Better Shelter

Thermal Comfort
-
Hot climate

 May 2024

Get in touch!

We support partners before, during and after the implementation of our shelters to get the most out of it.

If you have any questions regarding the implementation of our Shelter products, please get in touch.

You can reach us by phone, WhatsApp, Signal, WeChat and Telegram.

The purpose of this document is to show implementing partners the options for using RHUs and Structure.

If you find any inconsistency in the content of this document or have any suggestions, we would love to hear from you. Please see our website for the latest resources.

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Executive Summary

Thermal comfort is much more than just air temperature, it is the complex mechanism between a human being's body, its mind, the shelter and the climate.

The Relief Housing Unit (RHU) is a modular all-weather shelter for global use and to make it better fit for hot climates it can be adapted. A lot of thermal comfort adaptation have been done to the RHU by user and organisation in the field over the years, an overview is given in this document. A mitigation order can be followed to overcome overheating firstly by blocking the sun before it reaches the shelter, secondly to block the heat when it reaches the shelter and lastly (and least preferred) to get rid of the heat by means of ventilation.

General guidance:

- Environmental factors and personal factors determine thermal comfort.
- The order of mitigation should be followed when adjusting the RHU for thermal comfort
- Different adaptations gathered from the field that show possibilities
- The adaptation method is very much depended on local context and resources
- Each adaptation comes with certain risks which should be evaluated beforehand

Lessons learned:

- Many practical adaptation to tackle hot weather are collected in this document but there is a need to further evaluated to determined the effect.
- All adaptation have pro’s and con’s
- Financial and local resources (materials, energy, craftsmanship, labour etc available) often determine the ability to improve.

“that condition of mind that expresses satisfaction with the thermal environment and is assessed by subjective evaluation.”

Thermal comfort

Thermal comfort is a result of:
environmental factors (such as climate and the shelter's envelope) and personal factors (including the individual's characteristics and preferences).

Thermal comfort inside of a shelter is determined by:
Indoor temperature, humidity, radiation temperature, air flow and solar radiation.

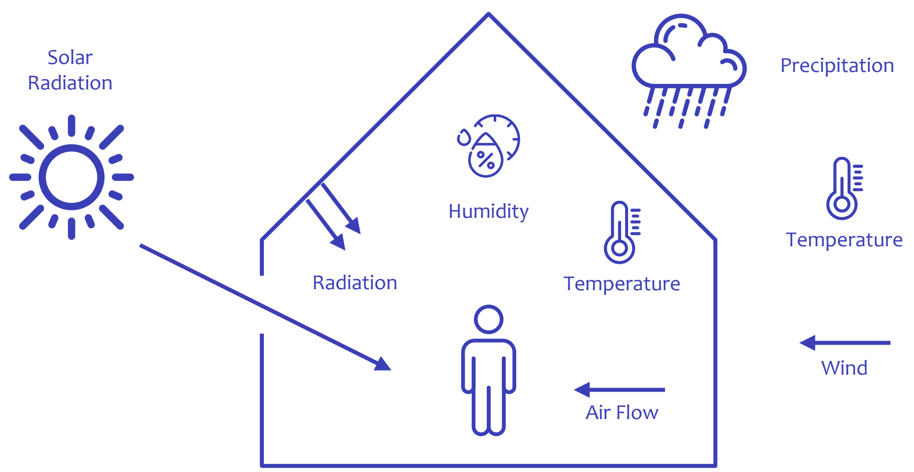
Whether a human being feels comfortable is depended on:
Clothing, metabolic rate, environmental factors, individual preferences, acclimatization, age, and health.

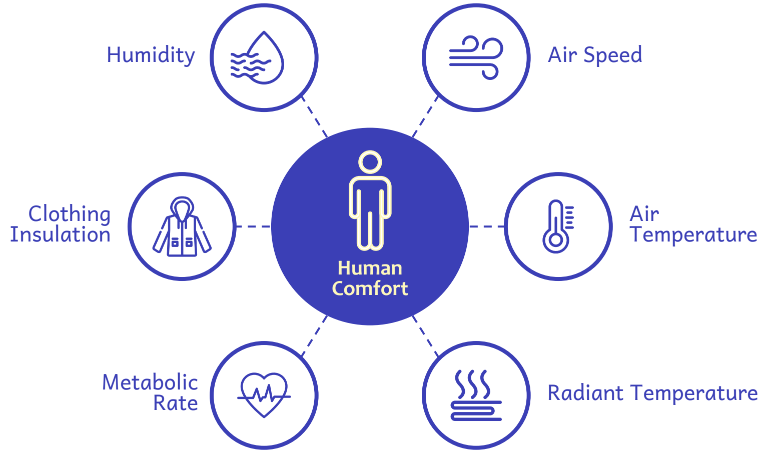
Occupants control their thermal environment by:
Clothing, adjusting windows/vents, using fans, personal heaters/coolers, and sun shades.

> **"That condition of mind that expresses satisfaction with the thermal environment and is assessed by subjective evaluation."**
> (ASHRAE, 2017)

> **"It is the range of environmental conditions for which minimum body heat production is needed to maintain the core temperature of 37°C"**
> (Holmes et al., 2016).

ASHREA: American Society of Heating, Refrigerating and Air-Conditioning Engineers





Thermal Comfort – Hot climate

- Infrared radiation is a significant component of the heat we feel, therefore we prefer shaded places when it is hot.

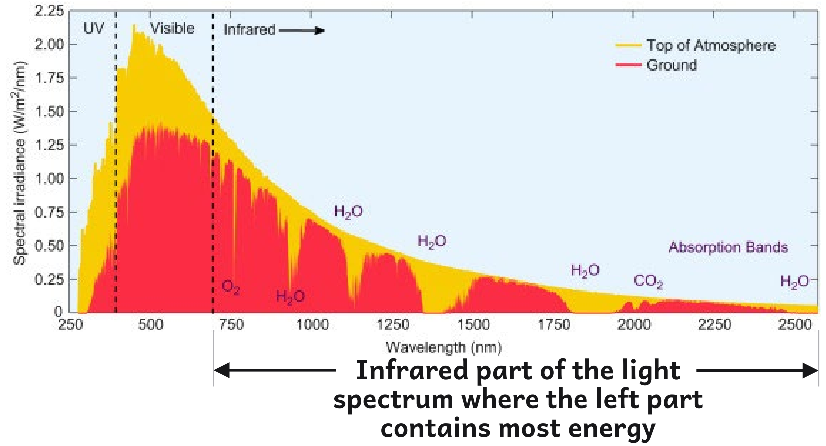
- In a high humidity and shaded environment where the air temperature is close to or higher than normal body temperature, the body is no longer able to cool effectively through sweating.

  For older and sick people, this critical temperature is even lower

- Overheating of a shelter occurs when the indoor temperature becomes uncomfortably high for its occupants.

- In lightweight structures (such as RHUs or tents), overheating is primarily determined by solar radiation.

Spectrum of Solar Radiation (on earth)



Heat index

Relative humidity	Temperature															
	80 °F (27 °C)	82 °F (28 °C)	84 °F (29 °C)	86 °F (30 °C)	88 °F (31 °C)	90 °F (32 °C)	92 °F (33 °C)	94 °F (34 °C)	96 °F (36 °C)	98 °F (37 °C)	100 °F (38 °C)	102 °F (39 °C)	104 °F (40 °C)	106 °F (41 °C)	108 °F (42 °C)	110 °F (43 °C)
40%	80 °F (27 °C)	81 °F (27 °C)	83 °F (28 °C)	85 °F (29 °C)	88 °F (31 °C)	91 °F (33 °C)	94 °F (34 °C)	97 °F (36 °C)	101 °F (38 °C)	105 °F (41 °C)	109 °F (43 °C)	114 °F (46 °C)	119 °F (48 °C)	124 °F (51 °C)	130 °F (54 °C)	136 °F (58 °C)
45%	80 °F (27 °C)	82 °F (28 °C)	84 °F (29 °C)	87 °F (31 °C)	89 °F (32 °C)	93 °F (34 °C)	96 °F (36 °C)	100 °F (38 °C)	104 °F (40 °C)	109 °F (43 °C)	114 °F (46 °C)	119 °F (48 °C)	124 °F (51 °C)	130 °F (54 °C)	137 °F (58 °C)	
50%	81 °F (27 °C)	83 °F (28 °C)	85 °F (29 °C)	88 °F (31 °C)	91 °F (33 °C)	95 °F (35 °C)	99 °F (37 °C)	103 °F (39 °C)	108 °F (42 °C)	113 °F (45 °C)	118 °F (48 °C)	124 °F (51 °C)	131 °F (55 °C)	137 °F (58 °C)		
55%	81 °F (27 °C)	84 °F (29 °C)	86 °F (30 °C)	89 °F (32 °C)	93 °F (34 °C)	97 °F (36 °C)	101 °F (38 °C)	106 °F (41 °C)	112 °F (44 °C)	117 °F (47 °C)	124 °F (51 °C)	130 °F (54 °C)	137 °F (58 °C)			
60%	82 °F (28 °C)	84 °F (29 °C)	88 °F (31 °C)	91 °F (33 °C)	95 °F (35 °C)	100 °F (38 °C)	105 °F (41 °C)	110 °F (43 °C)	116 °F (47 °C)	123 °F (51 °C)	129 °F (54 °C)	137 °F (58 °C)				
65%	82 °F (28 °C)	85 °F (29 °C)	89 °F (32 °C)	93 °F (34 °C)	98 °F (37 °C)	103 °F (39 °C)	108 °F (42 °C)	114 °F (46 °C)	121 °F (49 °C)	128 °F (53 °C)	136 °F (58 °C)					
70%	83 °F (28 °C)	86 °F (30 °C)	90 °F (32 °C)	95 °F (35 °C)	100 °F (38 °C)	105 °F (41 °C)	112 °F (44 °C)	119 °F (48 °C)	126 °F (52 °C)	134 °F (57 °C)						
75%	84 °F (29 °C)	88 °F (31 °C)	92 °F (33 °C)	97 °F (36 °C)	103 °F (39 °C)	109 °F (43 °C)	116 °F (47 °C)	124 °F (51 °C)	132 °F (56 °C)							
80%	84 °F (29 °C)	89 °F (32 °C)	94 °F (34 °C)	100 °F (38 °C)	106 °F (41 °C)	113 °F (45 °C)	121 °F (49 °C)	129 °F (54 °C)								
85%	85 °F (29 °C)	90 °F (32 °C)	96 °F (36 °C)	102 °F (39 °C)	110 °F (43 °C)	117 °F (47 °C)	126 °F (52 °C)	135 °F (57 °C)								
90%	86 °F (30 °C)	91 °F (33 °C)	98 °F (37 °C)	105 °F (41 °C)	113 °F (45 °C)	122 °F (50 °C)	131 °F (55 °C)									
95%	86 °F (30 °C)	93 °F (34 °C)	100 °F (38 °C)	108 °F (42 °C)	117 °F (47 °C)	127 °F (53 °C)										
100%	87 °F (31 °C)	95 °F (35 °C)	103 °F (39 °C)	112 °F (44 °C)	121 °F (49 °C)	132 °F (56 °C)										

Key to colors: Caution · Extreme caution · Danger · Extreme danger

Source: National Oceanic and Atmospheric Administration - National weather service

Background

After the launch of RHU version 1.0 it became known that thermal comfort inside the RHU in some operation have been identified as an issue.

With the RHU, as with most temporary shelter, temperatures indoor sometimes reach higher values then outdoor because of limitations of the structure.

Two more ventilation openings were added in RHU version 1.2.

RHU 1.0 – 1 ventilation opening each side

RHU 1.2 – Double ventilation openings each side

Background

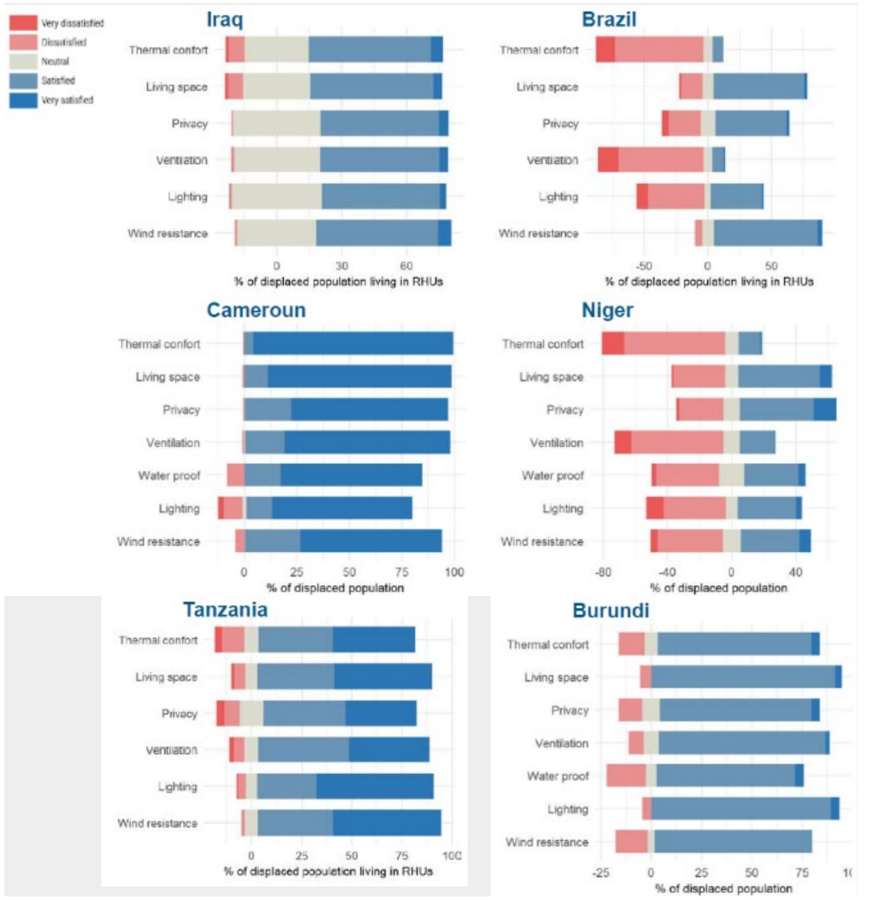
IMPACT initiative assessment

ordered by UNHCR in 2019 interviewed user of the 1.0 and 1.2 on important functions of the shelter.

Thermal comfort was one of these functions.

Result show that in Brazil and Niger POCs were most dissatisfied with the thermal comfort.

Female residents are less satisfied than male residents.



Feedback Iraq, Brazil, Cameroun, Niger, Tanzania and Burundi

Overheating mitigation order

Mitigation order
To mitigate heat radiation from the sun on a lightweight structure like the RHU or a tent a hierarchy can be followed.

1. Blocking the sun before it reaches the shelter

Blocking the sun can be done by having a shade net or an additional roof above the shelter.
Special attention should be put on the **distance** between the shelter and the addition and the possible consequences of the addition on **wind and fire safety***. Additions might also attract **vectors** or other animals.

2. Blocking the sun on/in the façade/roof

Blocking the sun can be done by adding a reflective layer on the outside or adding for example a rug or insulation.
Special attention should be put on the possible consequences for **fire safety*** and **wind, rain and moisture safety** around attaching materials.

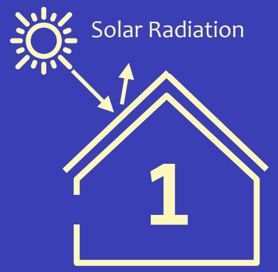
3. Removing the heat after entering

This can be done by adding more windows, ventilations, dessert coolers, wetting the floor or air conditioners. Window and door placement should be selected on predominant wind-direction.
Special attention should be put on **wind safety**.

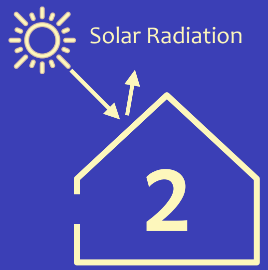
Mitigation 1 is most preferred from heat radiation point of view , mitigation 2 less and 3 is far from ideal.

*See for more information the Fire Safety information leaflet

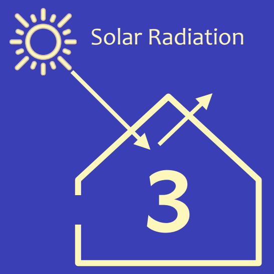
Order of mitigating heat radiation



Blocking the sun before it reaches the shelter



Blocking the sun on/in the panel



Removing the heat after entering

What was tested in the field by our partners

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Hereafter examples of modification work done by our partners will follow, please use for inspirational purpose only. Please get in though with us to find the best adaptation for your location and your specific needs.

Things to consider
Financial and local resources (availability of materials, energy, craftsmanship, labour etc) often determine the ability to improve. Local adaptation are mostly preferred because they stimulate local economy, are likely cultural accepted and can be repaired locally.

Risk evaluation
It is important that risks that come with these mitigations are evaluated to limit potential damages to people, animals and surrounding.
Risks to consider:

- Fire risk
- Structural risk (e.g. wind)
- Water and moisture risk
- Risk for vectors/animals
- Human risk

What we have seen in the field

- Shade nets
- Additional roofs
- Additional openings
- Mechanical ventilation
- Inner ceilings
- Insulation
- Watering the floor
- Air conditioners
- Desert coolers

What was tested in the field by our partners

Shade Net

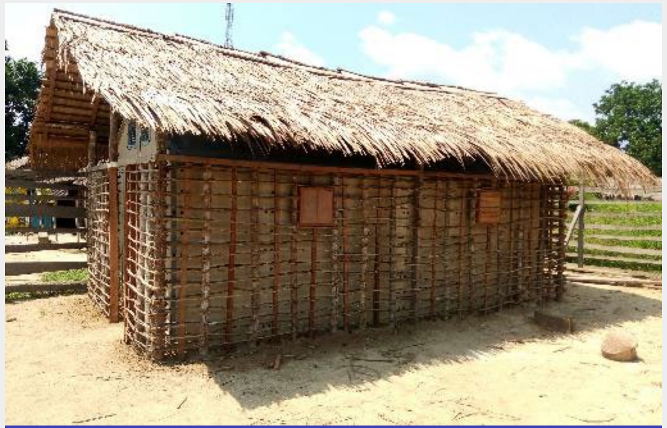
Ecuador, 2020

Brazil, 2021

Additional Roofs

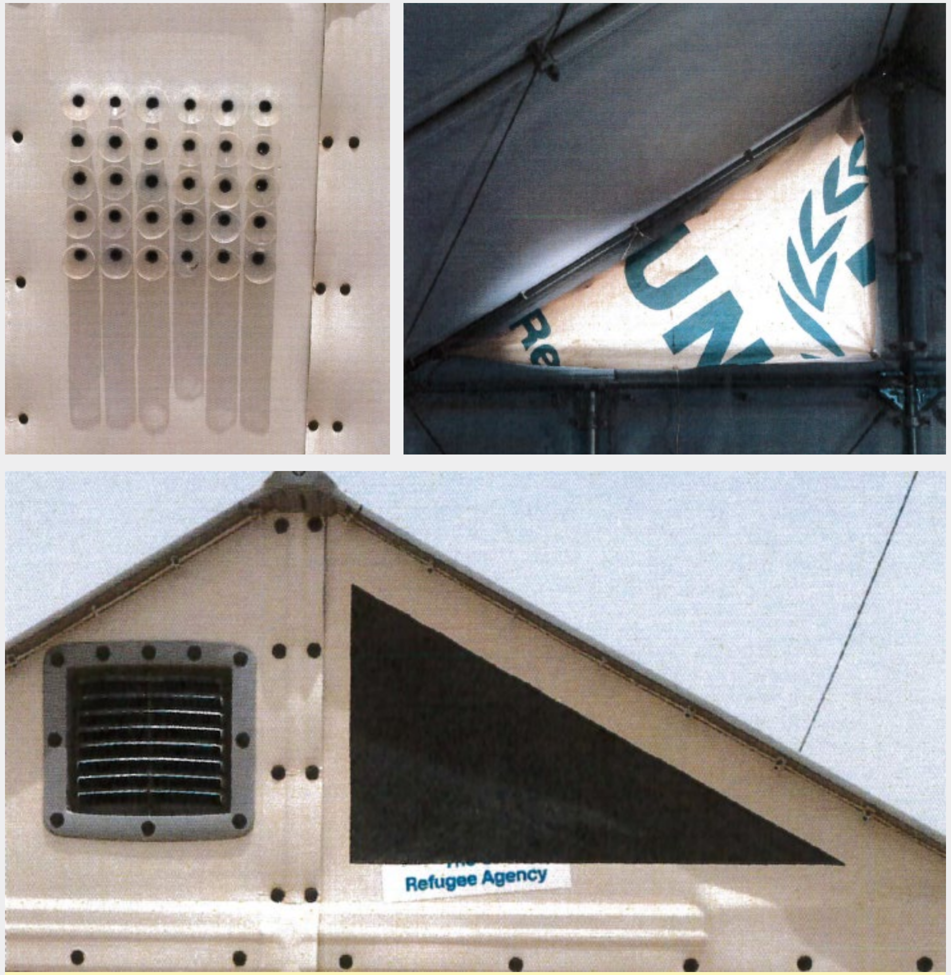
Rep. of Congo, 2019

Brazil, 2021



Rep. of Congo, 2021

What was tested in the field by our partners



Djibouti, 2016

Brazil, 2018

Ethiopia, 2014

Additional Openings

What was tested in the field by our partners

Additional Openings




NW Syria, 2021

Brazil, 2021

What was tested in the field by our partners

Insulation

NW Syria, 2020

Greece, 2021

NW Syria, 2021

Iraq, Kurdistan, 2014

Desert coolers

Iraq, Kurdistan, 2014

Iraq, Kurdistan, 2014

Watering the floor

Ethiopia, 2014

What was tested in the field by our partners

Air Conditioners

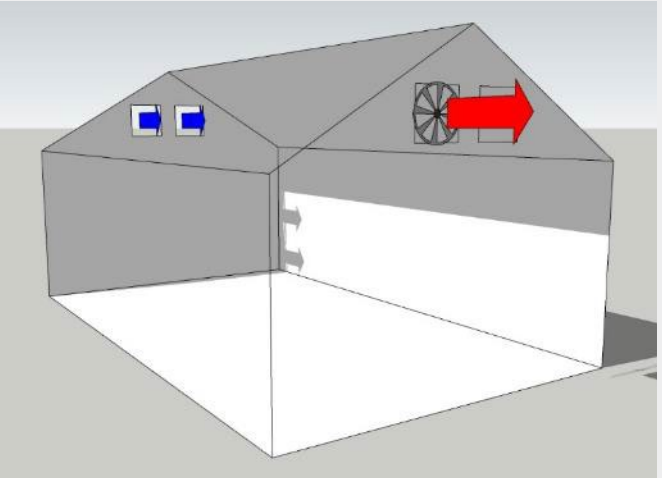

Ethiopia, 2013


Colombia, 2020


Mexico, 2020

Mechanical Ventilation


Bangladesh, 2018



Bangladesh, 2018

What was tested in the field by our partners

Almost all interventions contribute to increased thermal comfort but this is mainly backed by anecdotal evidence.

Passive interventions such as shade nets and additional roof are preferred above active interventions because they use energy.

How much these interventions contribute is unknow.
To understand this, more measurement are ongoing.

Research project initiated or joined:

- Healthy Housing For The Displaced - Finished
- Eindhoven University Technology - Finished
- University of Baghdad
- Hot climate testing India
- Cold climate testing Sweden

Temperature logging 2020-2021 (Gaziantep, Turkey)

Results from the research projects

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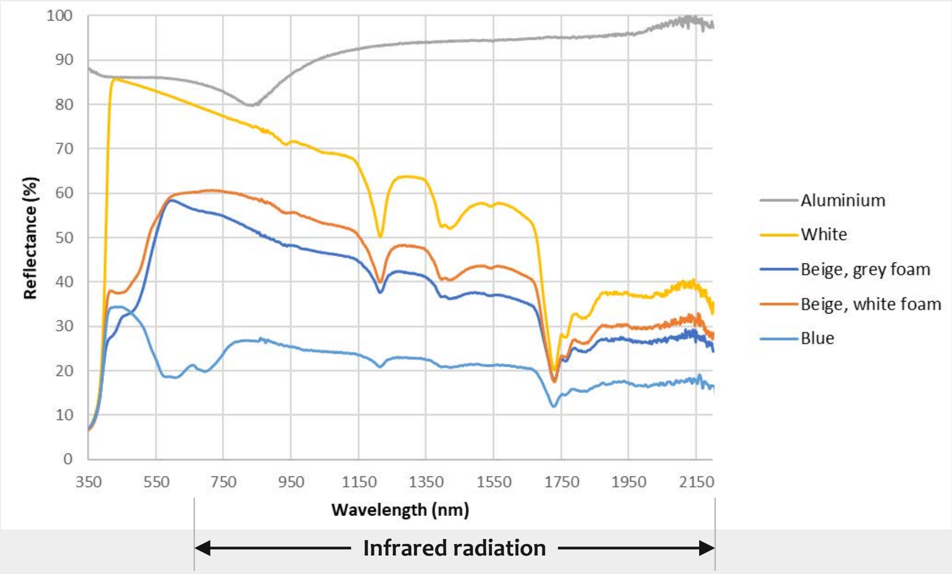
Improvements suggested

- Addition of thermal mass (walls and floor slab)
- Addition of roof insulation
- Roof shading
- Aluminium colour for all panels
- Lower infiltration (40 to 10 ACH)
- Increased cross-ventilation (window/vent open)
- White colour for all panels

More realistic



Lessons learned

Many practical adaptation to tackle hot weather are collected in this document but there is a need to further evaluated the determined effect.
All adaptation have pro's and con's.
Financial and local resources (materials, energy, craftsmanship, labour etc available) often determine the ability to improve.

Hot climate

- Blocking of solar energy should be done as early as possible e.g. with shade nets or reflective panels.
- Window and door placement should be selected on predominant wind-direction.
- Forced ventilation by a fan in front of a ventilation opening can likely decrease the temperature inside the shelter more than natural ventilation.
- White or aluminium foil on outside panels reduces indoor temperature.
- Blocking most IR-radiation means limited natural lighting through the roof and walls.