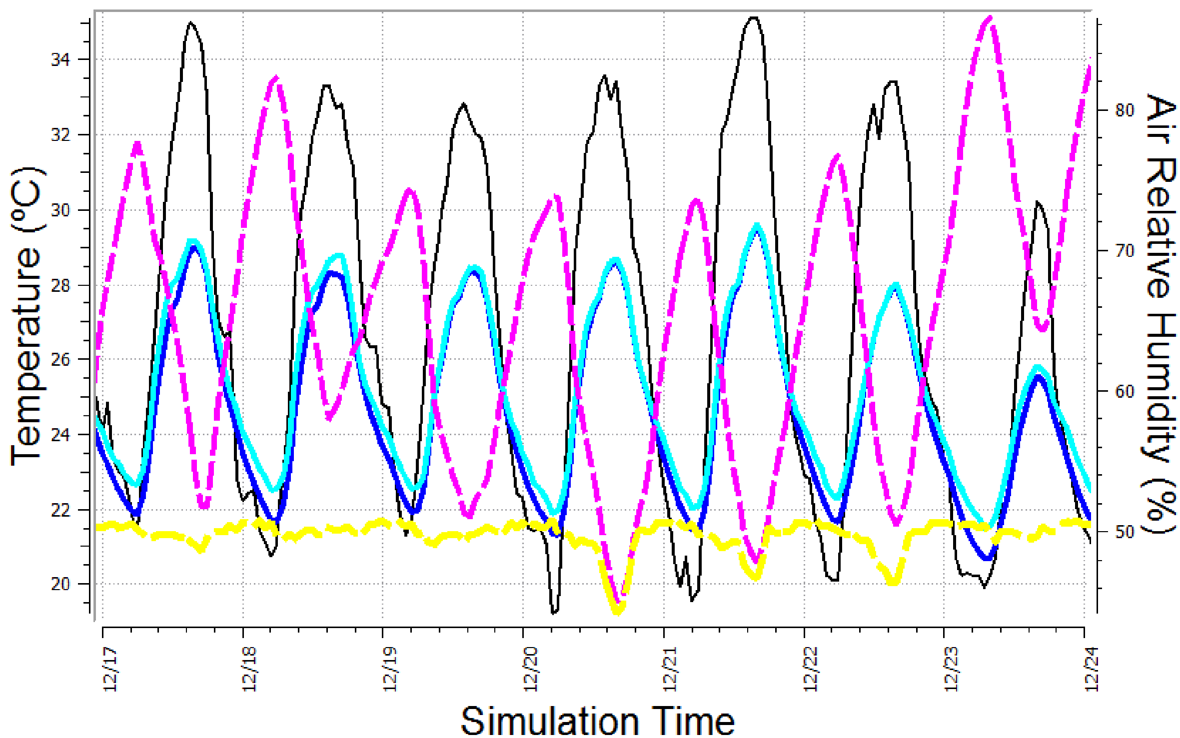
WET SEASON

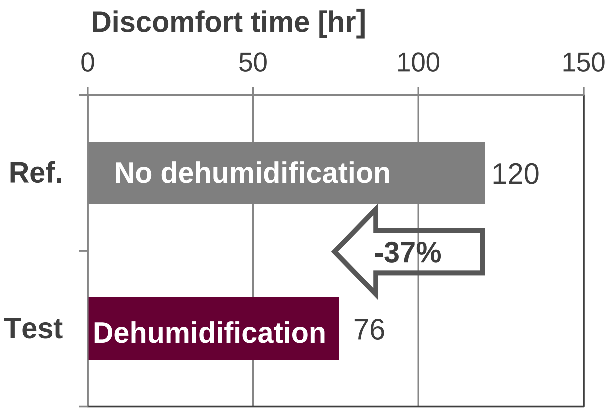


Energy simulation of an office building

Dehumidification

Reference Office Air Relative Humidity
Test Office Air Relative Humidity





Dec. 14th-28th

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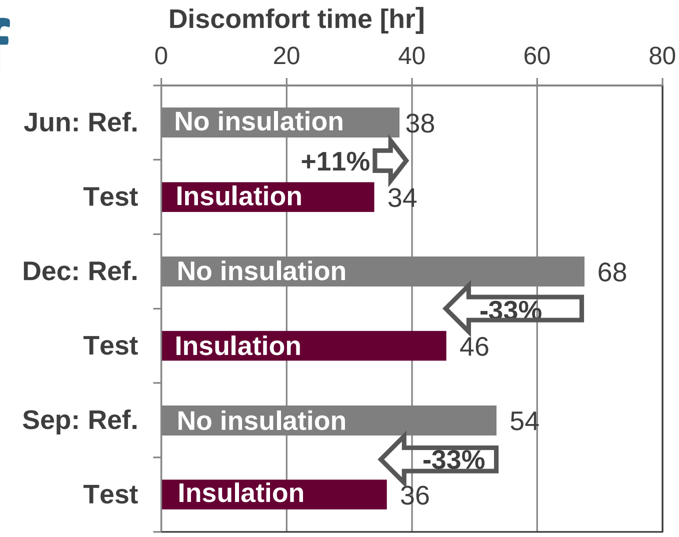
Thermal insulation in the roof



Non insulated roof U-value= 1.98 W/m^2 K

Insulated roof U-value= 0.25 W/m^{2}K

12 cm of XPS

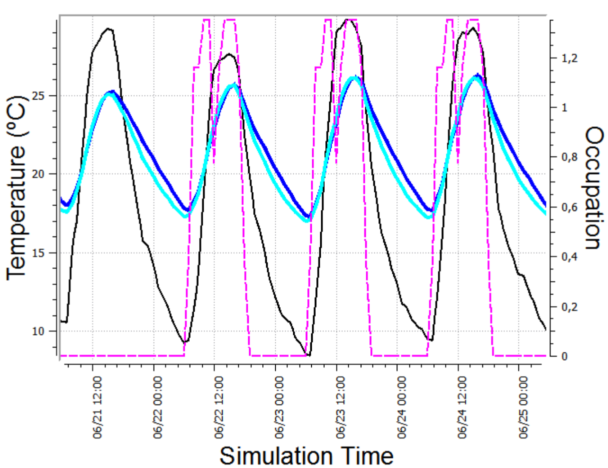
Outdoor Temperature

Reference Office Temperature

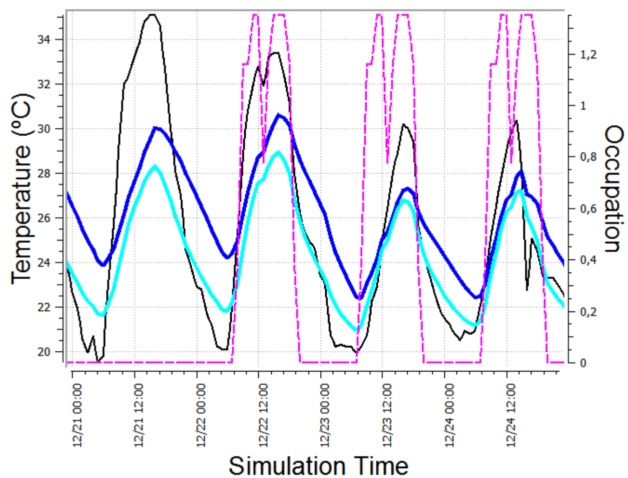
Test Office Temperature

Occupation Ratio

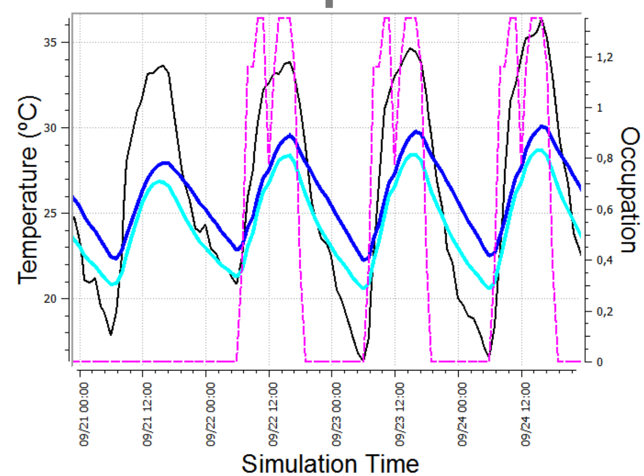
June



December



September



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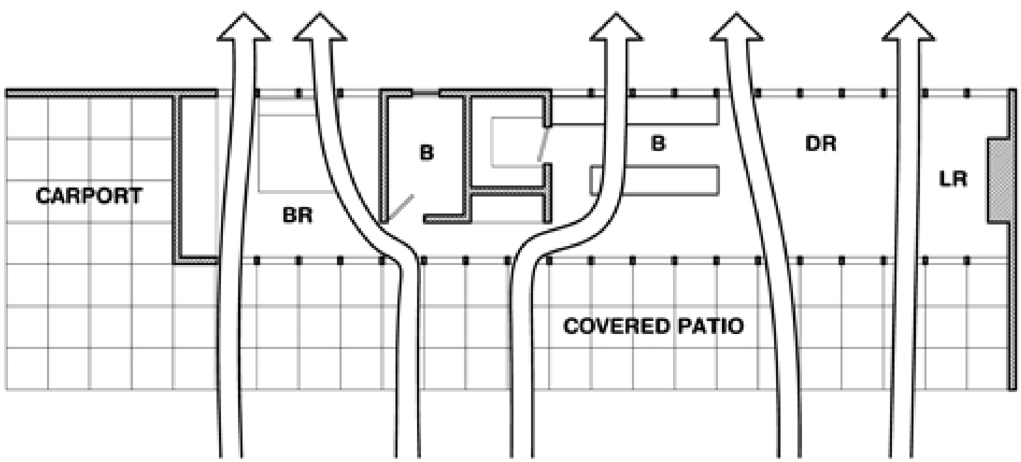
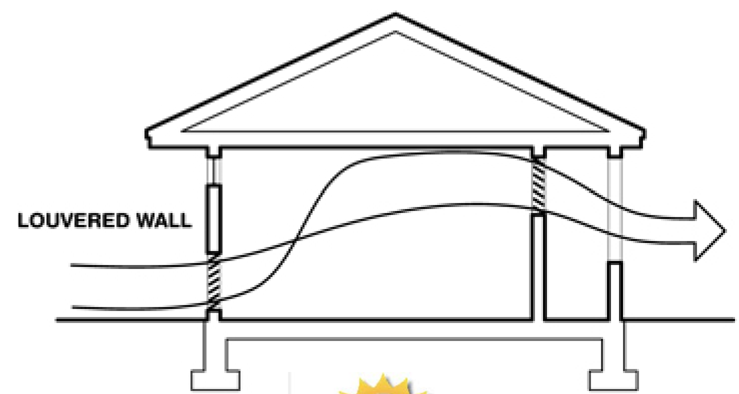
5. Results

The more significant improvement performances were found in the following strategies:

- 1st: Cooling by high thermal mass with night ventilation: 89% improvement.





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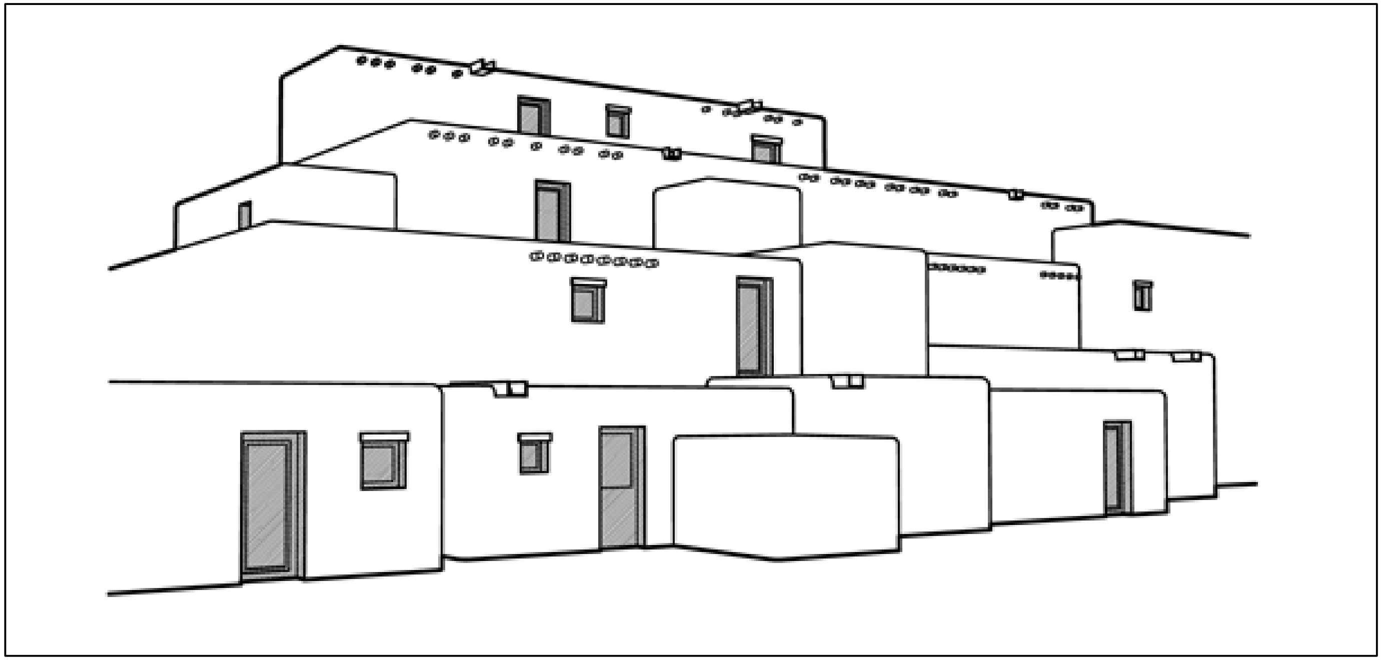
Energy simulation of an office building

5. Results

The more significant improvement performances were found in the following strategies:

- 2nd: Cooling through a high thermal mass: 83% improvement.



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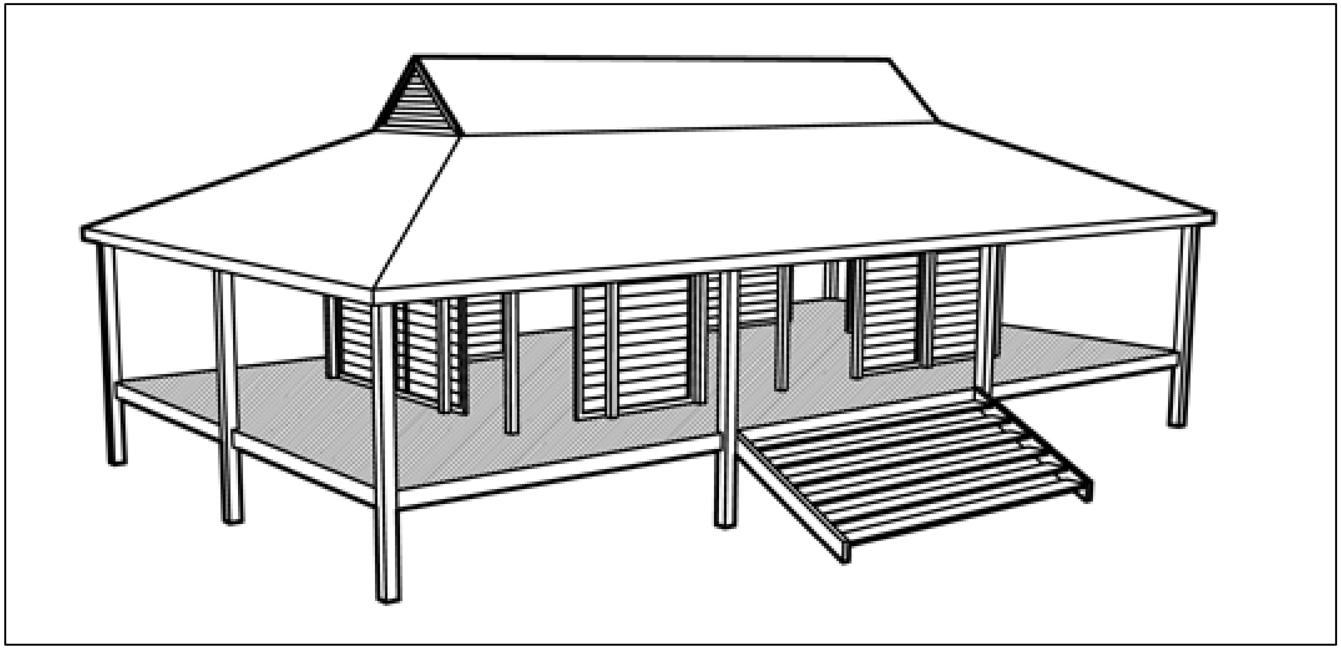
Energy simulation of an office building

5. Results

The more significant improvement performances were found in the following strategies:

- 3rd: Solar protection on the north facade: 34% improvement (and even better, 52%, if we take the 90% acceptability limits).



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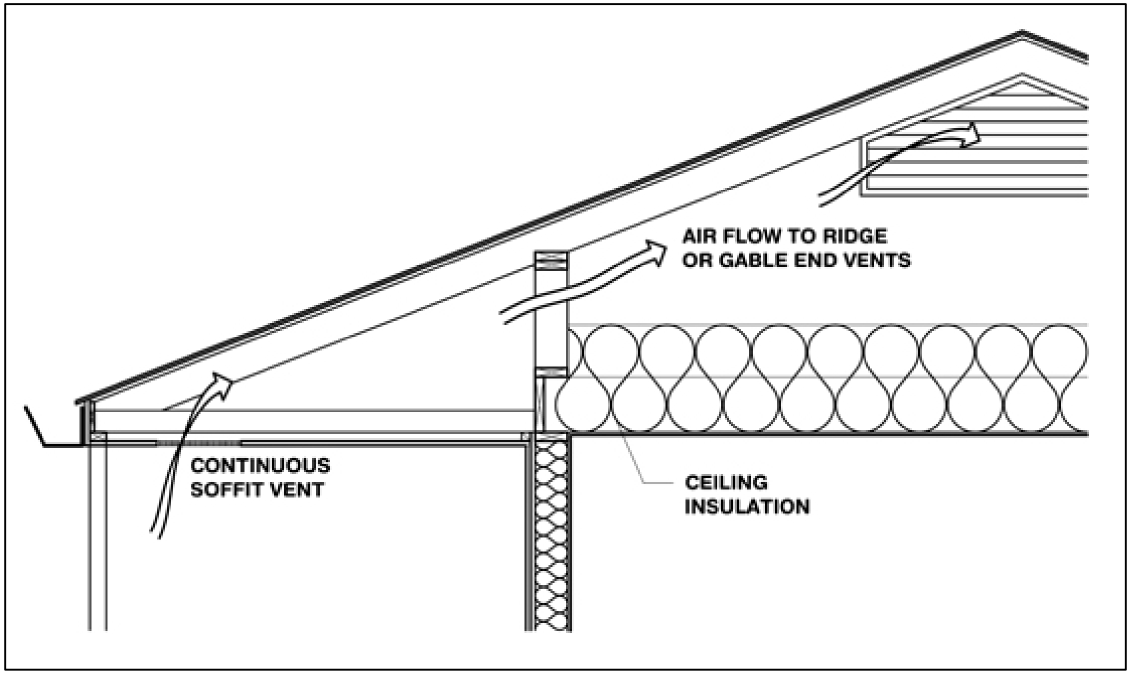
Energy simulation of an office building

5. Results

The more significant improvement performances were found in the following strategies:

- 4th: Thermal insulation in the roof during the Solstice of December and the Equinox of September: 33% improvement.



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6. Conclusions

- The use of passive systems contributes to reduce the discomfort time of buildings in tropical climate.
- A combination between high thermal inertia with nocturnal ventilation, the use of solar protections on the north facade, dehumidification, and the use of thermal insulation in the roof is fundamental for achieving the thermal comfort in buildings located in tropical savanna climate.
- The use of natural ventilation in the office has to be limited to the night, when it is effective due to the outdoor lower temperatures.
- The implementation of these passive systems depends on the early stages of the design building process of new and renovated buildings.
- Nearly Zero Energy Buildings would require the implementation of passive systems in the design phase and the spread of this knowledge among technicians.

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