Better Shelter

Thermal Comfort

–

Cold climate

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 cold 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. To mitigate cold three options are available; insulating the shelter, heating the shelter by means of a heater or (less preferred) giving the inhabitant more clothing.

General guidance:

- Environmental factors and personal factors determine 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
- Both active heating and insulation improves thermal comfort during winter but require a risk analysis

Lessons learned:

- Many practical adaptation to tackle cold 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.

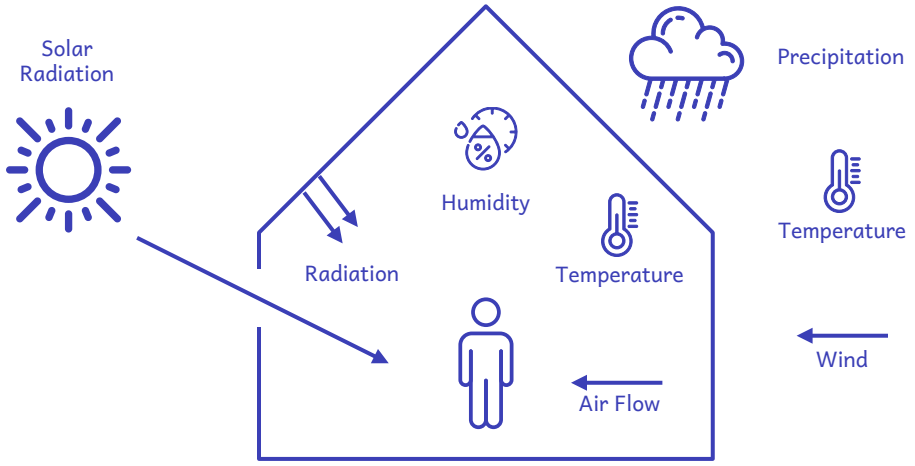
Whether a human being feels comfortable is depended on:
Clothing, metabolic rate, environmental factors, individual preferences, acclimatization, age, and health.

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



ThermalComfort – Cold climate

- A person with clothes on can starts to feel cold at below 25°C.
- When the core body temperature drops below 35 °C on goes into a state of hypothermia
- A sleeping human produces 85W of heat and a candle 100W
- The WHO recommends an indoor temperature of at least 18°C in winter to pose minimal risk to health, especially for vulnerable groups.*
- In light weight structures (RHU) most energy losses are transmission losses through walls, roof and floor.
- A building loses energy (heat) through transmission, ventilation, infiltration, radiation, and moisture migration.
- The inside temperature is a result of the balance between energy gains (metabolism, heater and sun) and energy losses (transmission, ventilation and infiltration).

*Telfar Barnard, L. et al. (2018) Report of the systematic review on the effect of indoor cold on health, part of WHO Housing and health guidelines.

Thermal Comfort – Cold climate

Mitigation cold

There are several ways to mitigate cold namely insulating by means of adding insulation or clothing and heating.

Insulating

Insulating can be done by adding insulation to the walls, roof and floor. By insulating energy losses can be reduced and heat can be kept in the building envelope.
Special attention should be put on **fire safety*** and **water & moisture control** inside the insulation and inside the shelter.

Heating

This can be done by adding a heater inside the shelter.
Special attention should be put on **fire safety* and fume exhaustion** but also on the choice of heater * and fire risks.

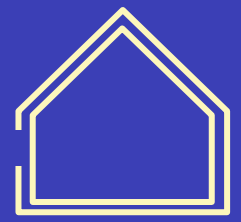
Clothing

By adding more clothing and/or blankets to the inhabitant, it traps standing air that acts as an insulator.
Please note that this is the least preferred method.

Temperatures below freezing point likely require both insulation and heating.

*See for more information the Fire Safety resources!

Mitigating cold



Insulating

Heating

More clothing

RHU winterization

- The Relief Housing Unit (RHU) is a modular all-weather shelter for global use.

- For use in cold climate, the shelter needs to be winterized, i.e. insulated and heated.

Better Shelter has collaborated and supported several partners in winterizing the RHU:

- Red Cross Morocco winterization/summarization of family shelters in Morocco, Q2-Q3 2024
- MSB / DG-ECHO winterization of family shelters in Ukraine, Q3-Q4 2022.
- EuroRelief winterization of ca. 240 family shelters in Mavrovouni camp Lesvos, Greece, 2021-2022.
- Shelter cluster NW Syria winterization of family shelter by means of a heater Q1 2020
- UNHCR winterization of reception centres in the Balkans, 2015-2016.

Moroccan Red Crescent upgrade 2024 for Morocco earthquake response

What was tested in the field by our partners

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 solution 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
- Water & moisture risk
- Structural risk (e.g. wind)
- Human risk

What we have seen in the field
Floor insulation
- Styrofoam plates and chipboard/plywood for flooring
- Pallets with insulation
- Decking

Wall/roof insulation
- Stone wool
- Glass wool
- Plastic sheeting

Heaters
- Electric
- Gas
- Kerosine/diesel/oil
- Olive pits
- Wood

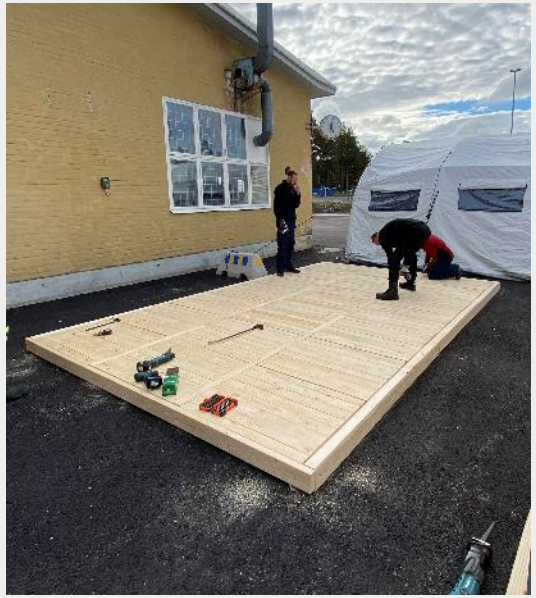
What was tested in the field by our partners

Insulation: mineral wool
Thickness: 50mm

Moroccan Red Crescent + IFRC winterization upgrade 2024 for Morocco earthquake response

Insulation

What was tested in the field by our partners



MSB winterization upgrade 2022 for Ukraine response - prototype

Insulation: mineral wool
Thickness: 100mm

Insulation

What was tested in the field by our partners

MSB winterization upgrade 2022 for Ukraine response

Insulation: mineral wool
Thickness: 100mm

Insulation

What was tested in the field by our partners

"A few women came up to us to say thank you because it's been making a huge difference. One woman has arthritis and it's been getting less painful because it's warmer inside her place. Some women don't even use their heater anymore and can live in t-shirts in the wintertime in their RHUs."

Refugee statements through EuroRelief January 2022

Insulation: mineral wool
Thickness: 30-50mm

Lesvos Greece, 2021 – Insulation at scale

Insulation

What was tested in the field by our partners

Lesvos Greece, 2016

Iraq, Kurdistan, 2014

NW Syria, 2021

Heaters

What was tested in the field by our partners

UNHCR Winterization upgrade 2015-2016

For a BOQ of this adaptation see appendix 5

RHU winterization approach for Ukraine

Design objective

Together with MSB, Better Shelter has developed and tested a winterization approach for the Ukraine response, which:

- provides adequate indoor temperatures during winter
- is possible to retrofit to already installed RHU (and thereby enable a phased approach where the RHU is provided in phase 1 and winterization in phase 2)
- consists of standard building materials commonly available in the supply chain in and around Ukraine.
- Cost of approximately 1000-1500 Euro for 1 shelter of 17.5m^2
- Installation time of less than six hours

General description

Foundation and floor

- Raised floor/deck made of joists and plywood
- 50mm hard insulation below floor
- RHU installed on top
- Plastic sheeting floor

Externally

- Wooden frames around openings
- Tarpaulin skirts for water proofing
- Wooden frame over RHU walls and roof with a 1200mm distance
- Stone wool 100mm
- Tarpaulin to cover gable, walls and roof
- RHU door, window and ventilation frames installed

Please see Annex 1 for a BoQ and Annex 2 for a more step-by-step description.

Better Shelter

Climate chambre test

Better Shelter has tested the RHU (17.5m2) in a climate chambre, where it was built and winterized, and equipped with sensors and heaters.

Winterization: wood framing around openings and Centre to Centre (C-C) every 1200mm, 100mm stone wool on walls and roof, plastic sheeting, pallets on floor + 50mm of stone wool/polystyrene + 15mm plywood floorboards, 50mm of stone wool in door opening.

The internal and external temperatures were measured, while the climate chambre temperature was lowered to -20°C. All ventilation openings were closed.

Results from the tests show:

- a temperature difference of 37-degrees between the interior and the exterior is achieved with insulation and the use of a 2100W heater.
- Since there was no soil nor wind affecting the temperature in the shelter, it is estimated that a **temperature difference of around 28-degree** can be reached in the field with a 2100W heater. **E.g., -15°C outside and +13°C inside if properly build.**
- **To compensate for the opening of the door or ventilating a bigger heater than 2100W is needed.**

The difference in temperature can be increased if the heater power is increased or more than 100mm insulation is applied.

Points of attention

Please note that the amount of insulation depended on the climate and amount of heat generated inside the shelter.

Installation of mineral wool insulation is preferably installed on the outside to ease applicability and dust during installation.

Stone wool is preferred above glass wool as it itches a bit less.

Fireproof insulation materials such as mineral wool are always preferred above fire prone materials such as polystyrene, polyethylene, polyurethan etc.

Moisture open insulation materials should be protected from moisture that comes from inside shelter e.g. cooking, exhaling etc but also moisture from for example the soil. Mineral wools, cellulose and natural fibre can absorb water that comes from e.g. a badly fixed tarpaulin.

When moisture or water enters the insulation material it loses it insulative property.

For heater options please see the Fire safety resources and be aware that chimney exits could get hot and could melt/ignite insulation materials.

Please contact us if you have if you have any question

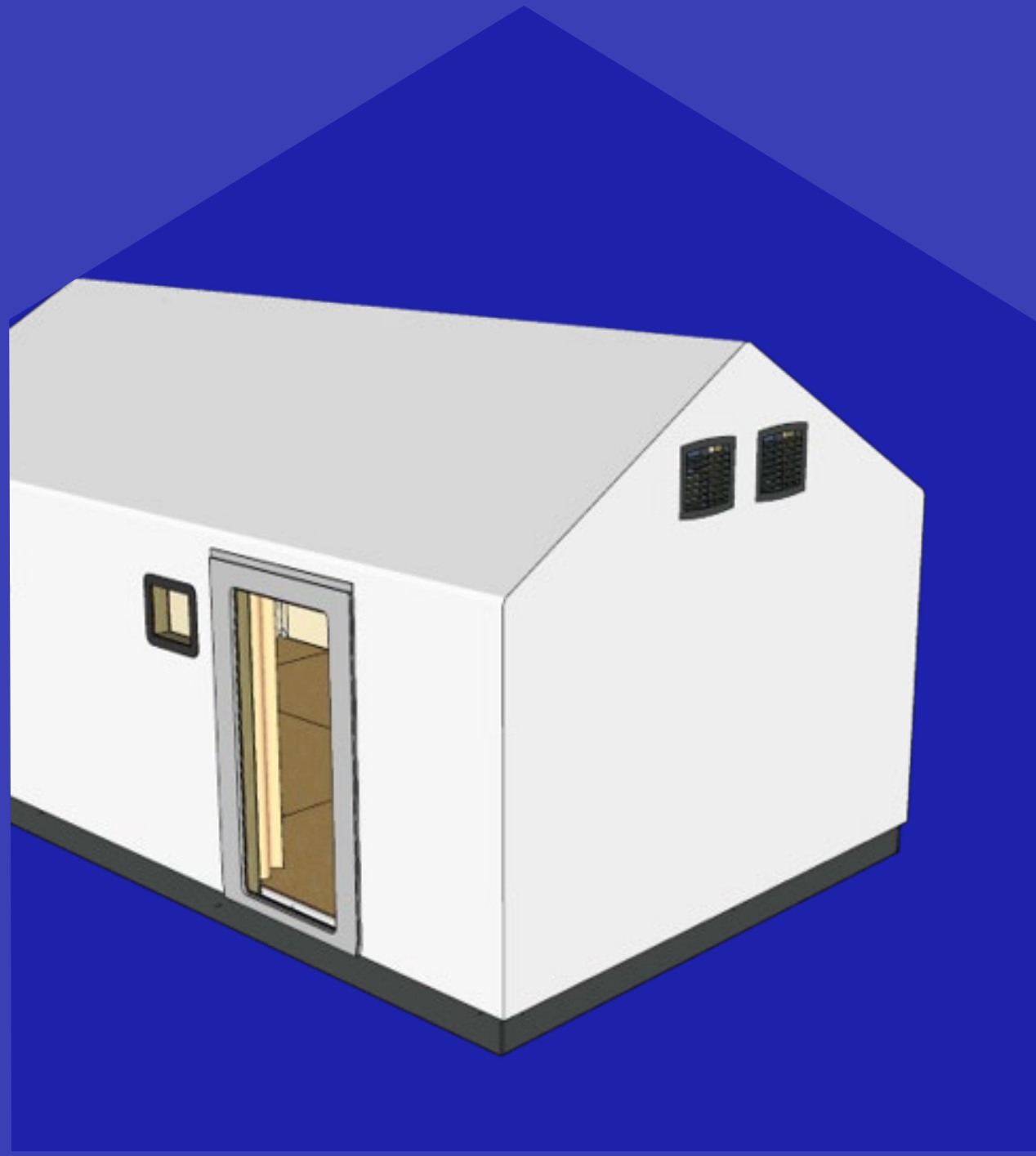
Lessons learned

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

Cold climate

- By insulating the RHU the shelter can be used under winter conditions, often in combination with a stove.
- A stove on wood, olive pit fuel or kerosene increases the temperature significantly but comes with a fire risk.
- Adding insulation reduces energy needs but requires fire risk analysis and potentially fire risk mitigations.
- Guidance can be given on heating modalities together with fire risk mitigations.

Appendixes

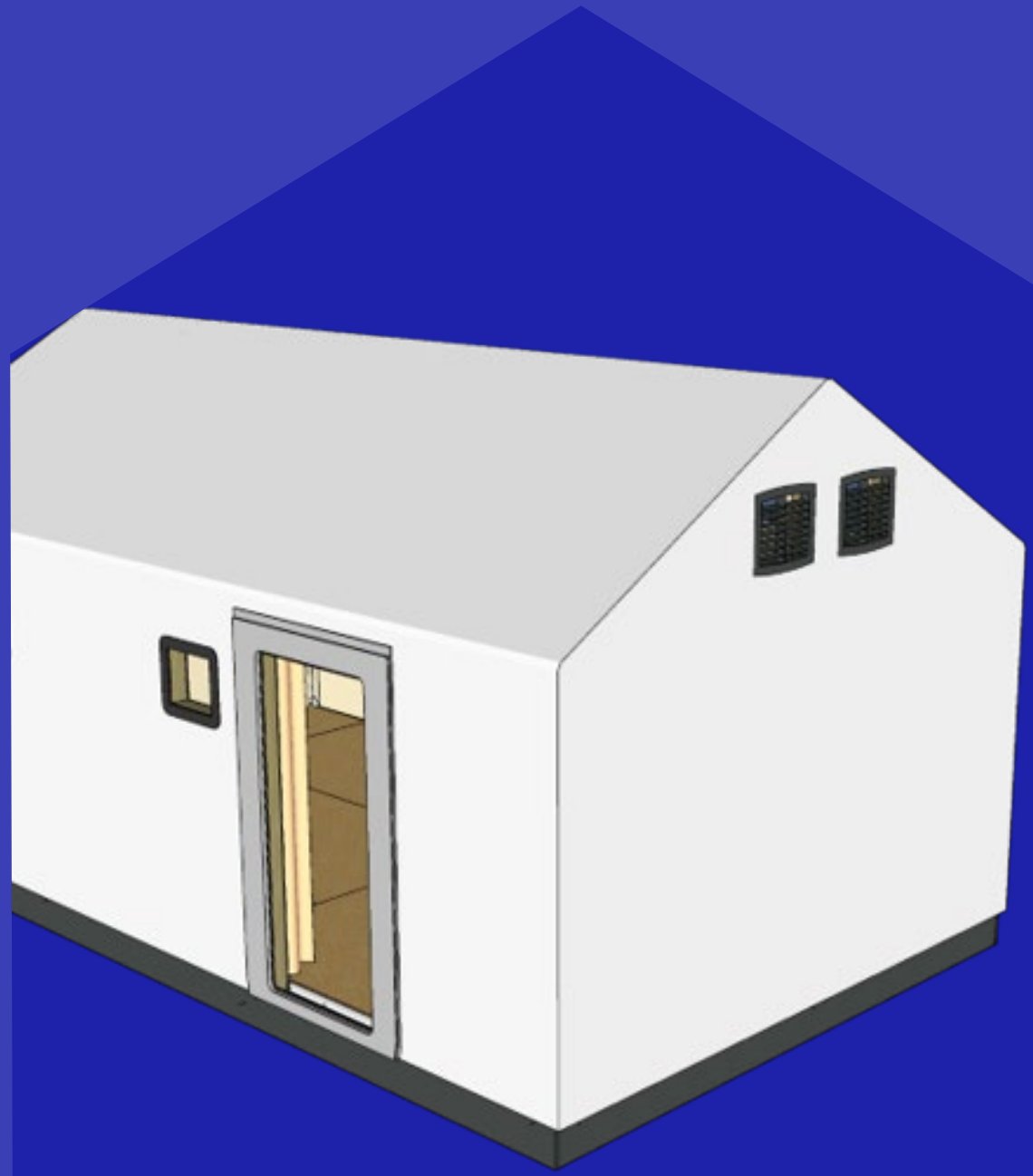


Appendix 1 – RHU winterization approach BoQ

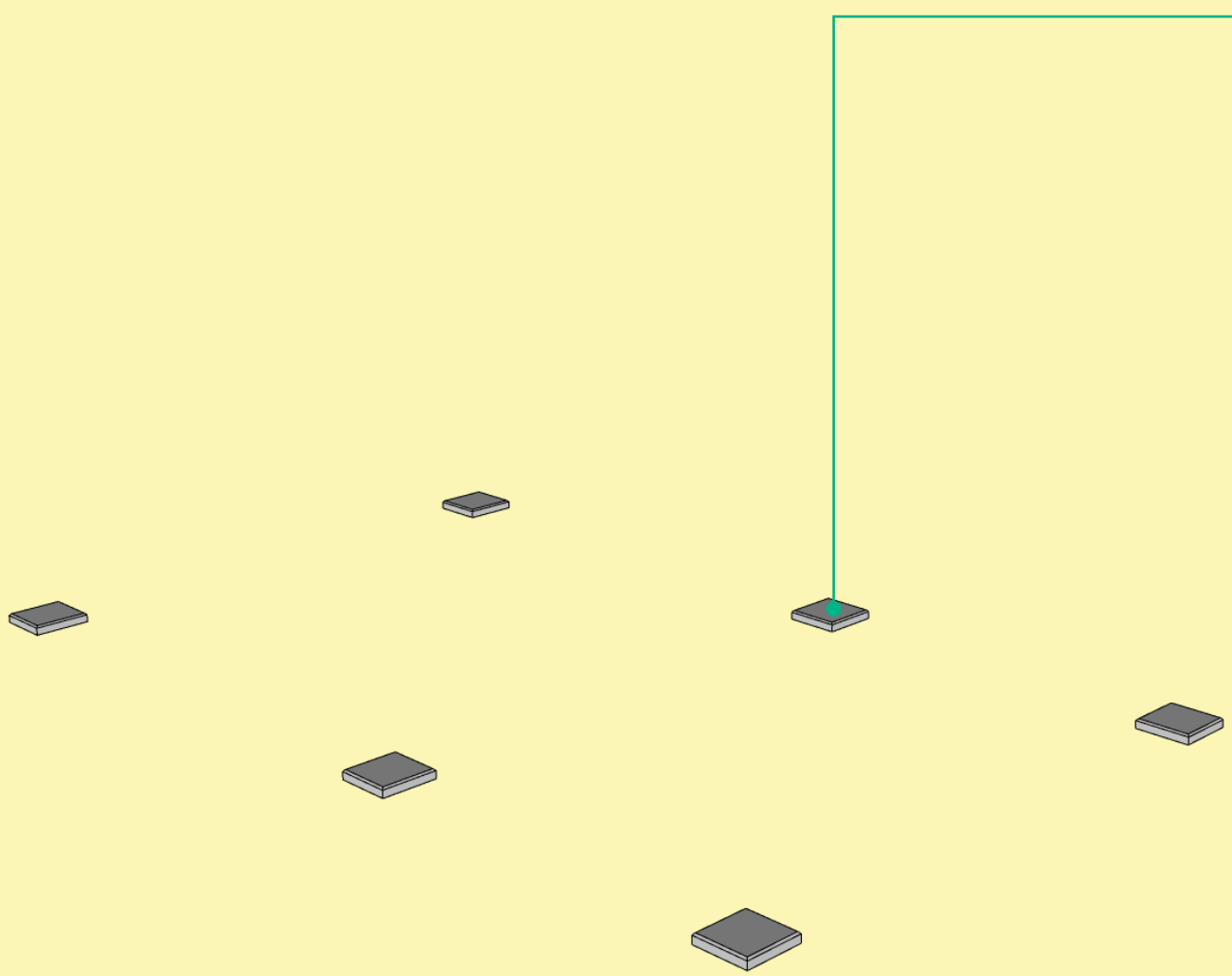
Winterization of a 3 bay, 17.5m2 RHU (single unit), estimated quantities

Element	Material	Specifications	Unit	Amount	Comment	Link to product
Floor, construction, footing	Concrete tiles	350 x 350 x 50mm (or a local available equivalent)	pcs	6		
Floor, structural, beams	Wood	alternative, 45 x 145 x 3600mm, pressure impregnated	pcs	15		
Floor, structural, beams	Wood	alternative, 45 x 145 x 4200mm, pressure impregnated	pcs	-		
Floor, structural, floor	OSB	1220 x 2440 x 18mm	pcs	7		
Floor, insulation	Polystyreen	50mm thick, 600 x 1200mm	pcs	29	Please consider fire safety	
Floor, plastic sheeting	HDPE tape fabric, LDPE coating	delivered with RHU	pcs	0	incl. in RHU box B	
Floor, plastic sheeting	HDPE tape fabric, LDPE coating	Size:2,3x4m, 180 gram/m2, 100Kly	m2	-		
Tarpaulin	HDPE tape fabric, LDPE coating	Size:roof 8,5x8,5, gable 2x 4x3,5m, 200 gram/m2, 300Kly	m2	85	Durable and UV resistant	https://landskroon.nl/products/super-tarp-premium/
Walls, insulation	Stonewool	Stone insulation panels 95X580X1170mm ~0.035W/mK	pcs	91		https://www.rockwool.com/se/produkter-och-konstruktioner/produktoversikt/byggisolering/flexibatts-1/
Walls & roof, frame	Wood	28 x 95 x 4200mm, impregnated wood	pcs	19		
Window, frame	Wood	28 x 95 x 4200mm, impregnated wood	pcs	2		
Ventilation, frame	Wood	28 x 95 x 4200mm, impregnated wood	pcs	2		
Door, frame	Wood	28 x 95 x 4200mm, impregnated wood	pcs	1	plus left overs window and ventilation frames	
Fastening & Fitting	Screws	40 x 4mm, galvanised	pcs	366	Screw for roof/wall woodwork	
Fastening & Fitting	Screws	80 x 5mm, galvanised	pcs	60	Floor beam screws	
Fastening & Fitting	Screws	65 x 4mm, galvanised	pcs	116	Screws for insulation	
Fastening & Fitting	Screws	40 x 4mm, galvanised	pcs	84	OSB to floor beams screws	
Fastening & Fitting	Screws	40 x 4mm, galvanised	pcs	96	Tarpaulin screws	
Fastening & Fitting	Screws	40 x 4mm, galvanised	pcs	90	Screws for opening	
Fastening & Fitting	Plastic disk	Disks to fixate insulation by screw	pcs	116		
Fastening & Fitting	Washers	M5, 25mm, galvanised	pcs	282	Openings, tarpaulin, panel	
Fastening & Fitting	Gaskets	Rubber, 25mm	pcs	186	For water tightening of the tarpaulin	
Fastening & Fitting	Tape	Ducttape 50mmx50m	pcs	1		
Window, Glass	Plexiglass	Plexiglas windows 2mm, single window panel	pcs	4	ca. 333x297mm / pcs	

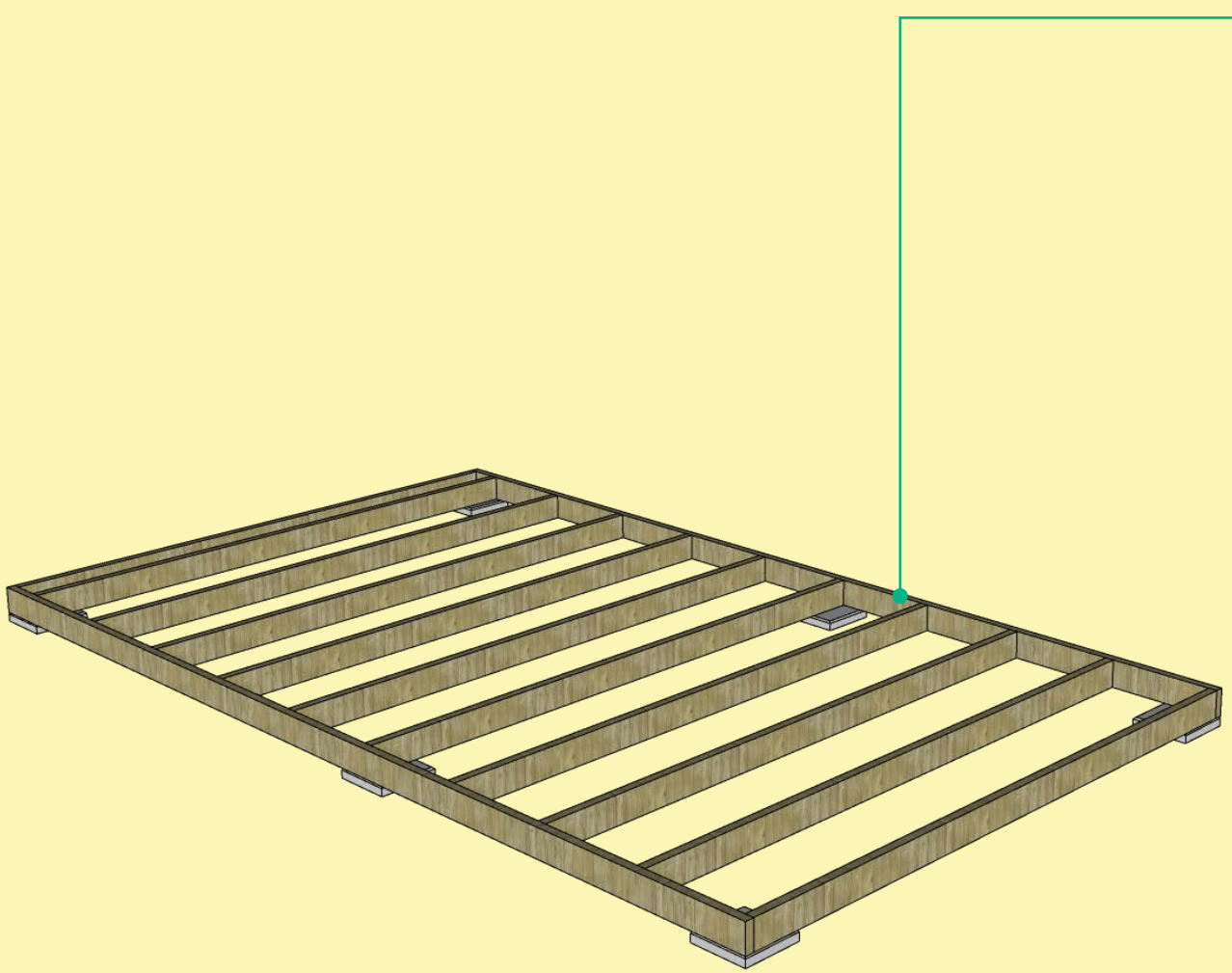
Appendix 2– RHU winterization approach



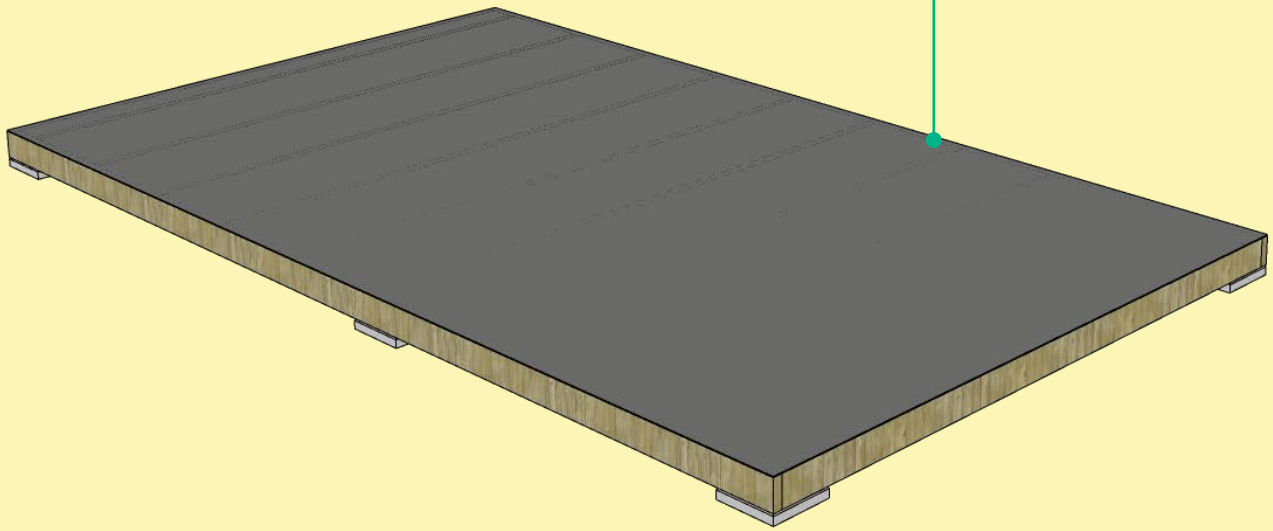
Step by step RHU Winterization



Step by step RHU Winterization



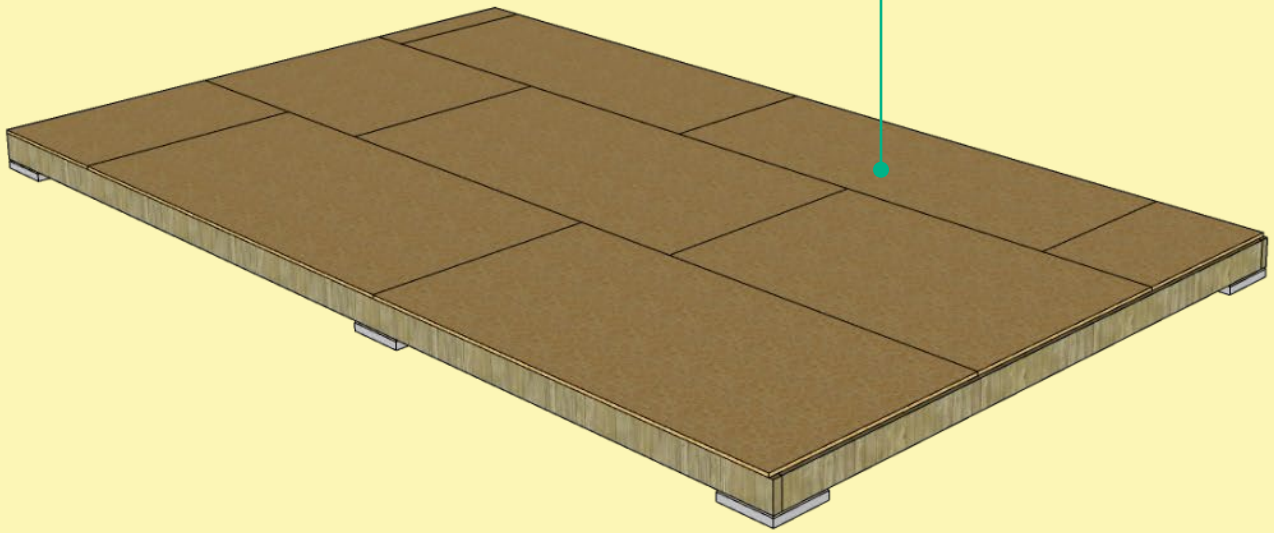
Step by step RHU Winterization



Attach tarpaulin to floor beams: tarpaulin from RHU

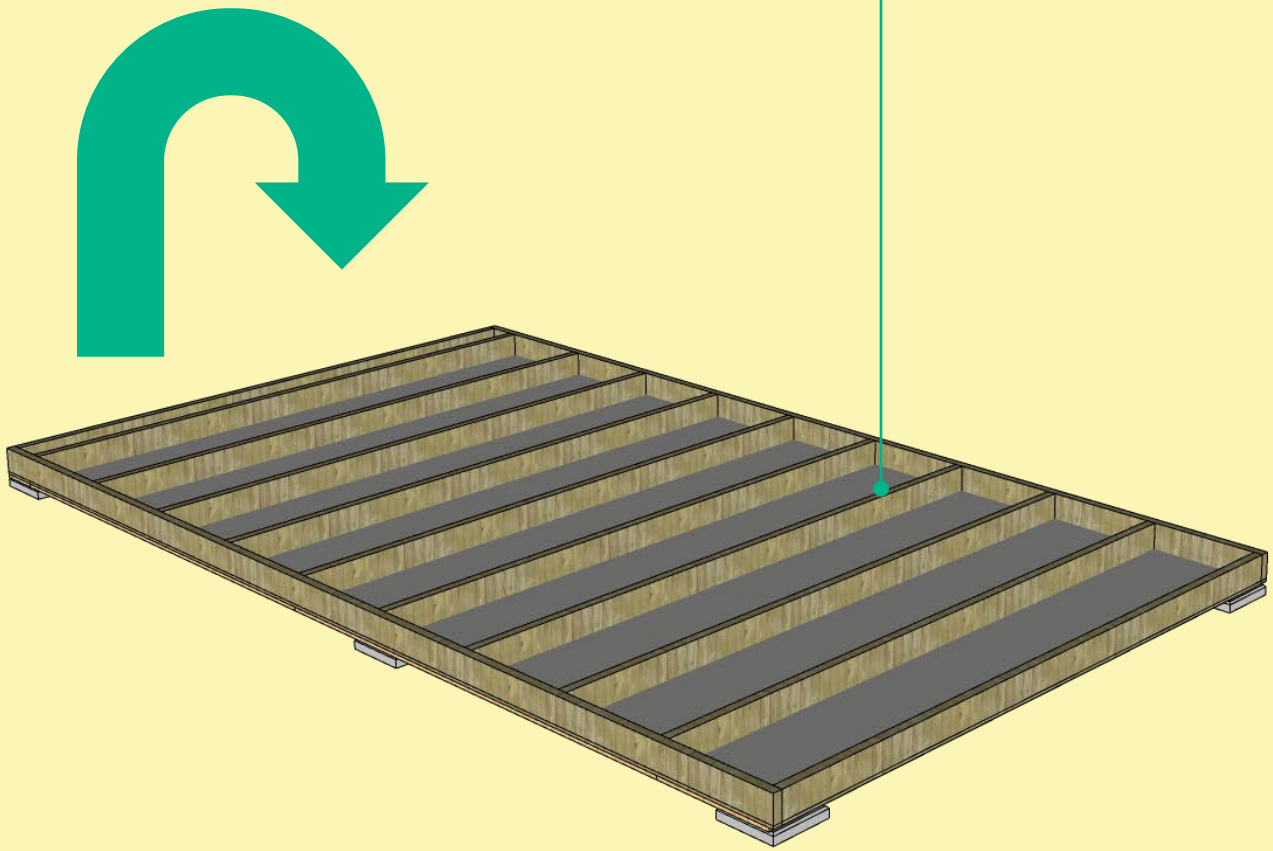
Step by step RHU Winterization

Install floor sheets and continue with placing skirting and floor insulation as described in the ‘standard’ design.

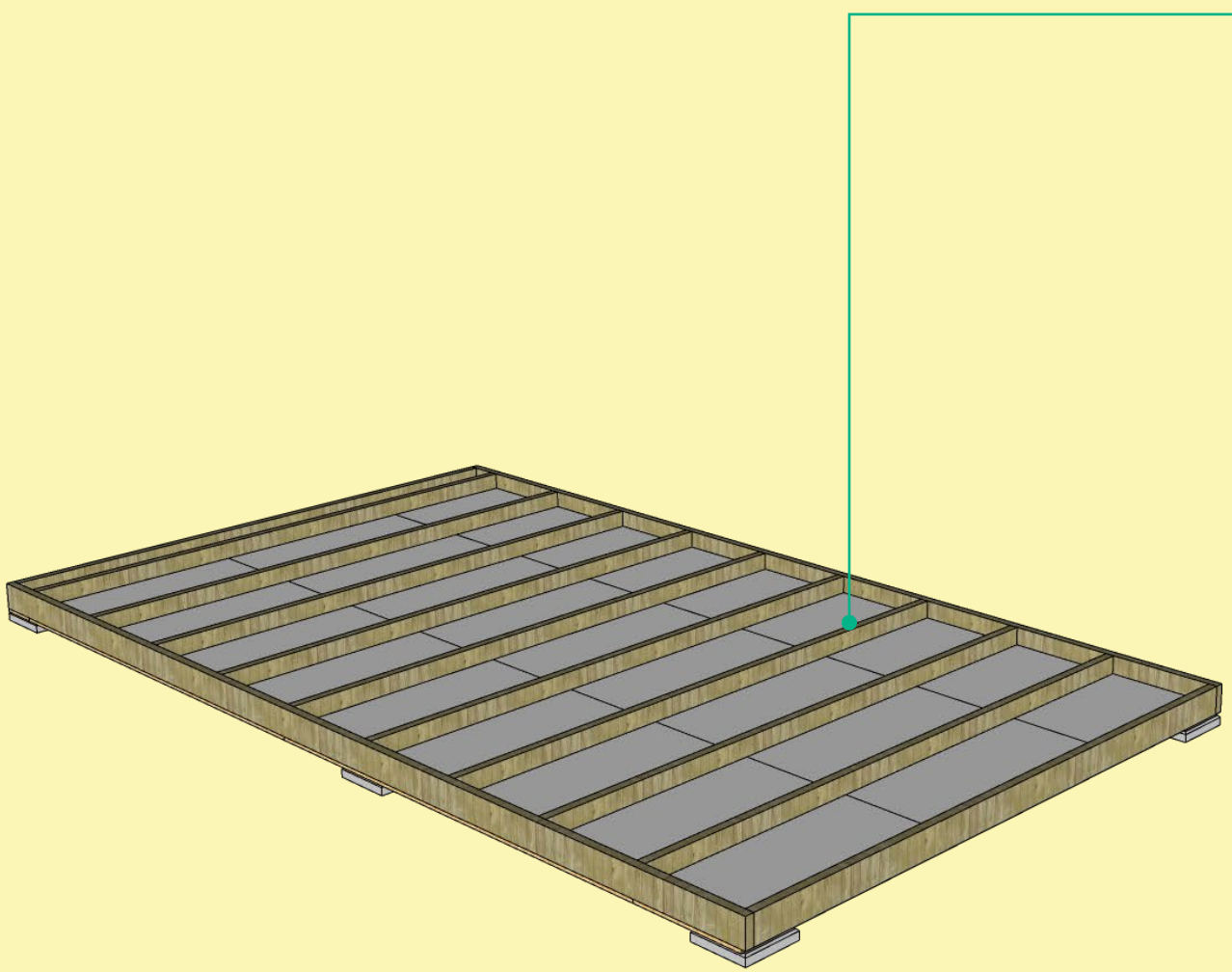


Step by step RHU Winterization

Flip the floor upside down. This can be done in as one or multiple pieces depending on the weight and amount of people available

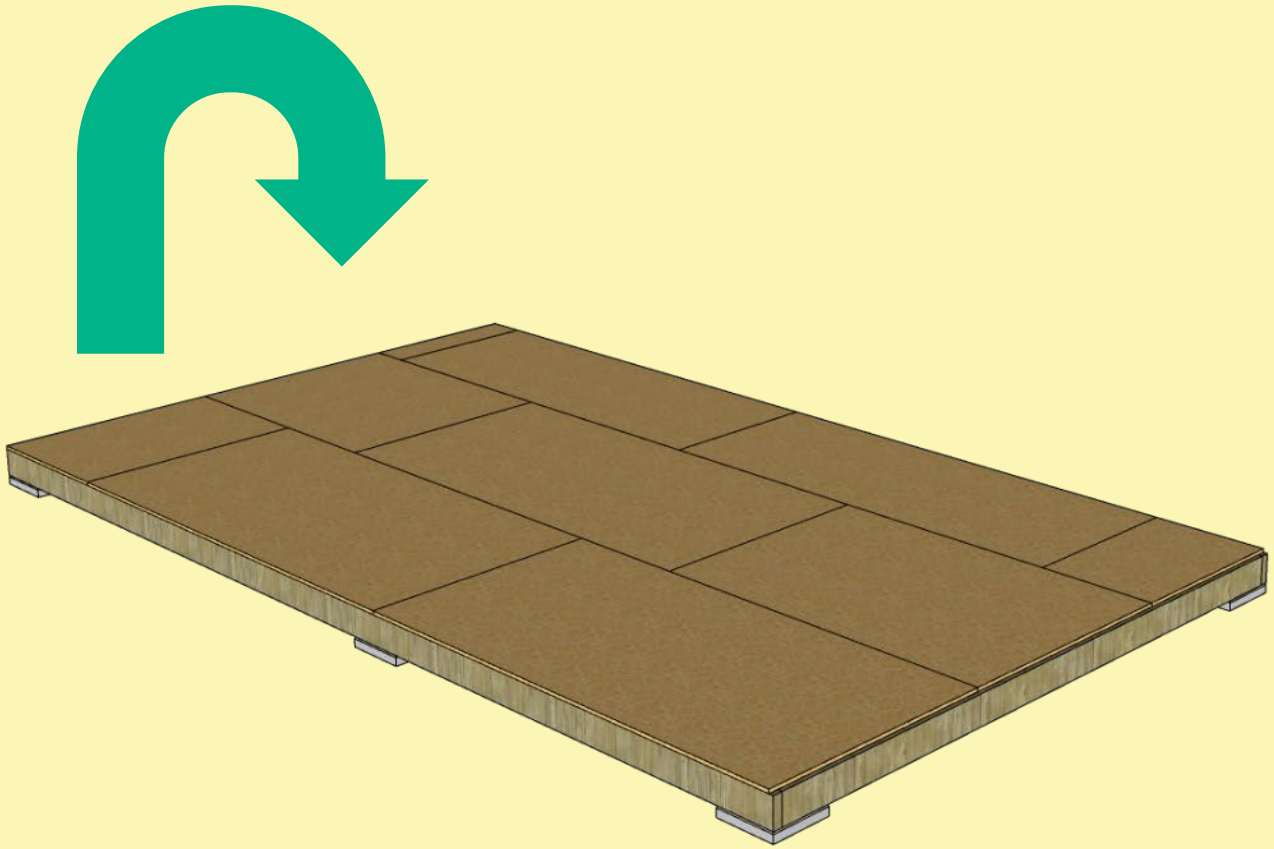


Step by step RHU Winterization



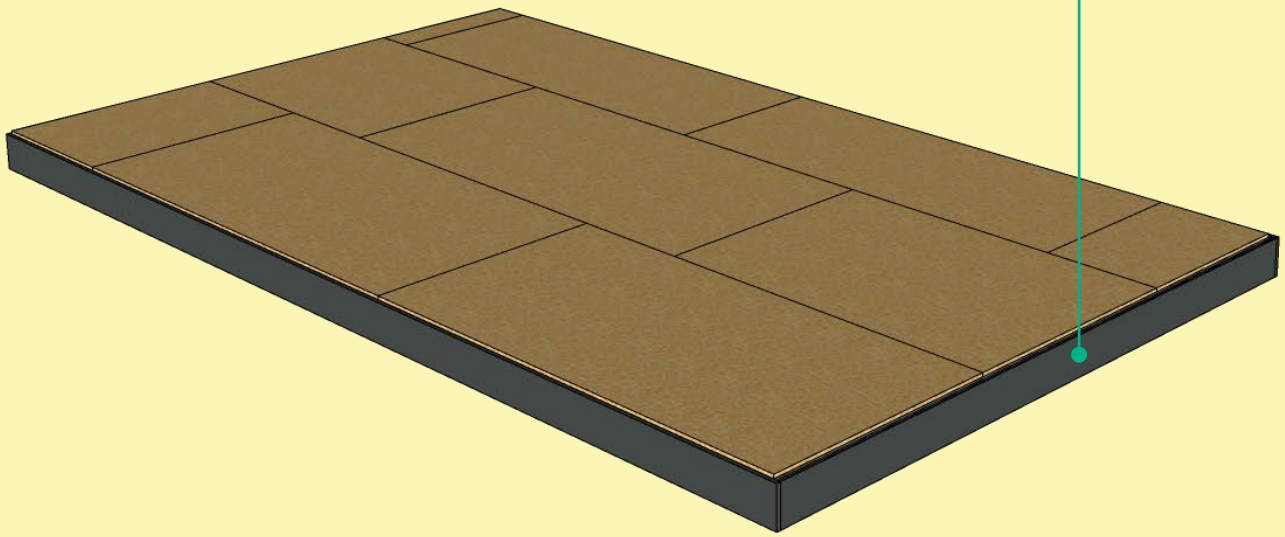
Step by step RHU Winterization

Flip the floor with the right side up



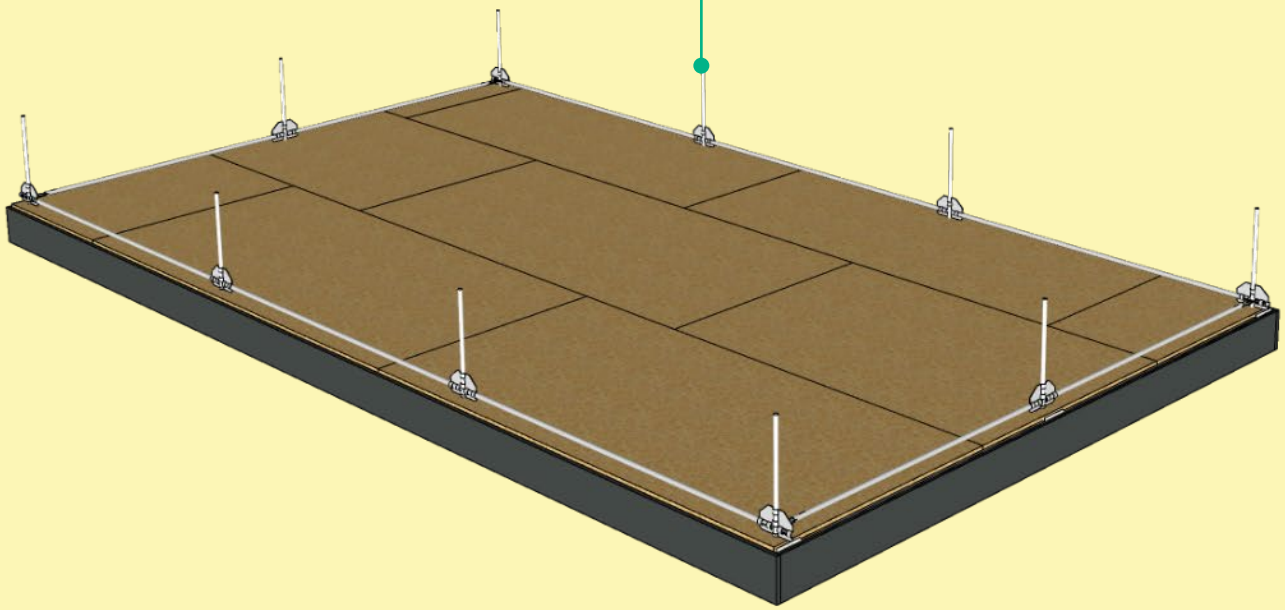
Step by step RHU Winterization

Add skirting around the edges of the floor

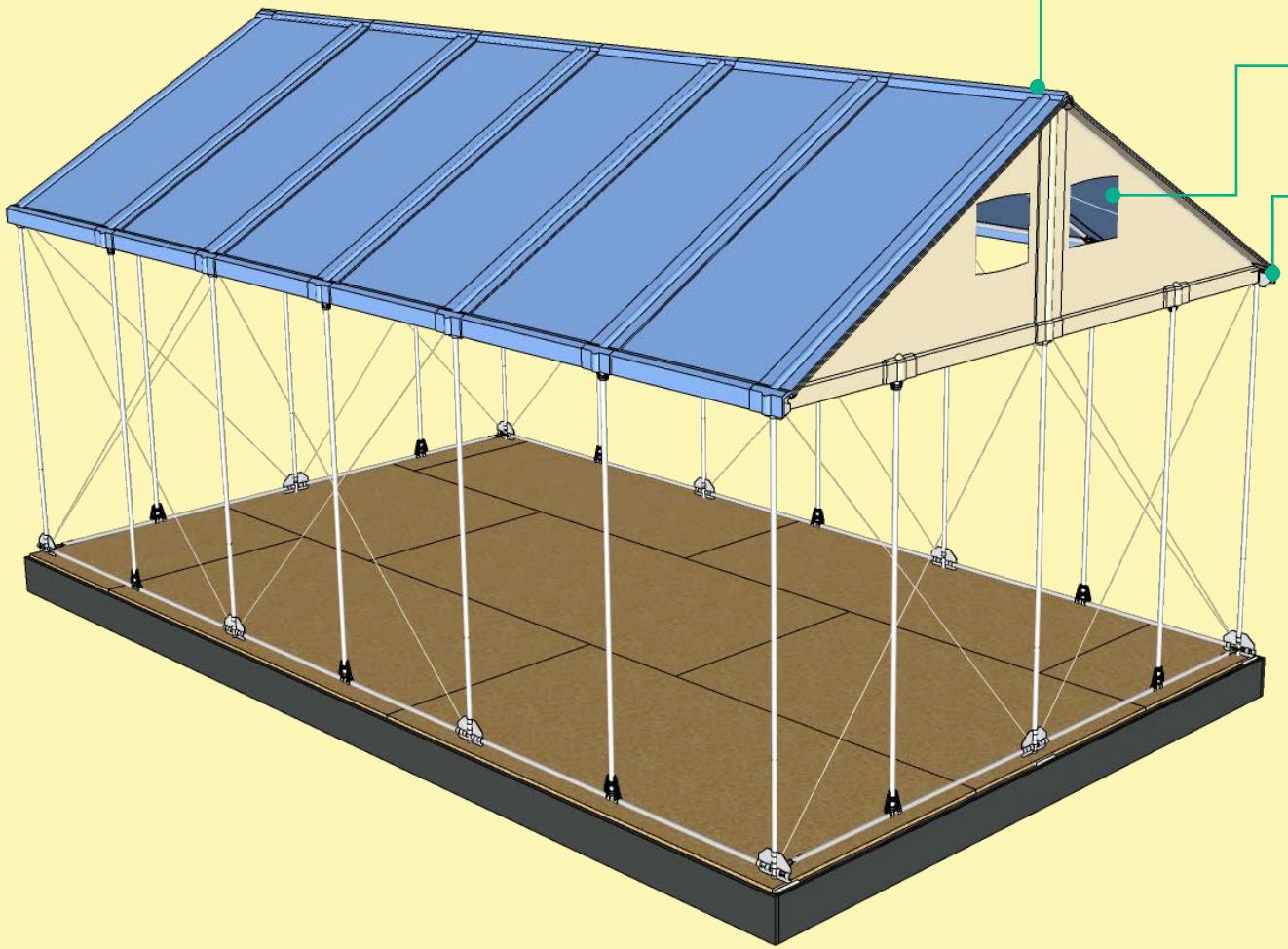


Step by step RHU Winterization

Install foundation of the frame following the standard assembly manual



Step by step RHU Winterization



Install roof: following the RHU manual install the roof including roof panels and gable panels on the structure.*

* The ventilation windows will be installed at a later time (4 x)

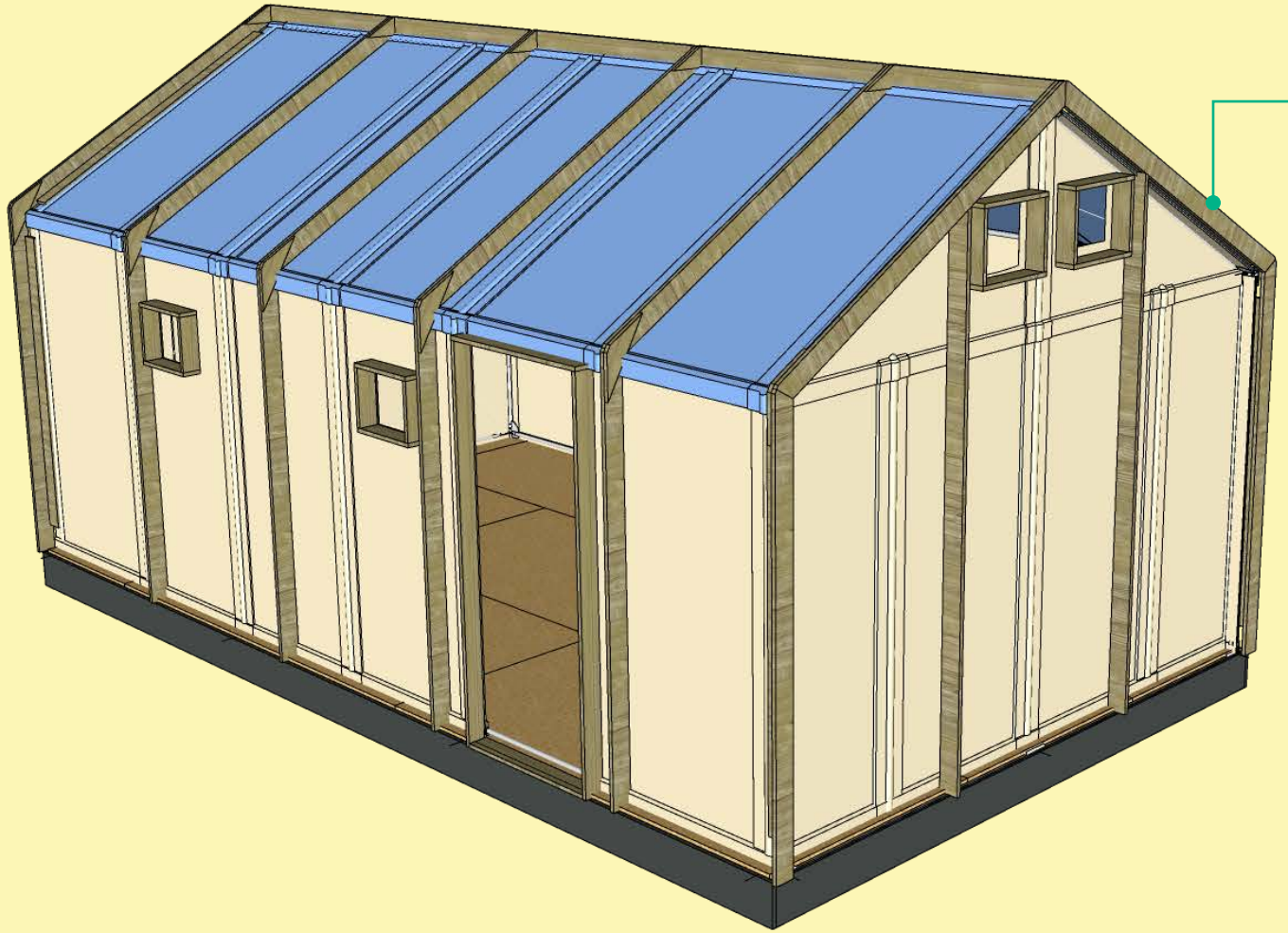
* Ridge hats not installed (6x)

Step by step RHU Winterization

Wall panels: according to RHU manual*

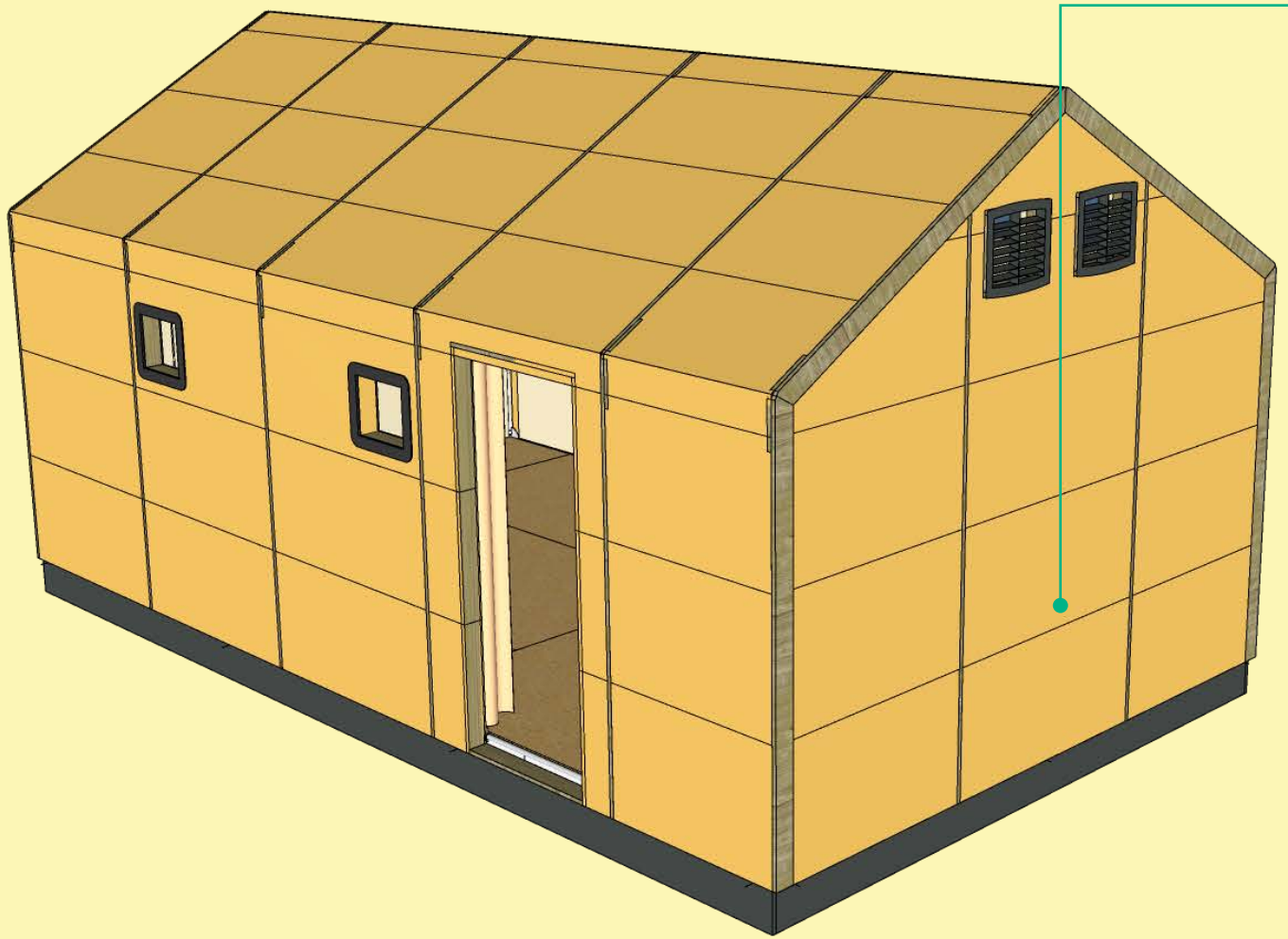
*leave windows out at this point in the assembly

Step by step RHU Winterization



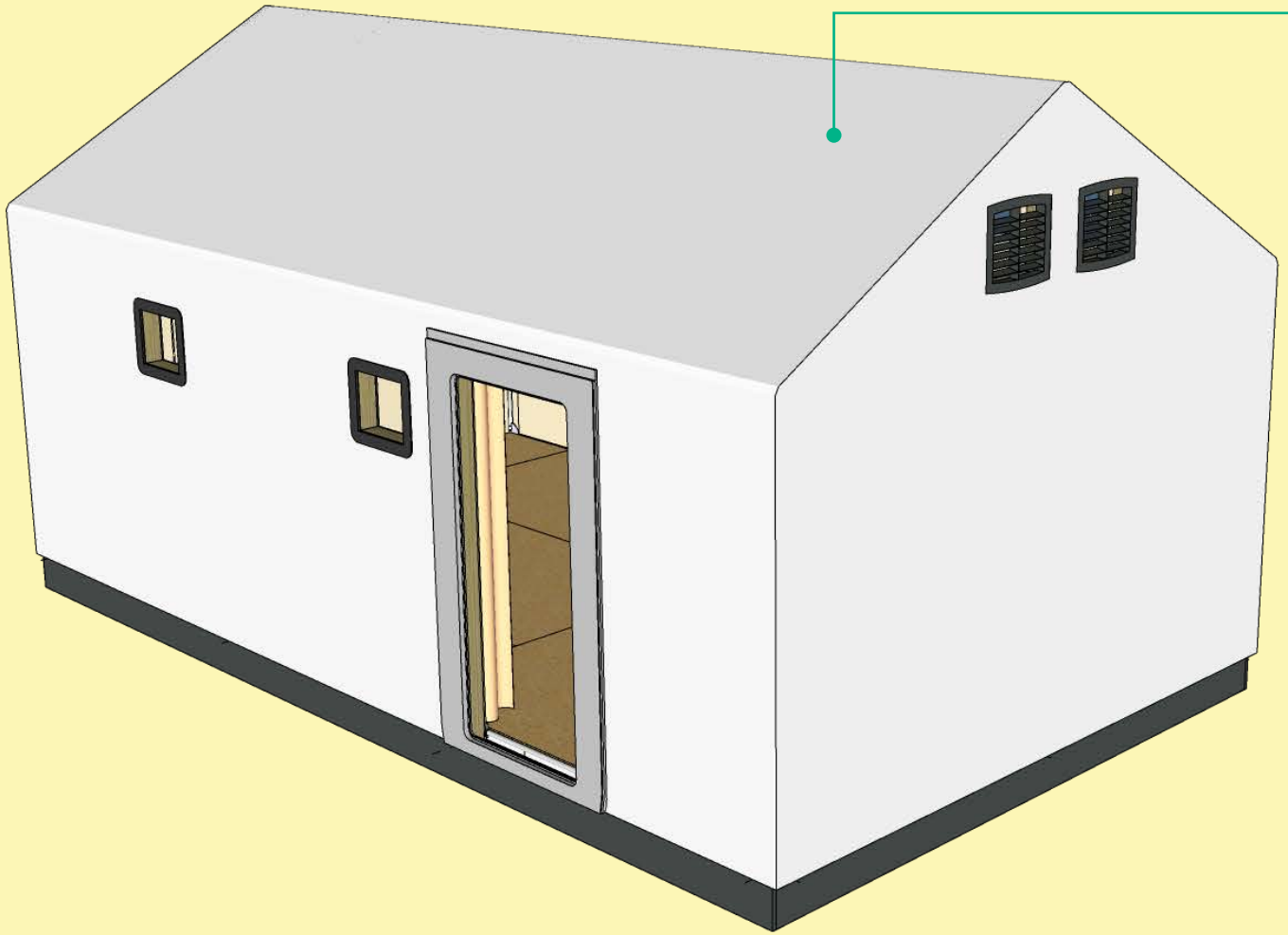
Wood framing: creates attachment points for tarpaulin and openings and prevents insulation from being compromised

Step by step RHU Winterization



Roof and Wall insulation: install stone wool insulation, 100mm on all walls and roof surfaces

Step by step RHU Winterization

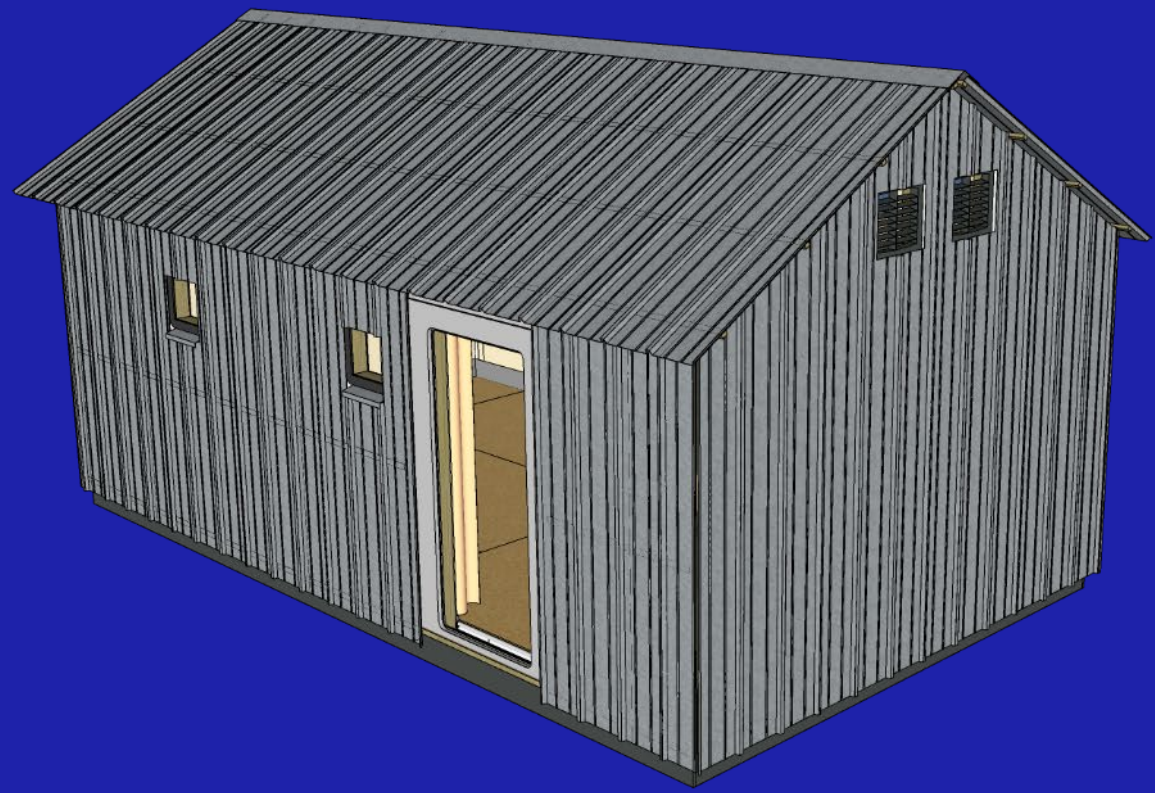


Install tarpaulin: attachments according to plasticsheeting guideline. Pay extra attention to waterproofing: use washers and rubber gaskets to close off attachments.

Quality of tarpaulin and attention to detail is of the utmost importance. The insulation is sensitive to moisture to preventing water from passing through the tarpaulin is imperative.

Plasticsheeting guideline at www.plasticsheeting.org

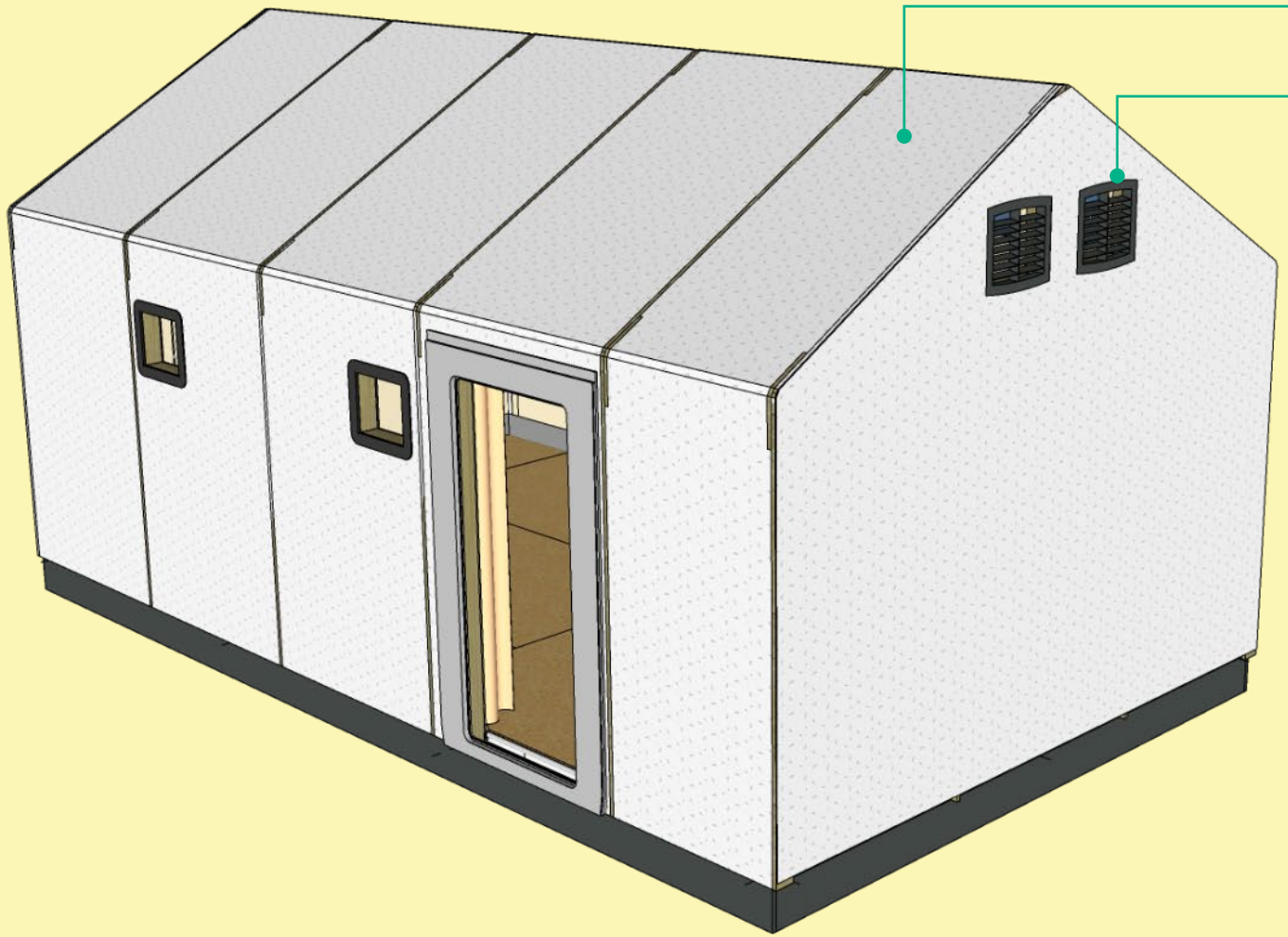
Appendix 4– RHU winterization approach upgrade roof/walls



Step by step RHU Winterization

Please see slide 10 to 22 for previous steps

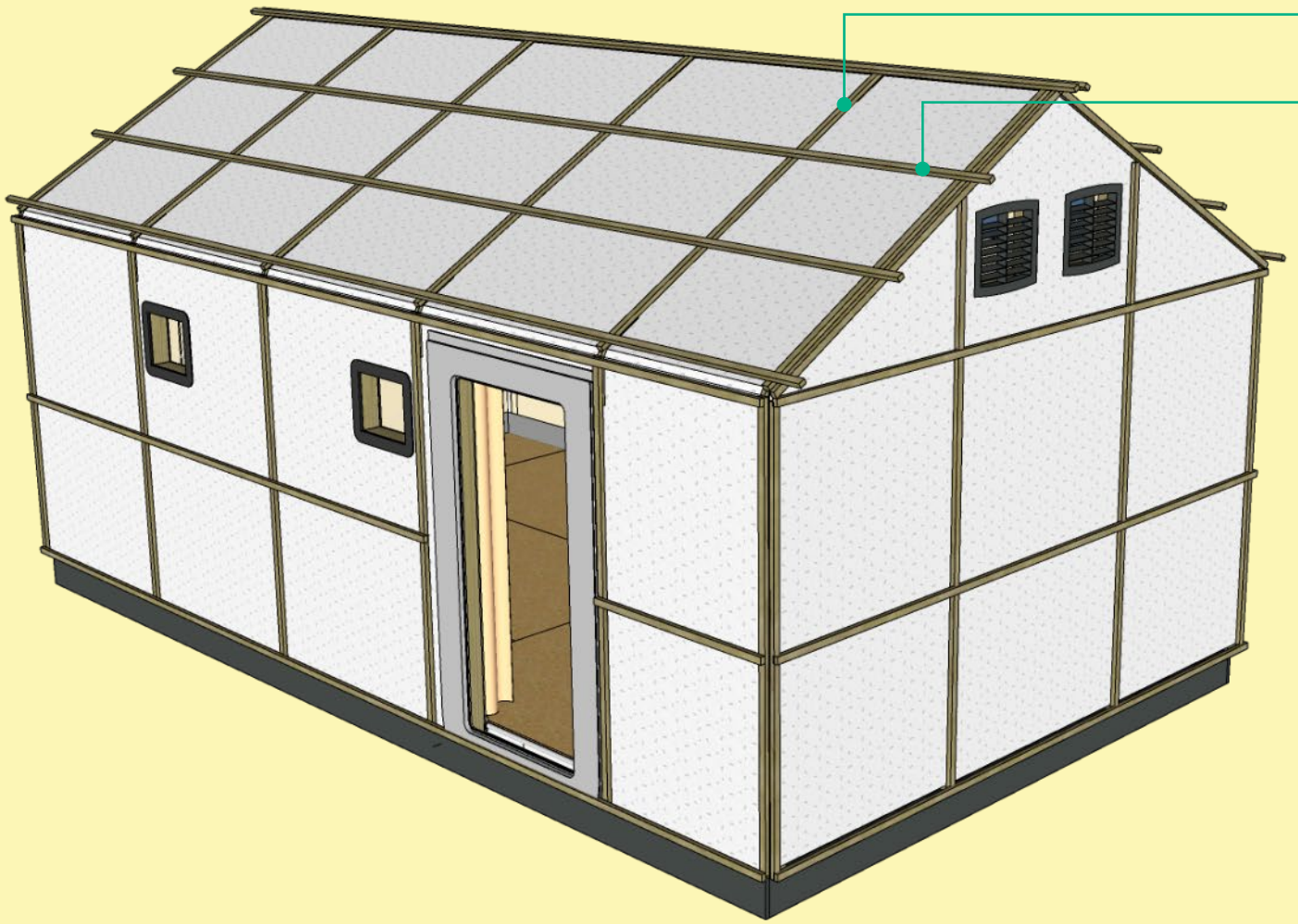
Upgrade



Place vapor open membrane such as Tyvek on the insulation according to the product specifications

Tape off membrane on wooden window and door frames and reassemble frames

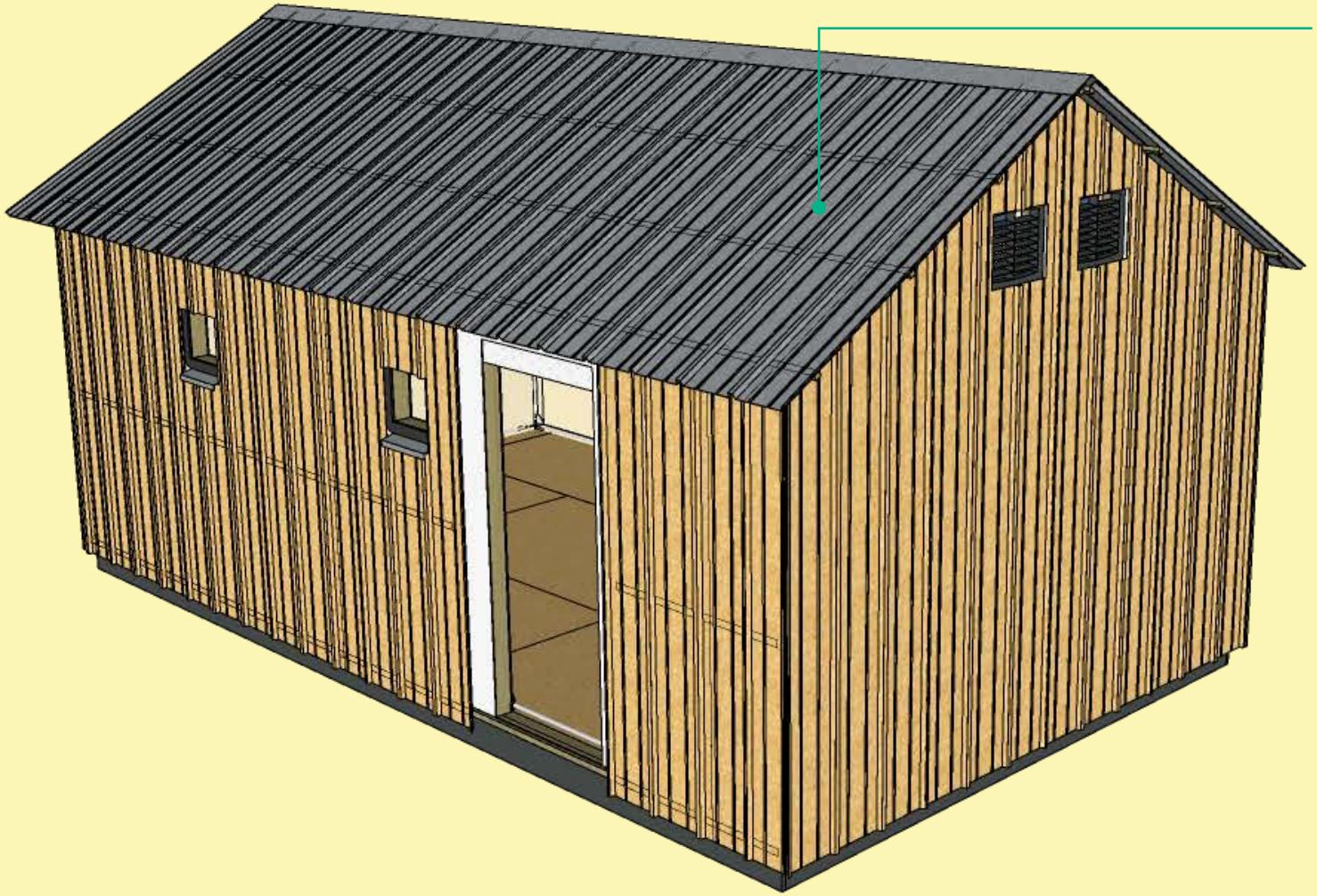
Upgrade



Place wooden battens vertically on top of the membrane at the locations of the wooden frames.

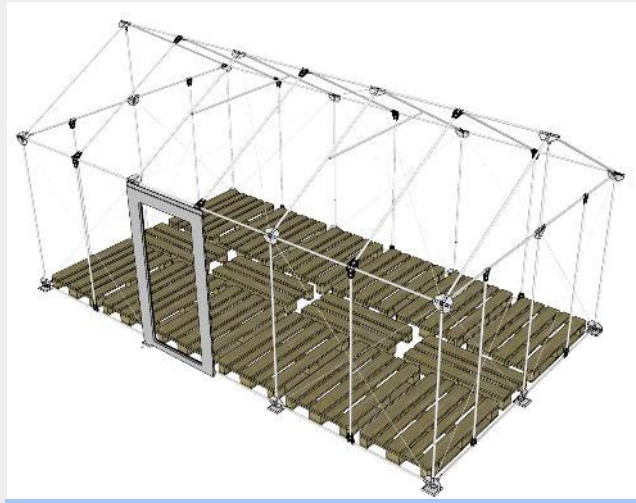
Place wooden battens horizontally on top of the previous battens

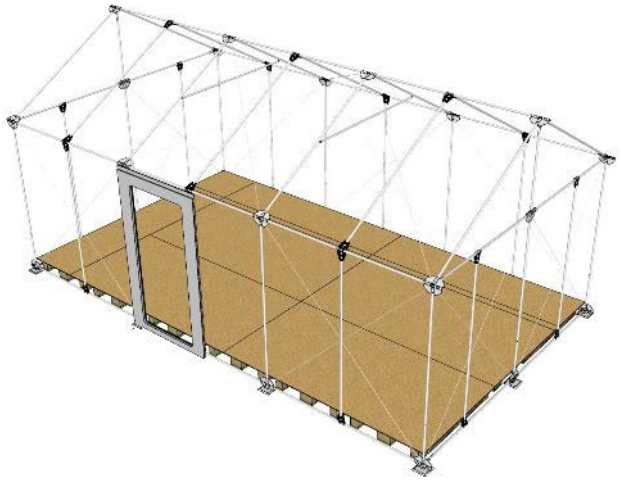
Upgrade

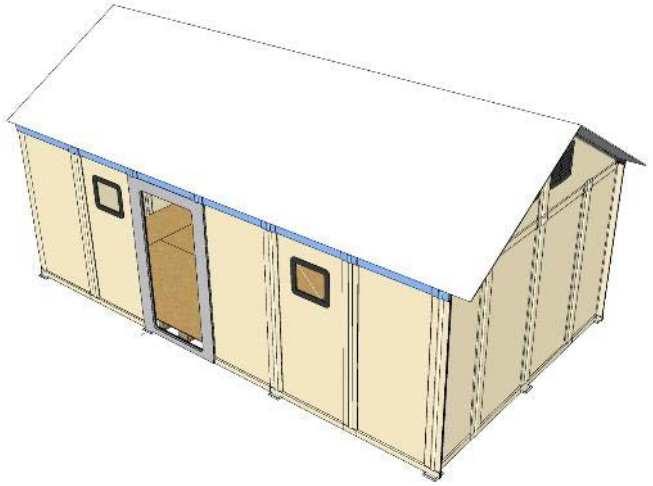


Install lightweight finishing layer such as CGI on roof and walls or wood on the walls

Appendix 5







FLOOR:
A raised floor made out of pallets and covered with plywood

ROOF:
Covered with plastic sheeting

HEATING:
A 2kW heater

Bill of Materials for Insulation

			Quantity/RHU	
Adaptation 1 – RHU with roof tarpaulin, pallet/plywood floor and heater				
Plastic sheeting (4m role width)	1 sheets	6 m	6 m1	10% roll
Pallets (Euro size)			16 pcs	16 pcs
Plywood (1220x2440mm) 15-18mm			6 pcs	6 pcs
Heaters 2kW min			1 pcs	1 pcs
Woodscrew 4.5x40mm	6 per pallet		88 pcs	88 pcs
Adaptation 2 – RHU with full tarpaulin cover, insulation/plywood floor and heater				
Plastic sheeting (4m role width)	3 sheets	6 m		18 m1
Hard pressed insulation material min. 30mm				17,3 m2
Plywood (1220x2440mm)				6 pcs
Heaters 2kW min				1 pcs
Woodscrew 4.5x40mm				40 pcs