FLOATING HOUSE, THE PHILIPPINES

Recommendation for Improvements of the Building Design
by Evaluating the Indoor Environmental Quality of the Pilot Project
in Macabebe, the Philippines

Reji Benoy

Content

Why This Project?

Personal Experience: Chennai Flood, 2015

Personal Experience: Chennai Flood, 2015

Kerala Flood, 2018 (source: teambhp.com)

Personal Experience

Why This Project?

A scenario [Source: Pieter Ham]

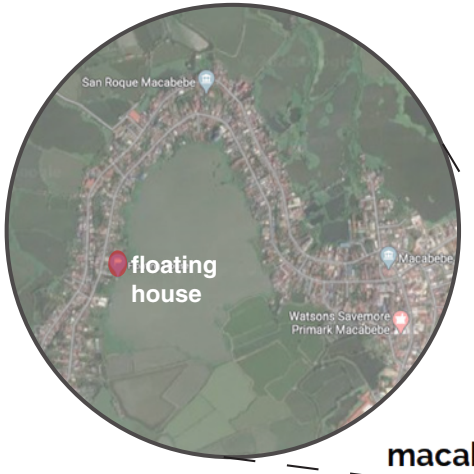
The Project: **compassion + technology**

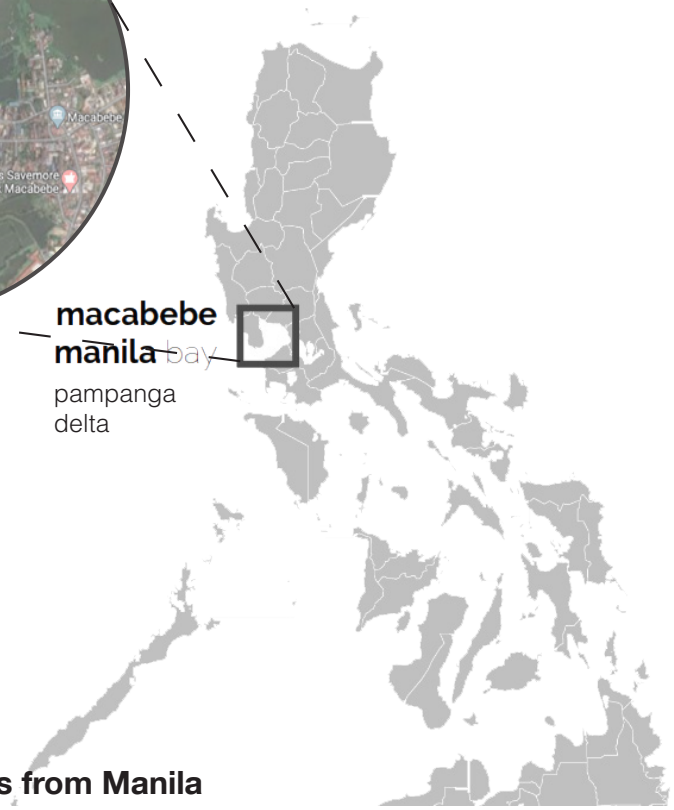
to improve the well-being of people.

An Opportunity to Learn!

Introduction

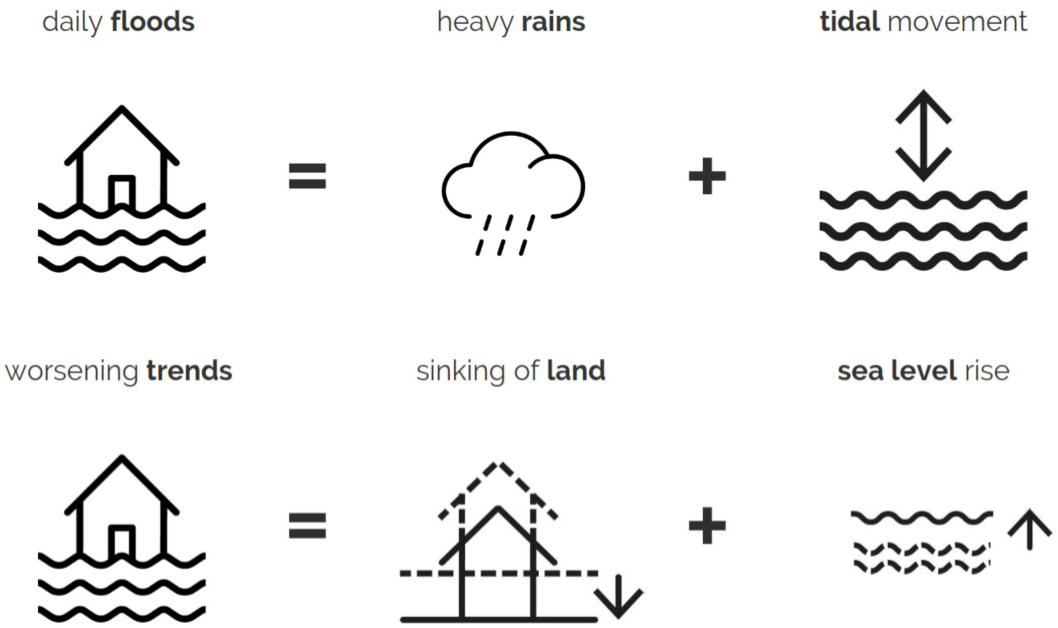
Location





- about **70 kms from Manila**

Location [Source: Pieter Ham]



Scenario [Source: Pieter Ham]

- In addition: **housing backlog**

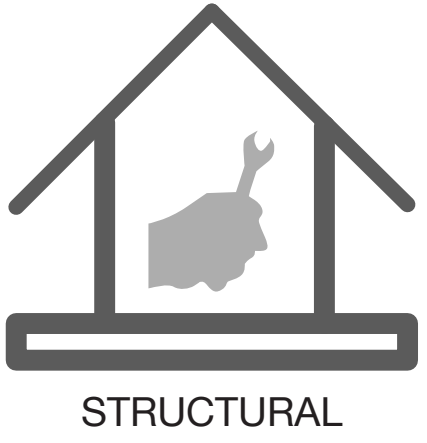
Introduction

Pilot Floating House

Pilot Floating House [Source: Pieter Ham]

Problem Statement

Now it is important to see **how the house performs in real life**



to **recommend improvements,** for the well being of the occupants

Objectives

Main Objective

To **recommend improvement strategies** for the design of the low-income houses, in the Philippines, by **evaluating the indoor environmental quality** of the pilot floating house project.

Sub Objective:

To develop **a cost-effective measuring and remotely accessible monitoring device** for the indoor comfort parameters in the pilot floating house.

Research Questions

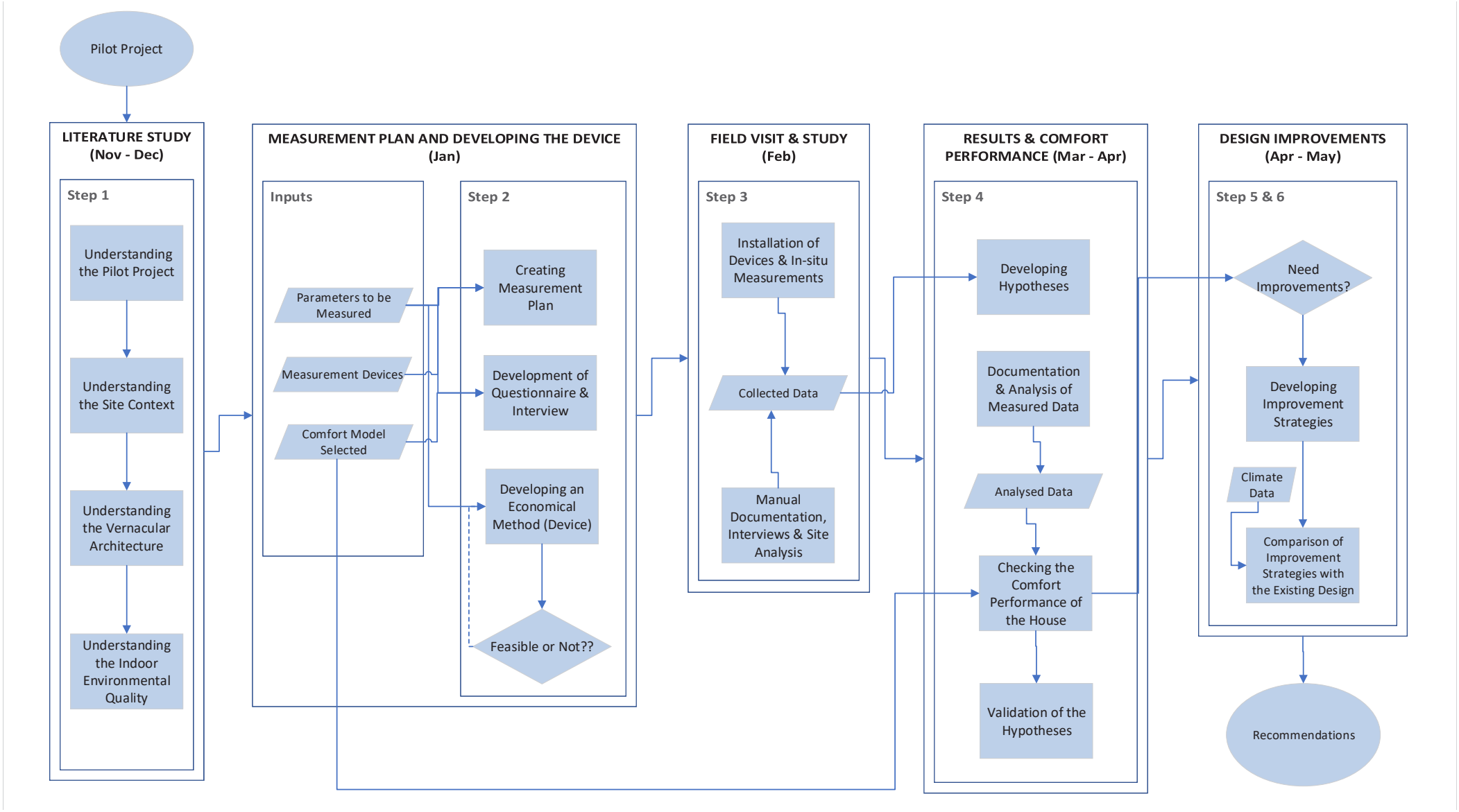
Main Research Question

What **vernacular design strategies** can be advised for the design of the low-income houses, in the Philippines, by **evaluating the indoor environmental quality** of the pilot floating house project?

Research Questions

1. How is the pilot floating house in the Philippines **designed and constructed in terms of passive design**?
2. What are the **comfort parameters that need to be measured**, which influence the indoor environment quality of the housing type?
3. How to **develop a measurement plan and monitoring system** for indoor environmental quality of the pilot project?
4. How does the **pilot floating house perform** in terms of the measured results?
5. What are the **improvement strategies** needed to provide better indoor environment for the housing type with respect to the analyzed data?
6. How do the **improved strategies perform when compared to the existing design**?

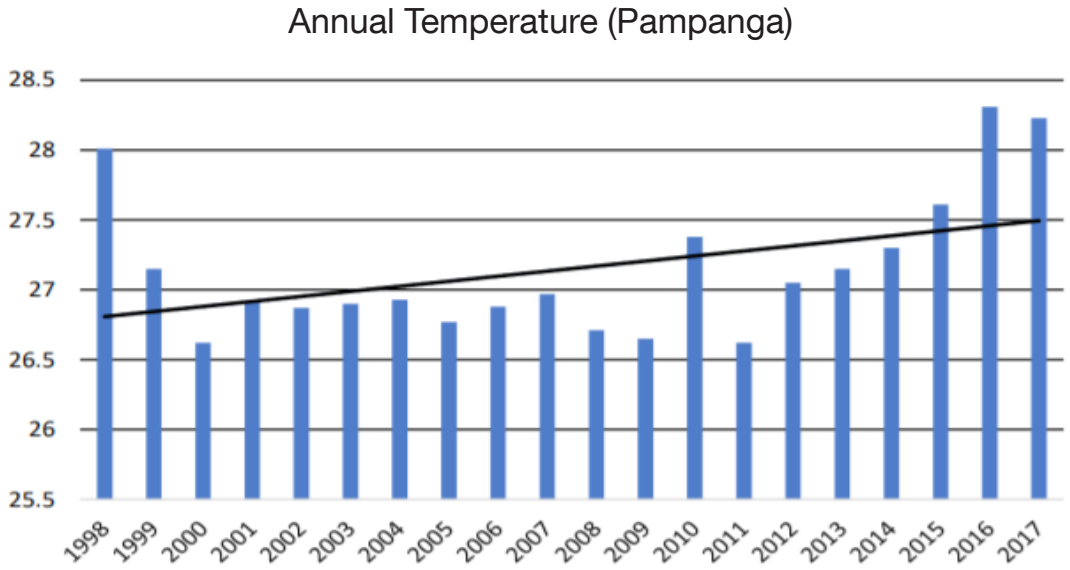
Work Flow

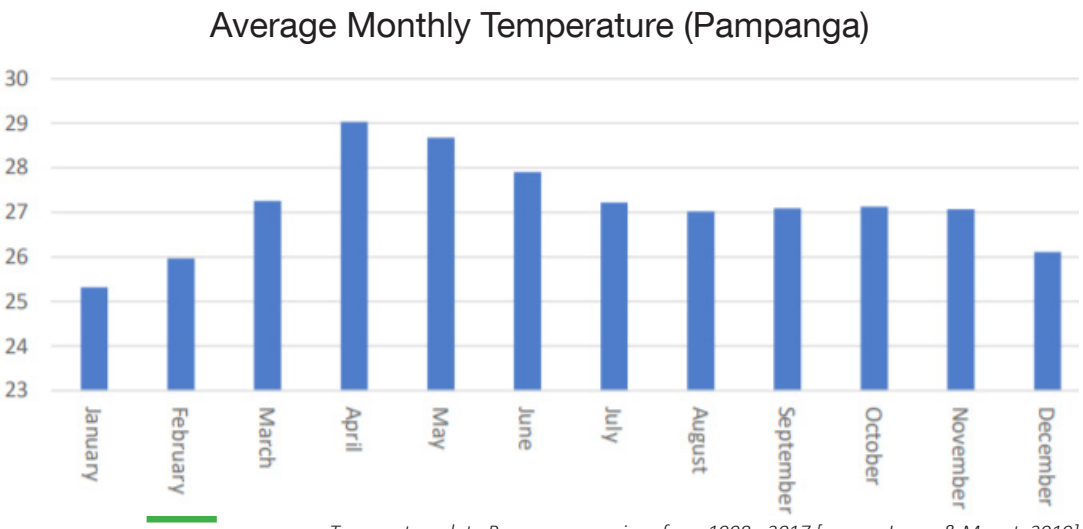

Pilot Project
LITERATURE STUDY (Nov - Dec)
Step 1
Understanding the Pilot Project
Understanding the Site Context
Understanding the Vernacular Architecture
Understanding the Indoor Environmental Quality
MEASUREMENT PLAN AND DEVELOPING THE DEVICE (Jan)
Inputs
Parameters to be Measured
Measurement Devices
Comfort Model Selected
Step 2
Creating Measurement Plan
Development of Questionnaire & Interview
Developing an Economical Method (Device)
Feasible or Not??
FIELD VISIT & STUDY (Feb)
Step 3
Installation of Devices & In-situ Measurements
Collected Data
Manual Documentation, Interviews & Site Analysis
RESULTS & COMFORT PERFORMANCE (Mar - Apr)
Step 4
Developing Hypotheses
Documentation & Analysis of Measured Data
Analysed Data
Checking the Comfort Performance of the House
Validation of the Hypotheses
DESIGN IMPROVEMENTS (Apr - May)
Step 5 & 6
Need Improvements?
Developing Improvement Strategies
Climate Data
Comparison of Improvement Strategies with the Existing Design
Recommendations

1. How is the pilot floating house in the Philippines **designed and constructed in terms of passive design**?

Pilot Floating House

Climate





Temperature data Pampanga province from 1998 - 2017 [source: Lacap & Magat, 2019]

Philippines in General

Tropical and maritime climate:

High Temperature & High Humdity

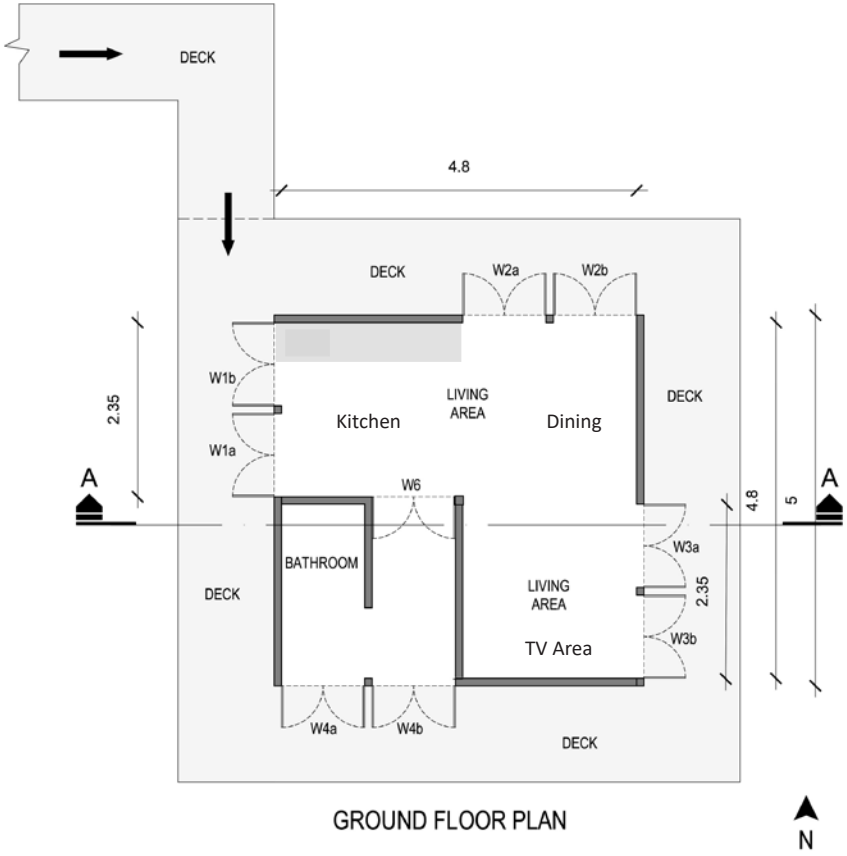
Pilot Floating House

Site

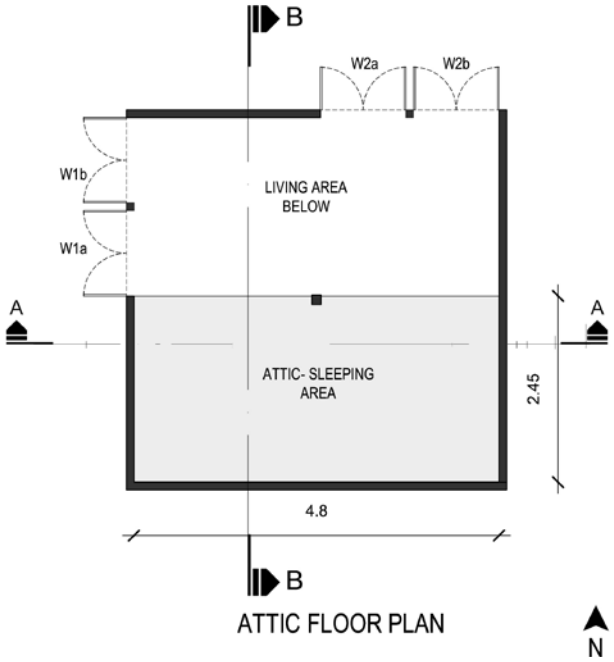
Site Plan

Pilot Floating House

Floor Plans



GROUND FLOOR PLAN



ATTIC FLOOR PLAN

Pilot Floating House

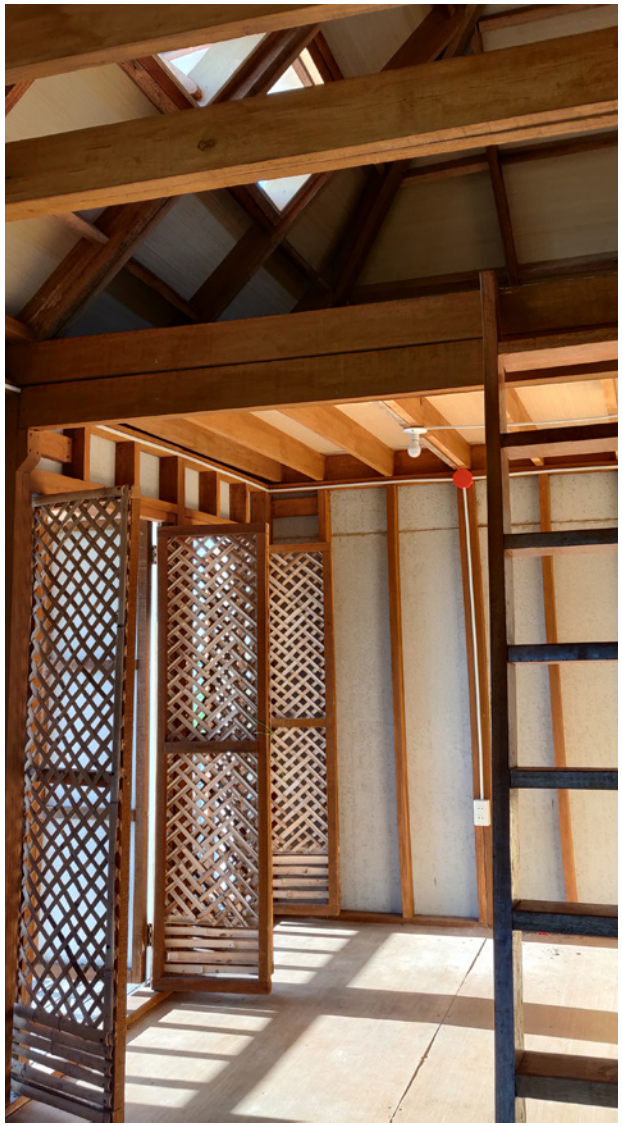
Spaces

Entrance

Kitchen

Pilot Floating House

Spaces: GF



Dining & TV Area

Pilot Floating House

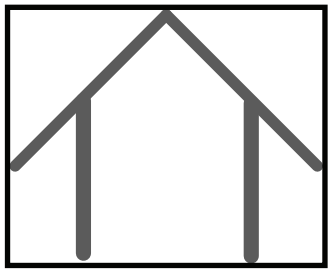
Spaces: Attic

Attic Floor

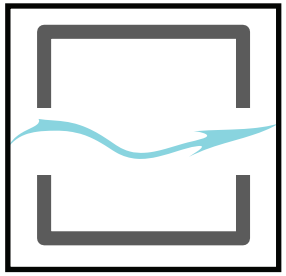
Pilot Floating House

Vernacular Strategies

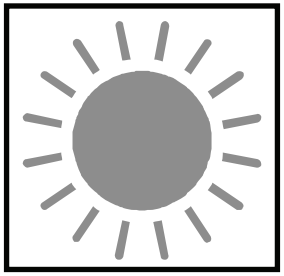
Bahay Kubo [source: https://balay.ph]



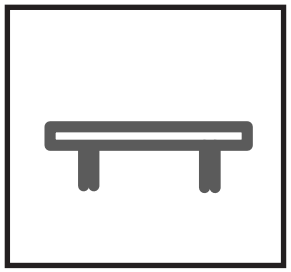
Sloped Roof



Natural Ventilation



Natural Light



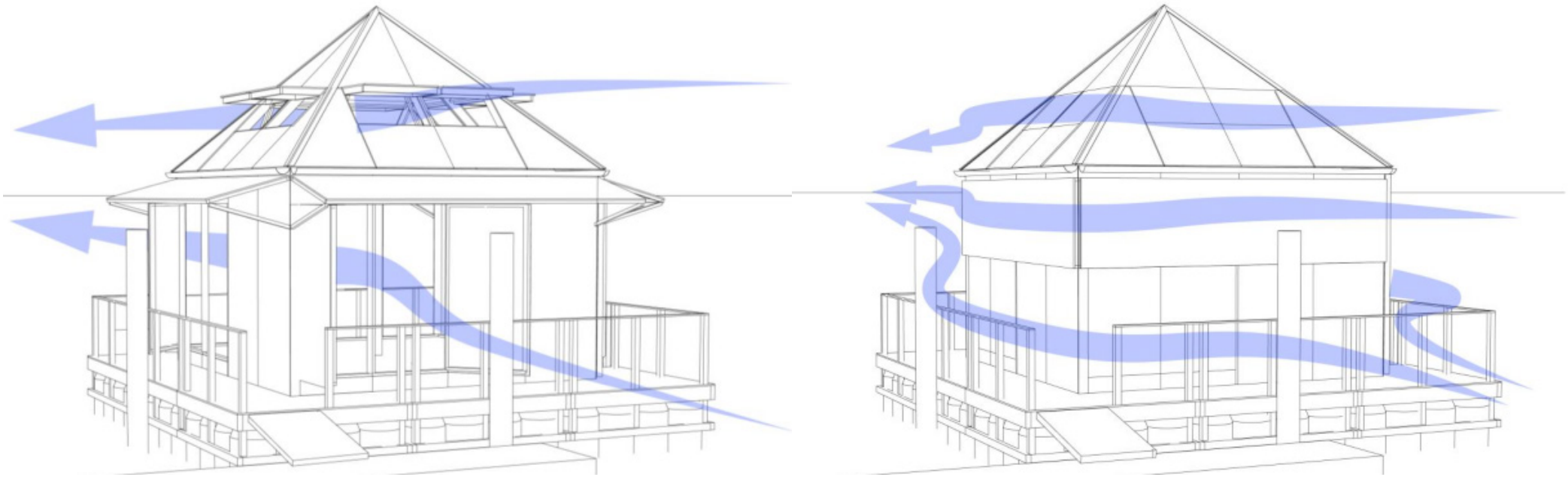
Stilt

Pilot Floating House

Construction

Construction Photos [source: Ham, 2019]

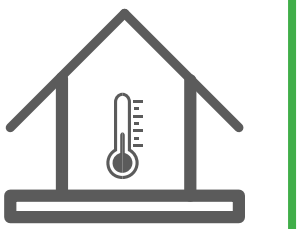
Pilot Floating House



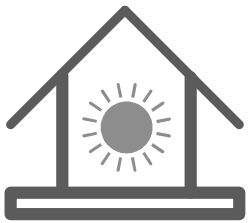
Natural Ventilation (left), Typhoon resilient (right) [source: Ham, 2019]

2. What are **the comfort parameters that need to be measured**, which influence the indoor environment quality of the housing type?

IEQ (Comfort Parameters)

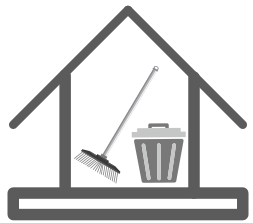

Thermal


Air


Light

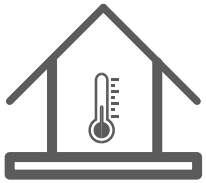

Acoustic


Ergonomics

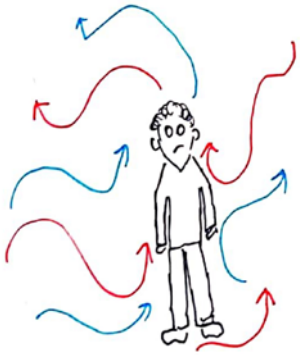

Cleanliness

IEQ (Comfort Parameters)

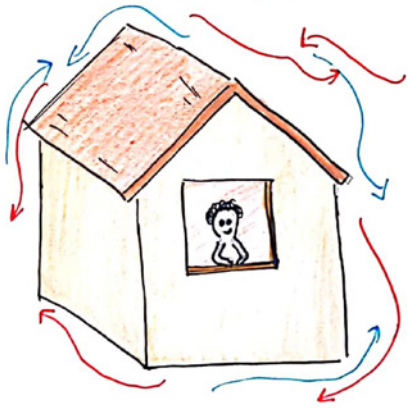
Thermal Comfort



Undesirable Heating & Cooling



A good Environment

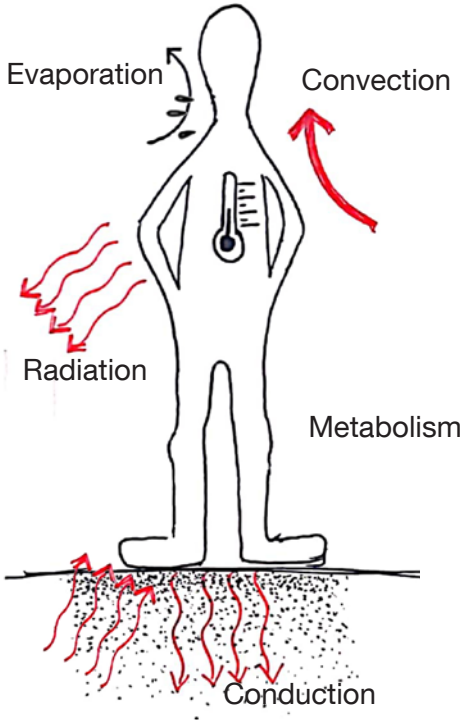


Shivering

Sweating

Body

Each person percieves and responds differently



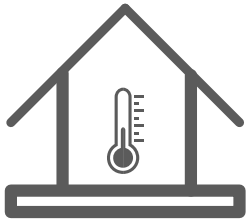
Regulatory Mechanisms

1. Heat Gain
   i. Metabolism
   ii. Conduction
   iii. Convection
   iv. Radiation
2. Heat Loss
   i. Conduction
   ii. Convection
   iii. Radiation
   iv. Evaporation

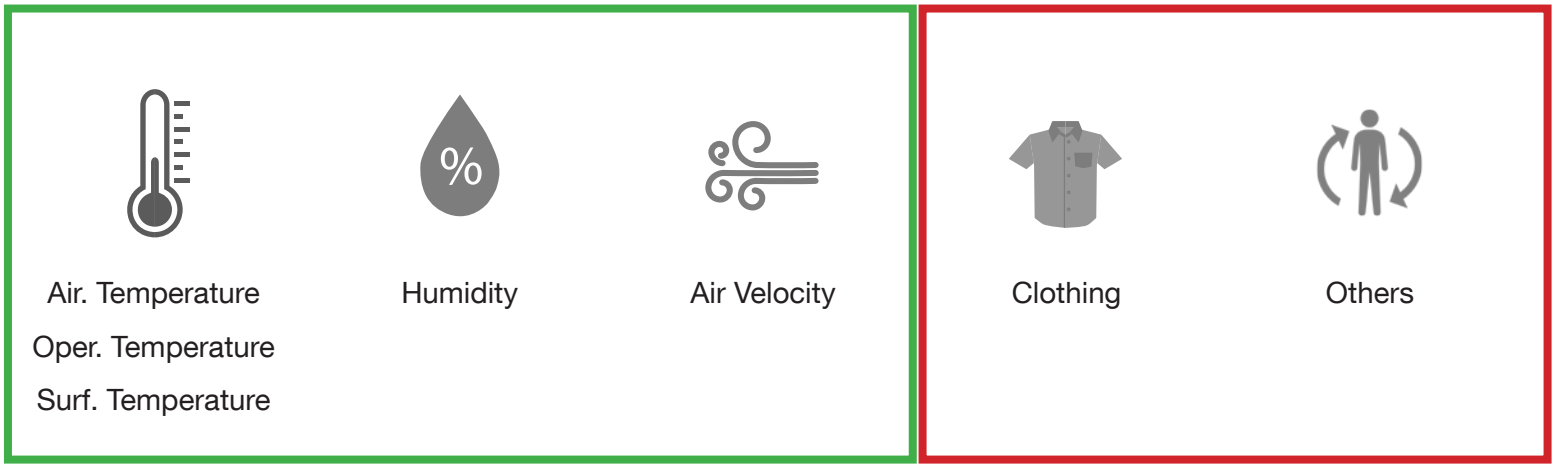
Thermal Balance: (+) Heat Gain = (-) Heat Loss

IEQ (Comfort Parameters)

Thermal Comfort

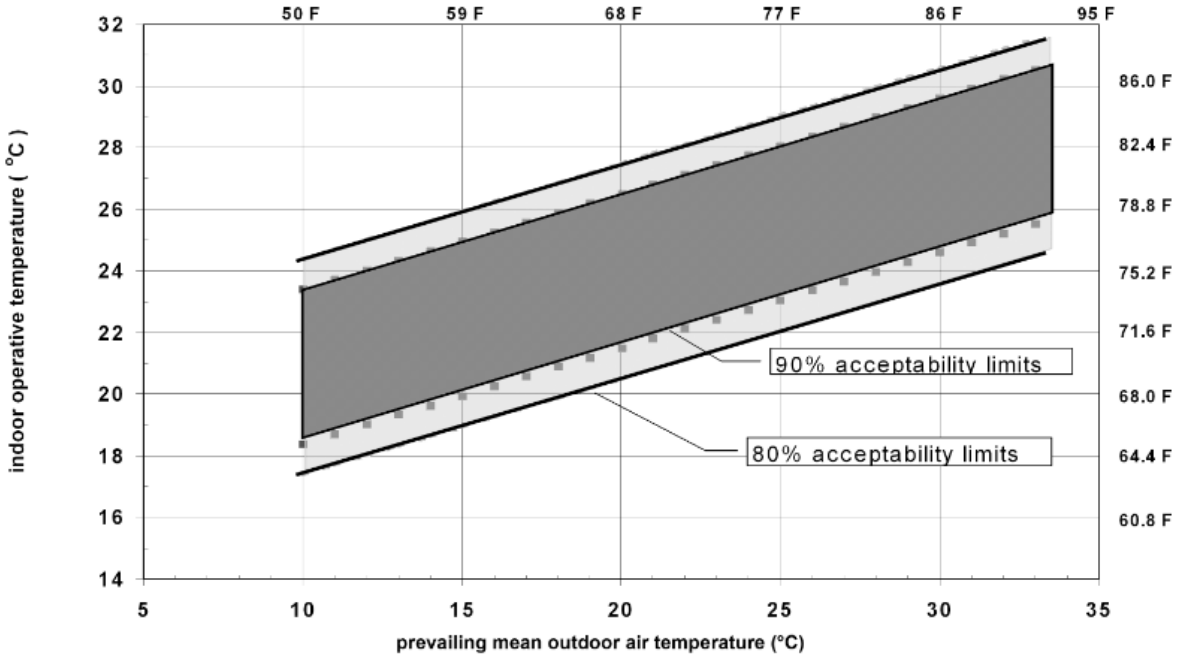


Thermal



IEQ (Thermal Comfort)

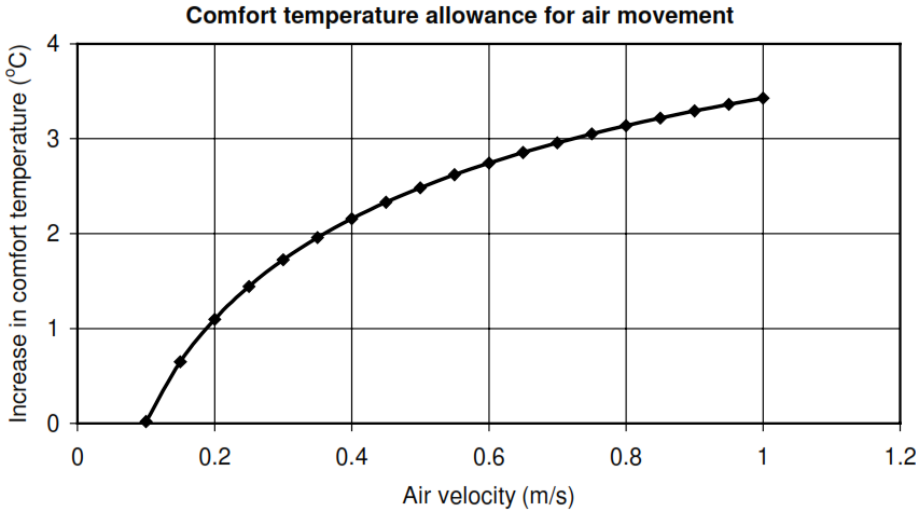
Comfort Model Selection



ASHRAE adaptive comfort graph [source:ASHRAE 55-2010]

Adaptive Comfort Model for Manila, the Philippines

Air Velocity & Comfort Temperature



Increase in comfort performance with air velocity [Nicol, 2004]

3. How to **develop a measurement plan and monitoring system** for indoor environmental quality of the pilot project?

Measuring & Monitoring

Devices

	Hobo Data logger + External Sensor + Black Globe	Thermochron I-Buttons	Extech Hotwire Anemometer
Measures	D.B.T & O.T R. H	Inner Surface Temperature	Air Velocity
Type	Continuous measurement	Continuous measurement	Spot measurement
Interval	5 minutes	10 minutes	Multiple
Location	TV Area, Dining, Kitchen @ 1.5 m ht Attic @ sleeping ht	TV Area, Dining, Kitchen @ 1.5 m ht Roof @ almost center	Center of openings, centre of room, Outdoor & multiple directions

Measuring & Monitoring

Field Visit

Measurement Period

1. February 08:
2. February 09:
3. February 10:
4. February 11:
5. February 12:
6. February 13:
7. February 14:
8. February 15:
9. February 16:
10. February 17:

For 9 days

Measuring & Monitoring

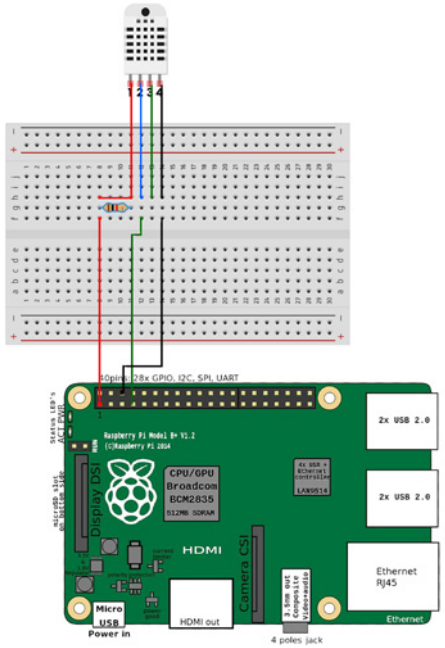
IoT Monitoring Device

Raspberry Pi

DHT22 Sensor

Python3

Ubidots IoT



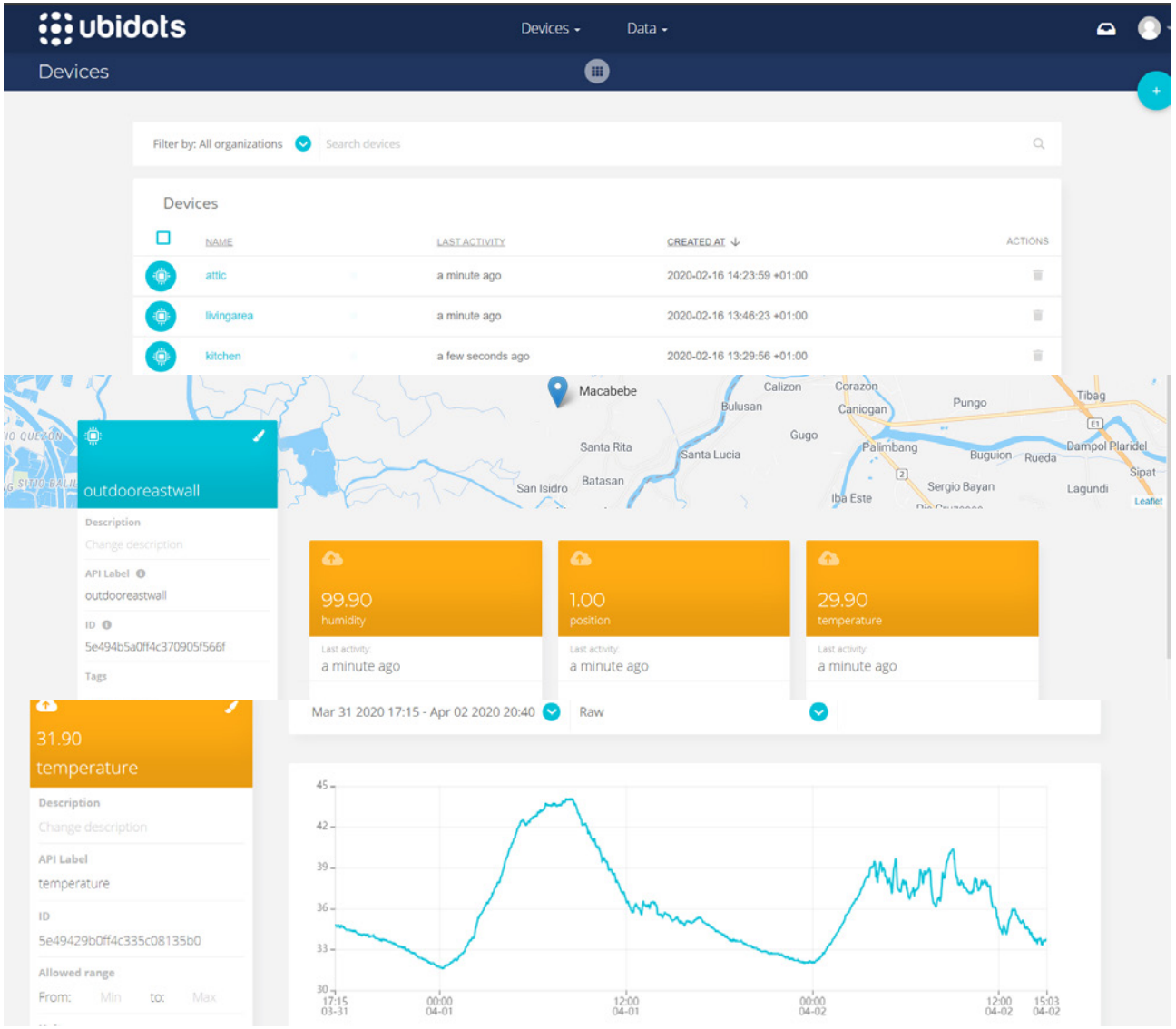
Continuous measurement @ 3 mins interval

Living & Kitchen @ 1.5 m ht
Attic @ sleeping ht

Measuring & Monitoring

IoT Interface

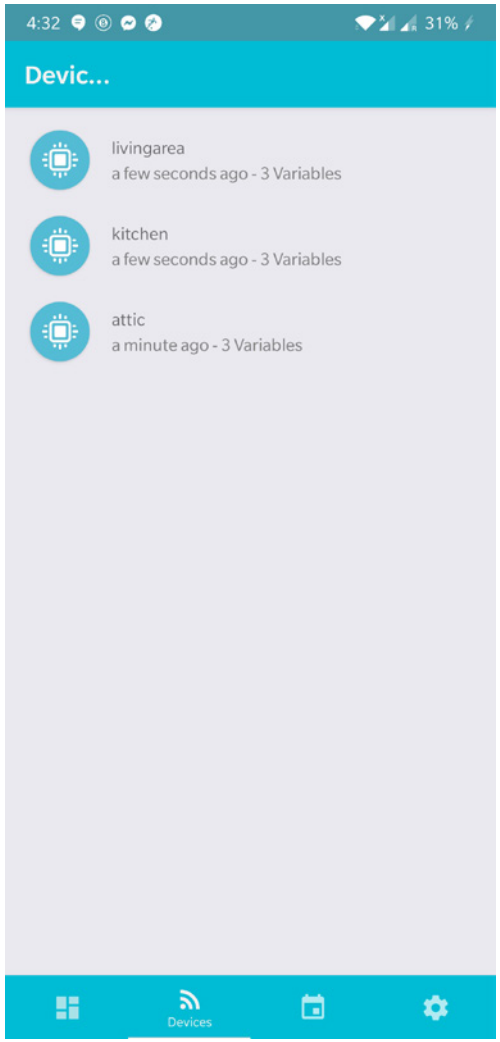
https://industrial.ubidots.com/app/devices/

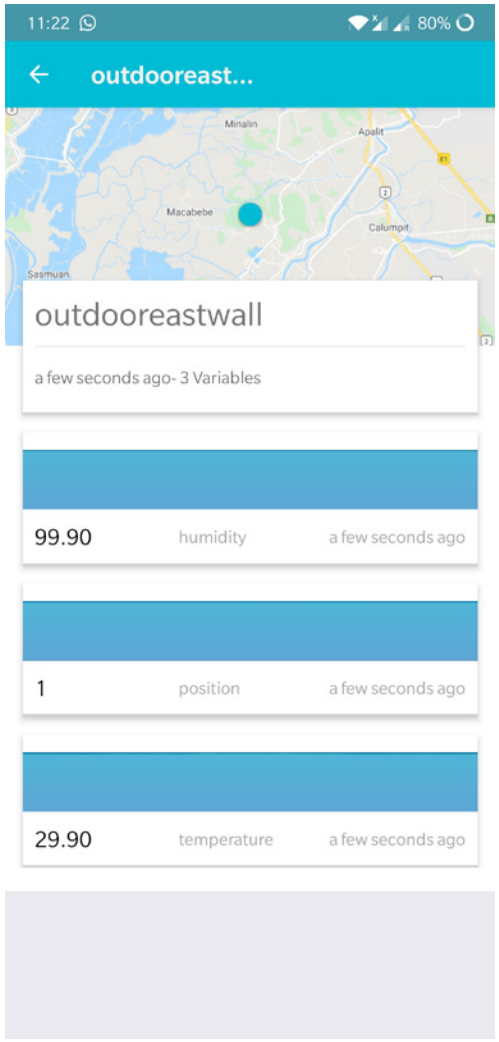


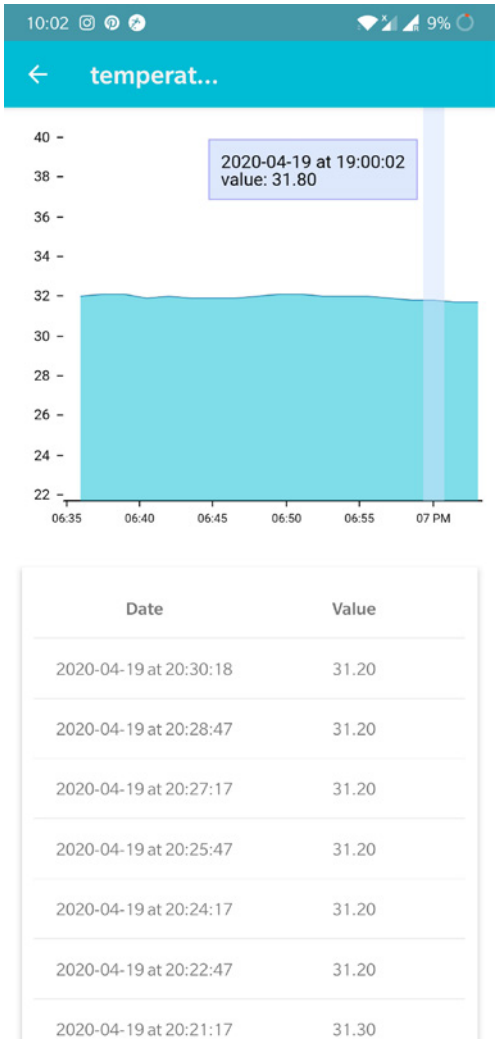
Ubidots website interface: live monitoring

Measuring & Monitoring

IoT Interface







Ubidots cellphone application: live monitoring

Measuring & Monitoring

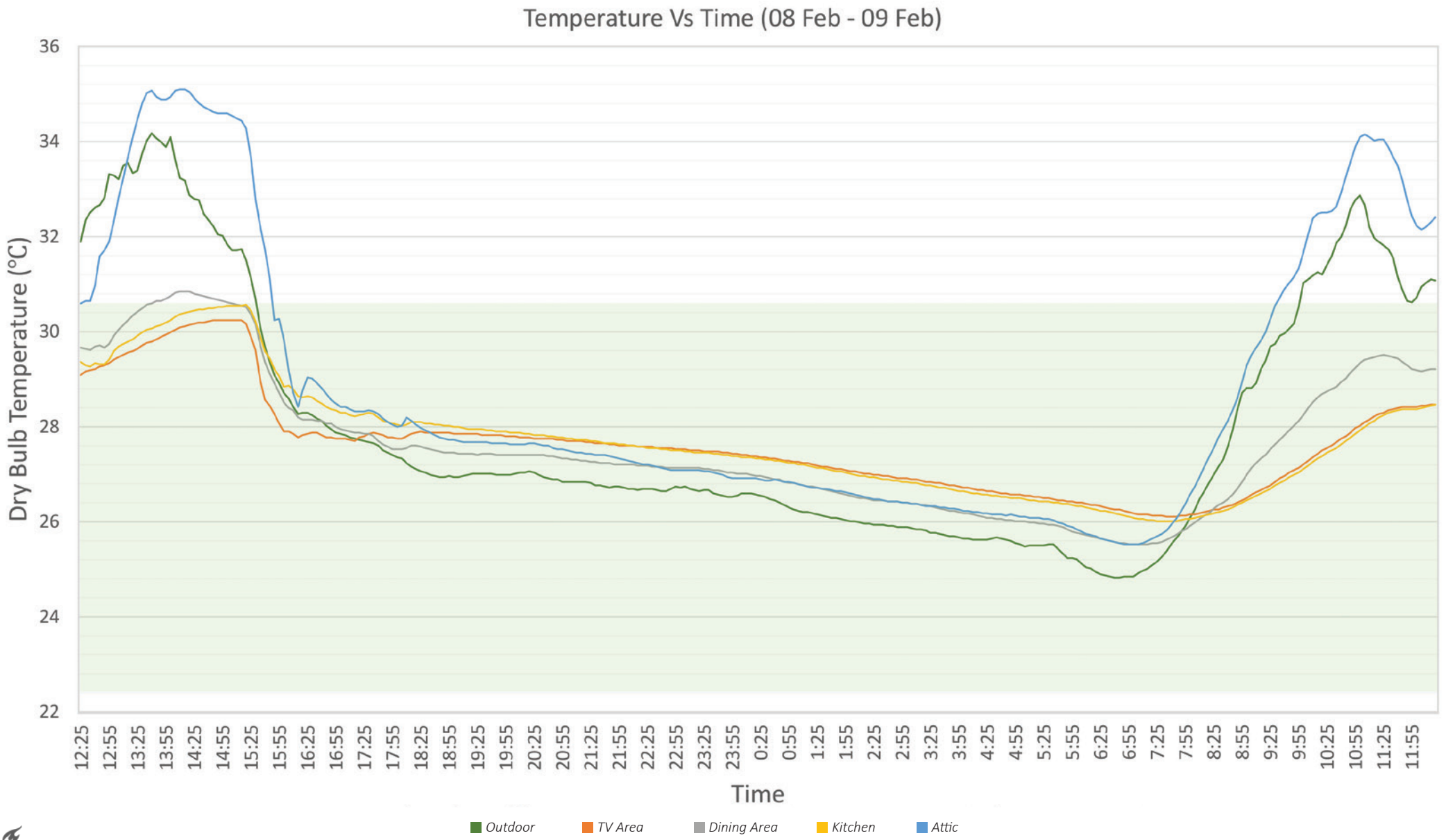
Hypotheses

1. “the building interior is expected to be **responsive to the outdoor temperature**”
2. “the building **interior is expected to have lower temperature than outdoor during the day and the other way during the night**”.
3. “**the attic is expected to be the hottest space i**n the building during most of the day”.
4. “the indoor spaces are **expected to have good air movement**”.

4. How does the **pilot floating house perform** in terms of measured results and observations?

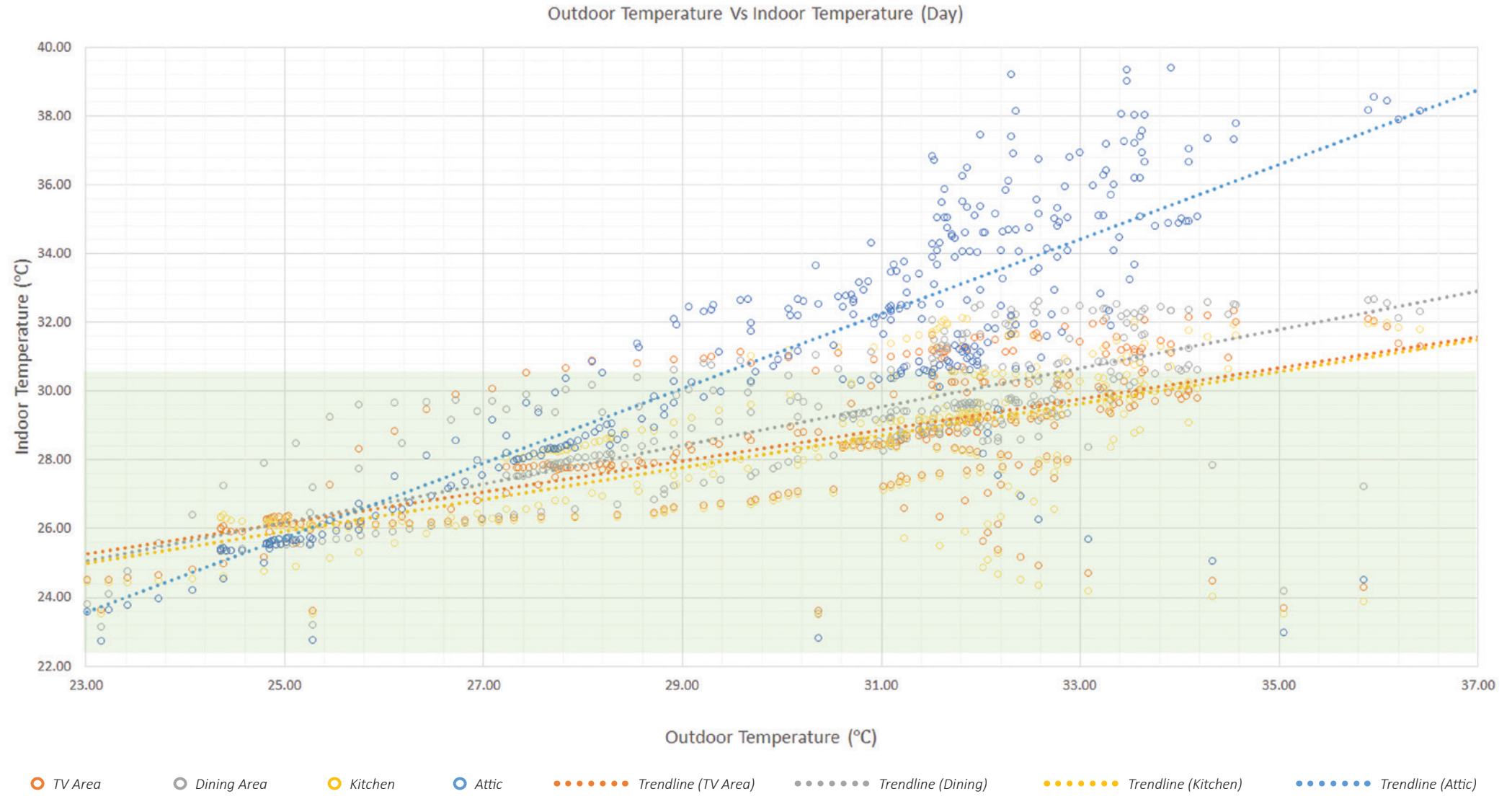
Comfort Performance

Temperature against Time



Comfort Performance

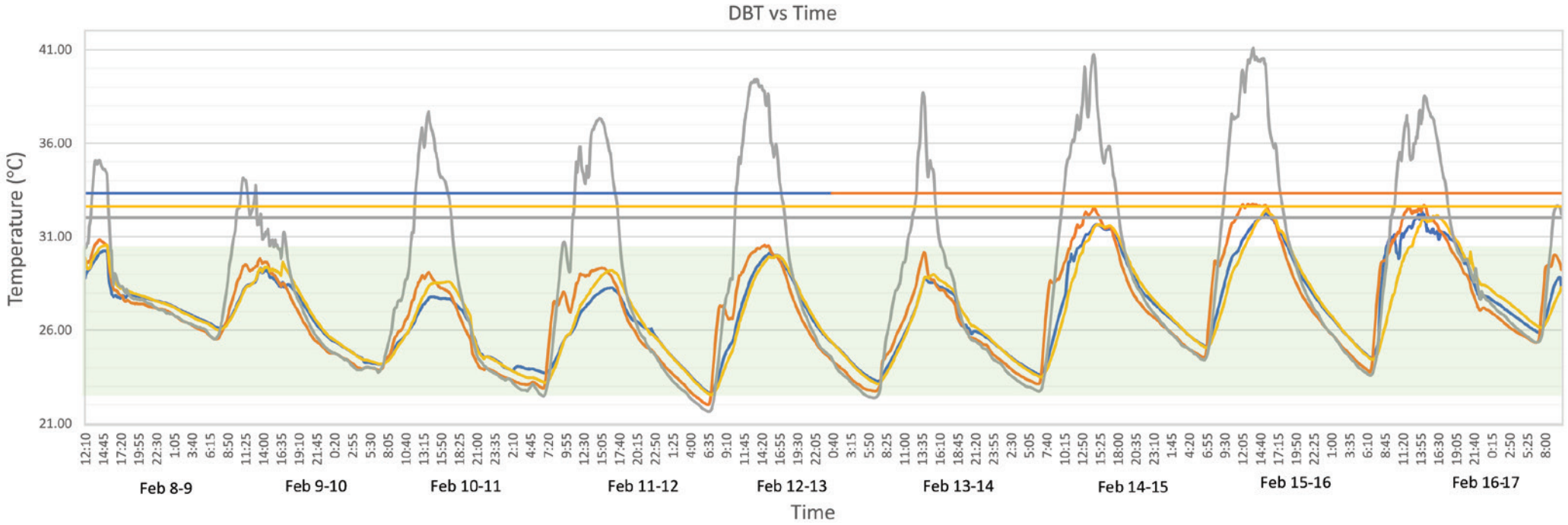
Indoor Temp against Outdoor Temp: Day



Whole period: day time

Comfort Performance

Indoor Temp: Whole Period



Space	TV Area	Dining Area	Kitchen	Attic
Increase in Comfort Temp.	2.8°C	2.8°C	2.1°C	1.5°C

Low: < 0.3 m/s Moderate: 0.3 m/s to <0.65 m/s High: 0.65 m/s and higher *[Toe & Kubota, 2013]*

Location		W 1 (West facing)	W 2 (North Facing)	W 3 (East Facing)	TV Area	Dining Area	Kitchen	Roof Opening East	Roof Opening West	Attic
Avg Air Velocity	m/s	0.47	0.87	1.01	0.63	0.62	0.40	0.94	0.64	0.31
Max Avg/measurement		0.63	2.55	1.54	1.01	0.87	0.60	1.34	0.96	0.50
Min Avg/measurement		0.31	0.34	0.58	0.30	0.39	0.21	0.54	0.46	0.14

Comfort Performance

Hypotheses to Results

1. “the building interior is responsive to the outdoor temperature”
2. “the building interior has lower dry-bulb temperature than outdoor during the day, except attic and the other way during the night”.
3. “the attic is the hottest space in the building during most of the day”.
4. “The indoor spaces are having good air movement except attic”. Air velocity at the openings are similar to that of outdoor air velocity.

Results IoT Monitoring Device

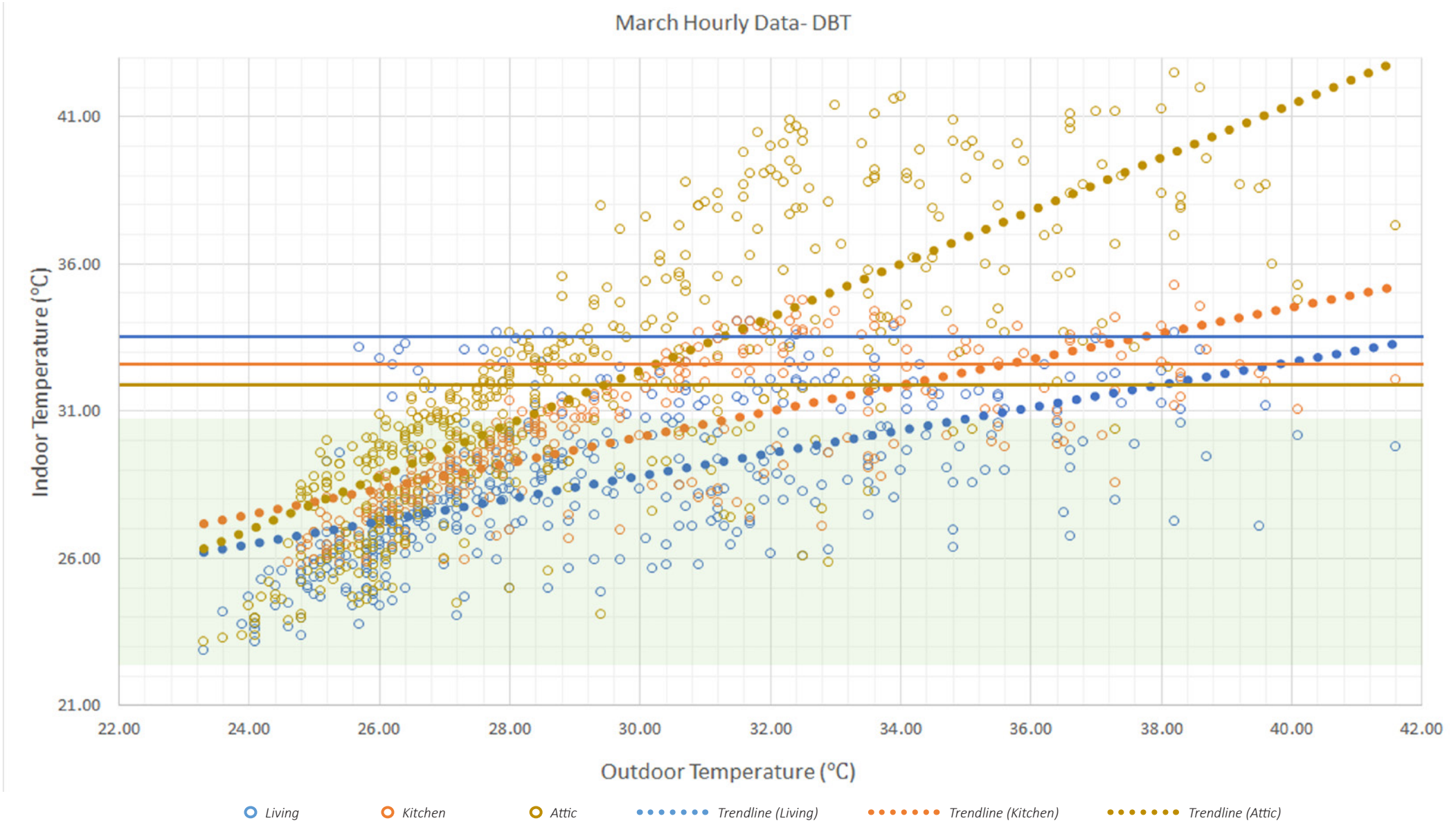
Comparison

	Hobo TV Area	Raspberry Pi	Difference
	◦C	◦C	◦C
02/17/20 12:00:00 AM	27.70	29.50	1.80
02/17/20 01:00:00 AM	27.43	29.40	1.97
02/17/20 02:00:00 AM	27.19	29.10	1.91
02/17/20 03:00:00 AM	26.89	28.80	1.91
02/17/20 04:00:00 AM	26.65	28.50	1.85
02/17/20 05:00:00 AM	26.35	28.20	1.85
02/17/20 06:00:00 AM	26.11	27.90	1.79
		Average	1.87

	Hobo Attic	Raspberry Pi	Difference
	◦C	◦C	◦C
02/17/20 12:00:00 AM	27.481	29.40	1.92
02/17/20 01:00:00 AM	27.063	29.00	1.94
02/17/20 02:00:00 AM	26.818	28.70	1.88
02/17/20 03:00:00 AM	26.402	28.30	1.90
02/17/20 04:00:00 AM	26.085	28.00	1.92
02/17/20 05:00:00 AM	25.768	27.70	1.93
02/17/20 06:00:00 AM	25.501	27.40	1.90
02/17/20 07:00:00 AM	25.355	27.30	1.94
		Average	1.92

IoT Monitoring Device

Indoor Temp: Whole Period



Comfort Performance

Other Observations

Existing door shutters

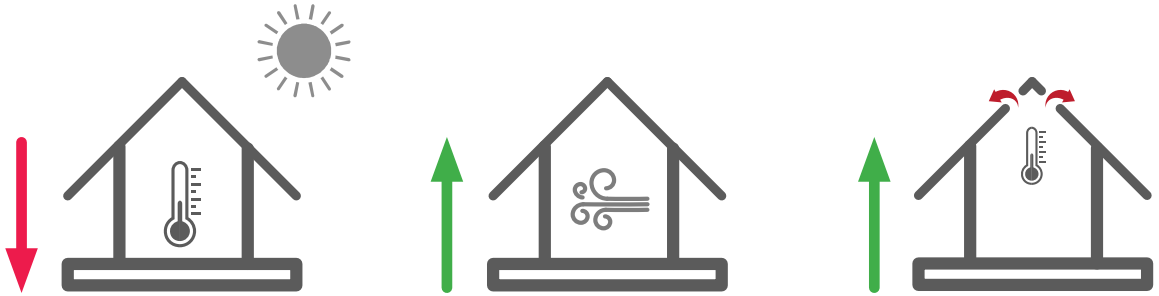
Comfort Performance

Summary

1. During the hottest days **the attic floor gets hotter than the upper comfort level by around 11°C**
2. **Air velocity is relatively low in the attic** compared to that of the other spaces in the house
3. Less options in terms of **controlling air velocity, privacy and user-friendliness**
4. IoT device is relaiable **but needs calibration and improvement**

Comfort Performance

Inference



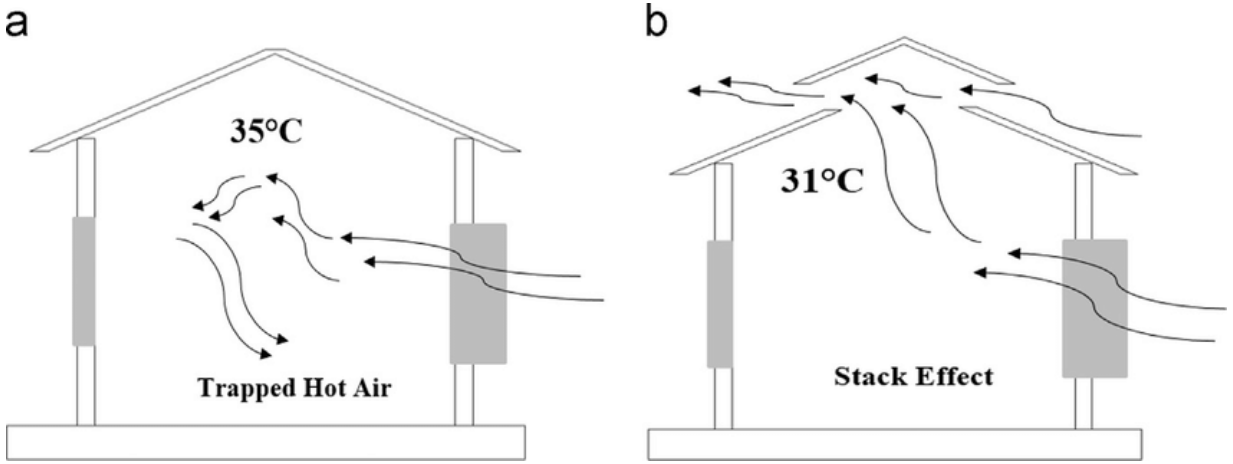
In addition

1. User-friendliness
    i. controlling the air velocity
    ii. controlling the privacy
2. Smarter and easier way to open and close the shutters

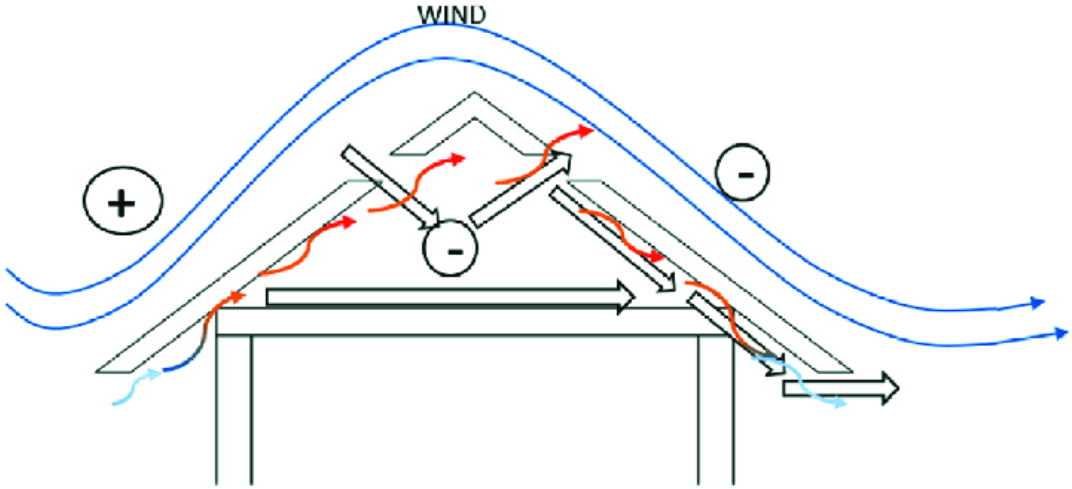
5. What are the **improvement strategies needed** to provide better indoor environment for the housing type with respect to the analyzed data?

Improvement Strategies

Literature Study



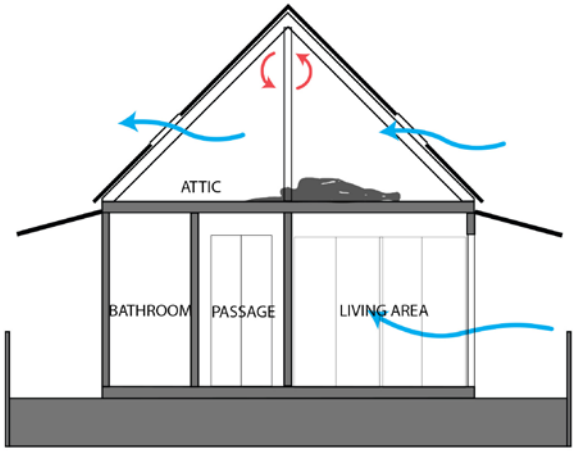
Effect of roof opening [source: Roslan et al, 2015]



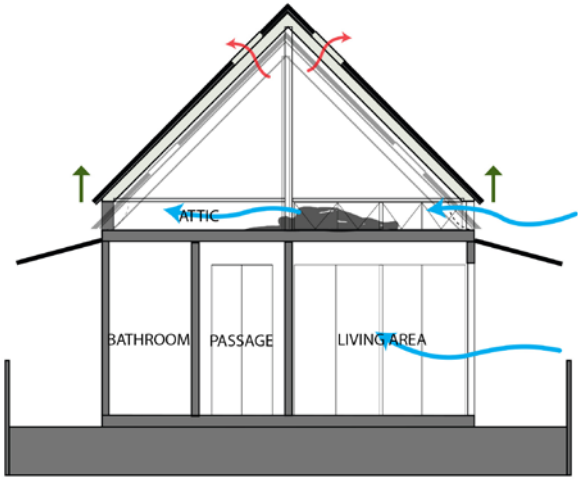
Effect of attic ventilation [source: Roslan et al, 2015]

Improvement Strategies

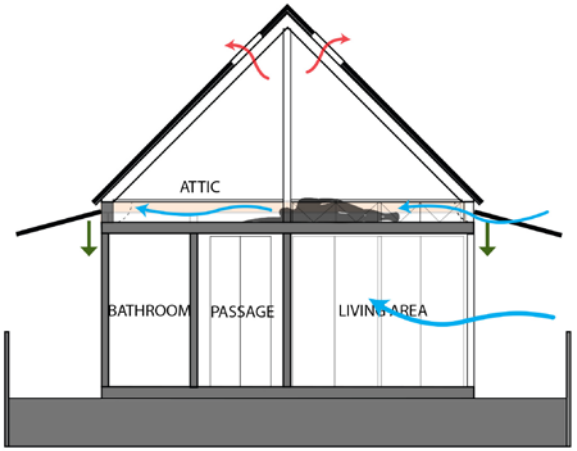
Options



Existing scenario



Option 1

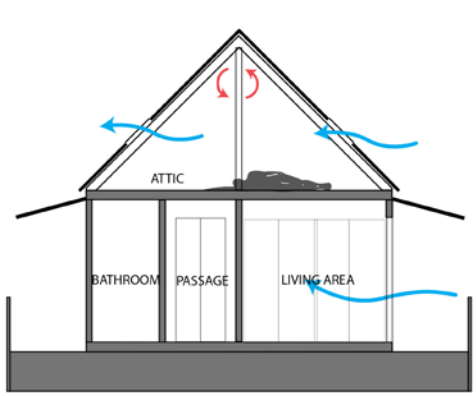


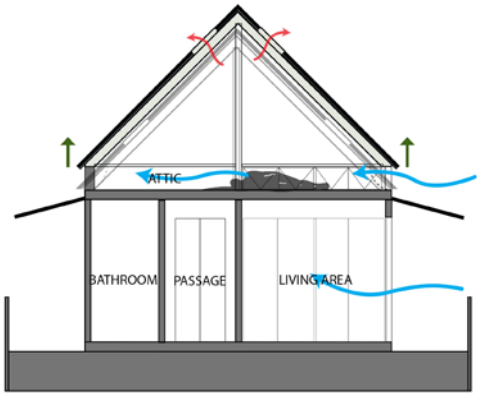
Option 2

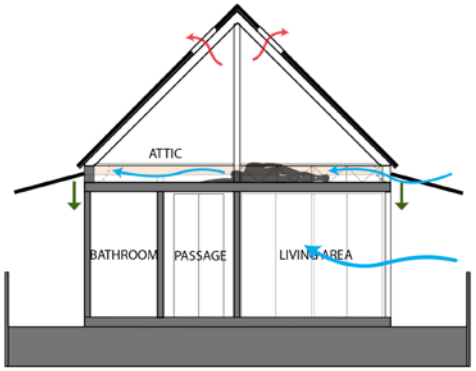
6. How do the **improved strategies perform** when compared to the existing design?

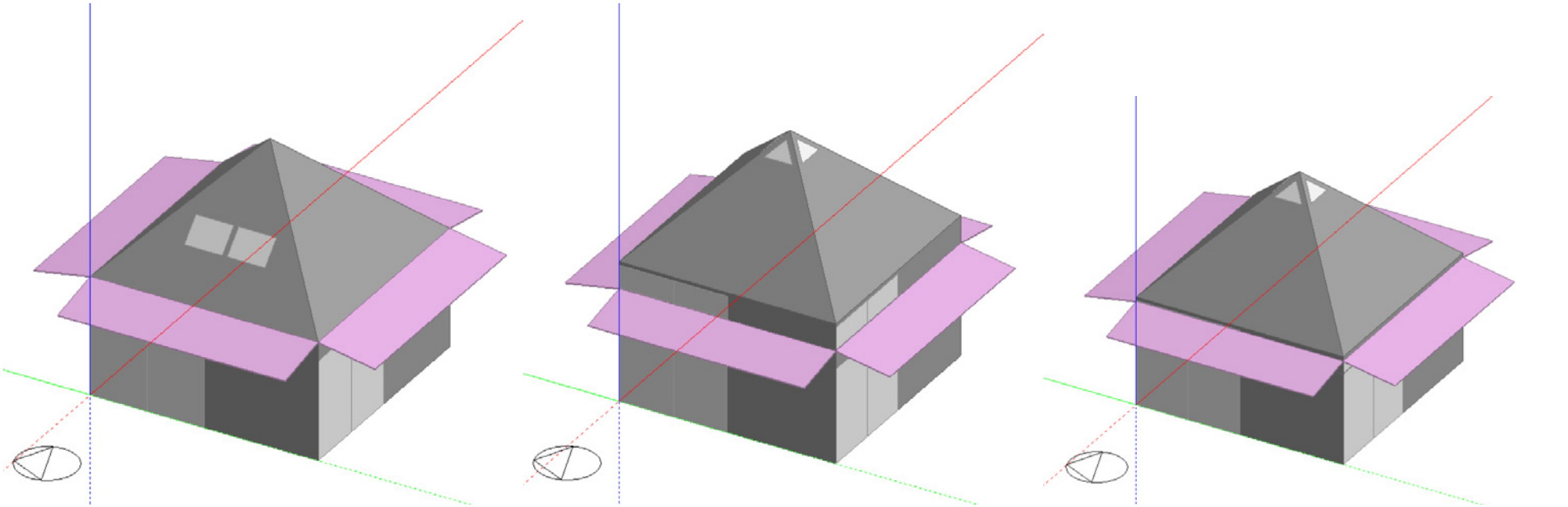
Performance of Improved Strategies

DesignBuilder Models





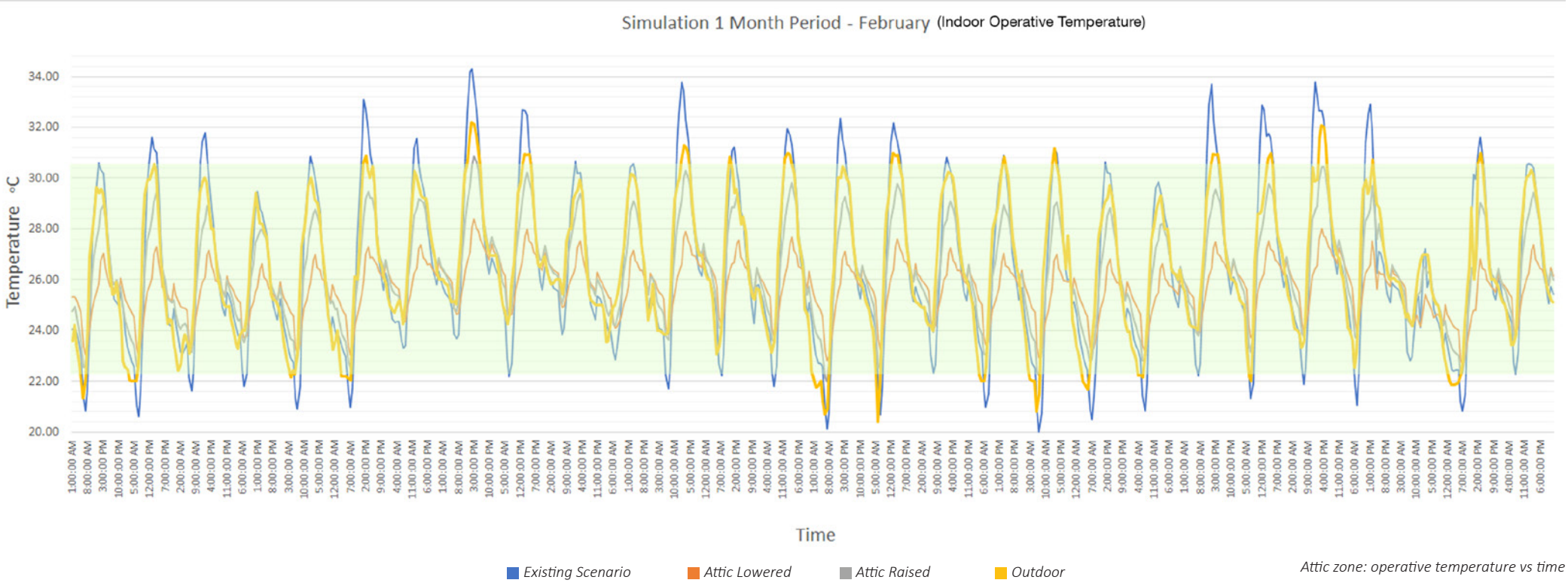




DesignBuilder models

Performance of Improved Strategies

Result: Attic Zone



Attic zone: operative temperature vs time

1. **Attic lowered option performs better** with the daily maximum temperatures around 4°C to 6°C lower than existing design
2. **Existing design goes below the lower comfort level** by around 2°C during certain days, lower than that of the outdoor temperature **due to radiative cooling.**

What **vernacular design strategies** can be advised for the design of the low-income houses with attic floor, in the Philippines, by **evaluating the indoor environmental quality** of the pilot floating house project?

Final Design Improvements

Features from Vernacular Architecture

Thatched Bahay Kubo with roof opening, Hagonoy

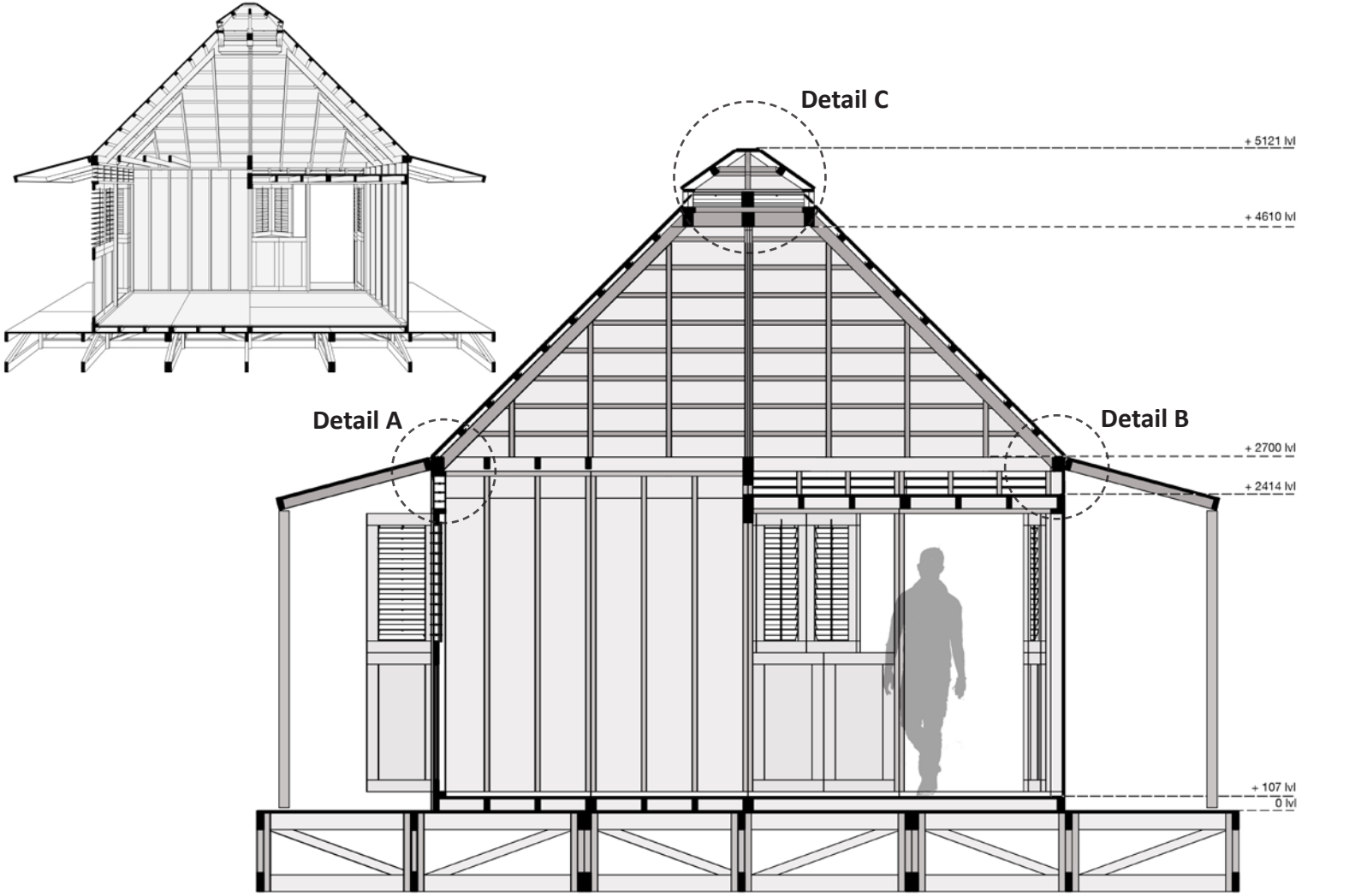
A building under construction, Palawan

Warehouse + house, Palawan

A house, Palawan

Final Design Improvements

Drawings



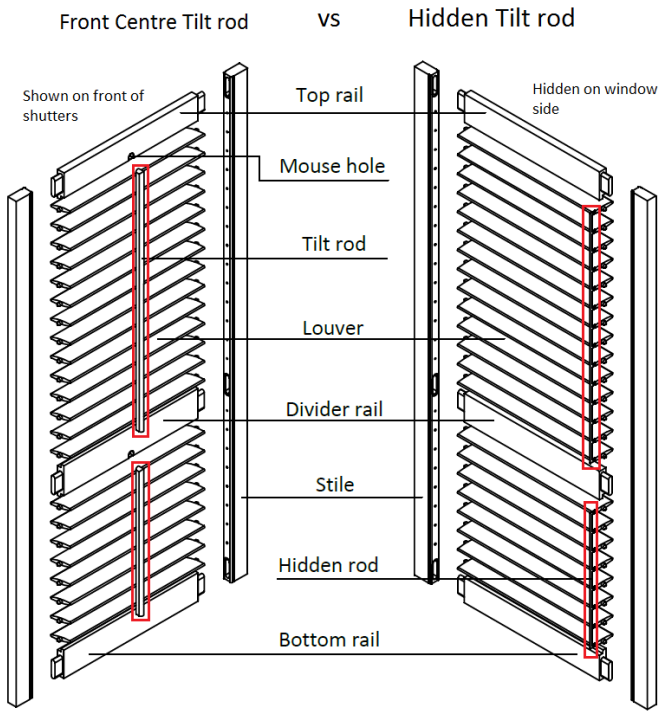
All dimensions in mm

Section

Final Design Improvements

Controlling Air Velocity and Privacy

Plantation shutter in a local house, Palawan



Plantation shutter details [source: diyplantationshutters.com]

Final Design Improvements

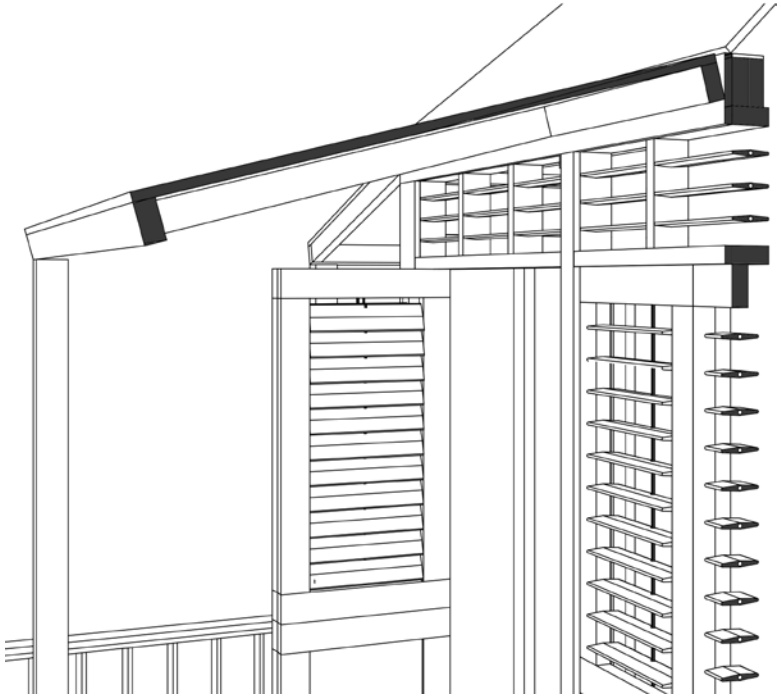
Controlling Air Velocity and Privacy

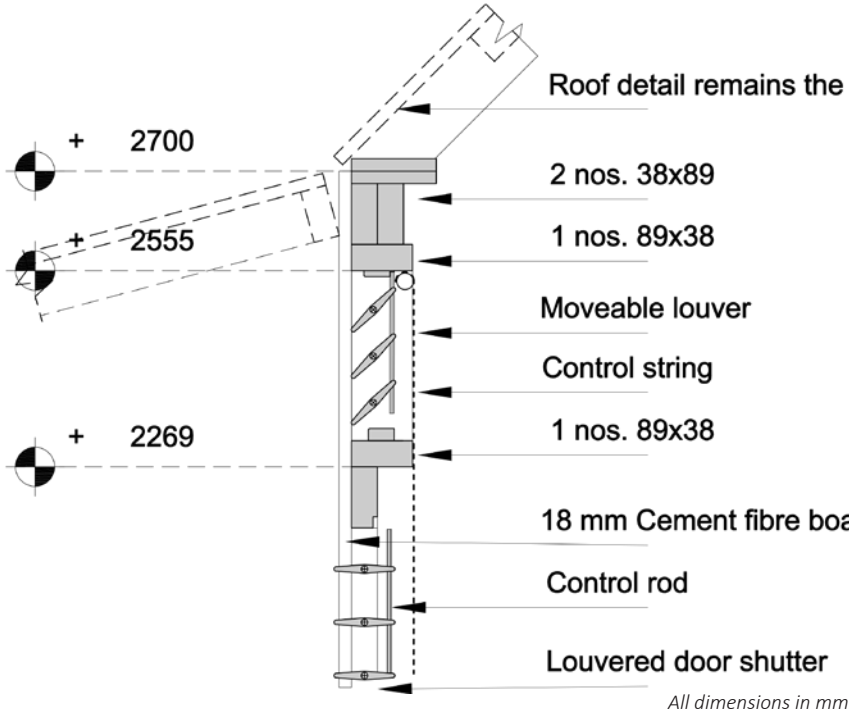
Louvered windows in a school building, Macabebe

Louvered windows in a school building, Macabebe

Final Design Improvements

Drawings



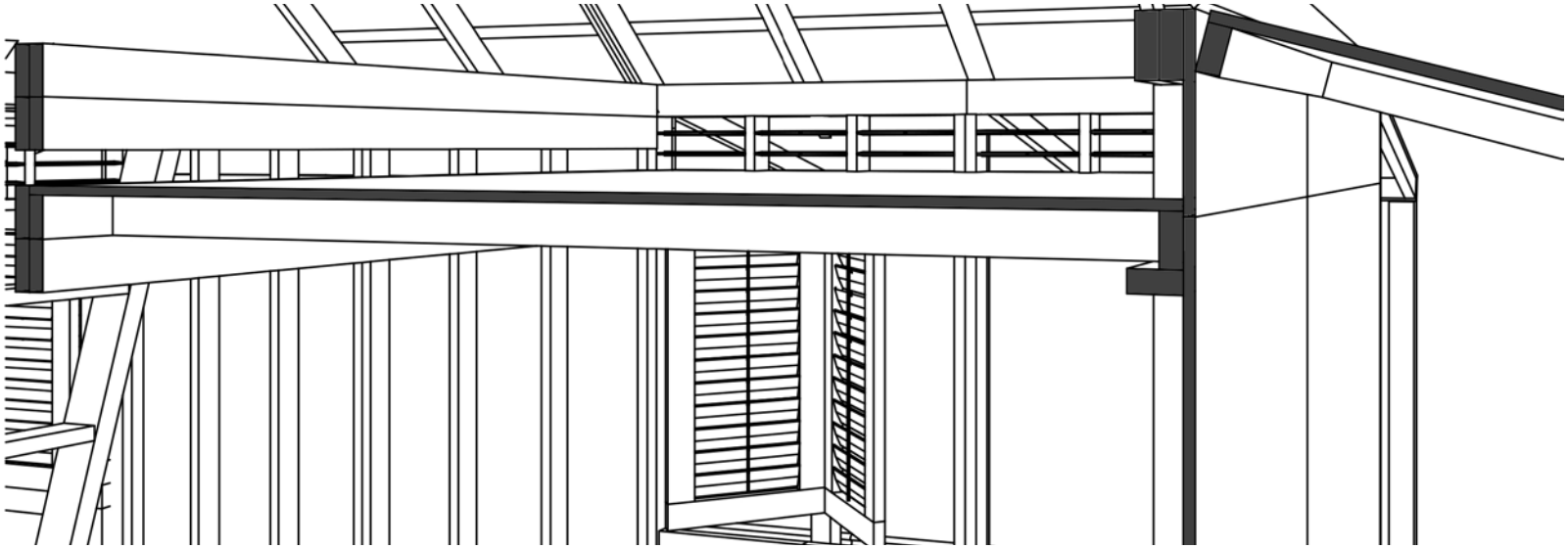


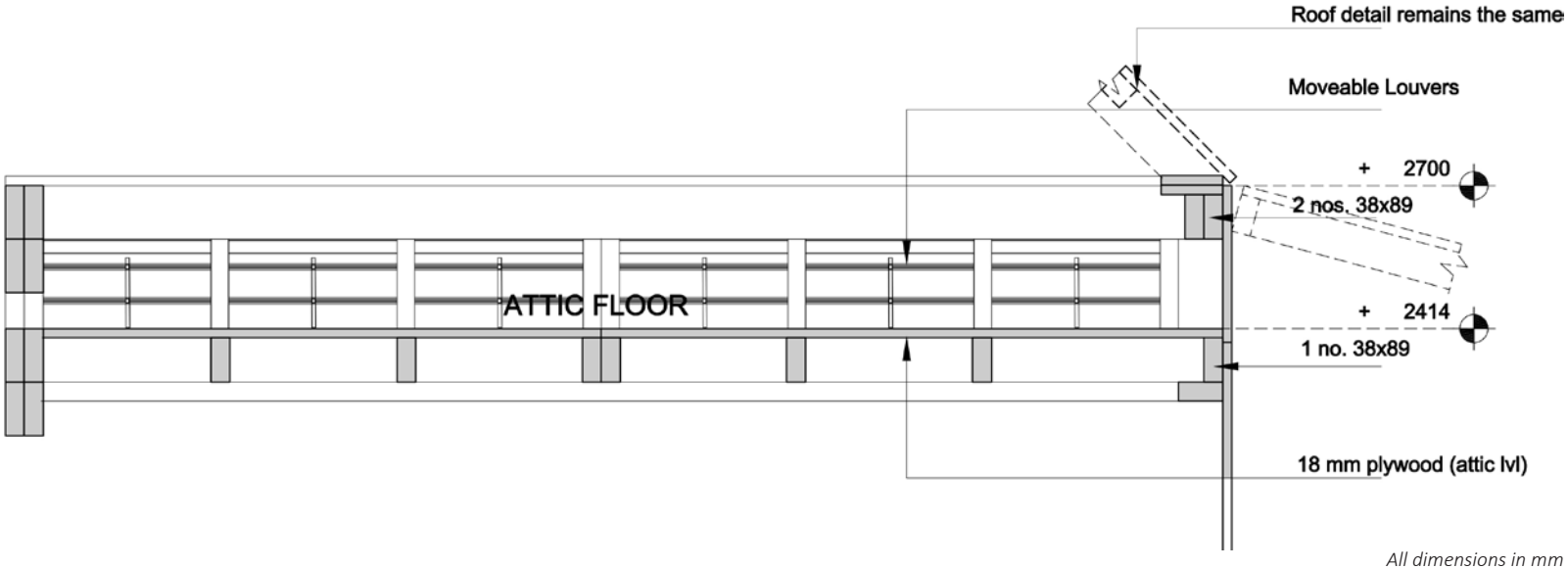
All dimensions in mm

Detail A

Final Design Improvements

Drawings



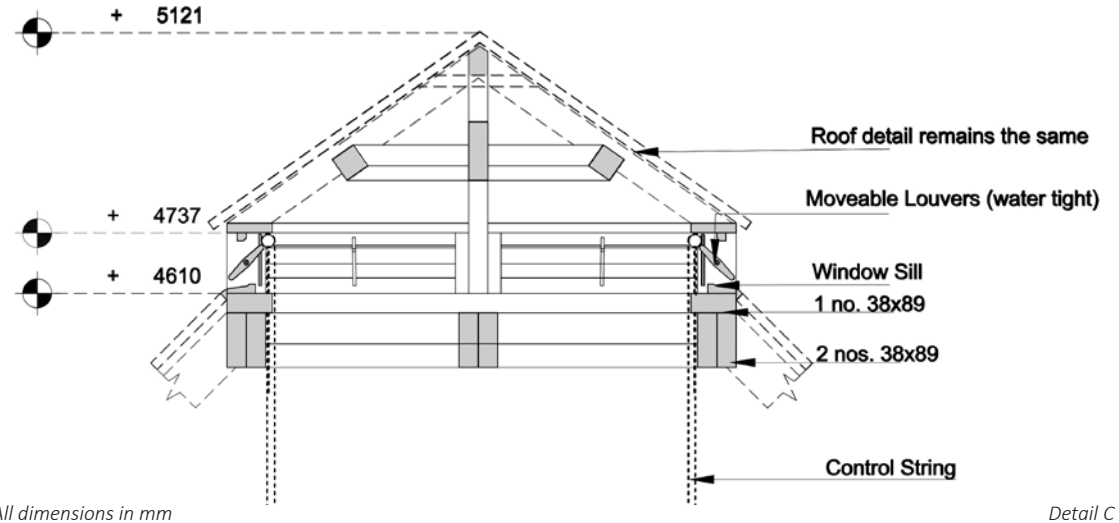


All dimensions in mm

Detail A

Final Design Improvements

Roof Openings



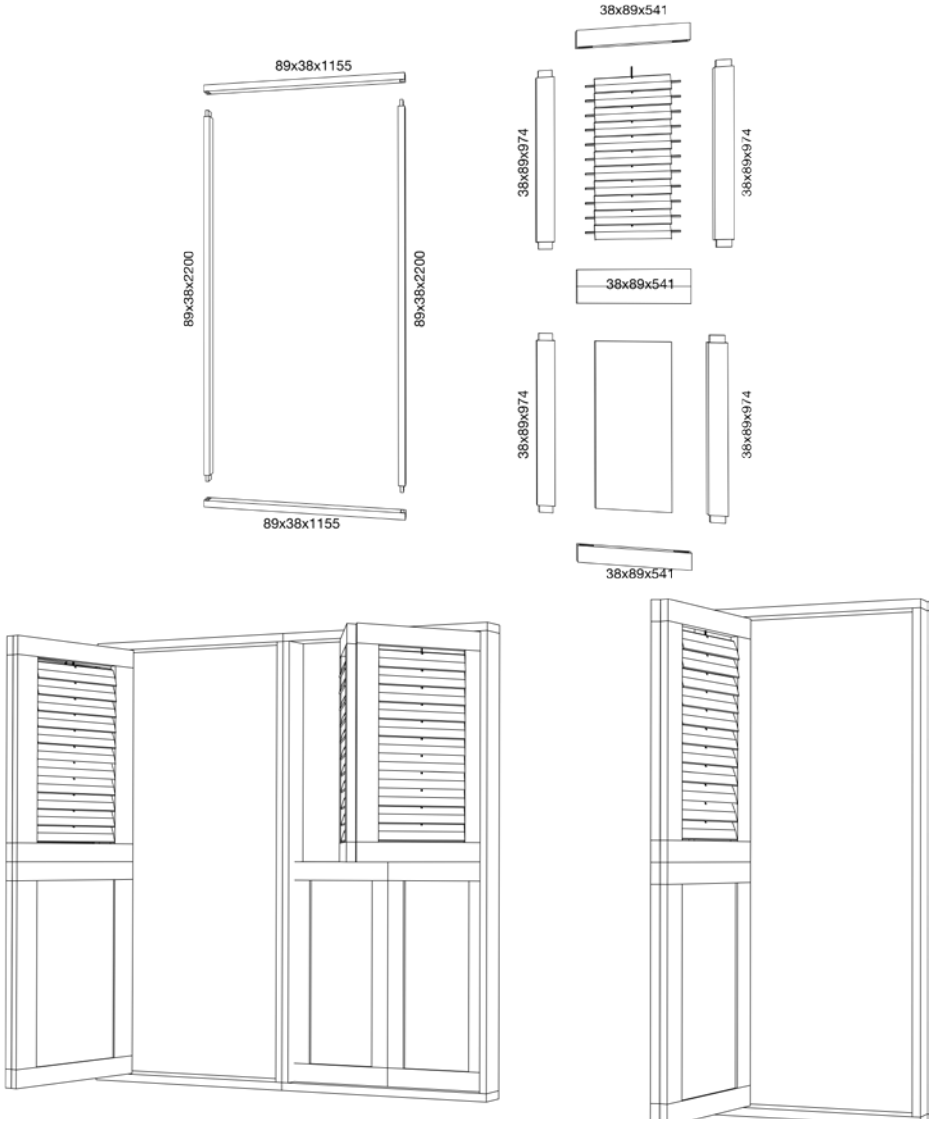
All dimensions in mm

Detail C

Final Design Improvements

Ground Floor Openings

Dutch door [source: EEHE]



Door detail

Final Design Improvements

Exterior View

Final Design Improvements

View From Kitchen

Final Design Improvements

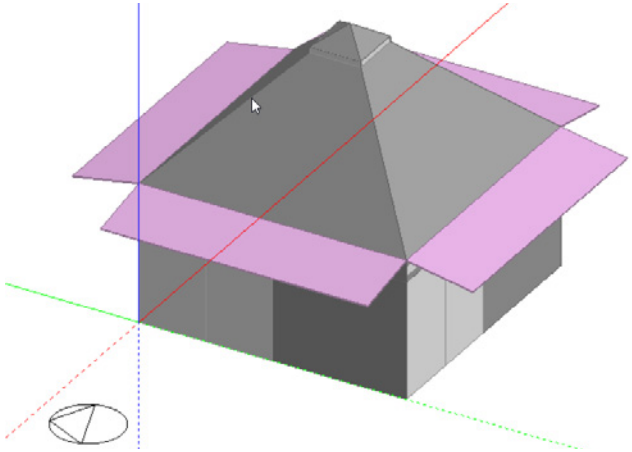
View from the Dining

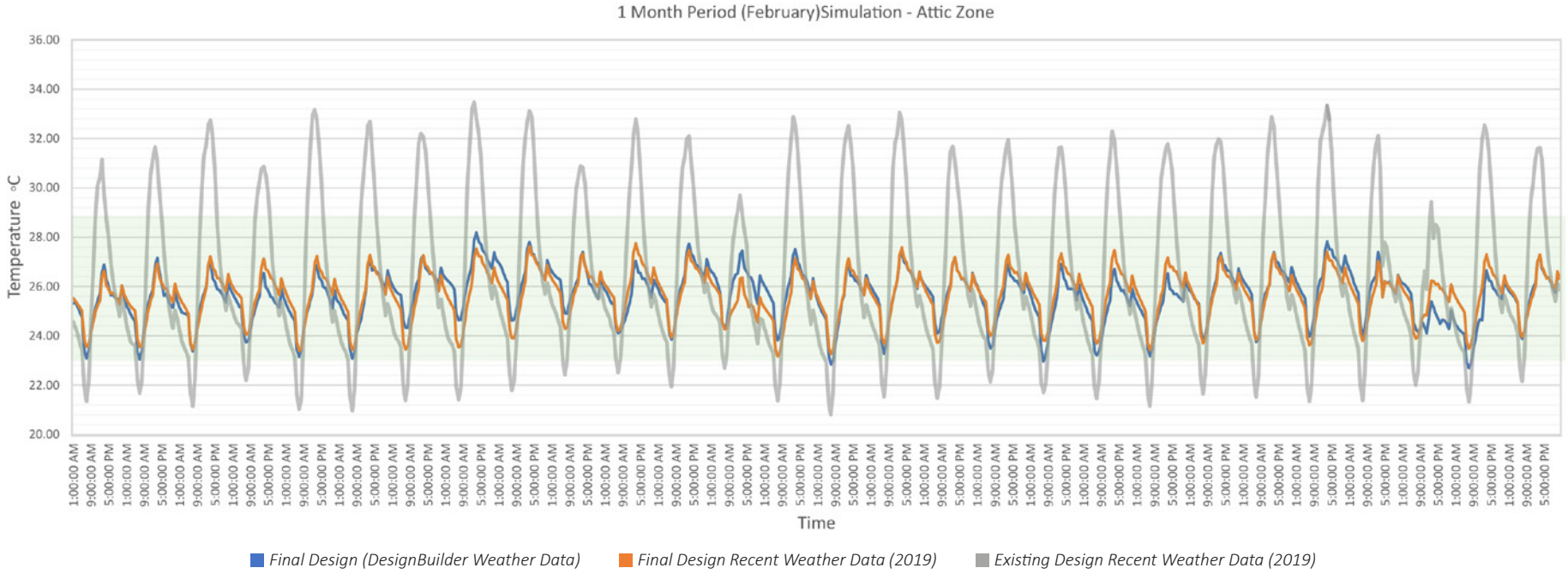
Final Design Improvements

View from the Attic

Final Design Improvements

Comfort Performance: Attic Zone





Final Design Improvements

Recommendations

1. **Lowering the attic floor**: The attic floor is lowered by 286 mm to the top of the door openings.
2. **Openings at sleeping level:** 178 mm high at the sleeping area and 246 mm high other openings.
3. **Roof openings:** Roof openings are provided by creating a double hip roof.
4. **Collapsible louvered doors:** Help in controlling air velocity and privacy.

Further Studies & Limitations

Further Studies

1. **Calibration & Improvement**: of the IoT monitoring device
2. **Optimization**: the opening size, roof structure, indoor wind flow
3. **Effect of radiative cooling**
4. Materials

Limitations

1. Building was **unoccupied** during the field visit. Interviews could not be carried out
2. **Calibration of DesignBuilder model** with in situ measurement is not done

Thank You!!!

Questions !