**Personal information**
Marijn Soeterbroek (4367626)

**Studio**
Architectural Engineering
Design tutor: Pieter Stoutjesdijk
Research tutor: Martin Tenpierik

# **P2** | Graduation Studio aE

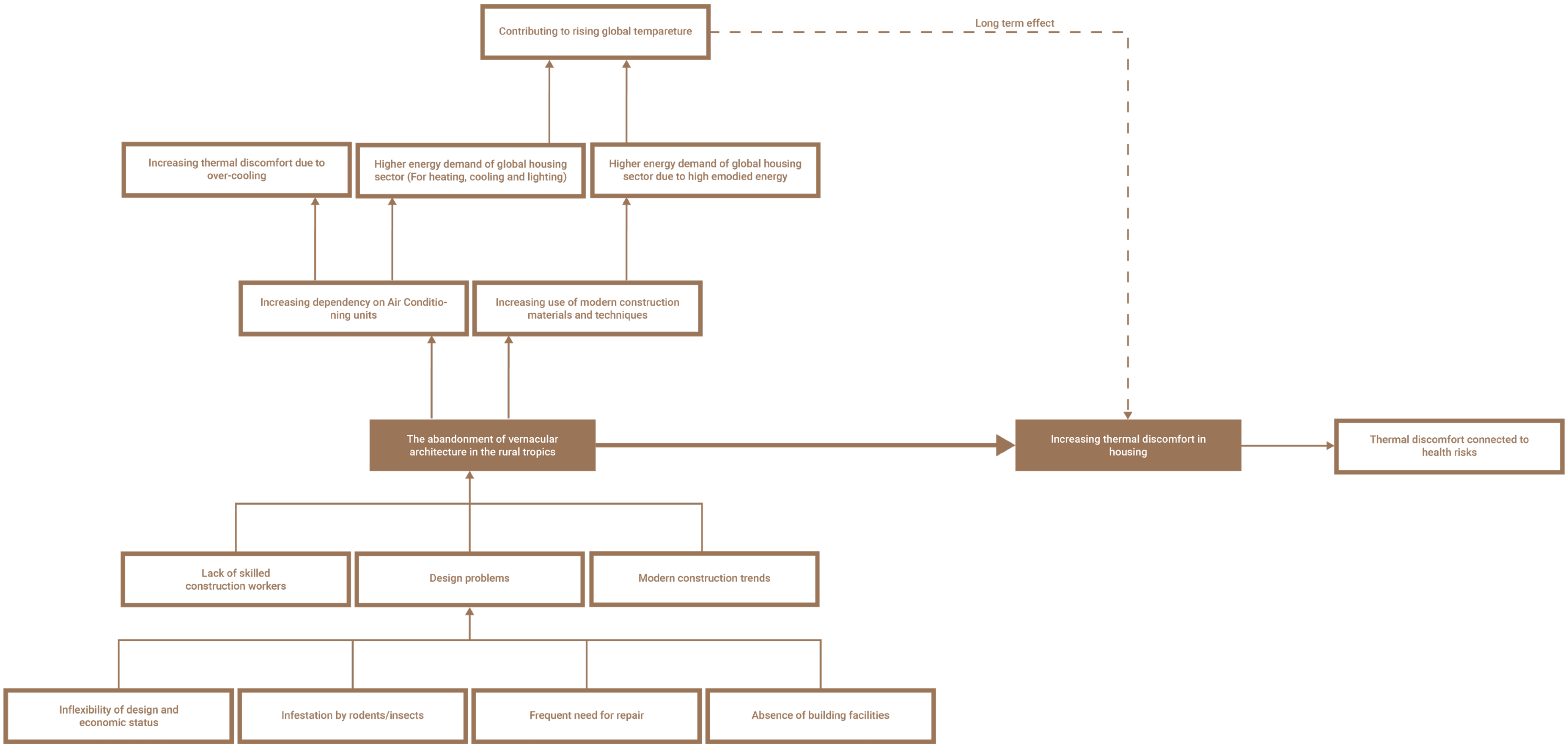
**Problem statement**

Design question

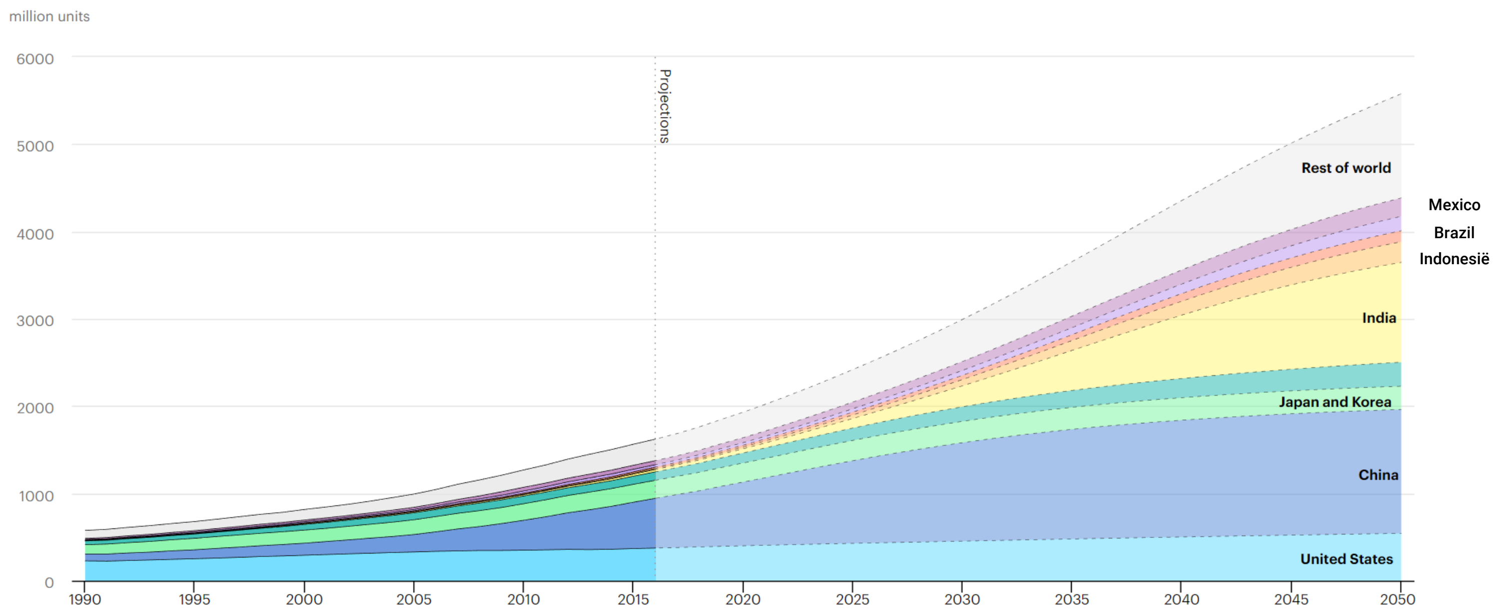
Research question

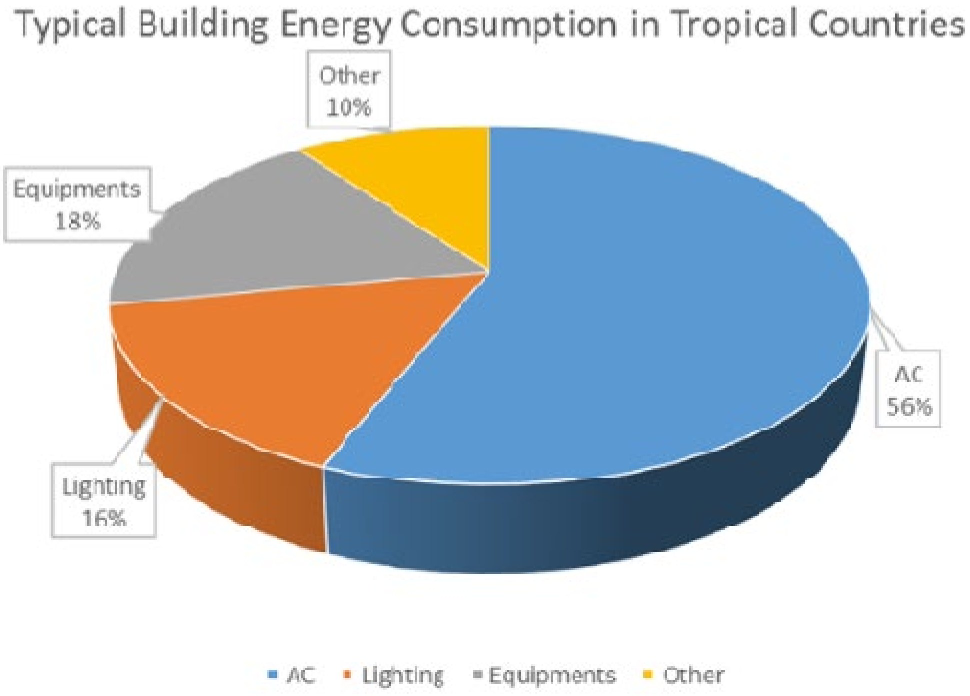
Design criteria I - V

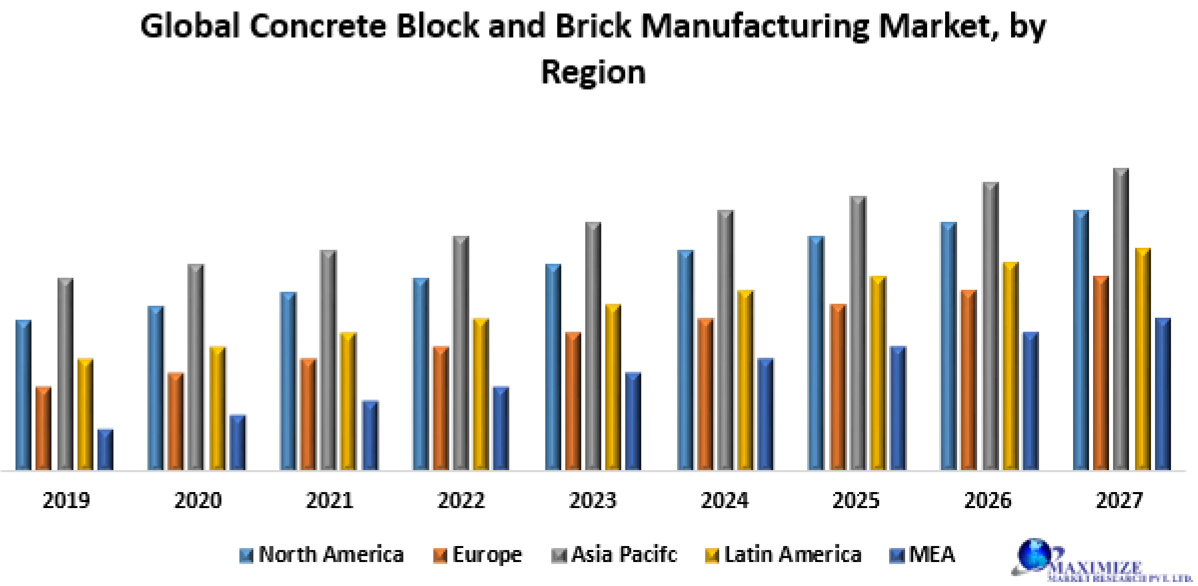
Design proposal

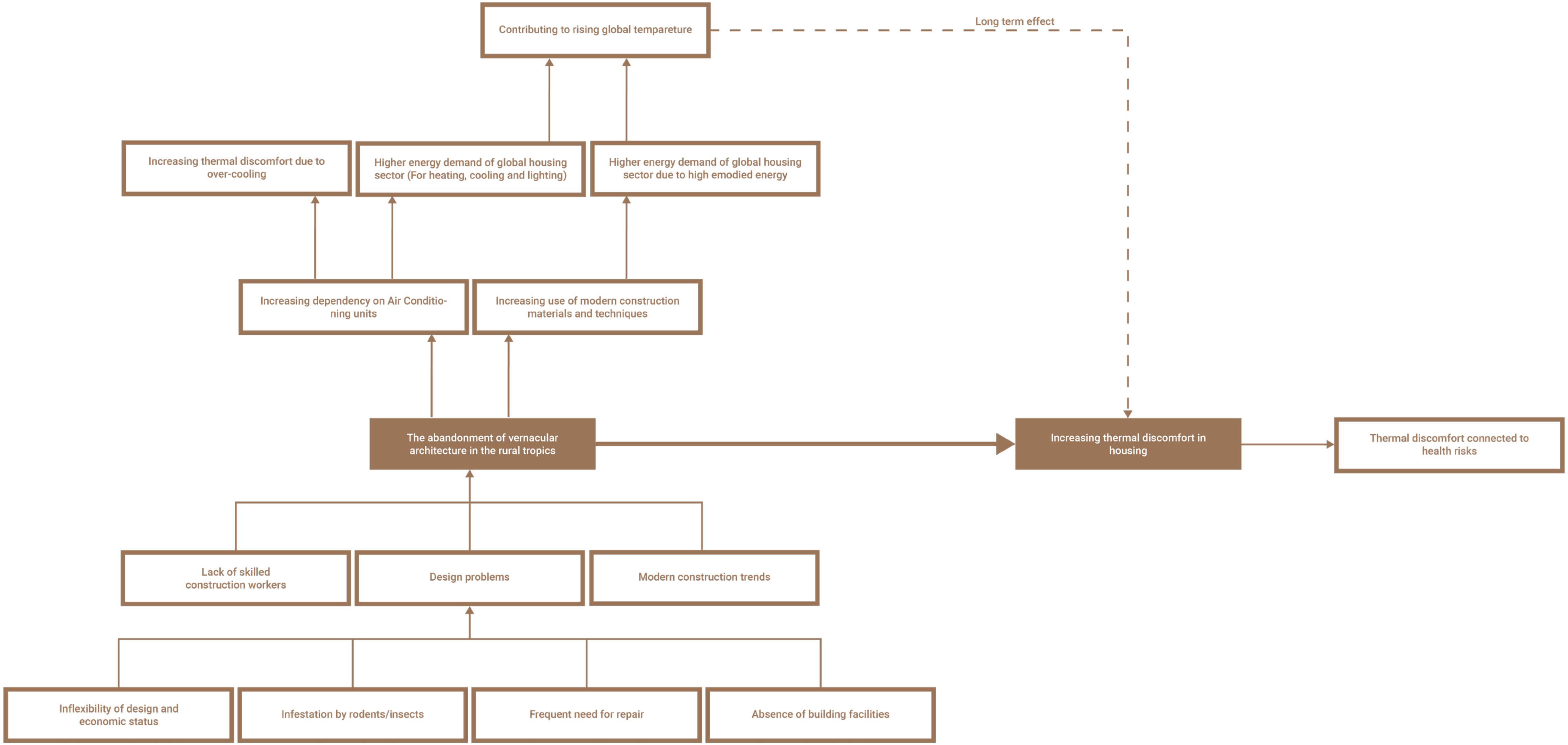

Contributing to rising global tempareture
Long term effect
Increasing thermal discomfort due to over-cooling
Higher energy demand of global housing sector (For heating, cooling and lighting)
Higher energy demand of global housing sector due to high emodied energy
Increasing dependency on Air Conditio-ning units
Increasing use of modern construction materials and techniques
The abandonment of vernacular architecture in the rural tropics
Increasing thermal discomfort in housing
Thermal discomfort connected to health risks
Lack of skilled construction workers
Design problems
Modern construction trends
Inflexibility of design and economic status
Infestation by rodents/insects
Frequent need for repair
Absence of building facilities

# Projected demand AC unit's




Typical Building Energy Consumption in Tropical Countries
Other 10%
Equipments 18%
AC 56%
Lighting 16%
AC
Lighting
Equipments
Other


Global Concrete Block and Brick Manufacturing Market, by Region
2019
2020
2021
2022
2023
2024
2025
2026
2027
North America
Europe
Asia Pacifc
Latin America
MEA
MAXIMIZE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Absence of building facilities

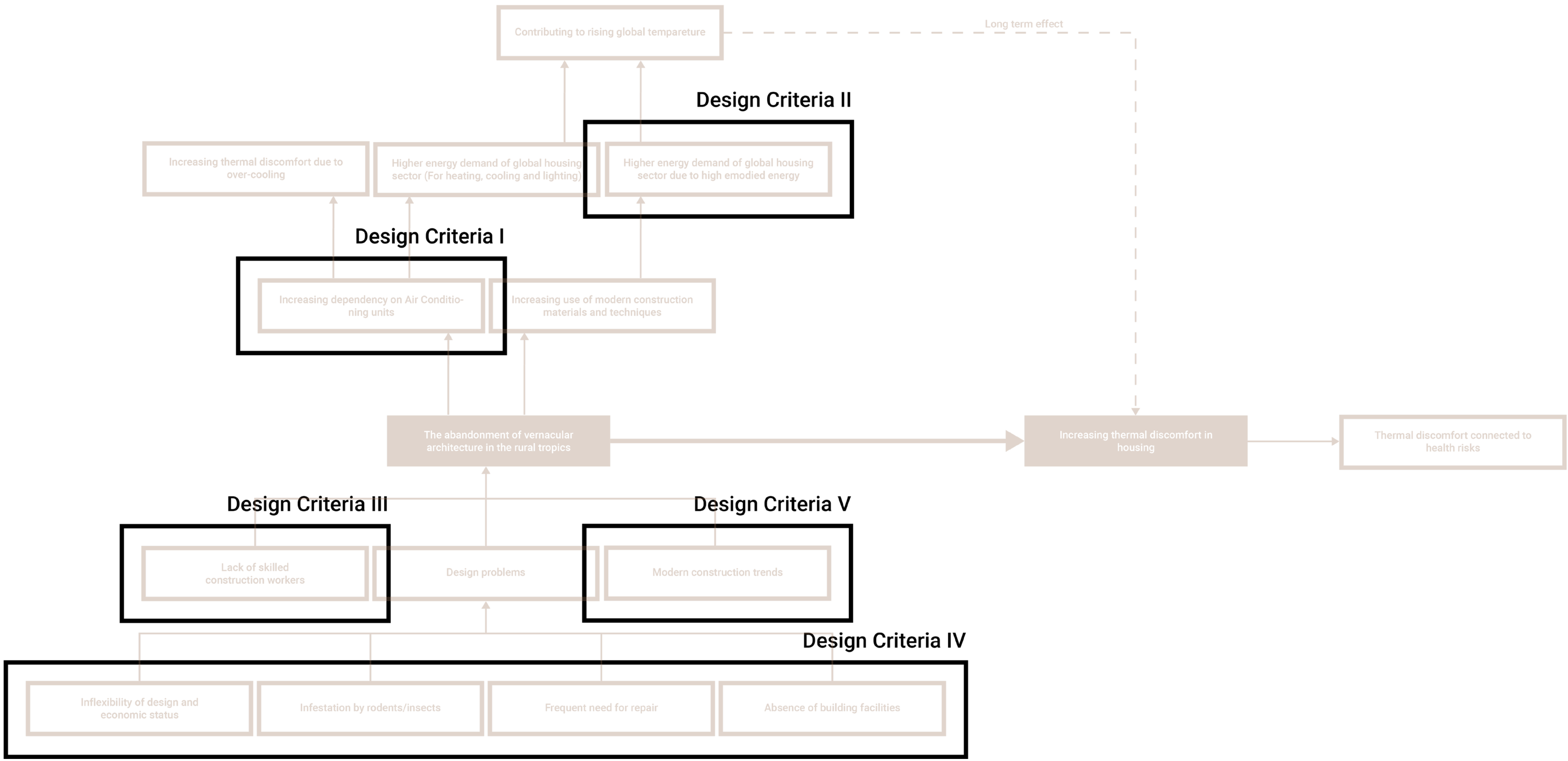
Problem statement

**Design question**

Research question

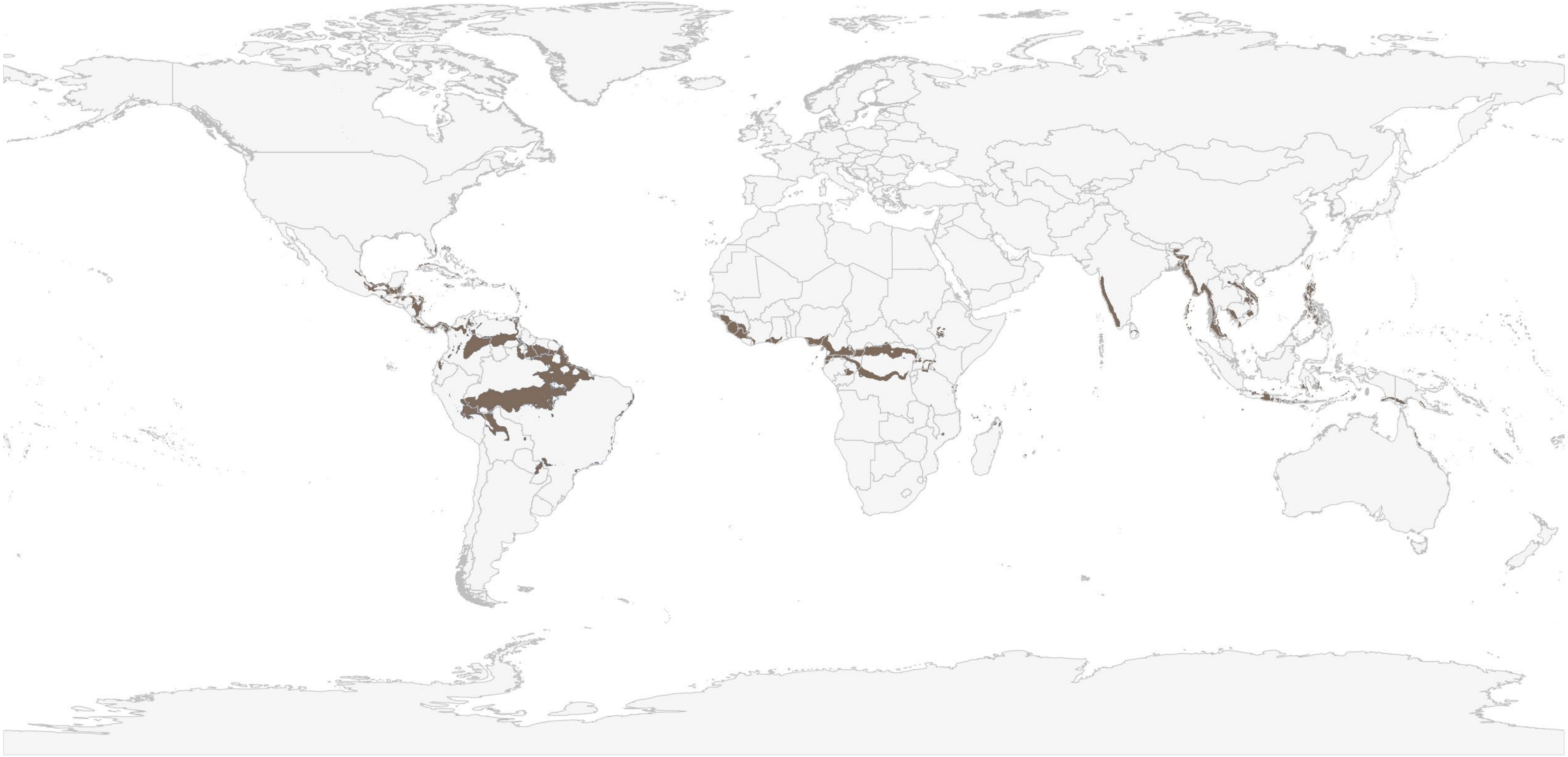
Design criteria I - V

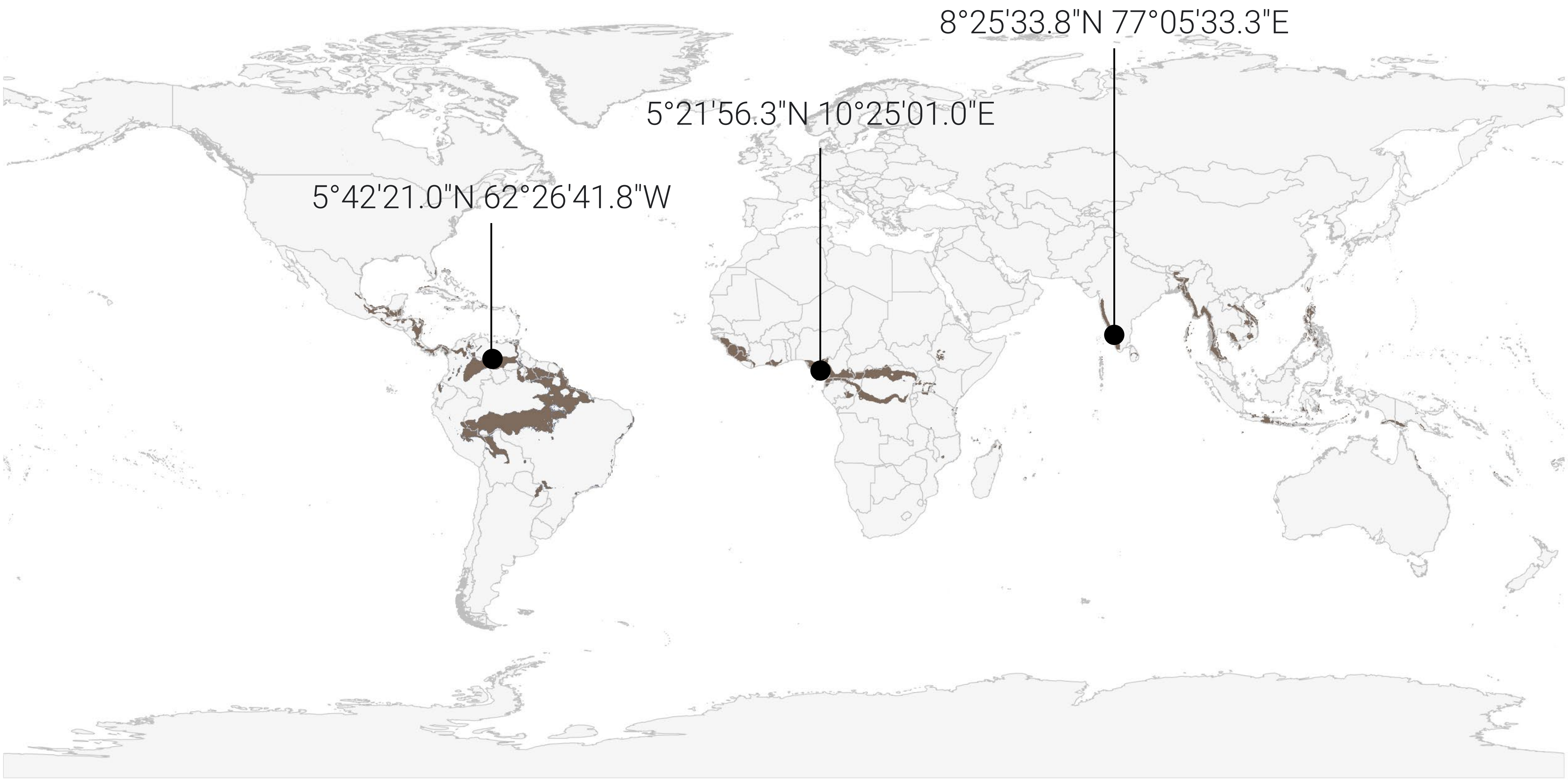
Design proposal

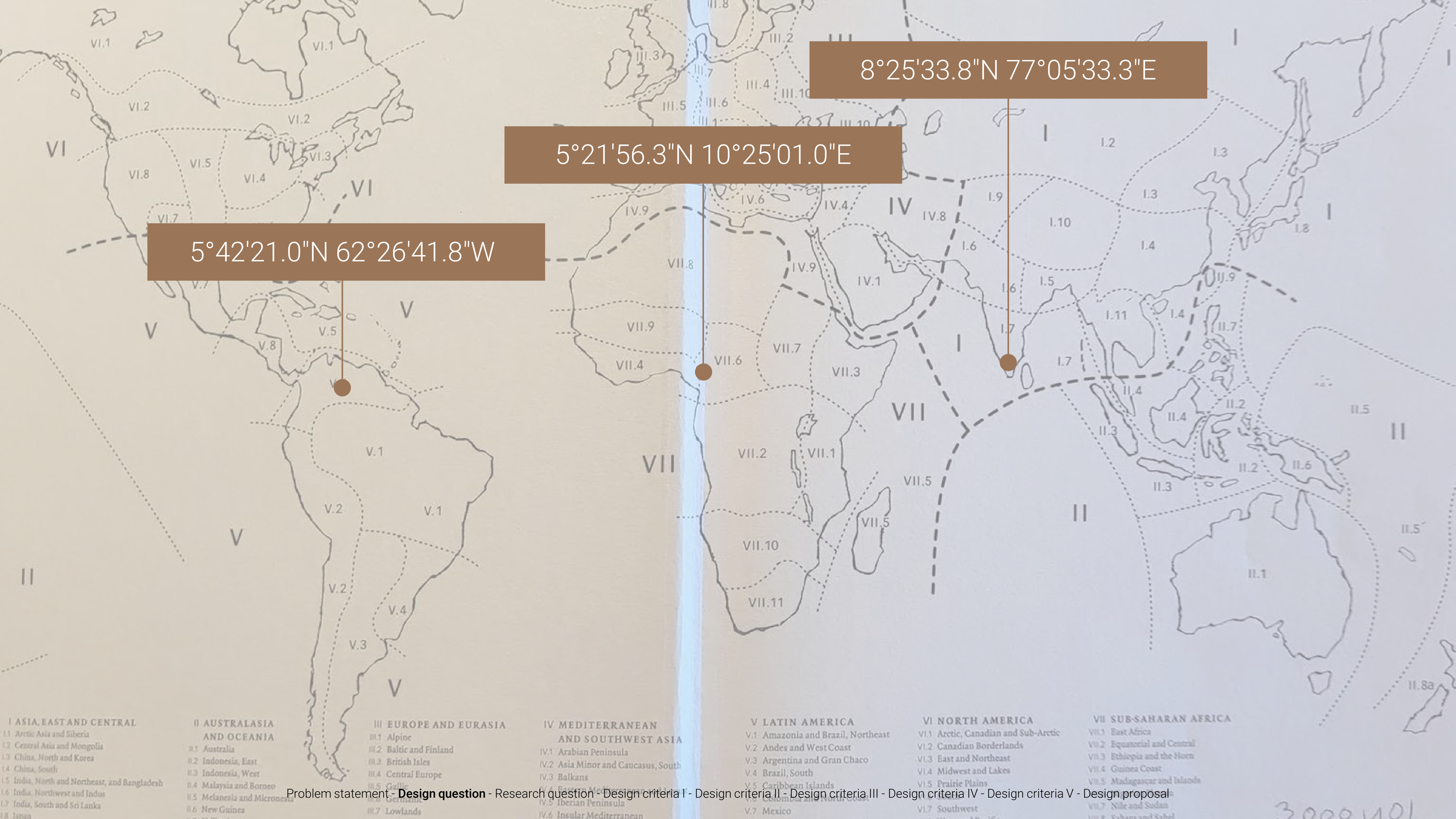

Contributing to rising global tempareture
Long term effect
Design Criteria II
Increasing thermal discomfort due to over-cooling
Higher energy demand of global housing sector (For heating, cooling and lighting)
Higher energy demand of global housing sector due to high emodied energy
Design Criteria I
Increasing dependency on Air Conditio-ning units
Increasing use of modern construction materials and techniques
The abandonment of vernacular architecture in the rural tropics
Increasing thermal discomfort in housing
Thermal discomfort connected to health risks
Design Criteria III
Design Criteria V
Lack of skilled construction workers
Design problems
Modern construction trends
Design Criteria IV
Inflexibility of design and economic status
Infestation by rodents/insects
Frequent need for repair
Absence of building facilities

| | |
|---|---|
| **Design Criteria I:** | Passively provide [adaptive] thermal comfort |
| **Design Criteria II:** | Fully bio-based |
| **Design Criteria III:** | Buildable with local construction workers |
| **Design Criteria IV:** | Adaptable to users from different regions |
| **Design Criteria V:** | Building system that can be implemented throughout tropical climate region |

How can a **fully biobased rural dwelling for a tropical climate** be designed that passively provides thermal comfort, is buildable by local construction workers, and can be adapted to the specific needs of users/communities from different regions?




8°25'33.8"N 77°05'33.3"E
5°21'56.3"N 10°25'01.0"E
5°42'21.0"N 62°26'41.8"W


5°42'21.0"N 62°26'41.8"W
5°21'56.3"N 10°25'01.0"E
8°25'33.8"N 77°05'33.3"E
I ASIA, EAST AND CENTRAL
I.1 Arctic Asia and Siberia
I.2 Central Asia and Mongolia
I.3 China, North and Korea
I.4 China, South
I.5 India, North and Northeast, and Bangladesh
I.6 India, Northwest and Indus
I.7 India, South and Sri Lanka
II AUSTRALASIA AND OCEANIA
II.1 Australia
II.2 Indonesia, East
II.3 Indonesia, West
II.4 Malaysia and Borneo
II.5 Melanesia and Micronesia
II.6 New Guinea
III EUROPE AND EURASIA
III.1 Alpine
III.2 Baltic and Finland
III.3 British Isles
III.4 Central Europe
III.7 Lowlands
IV MEDITERRANEAN AND SOUTHWEST ASIA
IV.1 Arabian Peninsula
IV.2 Asia Minor and Caucasus, South
IV.3 Balkans
IV.5 Iberian Peninsula
IV.6 Insular Mediterranean
V LATIN AMERICA
V.1 Amazonia and Brazil, Northeast
V.2 Andes and West Coast
V.3 Argentina and Gran Chaco
V.4 Brazil, South
V.5 Caribbean Islands
V.7 Mexico
VI NORTH AMERICA
VI.1 Arctic, Canadian and Sub-Arctic
VI.2 Canadian Borderlands
VI.3 East and Northeast
VI.4 Midwest and Lakes
VI.5 Prairie Plains
VI.7 Southwest
VII SUB-SAHARAN AFRICA
VII.1 East Africa
VII.2 Equatorial and Central
VII.3 Ethiopia and the Horn
VII.4 Guinea Coast
VII.5 Madagascar and Islands
VII.7 Nile and Sudan

Problem statement

Design question

**Research question**

Design criterial I - V

Design proposal

How and to what extend do **bioclimatic strategies** in **vernacular architecture** provide adaptive **thermal comfort** in a tropical monsoon climate?

Problem statement

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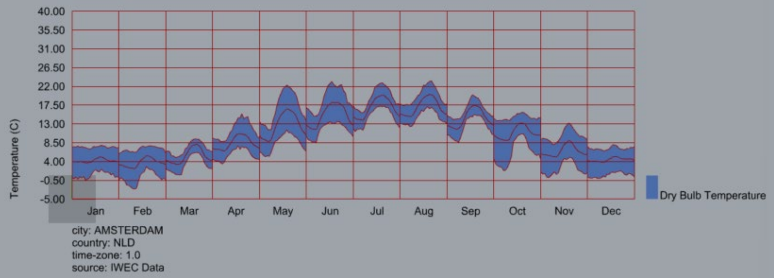
Research question

**Design criteria I: Passively provide thermal comfort**

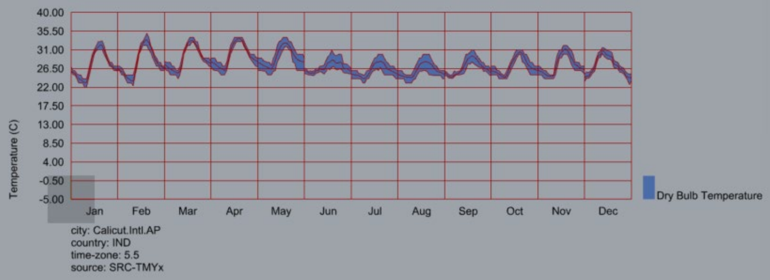
Design proposal

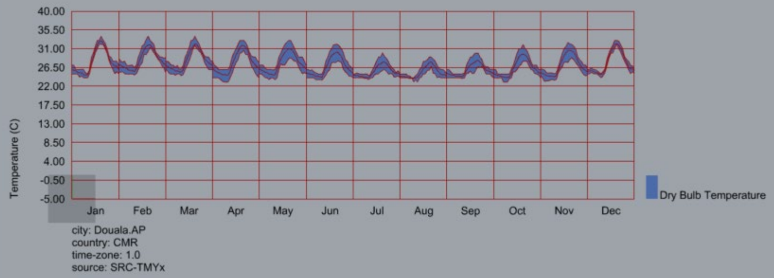
# Dry Bulb Temperature [Monthly plot]

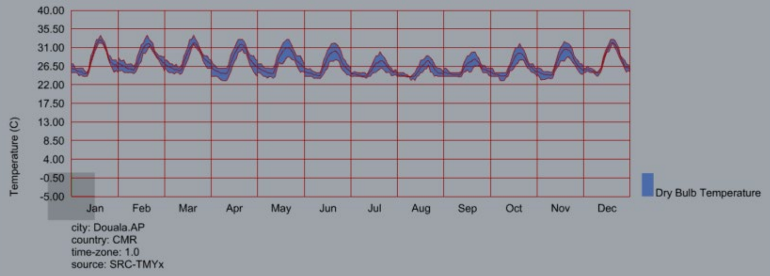
## Netherlands




## Tropical monsoon climate

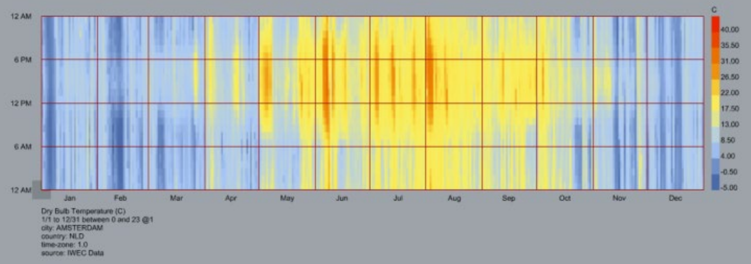


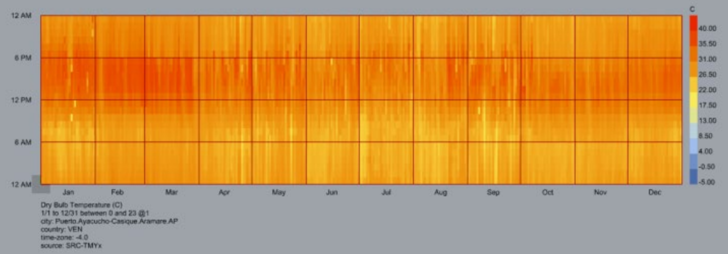



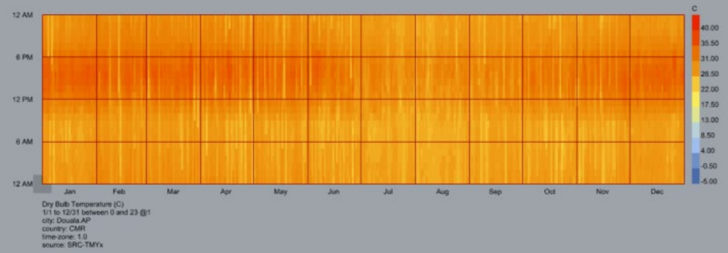
# Dry Bulb Temperature [Hourly plot]

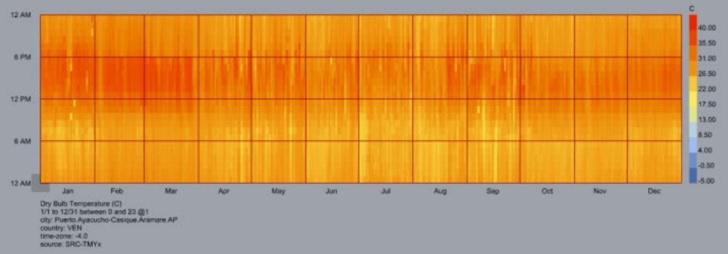
## Netherlands




## Tropical monsoon climate

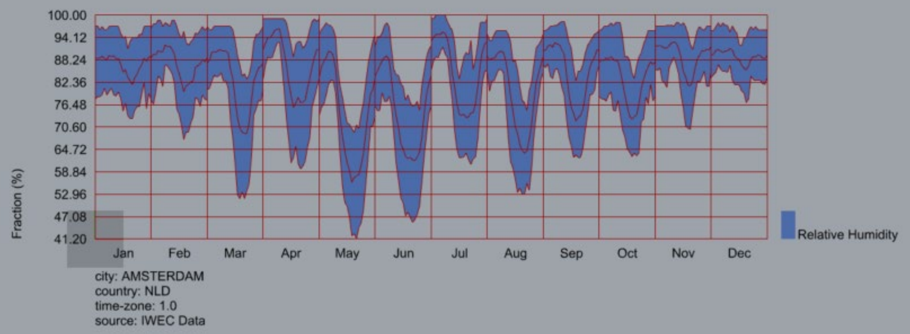


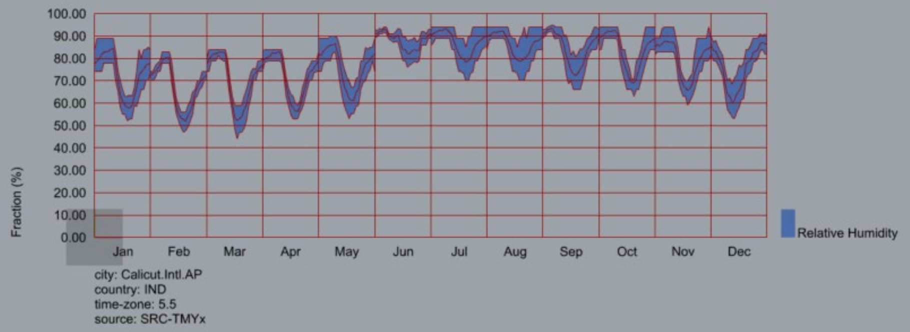



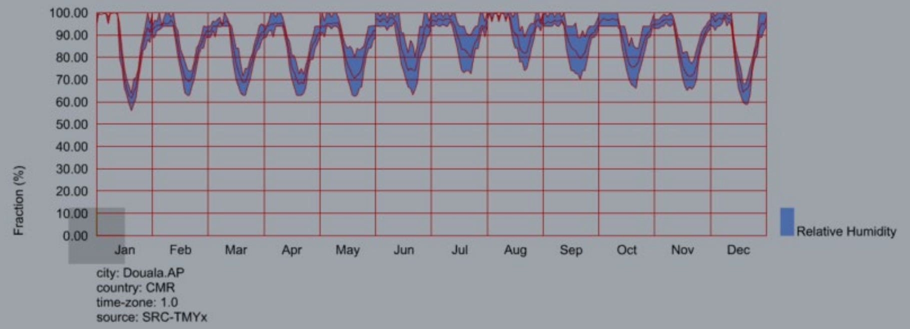
# Relative Humidity [Monthly plot]

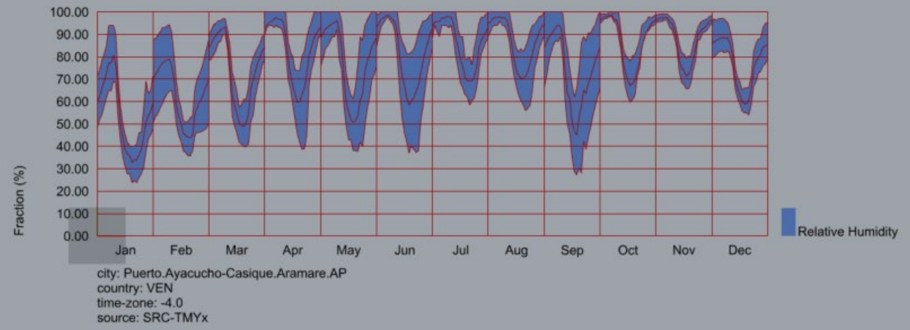
## Netherlands




## Tropical monsoon climate

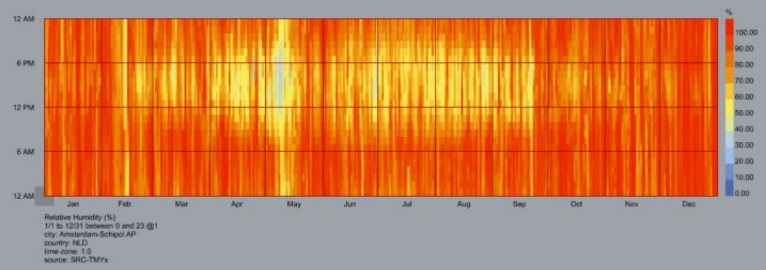


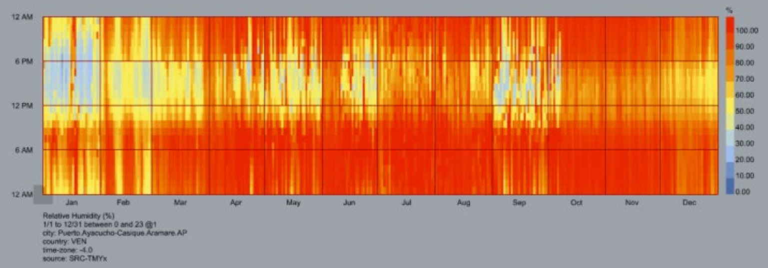



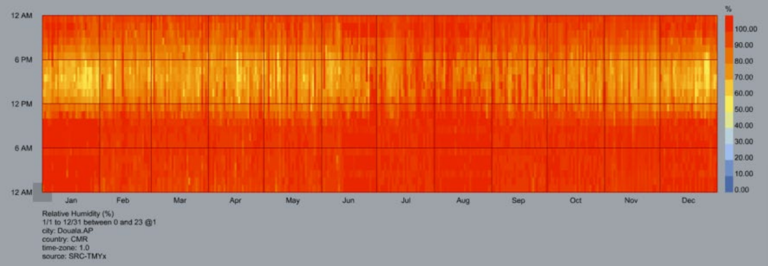
# Relative Humidity [Hourly plot]

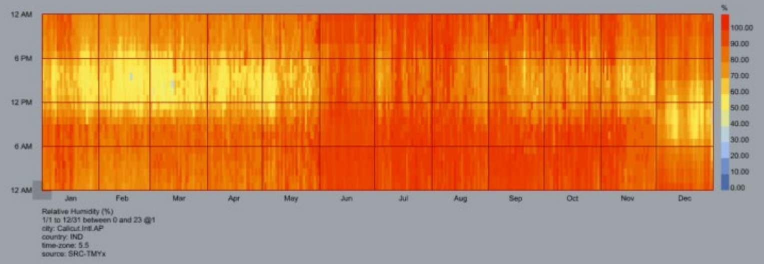
## Netherlands




## Tropical monsoon climate

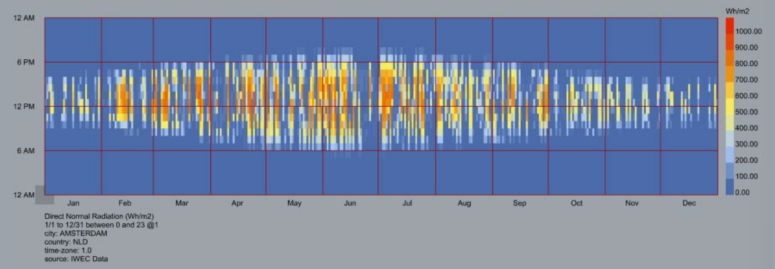


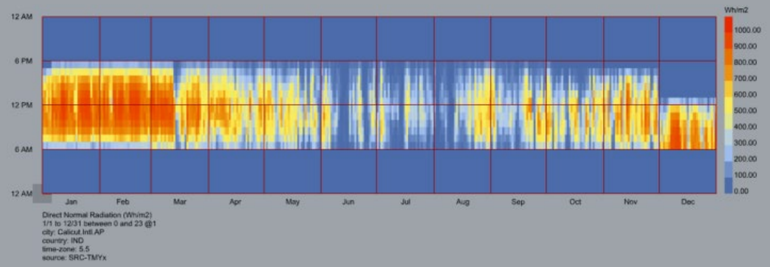



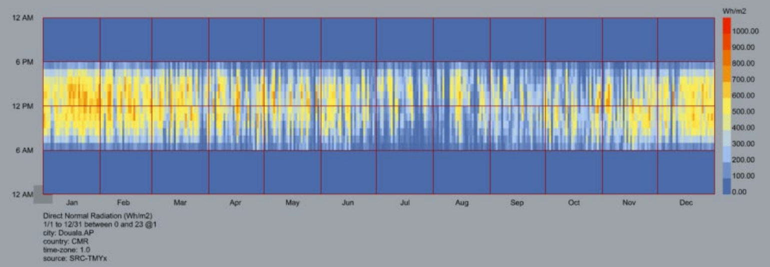
# Solar radiation [Hourly plot]

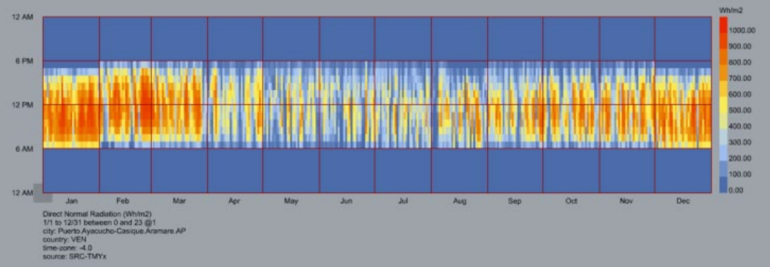
## Netherlands




## Tropical monsoon climate

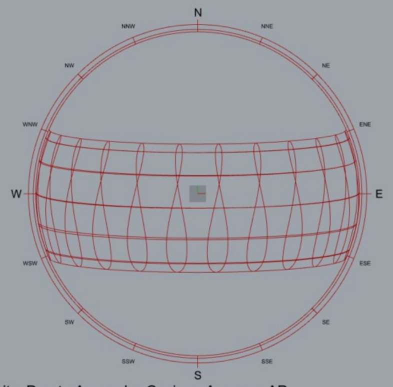


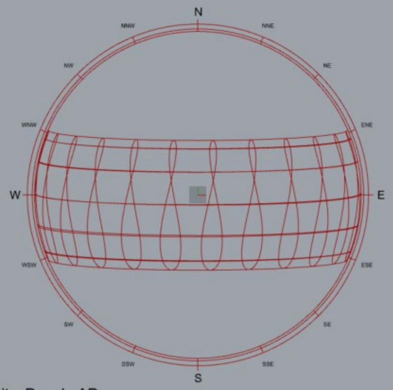



# Sun path

## Tropical monsoon climate

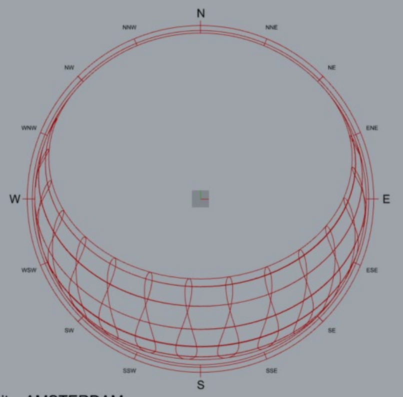



city: Puerto.Ayacucho-Casique.Aramare.AP

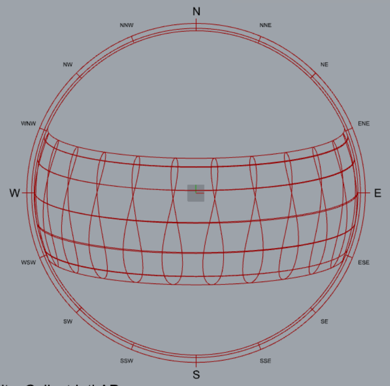



city: Douala.AP

## Netherlands



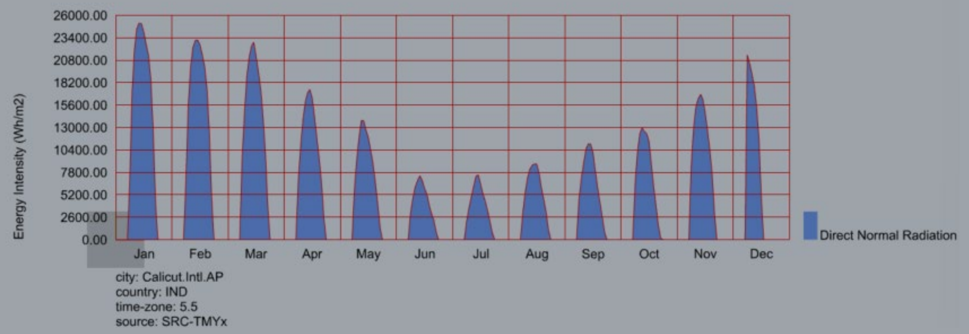

city: AMSTERDAM

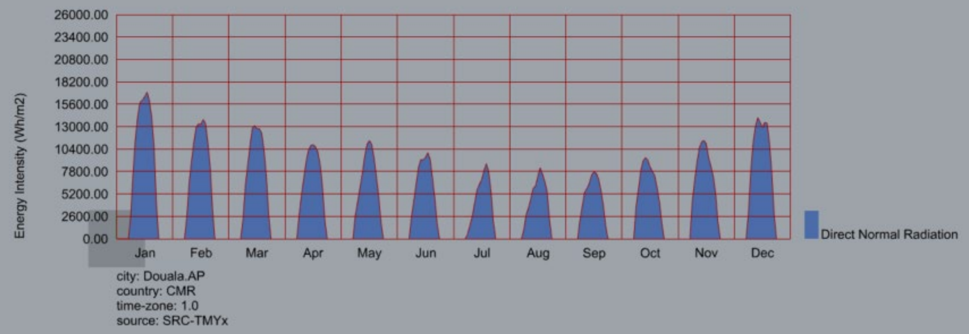



city: Calicut.Intl.AP

# Solar radiation [Monthly plot]

## Tropical monsoon climate

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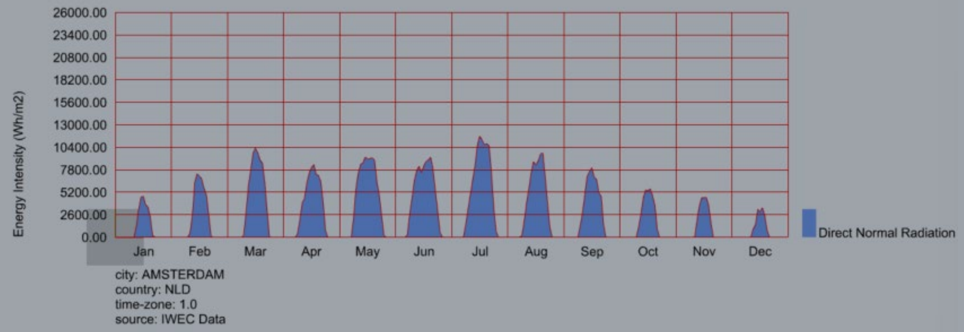
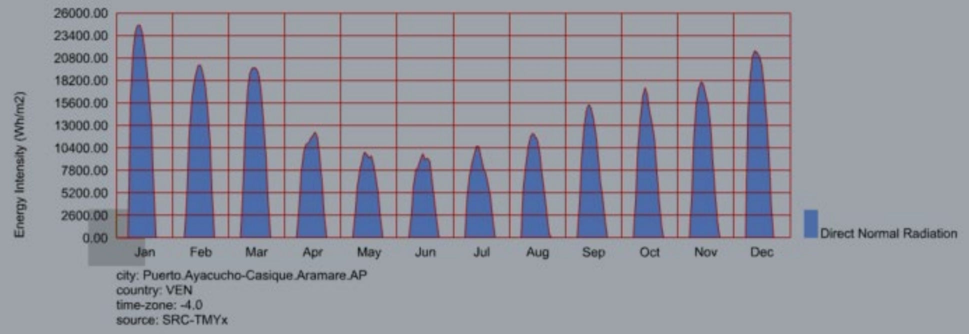
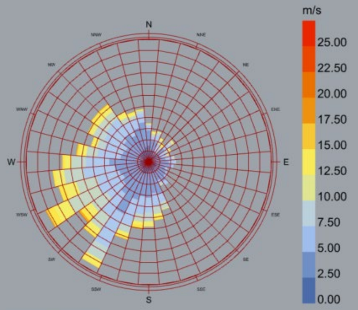


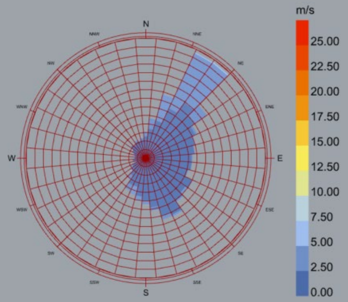
# Wind direction and speed [m/s]

## Netherlands

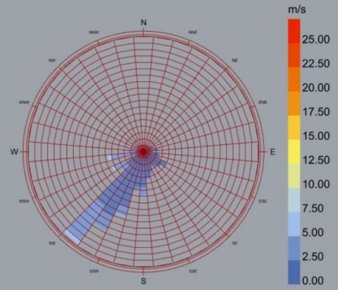



Wind Speed (m/s)
city: AMSTERDAM
country: NLD
time-zone: 1.0
source: IWEC Data
period: 1/1 to 12/31 between 0 and 23 @1
Calm for 0.66% of the time = 58 hours.
Each closed polyline shows frequency of 0.6% = 50 hours.

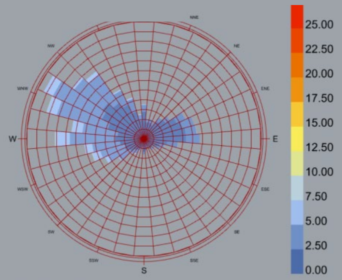
## Tropical monsoon climate




Wind Speed (m/s)
city: Puerto.Ayacucho-Casique.Aramare.AP
country: VEN
time-zone: -4.0
source: SRC-TMYx
period: 1/1 to 12/31 between 0 and 23 @1
Calm for 1.2% of the time = 105 hours.
Each closed polyline shows frequency of 0.6% = 50 hours.



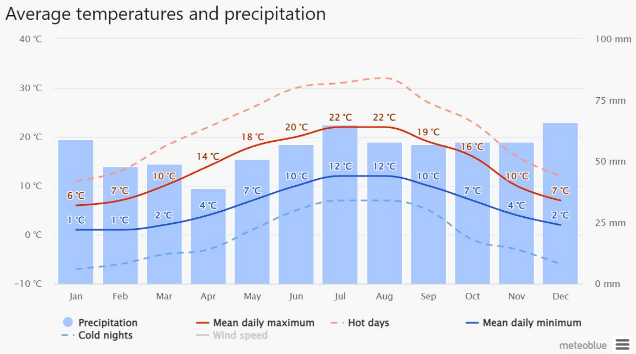

Wind Speed (m/s)
city: Douala.AP
country: CMR
time-zone: 1.0
source: SRC-TMYx
period: 1/1 to 12/31 between 0 and 23 @1
Calm for 29.09% of the time = 2548 hours.
Each closed polyline shows frequency of 0.8% = 50 hours.



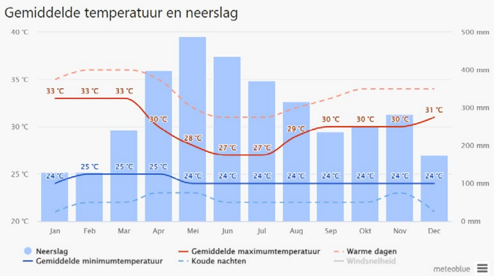

Wind Speed (m/s)
city: Calicut.Intl.AP
country: IND
time-zone: 5.5
source: SRC-TMYx
period: 1/1 to 12/31 between 0 and 23 @1
Calm for 16.97% of the time = 1487 hours.
Each closed polyline shows frequency of 0.7% = 50 hours.

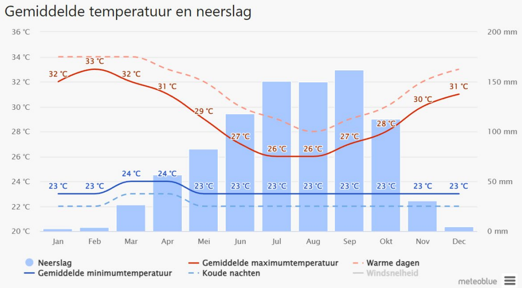
# Precipitation [mm]

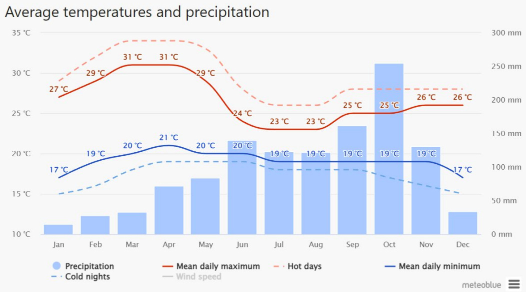
## Netherlands




## Tropical monsoon climate



# Tropical monsoon climate characteristics

**High solar radiation on west, east and horizontal surfaces** (constant throughout the  day and season)

**High average temperature** (constant throughout the  day and season)

**High average relative humidity** (constant throughout the  day and season)

**High precipitation** (constant throughout season and increase during monsoons)

1.Building orientation and shape

2.Solar shading

3.Natural ventilation (cross ventilation (a), stack ventilation (b), single-side ventilation (c))

4.Natural lighting techniques

5.Light weight construction

6.High thermal mass

7.Evaporative cooling

8.Earth cooling

9.Passive cooling by using color

10.Thermal insulation by material

11.Thermal insulation by design (e.g., well ventilated attic, double-skin façade…)

12.Passive solar energy

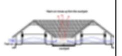
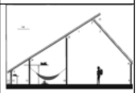
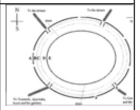
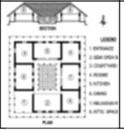
13.Storm prevention

14.Flood prevention

15.Rainwater discharge

16.Moisture and condensation prevention

17.Others

| Climatic Feature | Vernacular house Kerala | | | Vernacular house Bamiléké | | | Vernacular house Piaroa | | |
|---|---|---|---|---|---|---|---|---|---|
| | Description Bioclimatic strategy | No. | Image | Description Bioclimatic strategy | No. | Image | Description Bioclimatic strategy | No. | Image |
| High solar radiation on west, east and horizontal surfaces | Deep eaves (0,7m) and external verandahs to protect (west) walls from excessive heat gain. | |  | granaries between the roofs and ceilings to insulate from heat gain. | |  | Absence of windows to prevent heat gain on west and east walls. | |  |
| | Opposite roof windows at the ridge to stimulate cross and stack ventilation, that prevents heat accumulation. | |  | 0,4-0,5m thick grass thatched roofs for insulate against heat gain. | |  | Use of natural roofing material (palm thatch) for high insulation value. | |  |
| | Wood fenestration opposite walls to improve cross ventilation. | |  | Small door and Absence of windows to prevent solar radiation entering the building. | |  | | | |
| High average temperature | Central courtyard improves natural ventilation by inducing air temperature differences. | |  | Second facade to protect inner walls from solar radiation on west and east façade. | |  | Open facade towards courtyard to naturally ventilate dwelling. | |  |
| High average humidity | Lifted plinth to prevent moisture accumulating. | |  | Waffled wall that allows for infiltration to mitigate accumulated heat and humidity. | |  | Open facade towards courtyard to naturally ventilate dwelling. | |  |
| | Heigh room and ceiling height (3-5m) to vertically stratify thermal comfort. | |  | | | | | | |
| High precipitation | Deep eaves (0,7m) Discharge water improves lifespan of window and doorframes. | |  | 0,7m eaves al around the building to protect facades from heavy rainfall. | |  | Multiple drains to manage large amounts of precipitation. | |  |
| | Steep roof angle (30-40°) to quickly discharge precipitation and prevent moisture accumulation. | |  | Steep roof angle (45-60°) to quickly discharge precipitation and prevent moisture accumulation. | |  | | | |
| | Verandahs externally around the building to protect walls from sun and rain. | |  | | | | | | |

**1.Building orientation and shape**

**2.Solar shading**

**3.Natural ventilation (cross ventilation (a), stack ventilation (b), single-side ventilation (c))**

4.Natural lighting techniques

5.Light weight construction

6.High thermal mass

7.Evaporative cooling

8.Earth cooling

9.Passive cooling by using color

**10.Thermal insulation by material**

**11.Thermal insulation by design (e.g., well ventilated attic, double-skin façade…)**

12.Passive solar energy

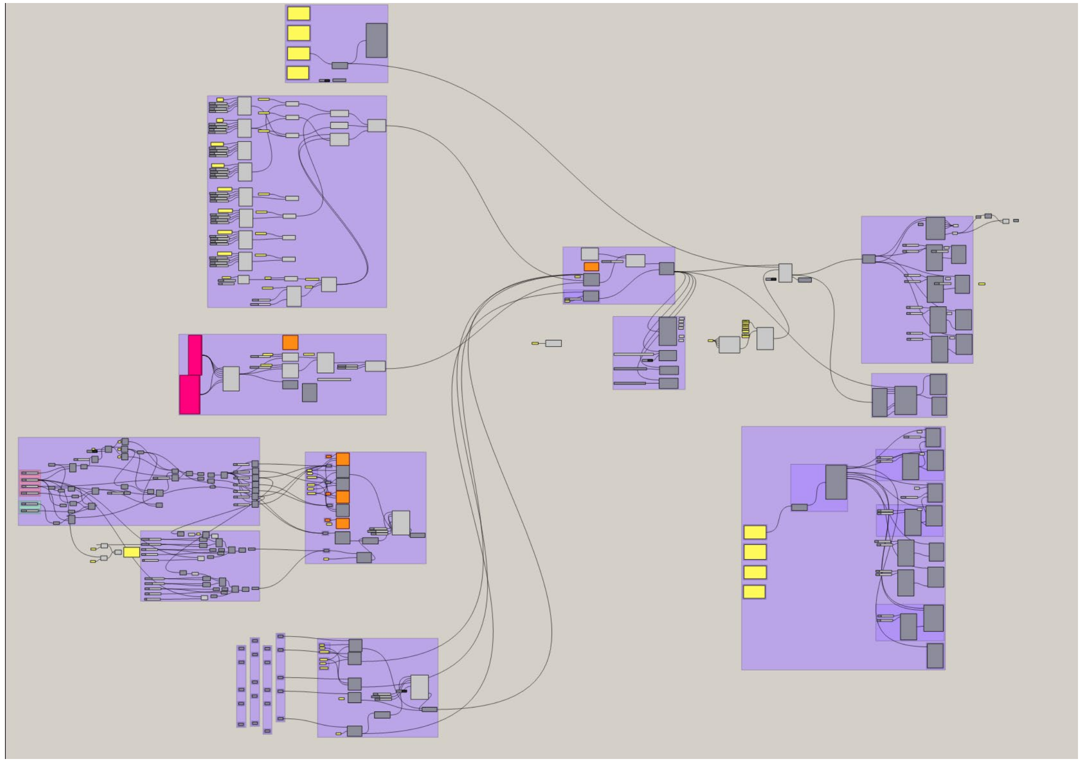
13.Storm prevention

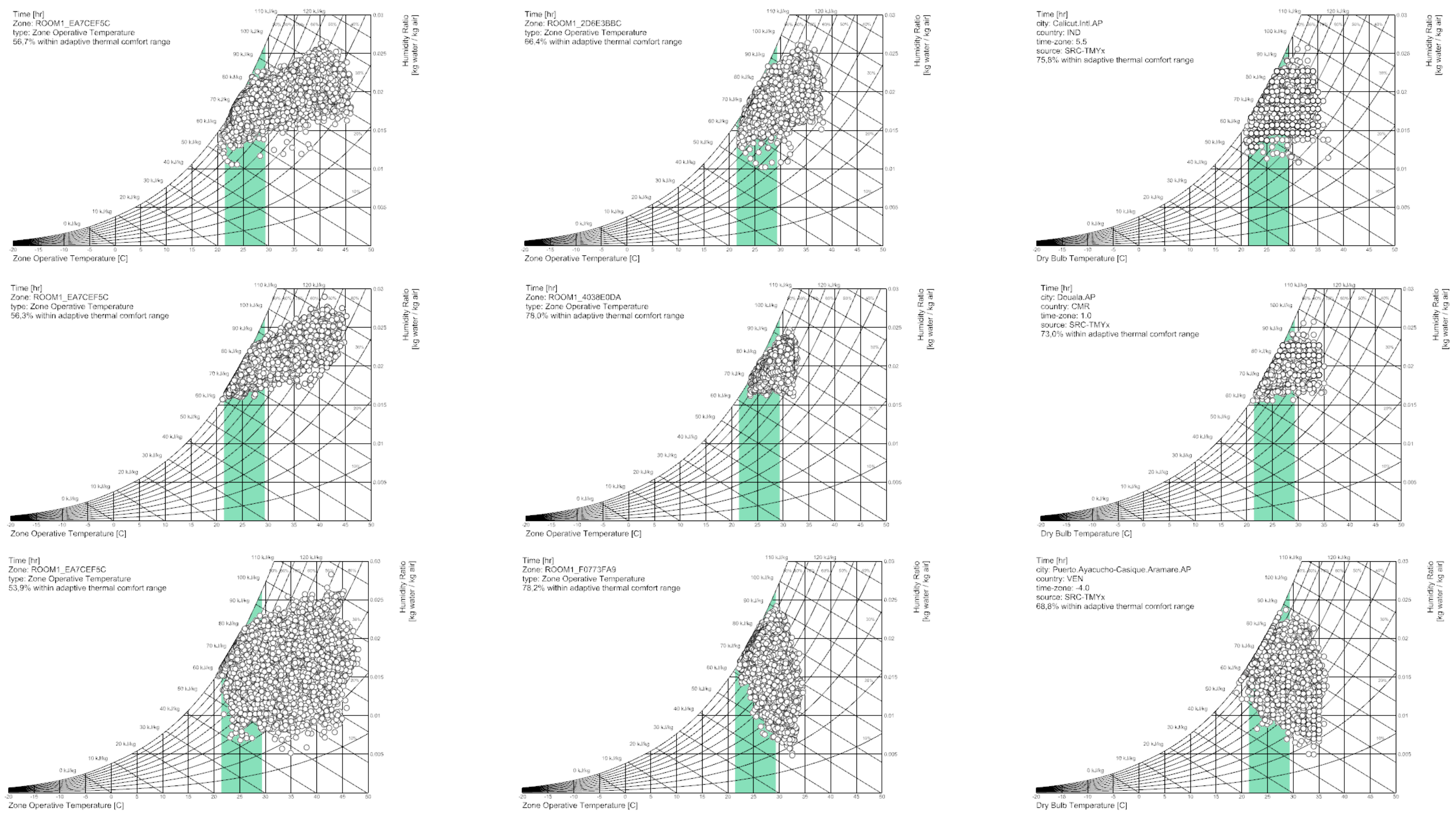
14.Flood prevention

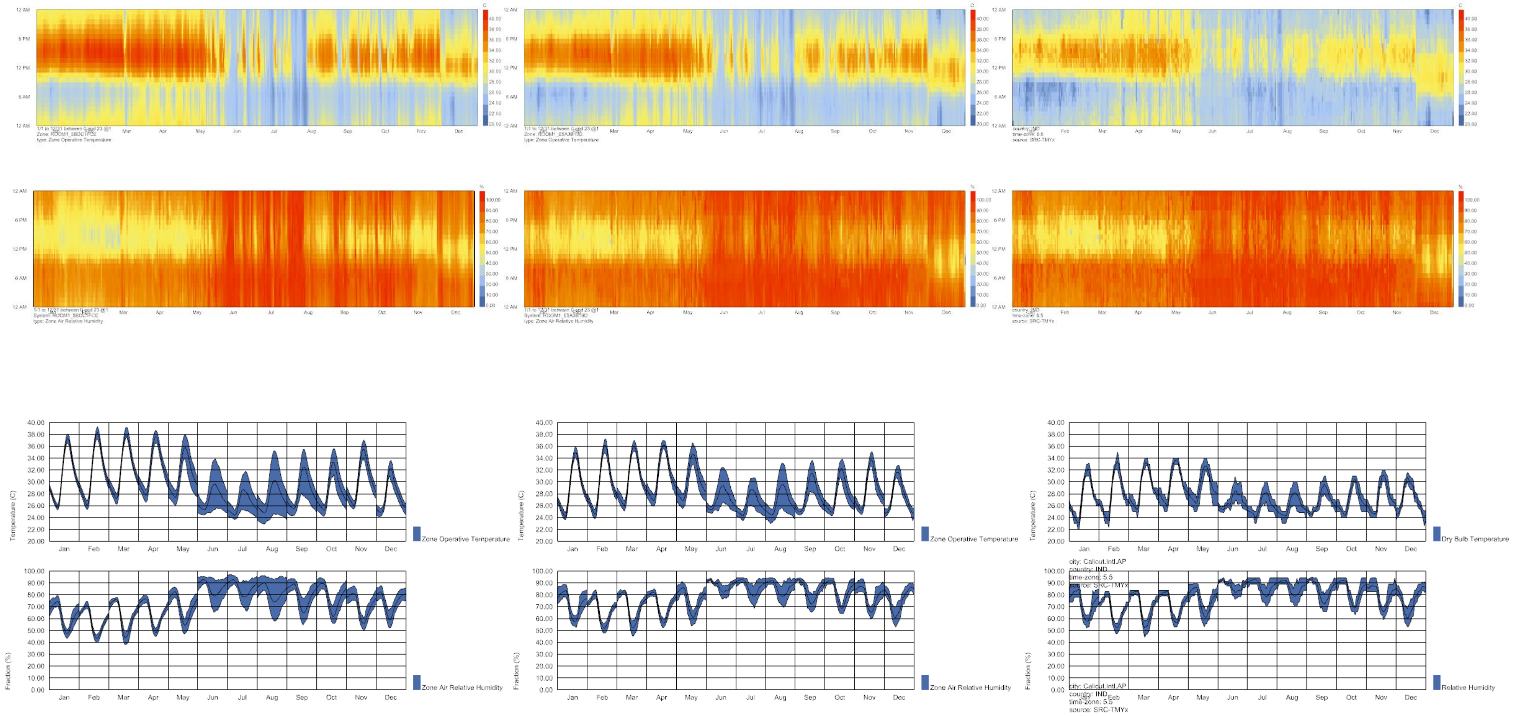
**15.Rainwater discharge**

16.Moisture and condensation prevention

17.Others




Time [hr]
Zone: ROOM1_EA7CEF5C
type: Zone Operative Temperature
56,7% within adaptive thermal comfort range
Zone Operative Temperature [C]
Humidity Ratio [kg water / kg air]
Time [hr]
Zone: ROOM1_2D6E3BBC
type: Zone Operative Temperature
66,4% within adaptive thermal comfort range
Zone Operative Temperature [C]
Humidity Ratio [kg water / kg air]
Time [hr]
city: Calicut.Intl.AP
country: IND
time-zone: 5.5
source: SRC-TMYx
75,8% within adaptive thermal comfort range
Dry Bulb Temperature [C]
Humidity Ratio [kg water / kg air]
Time [hr]
Zone: ROOM1_EA7CEF5C
type: Zone Operative Temperature
56,3% within adaptive thermal comfort range
Zone Operative Temperature [C]
Humidity Ratio [kg water / kg air]
Time [hr]
Zone: ROOM1_4038E0DA
type: Zone Operative Temperature
78,0% within adaptive thermal comfort range
Zone Operative Temperature [C]
Humidity Ratio [kg water / kg air]
Time [hr]
city: Douala.AP
country: CMR
time-zone: 1.0
source: SRC-TMYx
73,0% within adaptive thermal comfort range
Dry Bulb Temperature [C]
Humidity Ratio [kg water / kg air]
Time [hr]
Zone: ROOM1_EA7CEF5C
type: Zone Operative Temperature
53,9% within adaptive thermal comfort range
Zone Operative Temperature [C]
Humidity Ratio [kg water / kg air]
Time [hr]
Zone: ROOM1_F0773FA9
type: Zone Operative Temperature
78,2% within adaptive thermal comfort range
Zone Operative Temperature [C]
Humidity Ratio [kg water / kg air]
Time [hr]
city: Puerto.Ayacucho-Casique.Aramare.AP
country: VEN
time-zone: -4.0
source: SRC-TMYx
68,8% within adaptive thermal comfort range
Dry Bulb Temperature [C]
Humidity Ratio [kg water / kg air]


Zone Operative Temperature
Zone Operative Temperature
Dry Bulb Temperature
Temperature (C)
Zone Air Relative Humidity
Zone Air Relative Humidity
Relative Humidity
Fraction (%)
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

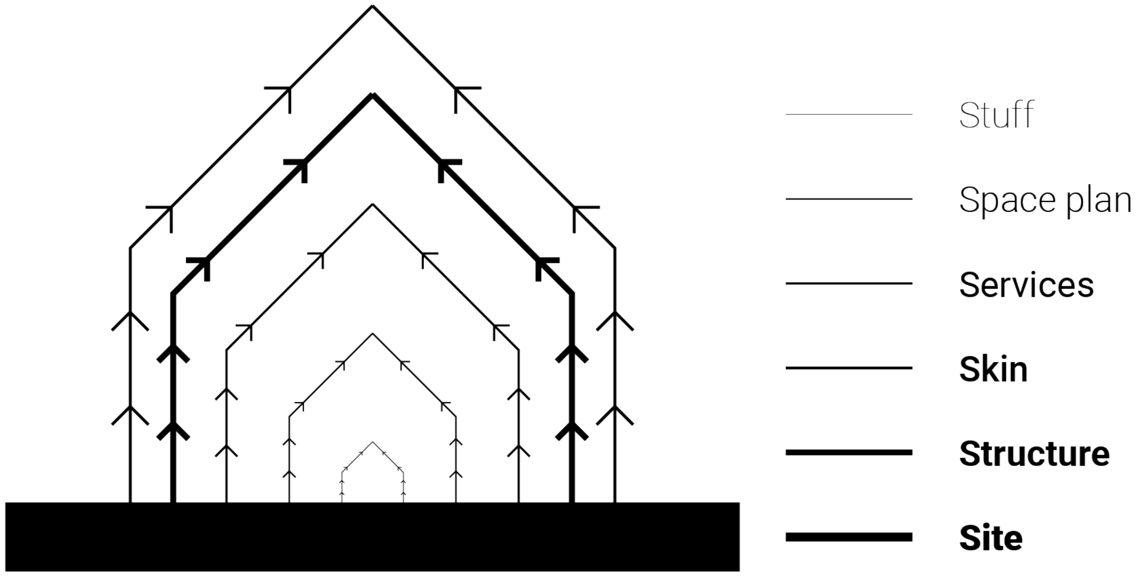
Problem statement

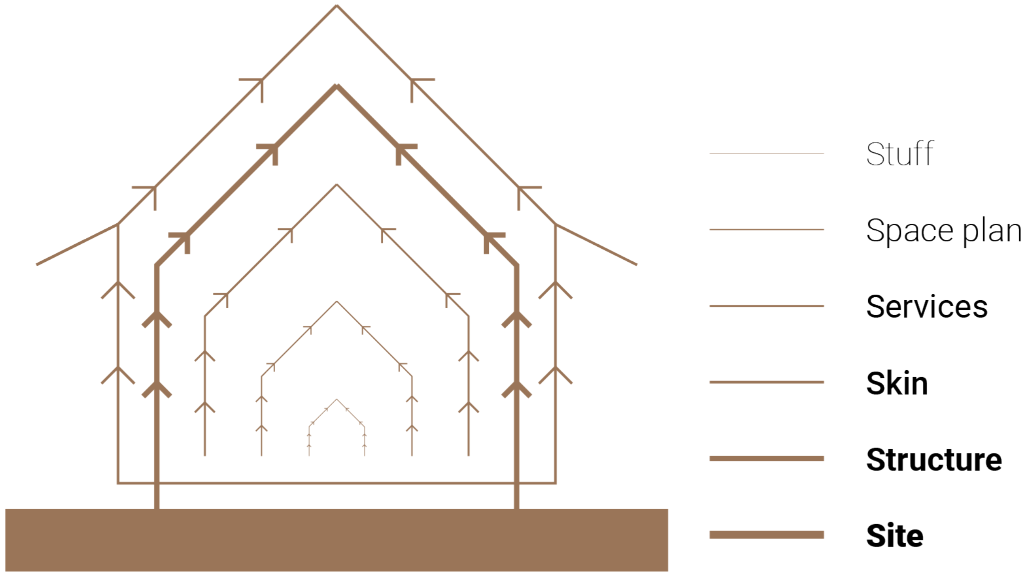
Design question

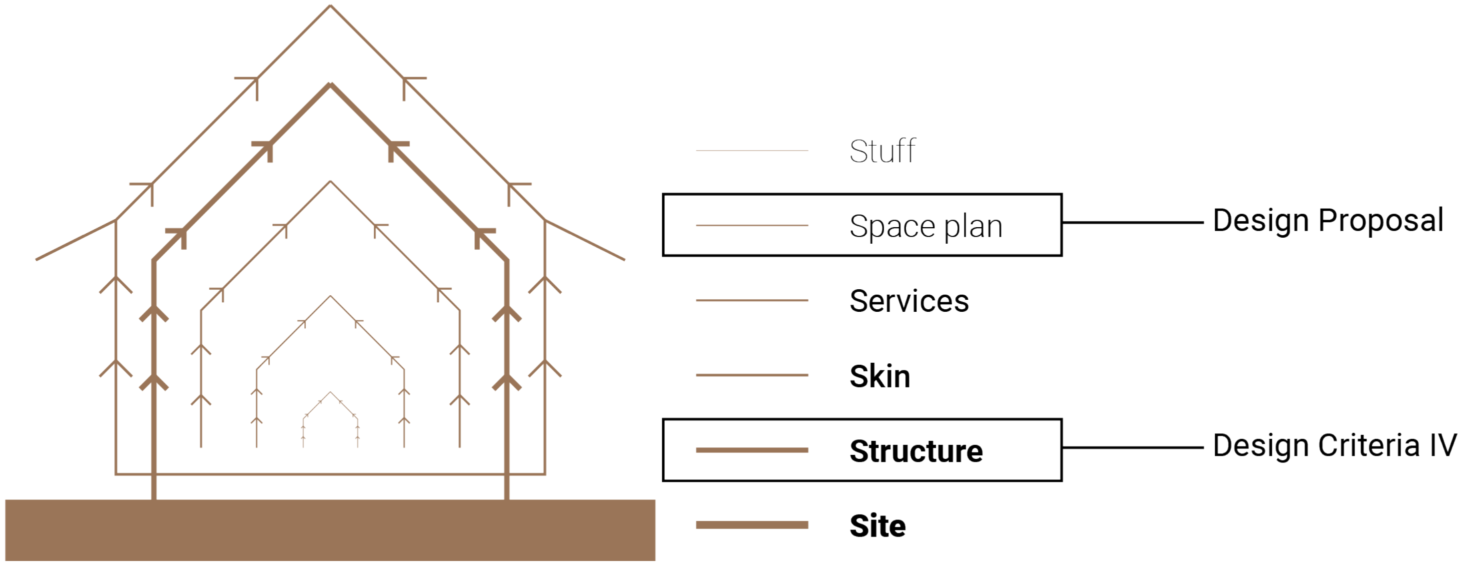
Research question

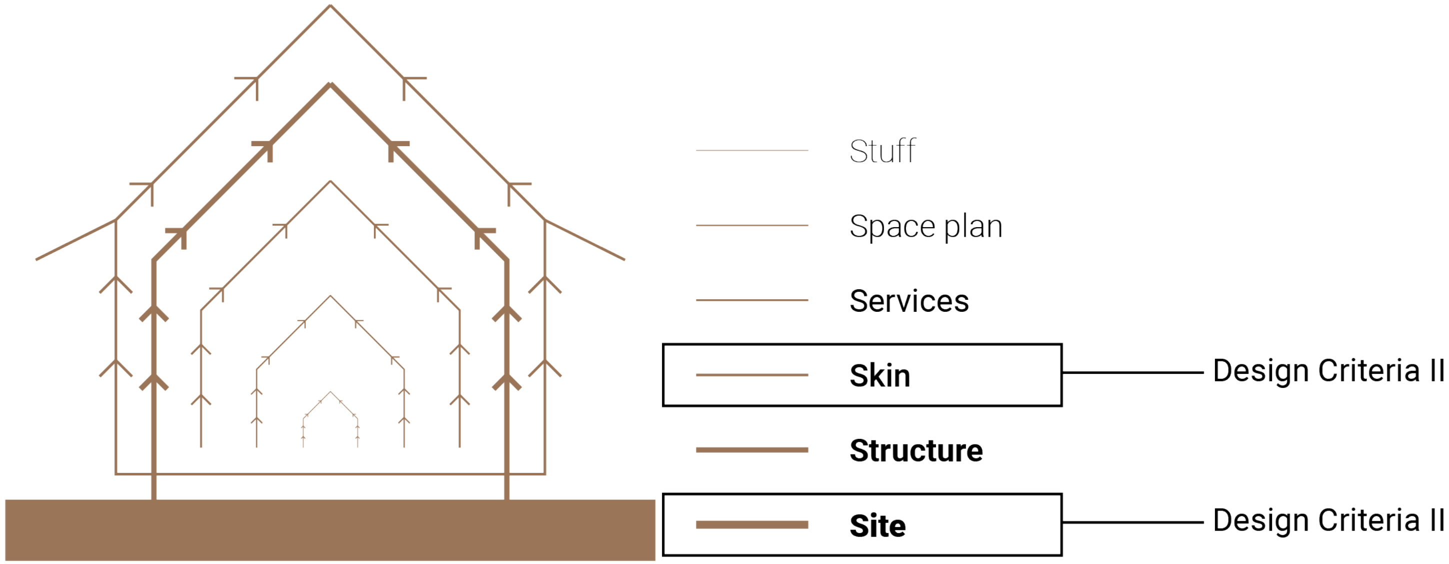
**Design criteria II: Fully bio-based**

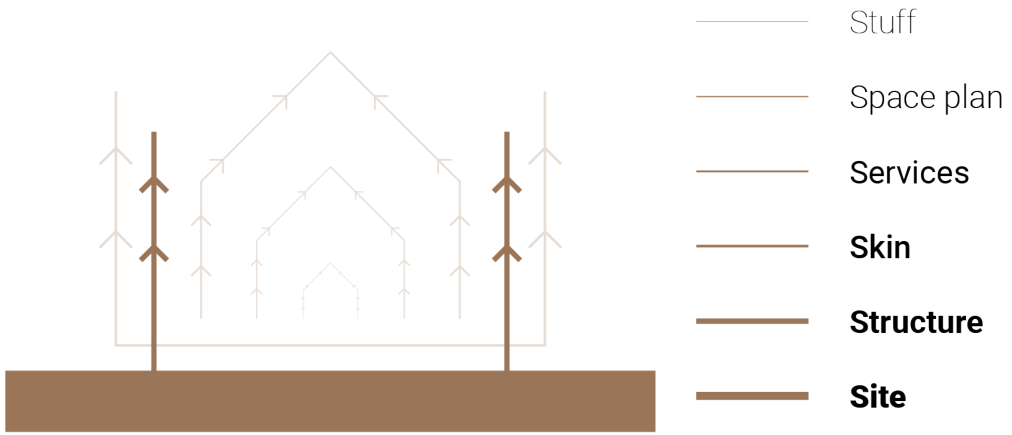
Design proposal

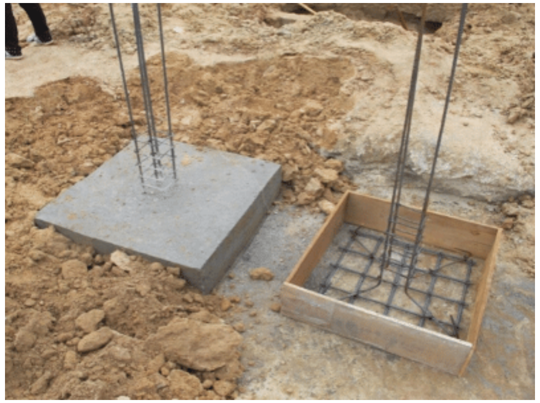

Stuff
Space plan
Services
Skin
Structure
Site

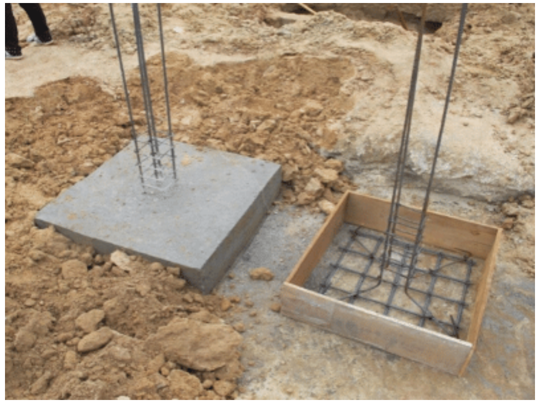

Stuff
Space plan
Services
Skin
Structure
Site


Stuff
Space plan
Services
Skin
Structure
Site
Design Proposal
Design Criteria IV


Stuff
Space plan
Services
Skin
Structure
Site
Design Criteria II
Design Criteria II


Stuff
Space plan
Services
**Skin**
**Structure**
**Site**


Stuff
Space plan
Services
Skin
Structure
Site

Palm thatched roofing - Grass thatched roofing - Clay tile roofing

Infestation and frequent need for repair, especially in critical areas

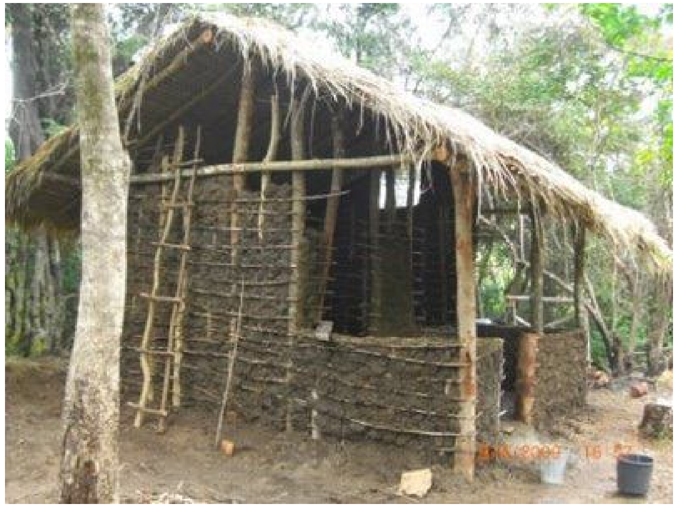
Lower insolation value, thus needing additional insolation

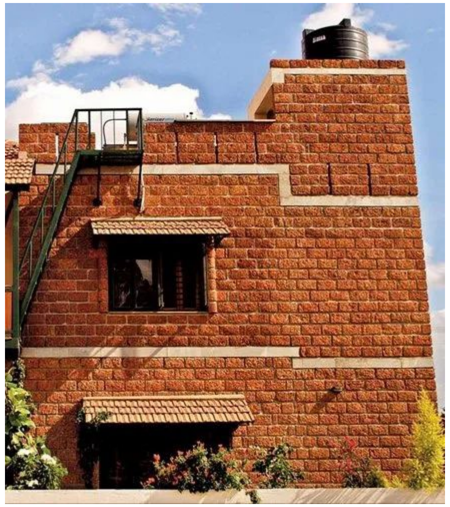





Stuff
Space plan
Services
Skin
Structure
Site

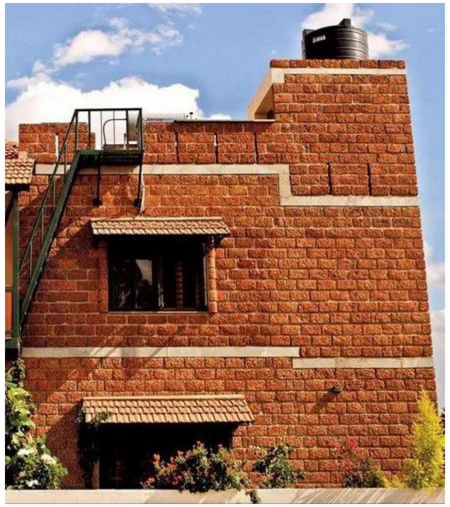
# Mud wattle walls – Laterite block walls





# Not compatible with building method





# Economic status, cracks, infestation


**MATERIAL DESCRIPTION:**
natural wood (exotic species from sustainable plantation), planed surface

**AVALIABLE ON THE MARKET:**

**COST:** €€€€€

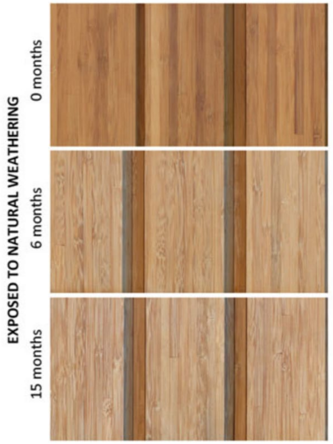
**DURABILITY:**

**FIRE RESISTANCE:**

**RECYCLABILITY:**

**MAINTENANCE EFFORT:**

| months | 0 | 3 | 6 | 9 | 12 | 15 |
|---|---|---|---|---|---|---|
| CIE L* | 63.4 | 72.9 | 75.2 | 76.4 | 77.4 | 76.2 |
| CIE a* | 8.7 | 7.9 | 6.5 | 6.0 | 5.4 | 5.8 |
| CIE b* | 23.3 | 20.7 | 17.2 | 16.8 | 15.6 | 16.8 |
| gloss | 5.2 | 8.2 | 8.6 | 7.2 | 7.4 | 7.4 |




**MATERIAL DESCRIPTION:**
natural material, glued composite, planed surface

**AVALIABLE ON THE MARKET:**

**COST:** €€€€€

**DURABILITY:**

**FIRE RESISTANCE:**

**RECYCLABILITY:**

**MAINTENANCE EFFORT:**

| months | 0 | 3 | 6 | 9 | 12 | 15 |
|---|---|---|---|---|---|---|
| CIE L* | 52.8 | 62.1 | 63.5 | 65.7 | 64.3 | 63.4 |
| CIE a* | 12.2 | 10.7 | 9.0 | 8.4 | 7.4 | 8.1 |
| CIE b* | 27.3 | 29.1 | 24.5 | 25.2 | 22.0 | 21.1 |
| gloss | 2.5 | 2.8 | 2.7 | 2.9 | 3.0 | 2.8 |


**MATERIAL DESCRIPTION:**
natural wood (hardwood), commonly available, finished with wax

**AVALIABLE ON THE MARKET:**

**COST:** €€€€€

**DURABILITY:**

**FIRE RESISTANCE:**

**RECYCLABILITY:**

**MAINTENANCE EFFORT:**

| months | 0 | 3 | 6 | 9 | 12 | 15 |
|---|---|---|---|---|---|---|
| CIE L* | 67.0 | 73.4 | 72.3 | 76.5 | 77.4 | 77.1 |
| CIE a* | 7.6 | 6.9 | 6.3 | 5.1 | 4.5 | 4.6 |
| CIE b* | 32.1 | 25.4 | 22.1 | 22.7 | 19.5 | 16.6 |
| gloss | 2.2 | 2.4 | 2.4 | 2.8 | 2.8 | 2.5 |


**MATERIAL DESCRIPTION:**
durable softwood with the surfaces carbonized with fire, finished with oil

**AVALIABLE ON THE MARKET:**

**COST:** €€€€€

**DURABILITY:**

**FIRE RESISTANCE:**

**RECYCLABILITY:**

**MAINTENANCE EFFORT:**

| months | 0 | 3 | 6 | 9 | 12 | 15 |
|---|---|---|---|---|---|---|
| CIE L* | 24.8 | 23.5 | 26.8 | 33.2 | 36.1 | 32.5 |
| CIE a* | 0.1 | 0.2 | 0.7 | 1.5 | 1.8 | 1.2 |
| CIE b* | 0.3 | -0.2 | 1.0 | 4.4 | 6.4 | 4.2 |
| gloss | 1.3 | 1.3 | 1.3 | 2.0 | 2.4 | 2.3 |


Stuff
Space plan
Services
Skin
Structure
Site

Problem statement

Design question

Research question

**Design criteria III: Buildable with local construction workers**

Design proposal


Google




















Lack of construction system

Nothing is demountable

Availability of construction equipment

No cranes used

Safety

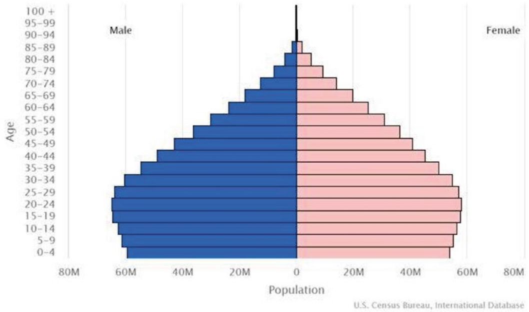
Problem statement

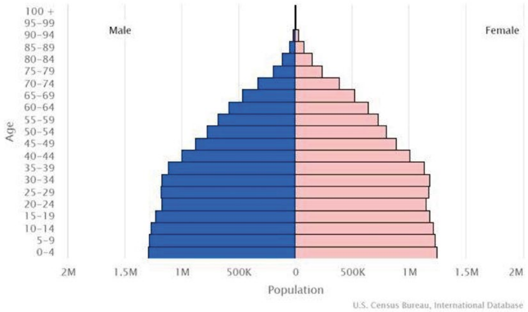
Design question

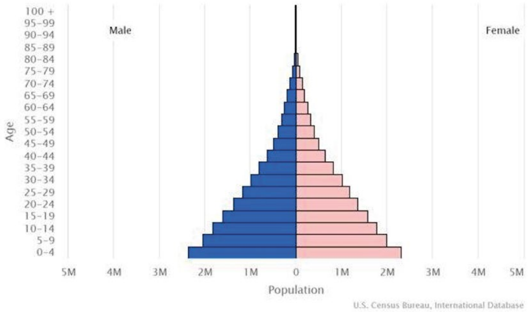
Research question

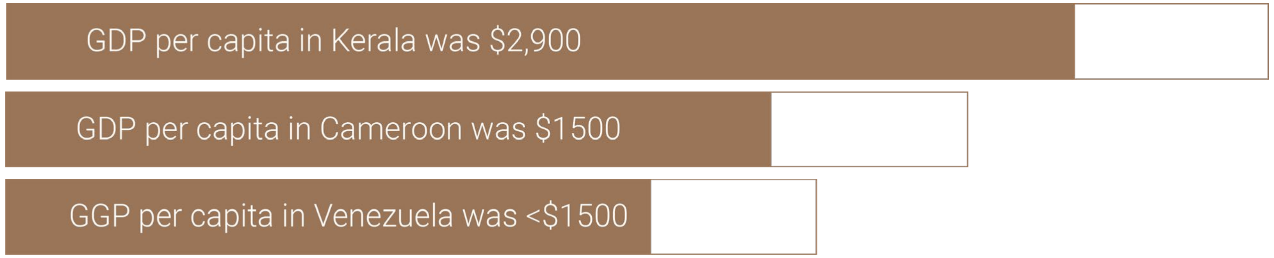
**Design criteria IV: Adaptable to users from different regions**

Design proposal


Male
Female
Age
Population
U.S. Census Bureau, International Database


Male
Female
Age
Population
U.S. Census Bureau, International Database


Male
Female
Age
Population
U.S. Census Bureau, International Database


GDP per capita in Kerala was $2,900
GDP per capita in Cameroon was $1500
GGP per capita in Venezuela was <$1500

## Cameroon

**agriculture:** 70%

**industry:** 13%

**services:** 17% (2001 est.)

## India

**agriculture:** 47%

**industry:** 22%

**services:** 31% (FY 2014 est.)

## Labor force - by occupation

**agriculture:** 7.3%

**industry:** 21.8%

**services:** 70.9% (4th quarter, 2011 est.)

Nuclear family
It consists of two
parents and children

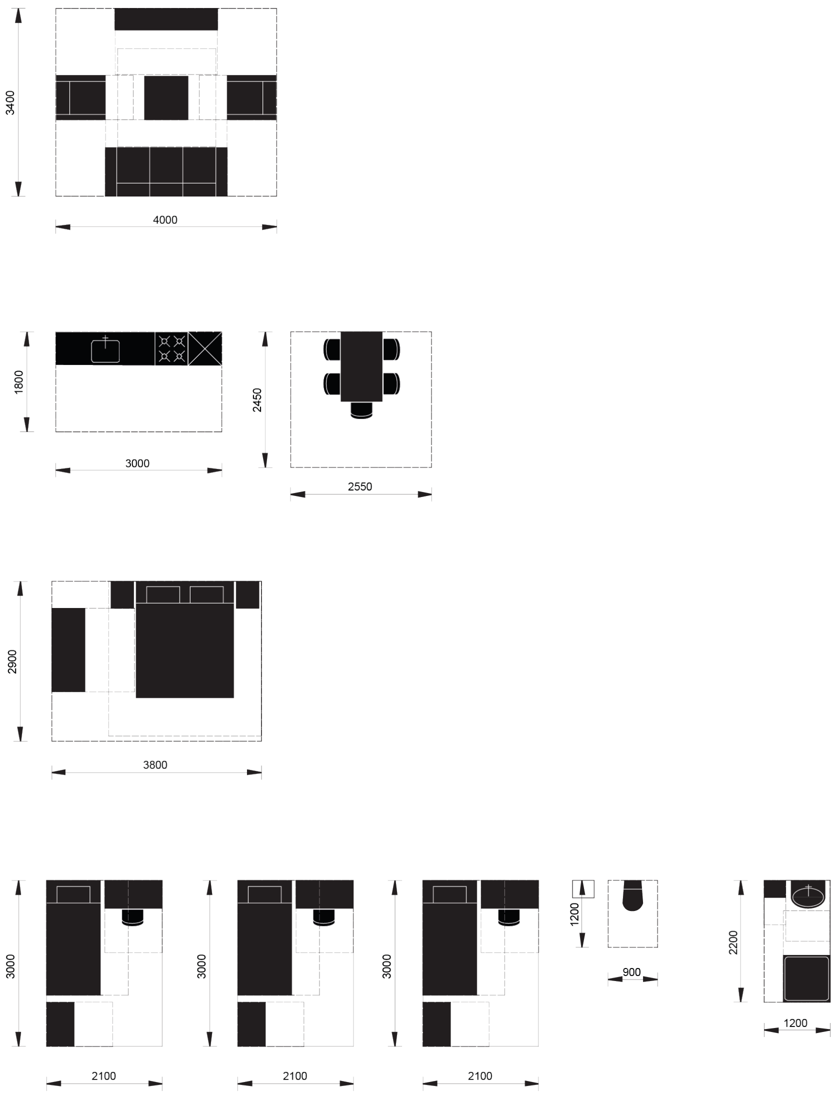
Single parents
A mother or father alone
raises a child

Extended family
It comprising of uncles,
aunts, nieces, and nephews
is becoming common

Childless family
The one that chooses to no
have children

Grandparent family
Grandparents raise their
grandchildren

Stepfamily
Many divorced, separated or
single form new relati-
onships


3400
4000
1800
3000
2450
2550
2900
3800
3000
2100
3000
2100
3000
2100
1200
900
2200
1200

**Nuclear family**
It consists of two
parents and children

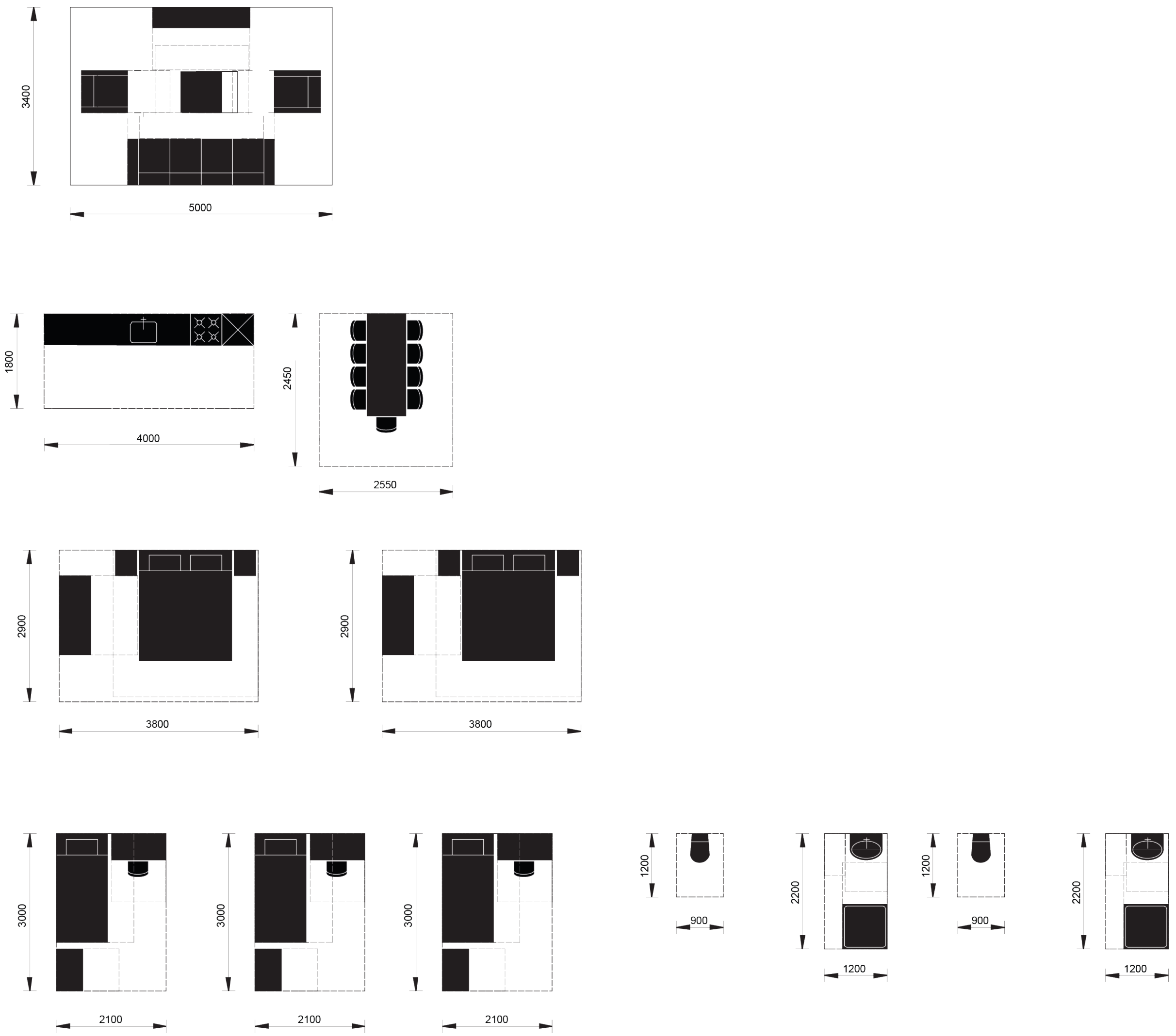
**Single parents**
A mother or father alone
raises a child

**Extended family**
It comprising of uncles,
aunts, nieces, and nephews
is becoming common

**Childless family**
The one that chooses to no
have children

**Grandparent family**
Grandparents raise their
grandchildren

**Stepfamily**
Many divorced, separated or
single form new relati-
onships


3400
5000
1800
4000
2450
2550
2900
3800
2900
3800
3000
2100
3000
2100
3000
2100
1200
900
2200
1200
1200
900
2200
1200

Problem statement

Design question

Research question

**Design criteria V: Building system that can be implemented throughout tropical climate region**

Design proposal

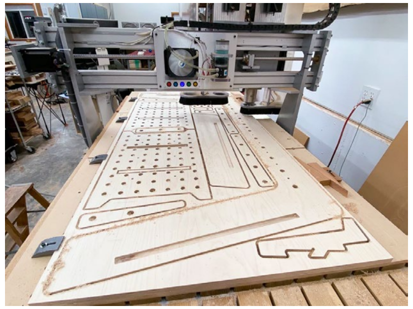
# Digital production technologies: three principle areas

### Generative procedures

also called primary shaping – describe technologies whereby a component part is manufactured from formless material, e.g. tiny particles. Transferred to the architectural setting, larger construction elements are made from small individual parts (e.g. 3D printing).

### Subtractive procedures

Subtractive procedures sever the cohesion of the component part at the point where it is processed. Here differentiations are made between cleaving, machining and removal procedures (e.g. milling).



### Transformative procedures

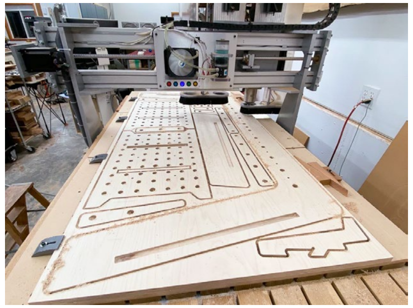
Transformative procedures retain the cohesion of the material and generate component parts through a lasting alteration to the shape of the unfinished parts. Generally this allows for the optimization of their initial condition (e.g. bending).

# Digital production technologies: three principle areas

### Generative procedures



### Subtractive procedures



### Transformative procedures

# Subtractive procedures

**T2: Overview of the most important subtractive procedures with a comparison of the most important process parameters relevant for the designer Before commissioning, a comparison of the cost-effectiveness and any necessary finishing is recommended. The manufacturing of processing templates may be worthwhile.**

| | **CNC punch TruPunch 5000** | **Lasering** | **Water jet (pure)** | **Water jet (abrasive)** | **Nibbling TruMatic 5000** | **Plasma cutting MicroStep** | **Milling 2-axial Bima 310** | **Milling 5-axial HERMLE C50U dynamic** | **Robotic lasering (multi-axial) ABB IRB 6650S** |
|---|---|---|---|---|---|---|---|---|---|
| Material | Sheets of steel, stainless steel, brass, aluminium and copper | Almost all materials | Rubber, plastic, foil, textiles, plywood, foam, paper, foodstuffs | Concrete, harder metals, glass, ceramics: also multi-layered and combination materials | Sheets of steel, stainless steel, brass, aluminium and copper | Conductive metal, raw materials | Wood, (aluminium), foam, cardboard | All common types of material including soft plastics | All common materials |
| Material thickness | Up to 8 mm | 400 mm (tube diameter) | Up to 350 mm | Up to 350 mm | Up to 8 mm | 3000 mm | Up to approx. 250 mm (with 100 mm drill) | Ø 700 mm to Ø 1150 mm | Dependent on laser |
| Size of construction part | 2550 × 1280 mm 3070 × 1660 mm | 4000 × 3000 mm 6000 × 2000 mm 16 × 2.5m | 3000 × 4500 mm | 2000 × 1000 mm 4000 × 3000 mm | 2500 × 1250 mm 3000 × 1650 mm | 30,000 × 8000 mm | 1450 × 3900 mm 1630 × 5000 mm | Ø 700 mm to Ø 1150 mm Large-scale mill up to 15 × 60 m | Almost any, Arm: 3.9 m |
| Speed (depending on material) | 1400 strokes/min | 300 m/min | 35 m/min | 35 m/min | 1200–2800 strokes/min | 6 m/min | Approx. 10 m/min | Up to 40 m/min | Dependent on laser |
| Accuracy | ± 0.1 mm | 0.05 mm | 0.025 mm | 0.025 mm | 0.03–0.01 mm | 0.2–0.5 mm/ depends on type of material/shape | 0.1–0.2 mm | Very accurate, in the μ region | Dependent on laser |
| Quality of cut | ⅔ of the length is waste edge | Very good, may leave behind black marks | Rough to very good | Rough to very good | ⅔ of the length is waste edge | Not a consistently smooth cut surface/ surface roughness | Ribbed to smooth | Very good | Dependent on laser |
| Waste caused by tool | 0 to 3 mm | 0.1–0.5 mm | 0.1–0.25 mm | 1 mm | 0 to 5 mm | 0.8–1.5 mm | 1 mm, dependent on the milling head | Slight, dependent on tool in to the μ region | Dependent on laser |
| Finishing needed | Yes, grinding the edges | Dependent on the material | Dependent on the material | Dependent on the material | Yes, grinding the edges | Yes, grinding | Grinding | Not necessary | Dependent on laser |
| Possible to parameterize | no | yes | yes | yes | no | yes | yes | yes | yes |
| Geometry options | 2D | 2D (3D) | 2D | 2D | 2D | 2D (3D) | 2D (3D) | 5-axial 3D | Multi-axial (6) 3D |
| Overall energy consumption | 25–50 kW | 100 kW | 37 kW dependent on pump | 37 kW dependent on pump | 25–50 kW | Approx. 80 A | 18 kW | 39–60 kW | Dependent on laser |
| Control data | e.g. dxf | e.g. dxf | 2D construction data, e.g. dxf | 2D construction data, e.g. dxf | e.g. dxf | e.g. dxf | dxf, dwg, IGES, STEP | IGES, SEP | Dependent on laser |
| Interim software | TrueTops | TrueTops Laser | No, plug & play | No, plug & play | ToPs 300 | AsperWin | Imawop | e.g. ITNC 530 | Mechanical cut/dependent on laser |

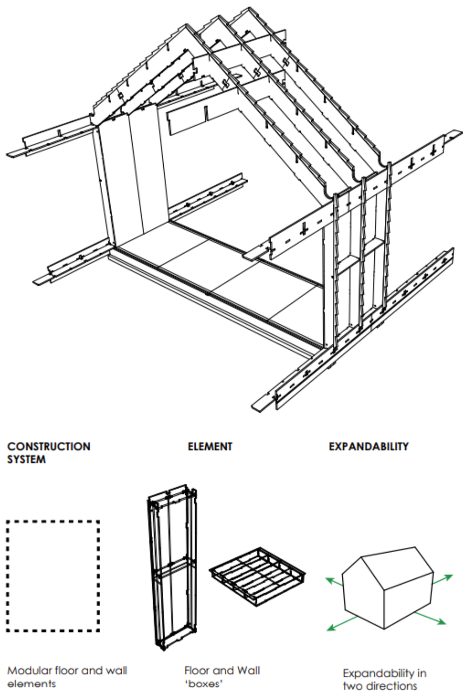
# Subtractive procedures

**T2: Overview of the most important subtractive procedures with a comparison of the most important process parameters relevant for the designer Before commissioning, a comparison of the cost-effectiveness and any necessary finishing is recommended. The manufacturing of processing templates may be worthwhile.**

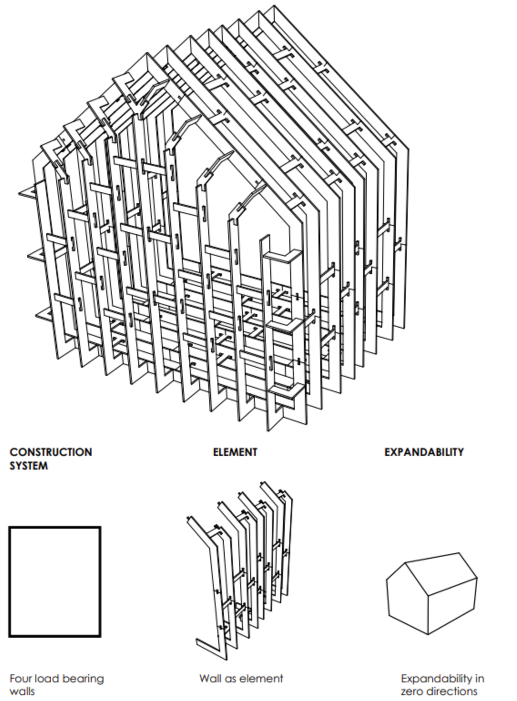
| | CNC punch TruPunch 5000 | Lasering | Water jet (pure) | Water jet (abrasive) | Nibbling TruMatic 5000 | Plasma cutting MicroStep | Milling 2-axial Bima 310 | Milling 5-axial HERMLE C50U dynamic | Robotic lasering (multi-axial) ABB IRB 6650S |
|---|---|---|---|---|---|---|---|---|---|
| Material | Sheets of steel, stainless steel, brass, aluminium and copper | Almost all materials | Rubber, plastic, foil, textiles, plywood, foam, paper, foodstuffs | Concrete, harder metals, glass, ceramics: also multi-layered and combination materials | Sheets of steel, stainless steel, brass, aluminium and copper | Conductive metal, raw materials | Wood, (aluminium), foam, cardboard | All common types of material including soft plastics | All common materials |
| Material thickness | Up to 8 mm | 400 mm (tube diameter) | Up to 350 mm | Up to 350 mm | Up to 8 mm | 3000 mm | Up to approx. 250 mm (with 100 mm drill) | ∅ 700 mm to ∅ 1150 mm | Dependent on laser |
| Size of construction part | 2550 × 1280 mm 3070 × 1660 mm | 4000 × 3000 mm 6000 × 2000 mm 16 × 2.5m | 3000 × 4500 mm | 2000 × 1000 mm 4000 × 3000 mm | 2500 × 1250 mm 3000 × 1650 mm | 30,000 × 8000 mm | 1450 × 3900 mm 1630 × 5000 mm | ∅ 700 mm to ∅ 1150 mm Large-scale mill up to 15 × 60 m | Almost any, Arm: 3.9 m |
| Speed (depending on material) | 1400 strokes/min | 300 m/min | 35 m/min | 35 m/min | 1200–2800 strokes/min | 6 m/min | Approx. 10 m/min | Up to 40 m/min | Dependent on laser |
| Accuracy | ± 0.1 mm | 0.05 mm | 0.025 mm | 0.025 mm | 0.03–0.01 mm | 0.2–0.5 mm/ depends on type of material/shape | 0.1–0.2 mm | Very accurate, in the μ region | Dependent on laser |
| Quality of cut | ⅔ of the length is waste edge | Very good, may leave behind black marks | Rough to very good | Rough to very good | ⅔ of the length is waste edge | Not a consistently smooth cut surface/ surface roughness | Ribbed to smooth | Very good | Dependent on laser |
| Waste caused by tool | 0 to 3 mm | 0.1–0.5 mm | 0.1–0.25 mm | 1 mm | 0 to 5 mm | 0.8–1.5 mm | 1 mm, dependent on the milling head | Slight, dependent on tool in to the μ region | Dependent on laser |
| Finishing needed | Yes, grinding the edges | Dependent on the material | Dependent on the material | Dependent on the material | Yes, grinding the edges | Yes, grinding | Grinding | Not necessary | Dependent on laser |
| Possible to parameterize | no | yes | yes | yes | no | yes | yes | yes | yes |
| Geometry options | 2D | 2D (3D) | 2D | 2D | 2D | 2D (3D) | 2D (3D) | 5-axial 3D | Multi-axial (6) 3D |
| Overall energy consumption | 25–50 kW | 100 kW | 37 kW dependent on pump | 37 kW dependent on pump | 25–50 kW | Approx. 80 A | 18 kW | 39–60 kW | Dependent on laser |
| Control data | e.g. dxf | e.g. dxf | 2D construction data, e.g. dxf | 2D construction data, e.g. dxf | e.g. dxf | e.g. dxf | dxf, dwg, IGES, STEP | IGES, SEP | Dependent on laser |
| Interim software | TrueTops | TrueTops Laser | No, plug & play | No, plug & play | ToPs 300 | AsperWin | Imawop | e.g. ITNC 530 | Mechanical cut/dependent on laser |

# **CNC Milling** Different structural systems

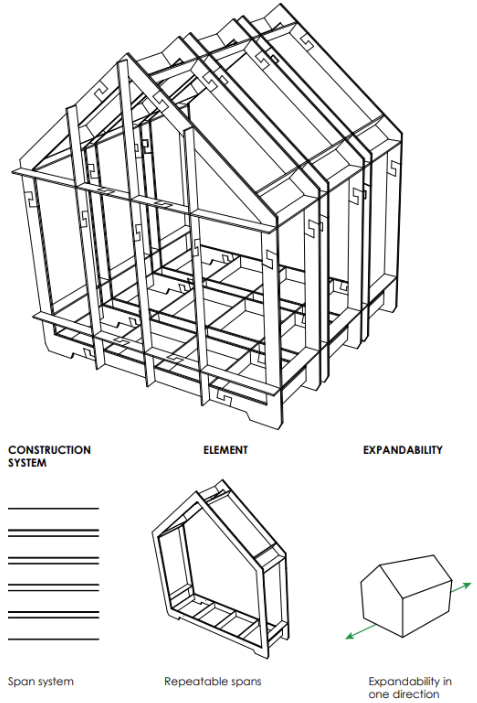
Appendix K, PAVILJOEN HUIS TER HEIDE



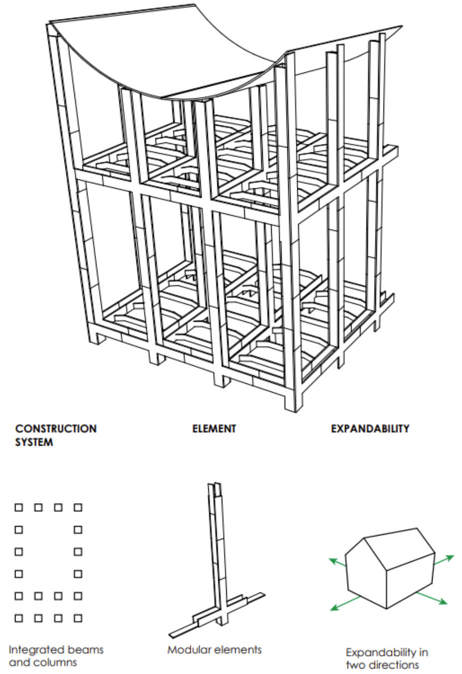

Appendix I, INSTANT-HOUSE




Appendix H, WIKI-HOUSE

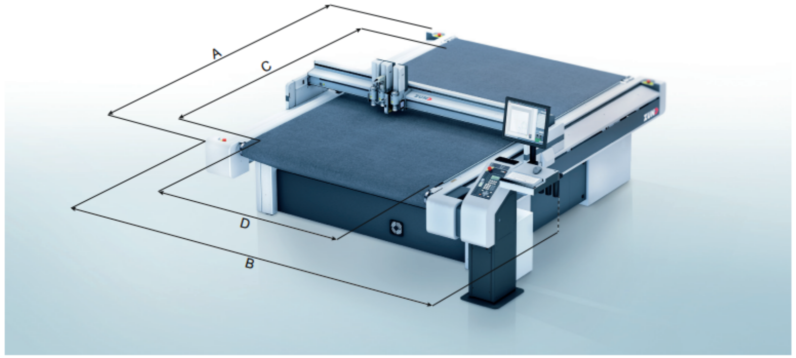



Appendix J, HAITI SHELTER



# Technical Data G3

**Base machine**
Dimensions, weight, material

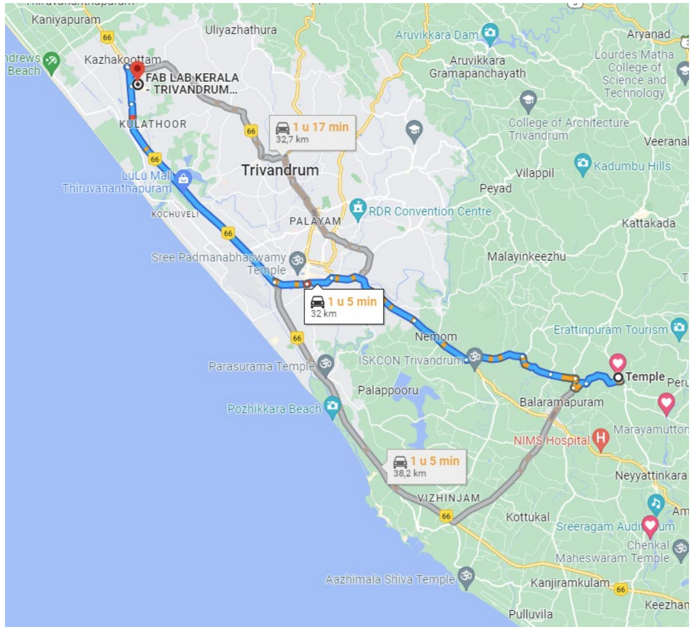


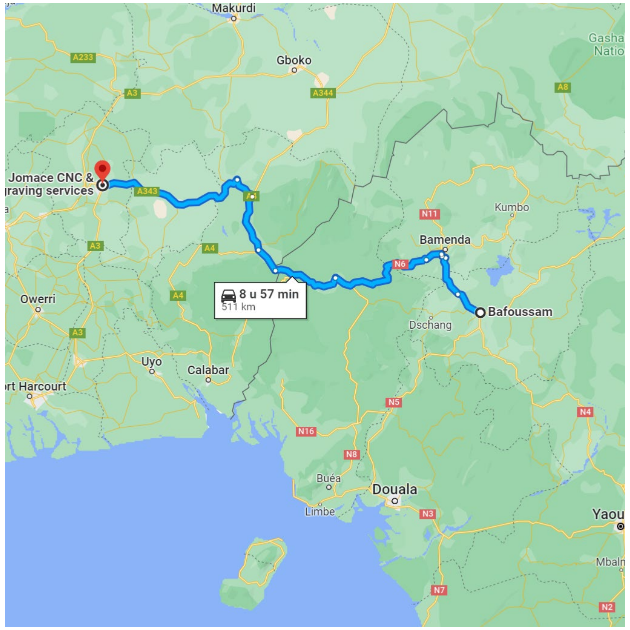

| Type | Working area (D x C) | Overall dimensions, incl. workstation (B x A) | Machine weight |
|---|---|---|---|
| M-1600 | 1330 mm × 1600 mm / 52" × 63" | 2680 mm × 2510 mm / 106" × 98" | 670 kg / 1480 lbs |
| M-2500 | 1330 mm x 2500 mm / 52" × 98" | 2680 mm × 3410 mm / 106" × 134" | 840 kg / 1855 lbs |
| L-2500 | 1800 mm x 2500 mm / 70" × 98" | 3150mm × 3410 mm / 124" × 134" | 970 kg / 2140 lbs |
| L-3200 | 1800 mm x 3200 mm / 70" × 125" | 3150 mm × 4110 mm / 124" × 162" | 1110 kg / 2450 lbs |
| XL-1600 | 2270 mm x 1600 mm / 89" × 63" | 3620 mm × 2510 mm / 143" × 98" | 890 kg / 1965 lbs |
| XL-3200 | 2270 mm x 3200 mm / 89" × 125" | 3620 mm × 4110 mm / 143" × 162" | 1280 kg / 2825 lbs |
| 2XL-1600 | 2740 mm x 1600 mm / 107" × 63" | 4090 mm × 2510 mm / 161" ×98" | 980 kg / 2160 lbs |
| 2XL-3200 | 2740 mm x 3200 mm / 107" × 125" | 4090mm × 4110 mm / 161" × 162" | 1420 kg / 3130 lbs |
| 3XL-1600 | 3210 mm x 1600 mm / 126" × 63" | 4560 mm × 2510 mm / 180" × 98" | 1120 kg / 2470 lbs |
| 3XL-2500 | 3210 mm x 2500 mm / 126" × 98" | 4560 mm × 3410 mm / 180" × 134" | 1430 kg / 3155 lbs |
| 3XL-3200 | 3210 mm x 3200 mm / 126" × 125" | 4560 mm × 4110 mm / 180" × 162" | 1610 kg / 3550 lbs |

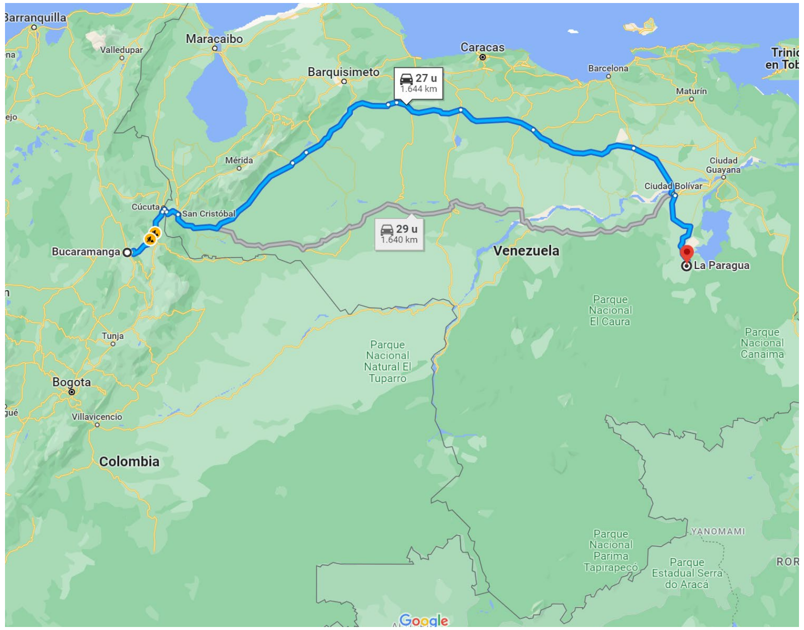
| Type | max. materialwidth cutter with static work surface | max. materialwidth cutter with material transport |
|---|---|---|
| M-series | 1610 mm / 63" | 1330 mm / 52" |
| L-series | 2080 mm / 81" | 1800 mm / 70" |
| XL-series | 2550 mm / 100" | 2270 mm / 89" |
| 2XL-series | 3020 mm / 118" | 2740 mm / 107" |
| 3XL-series | 3490 mm / 137" | 3210 mm / 126" |

Technical data subject to change without notice.

# India - Cameroon – Venezuela



Problem statement

Design question

Research question

Design criteria I – V

**Design proposal**

| | |
|---|---|
| **Design Criteria I:** | Passively provide [adaptive] thermal comfort |
| **Design Criteria II:** | Fully bio-based |
| **Design Criteria III:** | Buildable with local construction workers |
| **Design Criteria IV:** | Adaptable to users from different regions |
| **Design Criteria V:** | Building system that can be implemented throughout tropical climate region |

# After P2

# Questions & reflection