Coupling methodology of windows and ceiling fan occupant behaviour models with building energy models
A tropical case study

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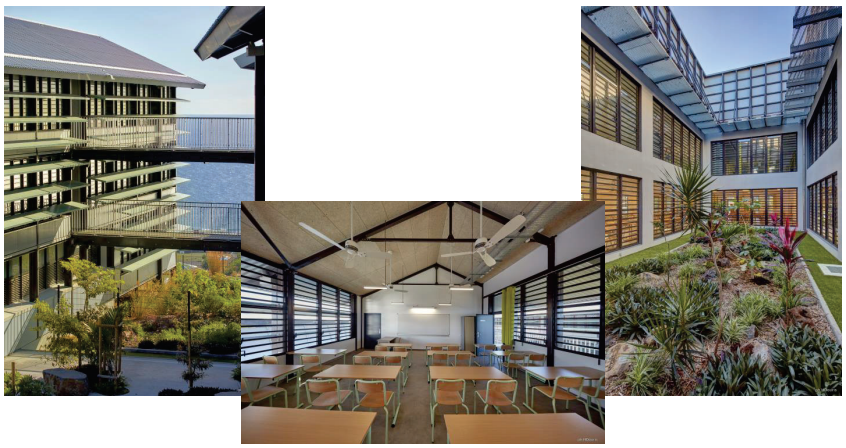
LEU REUNION, PART OF THE ILET DU CENTRE GROUP

BIOCLIMATIC BUILDING DESIGN IN HOT AND HUMID TROPICAL CLIMATES

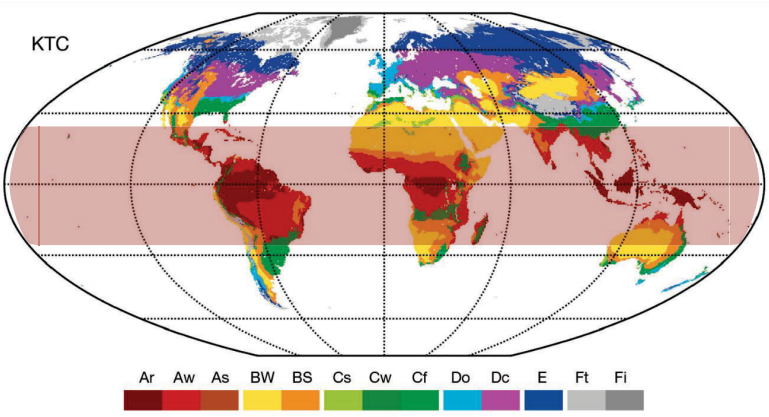


- **Solar protection**
- **Natural ventilation** to reduce the use of active and energy-consuming devices
- Solutions to couple **devices** when exclusive use of natural ventilation is not sufficient

Several ongoing research projects, including **a thesis on the comfort of mixed-mode buildings** and **a thesis defended in 2022 on occupant behaviours**

DEFINITION OF HUMID TROPICAL CLIMATE

FEATURES and ISSUES



According to Koppen-Trewartha
- Average monthly temperature > 18°C
- Rainfall threshold > 60mm over several months

The surface area of Aw subclass territories has increased since 1965-1994
(Belda et al. 2014)

50% of the population in the intertropical zone forecasted by 2050
(University f James Cook , Australia, 2014)

75% of the population in urban areas
(Rodrigues et al., 2019)

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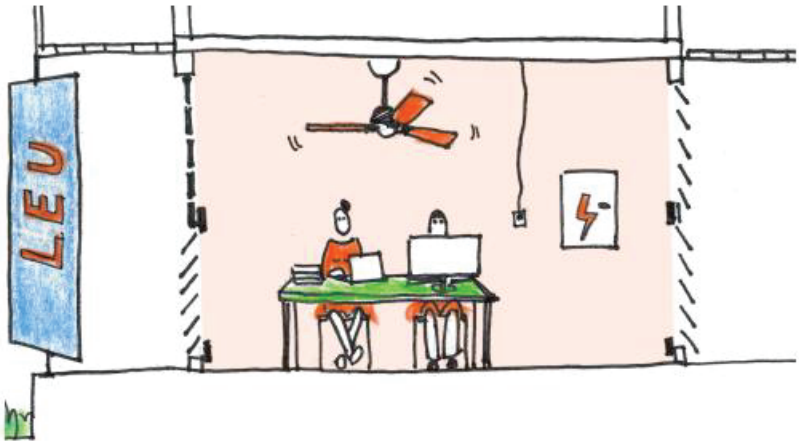
MIXED MODE BUILDINGS

DEFINITIONS

Passive cooling systems -> Openings
Low-energy cooling systems -> Ceiling Fans
High-energy mechanical systems -> HVAC

Zoned Mixte Mode Building
(Brager, 2006)

Different controls
(Raja, 2014)



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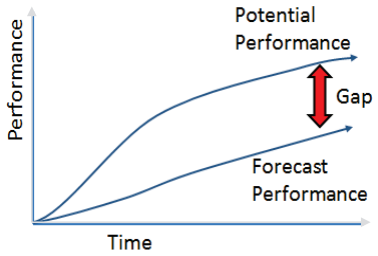
USER BEHAVIOUR IN MIXED MODE BUILDINGS

RESEARCH QUESTIONS



How to assess user behaviour in mixed-mode buildings operating with ventilation ?

How to estimate the presence of users on openings and ceiling fans during the design phase ?

1- Model behaviours based on measured data

2- Integrate these behavioural models into a building model

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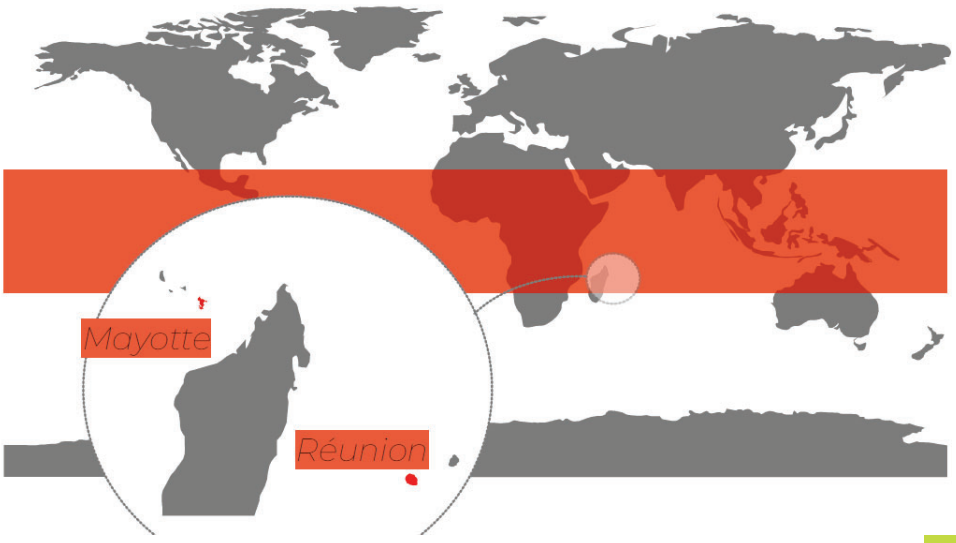
CASE STUDY IN REUNION ISLAND

ILET DU CENTRE OFFICE BUILDING



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CASE STUDY IN REUNION ISLAND

ILET DU CENTRE OFFICE BUILDING







310 m²

Two open plan floors (NV)

Singles offices (NV or AC)

Meeting rooms (AC)

IT room (AC)

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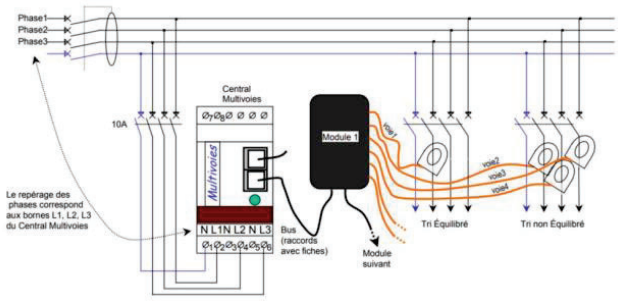
CASE STUDY IN REUNION ISLAND

FIELD MEASUREMENTS

- 37 position sensors NODON (ENOCEAN)
- Irregular timestamp
- 2 states [0 ou 1]



- Energy meters OMEGAWATT
- 1 min timestamp
- Ceiling fan power [W] and offices plug [W]

CASE STUDY IN REUNION ISLAND

FIELD MEASUREMENTS

- 9 TESTO 174H temp/rh sensors
- Regular timestamp
- Air Temperature (+/- 0.5°C) et relative humidity (+/- 3 %HR)

- Meteorological station

(Less than 1km far from site)

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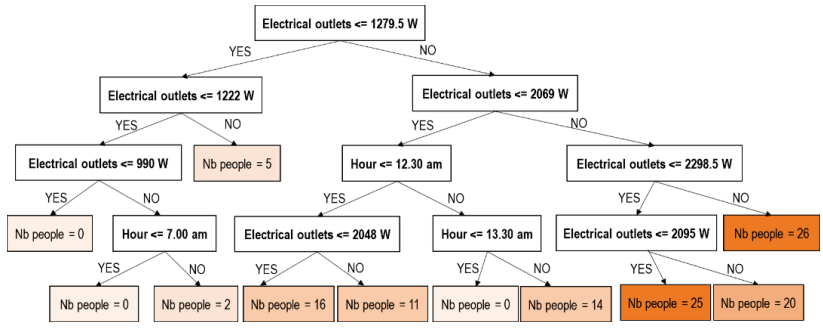
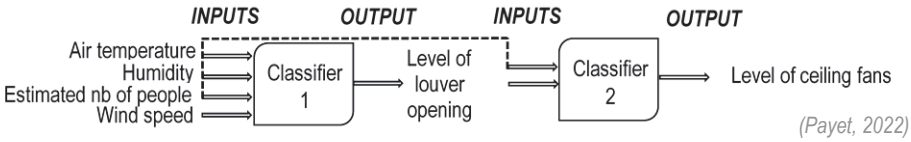
OCCUPATION AND BEHAVIOURS MODELS

CLASSIFICATION METHODS

Occupation model
(Decision Tree)



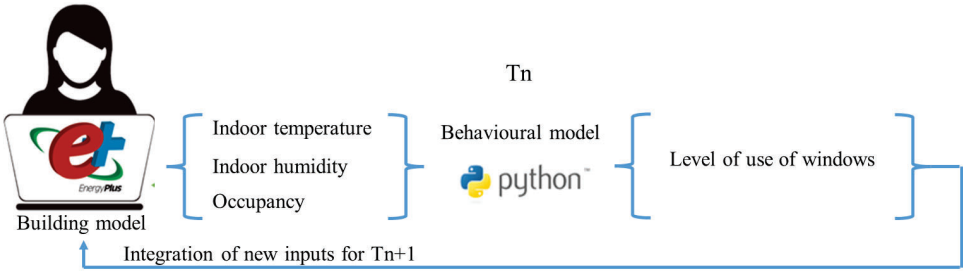
Ceiling fans and openings models
(Random forest)



(Payet, 2022)

IMPLEMENTING BEHAVIOURAL MODELS IN ENERGYPLUS

PYTHON PLUGIN METHOD



Method	Ease of implementation	Flexibility
Direct modelling	++++	+
Code customization	++	++
Customization of Core code	+	+++
Co-simulation	++	++++
Python plugin	+++	++++

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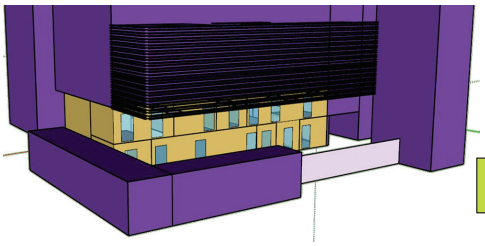
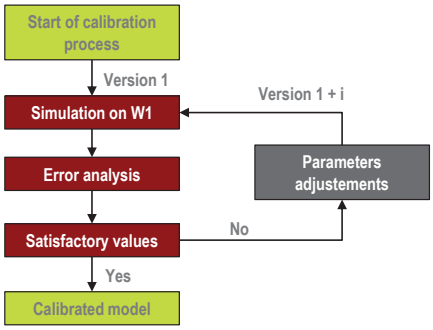
BUILDING ENERGY MODEL

VALIDATION (based on indoor conditions)





Week simulated	Step	From	To	Season	Internal heat gains from users
W1	Calibration	20/12/2020	27/12/2020	Summer	No
W2	Validation	01/12/2020	08/12/2020	Summer	Yes
W3	Validation	06/07/2020	13/07/2020	Winter	Yes
W4	Validation	05/10/2020	12/10/2020	Mid-season	Yes

Validation results	Standards
NMBEh ≤ 5.3 %	NMBEh ≤ 10 %
CV(RMSE)h ≤ 6.6 %	CV(RMSE)h ≤ 30 %
MADh ≤ 2.8 ◦C	(Baba, 2022)
MBEh ≤ 1.2 ◦C	(Baba, 2022)

- ASHARE Guideline 14 (Measurement and Energy Demand)
- Int. Measurement & Verification protocol recommanded by French Energy Agency ADEME
- Mean Bias Error & Mean Absolute Deviation

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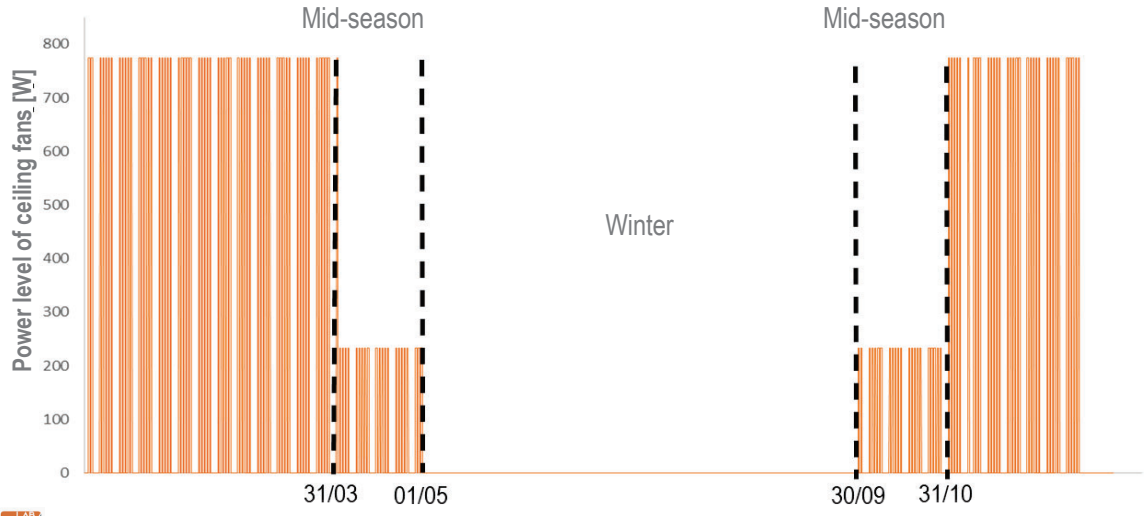
CONVENTIONAL DESIGN OFFICE MODEL FOR CEILING FAN USE

BASELINE METHOD



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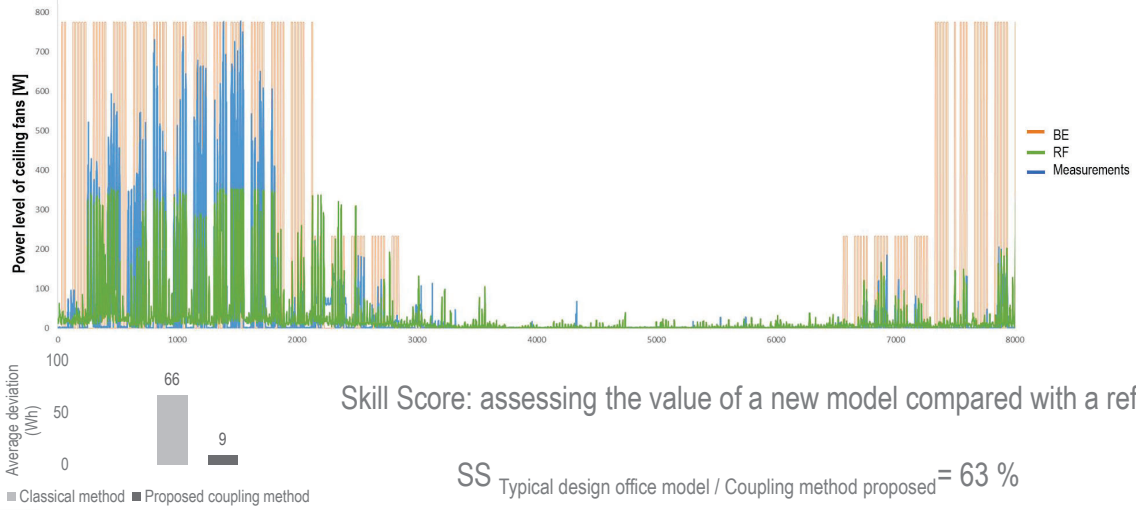
COMPARISON WITH OUR RESULTS

PROPOSED COUPLING METHOD NOTED in GREEN / baseline orange



Skill Score: assessing the value of a new model compared with a reference model

$SS_{\text{Typical design office model / Coupling method proposed}} = 63\ \%$

TO CONCLUDE

LIMITS OF THE PRESENT WORK

- Lack of generalisation capabilities
- Only NV + CF has been modeled so far (no AC+CF)
- Better estimate Ceiling Fans use but still need to improve related energy use for each predicted class

PERSPECTIVES

- Extend field measurement studies to other building types and user categories to better teach models
- Add a level of complexity for mixed-mode cooled building with AC
- Investigate new way to estimate class energy use (seasonal class / monthly class, add model input parameter(s))

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Thank you for your attention

Further readings:

Payet, Maareva, M. Boulinguez, M. David, P. Lauret, and F. Garde, 'Windows and ceiling fan occupant behaviour model coupling methodology with building energy models, a tropical case study', in Ventilation, IEQ and health in sustainable buildings, Copenhaguen Danemark, 2023

M. Boulinguez, O. Marc, and J. Castaing-Lasvignottes, 'Development of a simplified model for evaluating refrigeration capacity and power consumption of air conditioning units based on heat exchanger entropic temperature definition', presented at the International Congress of Refrigeration 2023, Paris, 2023. doi: 10.18462/iir.icr.2023.0781

Payet, M., 2022. *Simulation du comportement des usagers dans les bâtiments tertiaires à faible consommation énergétique, en zone tropicale (phdthesis).* University of la Reunion.

Payet, M., David, M., Lauret, P., Amayri, M., Ploix, S., Garde, F., 2022. *Modelling of occupant behaviour in non-residential mixed-mode buildings: The distinctive features of tropical climates.* Energy and Buildings 259, 111895. https://doi.org/10.1016/j.enbuild.2022.111895

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