Heat-Action in Informal Settlements:

Reflections on redesigning ‘Cool Roofs’ – beyond reflective coatings for energy poor communities in India

COOLING DOWN THE FAIR WAY

The (F)air conditioning campaign was created by a confluence of consumers and associations protecting the planet’s climate. Our program aims at reducing bills and greenouse gas emissions from the indoor cooling sector.

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PROBLEM STATEMENT

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Primary Home in Shindevasti, Pune

Space Use ~ 33 sq. ft/person

Electricity Use ~ 16 kWh/person/month

Luxury
is
Injurious
to
Health

2nd Home in Siolim, Goa

Space Use ~ 780 sq. ft/person

Electricity Use ~ 183 kWh/person/month

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- 60% Indians live in informal settlements; yet their heat stress is largely ignored by 'cooling efficiency' programs:
  - ✓ only 5 to 10% of India's built-space is 'formal architecture'
  - ✓ 1 architect per 20,500 citizens in India; European ratio is 1:1,880.
  - ✓ **most of India 'builds itself' through 'self-constructed' housing**

- Housing forms poorly weatherized; roof temperatures > 50^0C @ air temperatures < 32^0C, too hot to sleep before Midnight

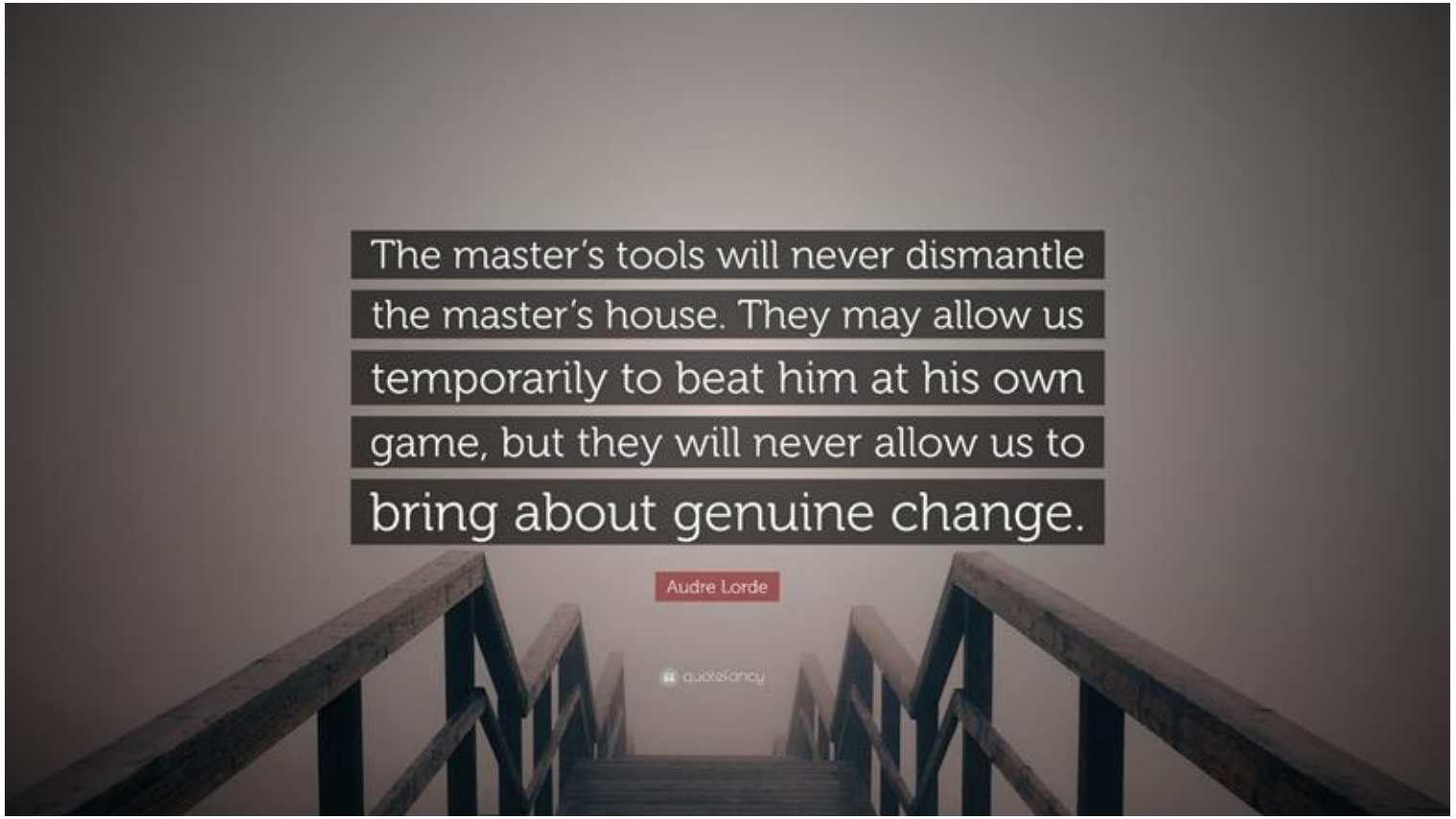
- Recurrent power outages and/or planned outages (load shedding) due to peak-demand from AC use by the affluent class; no backup power sources (diesel generators etc.) to even operate a ceiling or floor fan for basic comfort

- Heat stress disproportionately affects women; wake up much earlier to fetch water and cook - suffer the most from protracted sleep deprivation; **nascent epidemic of sleeping pills amongst women domestic workers emerging**

PRINCIPLES OF CHANGE

subversive idea:

can market mechanisms fix market failures?



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subversive idea:

no more ‘dreamed by the few’ for the ‘many’

Socio-Economic Principles

- **Co-creation and Diversity of solutions:** Unlearning the technocrat's approach - If all you have is a hammer, everything looks like a nail. Where the well-intentioned engineer moves around finding problems or even re-casting problems, to fit their solutions. 'Paint your roof white' smacks of elite condescension. A praxis embedded in community led co-creation of solutions.

- **Humility of praxis:** Doing 'development' only if the community reserves the right to say 'thanks, but no thanks'. How open would we be to our own homes being part of 'development' experiments?

- **Appropriate technology, resilience economy:** Local fabrication, maintenance without reliance on non-resilient corporate and global supply chains. AI, IOT, ML, next 'fad' please stay away

- **Patience in an emergency:** How rapidly do WE adopt 'sustainable' cooling solutions in our contexts? Need 'patience' for decentralized autonomous 'scaling' models to flourish

Design Principles

- **Modular:** to minimize installation time, minimize site-construction risks
- **Durable:** should outlast the payment period significantly
- **Dismantlable:** at the end of heat season, before cyclone season, or if evicted and need to setup in new location
- **No new vulnerabilities**: especially vulnerability to leakage during monsoons, seismic risks etc.
- **Should aim for co-benefits:** if air quality, leakage protection, livelihood, heat island, flood control, water conservation and aesthetic pleasure can all be considered
- **Electrical/Fire/Wind/Water/Physical Safety**
- **Maintenance is not a 'bad word':** 'service model' more important than 'zero maintenance' (like we would with AC)

SOLUTIONS DIRECTORY

Principle 1:
Radiant Barrier + Night Sky Radiation

Working Principle

Sub-Principle 1: External Solar Shade:

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 is ‘shaded’ through this mechanism in the day time.

Sub-Principle 2: Low-E Surface:

Most importantly, the underside of the exo-skeletal ‘active’ surface is a low-emissivity surface (e ~ 0.05): achieved through affixing aluminized layers such as cross-linked polyethylene foam (also known as XLPE) or Multi-Layered-Plastic sheets fabricated from upcycled packaging waste with the ‘shiny’ surface pointing downwards – in the direction of the roof. This ensures that the roof is shielded from approximately 95% (due to an emissivity ~ 0.05) of the radiant solar heat.

Sub-Principle 3: Night-Sky Radiation:

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 either folds into a stack of panels in its closed position, or assumes a vertical (perpendicular to the roof) positon, 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.

Variant 1: Chain Sprocket

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Variant 2: Pipe Motor

Variant 3: Space Frame

Variant 3: Space Frame

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Variant 4: Internal Dynamic Barrier

Variant 5: Vertical Cane Blind - Wall

Principle 2:
Thermal Mass
&
combination: Thermal Mass + Insulation + Low-e Surface

Working Principle

Water has the highest specific heat capacity of any commonly available fluid.

This solution increases the thermal mass of the roof i.e. its ability to store heat through the day.

Heat transfer process reversed during the night, through night sky radiation, which ‘recharges’ the thermal capacity of the water

A 10 sq.m . metal or cement-asbestos sheet roof with 750 x 1 liter PET water bottles absorbs approximately 180 W/m2 ~ 36% of the average solar radiation in tropical latitudes

Variant – Thermal Mass + Insulation + Low-E Surface

The PET bottles are suspended above the roof surface using insulating bamboo strips spanning a plastic container/crate, to create an air-gap that serves as insulation, and the bottom surface of the container/crate is lined with MLP to block radiation from heated surface of PET bottles during day time.

Variant 1: Water-filled PET Bottles – Low Density

Variant 2: Water-filled PET Bottles – High Density

Variant 3: Water-filled PET Bottles – High Density + Insulation + Low-E Surface

Principle 3:
Thermal Mass + Shading + Evapotranspiration

Working Principle

Sub-Principle 1: Thermal Mass:

Soil held in diverse physical configurations and ‘containers (e.g. grow-bags) functions as thermal mass, with enhanced efficacy as thermal mass when holding adequate moisture.

Sub-Principle 2: Shading:

Foliage of the living vegetation shields the roof from direct solar radiation.

Sub-Principle 3: Evapotranspiration:

Evaporation of water from the soil and foliage produces an adiabatic (evaporative) cooling effect stemming from the significant latent heat of evaporation of water.

Variant 1: Rooftop-Garden with High-Soil Mass

Variant 2: Rooftop-Garden - Low Soil Mass

Variant 3: Rooftop-Garden - Low Soil Mass – Passive Wicking

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Variant 3: Rooftop-Garden - Low Soil Mass – Passive Wicking

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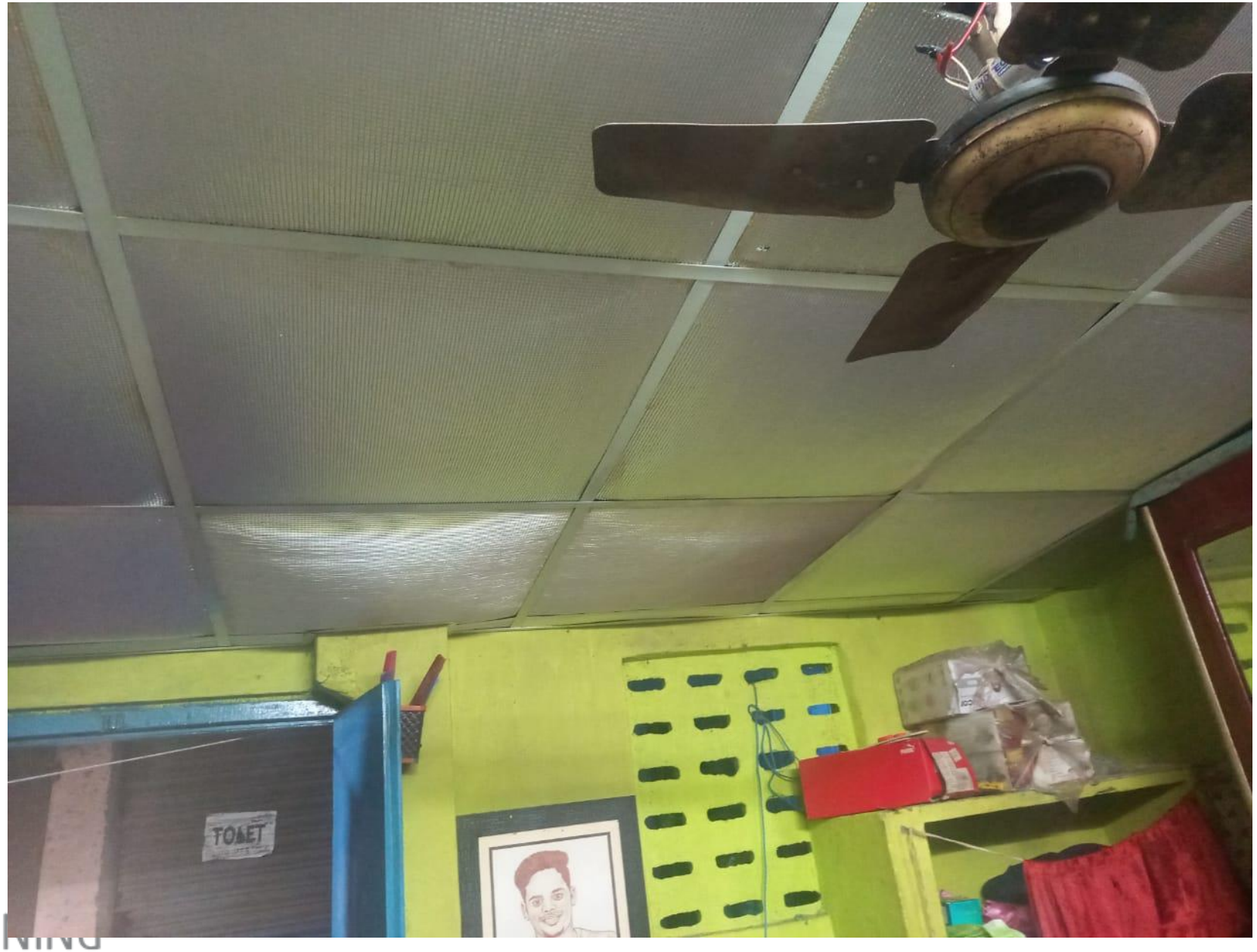
Principle 4:
Low-Emissivity Surface

Working Principle

The underside of the roof is covered with a low-emissivity surface (e ~ 0.05): cross-linked polyethylene foam (also known as XLPE) or Multi-Layered-Plastic sheets fabricated from upcycled packaging waste.

Mean Radiant Temperature (MRT) directly proportional to the Emissivity of radiating surfaces, the much lower emissivity of aluminized surfaces (~0.05) relative to Cement-Asbestos (~0.96) drastically reduces MRT

Variant 1: Alufoil



Variant 2: MLP

Principle 5:
Insulation
&
combination: Insulation + Low-e Surface

Working Principle

Insulation

The underside of the roof is covered with an insulating material (compressed biomass-based panels), to reduce conductive heat transfer through the roof surface to the air volume within the home.

Also, MRT is reduced due to lower surface temperature of insulating materials relative to the exposed underside of metal or cement-asbestos sheet roofs.

Variant – Insulation + Low-E Surface

The panel is encased in a sleeve of MLP to serve twin purposes of water & humidity-ingress resistance as well as reduced emissivity to further reduce solar heat gain in the living space below.

Variant 1: Forest-Grass Biomass Panel

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Variant 1: Forest-Grass Biomass Panel

Untreated Biomass Panel

Biomass Panel treated by Sodium Silicate solution

Variant 2: MLP-Covered Forest-Grass Biomass Panel

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THERMAL COMFORT PERFORMANCE - MYSORE

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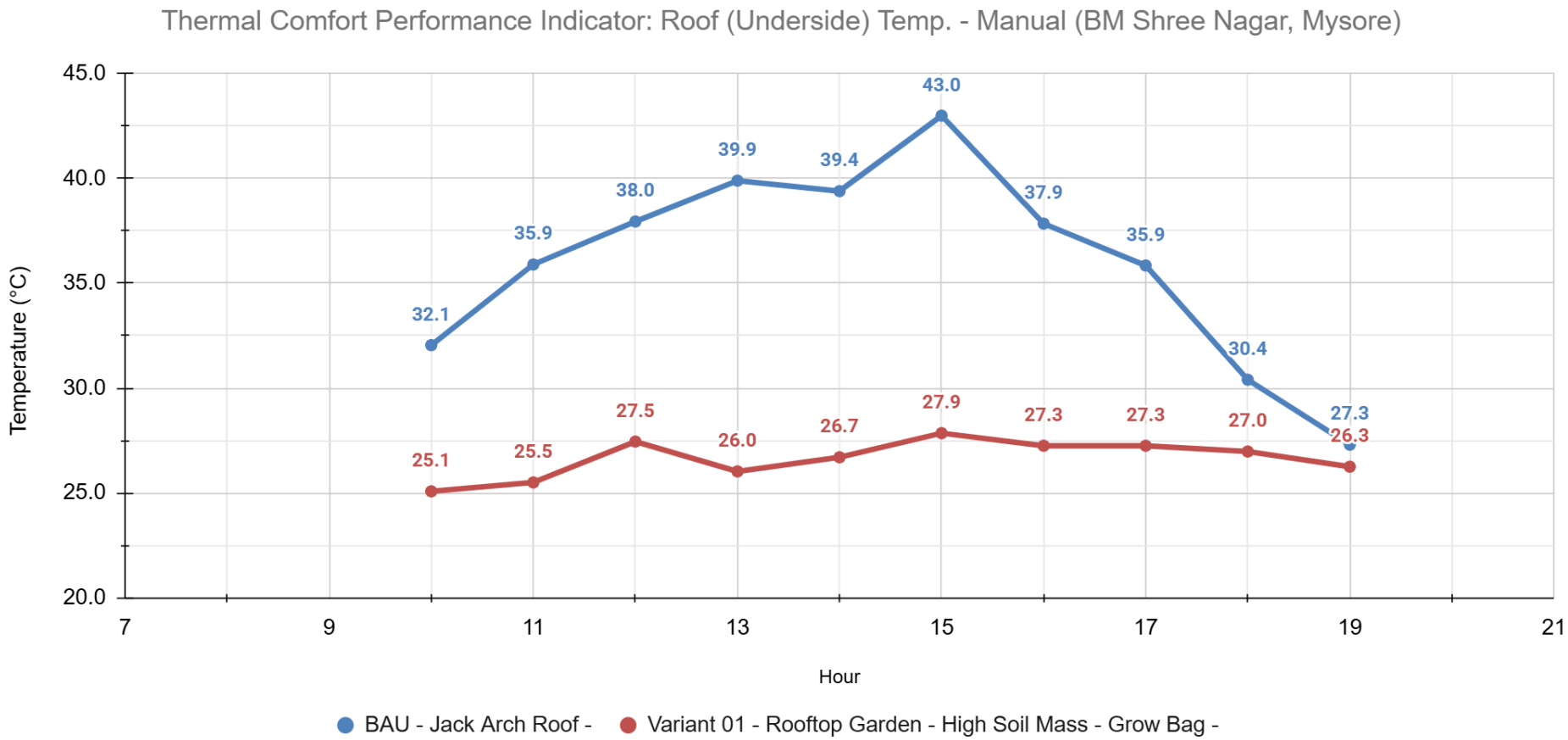
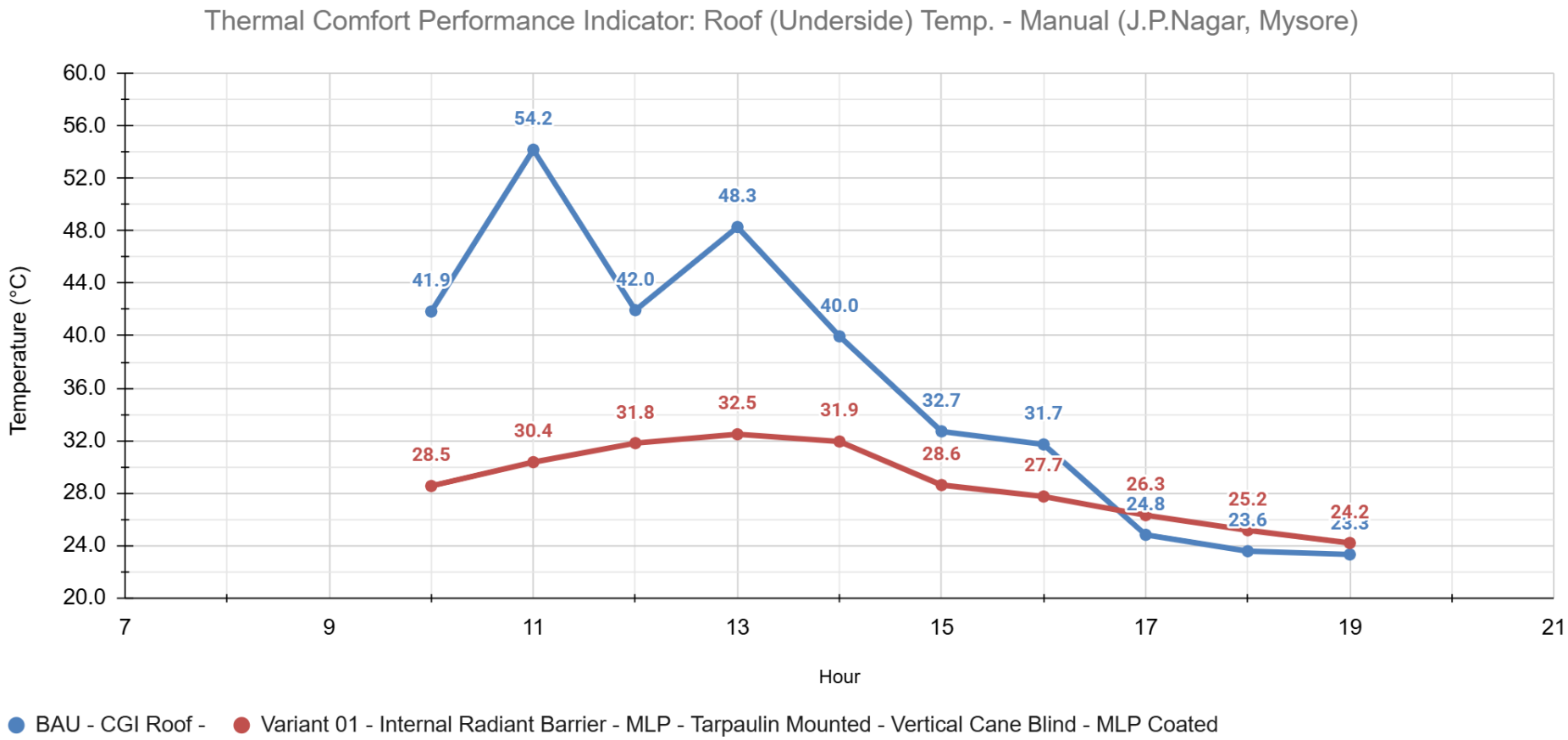
Thermal Comfort Performance Indicator: Roof (Underside) Temp. - Manual (BM Shree Nagar, Mysore)

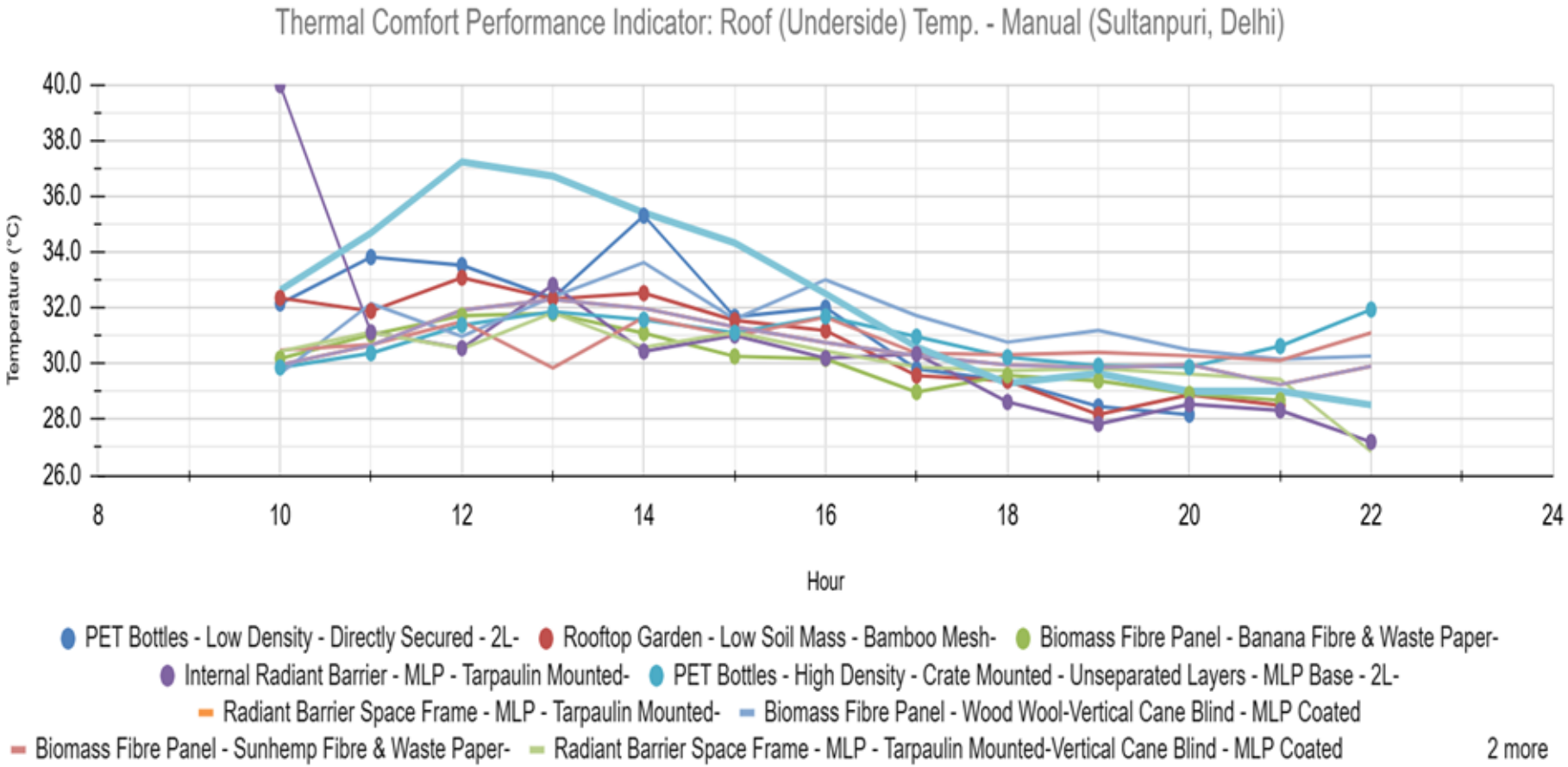


Thermal Comfort Performance Indicator: Roof (Underside) Temp. - Manual (JP Nagar, Mysore)

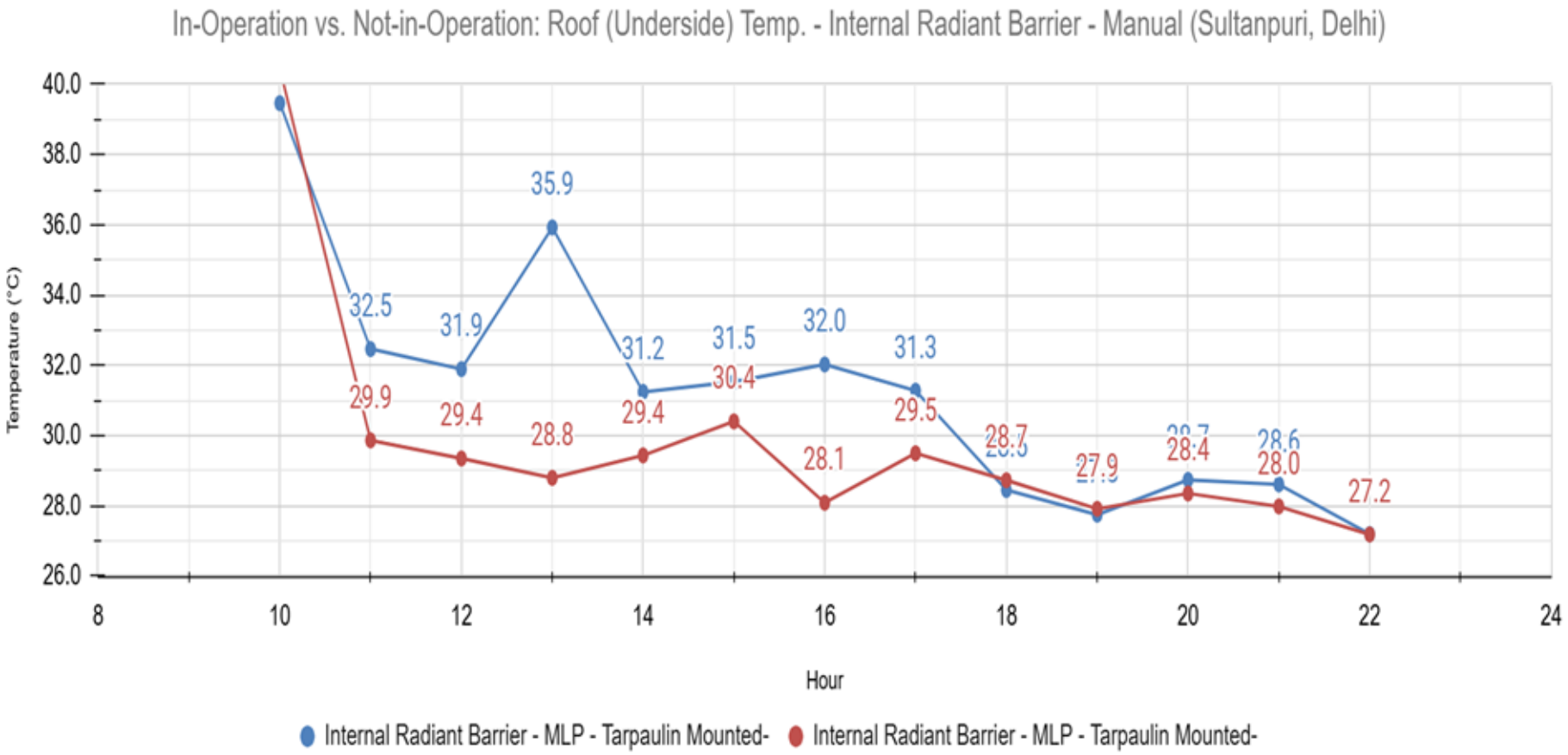


THERMAL COMFORT PERFORMANCE - DELHI

Thermal Comfort Performance Indicator: Roof (Underside) Temp. - Manual (Sultanpuri, Delhi)



In-Operation vs. Not-in-Operation: Roof (Underside) Temp. - Internal Radiant Barrier (Sultanpuri, Delhi)



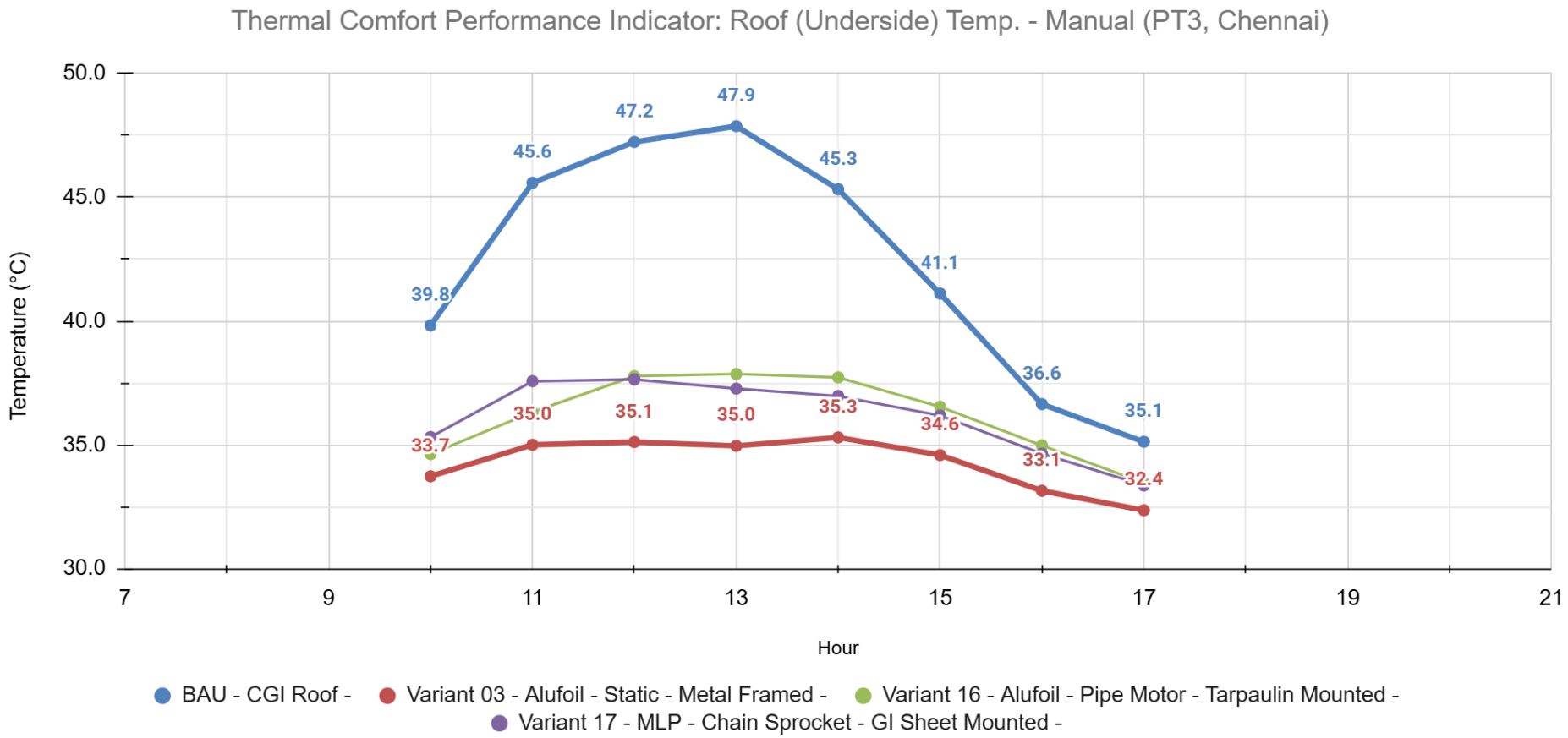
Performance Results

In terms of Peak Roof Radiant Temperature (Underside) Delta, the 'Ranking' of Solutions is as follows (highest rank = lowest Roof Radiant Temperature vs. BAU home):

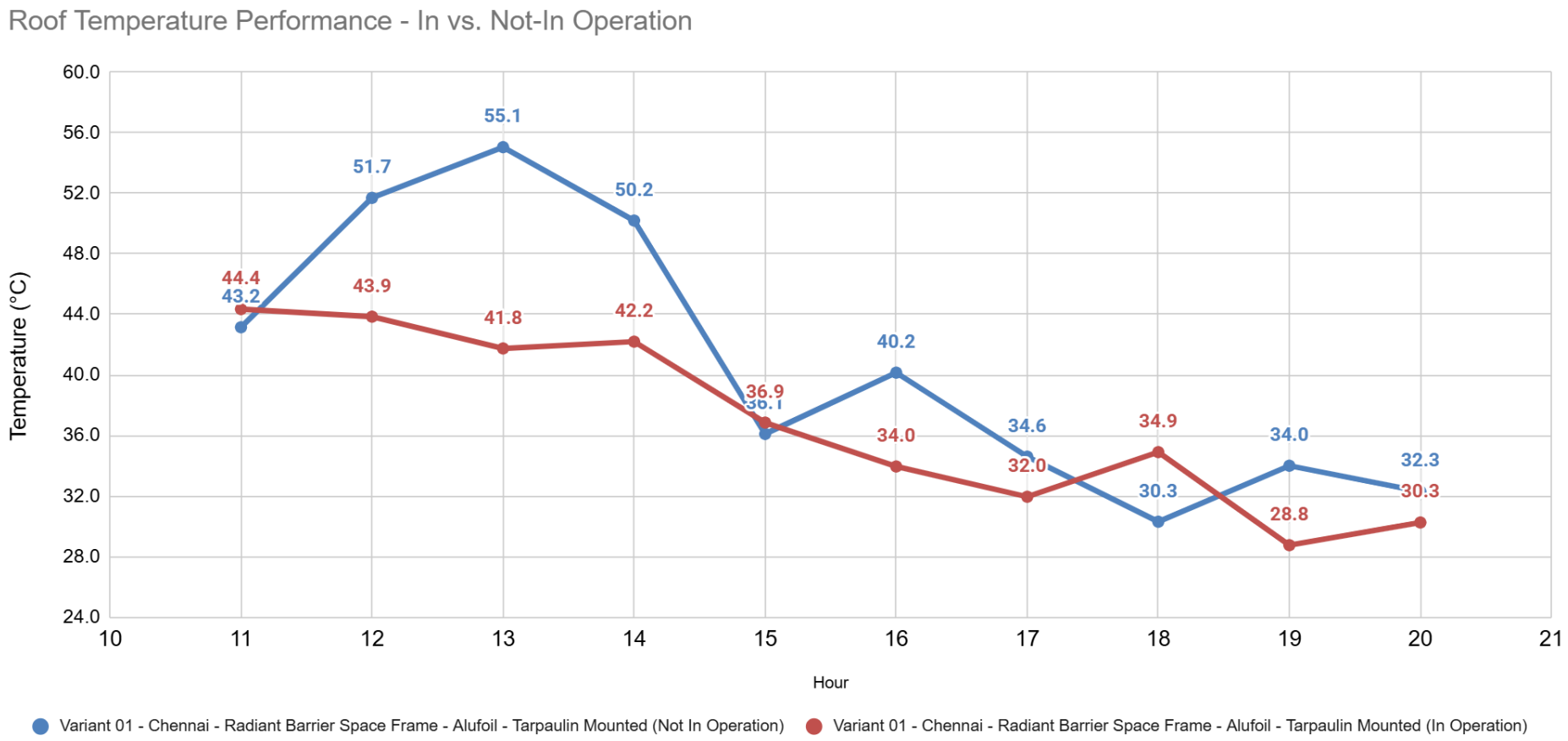
Rank	Solution	Delta (^{0}C)
1	Radiant Barrier Space Frame - MLP - Tarpaulin Mounted-Vertical Cane Blind - MLP Coated	6.9
2	Rooftop Garden - Low Soil Mass - Bamboo Mesh-	6.7
3	Biomass Fibre Panel - Wood Wool-Vertical Cane Blind - MLP Coated	6.7
4	Radiant Barrier Space Frame - MLP - Tarpaulin Mounted-	6.2
5	PET Bottles - High Density - Crate Mounted - Unseparated Layers - MLP Base - 2L-	5.8
6	Biomass Fibre Panel - Sunhemp Fibre & Waste Paper-	5.5
7	PET Bottles - Low Density - Directly Secured - 2L-	5.3
8	Biomass Fibre Panel - Banana Fibre & Waste Paper-	4.4
9	Internal Radiant Barrier - MLP - Tarpaulin Mounted-	4.4

THERMAL COMFORT PERFORMANCE - CHENNAI

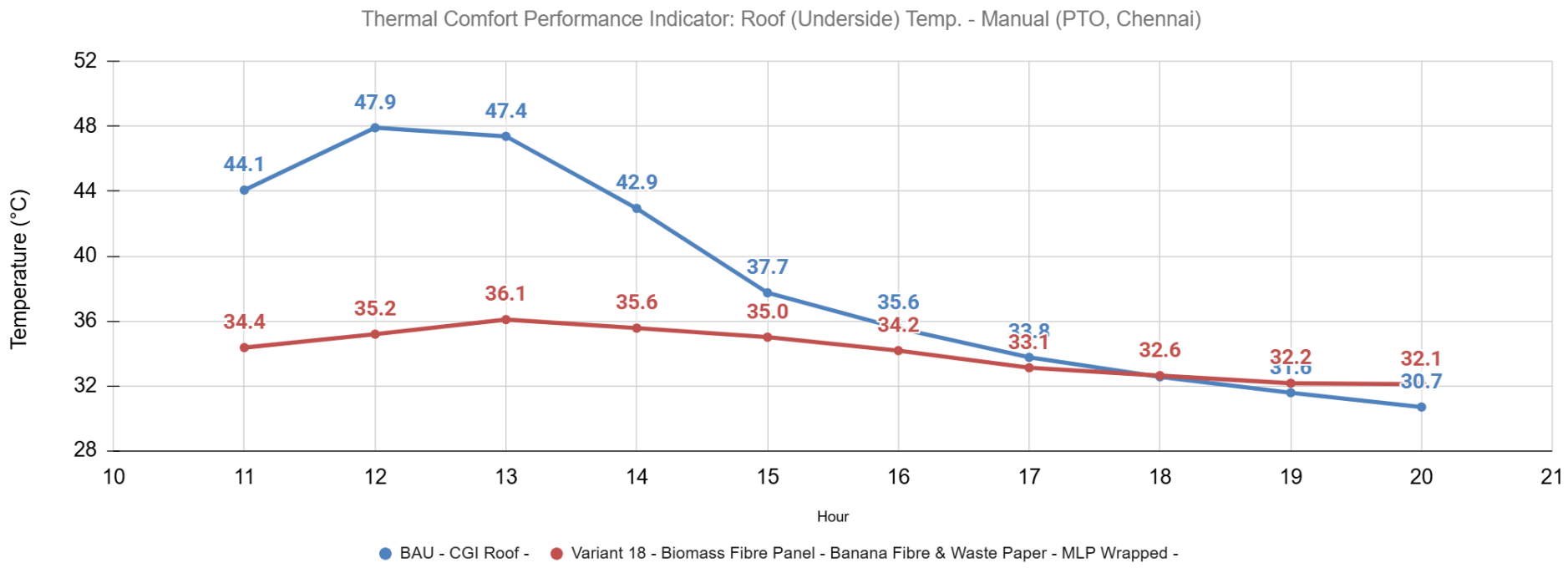
Thermal Comfort Performance Indicator: Roof (Underside) Temp. - Manual (Cluster 3, Chennai)



Thermal Comfort Performance Indicator: Roof (Underside) Temp. - Manual (Cluster 4, Chennai)



Thermal Comfort Performance Indicator: Roof (Underside) Temp. - Manual (Cluster 5, Chennai)



Performance Results

In terms of Peak Roof Radiant Temperature (Underside) Delta, the 'Ranking' of Solutions is as follows (highest rank = lowest Roof Radiant Temperature vs. BAU home):

Rank	Solution	Delta (^{0}C)
1	Variant 03 - Alufoil - Static - Metal Framed -	12.9
2	Variant 03 - Alufoil - Static – Wire Framed -	12.0
3	Variant 17 - MLP - Chain Sprocket - GI Sheet Mounted -	10.6
4	Variant 16 - Alufoil - Pipe Motor - Tarpaulin Mounted -	10.0

Research & Development & Deployment Facility (R&D&D)

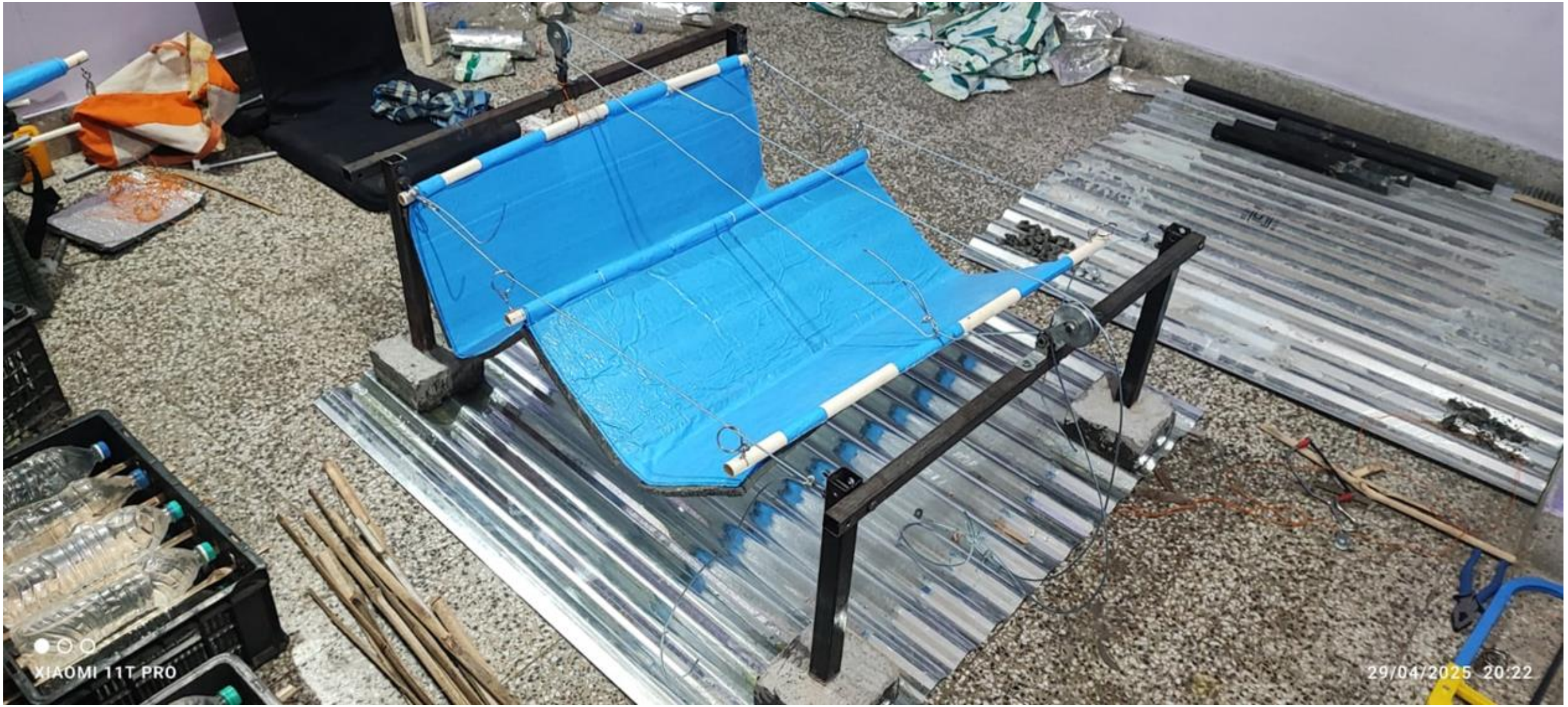
R&D&D Facility Status

1. USD 360,000 Seed-Funding Secured from Climateworks Foundation for 2-year Setup and Operations
2. Facility setup commenced in March 2026 – Pune, Paradsingha, Bangalore Creative Circus, Sir MVSA College, IISC, Navdarshanam (Bangalore)
3. 21 Civil Society Groups are in-principle committed to integrating patent-free solutions into their respective socio-economic 'scaling' models & programs:

1. Habitat for Humanity
2. Selco Foundation
3. Aga Khan Agency for Habitat India (AKAHI)
4. Roof Over Our Head (ROOH)
5. Azim Premji Foundation
6. Wipro Foundation
7. ADAPT Initiative
8. Island City Lab
13. Asian Council for Housing Rights (ACHR)
14. Jan Sahas
15. Housing and Land Rights Network
16. GERES
17. Energy Savings Trust
18. Maharashtra Social Housing Action League (MASHAL)
19. Habitat and Livelihood Welfare Association (HALWA)
20. Citizen Consumer Civic Action Group (CAG)
21. Hasiru Dala

Thermal Comfort Performance Test Beds

Thermal Comfort Performance Test Beds



Research & Development Plan

Solution Set Expansion

1. Alternate Materials
2. Passive Design Combinations
3. Passive Design Expansion
4. Sustainable Active Cooling Solutions
5. Rainwater Harvesting & Groundwater Recharge

Operation Mechanism Expansion

Technology Readiness Level Enhancement

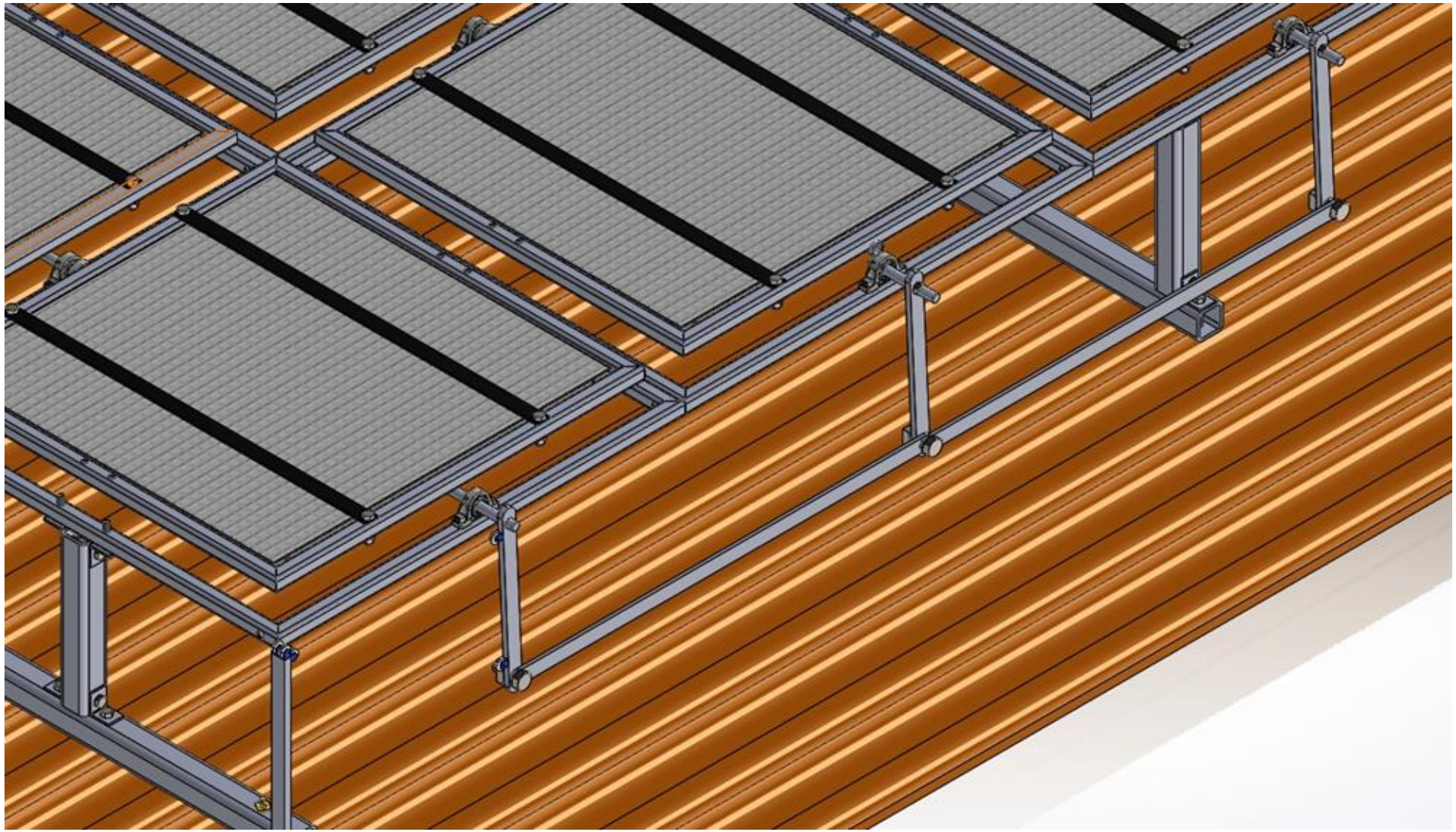
1. Modular Design
2. Design for Fabrication
3. Design for Disassembly
4. Accelerated Weathering Testing

Alternate Materials & New Passive Designs

System
Insulation – Mud Rolls with Cavity
Insulation – Pre-Fab Cavity Walls Panels
Insulation Panel/Crate – Packed Clay Pots
Insulation Panel/Crate – Packed Human Hair
Insulation Panel/Crate – Packed Used Rubber Tyres
Insulation Panel/Crate – Packed Clothing

System
Evaporative-Low-E-Reflective Retrofit Roof System
Thermal Mass: Honeycomb Interlocking Panel (Water Wall)
Thermal Mass: PET Bottles-with Plants
Thermal Mass: PET Bottles-with non-toxic food-grade dyes
Thermal Mass: PET Bottles-with reflective inner-bottom
Thermal Mass: PET Bottles-with rough high-emissivity and low-absorptivity plasters
Ventillation – Detachable Chimney
Ventillation – Dynamic Wind-Catcher (BED-ZED)

Modular Design



DIY Direct Evaporative Cooler

Phase Change Material ‘AC’

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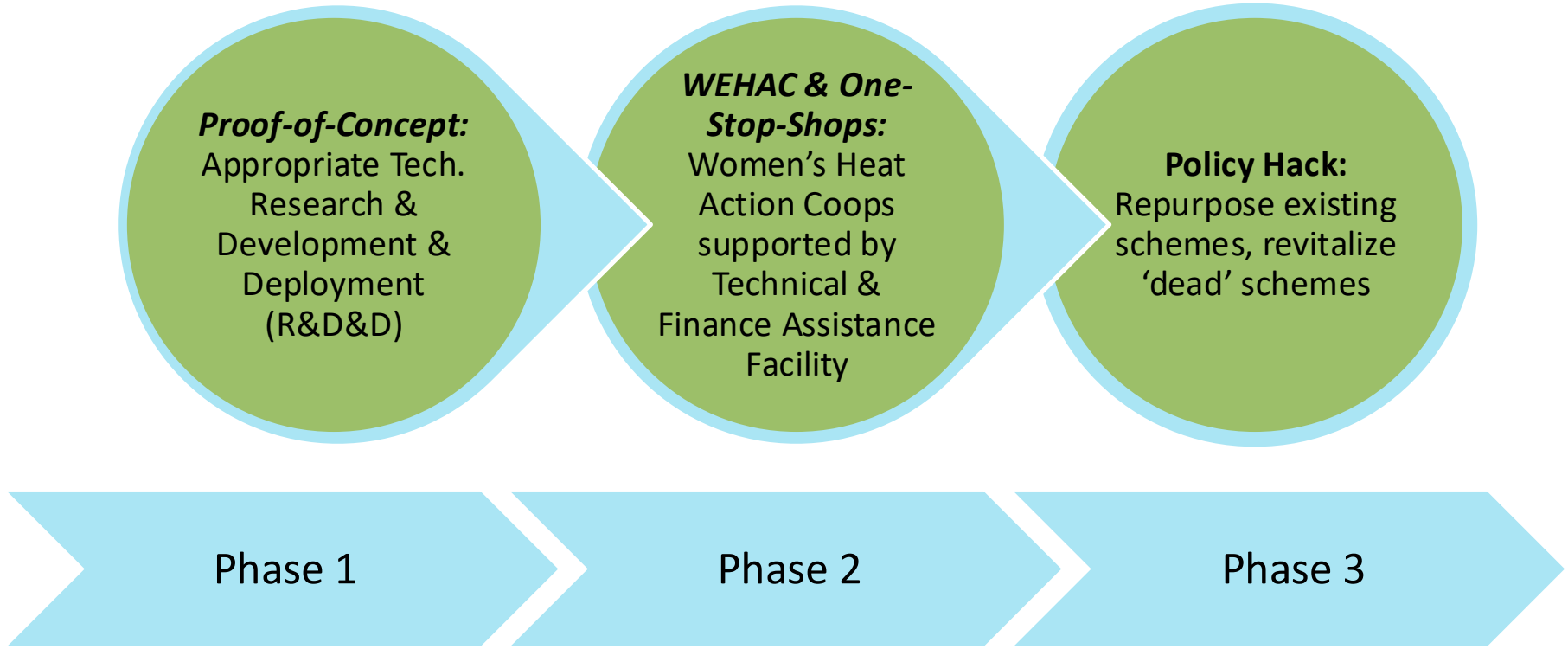
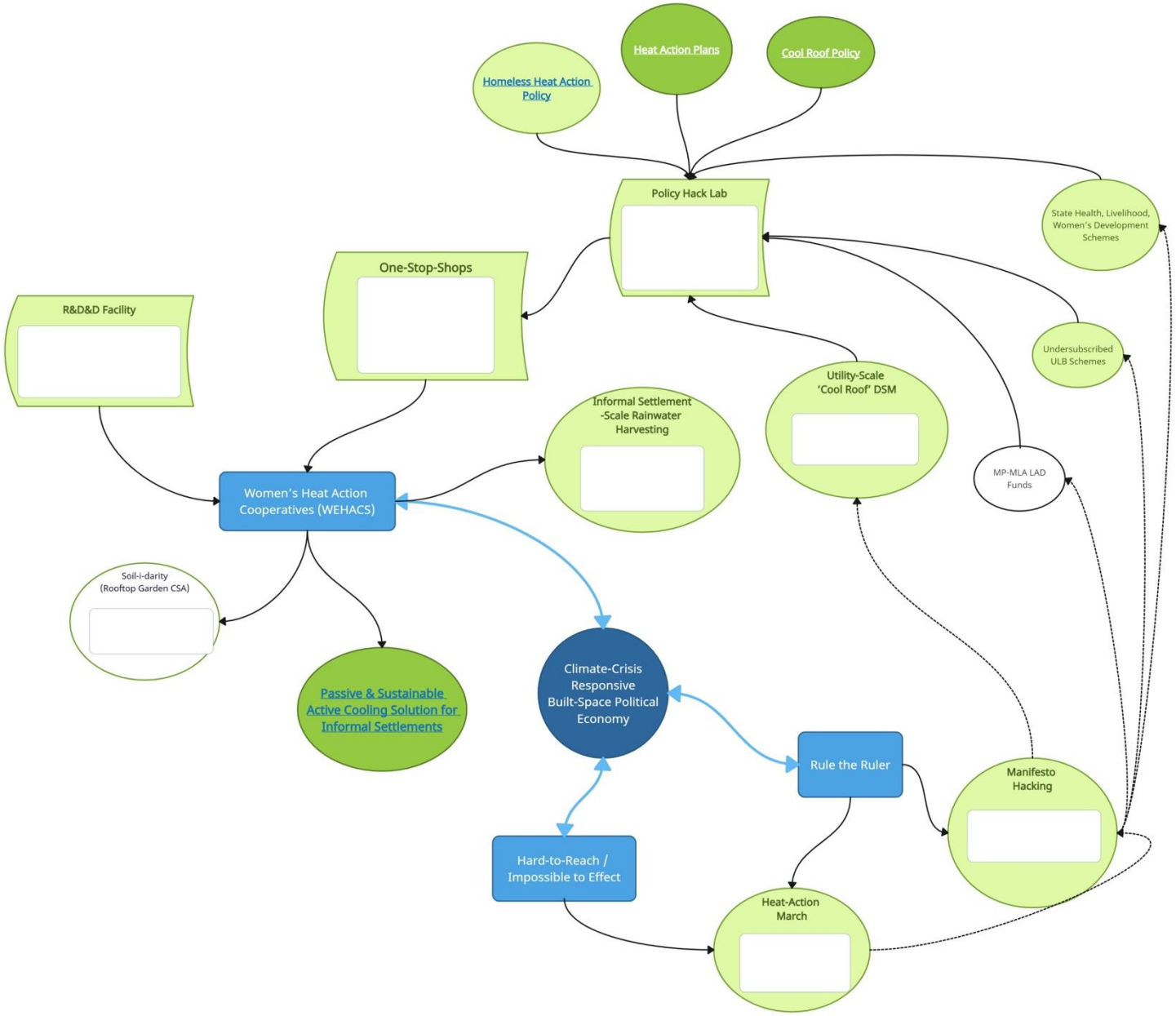
THEORY-OF-CHANGE

Framework Change: Foster Informal Housing Thermal Comfort & Women-Centric Political-Economy in India



Mindmap



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WEHAC

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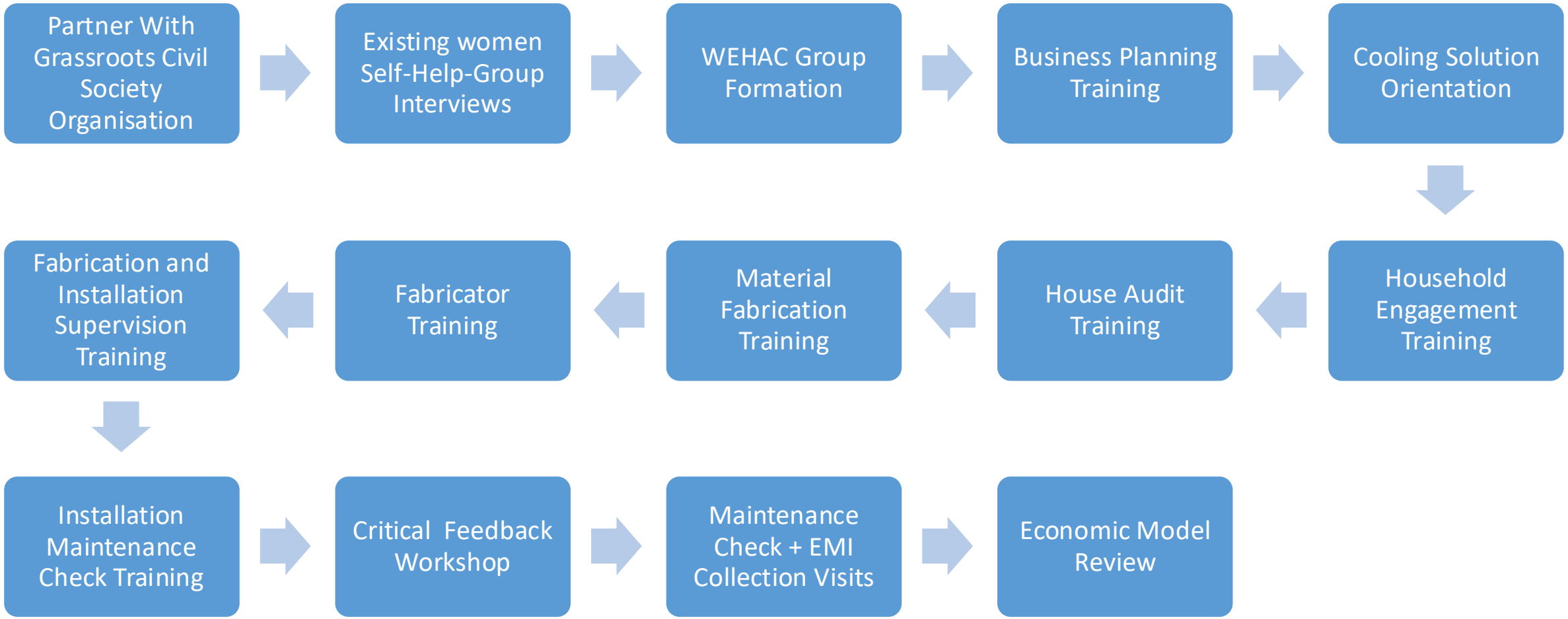
- **Objective :** To experiment with facilitating the installation of cooling products with a group of women from a marginalized urban settlement to:
    - Assess the feasibility of organizing a WEHAC
    - Assess the viability of the WEHAC economic model – earning a revenue of approx. 50% of household budget (INR 15,000/month – EUR 150) trough EMI's paid by customers of cooling solutions
    - Assess the effectiveness of pedagogical material developed to train WEHAC members and fabricators.
    - Harness learnings to inform next steps for the pioneer WEHAC and future WEHACs in other cities.

- **No. of Women Co-op Members:** 9
- **No. of Homes :** 35
- **Location :** Pulianthope, Chennai, Tamil Nadu
- **Types of cooling products offered by the pilot WEHAC :** Spaceframe, Biomass Panels, Internal Dynamic Barrier, Vertical Cane Blind
- **Timeline:** Jan 2024-June 2026
- **Source of funding (seed fund for WEHAC + training material development and implementation support) :** Wipro Foundation, Thoughtworks Foundation and City of Geneva

Process



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Process

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Process

WHAT IF THE TEMPERATURE DOES NOT REDUCE?

If you feel that the **product is not reducing indoor heat**, you can **call us**.

- **We will check** if the product is reducing roof-bottom temperature **by 4°C (minimum) at 1pm.**
- If the temperature drop is less than 4°C , **we will work on improving** the product.
- If there is **still no improvement**, we will **uninstall** the product.
- You can **stop future EMI payments.**

WHAT IF I MOVE?

If you live in a **rented house** and move:
Within the same settlement:
We will remove the cooling product and **install** it in your new home.
You can **continue your EMI payments**.

Moving to another settlement:
We will remove the product.
You can **stop future EMI payments**.

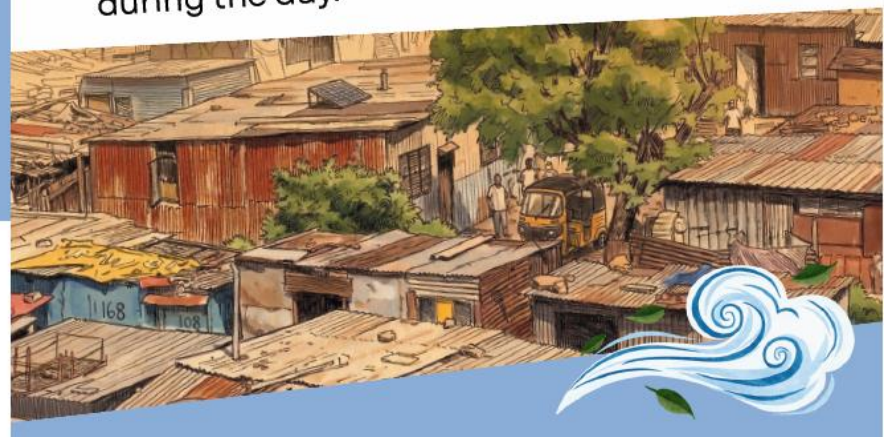
SERVICES OFFERED

- House audit
- Customised product fabrication and installation
- Post- installation maintenance and repair

CONTACT

WITH ABOVE-ROOF CURTAINS

There is a material called multi-layered plastic (MLP). When placed over your roof like a curtain, it can make your home cooler. This is because MLP does not let much heat pass through and blocks the sun's heat during the day.



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Process

STAY COOL BY DAY OR NIGHT

The system works **like a curtain** over your roof that you can open and close.

*When **covered** during the day, it blocks the sun's heat and keeps your home cool.*

*When **opened** in the evening, it helps release the trapped heat and cool the house.*

Reduce roof bottom heat **by at least 4°C** *measured at 1 PM*

Life span: **3 years**

Installation weight: **0.89kg/Sq.ft**

COST

EMI:
Monthly payment will be fixed based on how much your family can afford.

A Cost Reducing Option:
You can reduce the cost by helping with some work, if you are able. For example, you can help to stick sheets, apply glue, or assist in making the curtains.

Maintenance Fee:
No payment for the first 1 year after installation. After 1 year, you can pay either per visit or choose a monthly maintenance plan.

Repair Costs (Material & Labour):
No payment for the first 1 year after installation. After 1 year, you will need to pay for any repair as needed.

Initiation of EMI Payment:
One month after installation completion.

Duration of payment:
Dependent on solution cost and paying capacity.

INSTALLATION COST
INR 75
per sq ft

MAINTENANCE COST
No payment for first year
After that, optional at
INR 1800 *per year*

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Process

BEAT THE HEAT

WITH UNDER-ROOF CURTAINS

There is a material called multi-layered plastic (MLP). When hung under your roof like a curtain, it can make your home cooler. This is because MLP does not let much heat pass through.

WHAT IF THE TEMPERATURE DOES NOT REDUCE?

If you feel that the product is **not reducing indoor heat**, you can **call us.**

- **We will check** if the product is reducing roof-bottom temperature by **4°C (minimum) at 1pm.**
- If the temperature drop is less than 4°C , we will **work on improving the product.**
- If there is **still no improvement**, we will **uninstall** the product.
- You can **stop future EMI payments.**

WHAT IF I MOVE?

Under-roof curtains can **move with you!** It's **easy to uninstall** and take with you.

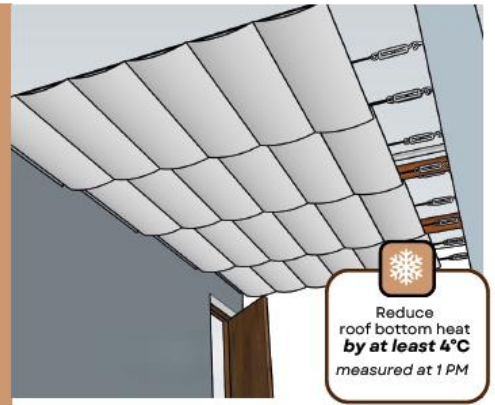
SERVICES OFFERED

- House audit
- Customised product fabrication and installation
- Post- installation maintenance and repair

CONTACT

fAIR CONDITIONING

Process



Reduce roof bottom heat **by at least 4°C** *measured at 1 PM*

Life span: **3 years**

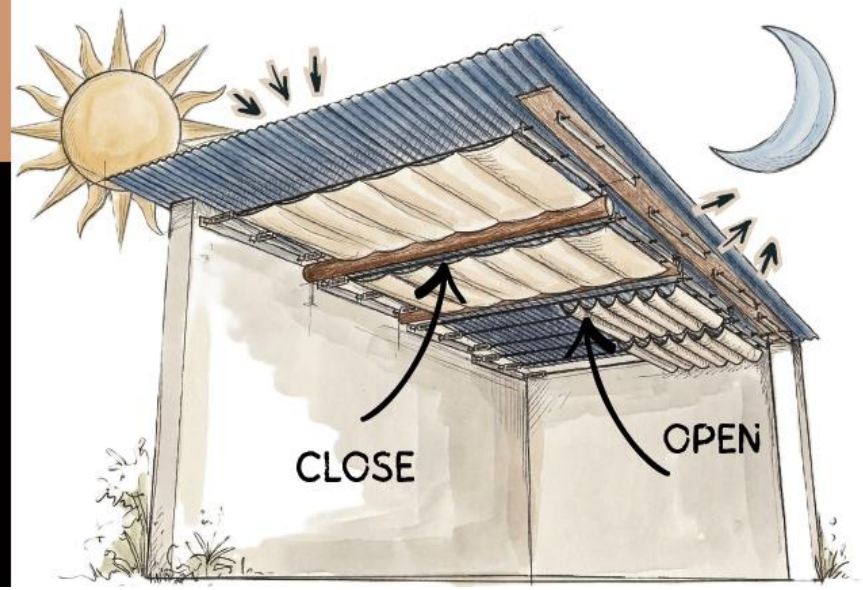
Installation weight: **0.1kg/Sq.ft**

KEEPS YOUR HOME COOL BY DAY....

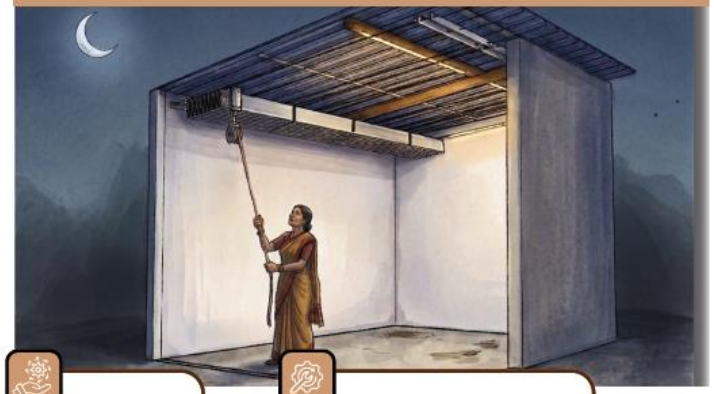
Cover the roof in the morning (around 8-9 AM) to stop the sun's heat from entering

...AND NIGHT

Open it in the evening (after 5-6 PM) to let any trapped heat go out



COST



INSTALLATION COST
INR 56
per sq ft

MAINTENANCE COST
No payment for first year
After that, optional at
INR 1800 *per year*

EMI:
Monthly payment will be fixed based on how much your family can afford.

A Cost Reducing Option:
You can reduce the cost by helping with some work, if you are able. For example, you can help to stick sheets, apply glue, or assist in making the curtains.

Maintenance Fee:
No payment for the first 1 year after installation.
After 1 year, you can avail monthly maintenance services by paying INR 1800/year.

Repair Costs (Material & Labour):
No payment for the first 1 year after installation.
After 1 year, you will need to pay for any repair as needed.

Initiation of EMI Payment:
One month after installation completion.
Duration of payment:
Dependent on solution cost and paying capacity.

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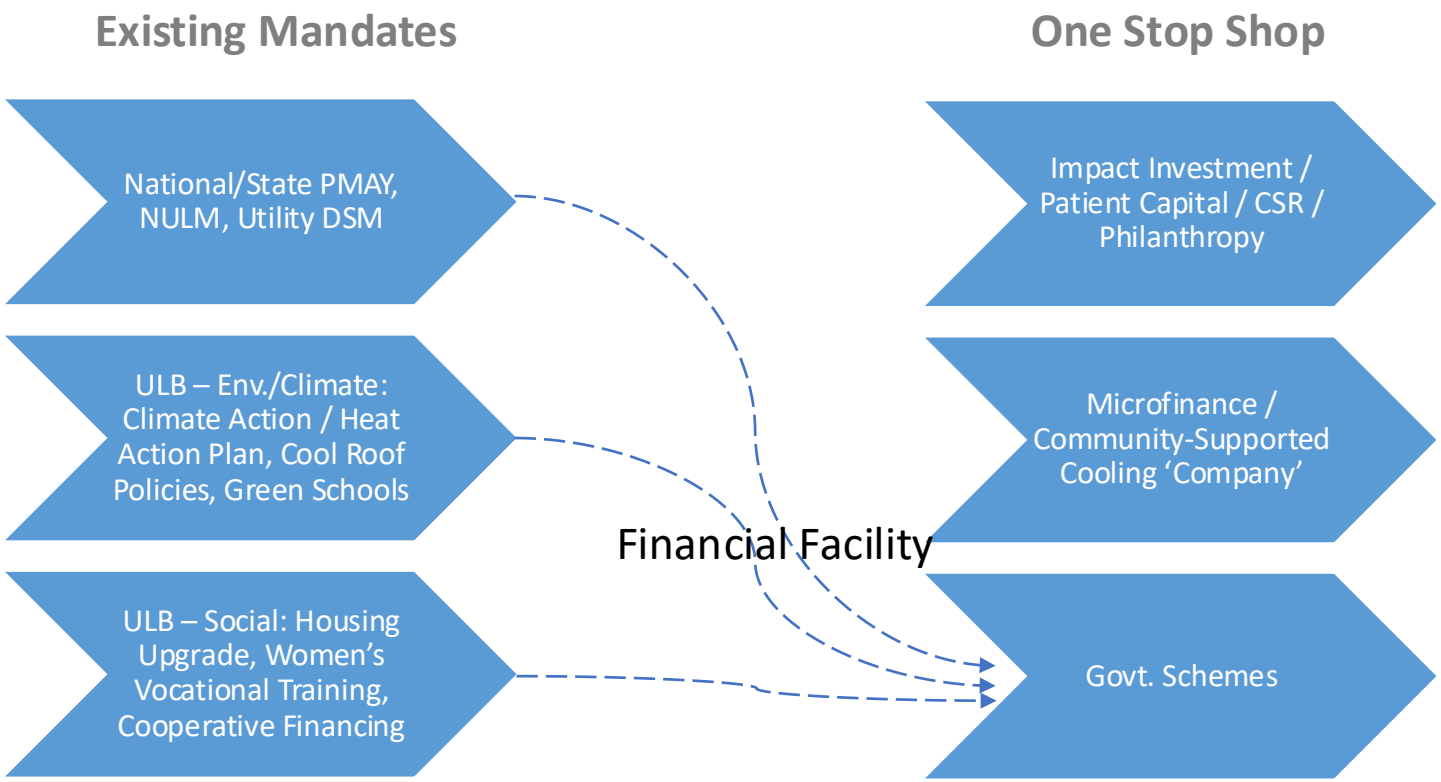
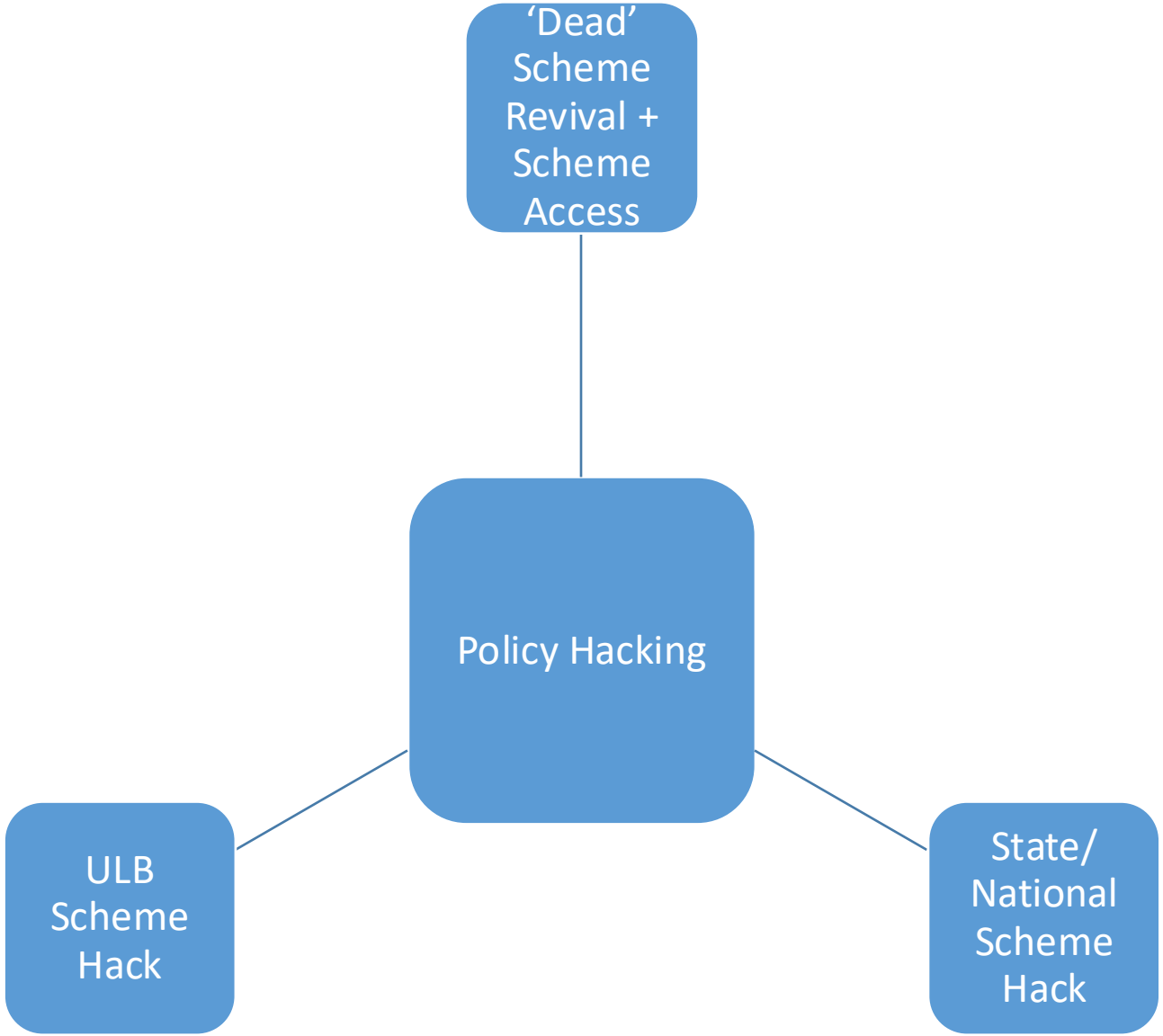
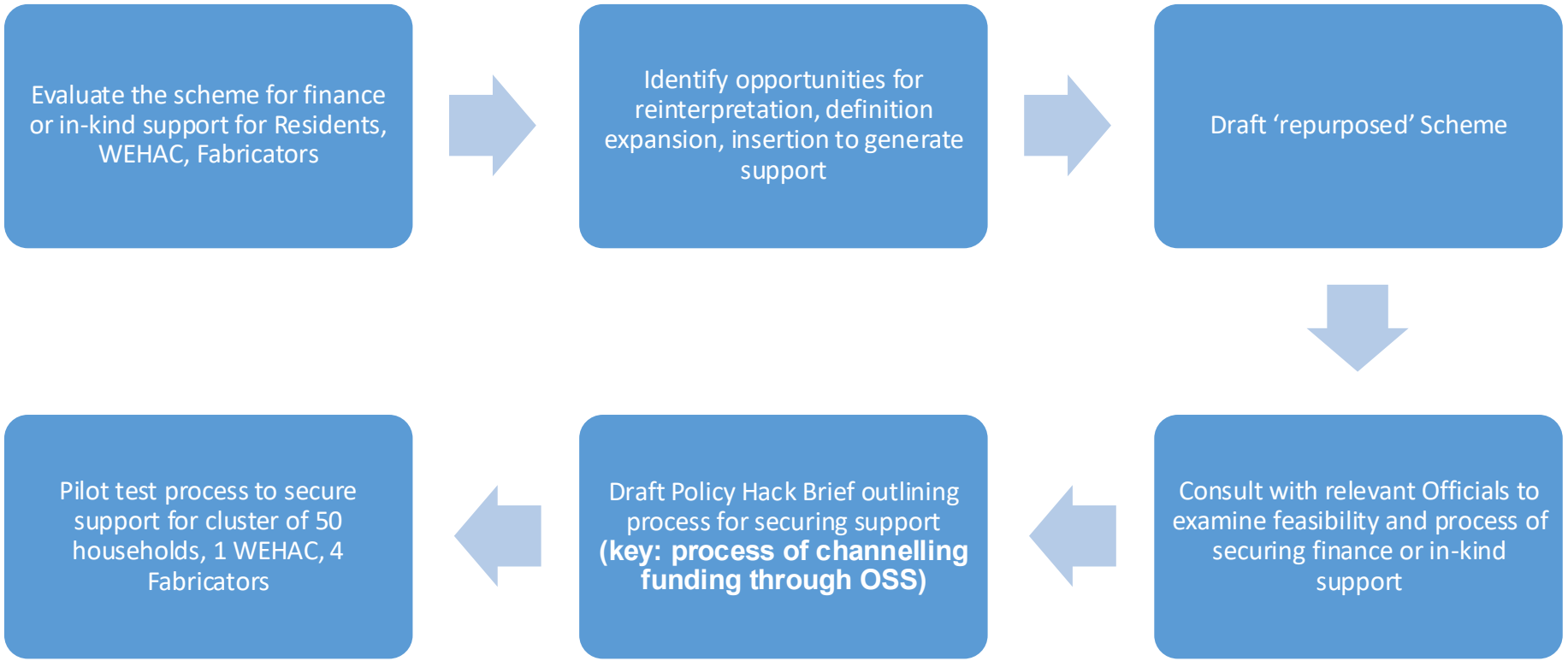
POLICY HACK

Framework Change: Foster Informal Housing Thermal Comfort & Women-Centric Political-Economy in India



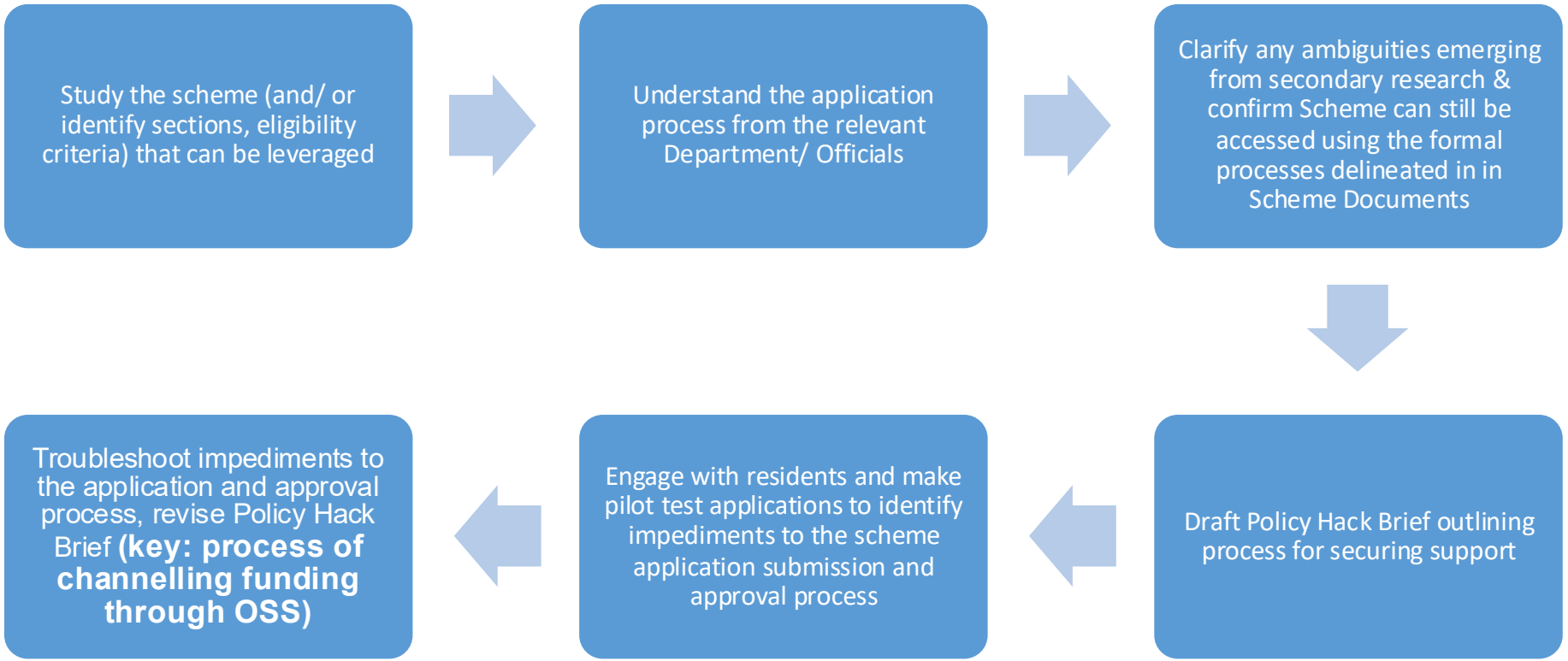

‘Dead’ Scheme Revival + Scheme Access
Policy Hacking
ULB Scheme Hack
State/ National Scheme Hack

ULB Scheme Hack Workplan



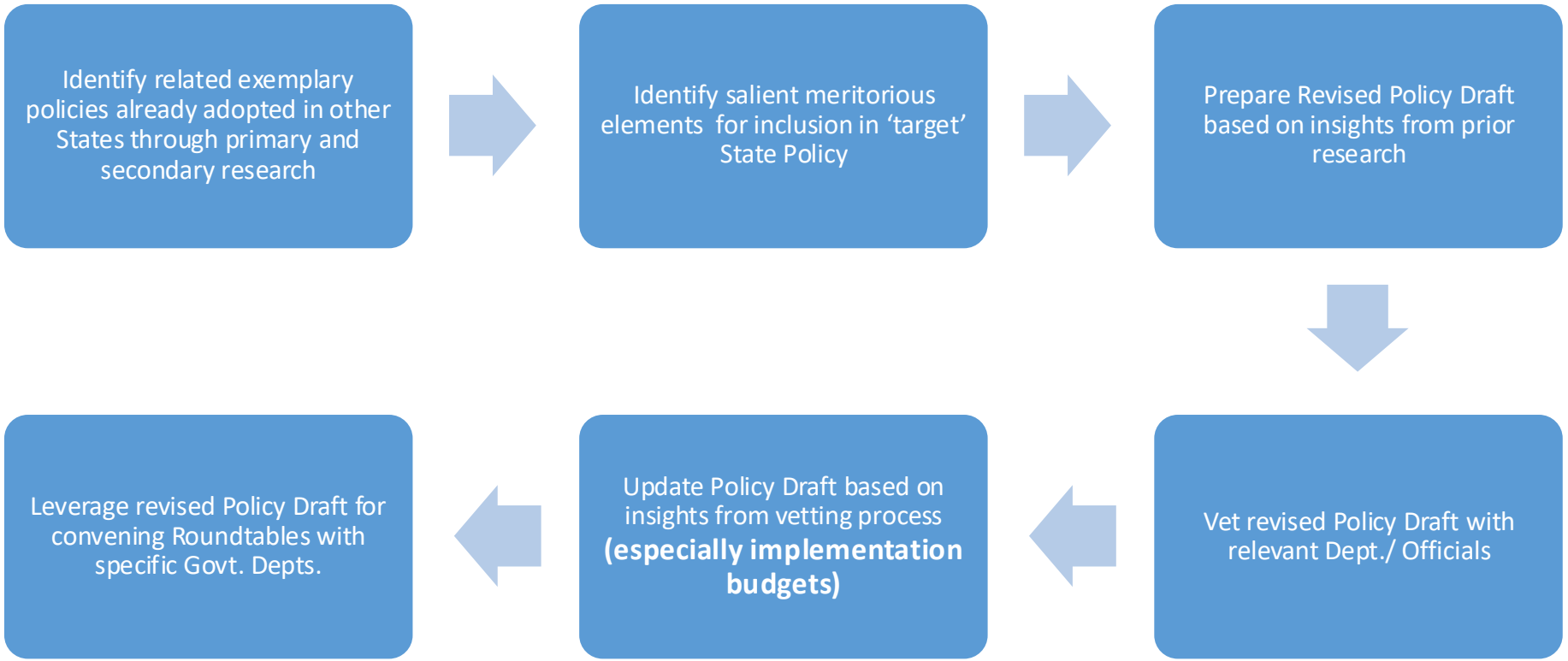
fAIR CONDITIONING

Dead-Scheme / Scheme Access Hack Workplan



fAIR CONDITIONING

State / National Policy Hack Workplan



fAIR CONDITIONING

MP/MLA LAD Hack Workplan