1. Solution 1: Ecoboard (with Sliding Mechanism)

WORKING PRINCIPLE

The exo-skeletal structure (functioning as a operable 'second' roof) extends over the entire primary roof in its open position, functioning as a radiant barrier that blocks solar radiation during the day time i.e. the roof if 'shaded' through this mechanism in the day time. After sun-down, to promote radiation of internally accumulated heat embedded in the roofing material and re-radiation of ambient heat absorbed during the day, the installed apparatus folds into a stack of panels in its closed position, thereby exposing a majority of the primary roofing material to the cool night sky which facilitates the process of natural cooling through night sky radiation. This diurnal cycle of operation restores thermal comfort conditions within the structure below to acceptable conditions that promote human wellbeing.

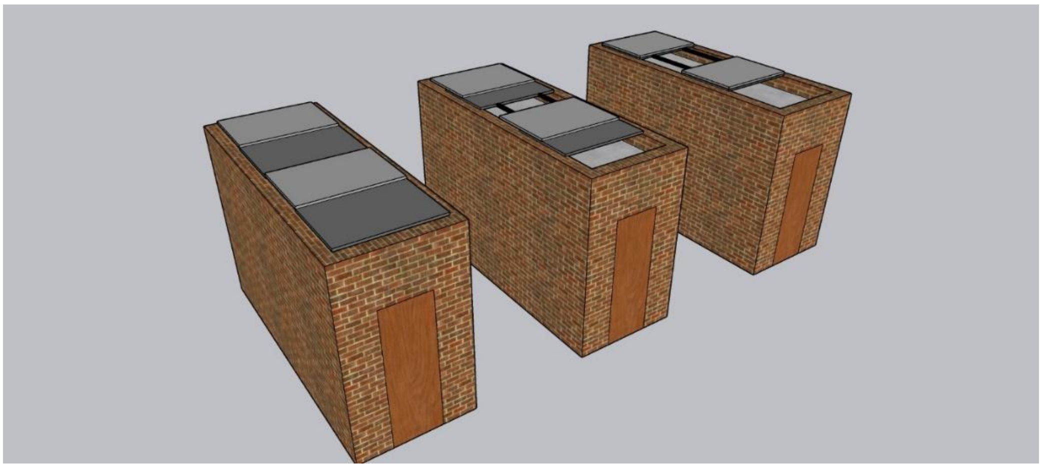
MATERIAL DESCRIPTION

These boards are made from multi-layer plastic which are hard to recycle and end up in landfills usually. Tetra packs and other plastic objects are compressed under high temperature to create a consolidated board that can later be used to make furniture, as doors and other objects.

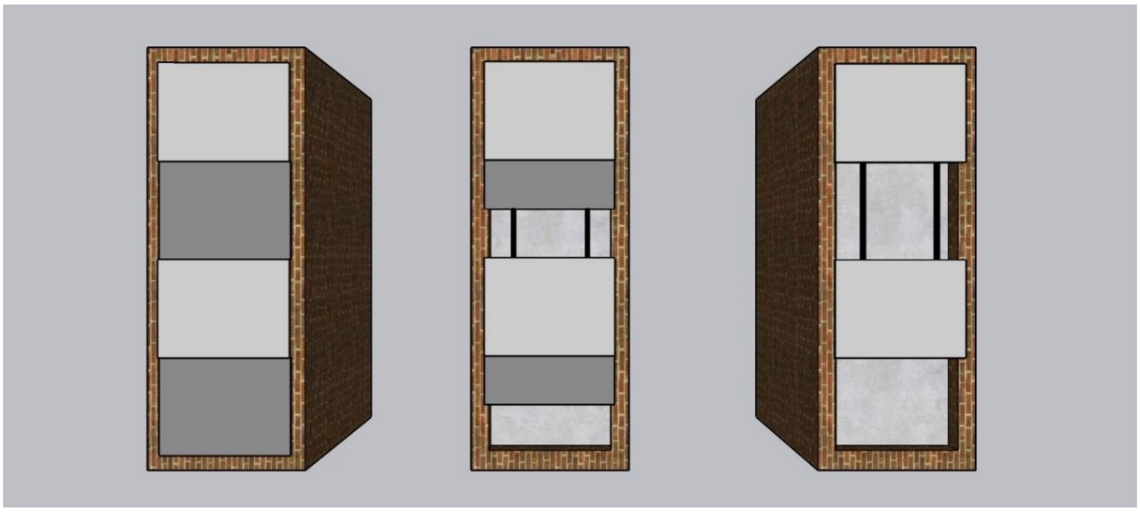
MECHANISM DESCRIPTION

The sliding mechanism operates like sliding drawers, wherein channels and rollers help slide the boards to one end of the house to allow night sky radiation to facilitate cooling within the house at night. A pulley mechanism is incorporated within the system to handle the sliding movement.

WORKING DRAWINGS



Sliding mechanism (upper view): (left to right) closed, opening, open



Sliding mechanism (upper view): (left to right) closed, opening, open

INSTALLATION IMAGE

Ecoboard Sliding (Closed)

2. Solution 2: Alufoil (with Chain and Sprocket Mechanism)

WORKING PRINCIPLE

The exo-skeletal structure (functioning as a operable 'second' roof) extends over the entire primary roof in its closed position, functioning as a radiant barrier that blocks solar radiation during the day time i.e. the roof is 'shaded' through this mechanism in the day time. After sun-down, to promote radiation of internally accumulated heat embedded in the roofing material and re-radiation of ambient heat absorbed during the day, the panels assume a vertical position, eliminating any impediment to heat transfer that is achieved by exposing the primary roofing material to the cool night sky which facilitates the process of natural cooling through night sky radiation. This diurnal cycle of operation restores thermal comfort conditions within the structure below to acceptable conditions that promote human wellbeing.

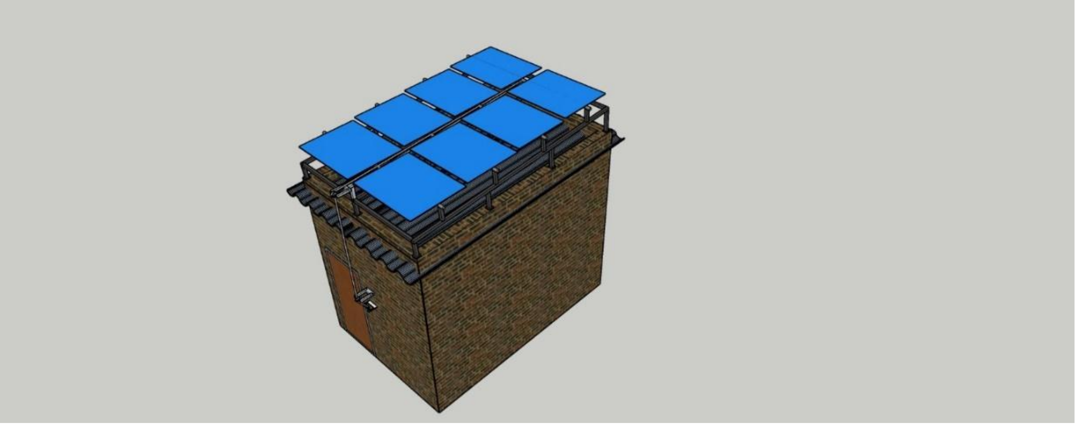
MATERIAL DESCRIPTION

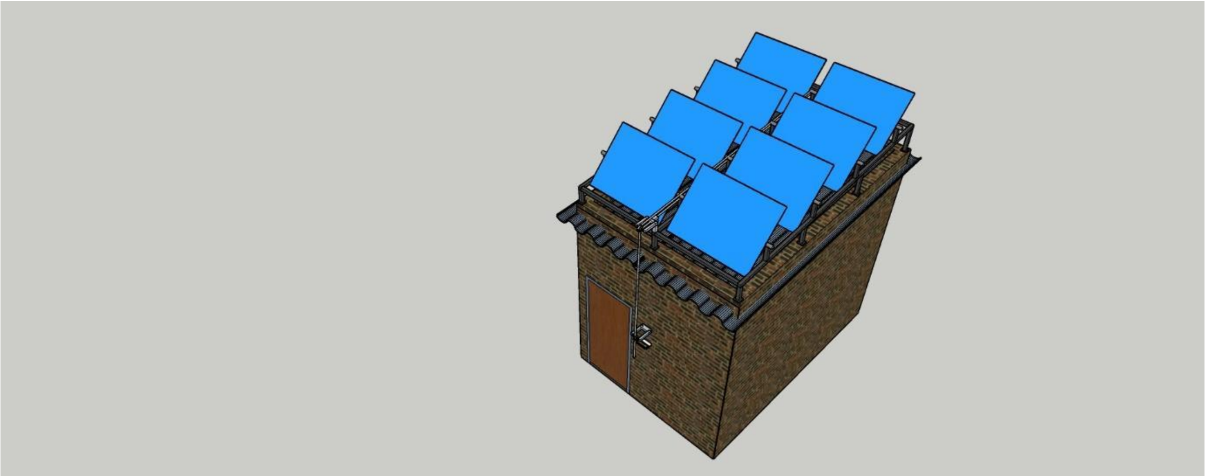
Cross-linked polyethylene foam (also known as XLPE) is a closed-cell foam characterised by a compact feel and resistance to water. It is covered with a low-emissivity and high reflectivity aluminium coating on one side which ensures no heat is emitted to the surrounding surfaces.

MECHANISM DESCRIPTION

The chain-sprocket mechanism works on the principle of louvres, wherein all the panels of the louvres get opened and closed at the same time to allow radiant barrier and night-sky radiation as required. The movement is enabled with the help of chain and sprockets. It is operated with the help of a bicycle pedal which can move the chain in both the directions to a certain extent to enable the dynamic motion.

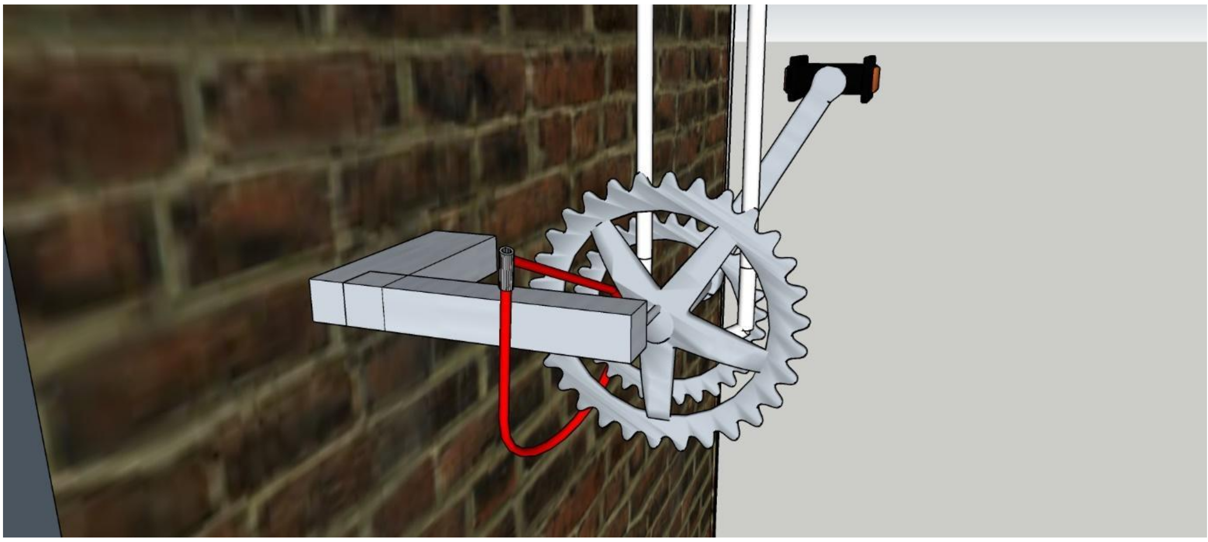
WORKING DRAWING





Chain sprocket upper view: Open panels

Chain sprocket: Operation



Pedal System: Zoomed view

INSTALLATION IMAGE

Alufoil Chain Sprocket Installation

3. Solution 3: Alufoil (with Pipe Motor)

WORKING PRINCIPLE

The Alufoil sheet (configured as a folded 'accordion' horizontally deployed 'curtain') extends over the entire primary roof in its closed position, functioning as a radiant barrier that blocks solar radiation during the day time i.e. the roof is 'shaded' through this mechanism in the day time. After sun-down, to promote radiation of internally accumulated heat embedded in the roofing material and re-radiation of ambient heat absorbed during the day, the Alufoil sheet retracts, eliminating any impediment to heat transfer that is achieved by exposing the primary roofing material to the cool night sky which facilitates the process of natural cooling through night sky radiation. This diurnal cycle of operation restores thermal comfort conditions within the structure below to acceptable conditions that promote human wellbeing.

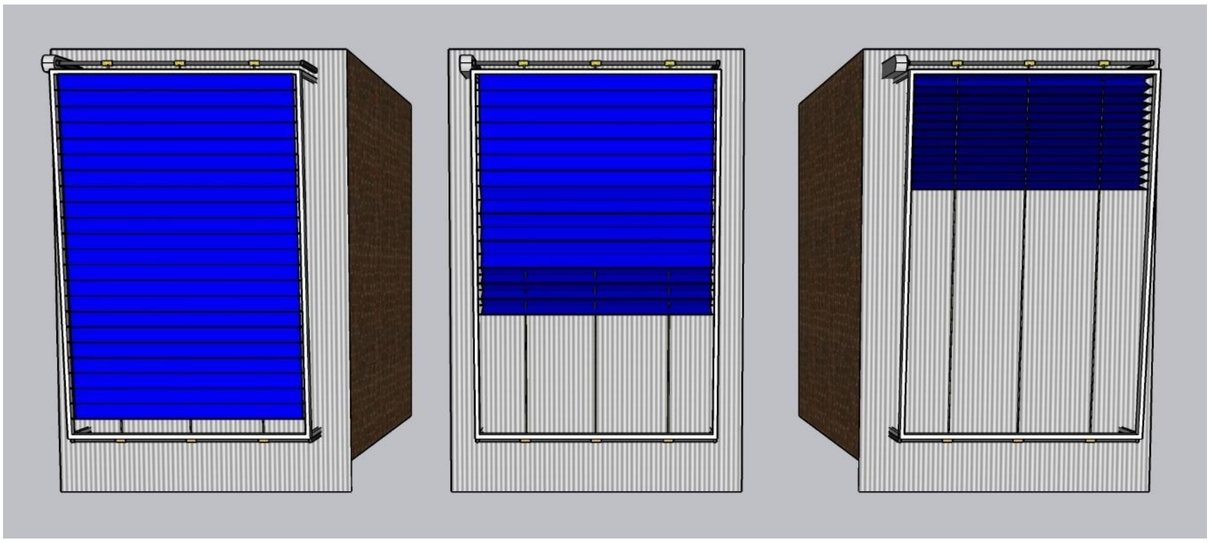
MATERIAL DESCRIPTION

Cross-linked polyethylene foam (also known as XLPE) is a closed-cell foam characterised by a compact feel and resistance to water. It is covered with a low-emissivity and high reflectivity aluminium coating on one side which ensures no heat is emitted to the surrounding surfaces.

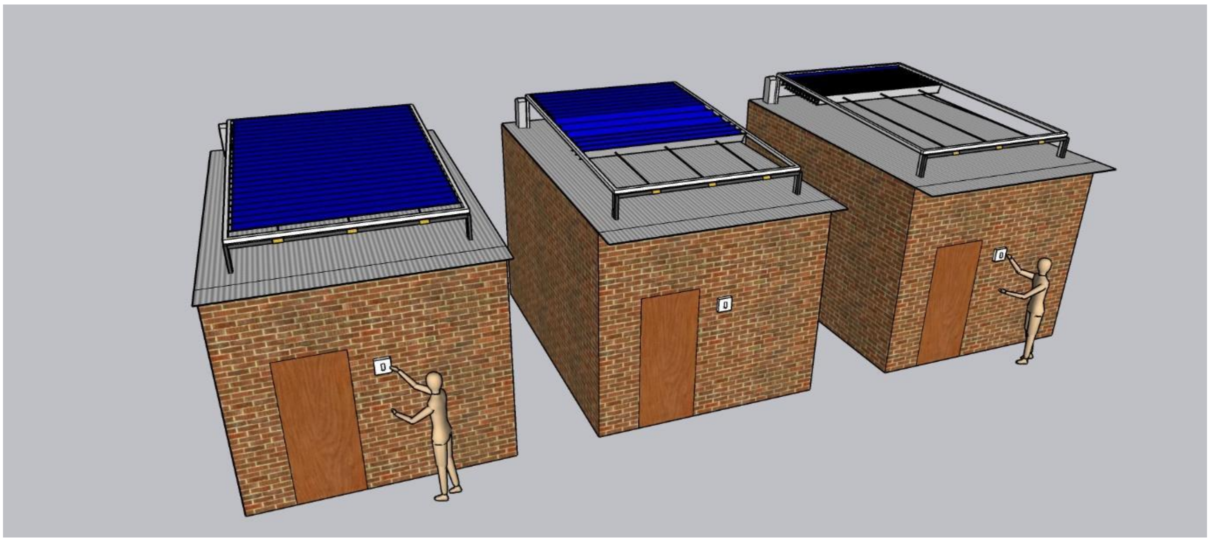
MECHANISM DESCRIPTION

The pipe motor mechanism is like an automated curtain mechanism where the Alufoil sheet can be folded and unfolded as required to work as a radiant barrier during the day and facilitate night sky radiation at night. The Alufoil is supported on a rope which winds and unwinds to enable opening and closing the Alufoil that is resting on it. The rope is wound on the pipe which is controlled by a motor. There is a switch to enable the opening and closing of the mechanism.

WORKING DRAWINGS



Pipe motor mechanism (uper view): (left to right) closed , opening, open



Pipe motor mechanism operation: (left to right) closed , opening, open

INSTALLATION IMAGE

Alufoil Pipe Motor (Closed)

4. Solution 4: Alufoil (Static)

WORKING PRINCIPLE

UNLIKE OTHER OVER-THE-ROOF EXO-SKELETAL INSTALLATION MECHANISMS THAT EMPLOY THE USE OF ALUFOIL SHEETS, THE STATIC INSTALLATION IS AN UNDER THE ROOF INSTALLATION. THE ALUFOIL, WITH ITS SHINY SIDE FACING DOWNWARDS, IS STUCK TO THE ROOF WITH THE HELP OF A STRONG ADHESIVE. IT SUPPORTS INSULATION AND ENSURES THAT THE HEAT COMING THROUGH THE ROOF DOESN'T GET TRANSFERRED TO THE HOUSE AS THE SHINY SIDE FACING DOWN DOESN'T EMIT THE HEAT ABSORBED BY THE FOAM.

MECHANISM DESCRIPTION

This is a fixed/static installation and does not involve moving parts.

INSTALLATION IMAGE:

5. Solution 5: Rooftop Gardening

WORKING PRINCIPLE

Facilitates reduction of heat ingress (i.e passive cooling) through shading provided by the leaf foliage of plants, thermal mass (increased thermal delay and high decrement factor to dampen the response of increased temperature outside leading to a less than proportional rise in temperature inside) of the soil, and evaporation/evapotranspiration (adiabatic cooling) effect of water evaporation from the soil and leaf surface enabling conductive heat loss from the roof sheet below which in-turn reduces mean radiant temperature of the occupied space below.

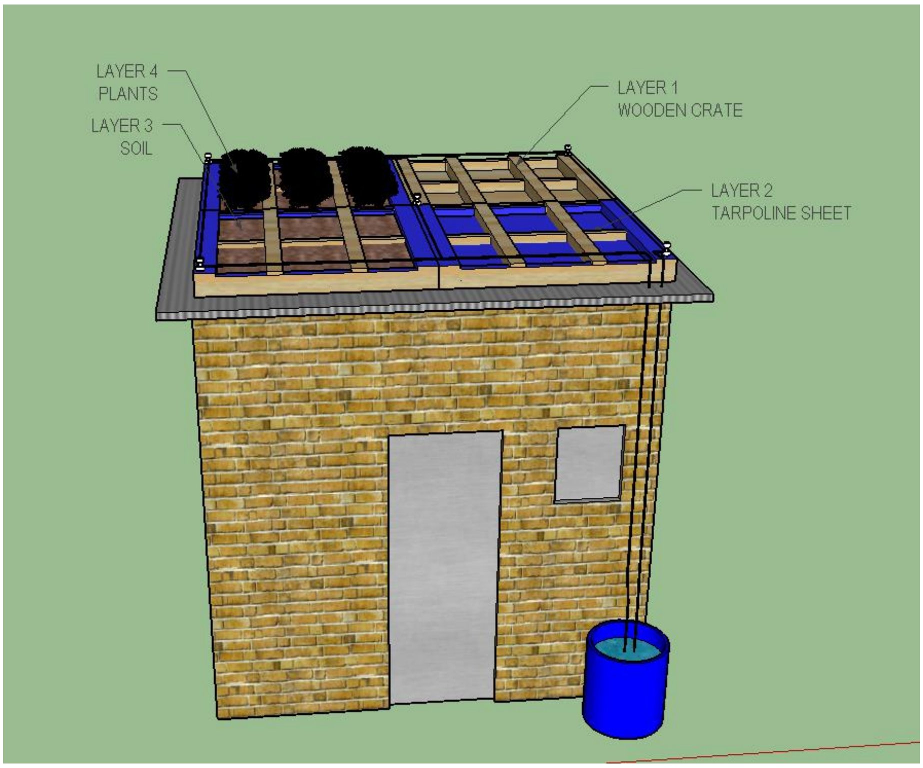
MATERIAL DESCRIPTION

A layer of vegetation cultivated in diverse ways on the roof eg. In pots, brick beds, wooden crates, grow bags, etc.

MECHANISM DESCRIPTION

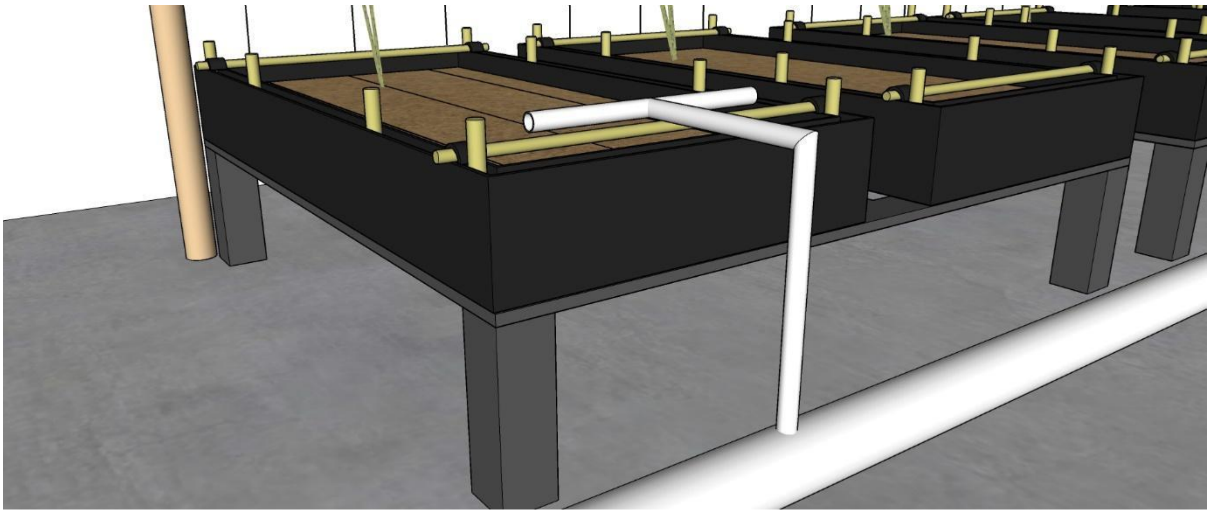
A rectangular or square structure with wooden planks installed on the roof serves as a growing space for vegetables and fruits which facilitate shading and cooling through the thermal mass of the soil, in addition to serving as a source of food for the homeowner. Alternatively, vegetables and fruits are grown over the roof in growbags. Growbags are made up bio fibre material. This installation supports cooling through shading and thermal mass of the soil, in addition to serving as a source of food for the homeowner.

WORKING DRAWING



Rooftop garden: zoomed out view.

Rooftop Garden: zoomed in roof view.



Rooftop Garden: Watering System

INSTALLATION IMAGE

Rooftop Garden: Grow Bag (left), Wooden Frame (right)

6. Solution 6: Dormer Window

WORKING PRINCIPLE

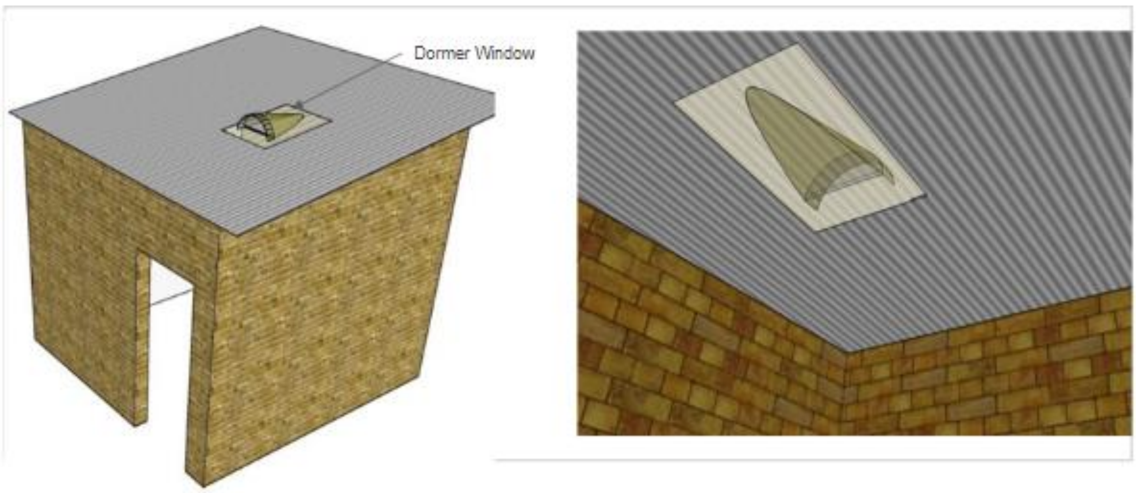
The mechanism works on the principle of convective ventilation where warm air rises up and vents out of the Dormer window. The window ideally needs to be fit on the highest available height for the principle to function. The fibre reinforced plastic is moulded into a hump with an opening at the bottom towards interior of the house to allow warm air to circulate and vent. The gap is covered with a metal net to prevent insects and other animals from getting in the house. The translucence of the fiber-glass material used for fabricating the molded window also enables the ingress of natural light into the interior space.

MATERIAL DESCRIPTION

Dormer window is a hump shaped window that is designed to be retrofitted onto existing corrugated steel/tin/cement roofs. It is made of fibreglass moulded into a hump to be retrofitted. The pane is made of translucent plastic to diffuse light and avoid glare.

MECHANISM DESCRIPTION

WORKING DRAWINGS



Over the Roof View | Under the Roof View

INSTALLATION IMAGE

Dormer Window: Indoor view

7. Solution 7: Wood Wool Panel

WORKING PRINCIPLE

Thermal Insulation

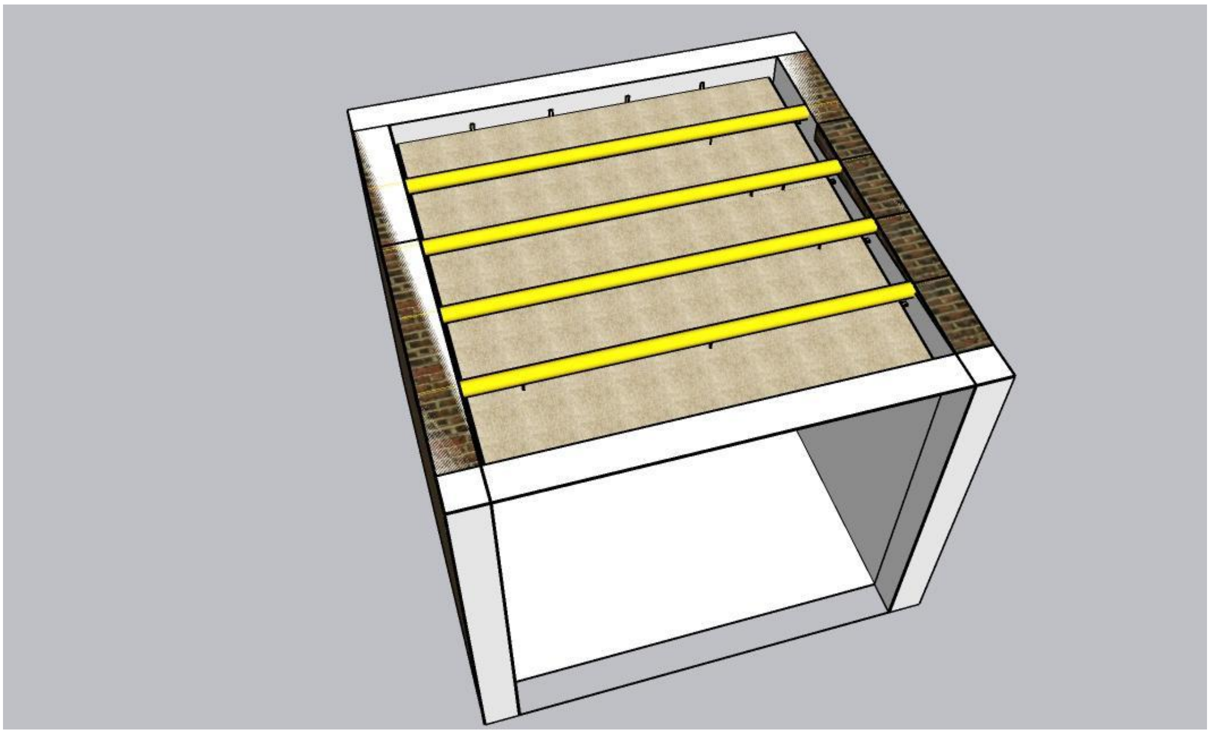
MATERIAL DESCRIPTION

Wood Wool Panel is an environment-friendly, recyclable material made from wood wool, cement and water. It is installed under the roof.

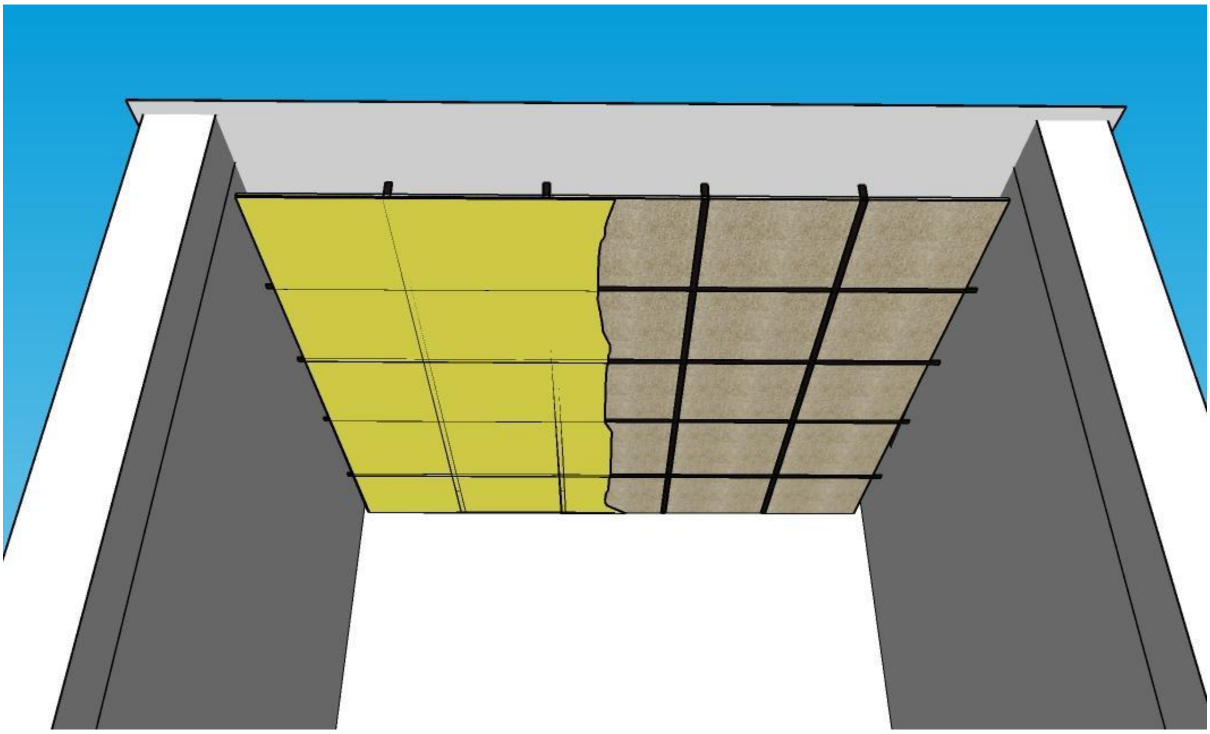
MECHANISM DESCRIPTION

This is a fixed/static installation and does not involve moving parts.

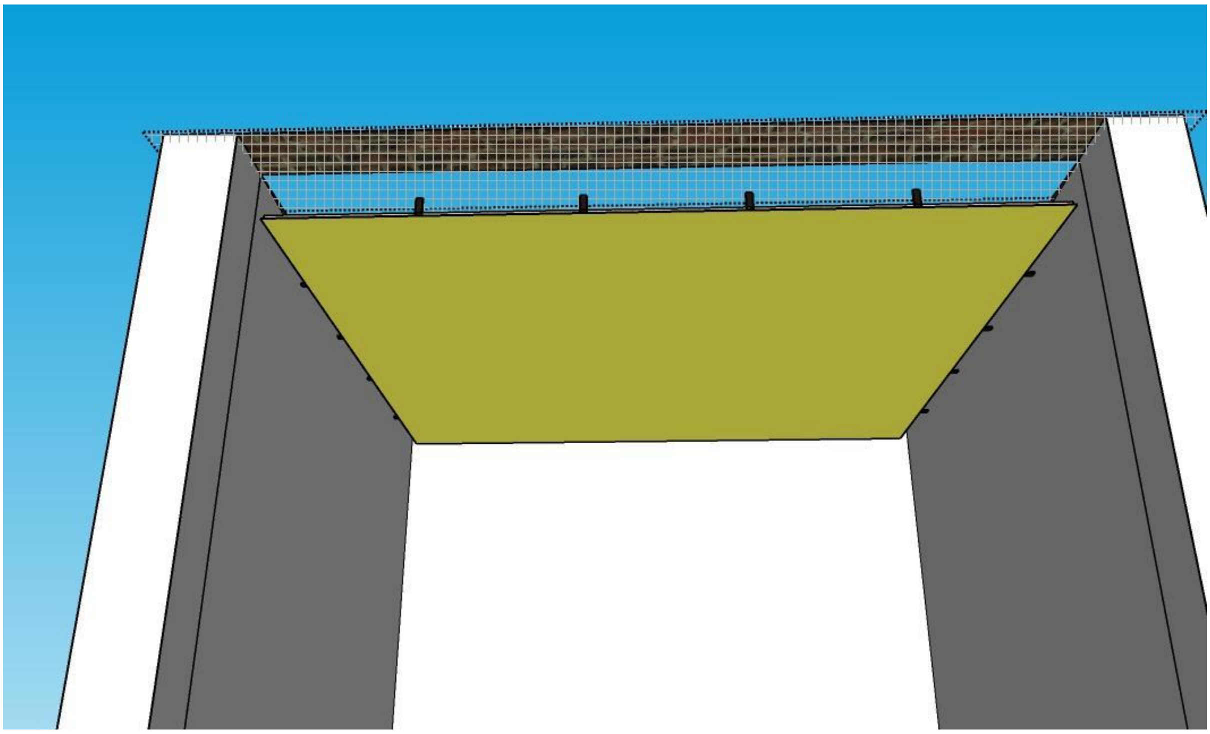
WORKING DRAWING



Wood Wool: Upper view (minus roof)



Wood Wool: Under the roof view (panels and silpaulin both visible)



Wood Wool: Under the roof view (silpaulin visible)

INSTALLATION IMAGE

8. Solution 8: Water-Filled PET Bottles

WORKING PRINCIPLE

Water has the highest specific heat capacity than any liquid. Specific heat is defined as the amount of heat one gram of a substance must absorb or lose to change its temperature by one degree Celsius. For water, this amount is one calorie, or 4.184 joules. Thus, it can absorb a lot of heat before its temperature rises. This trait helps it to stabilize temperature in its surroundings. To benefit from this heat resisting property of water, discarded PET bottles are filled with water and stuck on the roof. This low cost, zero energy passive thermal comfort solution increases the thermal mass of the roof i.e., its ability to store heat, for a longer duration before letting it seep into the house through the day and reversing the heat transfer process of the water during the night, since the warmed water during the day gets cooled during the night due to the drop in ambient temperature, which in turn keeps the roof cool the next morning even when the sun starts to heat up.

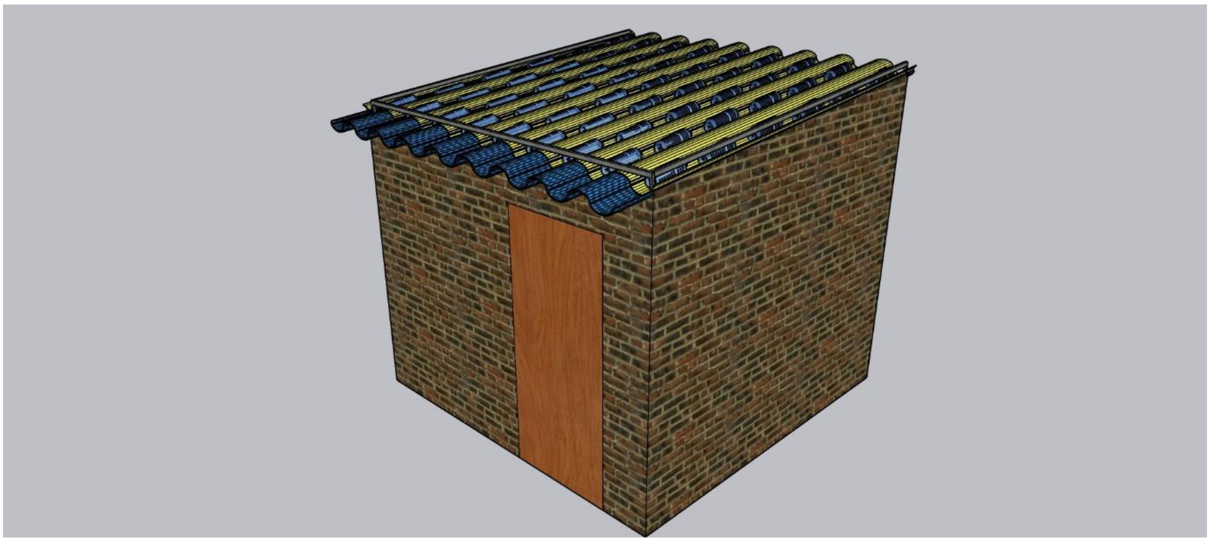
MATERIAL DESCRIPTION

Plastic PET Bottles which are generally used for packaging water or beverages are filled with water and placed above the roof.

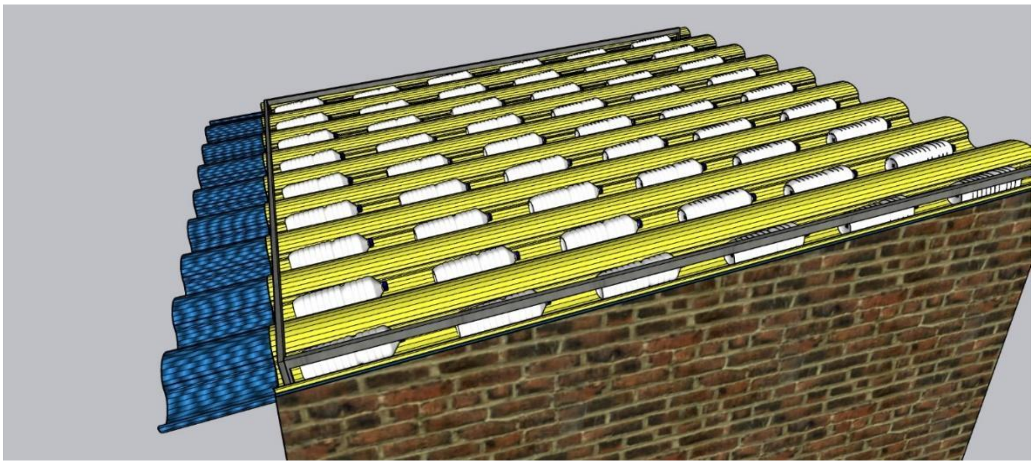
MECHANISM DESCRIPTION

This is a fixed/static installation and does not involve moving parts.

WORKING DRAWING



Water filled PET bottles: Zoomed out view



Water Filled PET bottles: Zoomed-in view

INSTALLATION IMAGE

9. Part B: What's on the horizon

In year 1 and first-half of year 2 we will work on further refining the human-centric/ergonomic and building physics aspects of the above mentioned 8 solutions, with architectural and engineering domain experts working alongside community members in a participatory design process – including trying 'combinations' of multiple solutions in the same home to evaluate the potential for synergistic effects where in the whole is greater than the sum of the parts. For instance, PET Bottles, Alufoil, Rooftop Gardening and Ecoboard will be applied above the roof with Wood-Wool Panels below to evaluate the enhanced thermal comfort benefits of this combined insulation with radiant barrier and thermal mass approach relative to solutions which pursue a single heat stress abatement strategy.

In years 2 and 3 a enhanced set of thermal comfort solutions will be developed and pilot tested through the same human-centric oriented and community-participation rooted inclusive 'development' approach. A preliminary list of these solutions in the nascent stage of development at this point, is presented below.

Besides this, years 2 and 3 will rigorously experiment with social, political and economic 'diffusion' and sustenance structures including integrating informal housing thermal comfort into municipal public health mandates and establishment of women's cooperatives to provide community oriented solutions through autonomous democratic operation at a small scale.

1	Radiative cooler coating material
2	Ice-box AC
3	Dessicant Dehumidifier
4	Dry Grass
5	Detachable Chimney
6	Thermocol Sheets
7	Cardboard
8	Wool Rugs on Walls/Roof
9	Wind Catcher
10	Cavity Walls
11	Cross Ventillation
12	Wall Insulation
13	DIY Evaporative Cooler
14	Modular Structure Cooling System
15	Clothing, hair, rubber tyres/tubes packed into a crates
16	Dynamic Wind-Catcher (BED-ZED)
17	Coconut leave thatching
18	Handwoven fabrics interwoven with 'technical' materials like alufoil/tetrapak
19	Inverted clay pot + filler material in modular crates
20	Tar sheets
21	Forced Ventillation

22	Arecanut Sheets
23	Dehumidifier (DIY)

Modular Sustainable Active Cooling System Descriptions:

1. **DIY (Do-It-Yourself) Structure Cooling Kit:** A structure cooling system removes the heat in the structure by way of water flowing through pipes. It impedes solar heat gain from roof and floors by absorbing it before causing thermal discomfort to occupants. The system comprises piping, storage tank, a cooling system and a pump which are locally available. The only active elements are a pump & fan that use negligible energy that a Solar PV Panel can address. For more information refer to the following link.
2. **DIY Evaporative Cooling Kit:** These systems work on the principle that water (like all liquids) extracts heat from the surrounding environment when it undergoes phase-change from a liquid to a vapor. In these systems, a fan draws hot outside air through the water-soaked pads. Adding heat to this water evaporates it. When this evaporated water vapor is combined in the air, the air temperature is reduced. A temperature reduction of as much as 20 degrees can be achieved using this system of cooling. These DIY coolers can be made from readily available local hardware materials and can be assembled by residents of informal settlements if supported through assembly instruction manuals developed through human-centric design processes.
3. **DIY Dessicant Dehumidification Wheel Kit:** Desiccant dehumidifiers contain a desiccant wheel with a silica gel surface, a drive motor and belt, a small heater (which can be solar-thermal powered to reduce dependence of electrical energy), and a blower. Damp outdoor air is drawn into the dehumidifier, passing through the slowly turning desiccant wheel where moisture is adsorbed and collected on the silica gel. Most of the dry air enters the indoor space in informal settlement homes while a small portion of the dry air is reactivated by heating through the solar thermal panel. This warmed, dry air, called regeneration air, is passed through the desiccant wheel to dissipate the moisture collected on its surface, regenerating the silica gel on the wheel. These low-energy dehumidification systems will become imperative to respond to extreme thermal stress (caused by a combination of high air temperatures and high humidity) in informal settlements in Indian cities which might be currently classified as belonging to hot-dry climatic zones (eg. Pune) but are anticipated to experience acute increases in humidity and precipitation as climate change effects intensify in the coming years and decades. The periods when high temperature and humidity intersect are significantly more hazardous to human health than when either one of these effects are dominant. At these times, merely relying on passive cooling solutions will not achieve adequate mitigation of heat stress that protects human health and wellbeing, and these active cooling solutions which can address extreme humidity, will become essential. Most elements of these DIY desiccant dehumidifiers can be made from readily available local hardware materials, regionally produced solar panels, and small amounts of industrial chemicals (silica-gel) and can be assembled by residents of informal settlements if supported through assembly instruction manuals developed through human-centric design processes.
4. **DIY Thermostorage 'Ice-Box' ACs:** These systems hinge upon the use of either chilled phase-change-materials (eg. silica gel packs used for household remedies for healing inflammations etc.) or ice blocks to achieve cooling and dehumidification of indoor spaces. The primary mechanism employed in these systems is the blowing of ambient air over these cold surfaces (configured as portable replaceable cartridges that can hold the gel packs or reusable plastic ice cubes) placed in insulated boxes (eg. thermocol boxes) and the re-directing of this cold air through tubes ducts etc. towards occupants of the indoor space (i.e. point of use cooling, similar to systems employed in automobiles and aircrafts which rely upon directly cooling the air volume around the occupant rather than cool the

entire volume of air in the space) The regeneration of the functional materials that have exhausted their cooling capacity can be accomplished at local small-scale solar-thermal energy based chilling plants (using Solar VAM Technology) and be operated by women's cooperatives as a micro-scale local business.