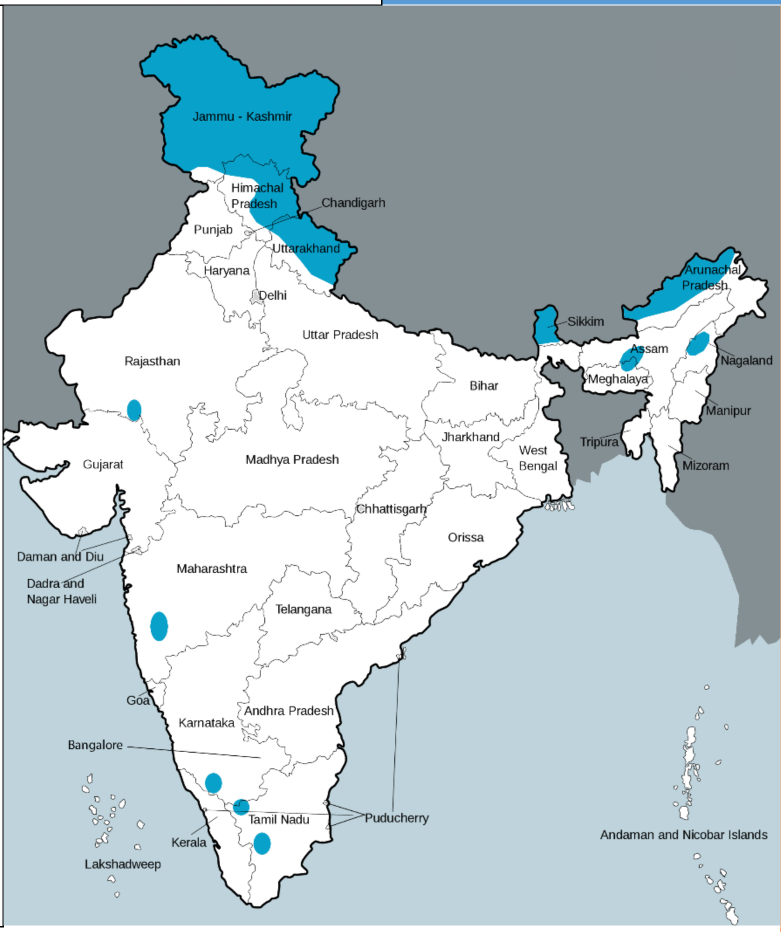
MaS-SHIP

Mainstreaming Sustainable Social Housing in India Project

Guidelines for integrating sustainability in social housing developments in India

October 2018

Cold climate zone



The purpose of this document is to compliment the guidance provided by the Government and Green Building certification bodies in India.

These guidelines are based on learning derived from the MaS-SHIP project as well as secondary literature.

Insights are also shared from resident surveys conducted in five social housing developments in India.

Incorporating these guidelines in the design and construction of social housing developments will contribute to enhance the sustainability and quality of life of the residents.

Key principles

- Provide convenient accessibility to basic day to day amenities and proper connectivity to places of work.
- Resist heat loss and retain internal heat with minimum loss to the environment through proper insulation and using materials with high thermal mass.
- Promote heat gain through trapping natural heat, avoiding shading, and using trees as wind barriers, but not as shading.
- Windows should allow for sufficient daylight penetration into regularly occupied areas, to promote natural heat gain.
- Increase buffer spaces and decrease the rate of ventilation inside the building to enhance thermal comfort in social housing.
- Maintain quality of construction to developing of cracks, breakage in walls and material joints. Adequate water proofing and good quality plumbing design and installation is imperative to avoid discomfort and damage.

Prominent Indian cities within the cold climatic zone (1)

Manali, Kullu, Leh (Ladakh), Shimla, Shillong, Srinagar, Sundernagar, Mahabaleshwar, Udhagamandalam.

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Climatic characteristics

- The regions where mean daily minimum dry bulb temperature of 6°C or less prevail during the coldest month of the year and where the altitude is more than 1200m above Mean Sea Level (M.S.L), may be classified as cold zones. (7)
- Mean monthly maximum temperature stays below 25°C.
- Relative humidity ranges from 30-80% as the cold category comprises of both dry and humid weather zones.
- Low solar radiation intensity in winter with a high percentage of diffuse radiation. Sky luminance values can be at an average of 6800 lux (3)

Climate data (1)		
Mean temperature	Summer midday	17 to 30 deg. C
	Summer night	4 to 17 deg. C
	Winter midday	-7 to 8 deg. C
	Winter night	-14 to 4 deg. C
	Diurnal variations	15 deg. C
Relative humidity	Min. 10%	Max. upto 95%
Rainfall	Variable - 500 to 1300 mm/year	

Average temperature and relative humidity in two prominent cities (2)

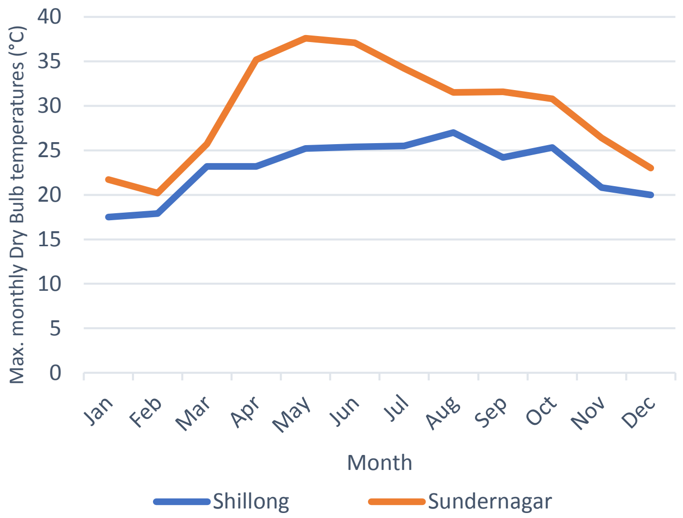

Figure 1: Monthly maximum dry bulb temperature

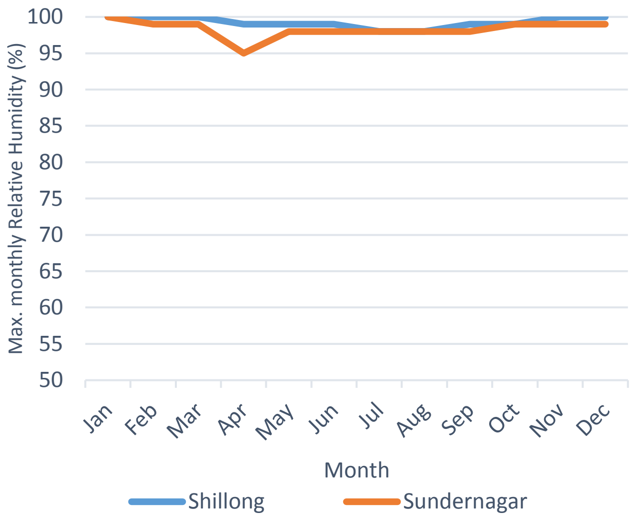

Figure 3: Monthly maximum relative humidity

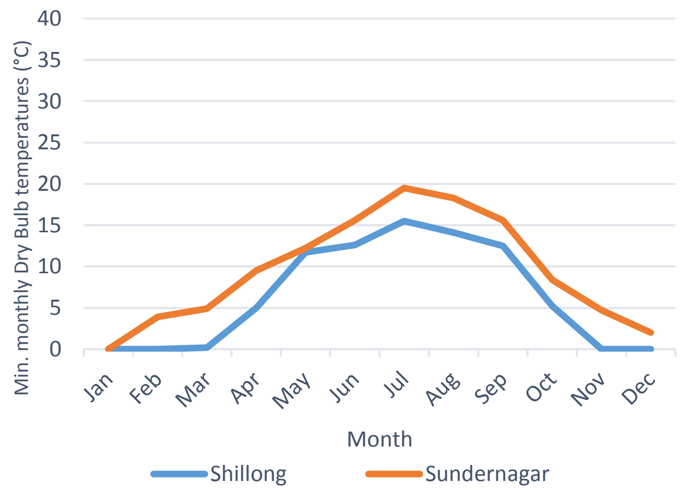

Figure 2: Monthly minimum dry bulb temperature

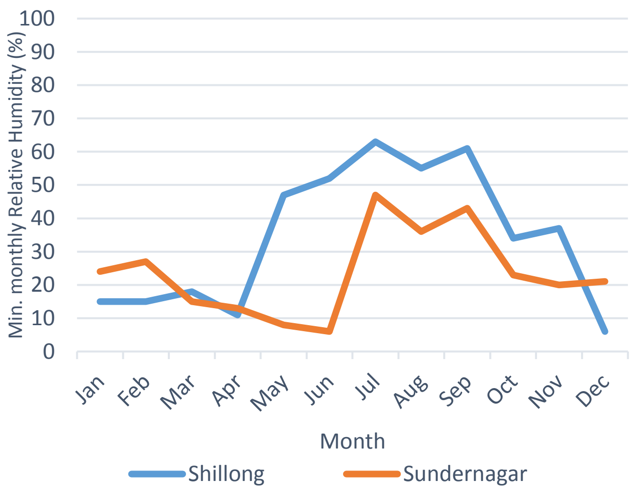

Figure 4: Monthly minimum relative humidity

Site Location

Convenient access to basic day to day amenities around the development has been identified as an important aspect of approach towards sustainability of a housing development. (3, 4).

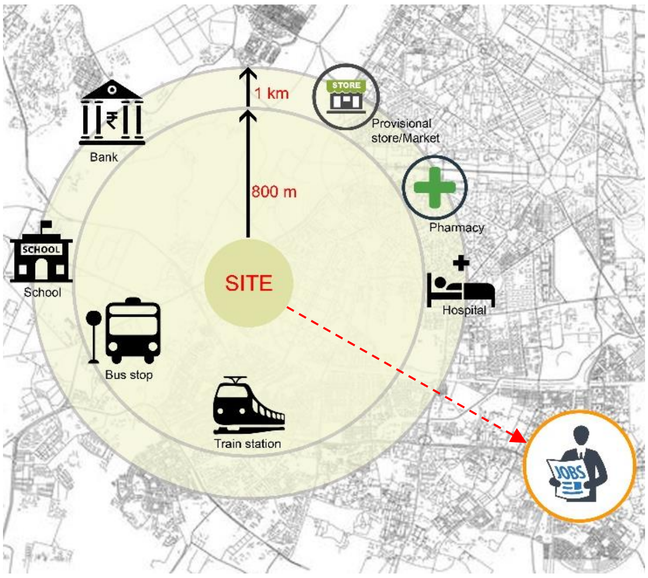

Figure 5: Site location

- Public transport facilities (intra-city station/bus stop/ metro) to be at a max. distance of 800 meters from the development.
- Basic amenities like hospital/clinic, pharmacy, schools, market/provisional store, ATM/bank to be within a walking distance of 1 km from the development.
- The site location should be such that it either provides the residents easy access to job opportunities or is well connected with the city's main commercial/employment centric areas where the residents work/could find work.

Figure 6: View of market near Jakkampudi colony in Vijayawada (Despite being 11km from the city centre, the residents of Jakkampudi colony had easy access basic amenities)

Massing and space plan

- In cold climate, heat gain is desirable. Hence, buildings should be located on the south slope of a hill or mountain for better access to solar radiation.
- The exposure to cold winds can be minimised by locating the building on the leeward side. Site features such as trees or landform can be identified as natural wind barriers. The building should be glazed in such a manner that minimum wind enters the building.
- Buildings must be compact with small surface to volume ratio to reduce heat loss.

Figure 7: Low S/V ratio to reduce heat loss. Source: adapted from (8)

- Buildings can be clustered together to minimise exposure to cold winds.
- The street orientation should be E-W to allow for maximum south sun to enter the buildings. The streets should be wide enough to ensure that buildings on either side do not shade each other.
- Open spaces between buildings must be such that they allow maximum solar rays to be incident on the building.

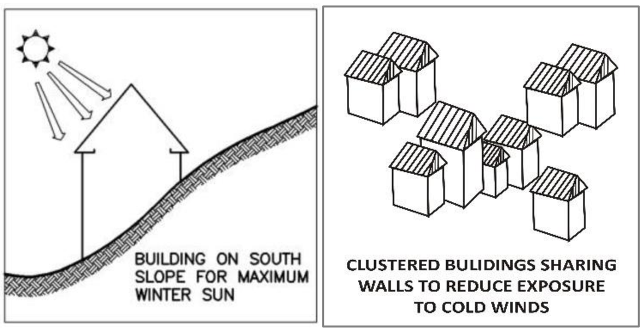

Figure 8: Building placement. Source: adapted from (8)

Building envelope

Thermal performance

In cold climates, buildings must be compact with small surface to volume ratios to reduce heat loss. High thermal mass helps reduce the speed of heat loss.

- The baseline thermal conductivity (U-value) value for different building components are provided below (4).

Building component	**U-value (W/m²K)**
Wall	≤2.5
Roof	≤1.2
Glazing	≤5.7
Glazing (SHGC)	
WWR <20%	0.8
WWR >20%	0.8

- Windows should face south to facilitate direct gain, while the north side of the building should be well-insulated.
- Living areas can be located on the southern side and utility areas such as stores can be on the northern side.
- Air-lock lobbies at the entrance and exit points of the building reduce heat loss. On the windward or north side, a cavity wall type of construction maybe adopted.
- Heat generated by appliances in rooms such as kitchens may be used to heat the other parts of the building. The south-facing walls (exposed to solar radiation) could be of high thermal capacity (such as Trombe wall) to store day time heat for later used.
- The insulation should have sufficient vapour barrier (such as two coats of bitumen, 300 to 600 gauge polyethylene sheet or aluminium foil) on the warm side to avoid condensation.
- A sufficiently sloping roof enables quick drainage of rain water and snow.
- Skylights on the roofs admit heat as well as light in winters. Skylights can be provided with shutters to avoid over heating in summers.
- The external surfaces of the walls should be dark in colour so that they absorb heat from the sun during the day.

Window openings and shading

- Openable Window to Floor Area ratio (WFRop) for cold climates should be a minimum of 8.33%. WFRop is calculated as a ratio between openable areas to built-up area of dwelling units (6). The window to wall ratio (WWR) on each façade should be determined based on the duration of sun exposure.
- Visible Light Transmittance of the non-opaque building envelope components (glass/ transparent/ translucent panels) should comply with the requirements given below (6):

Window-to-wall ratio	**Minimum VLT**
WWR <20%	≥75%
WWR 20 to 30%	≥50%
WWR 30 to 35%	≥40%

- It is advisable to have the maximum window area on the southern side of the building to facilitate direct heat gain.
- Double glazing with low-E glass or double clear glass performs better than single pane glass. They should be sealed effectively avoid heat losses during winter nights. Condensation in the air space between the panes should be prevented.
- External/fixed shading of windows is not desirable in this climate

Daylighting

- South to south-east orientation of large glazed areas are desirable for sunlight penetration in the daytime, with a high street-width to height ratio to allow direct sunlight in the living spaces.
- Multiple techniques, such as skylights and light shelves, may be utilised to maximise daylighting, as it aids in direct heat gain for the living areas.
- Diffused/reflected light may be introduced into the living space through reflective blinds or light coloured smooth surfaces outside the windows.

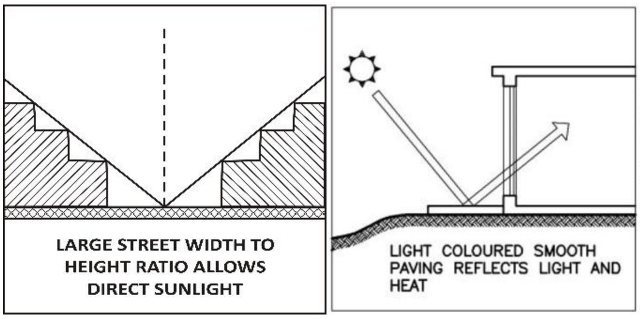

Figure 9: (Left) Street-width to height ratio for direct sunlight. (Right) Reflection of light and heat through light colored paving. Source: Adapted from (8)

Figure 10: Daylight penetration extent in a space.

Ventilation and passive heating strategies

- High rate of air exchange within the building is not desirable in the cold climate.
- In winter months in cold regions, the windows and other openings are generally kept shut; ventilation necessary for the control of odours and for the removal of products of combustion can be achieved either by stack action or by some infiltration of outside air due to wind action. (3)

Solar chimneys

- The system can be integrated with the roof or a wall and is a modification over Trombe Wall. Solar Chimney, on an external wall, enhances stack ventilation by providing additional height and well-designed air passages thereby increasing the air pressure differential. Via solar radiation, the chimneys warm the rising air which increases the difference between the temperatures of incoming and outflowing air. These measures increase the natural convection and enhance the draw of air through the building.

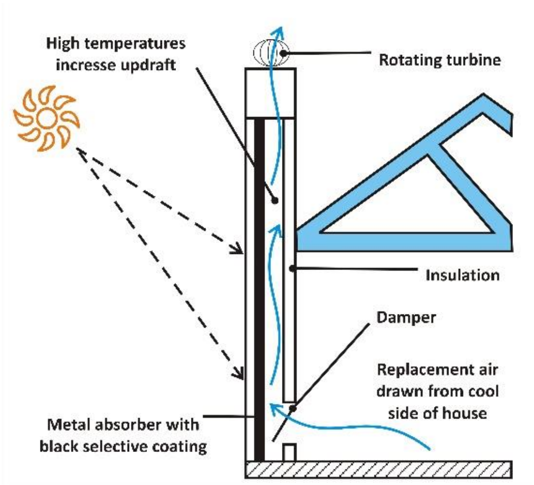

Figure 11: Solar chimney-wall.

Water Wall

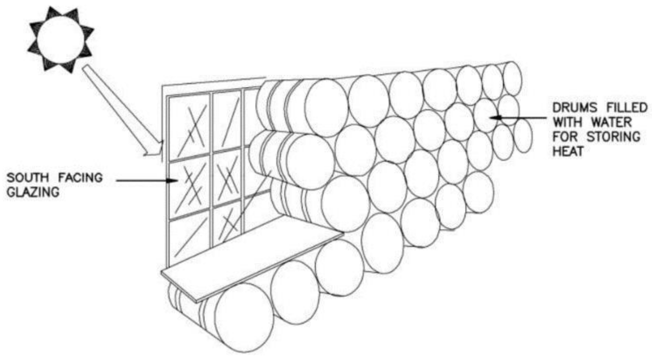

Figure 12: Water Wall. Source: Adapted from (8)

- Water walls are based on the same principle as that of the trombe wall, except that they employ water as the thermal storage material. Water walls are thermal storage wall made up of drums of water stacked up behind glazing. It is painted black externally to increase the absorption of radiation. This setup can store more heat than concrete walls due to higher specific heat.

Direct Gain System

- Direct gain is a passive heating technique that is generally used in cold climates. In this technique, sunlight is admitted into the living spaces directly through openings or glazed windows. The sunlight heats the walls and floors, which then store and transmit the heat to the indoor environment. The main requirement of a direct gain system are large glazed windows to receive maximum solar radiation and thermal storage mass.

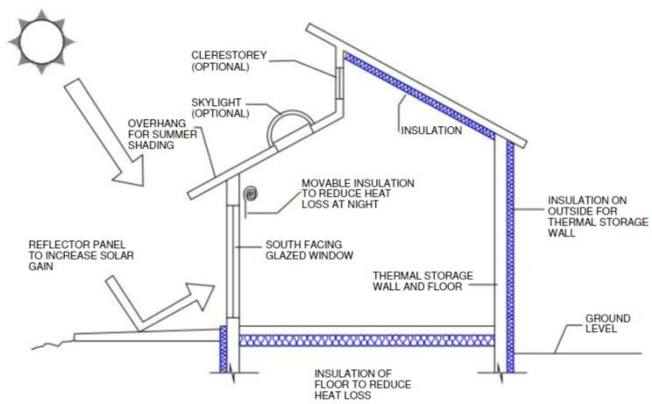

Figure 13: Direct gain system. Source: Adapted from (8)

During the day, the affected part of the house tends to get very hot, and hence thermal mass storage is provided in the form of bare massive walls or floors to absorb the heat. The stored heat is released at night for space heating. Carpets and curtains should not be used to cover the floors and walls used as storage mass because it impedes the heat flow rate. Suitable overhangs for shading and openable windows for ventilation must be provided to avoid overheating in the summer.

A solar air collector can be incorporated on the south facing slope of the roof and hot air from it can be used for space heating purposes.

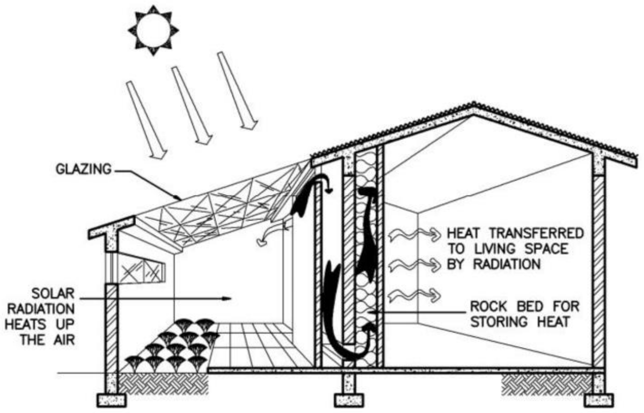

Figure 14: Solarium. Source: Adapted from (8)

Drainage & Waste management

- The site plan should be developed to minimize the disturbance caused to the existing natural habitat at the site. Detailed guidelines for providing and developing green areas at site are available in NBC vol 2, 2016.
- For safe drainage of such housing area catch drain (in the form of contour drain/graded drain) should be constructed on upstream of the built-up area to divert the upstream storm water runoff away from the housing area. Upstream face of such contour drain should be made permeable by providing weep hole and the downstream face and the base should be made impermeable. (9)
- Consider width of the drainage channel depending on the width of the natural drainage line and steepness of the side slope. Increase of width beyond natural available width may call for construction of higher and stronger side wall. Provide weep holes in the side wall so that high seepage pressure may not cause damage to the side wall of the drain. (9)

Water conservation

Rainwater Harvesting

- Capturing and preserving rain water is an efficient way to reduce portable water consumption and address water crisis.
- Rainwater harvesting can be done either for-
  I. Storage (underground or over-ground tanks) and direct use of rain water, or
  II. Charge into the ground – Ground water recharge.
- Wet and cold regions (North-east) are characterised with excessive rainfalls and high flooding. Providing pervious &/or semi-pervious surfaces on site, in the form of grass pavers, pebble beds etc. can also lead to less run-off and allow for ground water recharge through a larger area.

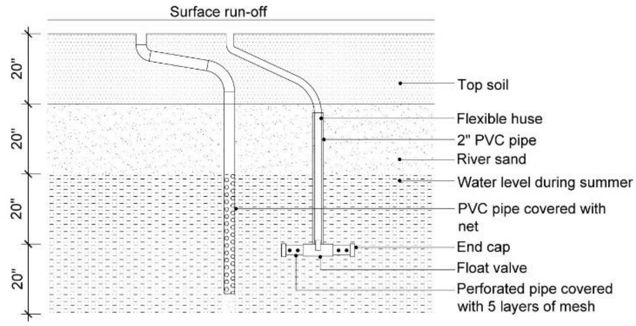

Figure 15: Rainwater harvesting combined with a pavement design at an interval dependent on the run-off. Image adapted from: Sustainable Building Design Manual, Vol.2

- The type & amount of rainwater harvesting suitable for a development varies and depends on the climatic zone, rainfall intensity, soil conditions, run-off volume and site design. NBC and Local Building Byelaws must be referred for planning and detailing RWH system in a development.

Building materials

Aim is to increase thermal capacity through thicker material sections and to increase thermal resistance through insulation. Therefore the conciderations for chosing materials in cold climate are:

- Low U-value
- High thermal mass
- Insulation

Autoclaved cellular concrete (AAC) block walls can save annual heating loads by 25.9% as compared to a brick wall. Plain concrete wall increases the load by 23.3% and hence should be avoided. Insulation of the walls helps improve performance significantly. Thermacol (EPS) insulated

- Roofing options with insulation are vital.
- Walls should be made of materials that lose heat slowly, which should include insulation.
- False ceilings with internal insulation such as polyurethane foam (PUF), thermocol (polystyrene),

wood wool, etc. are feasible for houses in cold climates.

- Aluminium foil is generally used between the insulation layer and the roof to reduce heat loss to the exterior.

- Stone and heavy resistant materials are used for building foundation, and in some parts the heavy materials are used for base course to prevent moisture. However, the buildings of these regions are generally built on the ground [5, 9, 10].

Impact on heating load

- Simulations were carried out to estimate the annual energy consumption per unit area due to heating, in a 4-storey building using DesignBuilder software. The Bhawana housing case study was used as a reference to model a social housing project in the context of India. The simulations were run for a single dwelling unit of 22.35 Sq. M. area situated on the top floor (4th floor). An electric heater (COP-0.9) was modelled.

- Occupancy and activity schedules were assumed from national standards, similar research work and homeowner's survey data collected as part of MaS-SHIP. A total of 16 existing and emerging building construction systems were assessed in comparison to the base-case. Comparative analysis between the annual heating load per Sq. M. shows the savings potential for each of these systems as enlisted in the table below.

	Cold		
	Base Case	**Heating energy ($kWh/m^2/yr$)**	
	Walling (12.5 mm cement plaster + 225 mm brick + 12.5 mm cement plaster)	**42.32**	
	Roofing (100 mm RCC + 100 mm lime concrete)		
		Savings from Base Case ($kWh/m^2/yr$)	**Savings In %**
	Improvements - Walling		
1	Fly-Ash brick work	1.63	4
2	AAC block masonry	5.31	13
3	Rat-trap Bond brickwork	2.18	5
4	Hollow concrete block masonry	1.68	4
5	Solid concrete block masonry	-6.83	-16
6	CSEB walling	1.41	3
7	Stonecrete blocks masonry	-19.16	-45
8	GFRG Panel System	-9.22	-22
9	Precast Large Concrete Panel system	0.98	2
10	Reinforced EPS Core Panel System	6.41	15
11	LGSFS-ICP	-28.11	-66
12	Monolithic Concrete Construction	-22.81	-54
	Improvements - Roofing		
1	Reinforced Brick Panel roofing	-0.15	-0.4
2	RCC Filler Slab roofing	-5.09	-12
3	Pre-cast RCC Plank & Joist roofing	3.59	8
4	Ferro Cement channel roofing	4.47	11

Note- Negative sign signifies that the building system impacts to a higher heating load than the base case.

- While AAC Block and Ferrocement channels have the highest savings potential, Light Gauge Steel Frame (LGSF) is among the materials performing the worst. The simulation has been run for a dwelling unit with exposed roof, hence the most drastic changes in heating load were observed in cases where the construction of roof changes.

Sustainability Assessment Tool

- The Sustainability Assessment Tool (SAT) is built on a Multi-Criteria Decision support system to provide the targeted beneficiaries with evidence based performance information. This would aid decision making in their choice of building materials and construction systems, both walling and roofing, for social housing projects in India.

- A total of 17 building materials and systems have been evaluated on the basis of 18 attributes categorized under 4 main criteria – Resource Efficiency, Operational Performance, User Experience and Economic Impacts

- The link to the SAT is: https://teriindia-my.sharepoint.com/:x:/g/personal/megha_behal_teri_res_in/EYFFmyuT1sdDjvod8oZqlK4BVw-OKPkVGVlnUn-8Rsro4g?e=sZrveE

- The SAT would enable the user to make an informed choice by providing:

- Order of preference of 17 walling & roofing building systems across all 18 attributes
- Order of preference of 17 walling & roofing building systems across selected attributes

- The SAT outputs are represented in the form of graphs which provide '**scores**' of the building materials and syastems with respect to the selected attributes. The scores have been calculated on the basis of absolute data gathered for 17 building materials and systems across 18 weighted attributes.
- Higher score of a building material or system with respect to others is an indicator of its better performance. Precisely, higher the score, better the building material or system.

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MaS-SHIP

Mainstreaming Sustainable Social Housing Project in India (MaS-SHIP) is a two-year research developed to promote sustainability in terms of environment performance, affordability and social inclusion as an integral part of social housing. Funded by United Nations Environment Programme (UNEP) 10 Year Framework of Programme on Sustainable Consumption and Production (10YFP).

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