

Passive Cooling Methods for Amphibious Flood-resistant Housing in Tropical Climates

MSc. Building Technology
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1st Mentor
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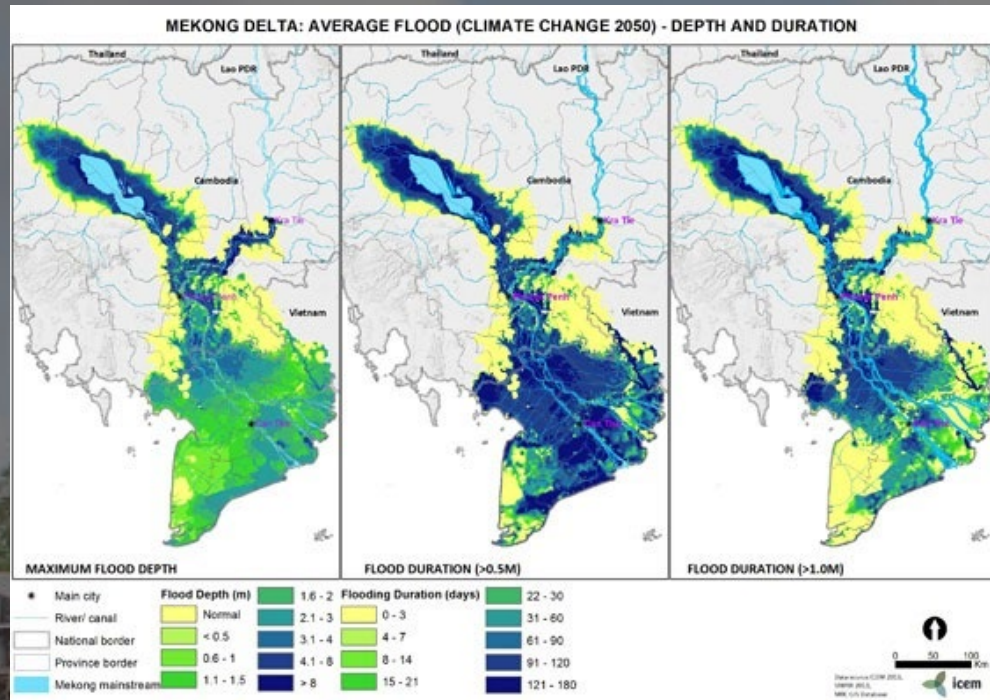
2nd Mentor
Dr.ir Martin Tenpierik

Delegate of the Board of Examinors
dr. Rene van der Velde





A. Problem Statement - Background



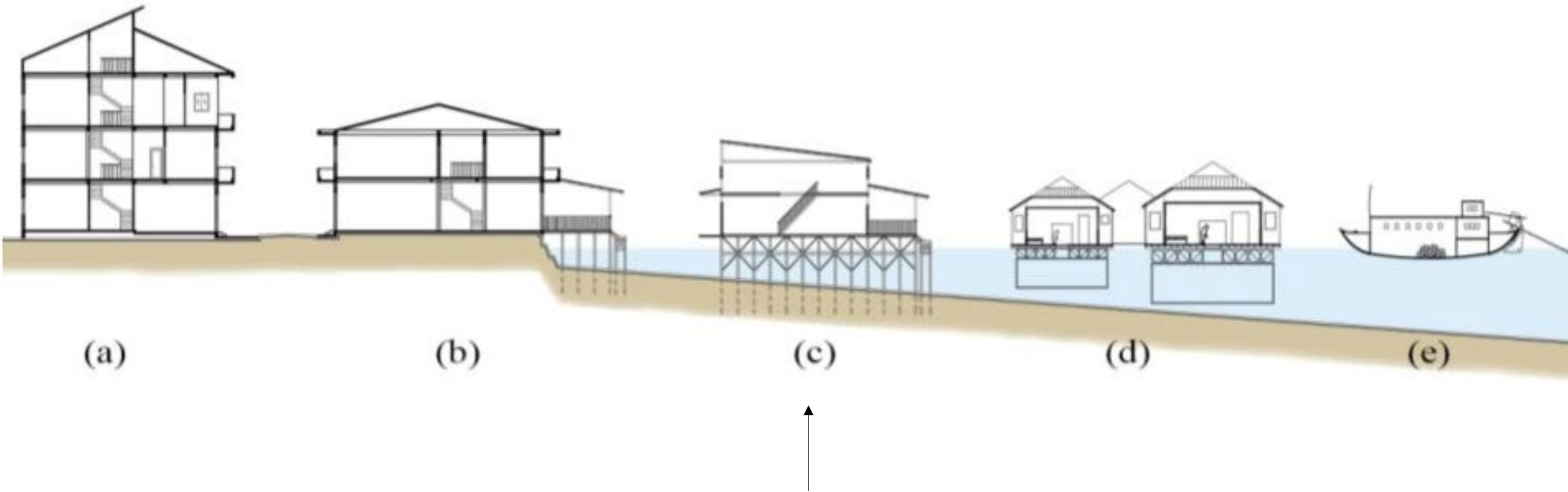
Source: ICeM.com

Sources:

Context - Low-lying areas, developing countries with hot climates



A. Problem Statement - Background



High-Pitched Roof

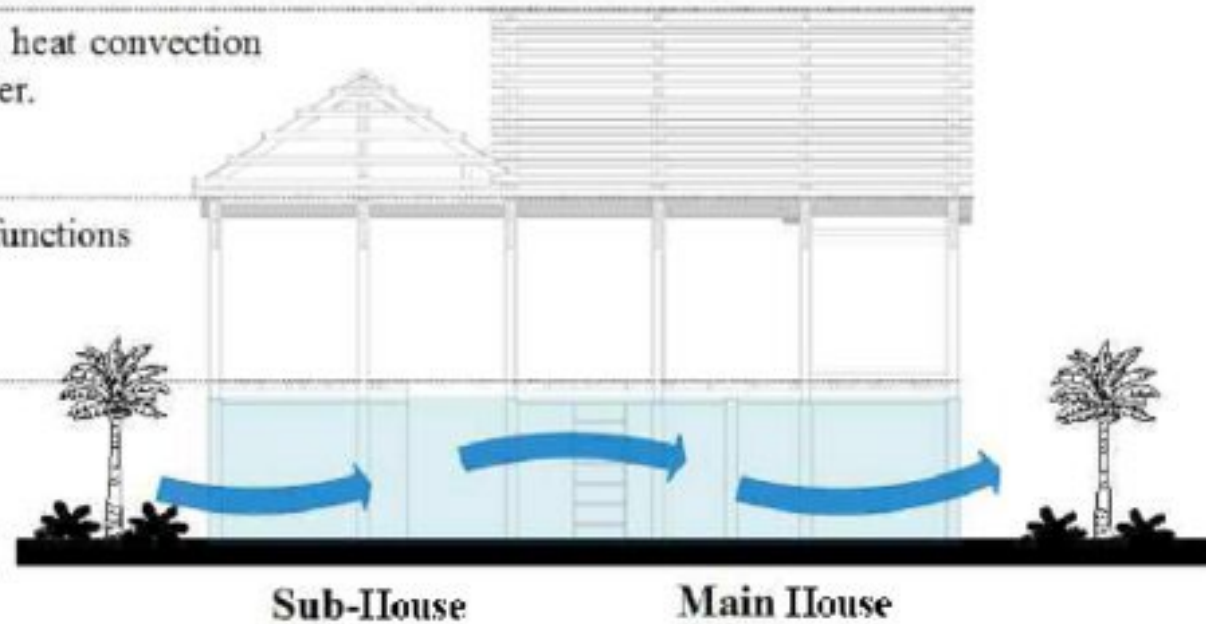
The high pitched roof helps heat convection and rapid drainage of rainwater.

Enclosed Space

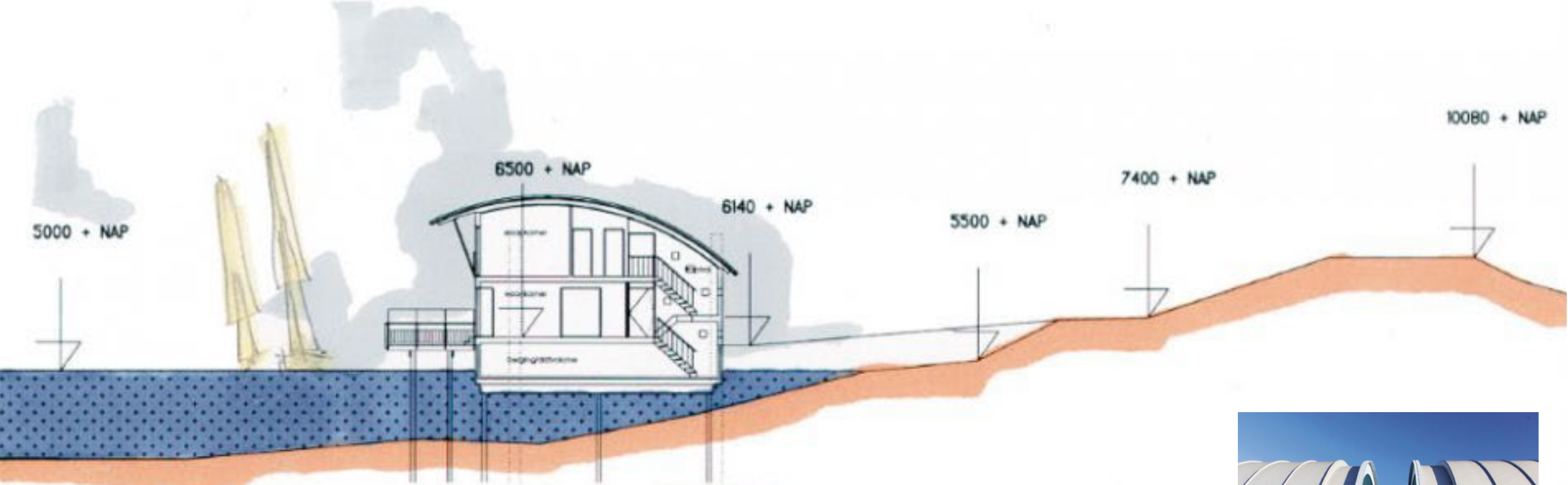
Space of living activities functions located on the first floor.

Stilt Space

This space is versatile for avoiding the water, and helping enhances natural cross ventilation.



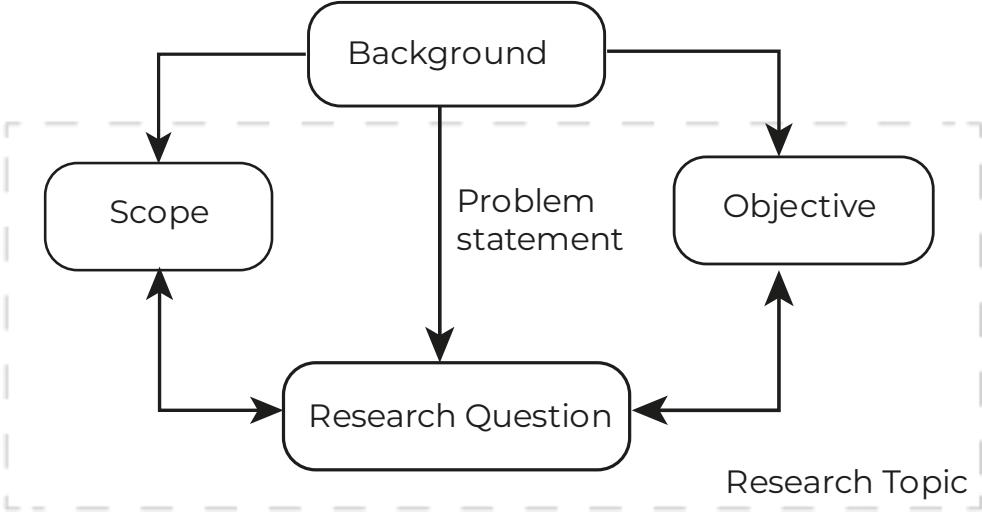
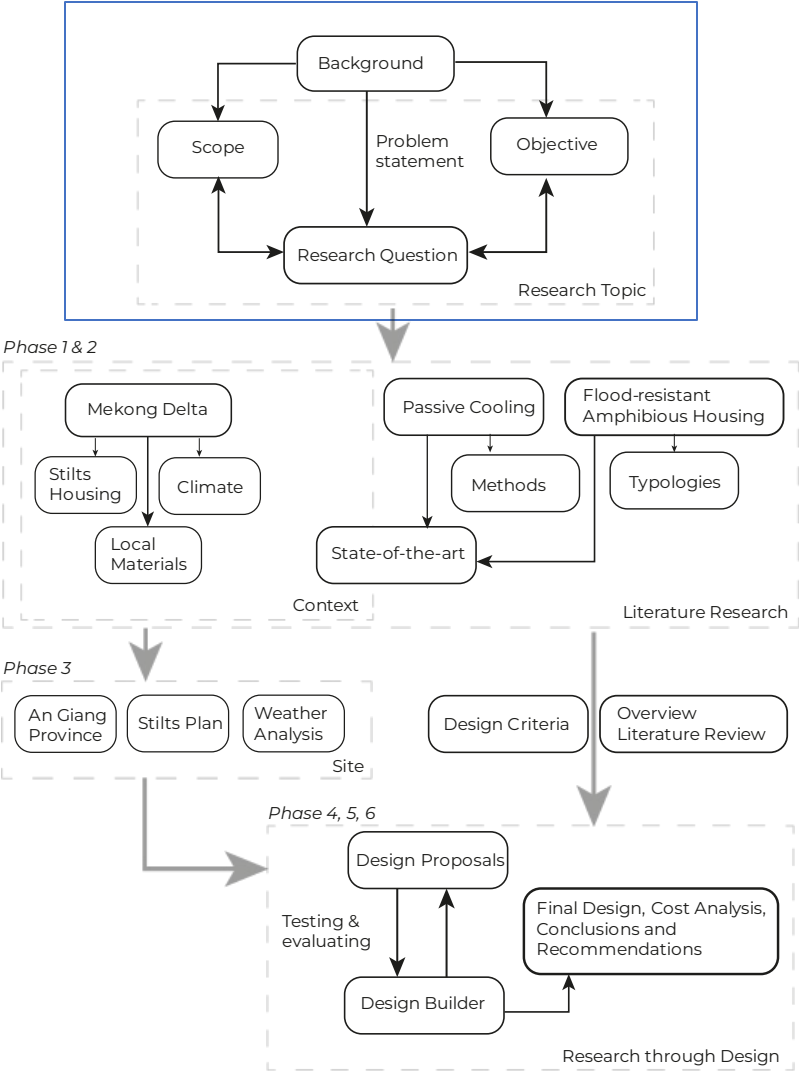




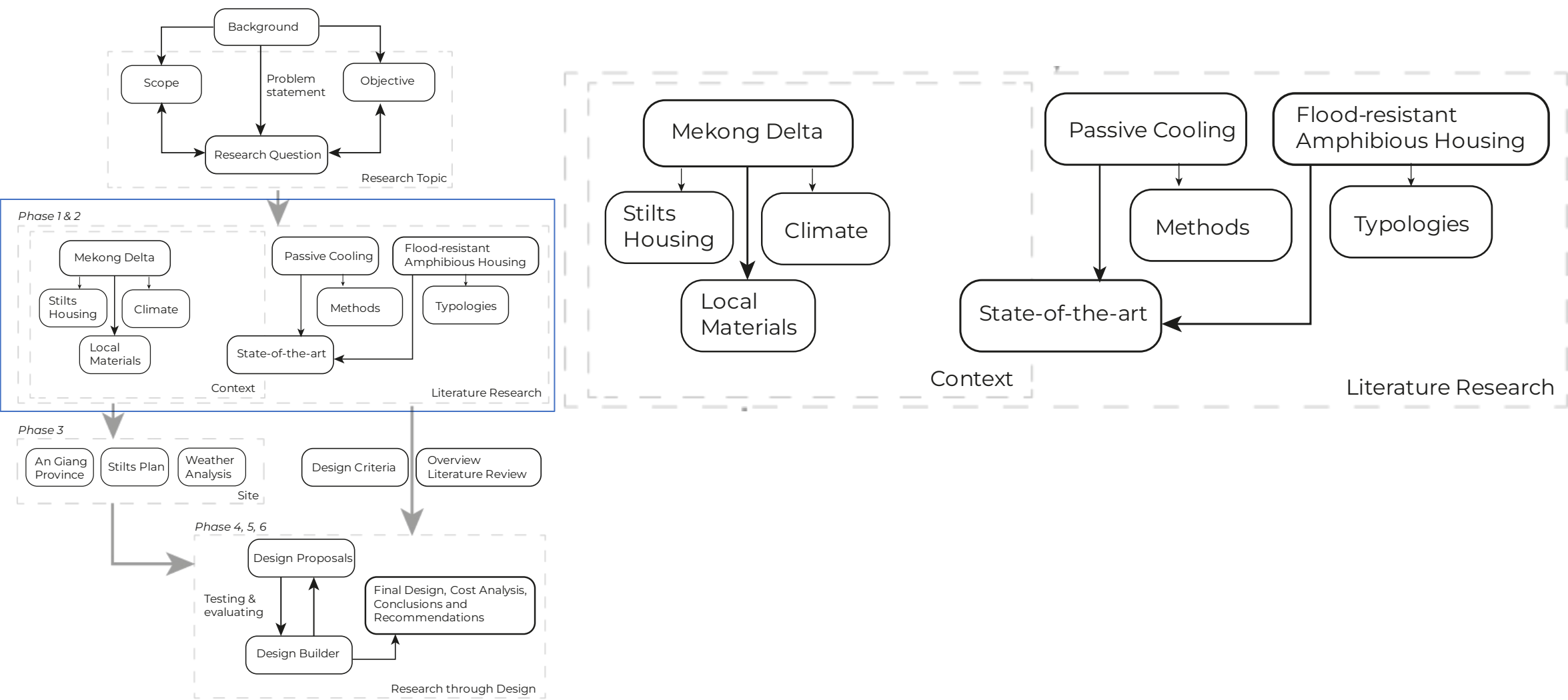
A. Research Question

How can low tech amphibious housing techniques lead to passive cooling to lower Energy Demands and create Flood-resistant housing? (Mekong Delta)

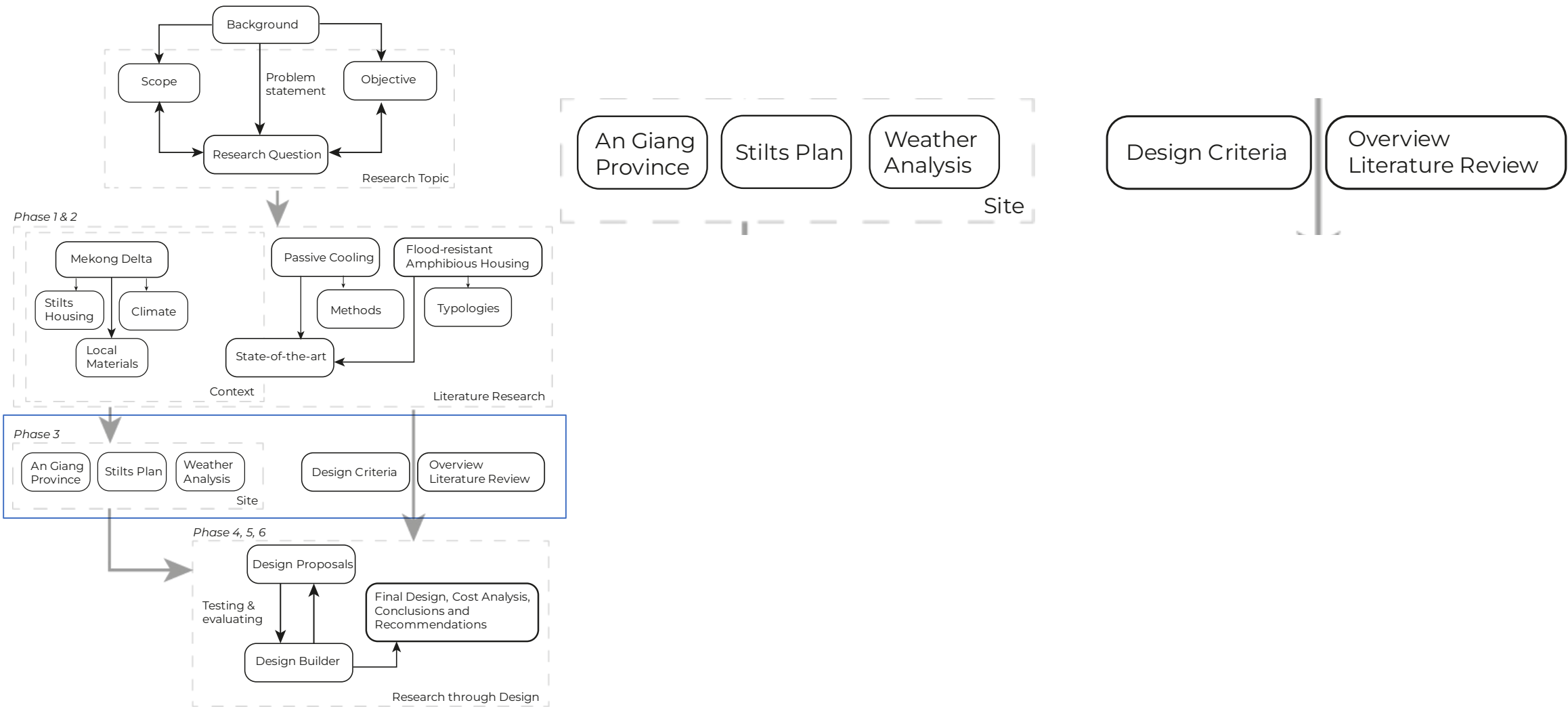
A. Methodology



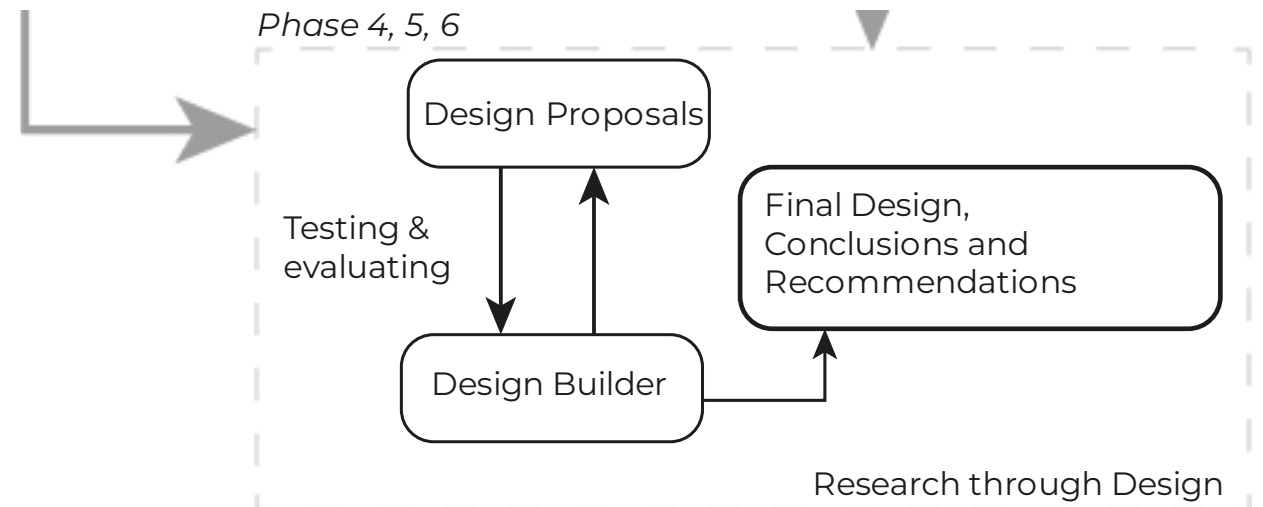
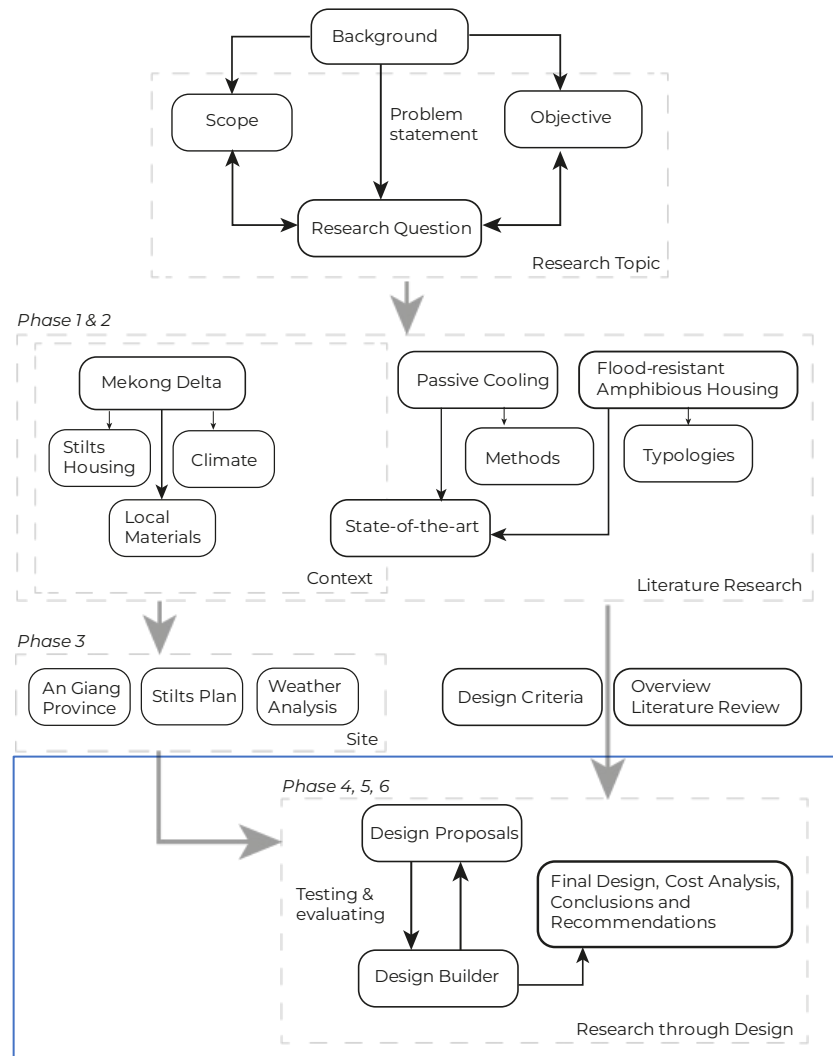
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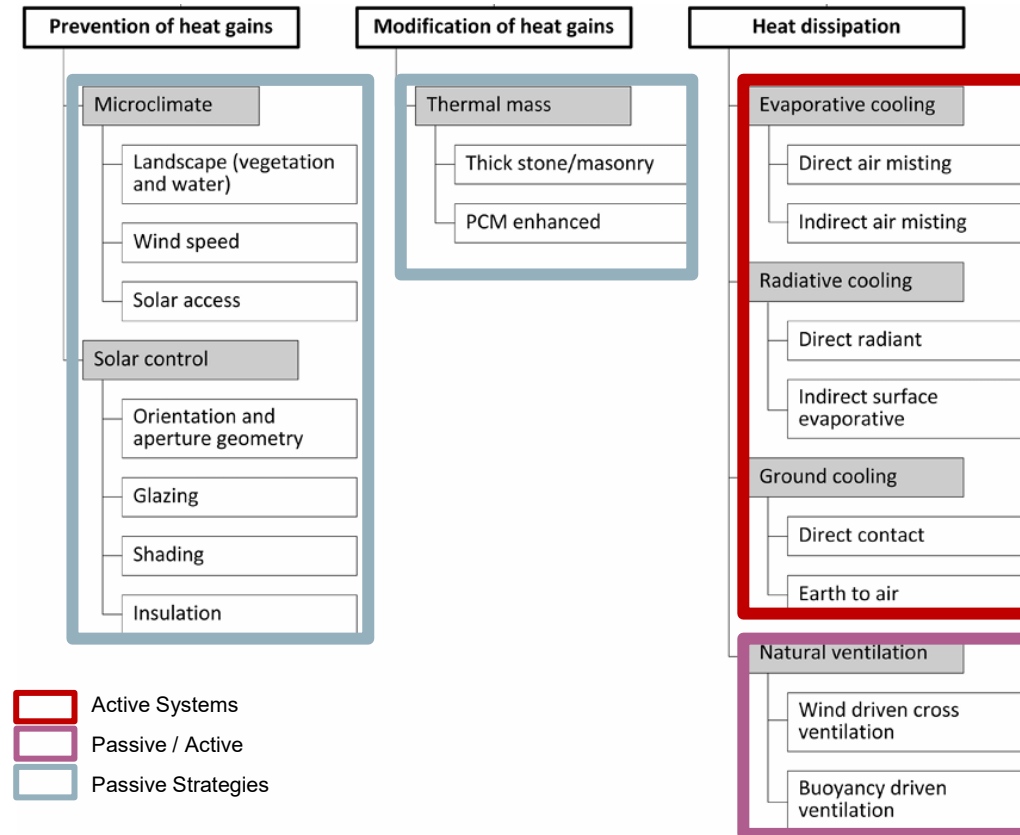
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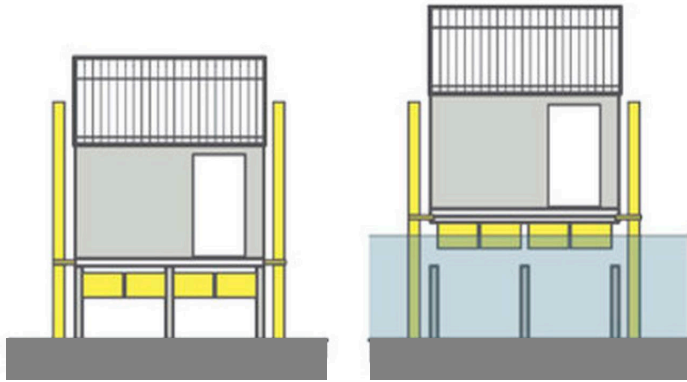
B. Summary Literature Review



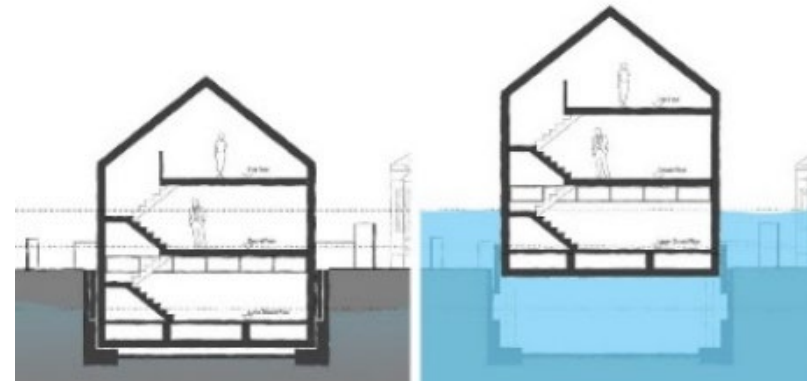
Passive cooling in Tropical Climates

B. Summary Literature Review

Vertical Guidance Posts



Floating Pontoons/Box



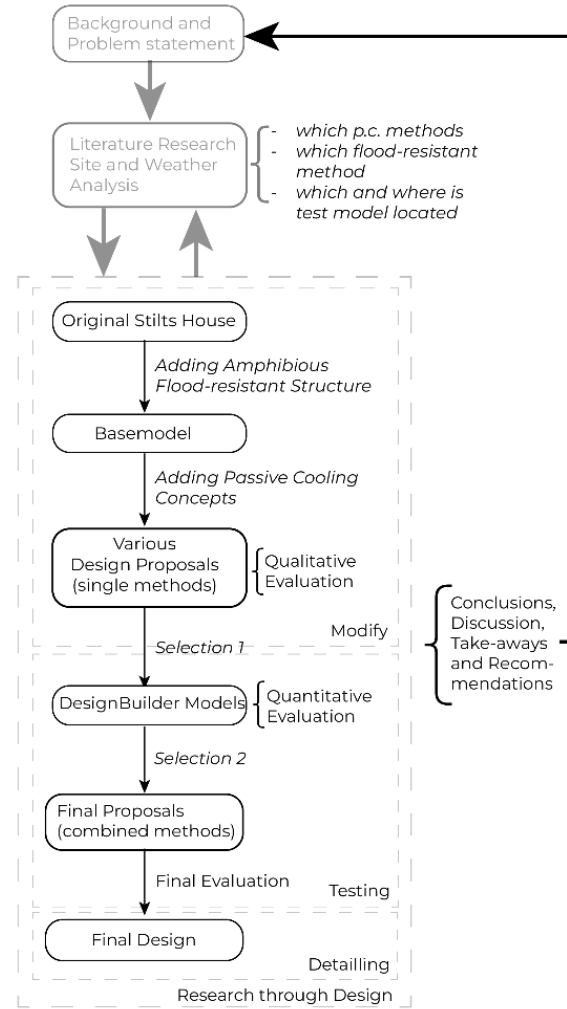
- €1385,57 – 1847,43 Euros/Unit (H&P Architects)

€2592,90 Euros/ unit (Prosun, 2011) - €750.000 Euros (3658,54 €/m²) (Coutts, 2018).

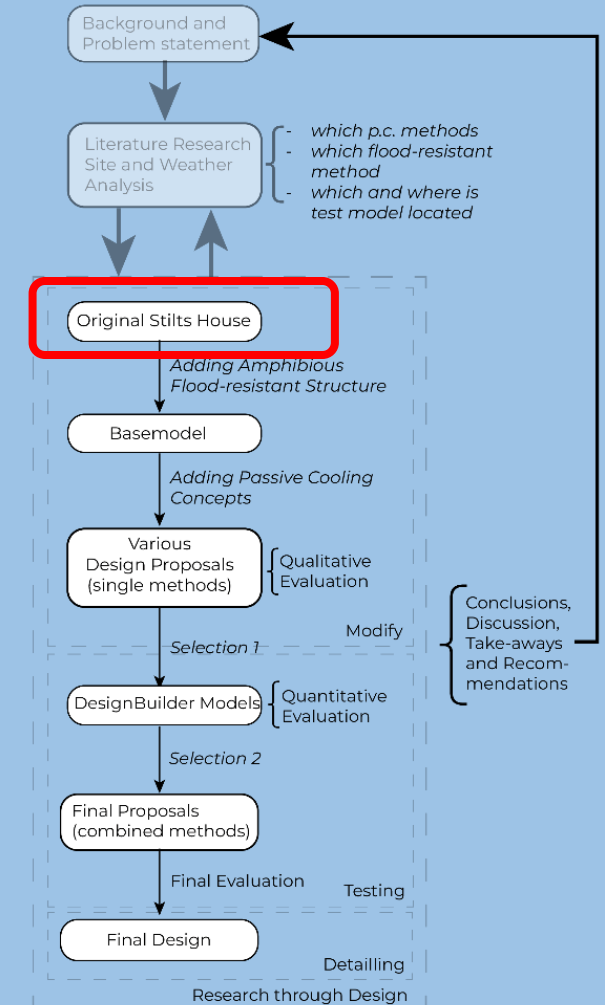
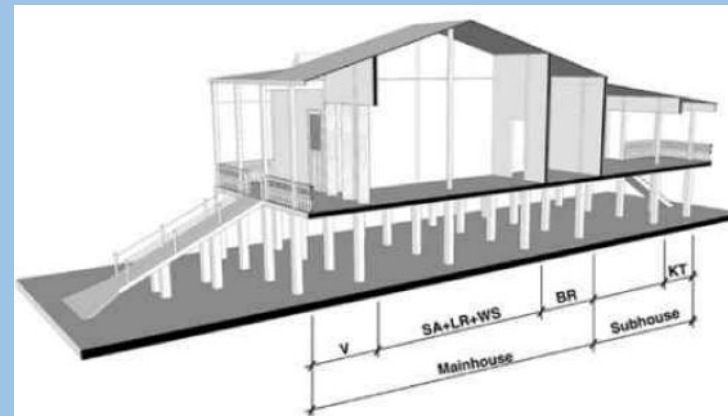
Flood-resistant Amphibious Structures

Source: amphibiousbuoyantfoundation.org,
Raksakul(2015); baka.uk; Prosun(2011)

C. Design Through Research



C. Context Assessment | Drawings | 3D section



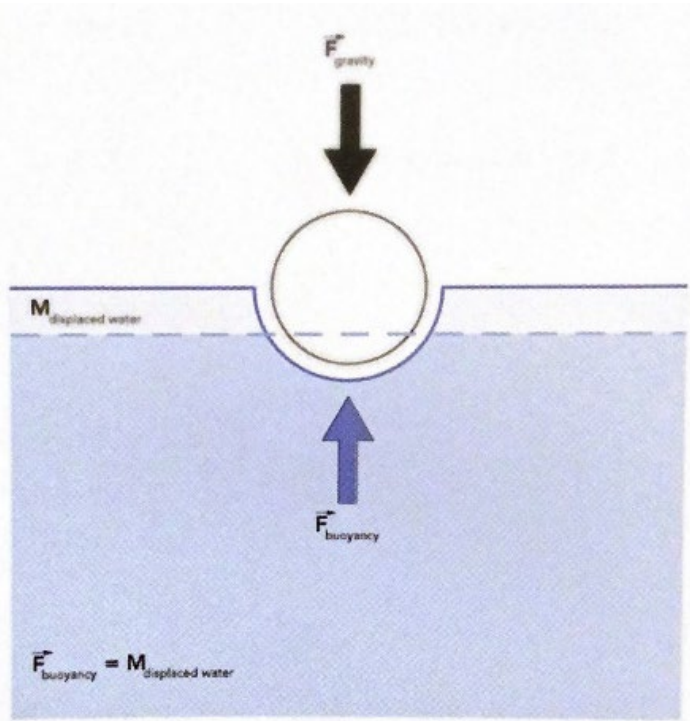
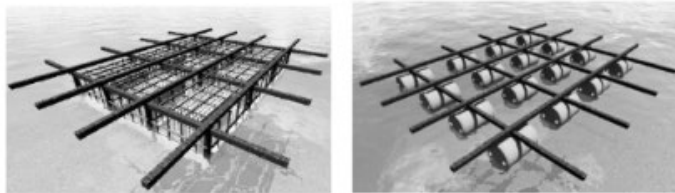
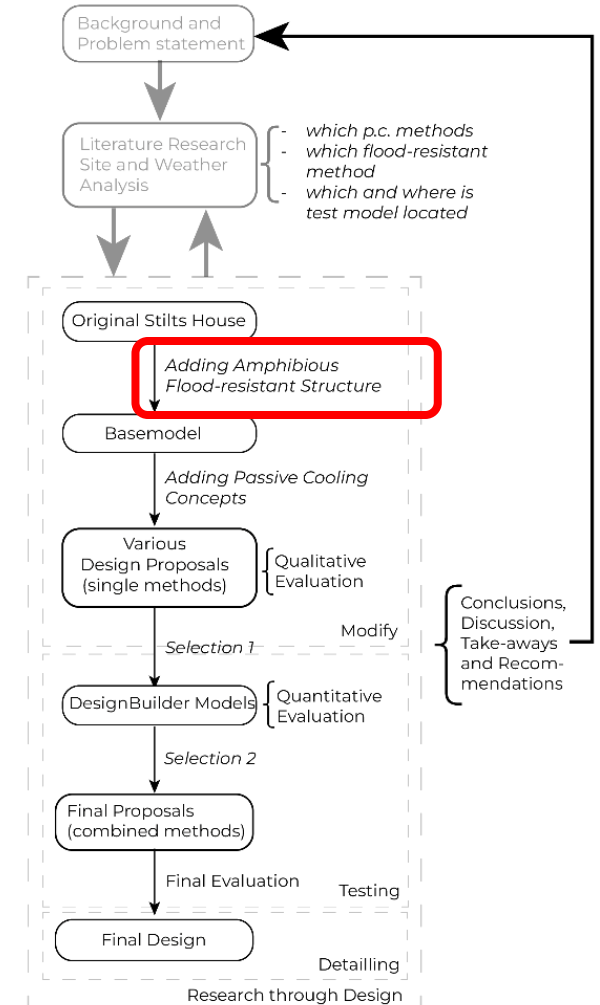


Fig. 3.3.3: Archimedes principle.

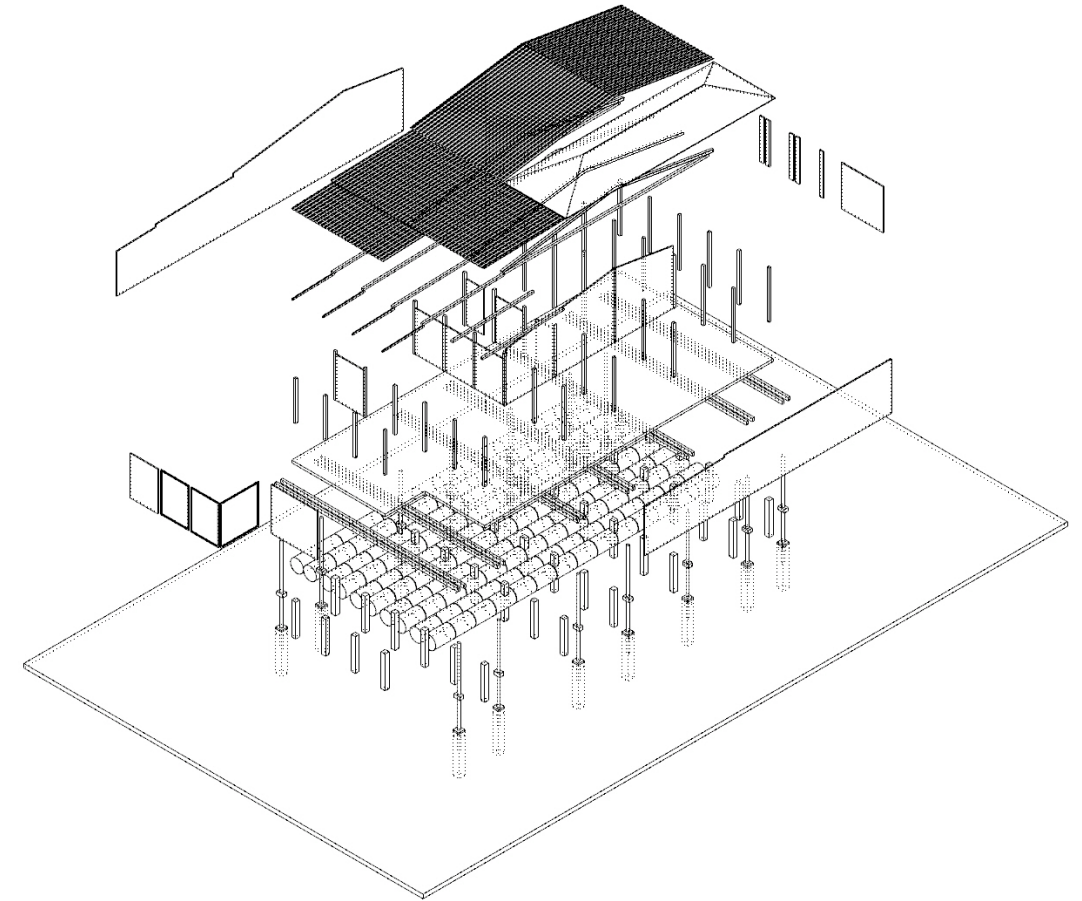


- For example if a house weighs about 220 tons, approximately 225m³ of water is displaced when it becomes buoyant. Another principle is the Pontoon's principle which states that **the mass or volume of the house should be less than the density of water.**



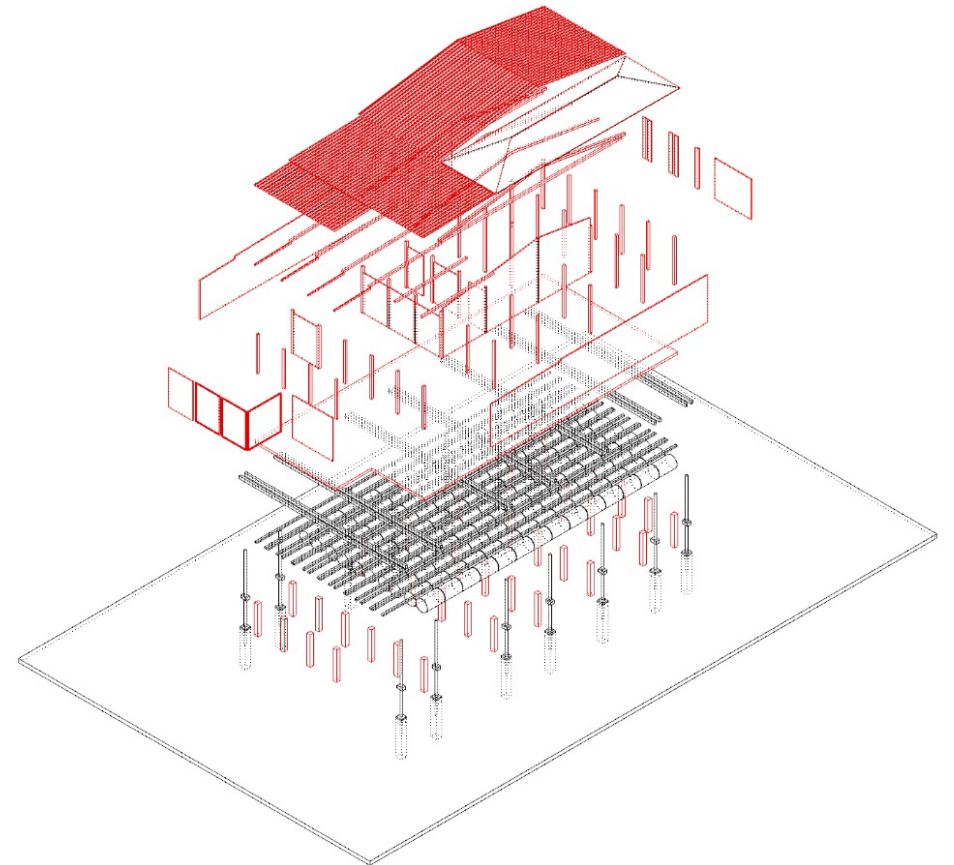
C. Proposals

		<i>Material</i>	<i>Density (kg/m3)</i>	<i>Volume (m3)</i>	<i>Weight (kg)</i>
Original stilts House	Stumps	Concrete	2400	3.456	8294.4
	Sill	Timber	700	0.007395	51.765
	Posts	Timber	700	0.95	665
	Rafters and beams	Timber	700	0.873	611.1
	Floor	Timber	700	3.72	2604
	External walls	Galvanized steel	7850	1.32	10336
	Internal walls	Plywood	600	1.05	630
	Roof	Galvanized steel	7850	1	7850
	<u>Total</u>				31042.3
Amphibious Structure	Recycled Plastic Pontoons	EPS	4.89	49.8	243.5
	Grid	Aluminum Strips	2700	0.11	283.5
	Extra Beams	Timber	700	4.4	3080
					3607
	Vertical guidance posts	Steel	7850	0.65	5102.5
	Mooring poles	Concrete	2400	2.52	6048
					34649.3



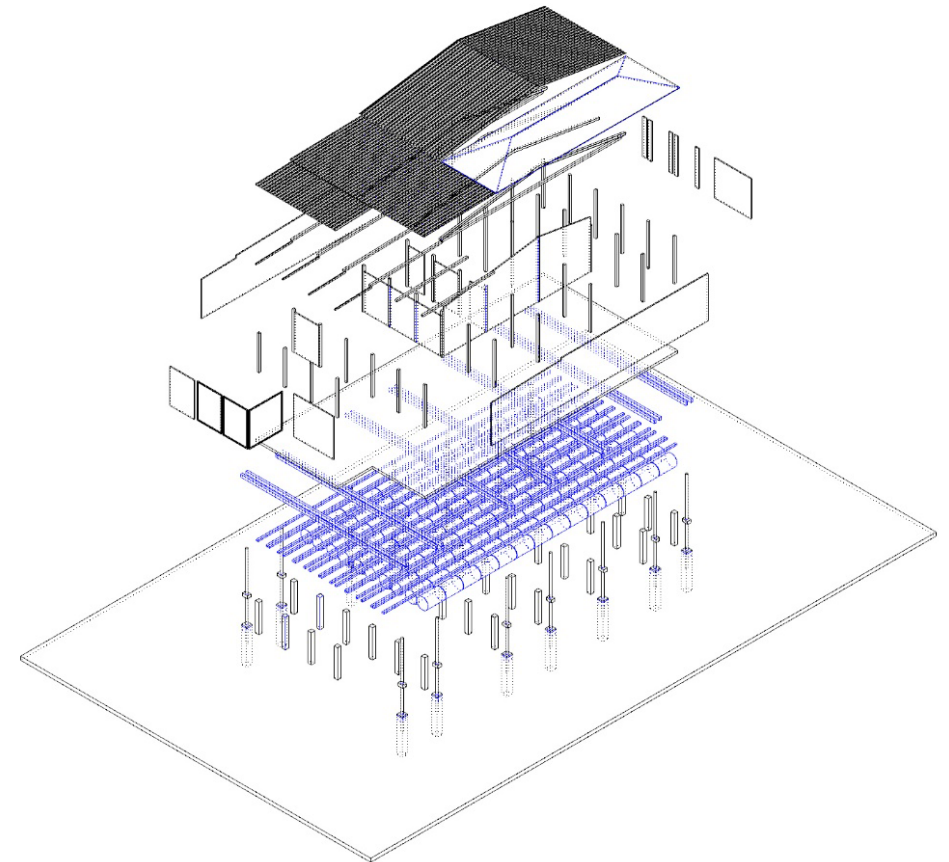
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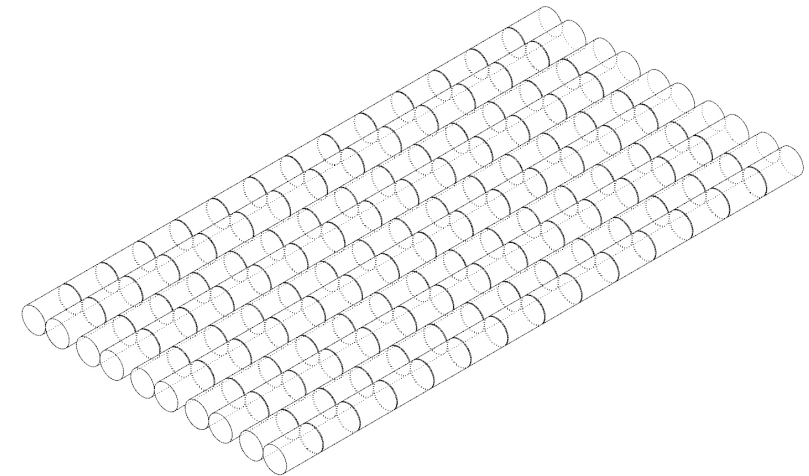
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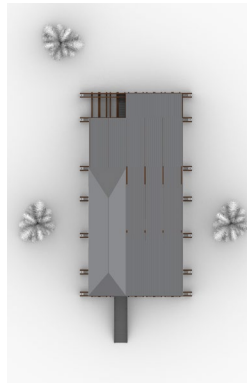
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	34649.3				

Dead weight = around 35 ton, so around 35 m3 of water is displaced.
 Pontoon volume = 49.8 m3 > dead weight
 Live loads < 15 ton



C. Proposals

Base Model – from Original Stilts House to Flood-resistant Amphibious House



Top



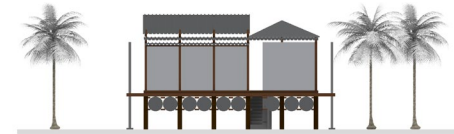
South



East

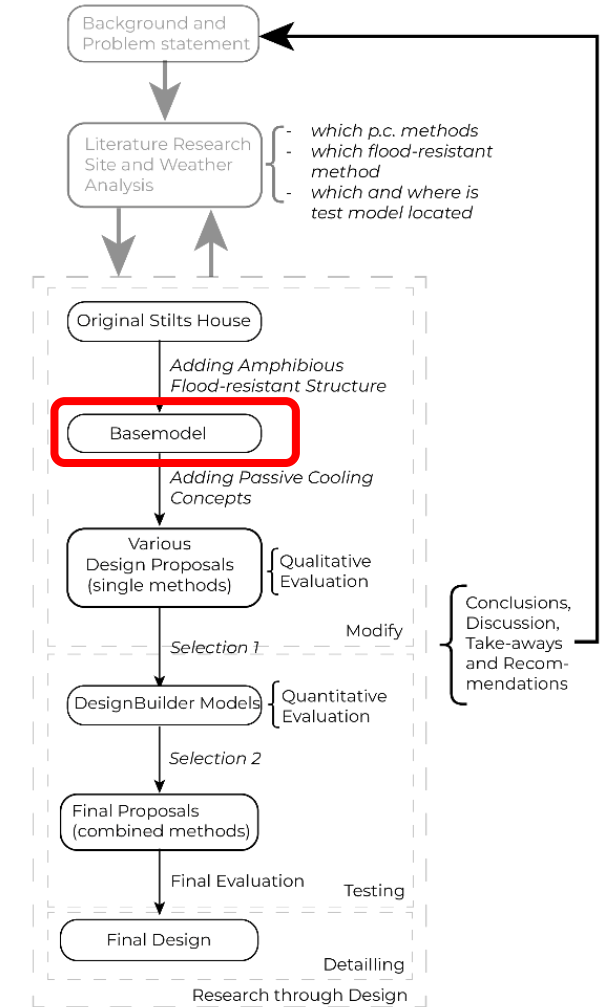



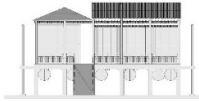



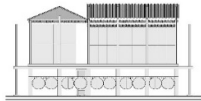


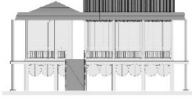
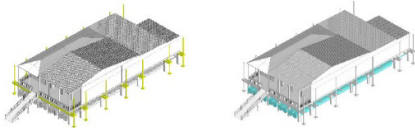

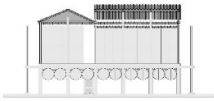



West

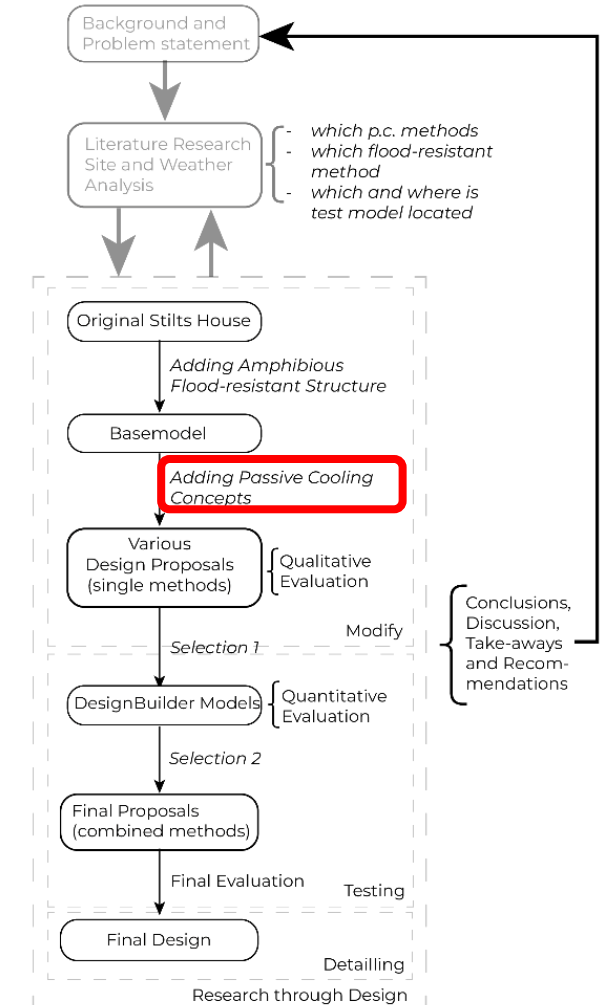


North

C. Proposals




Passive Cooling Methods	Concept	Concept Variations							
A. Wind/ Natural Ventilation									
	Through air flow through buoyancy layer	Barrel configuration 1	Barrel configuration 2	Barrel configuration 3	LWC Buoyancy	Floor Vents			
B. Shading				<p>Integration of these elements from the Amphibious structures:</p> 					
	Through louvres	Louvres	Overhang						
C. Thermal Insulation			<div><div>Vertical Guidance Posts</div><div>Buoyancy Elements</div></div>						
	Adding insulation to walls and roof	5 cm Glass wool							
D. Combined									
	As an extra ventilative and sunprotective skin	Double-skin facade	Tropic Roof						


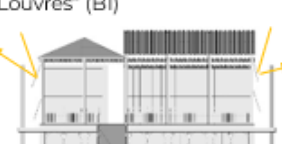
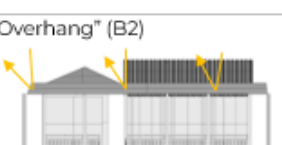
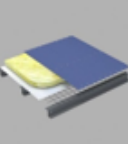



To explain the design proposals more further:



Base Model

A. Wind/natural Ventilation	Design Proposal	Description
	"Barrel Configuration 1" (A1)	This proposal is a variant with a different barrel configuration. Where the main goal is to create airflow under the house while it is floating on water(when the barrels touch the water surface).
	"Barrel Configuration 2" (A2)	This proposal is also variant with a different barrel configuration. The whole floating structure is more lower leveled. Where the main goal is to create airflow under the house while it is floating on water(when the barrels touch the water surface).
	"Barrel Configuration 3" (A3)	This proposal is a also variant with a different barrel configuration. Where the main goal is to create airflow under the house while it is floating on water (when the barrels touch the water surface).
	"LWC Buoyancy" (A4)	This proposal allows airflow to continue under the house with light-weight concrete as material. This has also been experimented with larger floating villages.  Source: Lightweight Concrete (LWC) - Types & uses (2017)

B. Shading	"Floor Vents" (A5)	This proposal allows air under the floor to exchange with inside air. To enable/enhance the effect the buoyancy is placed lower.  Source: registerandhardware.com [n.d.]
	"Louvres" (B1)	This proposal involves adding exterior louvres to the façade. This element can be attached to the vertical guidance posts. These can extra support the louvres. Enabling the user with the possibility of adjusting the shade to their own liking. 
	"Overhang" (B2)	This proposal involves extending the current roof edges and creating a greater overhang. Protecting the home against heat gain from the sun entering the home. 
	"5 cm Glass Wool in walls and roof" (C)	This proposal involves adding 5cm glass wool in the exterior walls and roofs. Absorbing radiant heat and preventing heat transfer. As well as noise(rain).  Source: cattuongcorp.com
D. Combined	"Double-skin Façade" (D1)	This proposal involves adding an extra skin to the existing structure. The structure can be supported by the vertical guidance posts and aims to reduce the heat gain during the day.  Source: archdaily.com

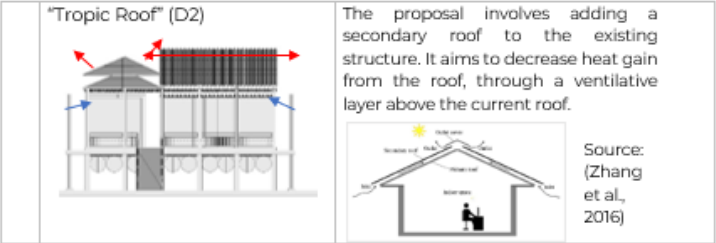
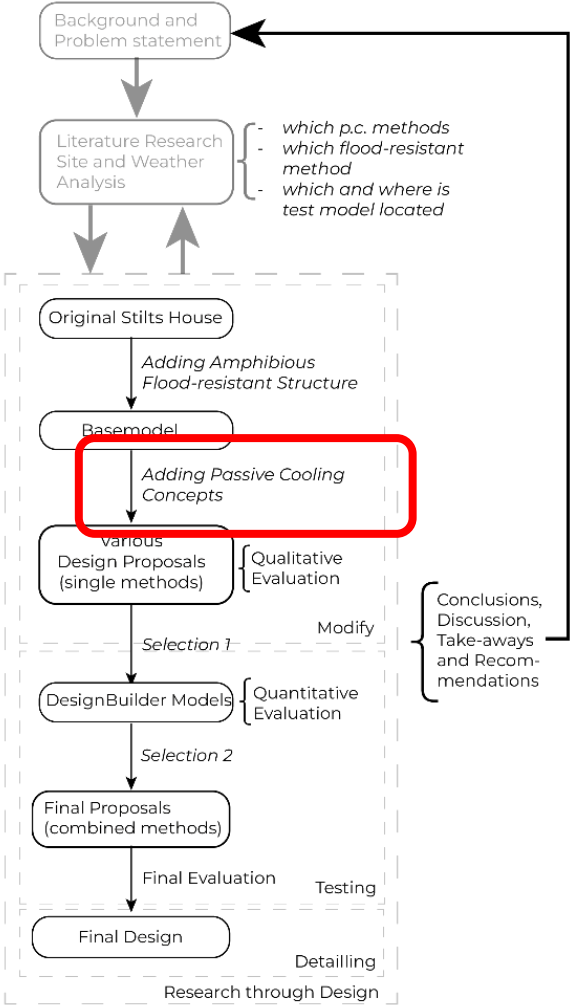





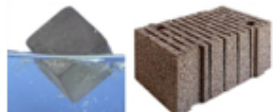
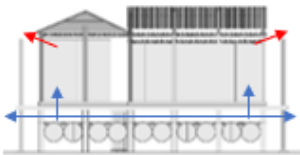
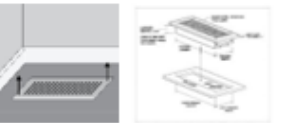

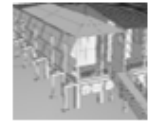

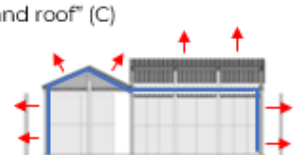
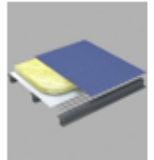

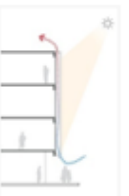


Fig. 5.12: Design Proposals (passive cooling strategies), made by author.



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C. Thermal Insulation	"Overhang" (B2) 	This proposal involves extending the current roof edges and creating a greater overhang. Protecting the home against heat gain from the sun entering the home.
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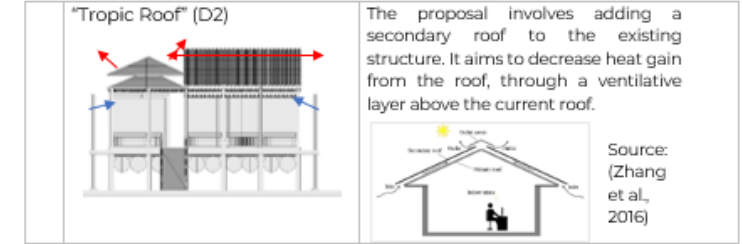
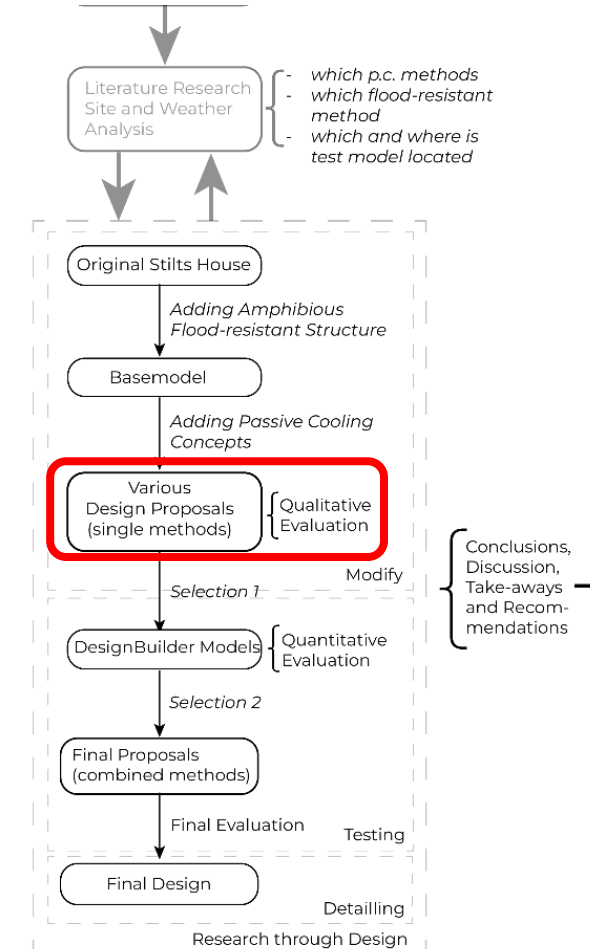


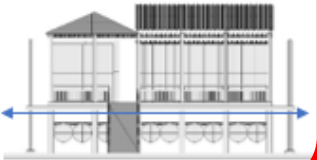


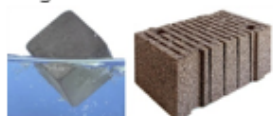
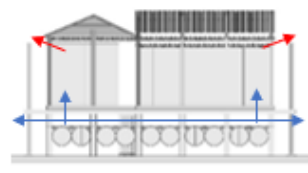
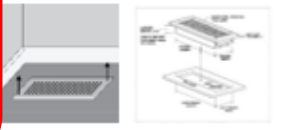
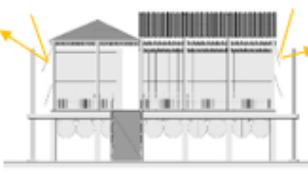


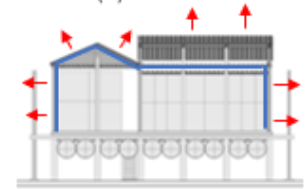
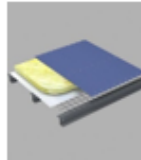




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	"5 cm Glass Wool in walls and roof" (C) 	This proposal involves adding 5cm glass wool in the exterior walls and roofs. Absorbing radiant heat and preventing heat transfer. As well as noise(rain).  Source: cattuongcorp.com
D. Combined	"Double-skin Façade" (D1) 	This proposal involves adding an extra skin to the existing structure. The structure can be supported by the vertical guidance posts and aims to reduce the heat gain during the day.  Source: archdaily.com

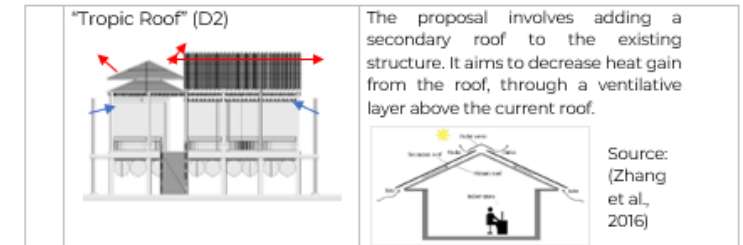
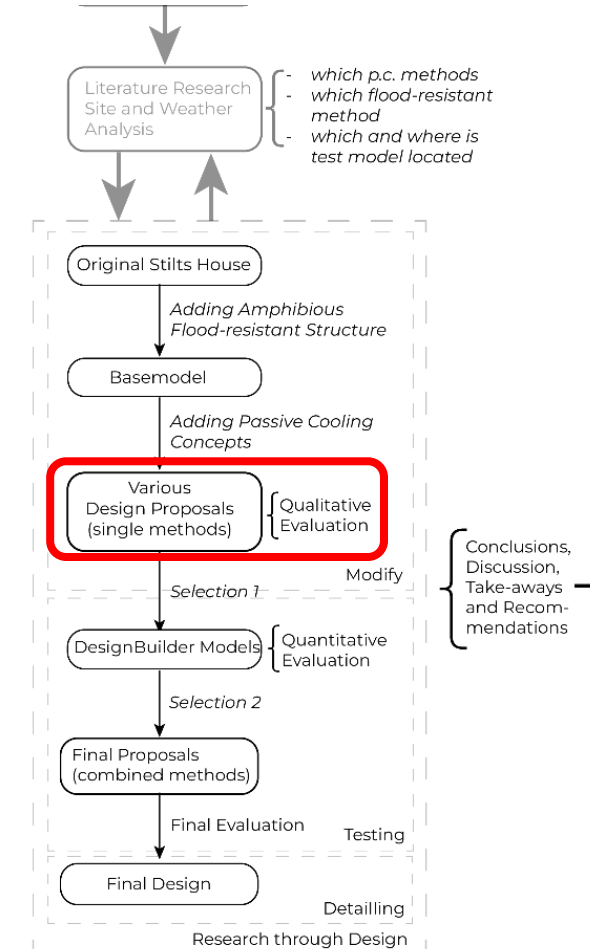


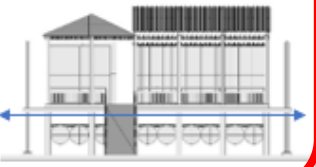


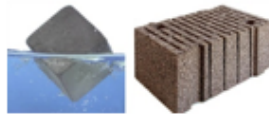

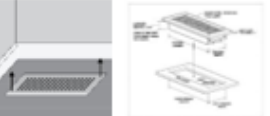

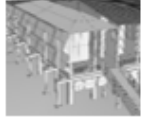

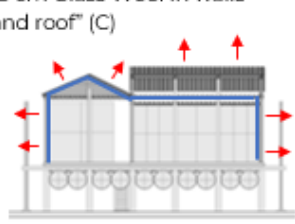


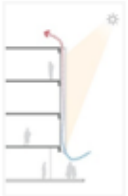


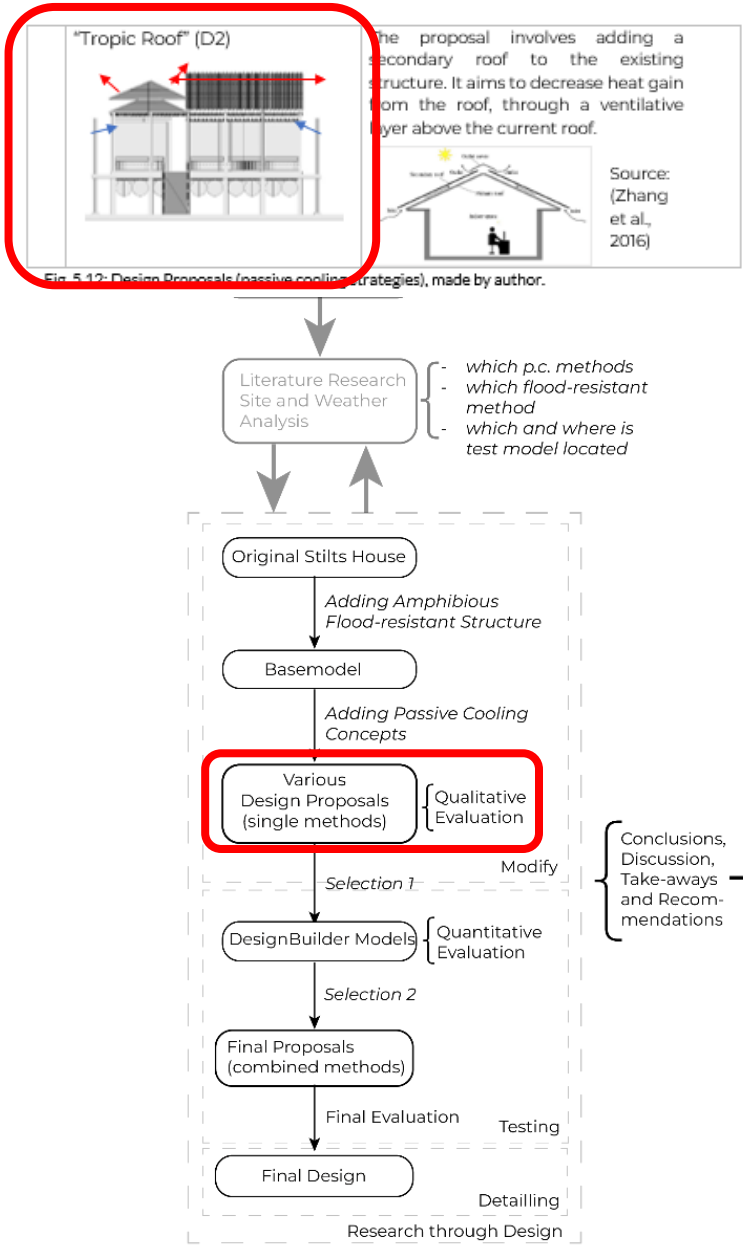
Fig. 5.12: Design Proposals (passive cooling strategies), made by author.








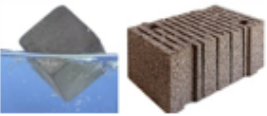
To explain the design proposals more further:

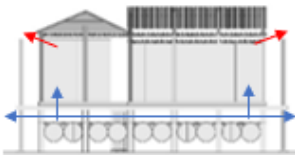
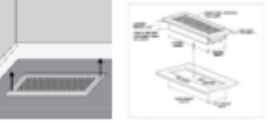

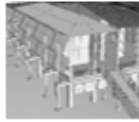

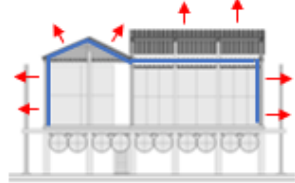



A. Wind/natural Ventilation		Base Model
		"Barrel Configuration 1" (A1) This proposal is a variant with a different barrel configuration. Where the main goal is to create airflow under the house while it is floating on water (when the barrels touch the water surface).
		"Barrel Configuration 2" (A2) This proposal is also variant with a different barrel configuration. The whole floating structure is more lower leveled. Where the main goal is to create airflow under the house while it is floating on water (when the barrels touch the water surface).
		"Barrel Configuration 3" (A3) This proposal is a also variant with a different barrel configuration. Where the main goal is to create airflow under the house while it is floating on water (when the barrels touch the water surface).
		"LWC Buoyancy" (A4) This proposal allows airflow to continue under the house with light-weight concrete as material. This has also been experimented with larger floating villages.  Source: Lightweight Concrete (LWC) - Types & uses (2017)

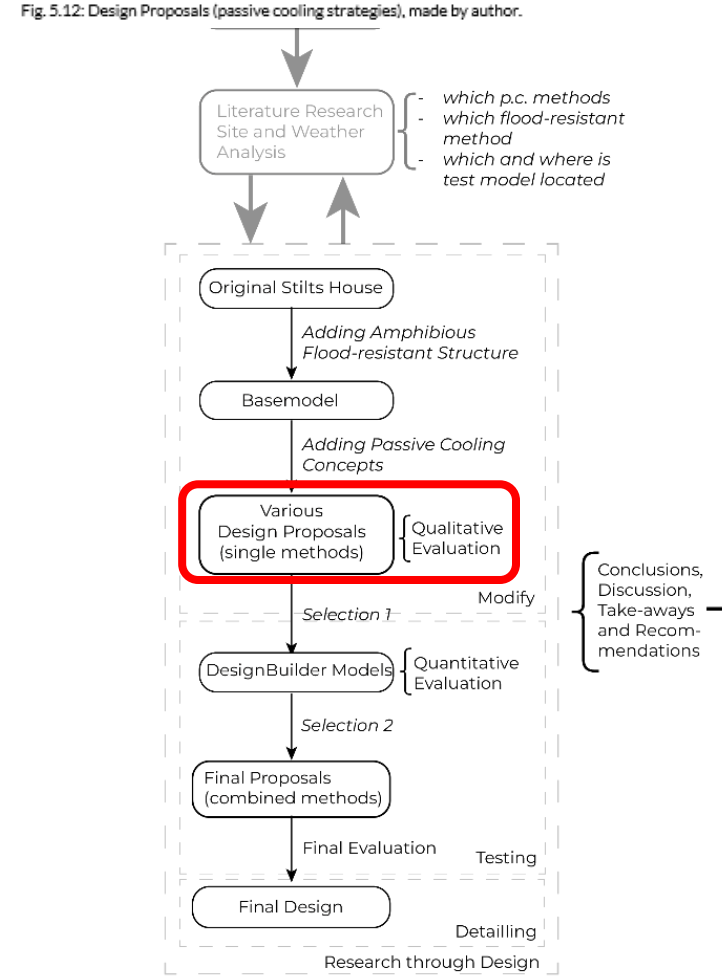
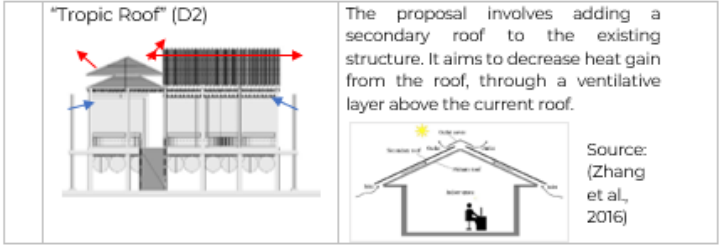
B. Shading C. Thermal Radiation D. Combined		"Floor Vents" (A5) This proposal allows air under the floor to exchange with inside air. To enable/enhance the effect the buoyancy is placed lower.  Source: registerandhardware.com (n.d.)
		"Louvres" (B1) This proposal involves adding exterior louvers to the façade. This element can be attached to the vertical guidance posts. These can extra support the louvres. Enabling the user with the possibility of adjusting the shade to their own liking. 
		"Overhang" (B2) This proposal involves extending the current roof edges and creating a greater overhang. Protecting the home against heat gain from the sun entering the home.
		"5 cm Glass Wool in walls and roof" (C) This proposal involves adding 5cm glass wool in the exterior walls and roofs. Absorbing radiant heat and preventing heat transfer. As well as noise(rain).  Source: cattuongcorp.com
		"Double-skin Façade" (D1) This proposal involves adding an extra skin to the existing structure. The structure can be supported by the vertical guidance posts and aims to reduce the heat gain during the day.  Source: archdaily.com



To explain the design proposals more further:

 <p>Base Model</p>	
Design Proposal	Description
"Barrel Configuration 1" (A1)	This proposal is a variant with a different barrel configuration. Where the main goal is to create airflow under the house while it is floating on water (when the barrels touch the water surface).
	
"Barrel Configuration 2" (A2)	This proposal is also variant with a different barrel configuration. The whole floating structure is more lower leveled. Where the main goal is to create airflow under the house while it is floating on water (when the barrels touch the water surface).
	
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"LWC Buoyancy" (A4)	This proposal allows airflow to continue under the house with light-weight concrete as material. This has also been experimented with larger floating villages.
	 <p>Source: Lightweight Concrete (LWC) - Types & uses (2017)</p>

A. Wind/natural Ventilation	"Floor Vents" (A5)	This proposal allows air under the floor to exchange with inside air. To enable/enhance the effect the buoyancy is placed lower.
		 <p>Source: registerandhardware.com (n.d.)</p>
	"Louvres" (B1)	This proposal involves adding exterior louvres to the façade. This element can be attached to the vertical guidance posts. These can extra support the louvres. Enabling the user with the possibility of adjusting the shade to their own liking.
		
	"Overhang" (B2)	This proposal involves extending the current roof edges and creating a greater overhang. Protecting the home against heat gain from the sun entering the home.
B. Shading		
	"5 cm Glass Wool in walls and roof" (C)	This proposal involves adding 5cm glass wool in the exterior walls and roofs. Absorbing radiant heat and preventing heat transfer. As well as noise(rain).
		 <p>Source: cattuongcorp.com</p>
C. Thermal Radiation	"Double-skin Façade" (D1)	This proposal involves adding an extra skin to the existing structure. The structure can be supported by the vertical guidance posts and aims to reduce the heat gain during the day.
		 <p>Source: archdaily.com</p>



To explain the design proposals more further:

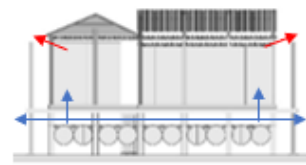


Base Model

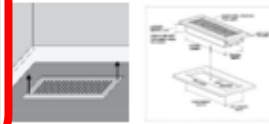
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A. Wind/natural Ventilation

"Floor Vents" (A5)



This proposal allows air under the floor to exchange with inside air. To enable/enhance the effect the buoyancy is placed lower.



Source: registerandhardware.com (n.d.)

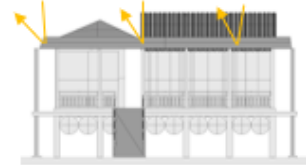
"Louvres" (B1)



This proposal involves adding exterior louvers to the façade. This element can be attached to the vertical guidance posts. These can extra support the louvres. Enabling the user with the possibility of adjusting the shade to their own liking.

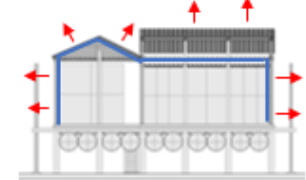


"Overhang" (B2)

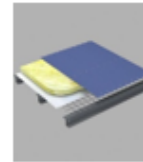


This proposal involves extending the current roof edges and creating a greater overhang. Protecting the home against heat gain from the sun entering the home.

"5 cm Glass Wool in walls and roof" (C)



This proposal involves adding 5cm glass wool in the exterior walls and roofs. Absorbing radiant heat and preventing heat transfer. As well as noise(rain).

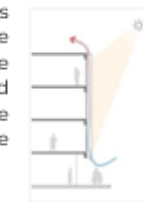


Source: cattuongcorp.com

"Double-skin Façade" (D1)



This proposal involves adding an extra skin to the existing structure. The structure can be supported by the vertical guidance posts and aims to reduce the heat gain during the day.



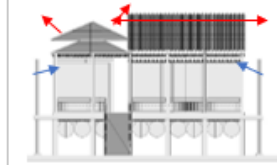
Source: archdaily.com

B. Shading

C. Thermal Insulation

D. Combined

"Tropic Roof" (D2)

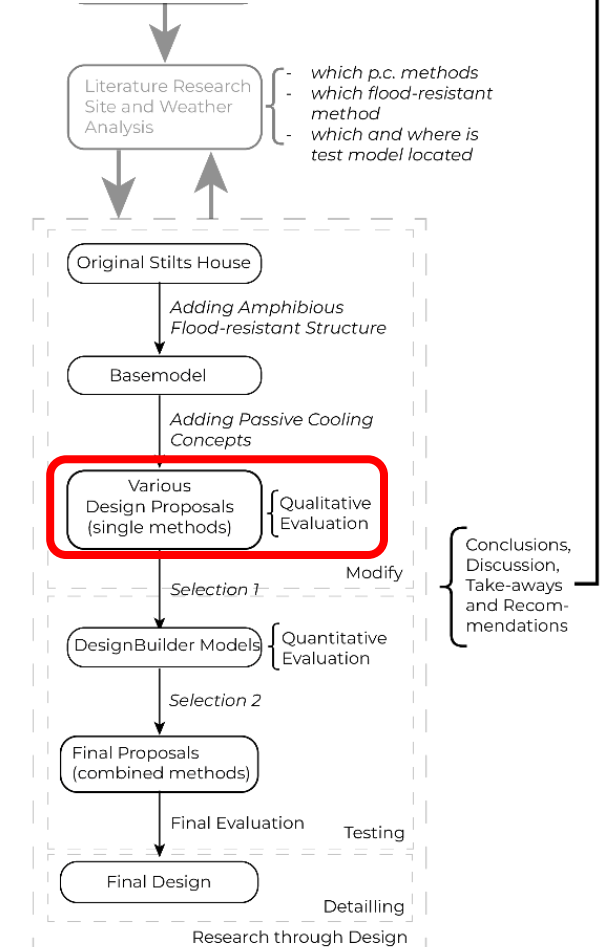


The proposal involves adding a secondary roof to the existing structure. It aims to decrease heat gain from the roof, through a ventilative layer above the current roof.

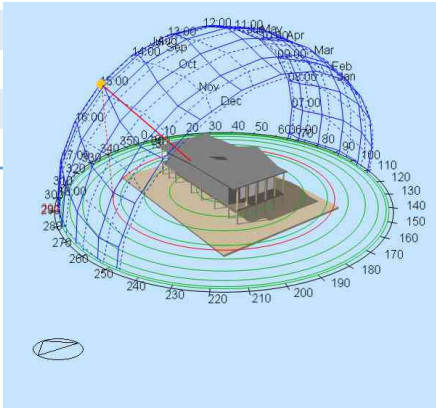
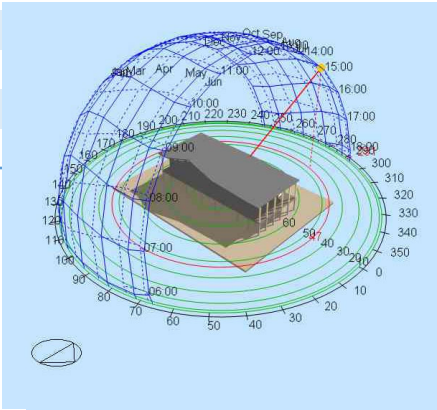


Source: (Zhang et al., 2016)

Fig. 5.12: Design Proposals (passive cooling strategies), made by author.



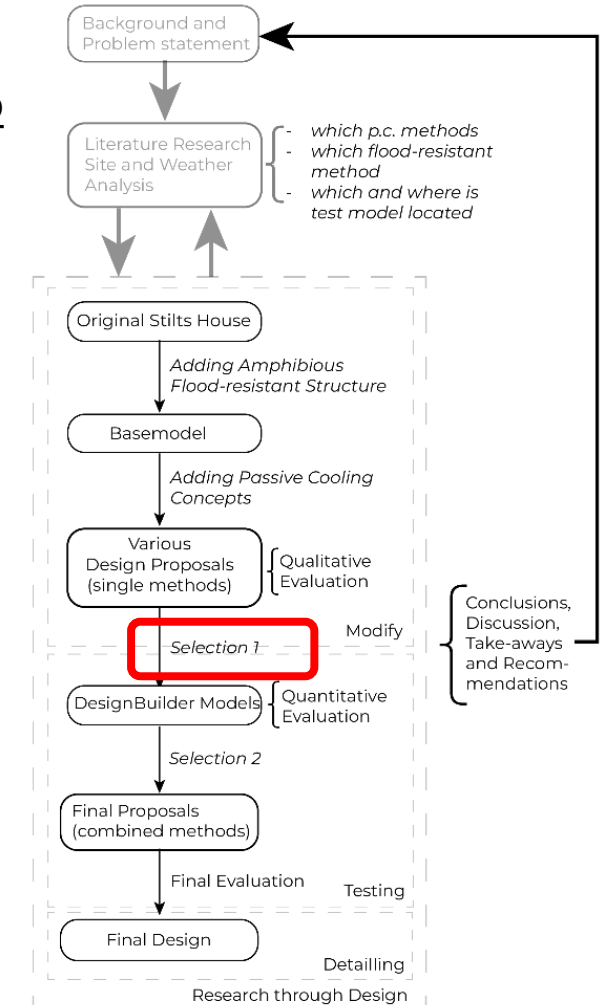
Input and Materials:			Heating Setpoint Temperatures	
1.	Walls	Uninsulated lightweight metallic cladding	Heating (Celsius)	5.0
2.	Floor	Timber floor	Heating set back (Celsius)	5.0
3.	Structure	Timber and concrete	Cooling Setpoint Temperatures	
4.	Inner Partitions	6mm plywood	Cooling (Celsius)	50.0
5.	HVAC	no heating, no cooling	Cooling set back (Celsius)	50.0
6.	Systems on/off	only lighting	Humidity Control	
7.	Occupancy (people/m2)	0.0188	RH Humidification setpoint (%)	10.0
8.	Activity	bed/living/kitchen	RH Dehumidification setpoint (%)	90.0
			Ventilation Setpoint Temperatures	
		winter	summer	Natural Ventilation
Outside temperature (Celsius)	22.1	34.1	Indoor min temperature control	no
Wind velocity (m/s)	4.7	0	Indoor max temperature control	no
			Minimum Fresh Air	
			Fresh air (l/s-person)	10.0
			Mech vent per area (l/m-s2)	0.0
			Lighting	
			Target Illuminance (lux)	100
			Default display lighting density (W/m2)	0



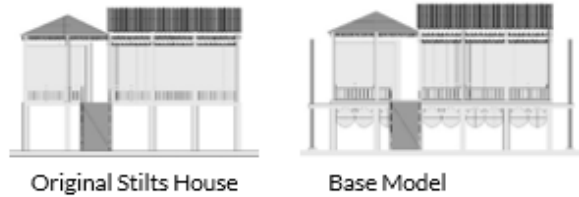
Sunpath diagram on July 15th 3am

C. Testing

- Group I: The Original Stilts House and Base Model during flood and dry scenario
- Group II: Base Model and Passive Cooling by Natural Ventilation/Wind, during flood and dry scenario
- Group III: Base Model and Passive Cooling by Shading
- Group IV: Base Model and Passive Cooling by Thermal Insulation
- Group V: Base Model and Passive Cooling by Multifaceted Interventions



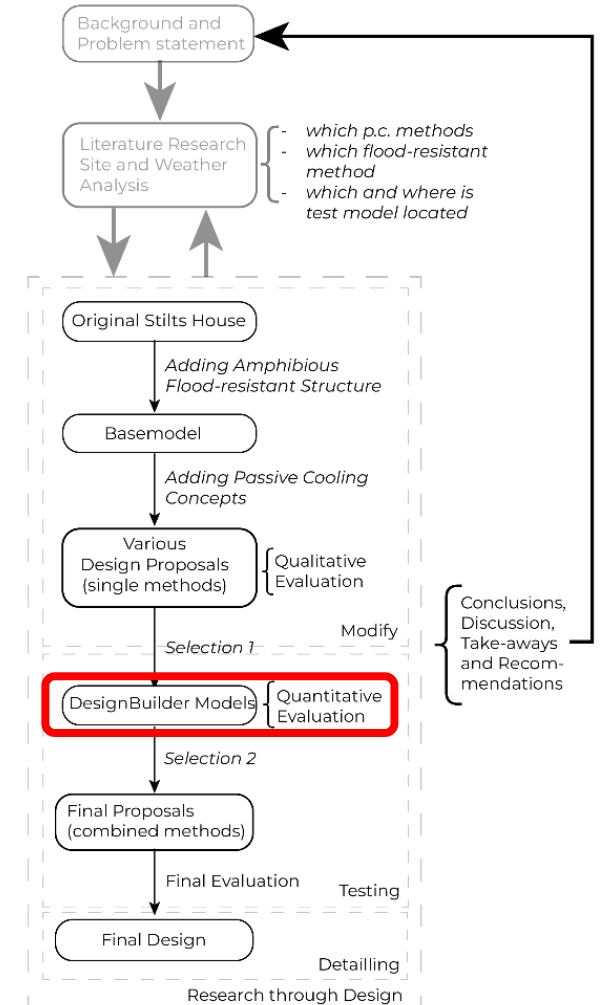
Group I: The Original Stilts House and Base Model during flood and dry scenario



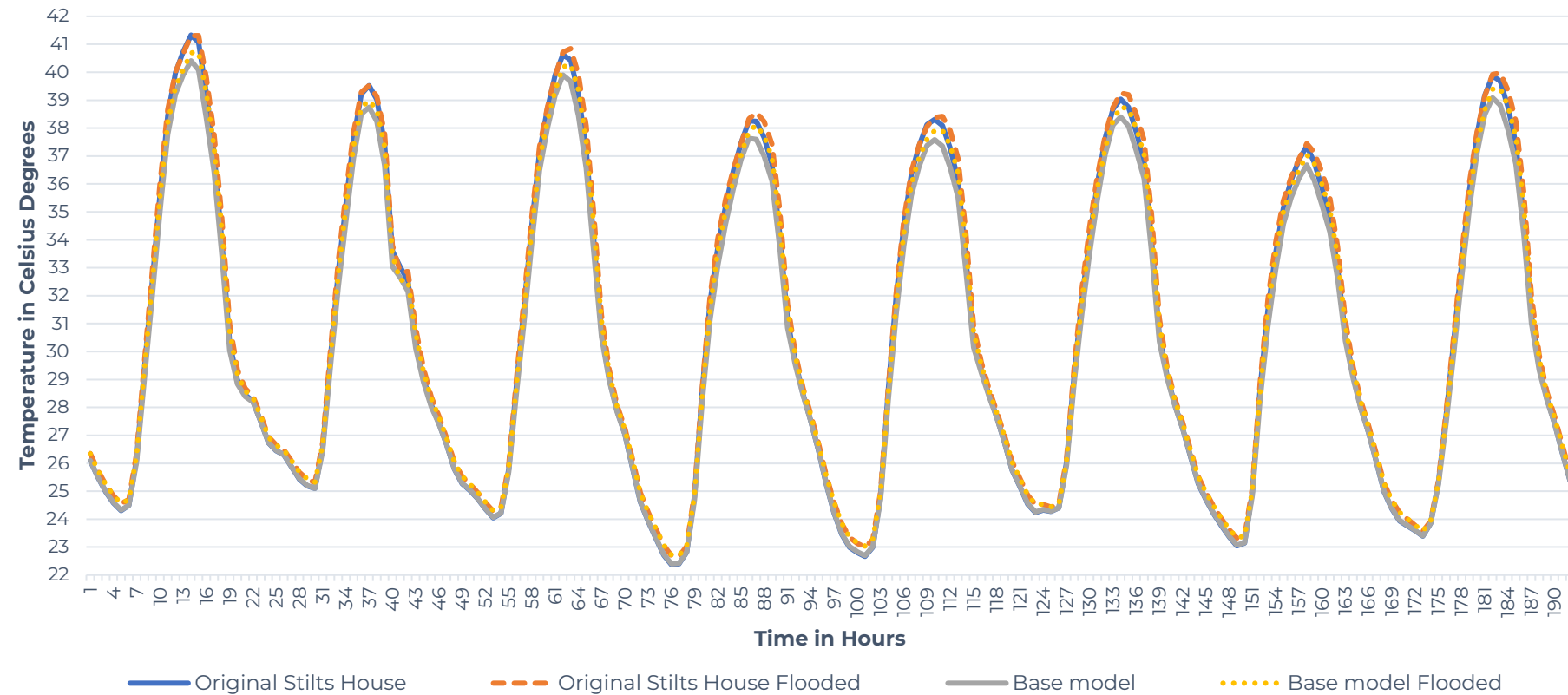
Flood Scenario is made by building Standard Component Blocks with a height of 1m. The Component Block's material is Water and Shades and Reflects.

Does the Operative Temperature increase/decrease after transforming the original stilts house into an amphibious flood-resistant house and or does it change during a flood?

How significant is this?



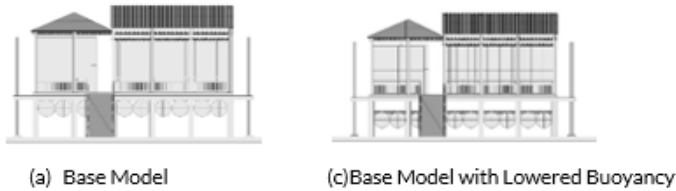
**Group I: The Original Stilts House and Base Model during flood and dry scenario, hourly
Operative Temperatures during 21st-28th of April**



Does the Operative Temperature increase/decrease after transforming the original stilts house into an amphibious flood-resistant house and or does it change during a flood?

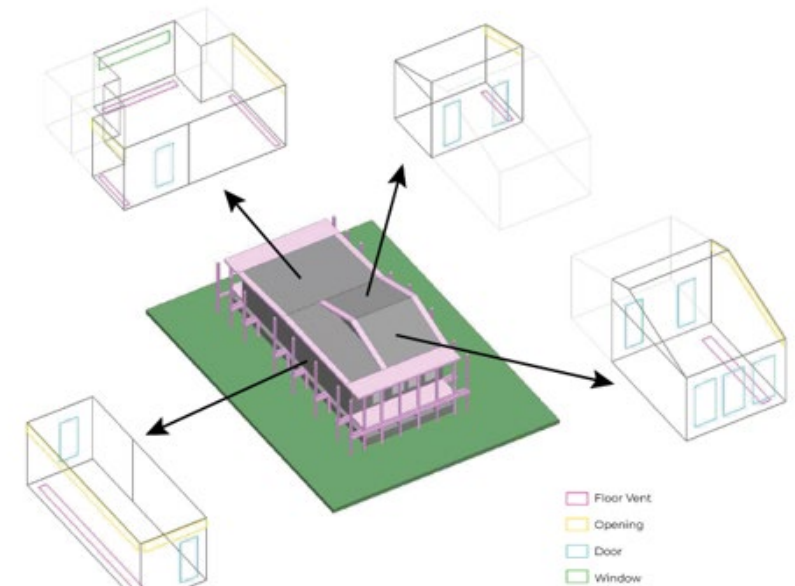
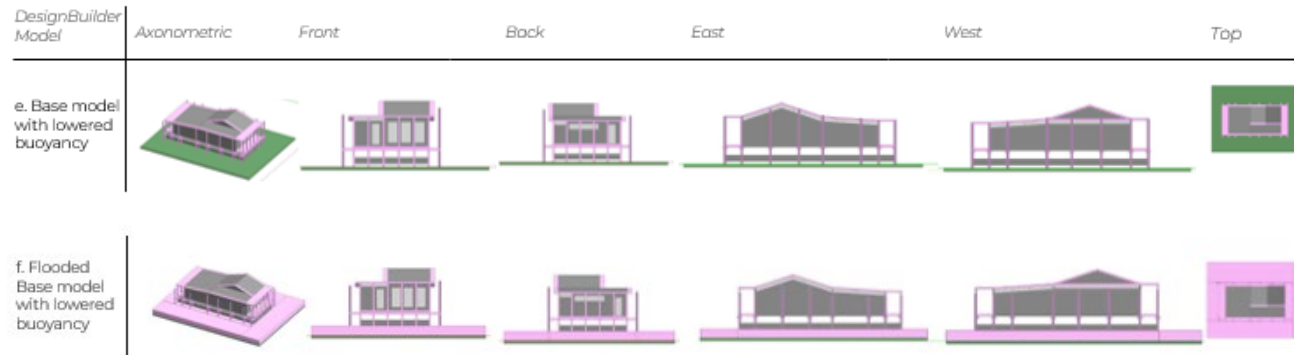
How significant is this?

Group II: Base Model and Passive Cooling by Natural Ventilation/Wind, during flood and dry scenario



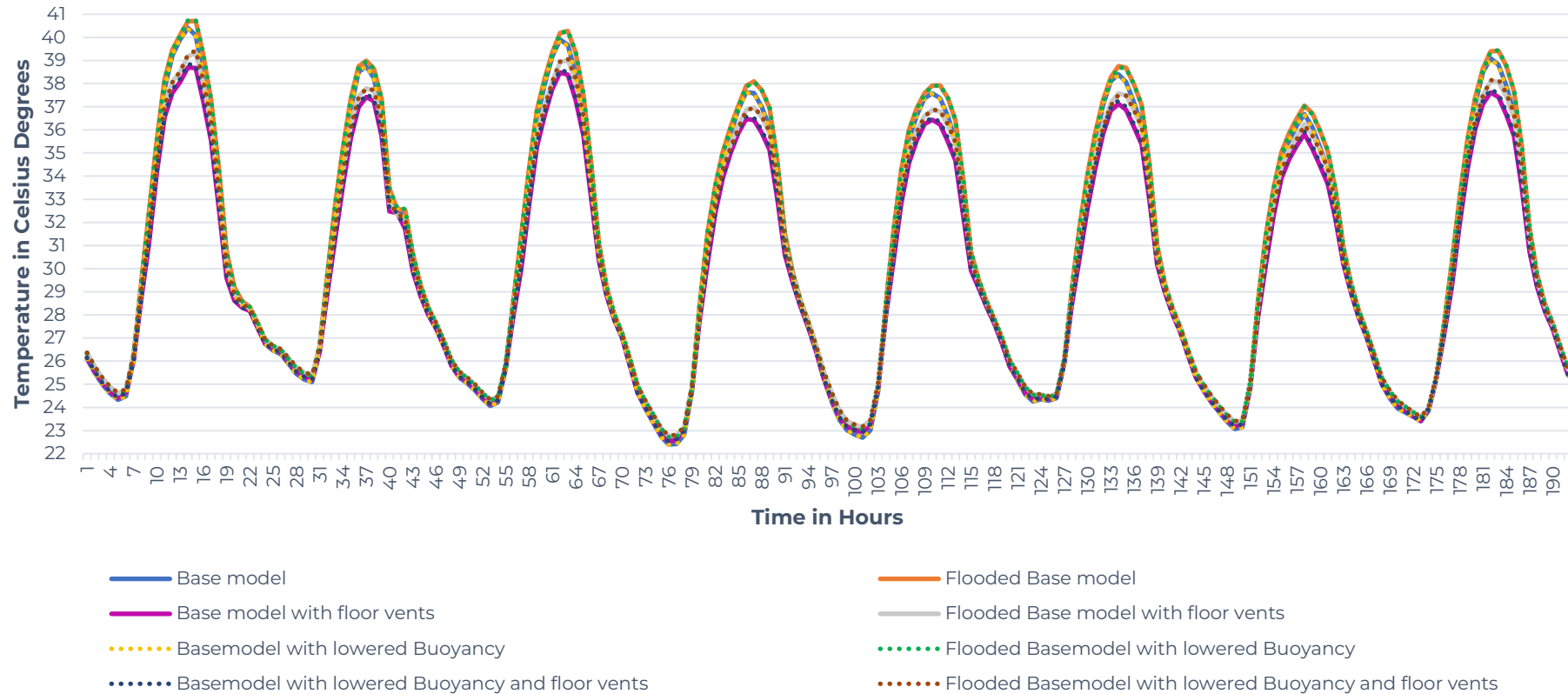
Simulations of:

- Base Model
- Flooded Base Model
- Base Model with Floor Vents
- Flooded Base model with Floor vents
- Base Model with Lowered Buoyancy
- Flooded Base Model with Lowered Buoyancy
- Base Model with Lowered Buoyancy and Floor Vents
- Flooded Base Model with Lowered Buoyancy and Floor Vents



Does lowering the buoyancy of the Base Model or integrating floor vents decrease the Operative Temperature? And what if It is combined? how significant is this?

Group II: Base Model and Passive Cooling by Natural Ventilation/Wind, during flood and dry scenario, hourly Operative Temperatures during 21st-28th of April



Does lowering the buoyancy of the Base Model or integrating floor vents decrease the Operative Temperature? And what if It is combined? how significant is this?

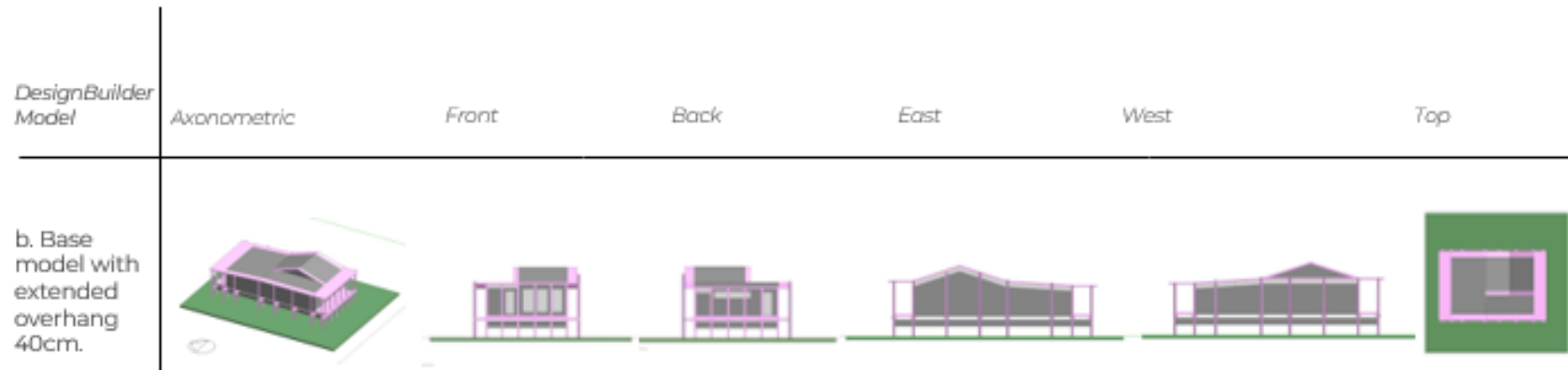
Group III: Base Model and Passive Cooling by Shading



a. Base Model

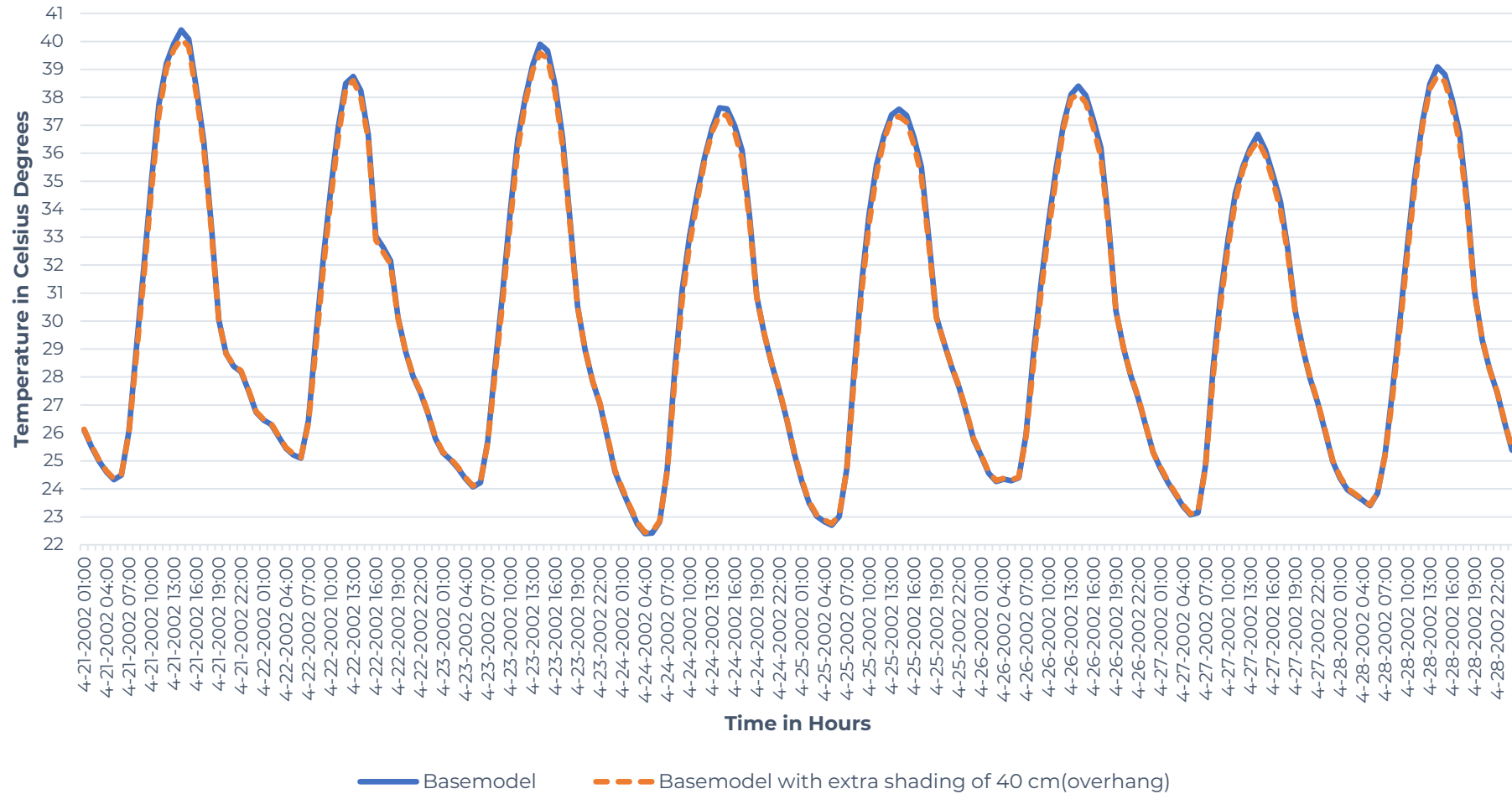


b. Base Model with extended overhang



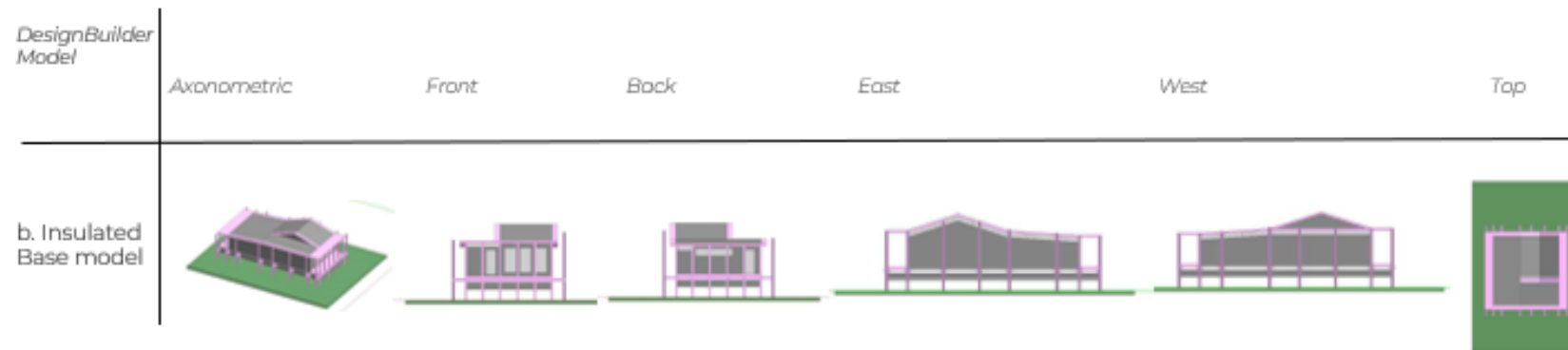
Does extending the overhang with 40cm decrease the Operative Temperature? If so, how significant is this?

Group III: Base Model and Passive Cooling by Shading, hourly Operative Temperatures during 21st-28th of April



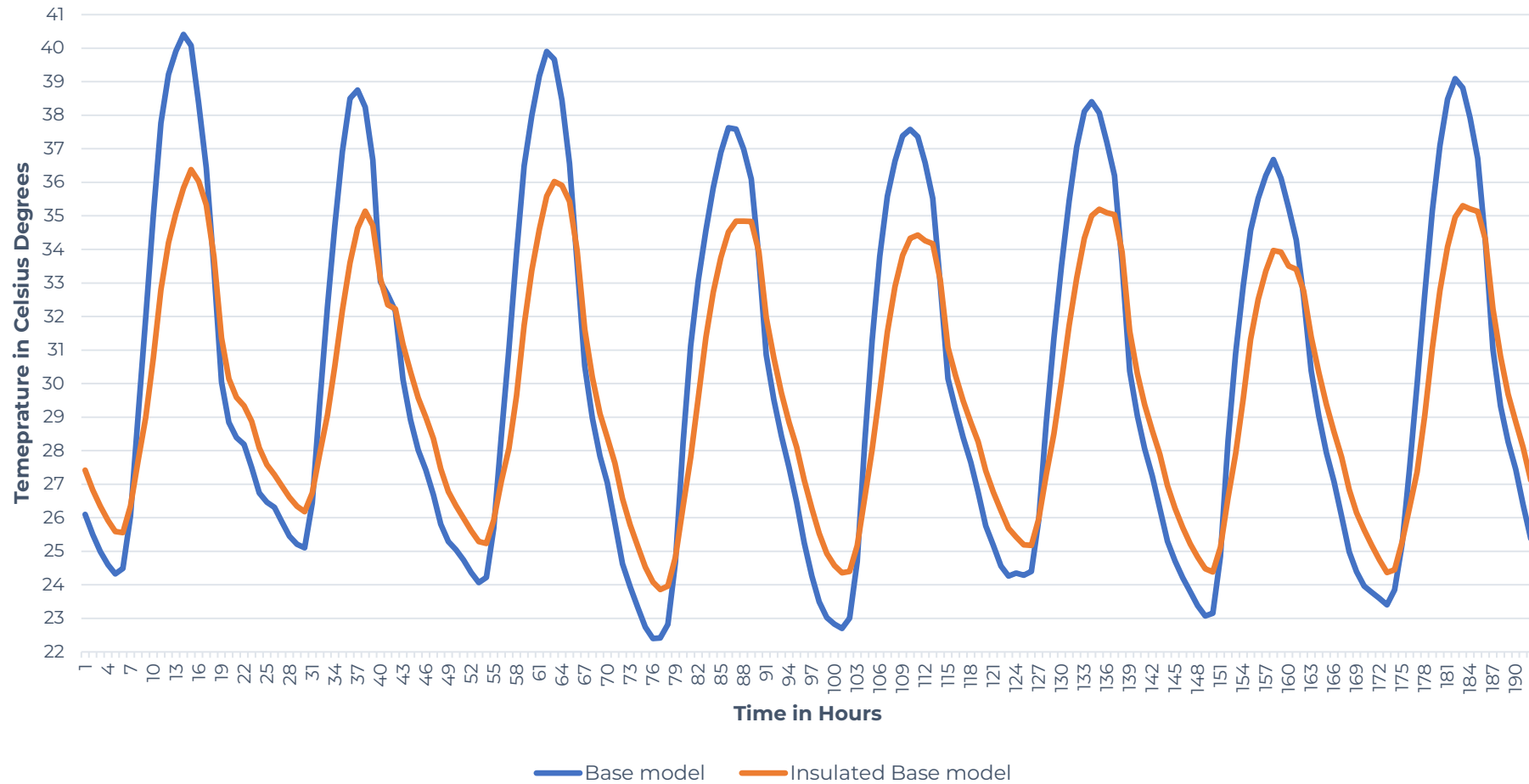
Does extending the overhang with 40cm decrease the Operative Temperature? If so, how significant is this?

Group IV: Base Model and Passive Cooling by Thermal Insulation



Does applying insulation of 5 cm Glass Wool to the walls and roof decrease the Operative Temperature and how significant is this?

Group IV: Base Model and Passive Cooling by Thermal Insulation, hourly Operative Temperature during 21st-28th of April

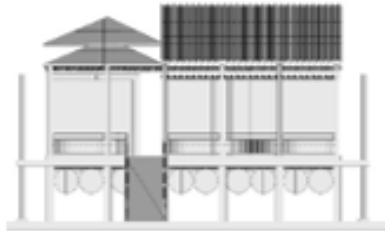


Does applying insulation of 5 cm Glass Wool to the walls and roof decrease the Operative Temperature and how significant is this?

Group V: Base Model and Passive Cooling by Multifaceted Interventions



a. Base Model



Tropic Roof

b. insulated

c. non-Insulated

d. insulated and Extra Vents



Double-skin Façade

e. Openings on Sides only (see fig. next page

f. Openings all sides

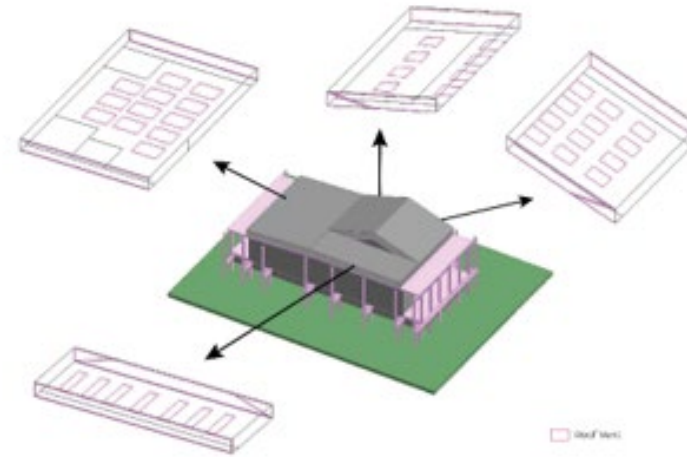
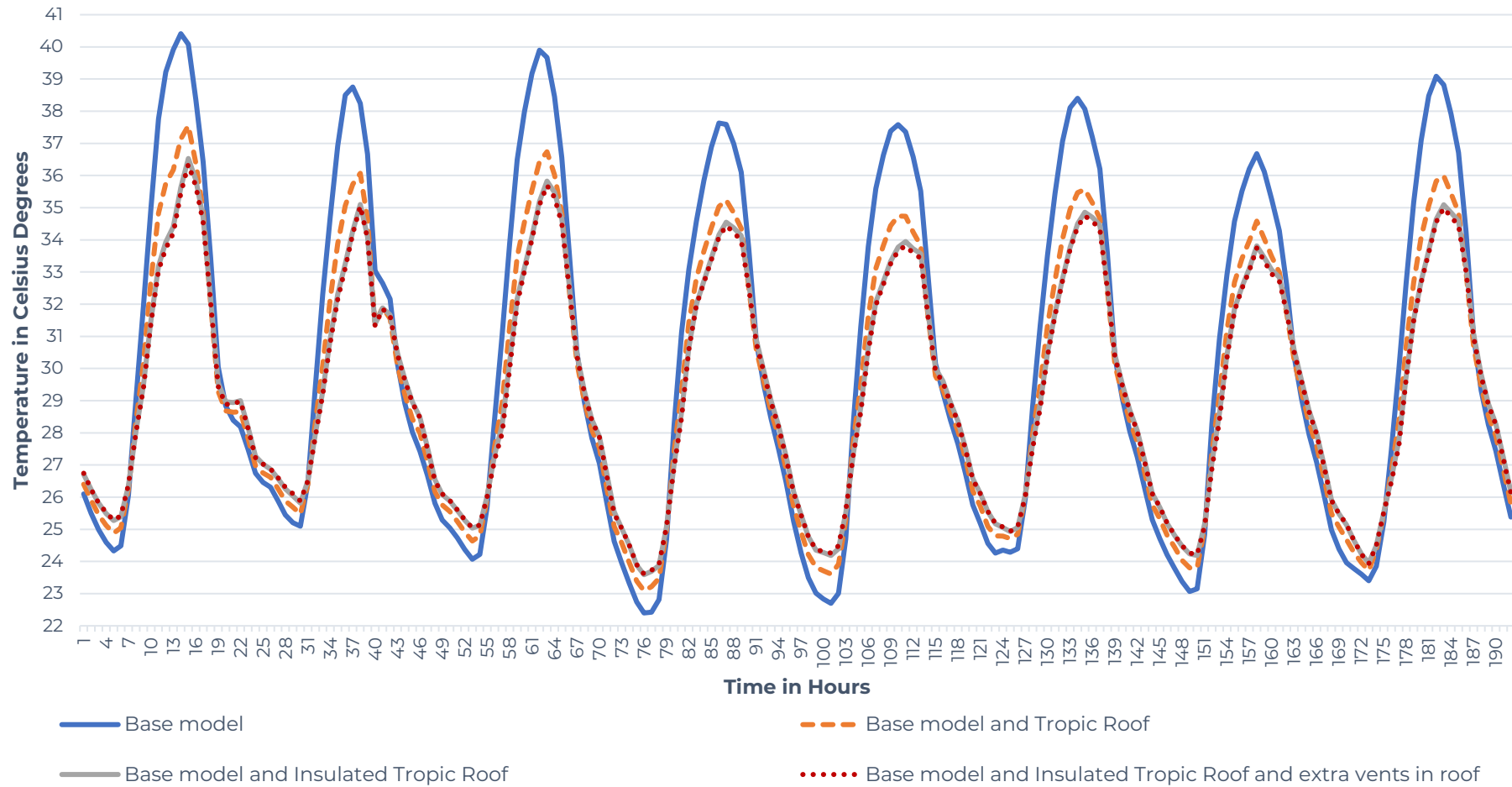


Fig. Tropic Roof and extra vents

DesignBuilder Models	Axonometric	Front	Back	East	West	Top
b/c/d. Base model with Tropic roof						
e. Base model with Double-Skin Façade (openings on sides)						
f. Base model with Double-Skin Façades (openings on all sides)						

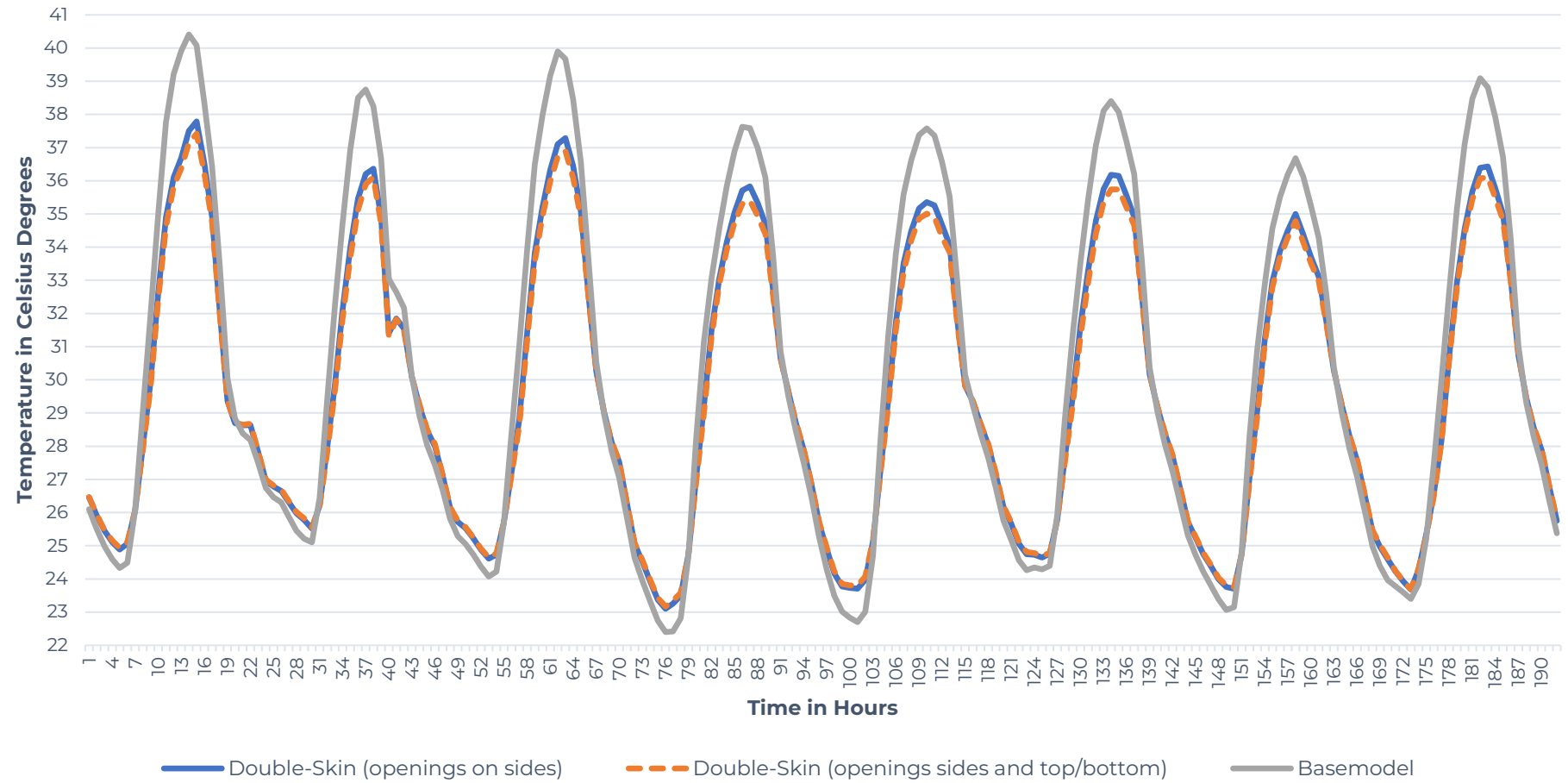
Can a Tropic Roof or Double-skin façade decrease the Operative Temperature? If so, how significant is this?

Group V: Base Model and Passive Cooling by Multifaceted Interventions (Tropic Roof), Hourly Operative Temperatures 21st-28th of April

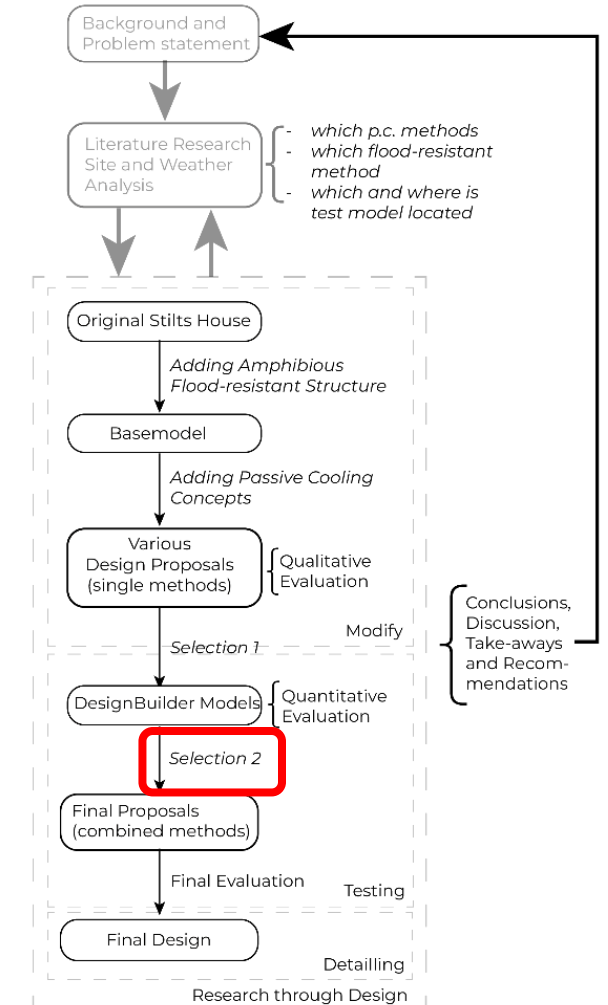
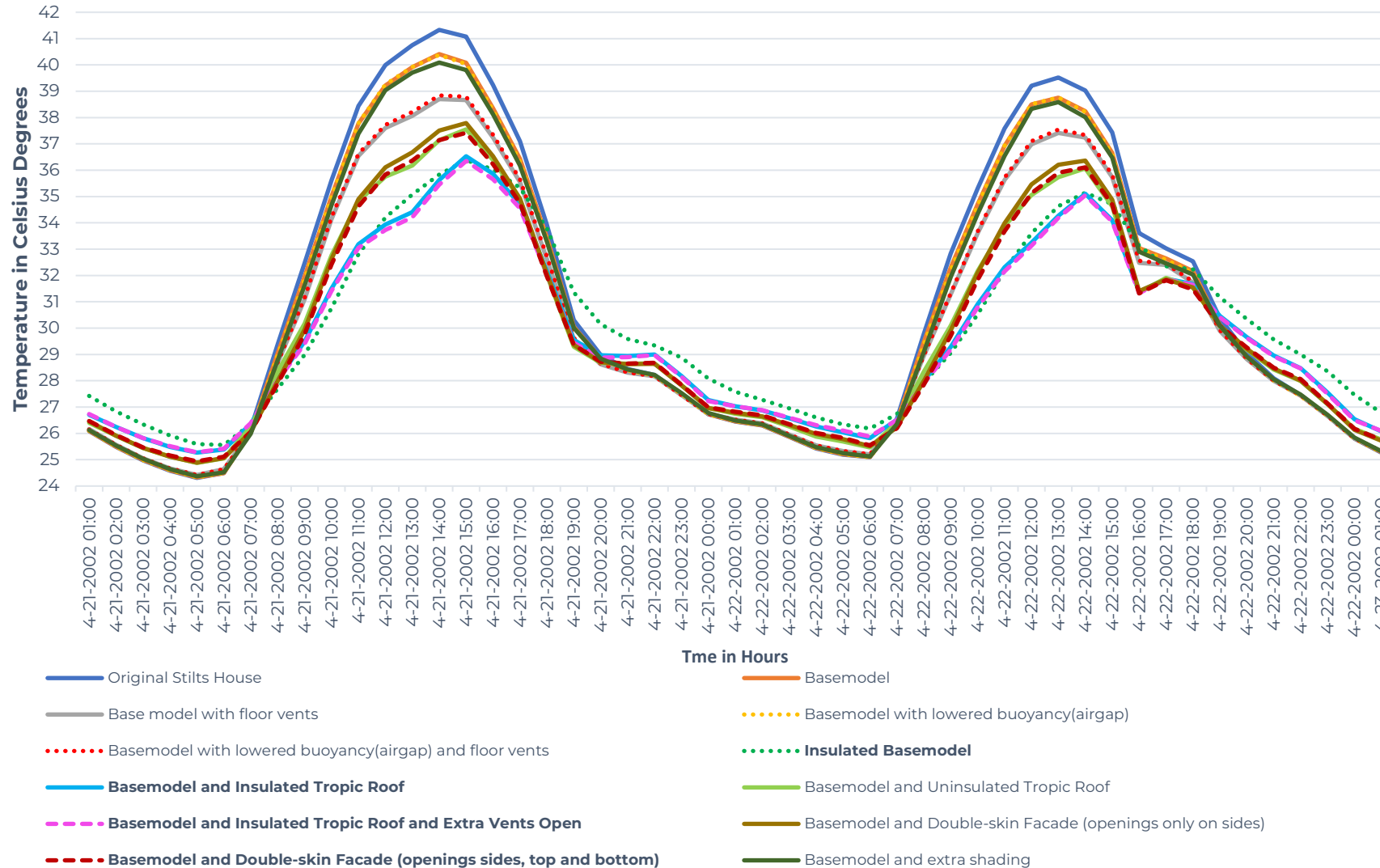


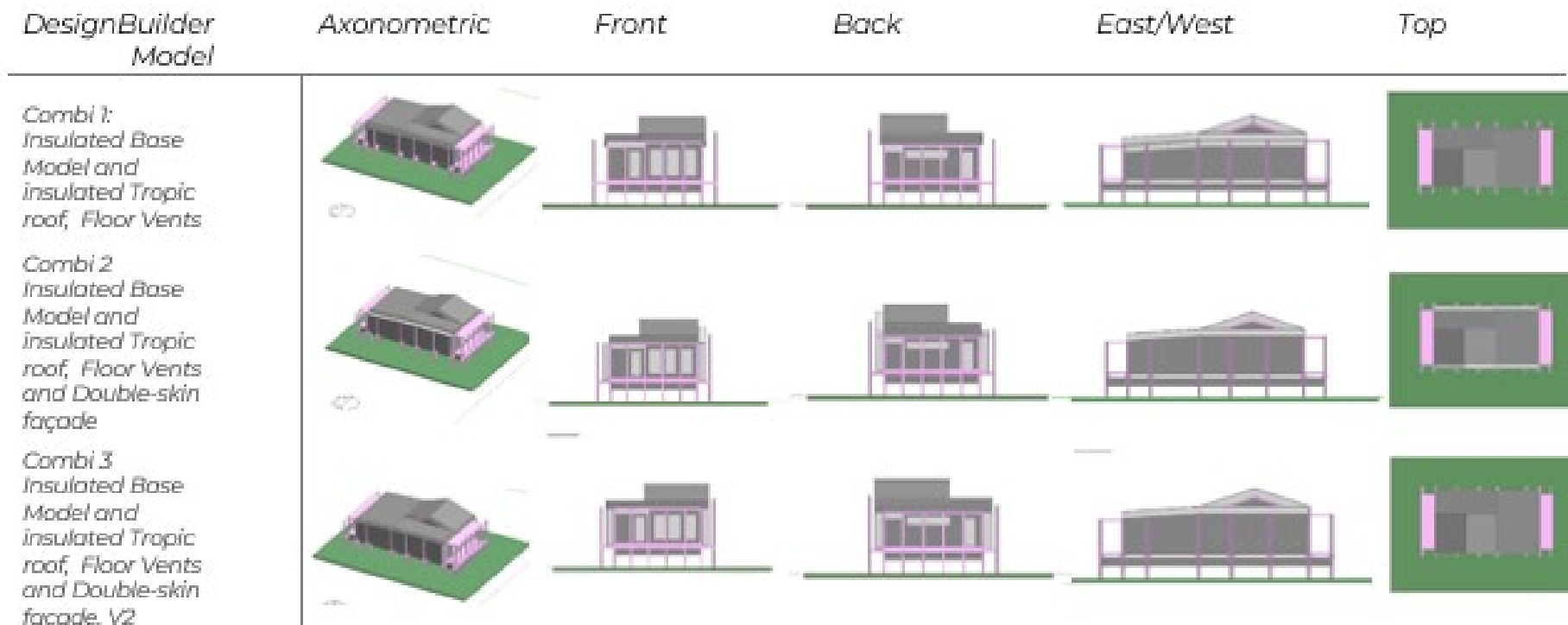
Can a Tropic Roof or Double-skin façade decrease the Operative Temperature? If so, how significant is this?

**Group V: Base Model and Passive Cooling by Multifaceted Interventions (Double-skin Facade),
Hourly Operative Temperatures 21st-28th of April**



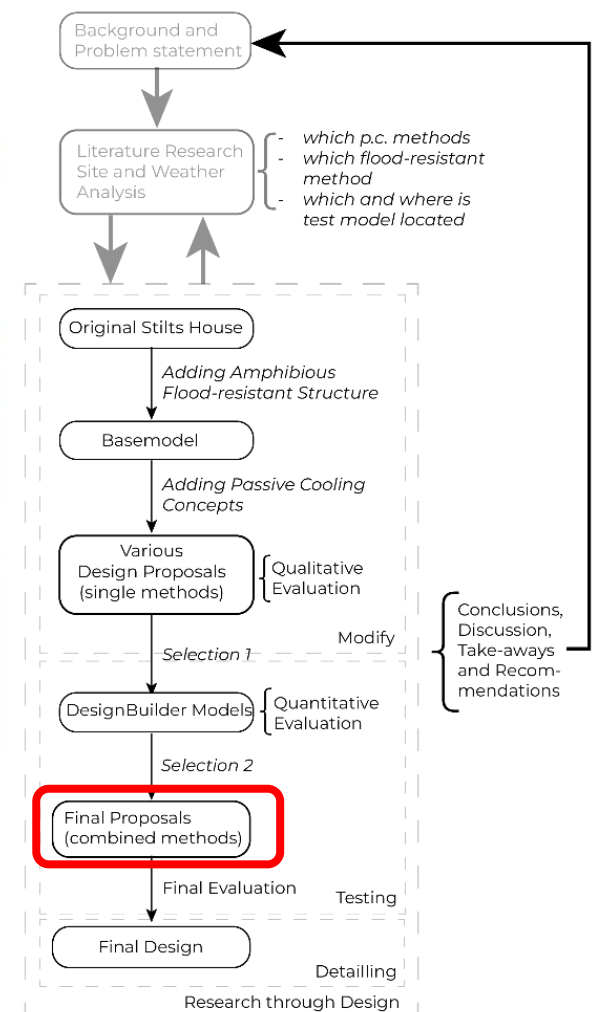
Summary all Passive Cooling Interventions on Base Model, hourly operative temperature during 21st-23rd of April



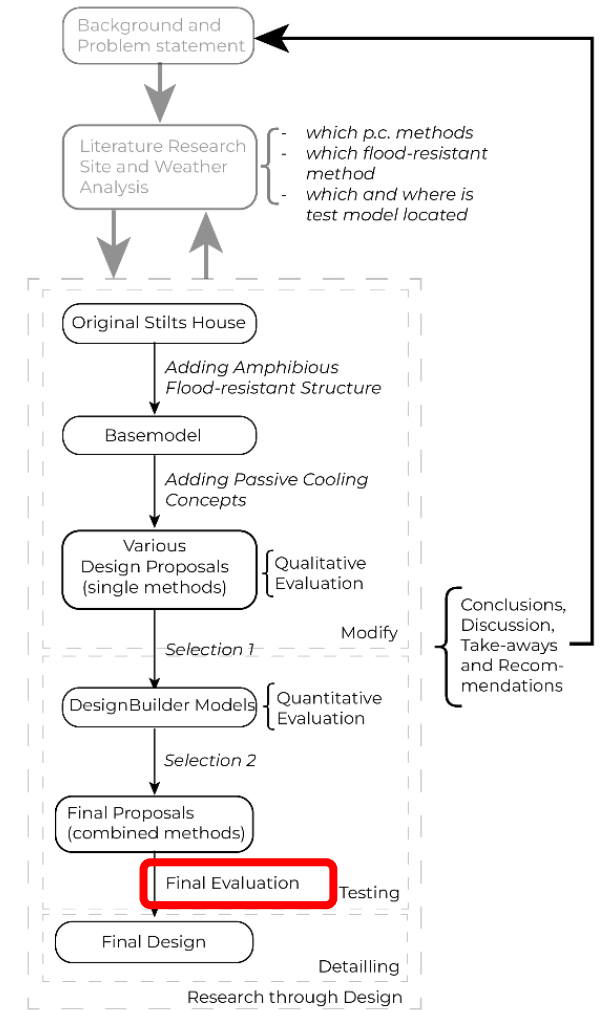
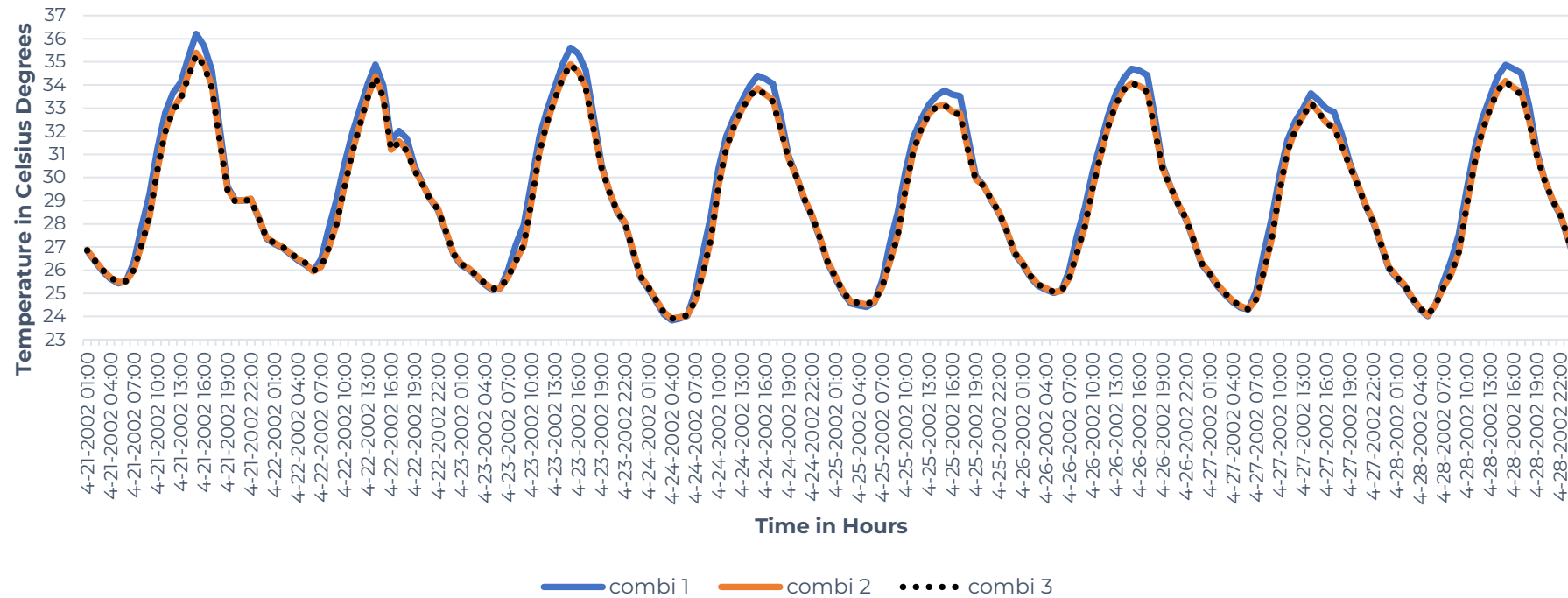


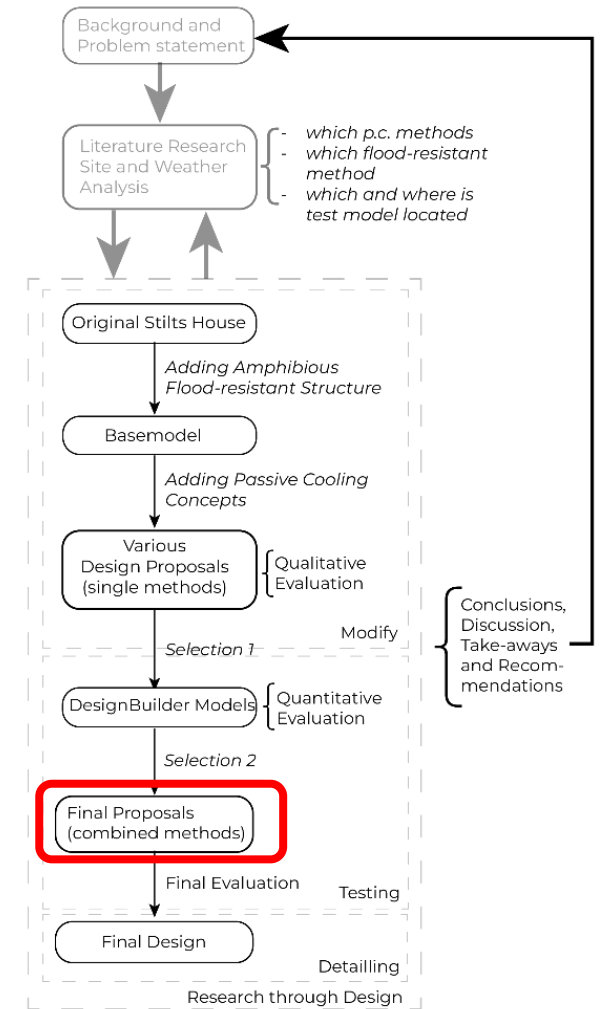
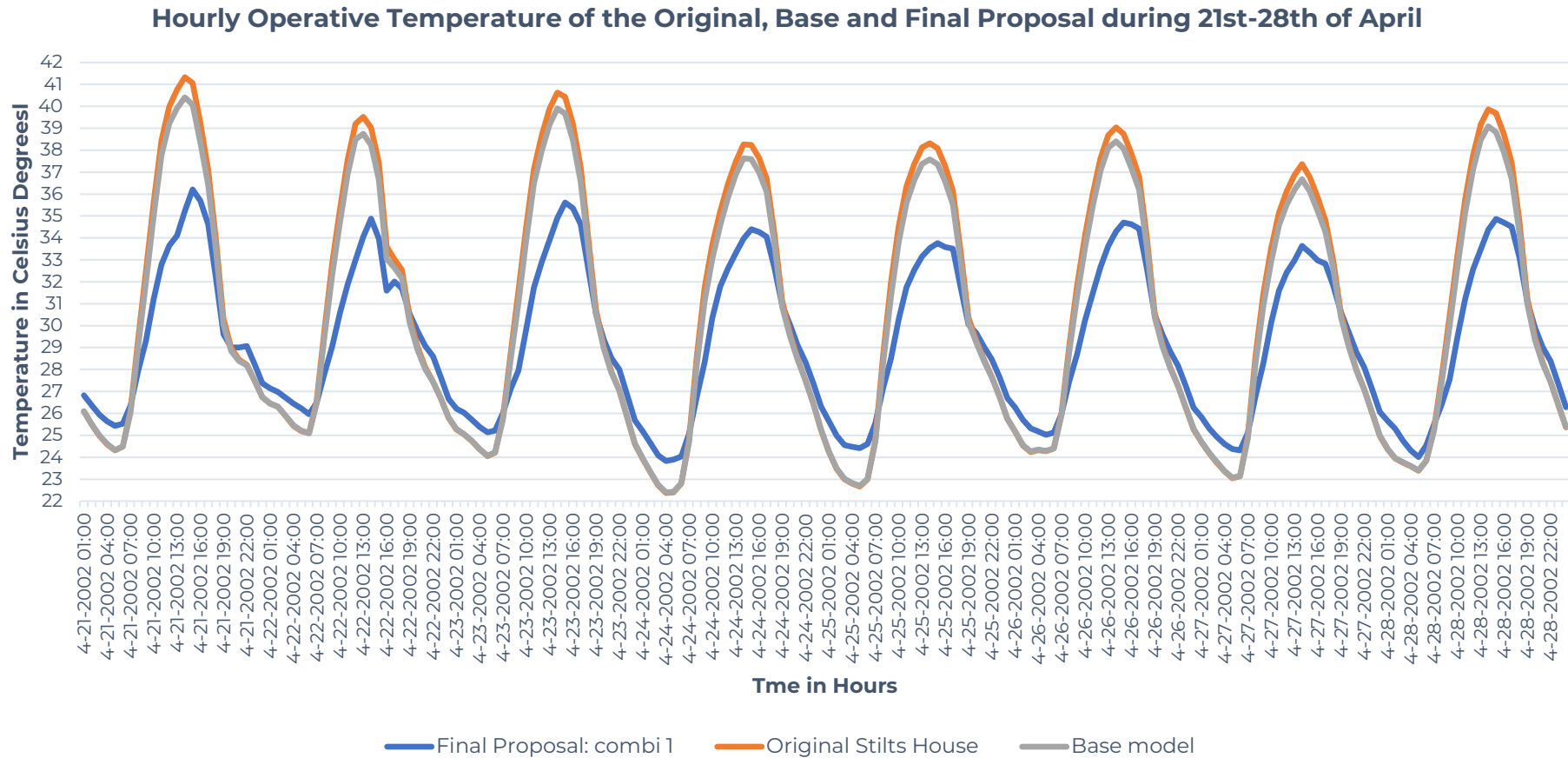
Does combining the following methods lead to better results and how significant is that?

1. Insulated walls and roof, Insulated Tropic Roof and Floor Vents
2. Insulated walls and roof, Insulated Tropic Roof and Floor Vents and a double-skin façade
3. Insulated walls and roof, Insulated Tropic Roof and Floor Vents and a double-skin façade (roof over façade)



Hourly Operative Temperature of three proposals of combined passive cooling concepts, during 21st-28th of April



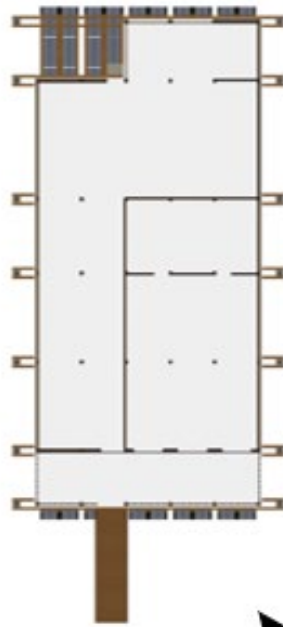


Top View

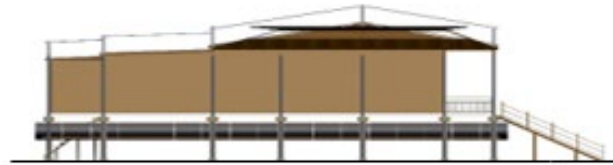


1:250

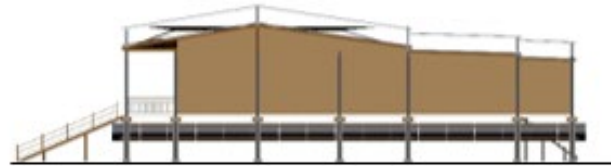
First Floor



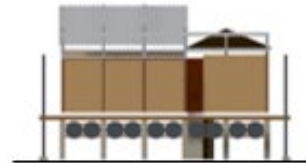
West View



East View



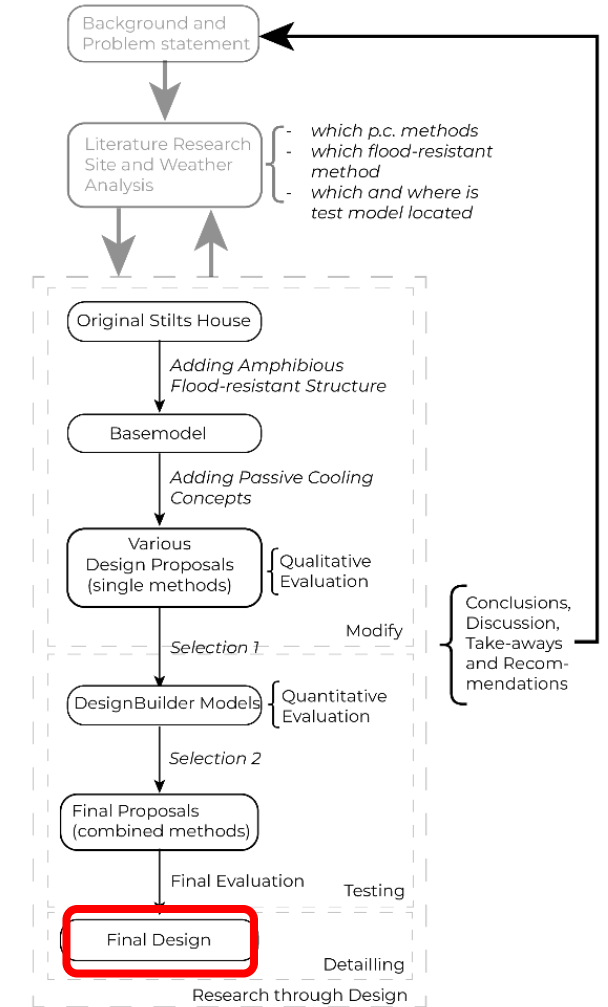
Front View



Back View



1:300



Discussion

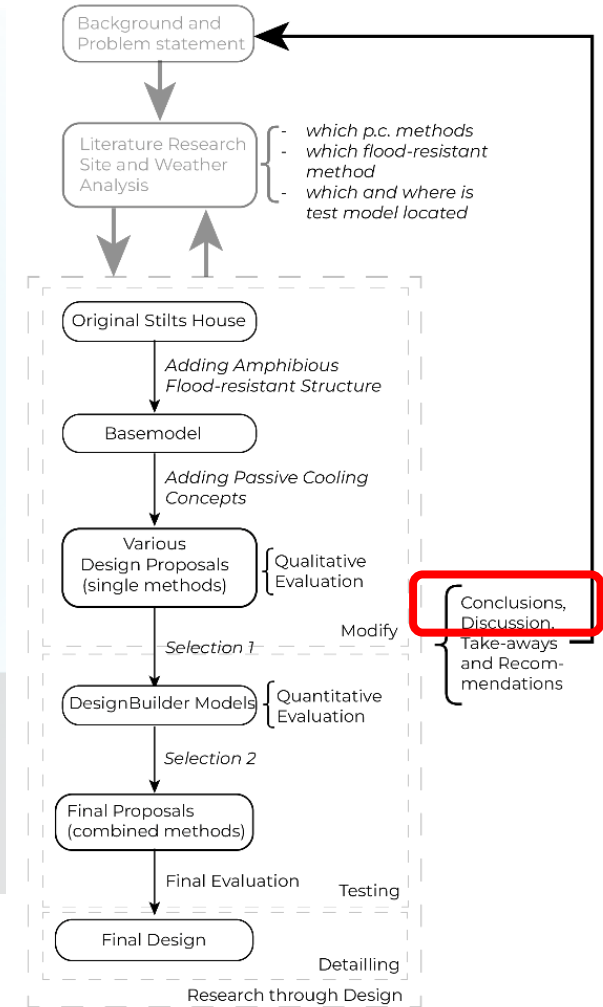
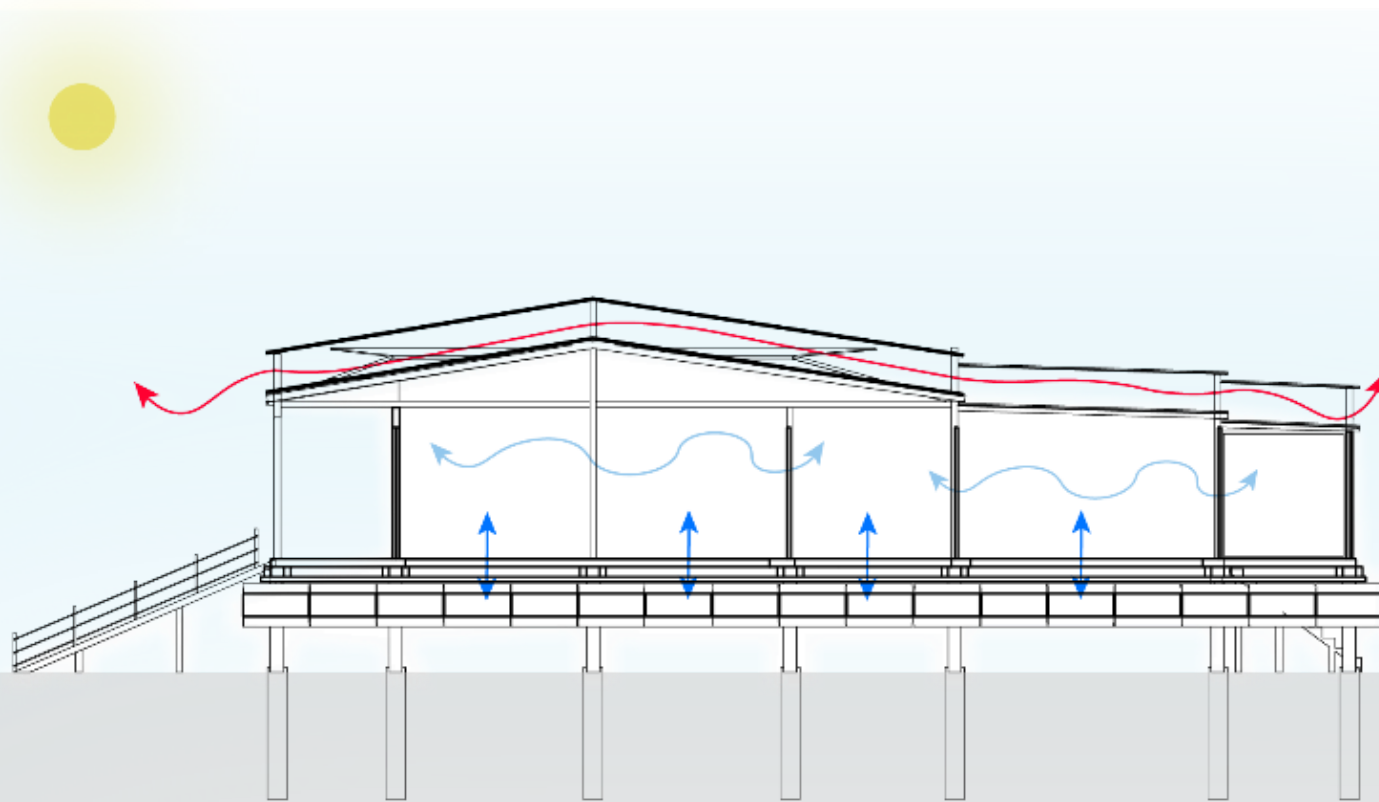
Limitations:

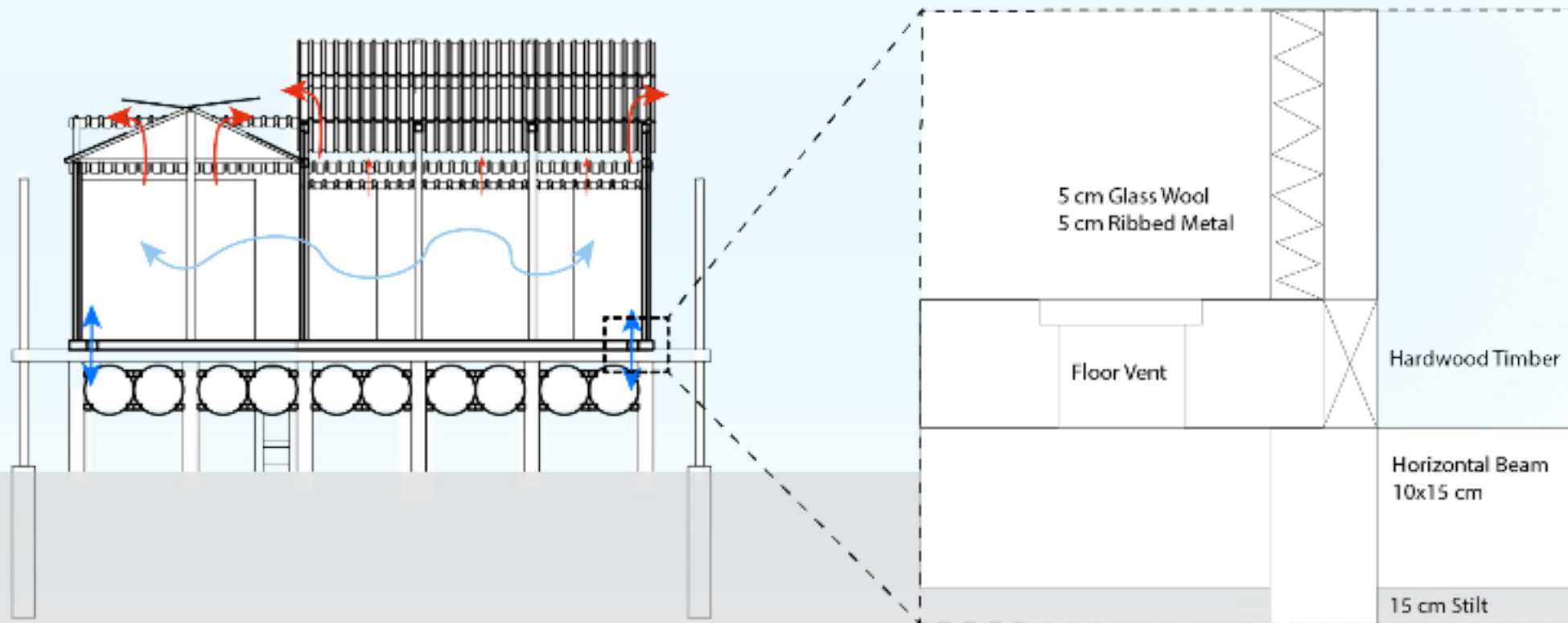
1. More in-depth and detailed Research Method (DesignBuilder)

2. Accuracy Input data

3. Revised Design Question: The question evolves from “How can we design...” to “How can we validate designs that incorporate flood-resistant amphibious housing with passive cooling interventions?”

Conclusion





- Is the Intervention worth to integrate?
- “Integration”

Further Recommendations

- The topic urges designers to use more sustainable materials to also include more climate resiliency and adaptability.
- Software improvements to give more freedom for designing and quick assessment on strength and buoyancy. (Materials and water contexts)
- Also more in-depth research can give better guidelines and lead to parametric design including more aspects of flooding, cooling etc. And making designs more inclusive and easier/faster. To help survive communities especially in vulnerable areas

