A CENTRE FOR SCIENCE AND ENVIRONMENT SCOPING PAPER

OPTIMIZING THE THIRD SKIN

Energy efficiency and thermal comfort in affordable housing

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ABBREVIATIONS

2BHK	Two bedroom, hall and kitchen
AAC	Autoclaved aerated concrete
BPL	Below poverty line
BMTPC	Building Material and Technology Promotion Council
CPWD	Central Public Works Department
CSMC	Central Sanctioning and Monitoring Committee
CSE	Centre for Science and Environment
CSEB	Compressed stabilized earth blocks
DNA	Dedicated nodal agencies
EWS	Economically weaker section
ECBC-R	Energy Conservation Building Code for Residential Buildings or Eco Niwas Samhita, 2018
EIA	Environment Impact Assessment
ESF	External shading factor
EPS	Extruded polystyrene
FAR	Floor area ratio
GBPN	Global Buildings Performance Network
GHMC	Greater Hyderabad Municipal Corporation
GDP	Gross domestic product
HUDCO	Housing and Urban Development Corporation
HFAPoA	Housing for All Plan of Action
ICAP	India Cooling Action Plan
LIG	Low-income groups
MoEF&CC	Ministry of Environment, Forest and Climate Change
MoHUA	Ministry of Housing and Urban Affairs
NBC	National Building Code
NGOs	Non-governmental organizations
O&M	Operation and maintenance
PMAY	Pradhan Mantri Awas Yojana
RESCO	Renewable energy service company
SHGC	Solar heat gain coefficient
SLNA	State level nodal authority
SLSMC	State Level Sanctioning and Monitoring Committee
TSHCL	Telangana State Housing Corporation Ltd
TSI	Tropical Summer Index
TSNPDCL	Telangana State Northern Power Distribution Company Limited
TSSPDCL	Telangana State Southern Power Distribution Company Limited
VLT	Visual Light Transmittance
WWR	Window–wall Ratio
WFRop	Openable window-to-floor area ratio

CHAPTER 1: WHY THIS STUDY?

It is now well accepted in the policy arena that the massive clamour for homes and the frenetic pace of construction of residential buildings across India needs strategies to reduce their environmental footprints. New generation policies are aiming to minimize impact of construction on land, materials, energy, water and waste. While policy goals of resource and energy savings are well understood, combining these efficiency goals with the target of delivering thermal comfort and better quality of life for all, especially the urban poor, has yet to receive adequate attention.

This discussion has become necessary in view of massive expansion of the affordable housing sector. Nearly 95 per cent of housing deficit is in the low-income category and only 5 per cent in the higher income category. Under the current flagship programme for affordable housing in urban and rural areas—Pradhan Mantri Awas Yojana (PMAY)—the target is to build 34 million dwelling units by 2022. The new housing policy and state support are catalysing massive investments in this segment to address housing deficit. India will add 360 million sq ft building footprint by 2022—nearly equal to 25 per cent of the total commercial space existing today.

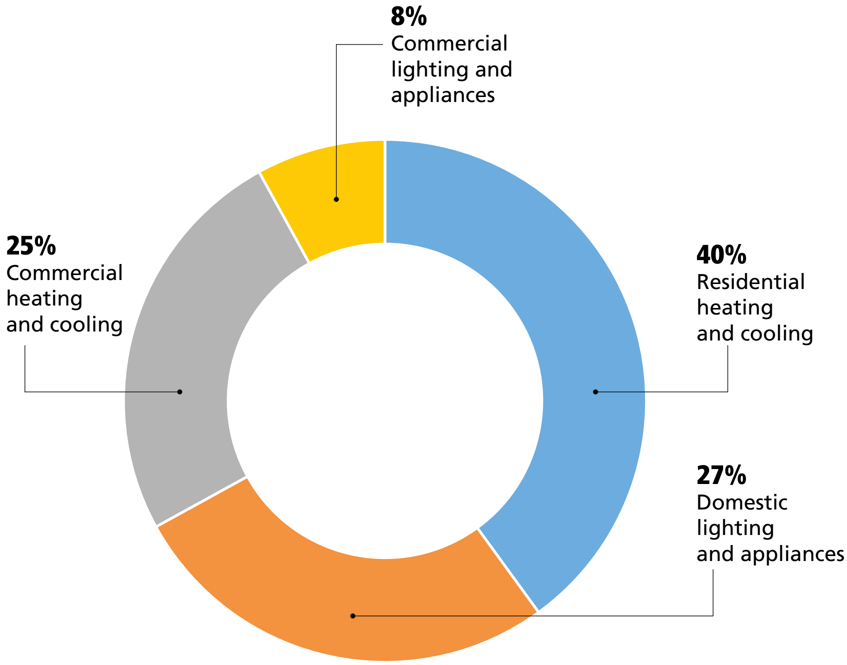
Given the urgency of the housing situation, current policies focus largely on speed, ease and cost of construction, adopting the use of building materials, and construction technologies and methods that speed up execution. There is no explicit focus on combining energy and material efficiency with achieving thermal comfort and improving quality of life.

These aspects can no longer be ignored. The 2015 NITI Aayog report on *Energy Efficiency and Energy Mix in the Indian Energy System (2030)* has estimated that the residential sector will overtake industry as the biggest electricity demand sector by 2030. At one level, more Indians will get access to *pucca* houses that will increase overall household demand for electricity. At another level, urban areas will see increased penetration of air conditioners (ACs): From one AC per 100 persons in 2015, to 15 ACs per 100 persons in the year 2047. This will result in an almost fivefold increase in electricity demand of this sector by 2030.

As of 2016, 30 per cent of all electricity consumed in India was by buildings, of which residential buildings used up 22 per cent.[1] Gross electricity consumption by residential buildings was around 50 TWh in 1995 and 220 TWh in 2015, i.e., a fourfold increase in 20 years. The annual electricity use per household is predicted to increase from 650 kWh in 2012 to 2,750 kWh by 2050, according to a study by Global Buildings Performance Network.[2] Clearly, a significant portion of the new energy demand will be driven by space cooling needs. The India Energy Security Scenarios (IESS)tool predicts residential heating and cooling demand will continue to dominate buildings' energy demand till 2047 (see *Graph 1: Distribution of components contributing to energy demand of buildings*).[3]

The affordable housing sector presents an even more complicated challenge. India Cooling Action Plan (ICAP), 2019, released by the Ministry of Environment, Forest and Climate Change (MoEF&CC), estimates that by 2038 a significant percentage of Indian households will be residing in buildings that would not be able to provide thermally comfortable indoors due to poor architectural design and warming of the urban environment. A significant proportion of the population will be without access to air conditioning or without any reliable mechanical means for cooling. If energy efficiency and thermal comfort goals are not combined, households will

Graph 1: Distribution of components contributing to energy demand of buildings



Source: Niti Aayog, 2017

make an early crossover and resort to active means of cooling (for example, by adopting ACs) to keep indoors comfortable.

Therefore, ICAP states that wider proliferation of thermally efficient built spaces with reduced heat load achieved through green walling (using walling assemblies that address questions of thermal performance by using optimized materials), shading and enhanced natural ventilation will be crucial to keep the requirement of active cooling in check. This will allow thermal comfort to be available for all while minimizing energy footprints of buildings in an increasingly climate-risked world.

The logic of this argument has led to policy convergence of two big ideas—planning and designing for energy efficiency as well as for thermal comfort. Both need to be aligned for best results.

Policies and regulations have converged to create this mandate of co-benefits. Energy Conservation Building Code (ECBC) has been augmented to bring residential buildings within its ambit. Bureau of Energy Efficiency (BEE) has issued the Eco-Niwas Samhita, 2018 (Energy Conservation Building Code for Residential Buildings or ECBC-R). Notified in December 2018, the code sets minimum performance standards for a building envelope to limit heat gain (in cooling-dominated climates) and heat loss (in heating-dominated climates). The code applies to (a) 'residential buildings' built on a plot area greater than or equal to 500 m^2 and (b) residential part of 'mixed land-use building projects' built on a plot area greater than or equal to 500 m^2. By definition, affordable housing sector falls within its ambit and must be guided by energy efficiency norms.

Simultaneously, ICAP has mooted the idea of comfort standards to ensure thermal comfort for all, including in the affordable housing sector. It recommends government support towards targeted programmes to enable thermal comfort for economically weaker section (EWS) and low-income groups (LIG). Government support for affordable housing includes strategies such as enforcing efficient building envelope guidelines from ECBC-R in the design and construction of housing for EWS and LIG to enable thermal comfort for all; and, funding and support for initiatives such as cool-roof programmes, off-grid micro-systems for cooling, and localized heat-action plans, led by local municipalities and nongovernmental organizations (NGOs).

This creates an opportunity to promote wider penetration of climate-responsive built spaces to keep indoor temperatures within an acceptable thermal comfort band through passive cooling, thus reducing the cooling load. This is an important step forward as it goes beyond assessing material and design from only the perspective of energy efficiency, instead creating an opportunity to align architectural design strategies, material choices, walling assembly and energy-efficient cooling technologies to maximize thermal comfort.

This spotlight on materials takes an integrated view of embodied energy of material that is influenced by the extraction, manufacture, transport of material, and construction, demolition and refurbishment, as well as walling assembly choices based on material and insulation options and architectural design that have bearing on operational energy to maintain human comfort. Currently, as part of the Technology Sub-mission, Building Material and Technology Promotion Council (BMTPC), the Ministry of Housing and Urban Affairs (MoHUA) promotes 24 alternative material and construction technologies. BMTPC has identified these technologies based on a diverse criteria that include strength, stability, fire resistance, thermal comfort, water tightness, constructability and economic viability.

However, this scoping study by Centre for Science and Environment (CSE) suggests that there is insufficient information to understand the overall ability of these materials to deliver on the requirements of environmental sustainability, thermal comfort and emissions intensity, and further investigation is needed.

In-depth field scoping investigation was carried out in one state (Telangana) to capture ground-level experiences with construction of affordable housing units to identify gaps and help chart a roadmap. Telangana's adoption of PMAY for implementation of a mass housing scheme has yielded important lessons. The investigation explored if Telangana has any long-term strategy (including a planning and fiscal framework) for mass housing to meet its stated housing goals. The study included an assessment of incentives offered to developers to catalyze construction. The study also reviewed the extent of penetration of alternative materials in government projects in Telangana and the criteria considered for choosing these materials along with planning, layout and design of housing stock under the scheme keeping in view factors of thermal comfort, energy efficiency and environmental sustainability.

Sample housing units in Telangana were checked to see if their design and use of material complies with the requirement of ECBC-R. This provided critical feedback for future intervention. In this context, adequacy of material attributes of some of the listed materials that have been defined in the compendium of BMTPC was also assessed.

As choice of materials was the explicit focus of this scoping study, assessment of brick production from the perspective of reducing lifecycle emissions was also considered. Brick is currently the dominant building material and will remain so in the foreseeable future, especially if thermal comfort requirements become important. As brick production has a huge environmental impact, it is important to focus on its footprints. Clean brick production is, therefore, necessary. A separate scoping study has been carried out for an in-depth case study of the brick sector in Maharashtra. This sets the stage for similar assessment of all materials to be used in the building sector.

Overall, this scoping study has been carried out within the policy context of environmental sustainability, energy efficiency and thermal comfort. Going forward, this analysis will look at the policy leverages and alignments that are needed among all key policies including Eco-Niwas Samhita, 2018; Technology Sub-mission; model building bye-laws, 2016; National Building Code, 2016;and Environmental Impact Assessment Notification.

NEXT STEPS BASED ON THE SCOPING

This scoping has demonstrated that there is enormous potential for energy and resource savings in the affordable housing sector while meeting the benchmark for thermal comfort and quality of life of the low-income groups. This combined goal becomes part of the mandate when the provisions of ECBC-R that focuses on energy efficiency requirements and ICAP's provision of adaptive thermal comfort for all are brought together.

The future work emerging from this scoping will influence and inform material and design guidelines for the affordable housing sector at the Central level; and building bye-laws, design guidelines and material choices at the state level. To enable this, detailed technical assessment of material and walling assembly techniques will be carried out; energy performance and thermal comfort levels in buildings will be evaluated; and bearing of architectural design and layout plans will be carried out to inform policies. Efforts will be made to coordinate with state-level agencies as well as the building industry and material providers for early mainstreaming of this change.

For this scoping study, CSE created a methodology to understand how current stock planning, layout and design internalizes thermal comfort, energy efficiency and environmental sustainability. It was revealed that the current design does not perform well when compared with the standards given in ECBC-R and the National Building Code (NBC), 2016. Components like heat transfer through opaque and non-opaque components of structure as well as natural daylighting do not hold upto the prescribed standards.

Various factors affect energy performance of building stock. The study takes a base case scenario of a sample affordable housing in Telangana and checks it for the openable window to floor ratio compliance, Visual Light Transmittance (VLT) compliance and Residential Envelope Transmittance Value (RETV) compliance. Research has established the role of orientation in bringing down the value of RETV in a sample affordable housing scheme by comparing the RETV of the worst-oriented with the best-oriented block. For instance, it was discovered that north–south orientation reduced RETV by up to 17.3 per cent compared to the east–west orientation. RETV represents the heat transmittance into a building through its envelope.

The scoping has made it clear that material choices cannot be made in isolation from architectural design and layout plans. Current design and material approach is able to deliver thermal comfort for 75 per cent to 82 per cent of the time in a year. However, this may vary from site to site. India has five climate zones and each state has adopted different housing typologies under their affordable housing schemes. There is a need to study the most representative typology in a particular climate zone.

This makes the case for a deep-dive study for Telangana and Karnataka that together comprise of four climate zones. The study will check compliance with ECBC-R and thermal comfort delivery, hence it will be able to address operational energy use in upcoming housing stock. Accordingly, the findings will guide state building bye-laws and housing schemes for a wider and mainstream approach to energy footprints of material use and the combined strategies for material and architectural design packages to optimize energy savings and thermal comfort.

PERFORMANCE OF CONVENTIONAL AND ALTERNATIVE MATERIALS AND WALLING ASSEMBLIES

It is also evident from the scoping that states are using alternative materials and construction technologies but primarily for speed and ease of construction to meet the target for housing units. For instance, Telangana is making shear wall structures using tunnel formwork technique and aluminium formwork technique, pre-cast concrete and aerated autoclaved concrete (AAC) blocks in some of the urban projects, while fly ash concrete bricks remain dominant. The costs of these materials and technologies is a little higher than conventional construction. But these materials are not optimally combined with design to get the best results with respect to energy efficiency and comfort.

There is, therefore, a huge need for informing the adoption of alternative material and walling assembly techniques. It is also important to leverage the building material compendium of BMTPC that inventorizes materials based on a range of attributes that have bearing on efficiency, safety and comfort. If this knowledge is further combined with architectural design packages and walling assembly approaches, significant efficiency and thermal comfort gains are possible. These interventions at the state level need to be further enabled through building bye-laws.

This spotlight on material takes an integrated view of embodied energy of materials that is influenced by extraction, manufacture, transport of material, construction, demolition and refurbishment; and also walling assembly choices based on material and insulation. BMTPC promotes 24 alternative materials and construction technologies in its compendium. It had identified these technologies based on criteria such as strength, stability, fire resistance, thermal comfort, water tightness, constructability and economic viability. The walling assembly of the base case was simulated with these materials and technologies and the RETV were re-calculated. Five out of 24 material and technologies are able to achieve the desired RETV keeping the same design. These technologies are fly-ash concrete blocks (150 mm thick), insulating concrete forms, plasmolite panel systems, emmedue systems and 150 mm AAC blocks.

Comparison of ECBC-R and thermal comfort analysis for these alternative materials and technologies has revealed that RETV's reliance on U-value may not be an effective approach. U-value essentially denotes the thermal insulation properties of a material. it may not be an appropriate indicator for a naturally ventilated or non-air conditioned building typology that most affordable housing projects are. The study has shown that the materials that have an average U-value can perform better for thermal comfort than the materials which have a superior U-value. This finding calls for further research on the performance of these materials for thermal comfort and energy efficiency combined. The research will build necessary guidance to achieve the objectives of the ICAP.

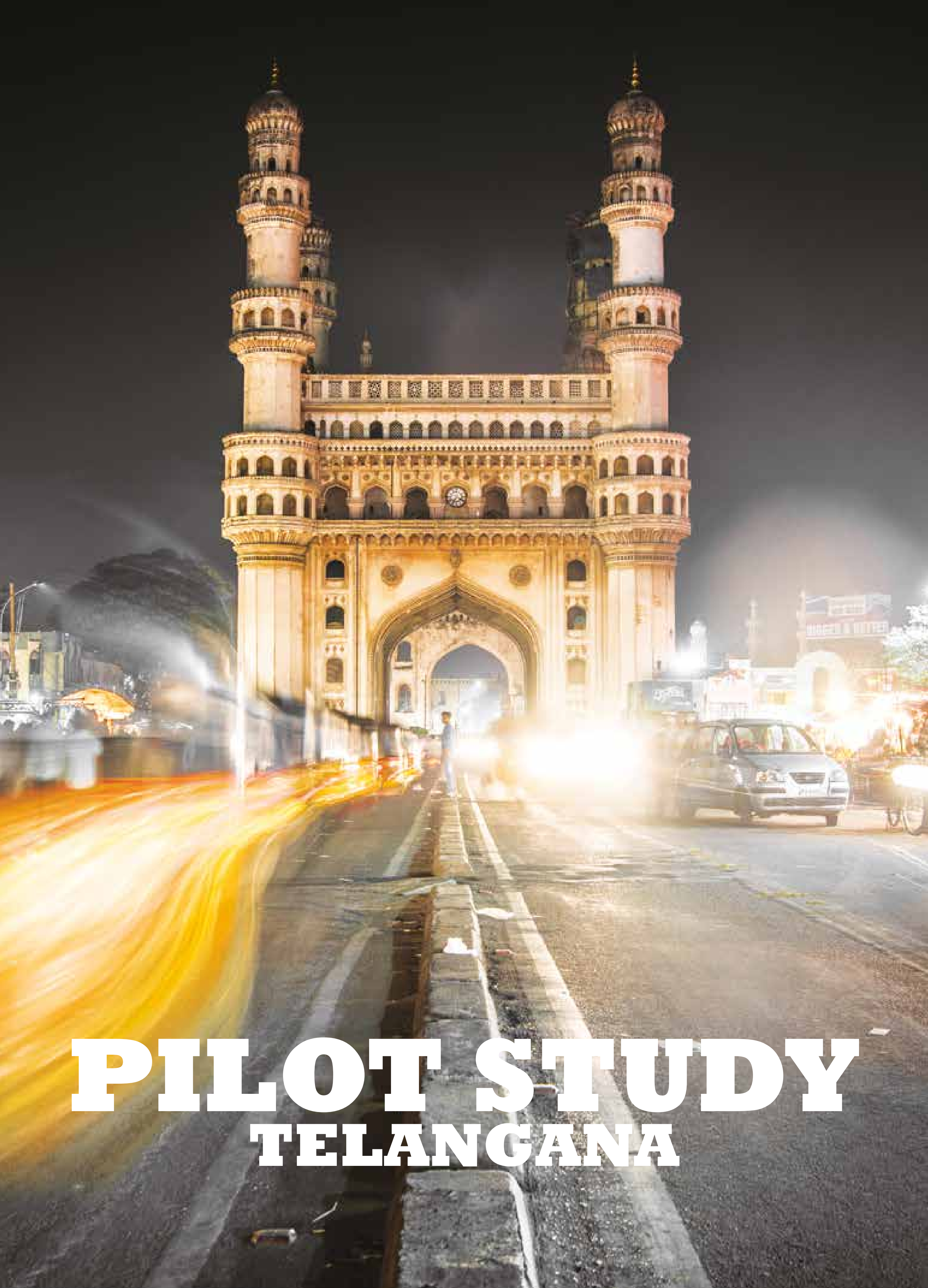
This evaluation suggests there is insufficient information to understand the overall ability of these materials to deliver on the requirements pertaining to environmental sustainability, thermal comfort and emissions intensity and needs further investigation. The use of these materials and technologies can be addressed in environmental regulatory frameworks such as Environment Impact Assessment (EIA) procedures. Burnt brick is still a predominant walling material and will take time to phase out if its green potential is not realised, so this sector should improve to perform as resource-efficient and low-carbon walling material. A separate scoping study established the challenges for cleaner and sustainable brick production in Maharashtra. It will require sustained efforts and a multi-faceted approach towards effective engagement with all stakeholders, including regulatory authorities and members of *Kumbhar* community, to build a consensus and move towards sustainable and cleaner brick production in a phased manner.

The identified high-performing materials and design elements that enable and foster thermal comfort while complying with ECBC-R, may have a higher cost implication and face market hurdles when used in mass housing schemes. State governments will need to work towards mechanisms to offset this additional cost. For instance, cross-financing under PPP by providing extra FAR or through viability gap funding. Such implementation mechanisms can be comprehensively addressed in state mass housing schemes or PPP toolkits.

NETWORK OF STAKEHOLDERS FOR ENABLING ACTION

Combining planning and designing for energy efficiency as well as for thermal comfort can only be possible through multi-stakeholder engagement involved with the implementation. In Telangana, support from Municipal Affairs and Urban Development Department and Housing Corporation, helped forward understanding on alternative material and formwork systems and pilot project experiences with new technologies. Roundtable engagement in Hyderabad involving technology providers active in the state and also nationally has indicated interest among alternate technology providers to leverage the emerging market. They are trying to be market-ready from the perspective of sustainability and getting their materials tested to enable accurate assessment and faster adoption.

Based on the scoping, this paper has been designed to influence and inform material and design guidelines for the affordable housing sector at the Central level and also inform building bye-laws and state-level guidelines. Overall, this paper addresses the policy context of environmental sustainability, energy efficiency and thermal comfort. Going forward, this analysis will examine in-depth the alignments needed among key policies.



PILOT STUDY
TELANGANA

CHAPTER 2: THE PILOT

Different states have different approaches to affordable housing schemes and the manner in which they have adopted PMAY differs as well. Preliminary assessment of affordable housing schemes in Gujarat, Rajasthan and Telangana shows that there are striking differences in their approaches. For instance, Telangana is developing housing, both urban and rural, only on government-owned land and allotting the houses to beneficiaries for free. Gujarat, on the other hand, has introduced affordable housing zones in the master plans of cities and has linked them with incentives to catalyze the market.

For this scoping exercise, we selected Telangana to assess the barriers and opportunities in aligning affordable housing agenda with adoption of sustainability measures. Telangana is a high growth state with a gross domestic product (GDP) growth rate of 10.4 per cent (higher than the national growth rate of 4.37 per cent) in 2017-18.[4] The state is rolling out an aggressive affordable housing scheme.

This in-depth field investigation in Telangana attempted to capture ground realties and experience with construction of affordable housing units to chart a roadmap for states. It explored how Telangana has adopted PMAY; incentives provided to catalyze construction; type and extent of penetration of alternative materials in government projects; and criteria for choosing materials and approving plans. It further assessed if Telangana has worked on planning, layouts and design of housing stock under the scheme from the perspective of thermal comfort, energy efficiency and environmental sustainability.

Efforts have also been made to understand the design and material connect to assess the gamut of alternative material that have already penetrated the sector to substitute clay bricks, and their comfort delivery potential pertaining to thermal performance and daylighting. This has been backed up by a detailed analysis of energy performance of sample buildings in Telangana to see if the materials, construction techniques and designs selected for the construction of affordable housing units comply with ECBC-R.

To illustrate the importance of considering attributes of materials that have a bearing on energy efficiency and thermal comfort, efforts were made to reassess the attributes of a select group of materials from the BMTPC compendium. The overall assessment shows that strengthening is needed in areas of identification of site location, layout planning, building typology and design in most projects.

Telangana's Department of Municipal Affairs and Urban Development had asked CSE to visit a few sites of construction and offer its comments and suggestions. In pursuit of this, CSE carried out case-specific assessments and convened urban local bodies to engage with them on sustainability guidelines focusing on design and materials. CSE reviewed the situation with the state ECBC chapter, Dedicated Nodal Agencies (DNAs) and other stakeholders.

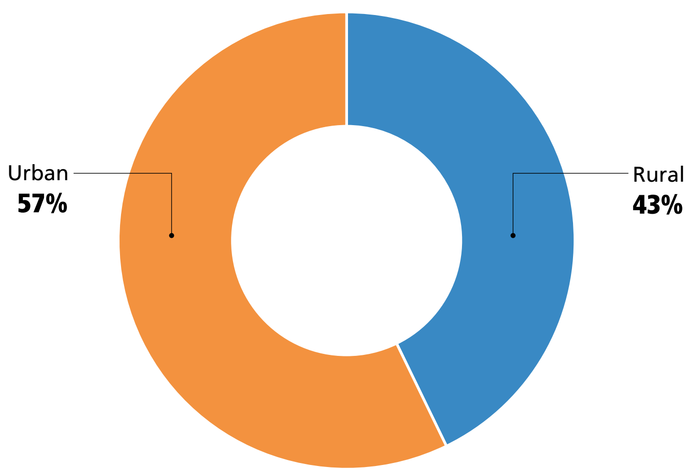
There is an enormous scope for research, technical support and handholding at the state-level to make the affordable housing stock compliant with relevant guidelines and to cut down operational energy use.

HOUSING DEMAND IN TELANGANA

In order to be considered for support under PMAY, states need to estimate their housing demand, prepare a Housing for All Plan of Action (HFAPoA), and submit it to the State Level Sanctioning and Monitoring Committee (SLSMC) and Central Sanctioning and Monitoring Committee (CSMC).

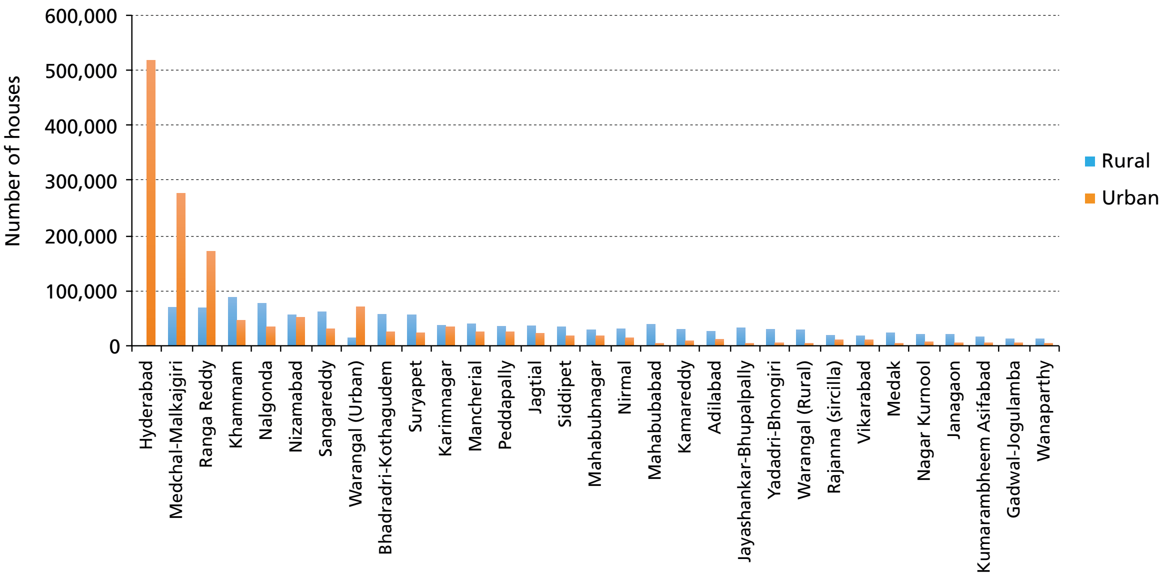
After the formation of the new state, Telangana conducted an integrated household survey in 2014. This survey revealed housing demand of 2,631,739 units—57 per cent urban and 43 per cent rural (see *Graph 2: Urban vs rural housing demand in Telangana)*. Households who do not have any member owning a house either in Telangana or anywhere else or are living on rent or in temporary shelters (plastic sheet roof shelters) have been considered for estimation of housing demand. Households living in government-provided housing have not been considered (see *Graph 3: District-wise housing demand in Telangana*). Major urban centres in Telangana include Warangal, Karimnagar and Nizamabad, apart from Hyderabad. District-wise distribution of housing demand reveals that about 64 per cent of the urban and 42 per cent of the total housing demand is concentrated in three districts: Hyderabad, Medchal-Malkajgiri and Ranga Reddy. Highest demand for rural housing comes from Khammam district, followed by Nalgonda, Sangareddy, Ranga Reddy, and Suryapet.

Graph 2: Urban vs rural housing demand in Telangana



Source: Telangana State Housing Corporation Ltd

Graph 3: District-wise housing demand in Telangana



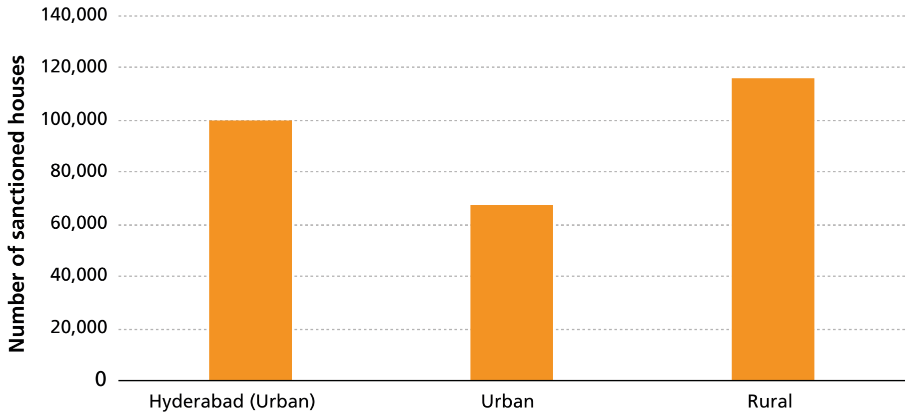
Source: Telangana State Housing Corporation Ltd

HOW TELANGANA ADAPTED PMAY TO CONSTRUCT MASS HOUSING

Telangana launched the Two-bedroom Hall Kitchen (2BHK) scheme in 2015, later rechristened as the Dignity Housing Scheme to dovetail PMAY.[5] The scheme allots for free a 560 sq ft dwelling unit to Below Poverty Line (BPL) families with reservations for marginalized castes and minorities in both urban (marginalized castes: 17 per cent; adivasis: 6 per cent; other minorities: 12 per cent and the rest for the general category) and rural (marginalized castes and adivasis: 50 per cent; other minorities: 7 per cent) areas.

District collectors are responsible for implementation in rural areas, and municipalities in urban areas and Greater Hyderabad Municipal Corporation (GHMC) in Hyderabad, Medchal-Malkajgiri, Sangareddy and Rangareddy districts. Out of the 283,401 units 'in progress' under the state scheme as of 31 January 2020, construction of 100,000 (35 per cent) units is being executed by GHMC, 67,019 units (24 per cent) by municipalities, and 116,382 units (41 per cent) by district collectors and gram panchayats (see *Graph 4: Urban–rural distribution of target houses in Telangana*). More than a third of the targeted houses are being constructed by GHMC. Being an urban local body, this is the first time GHMC has undertaken complete implementation of housing.

Graph 4: Urban–rural distribution of target houses in Telangana

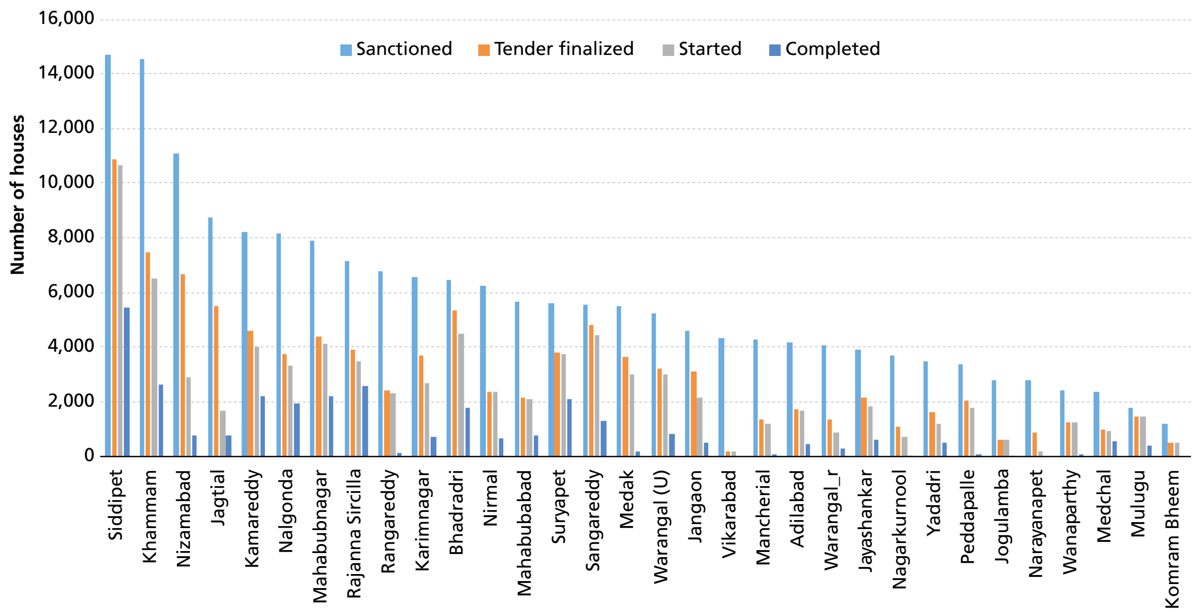


Source: Telangana State Housing Corporation Ltd

District-wise progress of the 2BHK scheme shows that Siddipet, Khammam and Nizamabad have the most number of units sanctioned in the state. Siddipet district leads with the highest number of completed units (see *Graph 5: District-wise progress of the 2BHK scheme*).

According to data received from Telangana State Housing Corporation Ltd (TSHCL), about 39 per cent units are at 90 per cent completion stage, and only 14 per cent units are reported to have been completed as of 31 January 2020. The state faced a slowdown due to legislative assembly elections held in December 2018.

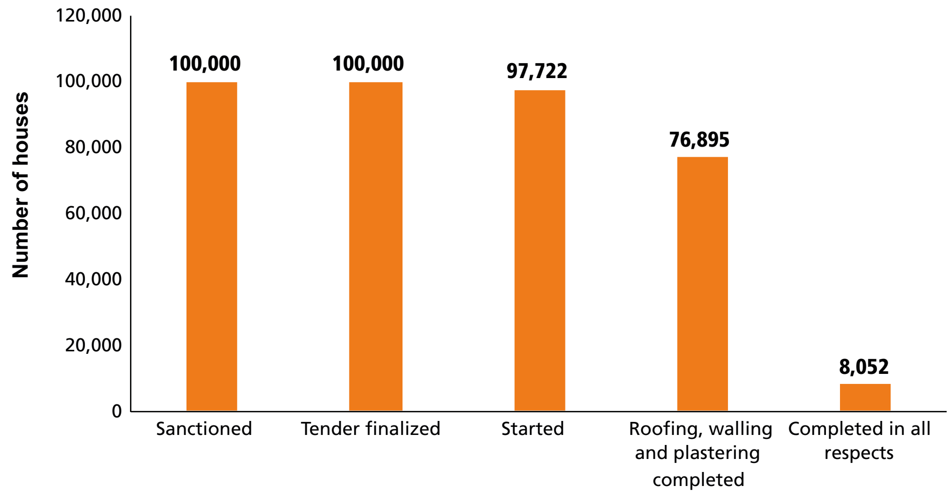
Graph 5: District-wise progress of the 2BHK scheme



Note: As of 31 January 2020
Does not include data for Hyderabad
Source: Telangana State Housing Corporation Ltd.

Of all the districts, construction has been taken up at an accelerated pace in Hyderabad by GHMC (see *Graph 6: Progress of the 2BHK scheme in Hyderabad*). Based on data shared by the state, construction has commenced on 97,722 units (97.72 per cent) of the 100,000 sanctioned units in the district. Of these, 76,895 units (76.9 per cent) are nearing completion and 8,052 units (8 per cent) were complete in every respect as of 31 January 2020.

Graph 6: Progress of the 2BHK scheme in Hyderabad



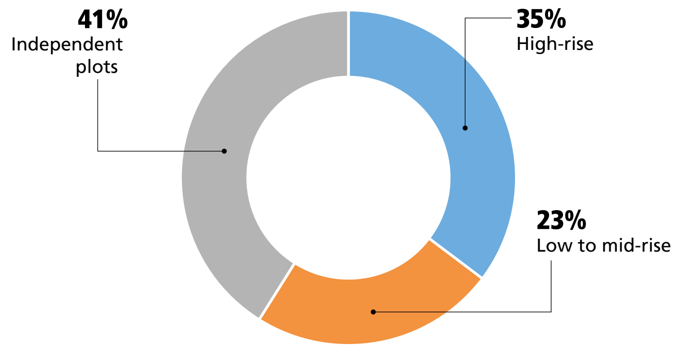
Note: As of 31 January 2020
Source: Telangana State Housing Corporation Ltd.

TSHCL is the state level nodal authority (SLNA) for Telangana. Maximum allotments of units have been capped at 1,600 units per legislative assembly, which is a much smaller number than the actual demand. While the state is working on the criteria to identify beneficiaries for allotment, it is likely to proceed with a lottery system. Respective local bodies and district collectors are responsible for identification and preparation of a list of beneficiaries for allotment.

CONSTRUCTION TYPOLOGY

The guidelines of the 2BHK scheme empower district collectors or commissioners and GHMC to take decisions regarding the construction typology. In rural areas, the guidelines fix the typology as independent houses with plot areas of 125 sq yd (1,345 sq ft) each. GHMC projects are mostly constructed as G+8 or G+9 structures, a few projects have G+5 to G+7 typologies. Municipalities have typologies ranging from G+1 to G+3 structures (see *Graph 7: The 2BHK scheme as per construction typologies*). Hence, it is a mix of high-, mid- and low-rise and independent units.

Graph 7: The 2BHK scheme as per construction typologies

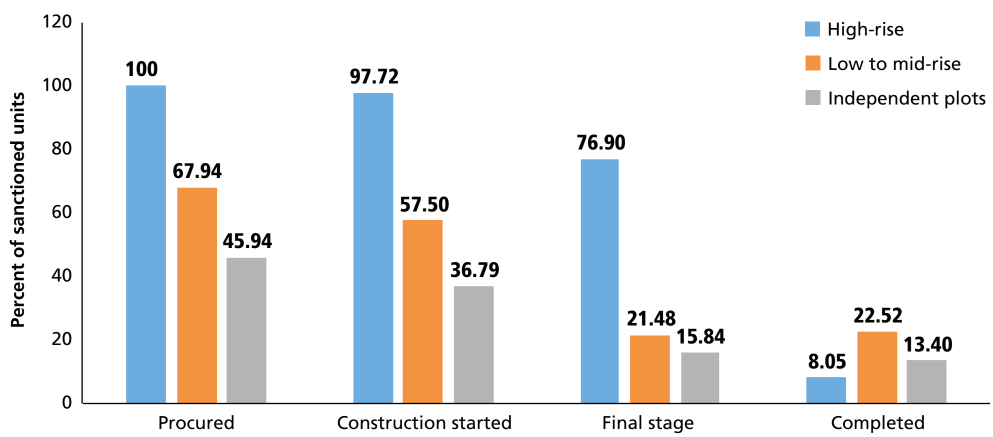


Source: Telangana State Housing Corporation Ltd.

Analyzing the 283,401 dwelling units as per construction typologies reveals that most units are being constructed as independent houses (41 per cent). This is followed by high-rise typologies, which constitute 35 per cent of the constructions. Low- to mid-rise typologies form the smallest component of houses constructed.

As far as the progress for different typologies goes, low- to mid-rise houses are witnessing fastest construction. About 23 per cent of the sanctioned units are reported to be complete under this category and another 22 per cent are nearing completion. Recalling the scenario in GHMC, where 8 per cent of sanctioned units are complete and 76.9 per cent are nearing completion, much of the scheme's progress will be guided by high-rise projects (see *Graph 8: Typology-wise progress of the 2BHK scheme*). Procurement has been difficult for projects with independent typologies, wherein only 46 per cent of the sanctioned units have been procured. About 68 per cent units in low to mid-rise typology are procured. The delay can be attributed to issues with land acquisition and lower profitability.

Graph 8: Typology-wise progress of the 2BHK scheme



Source: Telangana State Housing Corporation Ltd.

FINANCING

Preliminary profiling of Telangana revealed that the state government is taking up a huge financial burden under the scheme, which may not be feasible in the long run. Telangana is providing housing only on government-owned land and allotting it to beneficiaries for free. PMAY recognizes the Socio-economic Caste Census (SECC), 2011 data in determining the eligibility of a person to be a beneficiary. Telangana was formed in 2014 and underwent changes in administrative boundaries and demography after splitting from Andhra Pradesh. The state calculated its rural housing demand based on a fresh survey and plans to identify eligible beneficiaries using same data. Due to non-compliance with PMAY guidelines in terms of inability to use SECC data, Telangana is unable to avail funds under PMAY Gramin and is financing 100 per cent rural housing with state funds. This challenge is also an opportunity for the state to work independently and adequately address affordable housing development, including through sound fiscal strategies.

Since the state is bearing a majority of the costs, it is also looking for funding from external sources. For instance, government of Telangana raised a loan of Rs 3,344.76 crore from Housing and Urban Development Corporation (HUDCO) to fund construction of 60,000 dwelling units in 2015. This scheme included a mixed-use building approach leveraged for cross-subsidy. GHMC projects have provided for shops at the ground level to generate revenue to meet operation and maintenance costs.

Construction cost

The 2BHK scheme guidelines cap the cost of construction at Rs 5.3 lakh in urban areas and 5.04 lakh in rural areas. External infrastructure cost cannot exceed Rs 75,000 in urban areas and Rs 1.25 lakh in rural areas. However, actual costs in urban areas were found to be higher, as reported by state agencies. For houses in the GHMC area, state government's contribution is fixed at Rs 6.25 lakh (unit and infrastructure), Central government's at Rs 1.5 lakh (dovetailed to PMAY) and the remaining is gap-funded by GHMC (see *Table 1: Funding pattern adopted for the 2BHK scheme in the GHMC area*).

Table 1: Funding pattern adopted for the 2BHK scheme in the GHMC area

Contributor	Government of India	Government of Telangana	GHMC
Type of grant	Fixed	Fixed	Varies
Dwelling unit cost (Rs lakh)	1.5	5.5	0.15–0.9
Infrastructure cost per unit (Rs lakh)	-	0.75	-
Total cost per unit (Rs lakh)	7.9–8.65		

Source: Greater Hyderabad Municipal Corporation

GHMC began procuring 2BHK houses at the rate of Rs 900 per sq ft. It received a poor response from the construction market, which demanded rates as high as Rs 1,800 per sq ft. Currently, construction cost for developers has been capped at Rs 1,294 per sq ft in urban areas. This is at par with construction cost in other states, such as Rs 1,150 per sq ft (excluding Rs 50 per sq ft for operation and maintenance) in Rajasthan.

Incentive schemes

All 2BHK housing projects have been taken up on government land. In order to encourage developers to take up construction, the government has provided several incentives. Subsidies on construction materials are a major incentive. The government is providing materials—steel, cement and sand—at subsidized rates. The state is buying steel from manufacturers at a base rate of Rs 32,550 per tonne, following negotiations. In early 2018, the market value for steel jumped up to Rs 53,100 per tonne, putting much of the construction to halt due to unwillingness of the steel industry to supply at the discounted rate. The 2BHK scheme requires about 6 lakh tonnes of steel for the targeted 2.8 lakh housing units (1.45 lakh tonnes for rural houses, 1.04 lakh tonnes for urban and the remaining 3.5 lakh tonnes for the GHMC area). Considering the high demand, the government has reset the base price of steel to Rs 43,600 per tonne.[6]

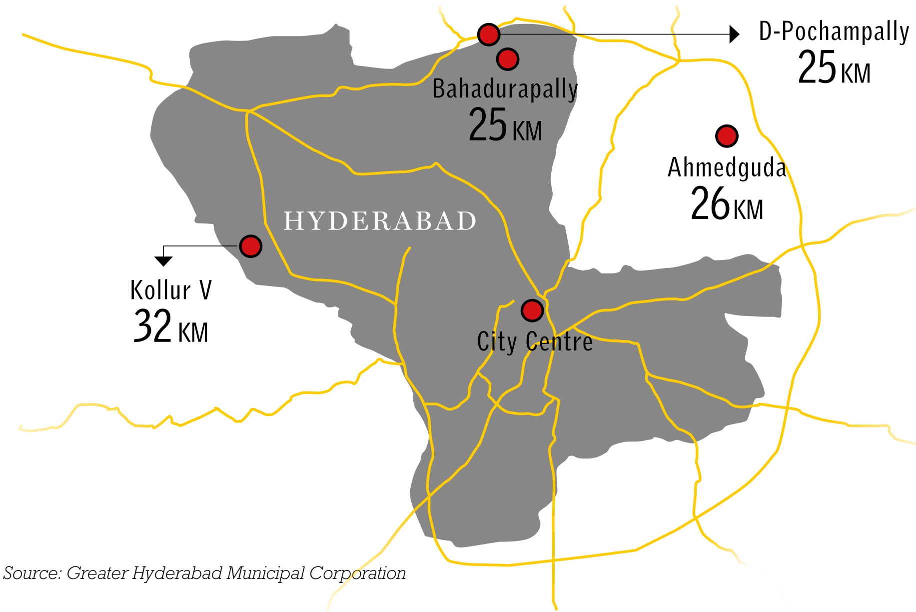
The state government has facilitated free of cost availability of sand to developers. Telangana State Sand Mining Rules, 2015 exempt sand extraction of any cost if it is to be used for housing of LIGs.[7]

The state government also entered into a memorandum of understanding with the Cement Manufacturers Association to supply 27.25 lakh million tonnes of cement at the rate of Rs 230 per bag. Transportation costs were settled at Rs 2 per bag.[8]

Land identification

The 2BHK scheme involves construction of dwelling units only on government land. Land cost is waived off for the developer. The mechanism coincides with Model 1 of the PPP policy for implementation of PMAY, except in the fact that beneficiaries are not liable to pay anything towards the 2BHK units. PMAY mandates states to identify land for affordable housing in the master plans of cities. In Telangana, implementing agencies in urban and rural areas have identified land at the periphery of legislative assembly areas as suggested under the 2BHK scheme guidelines. The other criterion is availability of land at low market prices. For instance, in Hyderabad, most project sites are located outside the GHMC area and near the Outer Ring Road (see *Map 1: Location of the 2BHK scheme project sites in Hyderabad*). Land prices near

Map 1: Location of the 2BHK scheme project sites in Hyderabad



Source: Greater Hyderabad Municipal Corporation

Workers preparing the formwork for monolithic concrete structures in Hyderabad

the Outer Ring Road range from Rs 18,000 to 22,000 per sq yd, while in the GHMC area they are Rs 40–50 thousand per sq yd. There is no special provisioning for affordable housing in the Hyderabad Metropolitan Development Plan, 2031. This, of course, has other implications such as increased distances and accessibility costs.

When planning housing for the poor, site selection is critical. Low-income groups earn a minimum labour wage and prefer to live near sources of livelihood. Relocating them to urban peripheries increases distances and transportation cost for them and makes the housing unaffordable. Governments need to plan these sites in conjunction with affordable travel options.

An inclusive provision in master plans can ensure affordable housing stock is integrated with the existing public transport system. For instance, Ahmedabad has notified a Residential Affordable Housing (RAH) zone along the ring road in its master plan. The RAH zone is well connected with the city's BRT system. Telangana's current housing scheme is addressing 10 per cent of the states established housing demand. In order to cater to the remaining and future housing demand, the state needs to work on mechanisms that link mass housing with availability of public transportation, especially for the poor.

TELANGANA HAS A GREAT OPPORTUNITY TO DEVISE A COHESIVE MASS HOUSING STRATEGY

The current scheme met 10.77 per cent of the total housing demand set in the state in 2014 as of 31 January 2020. While the 2BHK scheme is an instrument to guide supply of targeted housing stock under PMAY, there is no affordable housing strategy in place to sustain the state's current and future housing demand. Reservations exists for EWS and LIG households in housing projects as shown in the *Table*.[9]

Reservations for EWS and LIG households in housing projects

Areas	Site area	Reservation for EWS and LIG
Hyderabad Metropolitan Development Authority	4,000 m^2 and above	20 per cent of the developed land
Municipal Corporations and Development Authorities	3,000 m^2 and above	
Other Municipalities and Nagar Panchayats	2,000 m^2 and above	

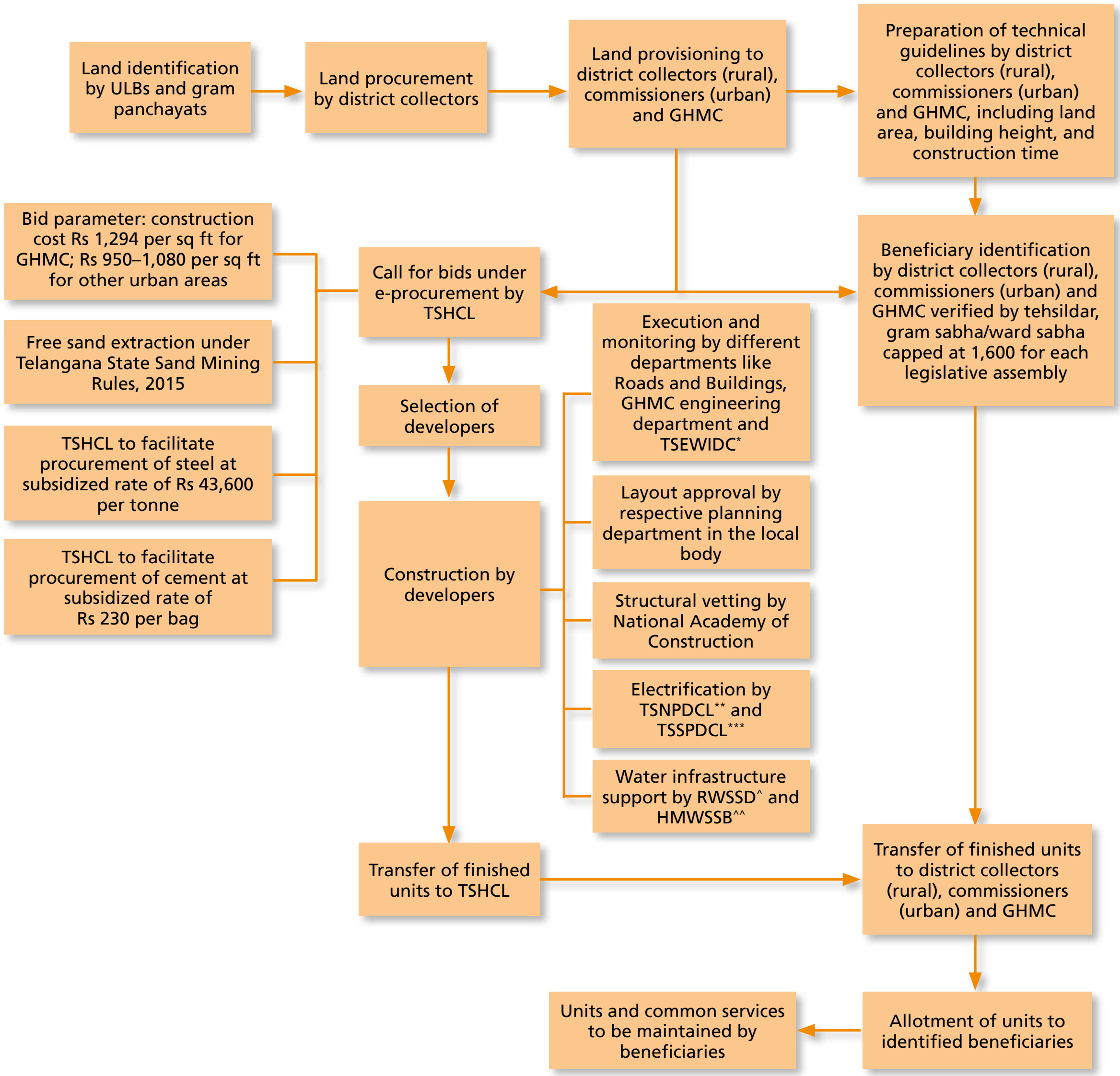
Source: Hyderabad Metropolitan Development Authority

All the projects under the current scheme have been built on government land. For each dwelling unit, Rs 1.5 lakh is provided by the government of India and Rs 6.25 lakh is provided by the government of Telangana. The remaining is gap-funded by GHMC in urban projects. In 2015, the state government also raised a loan of Rs 3,344.76 crore from Housing and Urban Development Corporation (HUDCO) as viability gap funding for construction of 60,000 dwelling units. However, the state has been unable to avail funds for rural housing under PMAY (Gramin) due to non-compliance with scheme guidelines. Hence, this segment is wholly funded by the state government itself.

ACTORS AND METHODOLOGY

The methodology adopted for the 2BHK scheme is summarized in *Figure 1: Actors involved and the implementation framework*.

Figure 1: Actors involved and the implementation framework



Notes:
* *Telangana State Education, Women and Infrastructure Development Corporation*
** *Telangana State Northern Power Distribution Company Limited*
*** *Telangana State Southern Power Distribution Company Limited*
^ *Rural Water Supply and Sanitation Department*
^^ *Hyderabad Metropolitan Water Supply and Sewerage Board*

Source: CSE compilation

CHAPTER 3: CONSTRUCTION MATERIALS

One of the key objectives of this scoping exercise was to identify and assess emerging technologies penetrating the affordable housing sector.

CSE's engagement with Housing Corporation of Telangana helped us to understand the alternative material and formwork systems in use and the experiences at the pilot project. There has been ample buy-in from alternative materials and technology providers for further investigation. A roundtable conducted in Hyderabad has indicated much interest among the vendors, who are now getting their materials tested to enable accurate assessment for faster adoption. One of the critical intervention points in the future will have to be knowledge building on material and walling assembly to inform policies and industry for optimum choices and gains.

The 2BHK scheme is mainly constructed using concrete fly ash bricks in a conventional structure. Under the Technology Sub-mission, a demonstration housing has been constructed in Gachibowli at Nirmiti Kendra using Coffor Technology. Only a small proportion of the housing stock under construction is using alternative material and technologies. The costs of these materials and technologies are a little higher than those used under conventional construction. These materials include:

- Shear wall using tunnel formwork technique
- Shear wall using aluminium formwork technique
- Pre-cast concrete
- AAC blocks

Use of fly ash bricks at D. Pochampally

SHEAR WALL TECHNOLOGY USING THE TUNNEL FORMWORK TECHNIQUE

RAMPALLY

GHMC's Rampally project is using the tunnel form technique to construct 6,240 2BHK apartment houses in Stilts(S)+10 buildings. This technique allows the wall and slab to be cast at once using a tunnel-like frame, which is reinforced with poured-in concrete. The exterior façade is later created with either cellular light-weight concrete (CLC) or AAC blocks.

This technology is attractive for development contractor for its time-saving characteristics. A combination of multiple formworks is capable of casting an entire floor of a building with a single pour-in of concrete. However, the large size of the tunnels requires cranes to move them around, which makes the technology unsuitable for small projects. The building structure thus formed is a load bearing structure.The need for finishing work is reduced, owing to the high-quality even surfaces. The technology is not indigenous as the tunnels are imported from Turkey. According to the contractor, the technique costs about Rs 50 per sq ft over GHMC's procurement rate of Rs 1,294 per sq ft.

Tunnel formwork in process leaving exterior façade to be completed with blocks

Reinforcement work to be moulded with tunnels and casted

Tunnel formwork post casting

Assembly of pre-cast staircase with the structure

Surface finish post casting

SHEAR WALL TECHNOLOGY USING THE ALUMINIUM FORMWORK TECHNIQUE

DUNDIGAL

At yet another site in Telangana, buildings are being constructed with shear wall using the aluminium formwork technique. About 864 2BHK units in S+S+9 buildings at Dundigal are being constructed using this formwork. As per this technique, all the building's structural or non-structural elements like beams, columns, walls, floors, slabs, opening for doors and windows are cast-in-place monolithically with an appropriate grade of concrete in one operation. The advantage of this technique over tunnel formwork is the lightness of the aluminium forms, which makes it easy for workers to carry it around. The technique was chosen by the contractor to save time. It costs around Rs 1,400 per sq ft. The need for plastering the walls is eliminated in this technique, as the surface finish is smooth and even.

Aluminium shuttering to be filled in with concrete mix

Aluminium formwork for exterior walls in a unit

Steel reinforcement work for stairs

Steel reinforcement work for slab

Surface finish post-casting

Partition walls made of AAC blocks

Surface finish eliminates the need for plaster

Building blocks under construction using the aluminium formwork technique

PRE-CAST CONCRETE

DUNDIGAL

The project at Dundigal also uses precast concrete to construct 1,512 2BHK houses in S+S+9 building structures. Building elements such as floor slabs and wall panels are cast with reinforced concrete on site and then assembled with the columns that are cast in-situ. The remaining elements like beams, hollow core roof slabs, staircase and landing are precast at a factory. The building is framed in a manner that obtains maximum repetitions of moulds. The technology offers speed of construction, and reduced labour and formwork requirement. However, the assembly has to be done with precision. The technology costs under Rs 1,400 per sq ft.

On-site casting of wall panels

Hollow-core slabs

Reinforcement and pre-cast wall panels

Assembly of pre-cast wall panels to columns casted in-situ

Interior surface finish post assembly of various pre-cast building elements

Reinforcement work for columns to be cast in-situ

A building block made using pre-cast technology

AUTOCLAVED AERATED CONCRETE BLOCKS

DUNDIGAL

GHMC's project at Dundigal is using AAC blocks to construct 1,620 2BHK houses. Other than this, the blocks are used as infill and partition walls in the buildings. AAC blocks use 60-65 per cent of fly ash. Aerated concrete makes them lighter, which reduces structural loads in the building and offers good insulation.

Exterior and interior walls made of AAC blocks

INFORMING BMTPC MATERIAL ATTRIBUTES

The choice of materials in affordable housing sector is largely governed by the Technology Sub-mission that was set up under PMAY in 2015 to enable preparation and adoption of layout designs and building plans appropriate to particular geo-climatic zones. The aim of the sub-mission is to assist states or cities in the deployment of disaster-resistant and environment friendly technologies for faster and cost-effective construction of houses.

The sub-mission concerns itself with, among other things, design and planning; innovative technologies and materials; green buildings using natural resources; and earthquake- and other disaster-resistant technologies and designs. To support this sub-mission, a cell has been setup in BMTPC. BMTPC was created by the erstwhile Ministry of Urban Development in 1990. This was done to bridge the gap between research and development and large-scale application of new building material technologies.

BMTPC periodically comes out with compendiums of prospective emerging technologies for mass housing. Three such compendiums have been released by BMTPC, the latest in September 2018. It has since been updated (see *Box: BMTPC Compendium of Alternative Construction Technologies for Mass Housing*).

The BMTPC compendium takes into account multiple attributes to judge a material.[10] These attributes are divided into two parts, mandatory attributes and preferred or desired attributes. Another classification by BMTPC splits attributes into three categories, primary (PA), secondary (SA) and tertiary (TA). Thermal Comfort and Embodied Energy are tertiary attributes. However, the compendium is not complete regarding information on these attributes. For example, a parameter such as thermal performance is not comparable across technologies as some mention the U-value, some mention the K-value and some mention the temperature change between the interior and exterior if a building is made using the technology. This makes comparison between technologies difficult.

The mandatory attributes include: Strength and Stability Requirements (SA); Performance and Statutory Compliance (SA); Fire Resistance (TA); Thermal Comfort (TA); Acoustic Performance (TA); Weather-Resistance (TA); and Water Tightness (TA). The preferred and desired attributes include: Functional Requirements (SA); Constructability (SA); Economic Viability (SA); Maintenance (SA); Sustainability (SA); and Finish Quality (SA).

This scoping review shows that the way material attributes are currently defined may not be adequate to achieve the desired goals. More sub-attributes are needed to strengthen the process and inform the approaches to walling assembly in buildings. Therefore, an effort has been made by this scoping exercise to assess 14 out of the 24 technologies given in the BMTPC compendium based on a diverse set of parameters. There is a detailed assessment of the materials that guides their adoption (see *Annexure 1: Analysis of attributes of select materials from the BMTPC compendium*).

This assessment is limited to analyzing only a few of the BMTPC attributes, mostly relating to thermal performance, sustainability, circularity, functionality and adaptability to changes of a material. This brings some attributes into a common measurement unit and complements the attributes mentioned by BMTPC. It also highlights how simple concepts of design ensuring adequate sunlight and ventilation should be adopted. Building this knowledge is important to further develop approaches to walling assembly.

Thermal comfort

BMTPC mentions thermal resistance or transmittance of a material assembly to judge its thermal comfort capability. However, thermal comfort is a more complex phenomenon and various factors play a part in ensuring it in a building apart from the materials used, such as orientation, mean radiant temperature, humidity and air velocity. This study defines two sub-attributes to further strengthen the approaches to walling assembly.

- **Thermal transmittance**: Solely for the purpose of judging a material's contribution to thermal comfort, this assessment uses thermal transmittance (also known as U-value) as an indicator. It is the heat transmission in unit time through unit area of a material or construction and the boundary air films, induced by unit temperature difference between the environments on either side. The unit of measurement of U-value is W/m^2K. A lower U-Value indicates a better insulated material. The value depends on the thermal properties and thickness of the material and assembly of multiple materials.

- **Presence of thermal bridges:** A thermal bridge is an area or component of a walling assembly that creates a path of least resistance for heat transfer due to lower thermal resistance than the surrounding material. Thermal bridges have been added as a cautionary parameter because thermal resistance or transmittance cannot be calculated

BMTPC COMPENDIUM OF ALTERNATIVE CONSTRUCTION TECHNOLOGIES FOR MASS HOUSING

The compendium mentions 24 technologies which are grouped together into a few categories

Formwork systems

Engineered formwork systems
Systems where concrete is poured and the formwork is disassembled on site and reused again. The technology only works when there are considerable repetitions in the design.

1. Monolithic concrete construction system
    a. Using plastic-aluminium formwork
    b. Using aluminium formwork

2. Modular tunnel form

Stay-in-place formwork systems
Systems where the formwork becomes part of the wall or roof assembly, the formwork is lost in the construction and may play a part in the structural strength or fire resistance or thermal properties of the wall assembly.

3. Insulating concrete forms
4. Monolithic insulated concrete system
5. Structural stay-in-place formwork system
6. Lost-in-place formwork system—plaswall panel system
7. Lost-in-place formwork system—plasmolite wall panels
8. Sismo building technology

Pre-cast sandwich panel systems

EPS-based systems
Pre-cast systems that use extruded polystyrene to enhance their thermal performance, they primarily use reinforced cement concrete or concrete as the other major component.

9. Advanced building system—emmedue

by merely adding various resistances on the walling assembly. Thermal bridges can hamper the thermal performance of a material and assembly. As an example, many technologies puncture the EPS used and their U-value has to be simulated and cannot be measured by thumb calculations.

Functional requirements

This attribute is defined by BMTPC as an ‘attribute for assessing the technology or system against generally accepted functional requirements of housing’. Functionality of materials includes design flexibility, restriction on the number of floors, service life and durability and end-user friendliness. This assessment adds two more sub-attributes:

10. Rapid panels
11. Reinforced EPS core panel system
12. Quickbuild 3D panels
13. Concrewall panel system

Other systems

Pre-cast systems that use other materials and are not necessarily extruded polystyrene-based.

14. Glass fibre reinforced gypsum panel system
15. Prefabricated fibre reinforced sandwich panels
16. Rising EPS (beads) cement panels

Light-gauge steel structural systems

Technologies that primarily use light-gauge steel as a structural material in beams, columns and trusses and have multiple walling options.

17. Light-gauge steel framed structure
18. Light-gauge steel framed structure with infill concrete panel technology

Steel structural systems

Technologies that primarily use steel as a structural material in beams, columns and trusses and have multiple walling options.

19. Factory-made fast track modular building system
20. Speed floor system

Pre-cast concrete construction systems

Pre-cast systems are either produced in a factory or elsewhere before being taken to the construction site. Some of these technologies offer load-bearing as well as non-load bearing options.

21. SRPL building system (wafflecrete)
22. Pre-cast large concrete panel system
23. Industrialized 3-S system using RCC precast with or without shear walls, columns, beams, cellular light-weight concrete slabs and semi-precast solid slab
24. Walltec hollowcore concrete panel

- **Ease of modification**: The ease with which future changes to the building can take place, such as through removing a wall or puncturing a wall for a window.
- **Height limitations**: The building height for which a technology has been used.

Constructability

BMTPC defines this attribute as the relative ease of construction under a selected building design. It is the extent to which a building design with a chosen technology provides for ease of construction while meeting the overall requirements of the building. This study adds three more sub-attributes:

- **Special equipment needed**: If any special equipment is required during manufacturing or implementation of the technology.
- **Labour needed**: If specialized labour or training is needed before the technology can be implemented.
- **Ease of non-repetitive design**: The ease with which a design can be made for a project in which a design is non-repetitive.

Sustainability

To meet the criteria of sustainability, it is important to reduce use of virgin materials, reduce energy and carbon footprint of materials, ensure it causes less pollution, and minimize waste without compromising on the project's economic viability and overall comfort, safety and other requirements of the occupants. This study adds several other sub-attributes for assessing sustainability.

- **Thickness of walling assembly for G+9 structure**: Thickness is an important parameter to understand, if the walling assembly takes up less space than conventional systems, then the inhabitants get more carpet area.
- **Plaster requirement**: Plaster requirement can add to the cost and time of construction, plaster does not add value to the structural strength of the assembly but rather is needed to even out a surface, an example being a burnt brick wall where upto 25 mm of plaster is needed to even out the irregularities caused by laying the uneven bricks; compare this to a cement fibre board where putty and paint can be applied directly.
- **Mass of walling assembly per unit area (m^2)**: A heavier walling assembly would result in the structure in itself being designed for heavier loads as compared to a lighter wall. This in turn would require more materials such as steel and concrete in the structure. These materials are high in embodied energy and consume significant amounts of water. Additionally, lighter materials have less embodied energy built in through transportation.
- **Recycled components**: Virgin raw materials usually rely on mining of non-renewable resources that are depleting at a fast rate and are responsible for high carbon emissions during their production. Recycled materials reduce the quantity of virgin raw materials needed while ensuring that smaller quantities of industrial or construction and demolition waste are generated. Industrial waste materials such as fly ash and gypsum are already used in brick production through some technologies. The guidelines of the Central Public Works Department (CPWD) titled *Sustainability Index and Guidelines for Materials (March 2014)* mention recycled content as an important criterion in choosing building materials.
- **Recyclability component**: It is important to assess if the material or the various components of the technology would be utilizable or would end up as waste once the life cycle of a building ends.
- **Market presence**: A higher number of production centres in the country would ensure better market penetrability and require less energy to transport the material, thus cutting down on emissions and transportation costs.
- **Imported components**: Any material not produced in the country will have to travel longer distances to reach the destination. This leads to high embodied energy. Locally produced material will promote the local economy and reduce transportation emissions.

This limited exercise essentially brings out how material attributes will have to be further understood for sustainable walling assembly and material choices in buildings. The study has added more sub-attributes to assess materials in terms of sustainability. Such an assessment will have to be taken forward.

Table 2: Sub-attributes for evaluation of materials and emerging technologies BMTPC vs CSE

Attribute	BMTPC sub-attributes	Sub-attributes added by CSE
Thermal comfort	Thermal resistance	Thermal transmittance
		Presence of thermal bridges
Functionality of a material	Design flexibility	Ease of modification
	Restriction on number of floors	
	Service life and durability	Height limitations
	End-user-friendliness	
Constructability	Simplicity in execution and versatility	Special equipment needed
	Design compatibility	
	Foundation type	Labour needed
	Skilled labour	
	Equipment	
	Construction safety	Ease of non-repetitive design
	Temporary services requirement	
Sustainability	Eco-friendly construction	Thickness of walling assembly for G+9 structure
		Plaster requirement
		Mass of walling assembly per m^2
	Embodied energy	Recycled components
		Recyclability component
		Market presence
		Imported components

Source: CSE analysis based on Multi-Attribute Evaluation Methodology for Selection of Emerging Housing Technologies

CHAPTER 4: ENERGY EFFICIENCY

The next big question is the energy performance of buildings based on their material choices, walling assembly and architectural design. We have considered the base case scenario of a sample affordable housing in Telangana and assessed its performance in terms of energy use and daylighting, based on the standards suggested by ECBC-R and NBC, 2016. The findings are discussed in this section.

The analysis revealed that RETV—i.e., value of heat gain in the units through non-opaque and opaque building elements—is greater than the required 15 W/m^2 as per ECBC-R. It complies with the standard only when oriented in the north–south directions, at 14.3 W/m^2. Daylighting analysis has revealed that under the current design, only 15 per cent of the area is day-lit.

ECBC-R and BMTPC's Technology Sub-mission anticipate that the country will undergo a transition and replace conventional development practices. There is an enormous potential for Telangana to leapfrog this transition and embed environmental sustainability, energy efficiency and thermal comfort in affordable housing development from the beginning.

ASSESSMENT OF ENERGY EFFICIENCY

Under PMAY, a massive stock is being built and at a rapid pace. Inefficient design and inappropriate choice of materials can put the stock to intensive energy use due to compromised thermal comfort. Further, the target clientele of this housing stock is the lower income strata. The cost of this elevated energy use can be unaffordable for them. Therefore, design and construction material choices to maximize thermal comfort and minimize energy use must be prioritized.

Operational energy use in buildings is a function of building design (including orientation and envelope) and materials used. Building orientation and form guides the wind, light and sun penetration in it. Building envelope plays a key role in the determination of the amount of daylight penetration and heat transfer in and out of the building. Building envelope includes the roof, walls, windows and doors that are exposed to the exterior. Heat transfer through the roof and walls is governed by the materials used. Therefore, thermal transmittance properties of materials is another factor determining thermal comfort in buildings. BEE acknowledges that energy demand in buildings can be cut down by up to 40 per cent by designing an efficient envelope.

This study uses one project of the 2BHK scheme as an example to understand the compliance requirements under ECBC-R and areas of intervention to improve energy performance of a site (see *Box: ECBC-R and operational energy*). An existing GHMC project site, located in the northern region of Greater Hyderabad Metropolitan Area, has been considered for the purpose of this evaluation. The project has identical blocks, which are oriented in only two directions, north–south and east–west. The project is simulated in four different orientations namely: North–south (0°), northeast–southwest (45°), east–west (90°) and northwest–southeast (135°).

Calculation of Visible Light Transmittance

There are three typical windows (W1, W2, and W3) in each dwelling unit of the sample case exposed to the ambient and two ventilators in the bathroom and toilet. A typical floor has four W1 windows, 16 W2 windows, 12 W3 windows, 12 D2 doors for balconies and 24 ventilators exposed to the ambient. Total non-opaque area is calculated using dimensions of the windows, doors and ventilators in the block (see *Table 3: Window and openable area details*). Total exposed surface area of a typical floor in a block has also been calculated (see *Table 4: Exposed surface area details*).

Table 3: Window and openable area details

Windows, ventilators and doors		Dimensions		Area (m^2)
Type	Number	Width (m)	Height (m)	
W1	4	1.5	1.2	7.2
W2	16	1.2	1.2	23.4
W3	12	0.9	0.9	9.72
D2	12	0.75	2.1	18.9
V	24	0.6	0.6	8.64
Total non-opaque area				67.5

Source: CSE computation

Table 4: Exposed surface area details

Façade	Total wall length exposed to ambient (m)	Total wall height exposed to ambient (m)	Gross wall area (m^2)
North	11.1	3	35.1
South	11.1	3	35.1
East	85.2	3	255.7
West	71.5	3	214.6
Total exposed area (excluding roof)			540.5

Source: CSE computation

The total non-opaque and exposed surface areas deliver 12.4 per cent or 0.144 of WWR in the site (since the site has identical blocks). According to ECBC-R, minimum VLT for WWR ≤ 0.30 is 0.27. The glass used in this case has a VLT of 0.85. Therefore, it complies with the daylighting requirement as suggested by ECBC-R.

Openable window-to-floor area ratio

Openable window area is the number of openings that allow ventilation in a dwelling unit. The non-opaque area of a typical floor of a building is 67.5 m^2, whereas the carpet area is 576.35 m^2 (see *Table 3: Window and openable area details*). This gives an openable window-to-floor area ratio (WFRop) of 11.7 per cent, which is lesser than the recommended WFRop for Hyderabad (composite climate), i.e., 12.5 per cent.

ECBC-R AND OPERATIONAL ENERGY

ECBC-R is the key regulatory tool to move housing stock towards thermal comfort and reduced energy use.[11] Notified in December 2018, the code is applicable to all residential buildings and residential parts of 'mixed land-use projects', both built on a plot area of larger than or equal to 500 m^2. However, states and municipal bodies may reduce the plot area in their area of jurisdiction.

ECBC-R has been prepared to set minimum building envelope performance standards to limit heat gains for cooling-dominated climates and to limit heat loss for heating-dominated climates, as well as for ensuring adequate natural ventilation and daylighting potential. The code also pushes for desired orientation of buildings which implies that better-oriented buildings find it easier to comply with certain aspects of the code. This is a welcome move as it promotes a more rigorous approach to passive design in architecture.

Building envelope design

ECBC-R mentions three aspects by which energy consumption can be reduced in a residential building.

Aspect 1: Envelope

Building envelope is majorly responsible for heat gains or losses from a building. The net heat gain rate through the building envelope divided by the area of building envelope (except roof) gives the Residential Envelope Transmittance Value (RETV) in Watt per square metre. The maximum value for each climate zone, except cold, is suggested as 15 W/m^2. Thermal transmittance through the roof is given separately as 1.2 W/m^2 and for cold climate zone as 1.8 W/m^2.

The RETV formula takes into account the following:

- Heat conduction through opaque building envelope components (wall, opaque panels in doors, windows, ventilators, etc.)

  Heat conduction through opaque building envelope components is dependent on many factors. The building envelope should be optimized in a way that ensures adequate daylight and ventilation in the building while minimizing heat gain or loss.

  Once this is done, the properties of the materials used come into play, thermal transmittance is a measure of how much heat a material allows to travel. Aso known as the U-Value, it is the heat

Residential Envelope Transmittance Value analysis

The study calculated RETV considering four identified directions and heat gain through non-opaque and opaque building elements (see *Table 5: RETV analysis of the sample project*). The walls are made of 150 mm thick fly ash concrete bricks, which have a U-value of 1.5 W/m^2 K. It is noteworthy that transmission gains are substantial from opaque building elements.

transmission in unit time through unit area of a material or construction and the boundary air films, induced by unit temperature difference between the environments on either side. Unit of U-value is W/m^2K. The U-value for a wall, roof or glazing indicates its ability to transfer heat through conduction.

- Heat conduction through non-opaque building envelope components (like transparent or translucent panels of windows, doors and ventilators)
- Solar radiation through non-opaque building envelope components (transparent or translucent panels of windows, doors, ventilators, etc.)

  Solar radiation through non-opaque components can be modified with the properties of the materials, however, this can also change with changes in the positioning and sizes of window shading devices. An indicator for this is the Solar Heat Gain Coefficient (SHGC) equivalent.

SHGC equivalent: SHGC equivalent is the SHGC for a non-opaque component with a permanent external shading projection. It is calculated by multiplying the External Shading Factor (ESF) with the SHGC of non-shaded non-opaque component.

Aspect 2: Openable window-to-floor area ratio
Openable window-to-floor area ratio determines adequate natural ventilation. It is suggested to be minimum 10 per cent for hot and dry climate zone, 16.66 per cent for warm and humid, 12.50 per cent for composite or temperate and 8.33 per cent for cold climate zone.

Aspect 3: Visible Light Transmittance
Visible Light Transmittance (VLT) is the amount of natural light entering from the non-opaque building envelope components. An express minimum VLT ensures adequate daylighting, thereby reducing energy requirement for artificial lighting. It is expressed in relation to a window–to–wall ratio of a building.

Window-to-wall ratio (WWR) is the ratio of the non-opaque building envelope components area to the envelope area (excluding roof) in a dwelling unit. It is important to optimize the WWR as higher WWR can lead to excess daylight in the spaces as well as increased heat gain inside buildings. Less WWR can result in loss of sufficient daylight in areas as well as reduction in natural ventilation in the building.

ECBC-R advises that:
a) With the WWR $\leq$ 0.15, minimum VLT should be 40 per cent
b) The WWR in residential buildings may not exceed 0.40.

The analysis reveals that RETV for three orientations at the sample project is greater than 15 W/m^2, making the project non-compliant with the requirements of ECBC-R. However, it was observed that north–south orientation delivers the lowest RETV followed by northeast–southwest and northwest–southeast, with the worst being the east–west orientation (see *Table 6: Orientation-wise RETV results for the sample project*).

Table 5: RETV analysis of the sample project

	Orientation			
	East–west (0^0)	Northwest–southeast (45^0)	North–south (90^0)	Northeast–southwest (135^0)
Envelope area (m^2)	493.7			
Non-opaque transmission gain (W)	1,973.8	1,736.4	1,387.9	1,733.8
Non-opaque radiation gain (W)	2,351.5	2,147.5	1,710.8	2,024.8
Opaque transmission gain (W)	4,234.7	4,227.0	3,953.9	4,225.8
Total transmission gain (W)	8,560.0	8,110.9	7,052.5	7984.4
RETV (W/m^2)	17.3	16.4	14.3	16.2

Source: CSE computation

Table 6: Orientation-wise RETV results for the sample project

Building orientation	Calculated RETV	Required RETV	Compliant?
	W/m^2		
North–south	14.3	<15	Yes
Northeast–southwest	16.2		No
East–west	17.3		No
Northwest–southeast	16.4		No

Source: CSE analysis

Findings of all the evaluations have been summarized in *Table 7: Summary of different analyses to check compliance with ECBC-R).* The sample housing project complies with VLT requirements but there is a palpable need and opportunity for improvement when it comes to openable window-to-floor area ratio and RETV.

Table 7: Summary of different analyses to check compliance with ECBC-R

Description	Standard requirement	Value in the sample project	Whether complaint with ECBC-R
Window-to-wall ratio	< 70 per cent	9.8 per cent	Yes
Visible Light Transmittance	> 0.27	0.85	Yes
Openable window-to-floor area ratio	12.5 per cent	11.7 per cent	No
RETV	15 W/m^2	14.3–17.3 W/m^2	No

Source: CSE analysis

RETV ANALYSIS WITH ALTERNATIVE MATERIALS

The study has further simulated the sample case with alternative materials compiled by BMTPC and conventional burnt clay brick to understand their compliance with ECBC-R, if used. In order to calculate their RETV, U-values have been selected (see *Table 8: U-value of alternative materials promoted by BMTPC*).

Table 8: U-value of alternative materials promoted by BMTPC

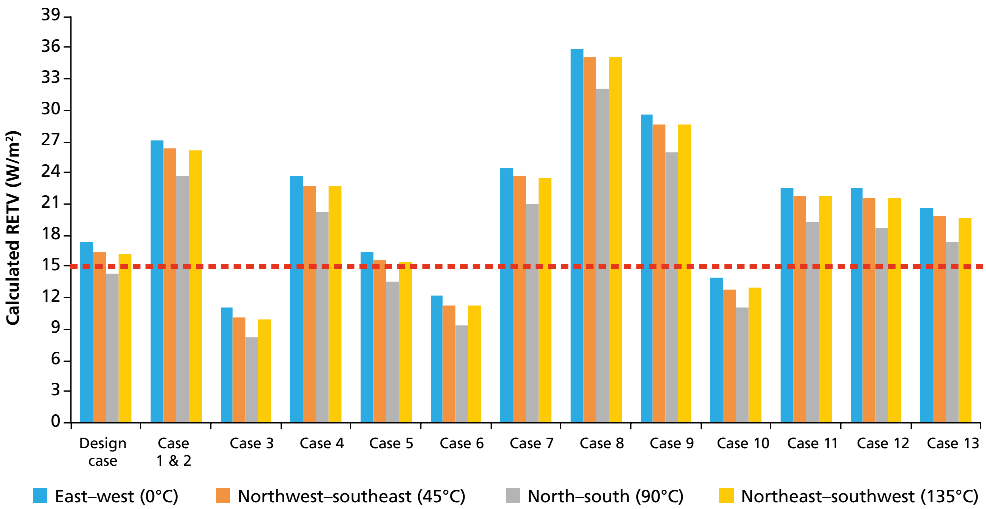
Case number	Description of exterior walling material	U-value (W/m^2K)
0	Design case—150 mm fly ash brick	1.5
1	Monolithic concrete construction using plastic–aluminium formwork	3.36
2	Modular tunnel form	3.36
3	Insulating concrete form	0.32
4	Lost-in-place formwork system—plaswall panel system	2.70
5	Lost-in-place formwork system—plasmolite	1.34
6	Advanced building system—emmedue	0.52
7	Glass fibre reinforced gypsum panel system	2.85
8	SRPL building system (Wafflecrete)	5.03
9	Pre-cast large concrete panel system	3.81
10	Industrialized 3-S system using cellular light-weight concrete slabs and pre-cast columns (with 150 mm AAC blocks for exterior walling)	0.87
11	Walltec Hollowcore concrete wall	2.50
12	Compressed stabilized earth blocks (CSEB)	2.47
13	Solid burnt clay brick	2.13

Source: ECBC-R, 2018

On being used in exterior walling and when oriented in four different directions, how the materials (or cases) perform or what RETV is yielded is demonstrated in *Graph 9: RETV analysis results of alternative materials promoted by BMTPC*.

The analysis reveals that very few materials are able to deliver desirable RETV, while some deliver it only in specific orientations. The conventional and widely accepted burnt clay brick is also not able to deliver good RETV. The scenario establishes two facts; firstly, that the building orientation interplays with material to deliver different RETVs. Secondly, there is an opportunity to work on the interplay between design and materials to arrive at mass housing stock that is thermally comfortable and uses less energy.

Graph 9: RETV analysis results of alternative materials promoted by BMTPC



DAYLIGHTING ANALYSIS

ECBC-R guidelines do not necessarily ensure good daylighting in all spaces of a residential area. The calculation only takes into account exposure of windows and not the entire exterior of a building or the thermal property of the materials used. Rooms or spaces that do not have a window or a single wall exposed to the exterior are not accounted for. As a result, the layout might demonstrate compliance with VLT values even when some spaces might not have daylight penetration at all. This concern has been demonstrated using a daylighting analysis.

The analysis has been carried out as per the requirement for a daylight factor under the National Building Code (NBC). The daylight simulation considers two scenarios:

Case 1 : Building is not shaded by any other building in its proximity

Case 2 : Self-shading of buildings due to close proximity as per the project layout

Ecotect software has been used to build the daylight model and Radiance tool to simulate it. Only the first floor has been modelled for the simulation as it represents the worst case scenario in terms of available light. The simulation reveals that the day-lit area is 47 per cent of the total living area in the project when the building is not shaded by any other building. Wherever the buildings are mutually shading each other, day-lit area is a mere 15 per cent. However, the design still delivers deceptively good VLT as per the ECBC-R. This concern can be worked at as a shortcoming in ECBC-R and steps taken at the state level so that such anomalies do not recur.

CHAPTER 5: THERMAL COMFORT

ICAP has mooted the idea of thermal comfort for all. It has highlighted the need for thermally efficient built spaces to keep the requirement for active cooling in check, especially in affordable housing. We have explored this at the sample affordable housing in Telangana based on the standards suggested by NBC, 2016.

The current design and material approach is able to deliver thermal comfort for 75–82 per cent of the time in a year. This analysis was carried out using simulations considering the thermal comfort range to be 18–32°C (as per NBC, 2016).

NBC, 2016 defines criteria for thermal comfort through three indices. One of them is the Adaptive Thermal Comfort Model. This model provides the design criteria indoor conditions for a building depending on its operation, i.e., whether it is naturally ventilated, mixed-mode or air-conditioned. Therefore, it uses operative temperature in the buildings in modelling.

For natural ventilated buildings, the model considers that occupants thermally adapt to the outdoor temperature of their location, which varies seasonally. It uses the 30-day outdoor running mean air temperature to arrive at the indoor operative temperature. The operative temperature is the average of air (dry bulb) temperature and mean radiant temperature. The indoor operative temperature range is the temperature range within which a majority of the occupants are likely to feel 'neutral' towards their indoor thermal environment, according to the model.[12]

This higher indoor operative temperature threshold for Hyderabad is 32°C, within which occupants will be thermally comfortable.[13] But this model does not delve into the relationship with natural ventilation that is crucial in residential buildings, particularly those meant for affordable housing.

The second index for thermal comfort is Tropical Summer Index (TSI). TSI is the temperature of calm air, at 50 per cent relative humidity, which gives a thermal sensation similar to the native or outdoor environment. It takes into account 'wet bulb' temperature, globe temperature and wind speed. Relative humidity at 50 per cent is taken as a representative intermediate value for the prevalent humidity conditions in India.[14]

The thermal comfort of a person lies between TSI values of 25°C and 30°C, according to NBC. It is tolerable between 30°C and 34°C (TSI), above which it gets too hot for the occupant. Hot and humid climates in the country require air movement or wind for a person to feel comfortable indoors. NBC has defined the appropriate wind speed for respective dry bulb temperature and relative humidity (see *Table 9: Desirable wind speeds for thermal comfort*).

Table 9: Desirable wind speeds for thermal comfort

Dry bulb temperature (^{0}C)	Relative humidity (per cent)						
	30	40	50	60	70	80	90
28	a	a	a	a	a	a	a
29	a	a	a	a	a	0.06	0.19
30	a	a	a	0.06	0.24	0.53	0.85
31	a	0.06	0.24	0.53	1.04	1.47	2.1
32	0.2	0.46	0.94	1.59	2.26	3.04	b
33	0.77	1.36	2.12	3	b	b	b
34	1.85	2.72	b	b	b	b	b
35	3.2	b	b	b	b	b	b

*Note: Values in **bold green** are wind speeds in m/s*
a: Comfortable even at zero value
b: Higher wind speeds will not provide thermal comfort but have been observed in practice
Source: National Building Code, 2016

Looking at the range defined by the NBC, at 30°C dry bulb temperature, wind speed in the range of 0.06 m/s to 0.85 m/s for relative humidity from 40 per cent to 90 per cent can achieve thermal comfort by ventilation. As per NBC, a fan is required to achieve a wind speed above 2 m/s in a room. With this logic, 32°C dry bulb temperature category has a wider range of combinations for relative humidity and wind speed. Hence, it was used for simulation of thermal comfort in our study.

The 32°C dry bulb temperature coincides with the threshold for thermal comfort for Hyderabad as per the Adaptive Comfort Model. The fact that the model uses operative temperature is not of much concern, as in a naturally ventilated building, dry bulb temperature and mean radiant temperature are generally comparable.

Keeping these factors (guided by the NBC) in mind, the logic used in the thermal comfort simulation is:

- Thermal comfort system: Natural ventilation with ceiling fans only
- Thermal comfort threshold: 32°C dry bulb temperature with upto 80 per cent relative humidity
- National ventilation (windows are open when):
    a. Indoor temperature is higher than outdoor temperature
    b. Night-time during summers, to allow purge
    c. Air changes are under 10 per hour, beyond which it is too windy

Simulation of the current design with alternative materials promoted by BMTPC establishes that a few materials do meet the RETV requirements. Compressed Stabilized Earth Blocks (CSEB), AAC blocks, insulating concrete forms, extruded polystyrene-shortcrete panel system and fibre cement board-concrete panel system deliver thermal comfort for more than 82 per cent of a year. Interestingly, materials such as CSEB and fibre cement board-concrete panel system do not perform at par with the RETV standards in ECBC-R, but they manage to provide thermal comfort. The analysis reveals that the current standards do not factor in the role of thermal mass in thermal comfort; a gap that needs to be addressed.

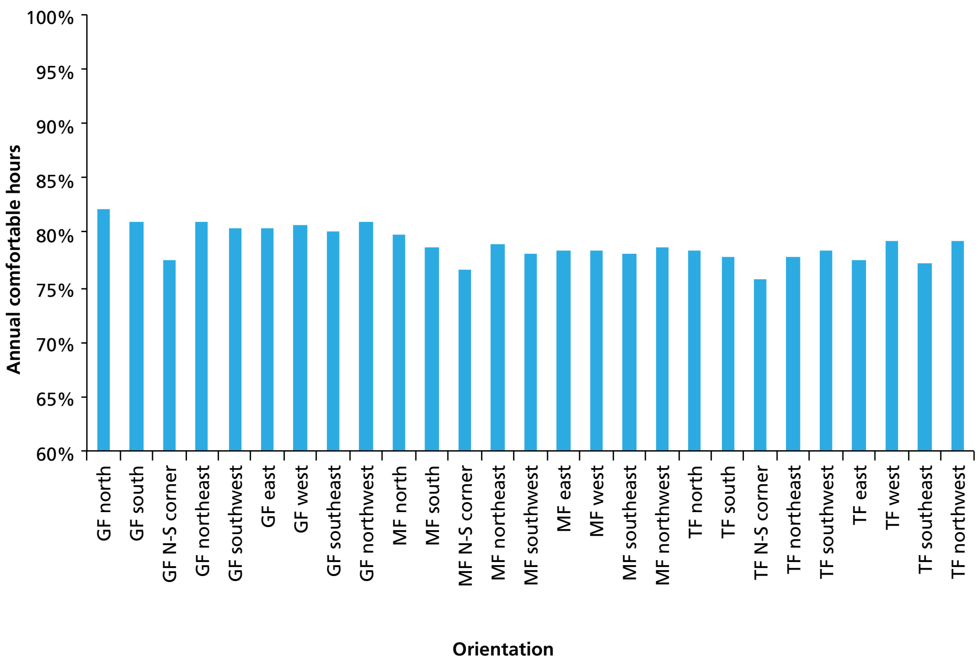
An analysis using a building-wide energy and thermal simulation approach has been conducted to calculate Energy Performance Index (EPI) of a typical building. The analysis also estimates indoor comfort conditions achieved in dwelling units facing different directions.

Different orientations have been tested by rotating the design by 45°, 90° and 135°. The layout has been simulated using various software and data inputs, including building parameters like construction materials, operation and occupancy schedules, internal lighting and equipment loads, natural ventilation logic and indoor thermal comfort in dwelling units, are calculated based on these factors. A few important assumptions used in the simulation (in addition to the ones already mentioned), are as follows:

- Interior lighting load: 5 W/m^2
- Interior equipment load: 10 W/m^2
- Number of occupants per dwelling unit: Four

The results have been plotted in *Graph 10: Results of the thermal comfort analysis*.

Graph 10: Results of the thermal comfort analysis

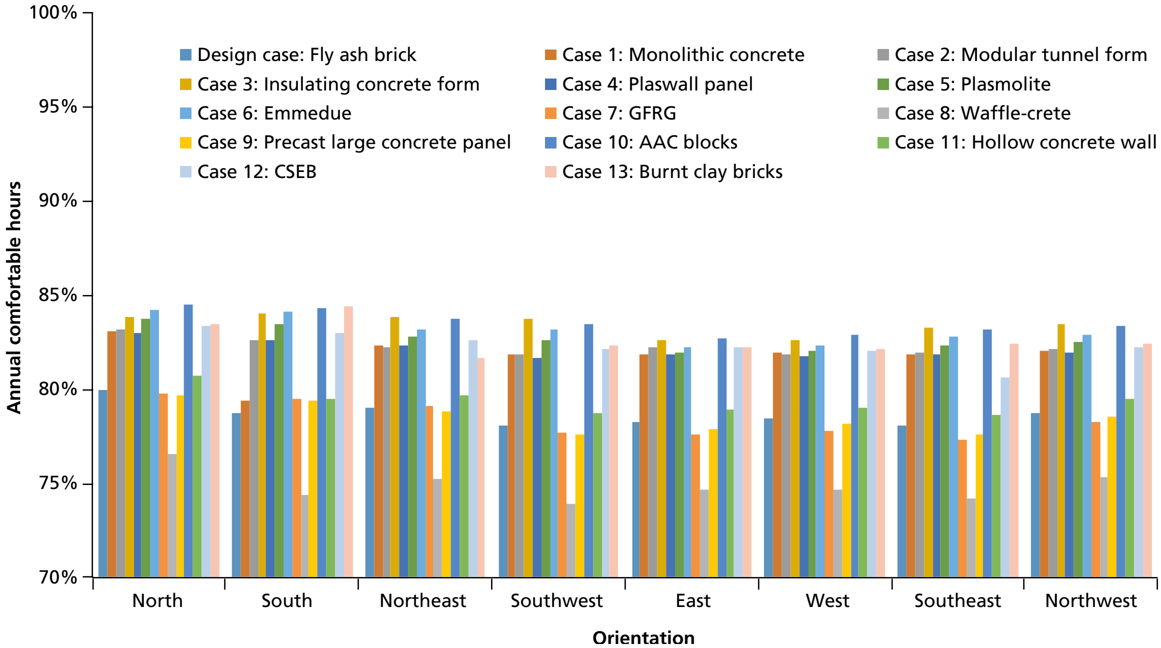


Source: CSE analysis

The existing design will achieve thermal comfort for a minimum 75 per cent period of the year to a maximum of 82 per cent period of the year. The simulated results also show that maximum thermal comfort will be achieved in units oriented in the north–south directions. These results are consistent with the calculated RETV where buildings with north–south orientation deliver the lowest RETV.

Further, the project model was simulated with variations in alternative materials and construction technologies as suggested by BMTPC, for comparison. The results have been compared for a central dwelling unit on an intermediate floor in the eight cardinal directions for each technology. Thirteen unique simulations have accrued (see *Graph 11: Results of thermal comfort analysis by changing materials*).

Graph 11: Results of thermal comfort analysis by changing materials



Source: CSE analysis

The analysis revealed that a 150 mm thick AAC block and insulating concrete form perform the best in terms of thermal comfort, while wafflecrete, glass fibre reinforced gypsum (GFRG) and precast large concrete panels are the worst performing technologies as per the native climate.

A comparison of the two analysis—RETV and thermal comfort—conducted for alternative materials reveals that a few materials, such as CSEB and solid burnt brick, which perform average in terms of RETV are still able to achieve good results in terms of thermal comfort. The reason can be attributed to their respective thermal mass.

For example, a 150 mm thick fly ash concrete brick has a superior thermal transmittance or U-value of 1.5W/m^{2}K when compared to that of a CSEB (with a U-value of 2.47W/m^{2}K), but CSEB performs better in terms of providing thermal comfort. CSEB has better thermal mass than a fly ash concrete brick. Technologies such as wafflecrete and GFRG perform the worst because they have neither high thermal mass nor low thermal transmittance. These results make materials with high thermal mass like CSEB a good option for rural housing in Telangana that are ground-level structures.

This leads us to the biggest learning: RETV in ECBC-R is not adequately representative of thermal comfort. There is opportunity to improve the code and incorporate the role of thermal mass of materials.

For a naturally ventilated or non-air conditioned building typologies (as most affordable housing projects are), focussing only on materials with thermal insulation properties may not be very effective in achieving thermal comfort. Walling assemblies combining materials with high thermal mass and insulation can result in better thermal comfort and energy performance and need to be explored.

Indian Standard SP:41 (S&T) (about performance of walling) states that the time taken to transfer heat increases by upto three times when the insulation is placed on the outside of the regular masonry external wall compared to when it is placed on the inside of the same wall. This means the sequence of the layers of materials makes a difference in the thermal comfort of an occupant, although U-value does not change. These combinations need to be explored in the context of affordable housing in different climate zones.

The complete methodology adopted for this study has been described in *Figure 2: Methodology adopted to check the performance of ECBC-R parameters, daylighting and thermal comfort.*

NEED A BENCHMARK FOR THERMAL COMFORT

State governments need to identify and set benchmarks for thermal comfort and link it with supply.

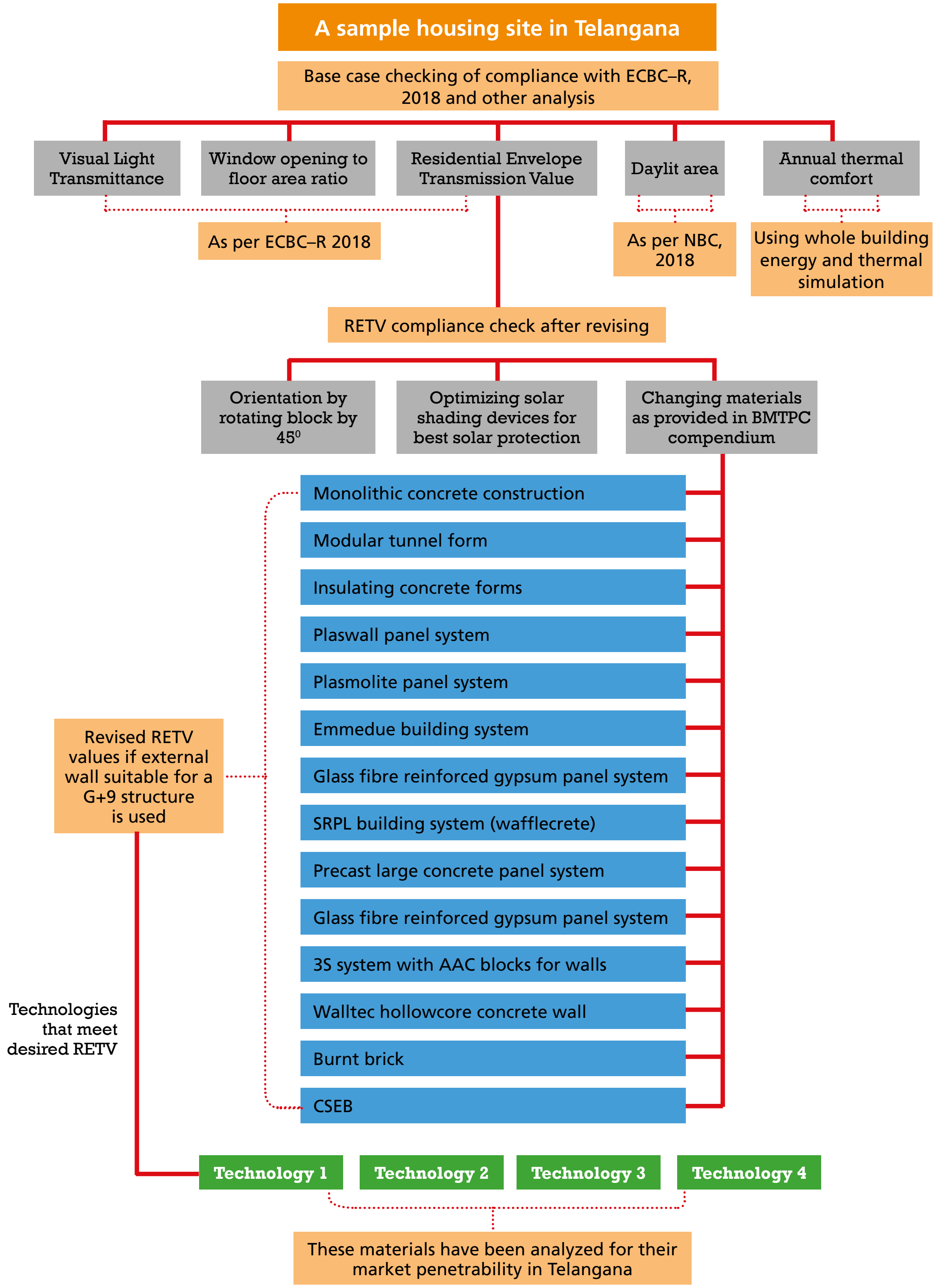
ECBC-R suggests benchmarks for energy efficiency and makes compliance mandatory. Therefore, governments need to check if the currently available or used materials in mass housing schemes are able to meet the standards given in ECBC-R. Further, the combination of materials and design needs to be checked for thermal comfort. This scoping study has assessed a sample housing project in a composite climate zone with high-rise typologies and a fixed layout. More studies need to be carried out for different climate zones, broad typologies and a representative layout adopted in state-level mass housing schemes. Continuing the work in Telangana, CSE is assessing different typologies such as G+3 or plotted independent houses in the climate zones incidental in the states of Telangana and Karnataka as a next step.

The study will be able to assess operational energy use in buildings as guided by design and materials. It will also enable an evaluation of life-cycle performance of materials with regard to environment. The assessments will then yield materials and design that achieve thermal comfort, and reduce energy use and environmental impact of mass affordable housing.

The results of the study will essentially inform the existing regulatory tools with a view to place safeguards for thermal comfort and environmental sustainability. For instance, operational energy is regulated by building bye-laws via provisions on envelope design, choice of materials and their thermal performance. Similarly, lifecycle performance of materials conveyed by emissions intensity, circularity, material use intensity (single or multiple materials) can be addressed in Environmental Impact Assessment and ECBC-R.

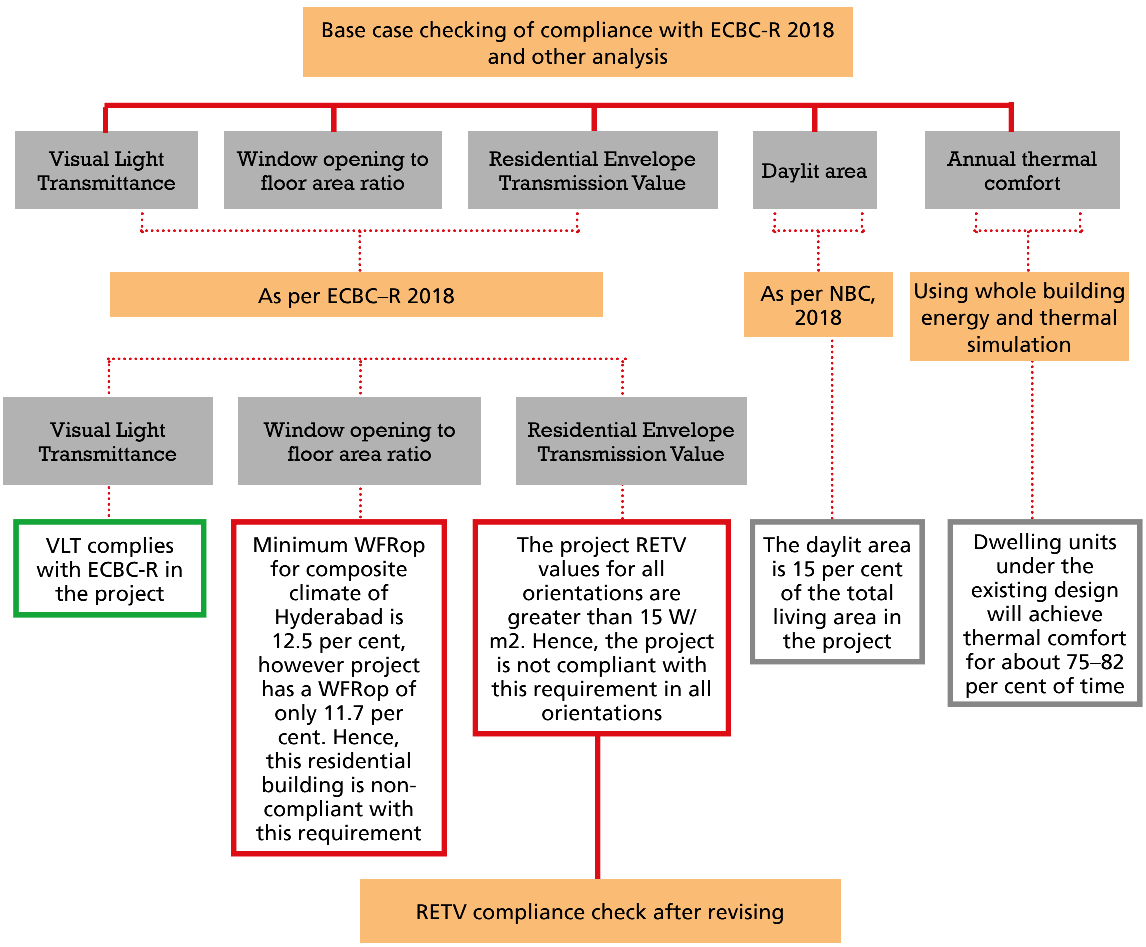
Identified high-performing materials and design elements that enable compliance with ECBC-R and contribute towards thermal comfort may have a higher cost implication when used in mass housing schemes. State governments will also need to work towards mechanisms to offset this additional cost. For instance, cross-financing under PPP by providing extra FAR or viability gap funding. Such implementation mechanisms can be comprehensively addressed in state mass housing schemes or PPP toolkits.

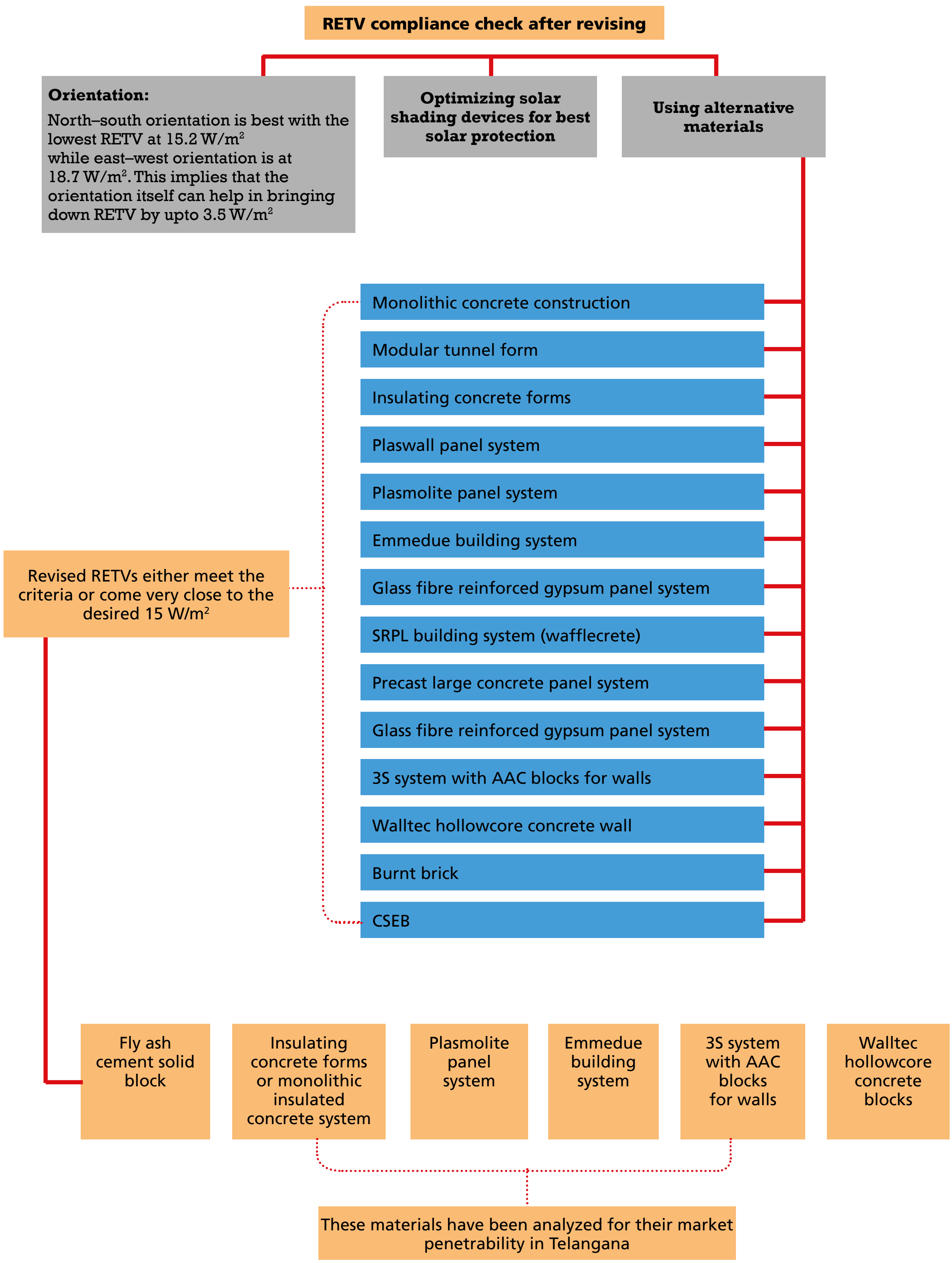
Figure 2: Methodology adopted to check the performance of ECBC-R parameters, daylighting and thermal comfort



Study summary

D. Pochampally, 2BHK affordable housing site, Telangana




RETV compliance check after revising
Orientation:
North–south orientation is best with the lowest RETV at 15.2 W/m²
while east–west orientation is at 18.7 W/m². This implies that the orientation itself can help in bringing down RETV by upto 3.5 W/m²
Optimizing solar shading devices for best solar protection
Using alternative materials
Monolithic concrete construction
Modular tunnel form
Insulating concrete forms
Plaswall panel system
Plasmolite panel system
Emmedue building system
Glass fibre reinforced gypsum panel system
SRPL building system (wafflecrete)
Precast large concrete panel system
Glass fibre reinforced gypsum panel system
3S system with AAC blocks for walls
Walltec hollowcore concrete wall
Burnt brick
CSEB
Revised RETVs either meet the criteria or come very close to the desired 15 W/m²
Fly ash cement solid block
Insulating concrete forms or monolithic insulated concrete system
Plasmolite panel system
Emmedue building system
3S system with AAC blocks for walls
Walltec hollowcore concrete blocks
These materials have been analyzed for their market penetrability in Telangana

Using alternative materials

- Monolithic concrete construction
- Modular tunnel form
- Insulating concrete forms
- Plaswall panel system
- Plasmolite panel system
- Emmedue building system
- Glass fibre reinforced gypsum panel system
- SRPL building system (wafflecrete)
- Precast large concrete panel system
- Glass fibre reinforced gypsum panel system
- 3S system with AAC blocks for walls
- Walltec hollowcore concrete wall
- Burnt brick
- CSEB

The result of thermal comfort achieved have been analyzed

The inference drawn from the comparison is that in non-air conditioned building typologies (typical for affordable housing), thermal mass plays an important role in achieving thermal comfort. RETV calculation in ECBC-R does not factor in the role played by thermal mass, hence a provision for incorporating the role of thermal mass of a material should be made

CHAPTER 6: SUMMARY OF ISSUES AND THE WAY FORWARD

Based on this scoping study, the following comments are being made in the hope that they will help to achieve improvements in the sector, both in terms of liveability of the new housing stock, as well as sustainability.

The combined mandate of energy efficiency and thermal comfort to govern affordable housing sector: Currently, there is a logical convergence of two big ideas—planning and designing for energy efficiency as well as for thermal comfort. Both they need to be aligned for best results. This co-benefit is now possible with the combined policy mandate of ECBC-R, that promotes energy efficiency, and ICAP, for adaptive thermal comfort standards and to ensure thermal comfort for all, including in the affordable housing for LIG households.

In addition, the Technology Sub-Mission; Model Building Bye-laws 2016; National Building Code, 2016; Environmental Impact Assessment Notification, and other such policy and legislative interventions will guide upcoming housing stock with regard to environmental sustainability, energy efficiency and thermal comfort. This presents an opportunity to promote wider penetration of climate-responsive built spaces to bring indoor temperatures within the acceptable thermal comfort band through appropriate material choices, walling assembly approaches and passive cooling to reduce cooling load. These tools have been introduced to replace conventional practices with more informed and environmentally sound techniques, for instance reduction of operational energy use by design and substitution of burnt clay bricks with alternative materials. This can mainstream environmental sustainability, reduce emissions intensity of materials, and help achieve energy efficiency and thermal comfort in affordable housing stock.

Different states have adopted PMAY guidelines in their own manner in their housing schemes. For instance, Telangana is developing housing, both urban and rural, only on government-owned land and private developers are undertaking construction at costs capped by the government. Irrespective of the models of implementation, the objective of energy efficiency, resource efficiency and decentralized services will have to be combined with the specific requirements of thermal comfort. This demands thermally efficient built spaces with reduced heat load with the help of green walling (walling assembly that addresses material and insulation needs), shading and enhanced natural ventilation. Doing so will help to reduce requirement of active cooling.

Affordable housing and energy efficiency: As part of the scoping study, we attempted to assess if the affordable housing stock being built complies with ECBC-R notified in 2018 for the residential sector. CSE established a methodology to understand how the current stock planning, layout and design internalizes thermal comfort, energy efficiency and environmental sustainability. The scoping reveals that the current design does not perform well when compared with the standards given in ECBC-R and NBC, 2016. Key findings reveal that components like heat transfer through opaque and non-opaque components of the structure as well natural day lighting do not hold up to the prescribed standards in all directions.

Various factors affect energy performance of build stock. The study takes a base case scenario of a sample affordable housing in Telangana and checks it for the openable window to floor ratio compliance, and VLT and RETV compliance. Research has established the role of orientation in bringing down RETV in the sample affordable housing scheme by comparing the RETV of the worst with the best orientation of blocks. For instance, it was discovered that north–south orientation reduced RETV by up to 17.3 per cent compared to the east–west orientation. RETV represents the heat transmittance into a building through its envelope.

The scoping has made it clear that material choices cannot be made in isolation from architectural design and layout plans. Current design and material approach is able to deliver thermal comfort for 75 per cent to 82 per cent of the total time in a year. However, this may vary from site to site. India has five climate zones and each state has adopted different housing typologies under their affordable housing schemes. There is a need to study the most representative typology in a particular climate zone.

This makes the case for a deep-dive studies for Telangana and Karnataka that together comprise of four climate zones. The study will check compliance with ECBC-R and thermal comfort delivery, hence it will be able to address operational energy use in upcoming housing stock. Accordingly, the findings will guide state building bye-laws and housing schemes for a wider and mainstream approach to energy footprints of material use and the combined strategies for material and architectural design packages to optimize energy savings and thermal comfort.

Performance of conventional and alternative materials and walling assemblies: It is also evident from the scoping that states are using alternative materials and construction technologies but primarily for speed and ease of construction to meet the target for housing units. For instance, Telangana is making shear wall structures using tunnel formwork technique and aluminium formwork technique, pre-cast concrete and AAC blocks in some of the urban projects, while fly ash concrete bricks remain dominant. The costs of these materials and technologies is a little higher than conventional construction. But these materials are not optimally combined with design to get the best results with respect to energy efficiency and comfort.

There is, therefore, a huge need for informing the adoption of alternative material and walling assembly techniques. It is also important to leverage the building material compendium of BMTPC that inventorizes materials based on a range of attributes that have bearing on efficiency, safety and comfort. If this knowledge is further combined with architectural design packages and walling assembly approaches, significant efficiency and thermal comfort gains are possible. These interventions at the state level need to be further enabled through building bye-laws.

This spotlight on material takes an integrated view of embodied energy of materials that is influenced by extraction, manufacture, transport of material, construction, demolition and refurbishment; and also walling assembly choices based on material and insulation. BMTPC promotes 24 alternative materials and construction technologies in its compendium. It had identified these technologies based on criteria such as strength, stability, fire resistance, thermal comfort, water tightness, constructability and economic viability. The walling assembly of the base case was simulated with these materials and technologies and the RETV were re-calculated. Five out of 24 material and technologies are able to achieve the desired RETV keeping the same design. These technologies are fly-ash concrete blocks (150 mm thick), insulating concrete forms, plasmolite panel systems, emmedue systems and 150 mm AAC blocks.

Comparison of ECBC-R and thermal comfort analysis for these alternative materials and technologies has revealed that RETV's reliance on U-value may not be an effective approach. U-value essentially denotes the thermal insulation properties of a material. it may not be an appropriate indicator for a naturally ventilated or non-air conditioned building typology that most affordable housing projects are. The study has shown that the materials that have an average U-value can perform better for thermal comfort than the materials which have a superior U-value. This finding calls for further research on the performance of these materials for thermal comfort and energy efficiency combined. The research will build necessary guidance to achieve the objectives of the ICAP.

This evaluation suggests there is insufficient information to understand the overall ability of these materials to deliver on the requirements pertaining to environmental sustainability, thermal comfort and emissions intensity and needs further investigation. The use of these materials and technologies can be addressed in environmental regulatory frameworks such as EIA procedures. Burnt brick is still a predominant walling material and will take time to phase out if its green potential is not realised, so this sector should improve to perform as resource-efficient and low-carbon walling material. A separate scoping study established the challenges for cleaner and sustainable brick production in Maharashtra. It will require sustained efforts and a multi-faceted approach towards effective engagement with all stakeholders, including regulatory authorities and members of *Kumbhar* community, to build a consensus and move towards sustainable and cleaner brick production in a phased manner.

The identified high-performing materials and design elements that enable and foster thermal comfort while complying with ECBC-R, may have a higher cost implication and face market hurdles when used in mass housing schemes. State governments will need to work towards mechanisms to offset this additional cost. For instance, cross-financing under PPP by providing extra FAR or through viability gap funding. Such implementation mechanisms can be comprehensively addressed in state mass housing schemes or PPP toolkits.

Network of stakeholders for enabling action: Combining planning and designing for energy efficiency as well as for thermal comfort can only be possible through multi-stakeholder engagement involved with implementation. In Telangana, support from Municipal Affairs and Urban Development Department and Housing Corporation, helped forward understanding on alternative material and formwork systems and pilot project experiences with new technologies. Roundtable engagement in Hyderabad involving technology providers active in the state and also nationally has indicated the interest among alternate technology providers to leverage the emerging market. They are trying to be market-ready from the perspective of sustainability and getting their materials tested to enable accurate assessment and faster adoption.

Based on the scoping study, this paper has been designed to influence and inform material and design guidelines for the affordable housing sector at the Central level and also inform building bye-laws and state-level guidelines. Overall, this paper addresses policy context of environmental sustainability, energy efficiency and thermal comfort. Going forward, this analysis will look at the leverages and alignments that are needed among all key policies.

ANNEXURES

ANNEXURE 1: Analysis of attributes of select materials from the BMTPC compendium

Name
Modular Tunnel form

Manufacturer
Outinord Formworks Pvt. Ltd

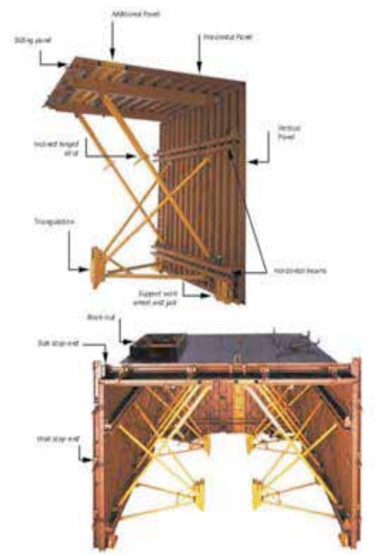
Description of Technology
Tunnel formwork is customized engineering formwork replacing conventional steel/plywood shuttering system. Two half shells when placed together form a room or cell and several cells make an apartment. In this formwork the concrete is poured thereby casting walls and slabs in a single pour. Each phase consists of a section of the structure that will be cast in one day. The phasing is determined by the program and the amount of floor area that can be covered in one day.

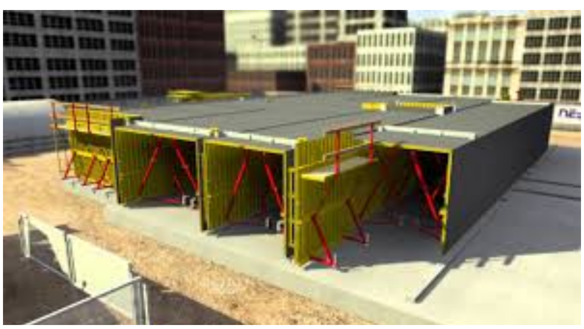
Advantages
Time taken for construction reduces.
Wastage is reduced.
Monolithic construction is better for earthquake resistance.
A single pour reduces the number of joints drastically as compared to other technologies.
Finished surface is good enough for paint or wallpaper to be applied directly.

Challenges
The formwork is imported from France as no plant is available in India.
External walls made using RCC through the technology will have a high thermal transmittance.
Modifications to these walls are very difficult as they are structural.
The formwork has little scope for variations and makes sense only if the units are repetitive.
Qualification criteria in government projects is very high such as organization turnover and experience etc.

Components of the exterior wall (in mm)	
Concrete	Steel Reinforcement
150	Embedded

Physical attributes of the external wall	
Width	180 mm
Mass	414 Kg/m^2
U-value	3.35 W/m^2 K
Imported Component	The entire formwork is imported from Lille, France
Steel Needed	NA





Recyclability component:
Concrete and Steel both are difficult to recycle.

Economic Viability in affordable housing:
Has been used in housing in affordable housing in Telangana

Structural safety: They can be used to construct high rise load bearing buildings.

Special equipment requirements:
Formwork, Concrete pouring machine, Crane

Labor used while working with technology:
15 people per shift can complete a 5000 sq.ft. construction

Notes:

The slow on-site implementation in government projects is hampering the growth of the technology in the country. The technology works best in the scenario with a time bound project but the delays in site make the technology lose its edge over conventional technologies.
There should be provisions in the policy to promote alternate technologies for all sizes of projects.
The formwork are good enough for a 1000 repetitions.

Production Penetrability: Production is currently being done in France for the Outinord formwork, however, local manufacturers are providing a similar technology in the country.

Name
Insulating Concrete Forms

Manufacturer
M/S RELIABLE INSUPACKS (P) LTD

Description of Technology
Insulating Concrete Forms (ICF) & Monolithic Insulated Concrete Systems (MICS) comprise of panels of two walls of Expandable Polystyrene (EPS) separated by a nominal distance of 150mm by hard plastic ties. These are assembled on site to hold reinforced concrete. The forms are open ended hollow polystyrene blocks which fit tightly together to form a shuttering system. Concrete is poured into the hollow space to form a continuous wall. When cured, this wall supports the structural loads from floors and roofs, and the shuttering provides thermal insulation.

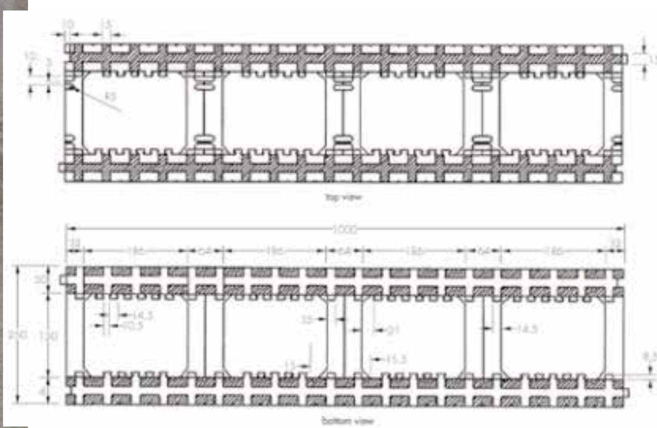
Advantages
Reduces construction time.
Reduction in labor demand.
One of the best insulation values amongst the technologies studied.
Better sound proofing qualities.
Better earthquake resistance.

Challenges
Wall Thicknesses are fixed.
Position of doors and windows are very difficult to change after construction.
Thickness of the wall is highest amongst the technologies studied.

Components of the exterior wall (in mm)					
Plaster	EPS	Concrete	EPS	Plaster	Steel Lattice
	50.8	100	50.8		-

Physical attributes of the external wall	
Width	250 mm
Mass	367.4 Kg/m²
U-value	0.32 W/m² K
Imported Component	None
Steel Needed	2.5-3kg/sq.ft.

Physical attributes of the internal wall	
Width	250 mm
Mass	367.4 Kg/m²
U-value	0.32 W/m² K
Imported Component	None
Steel Needed	2.5-3kg/sq.ft.



Recyclability component:
EPS and Concrete both cannot be recycled with ease.

Economic Viability in affordable housing:
Construction cost comes out to be 1100 Rs/ sq. Ft.

Structural safety: The walling assembly can be used to design low rise load bearing structures.

Special equipment requirements:
Trestles and Concrete pouring equipment.

Labor used while working with technology:
2 masons and 1 engineer can construct a medium sized house.

Notes:

The technology uses very minimal labor.

Thermal bridges are avoided between the two EPS panels as the plastic spacers do not puncture the EPS panels.

The thermal performance is one of the best amongst all technologies.

Production Penetrability: Currently the technology is only manufactured in Greater Noida

Name
Structural Stay in place formwork system

Manufacturer
Coffor Construction Technology Pvt. Ltd., Vadodara (Gujarat)

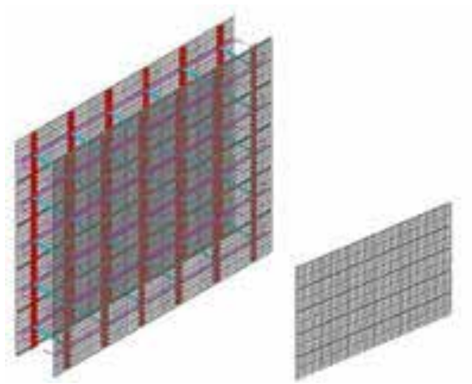
Description of Technology
It is a structural stay in place formwork system to build load bearing monolithic concrete wall structures . The formwork system comprises of two filtering grids made of rib mesh reinforced by 'C' channel vertical stiffeners. The grids are connected by rebar which act as horizontal stiffeners and connector which act as a shear link. The grids on both faces act as sacrificial formwork in which concrete is poured in-situ. After the erection of formwork panels in alignment, corners, edges of doors and windows frame are closed with rebar positioning & concrete of required grade is poured in the panels. The inside and outside walls are finished with cement plaster of suitable grade.

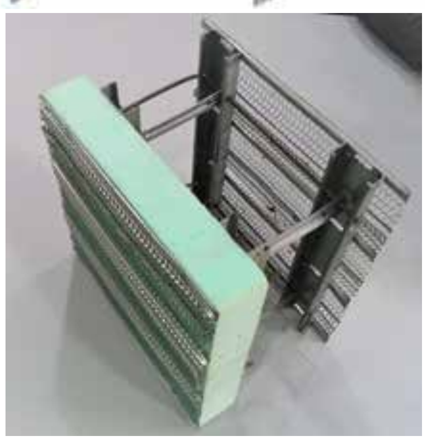
Advantages
Formwork panels require no crane hence smaller projects also feasible.
There is a 40% reduction in steel.
Foldable Formwork requires less space for transportation cutting down on transportation and embodied energy.
Variations is possible as the same formwork is not required to be repeated
Reduced Maintenance.

Challenges
The wall thicknesses are fixed.
Position of doors and windows are very difficult to change after construction.
Thermal bridges are formed in between the two sides of the metal mesh because of steel connectors.
U-value is poor and even the detail with insulation requires the EPS to be punctured hence creating thermal bridges.

Components of the exterior wall (in mm)					
Plaster	Concrete	Plaster			Steel Lattice
15	160	15			-

Physical attributes of the external wall	
Width	190 mm
Mass	450 Kg/m^2
U-value	3.29 W/m^2 K
Imported Component	None
Steel Needed	11kg/sq.m.





Recyclability component:
Concrete cannot be recycled with ease.

Economic Viability in affordable housing:

Structural safety:

Special equipment requirements:
Concrete Pouring equipment.

Labor used while working with technology:
Labor can work on site after a few hours of being trained.

Notes:

The technology is primarily used for load bearing construction.

The formwork is foldable and hence requires considerably less space to transport.

The use of technology eliminates the need for columns and beams.

Production Penetrability: Currently the technology is only manufactured in Vadodara

Name
Plaswall Panel System

Manufacturer
FTS Buildtech Pvt. Ltd., Mumbai

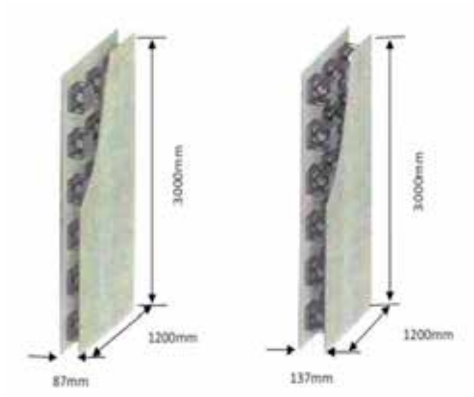
Description of Technology
It is a Lost in place formwork system, where in two fiber cement boards (FCB) of 6mm thickness are used. It uses HIMI (High Impact Molded Inserts) bonded between two sheets of FCB in situ and erected to produce a straight-to-finish wall. A monolithic structure is then created by filling the entire structure with M20 grade of concrete. Additional load capacity can be obtained by providing extra reinforcing bars and/or by increasing grade of the concrete.

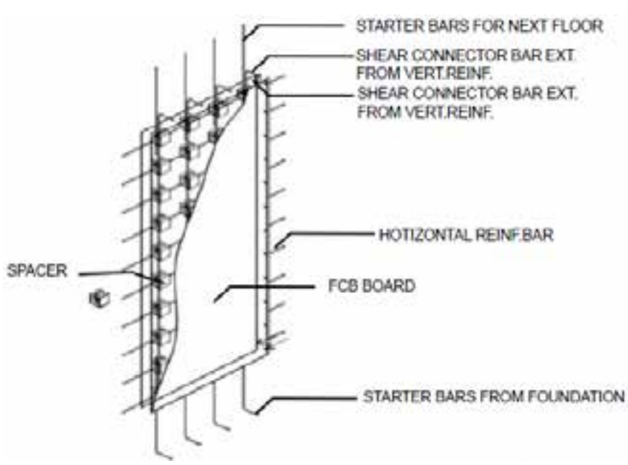
Advantages
It 30-50% faster.
Reduction in labor cost.
No on-site curing required.
Plastering is avoided.
It provides better earthquake resistance.
Crane is not required and hence can be used in small scale projects.

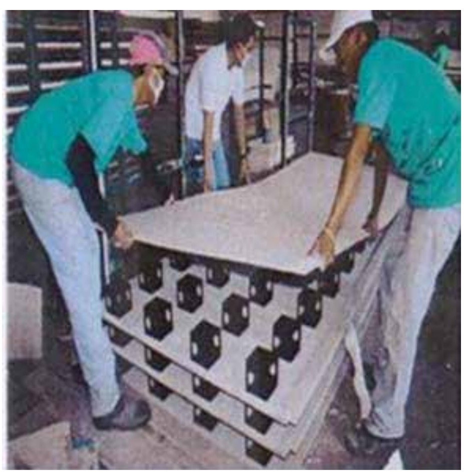
Challenges
The Fiber Cement board that is manufactured in India is brittle and of inferior quality hence it must be imported from Malaysia or Philippines.

Components of the exterior load bearing wall (in mm)			
Fiber Cement Board	Concrete	Fiber Cement Board	Plastic Spacers
6	75, 100, 125, 150, 218	6	-

Physical attributes of the external wall	
Width	230 mm
Mass	544.82 kg/m^2
U-value	2.7 W/m^2 K
Imported Component	Fiber Cement Board
Steel Needed	







Structural safety:

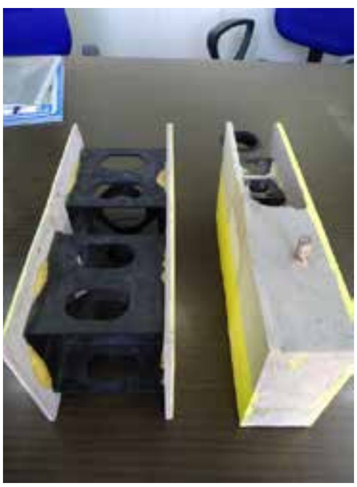
Special equipment requirements:
No special equipment required

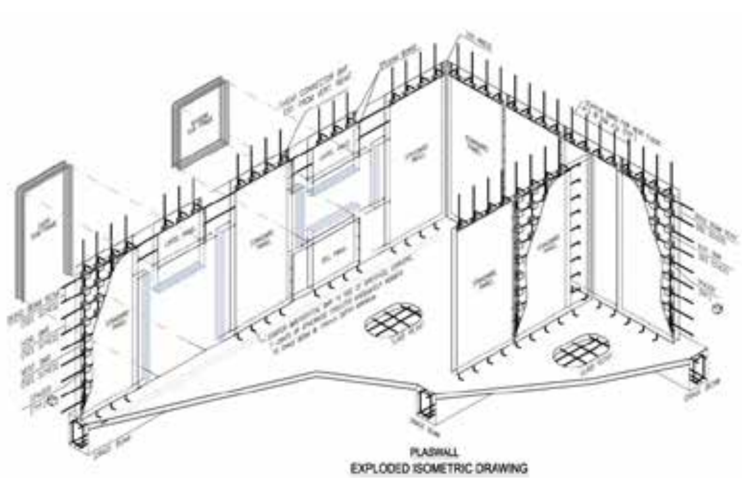
Labor used while working with technology:

Notes:

The technology saves on 4-5% of steel as compared to conventional technology.
No skilled labor is required, semi skilled carpenters will be required.
The main savings from the technology happen due to reduction in construction time and labor saving, however there is no significant saving in steel. The advantage one gets over burnt brick is that one achieves the same thermal transmittance values while saving on space. This thermal transmittance value improves as one increases the thickness of the wall.

Production Penetrability: The technology is manufactured in Mumbai but can be made in multiple places as no special equipment or machinery is required, however, the plastic spacers are locally manufactured, and the fiber cement boards are imported.





Name
Plaswall Panel System

Manufacturer
FTS Buildtech Pvt. Ltd. Mumbai

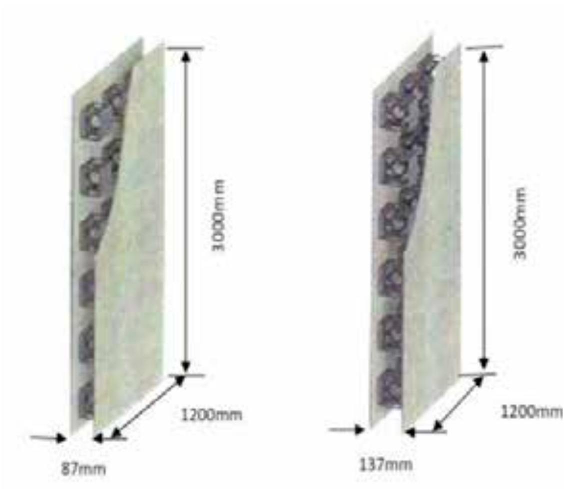
Description of Technology
It is a Lost in place formwork system, where in two fiber cement boards (FCB) of 6mm thickness are used. It uses HIMI (High Impact Molded Inserts) bonded between two sheets of FCB in situ and erected to produce a straight-to-finish wall & then the walls are filled with light weight concrete.

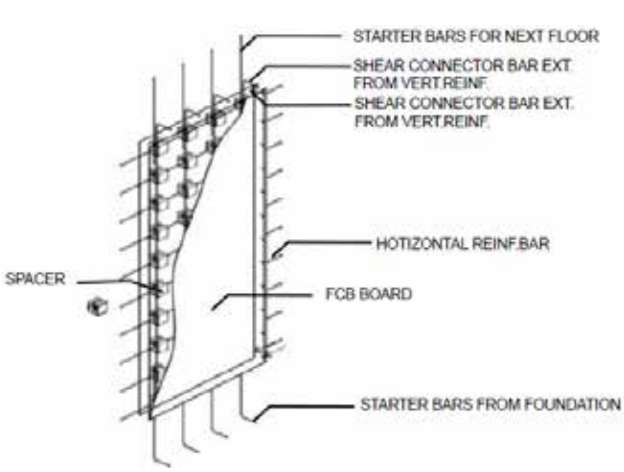
Advantages
It is 30-50% faster.
Labor requirement is reduced.
No on-site curing is required.
Plastering need is eliminated.
They have better earthquake resistance
Crane is not required and hence can be used in small scale projects.

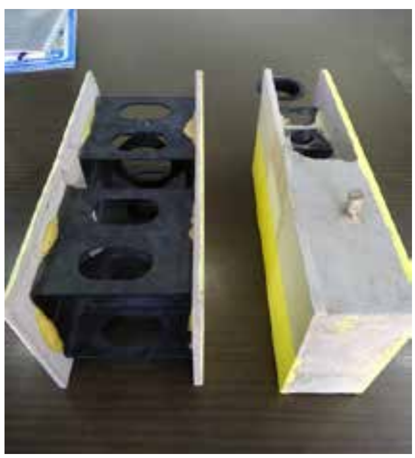
Challenges
The Fiber Cement board that is manufactured in India is brittle and of inferior quality hence it must be imported from Malaysia or Philippines.
Plasmolite technology has superior thermal resistance as compared to Plaswall but it can only be used as non-load bearing wall.

Components of the non load bearing wall (in mm)			
Fiber Cement Board	Concrete	Fiber Cement Board	Plastic Spacers
6	75, 100, 125, 150, 218	6	-

Physical attributes of the non-load bearing wall	
Width	87 mm
Mass	72.24 kg/m^2
U-value	1.33 W/m^{2}K
Imported Component	Fiber Cement Board
Steel Needed	







Recyclability component:
Concrete cannot be recycled with ease.

Economic Viability in affordable housing:

Recycled component used: The plastic spacers are made up of recycled plastic.

Special equipment requirements:
No special equipment required

Labor used while working with technology:

Notes:

The technology saves on 4-5% of steel as compared to conventional technology.

No skilled labor is required, semi skilled carpenters will be required.

The technology works in conjunction with the Plaswall technology where Plaswall is used for external walls.

Production Penetrability: The technology is manufactured in Mumbai but can be made in multiple places as no special equipment or machinery is required, however, the plastic spacers are locally manufactured, and the fiber cement boards are imported.

Name
Sismo Building Technology

Manufacturer
M K S Infosolutions, Manesar, Gurgaon.

Description of Technology
A slab and wall system, constructed without the use of columns or beams. SISMO technology walls can be used with conventional column- beam construction as well. The basic structure of the Sismo building module is steel wire lattice. At the exterior sides of the lattice, infill panels (EPS) are inserted, which is then filled with concrete.

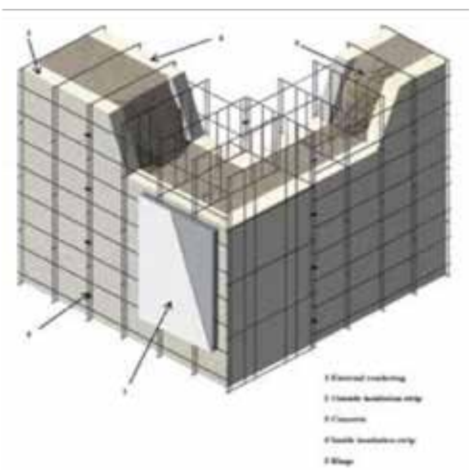
Advantages
Construction time is relatively less than red bricks.
There is a reduced labor requirement and cost.
It offers better thermal insulation.
It offers better sound proofing. qualities Better earthquake resistance

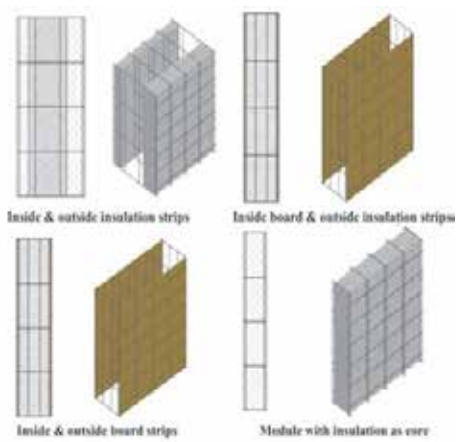
Challenges
Ready-mix concrete plant not available in hilly areas.

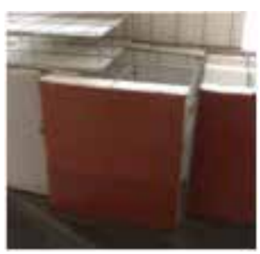
Components of the exterior wall (in mm)					
Plaster	EPS	Concrete	EPS	Plaster	Steel Lattice
15	50.8	100	50.8	15	-

Physical attributes of the external wall	
Width	230 mm
Mass	296.3 Kg/m^2
U-value	0.32 W/m^2 K

Physical attributes of the technology	
Width	130 mm
Mass	56.26 Kg/m^2
U-value	0.32 W/m^2 K







Recyclability component: Concrete, EPS and steel are difficult to recycle.

Economic Viability in affordable housing:

Structural safety: These walls can be used to build low to high rise load bearing structure and the monolithic structure is earthquake resistant.

Special equipment requirements: None.

Labor used while working with technology:

Notes:

Production Penetrability: They are manufactured in Manesar, Haryana but the raw materials are available throughout the country. The manufacturers have undertaken projects in West Bengal, Uttarakhand and Uttar Pradesh.

Name
Rapid Panels

Manufacturer
Worldhaus Construction Pvt. Ltd., Bangalore

Description of Technology

The Rapid Panel is a prefabricated assembly of high strength steel wire forming a 3-dimensional panel framework with a core of expanded polystyrene(EPS). During construction, Rapid Panels are installed as walls and/or slabs. Specified mixtures of mortar or concrete are applied to the surfaces of the panels to finish / complete the structure. The basic unit of the panel is the zig-zag truss. Steel wire is bent into a zig-zag shape to form a continuous chain of web member. This bent wire is then welded to continuous chord wires at every node to form the complete truss. The rapid panels are manufactured in fully automated plant.

Advantages

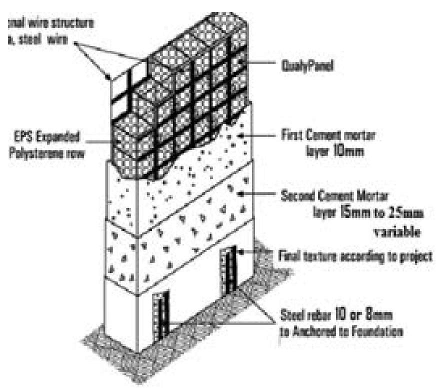
Formwork panels require no crane hence smaller projects also feasible.
30-40% less time needed in construction.
Up-to 30% labor savings in labor.
35-40% reduction in the dead load.
Beams can be avoided till a certain span when used as a roof slab.

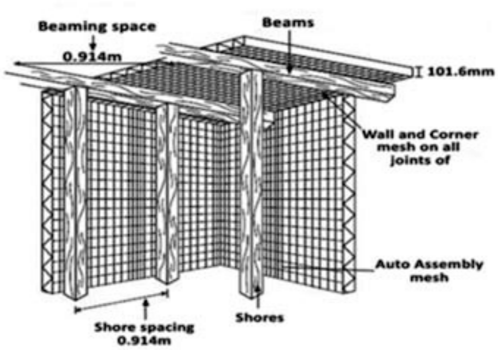
Challenges

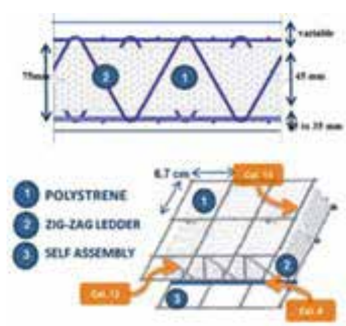
Load Bearing structures are only possible till G+3.
Panels are not produced in India. They are produced in Mexico and 50% of the panel cost is due to transportation.
Steel wires puncturing the EPS panel will act as thermal bridges.
Financing through Gramin banks is a challenge due to lack of awareness and confidence in technology.
Qualification criteria in government projects is very high such as organization turnover and experience etc.

Components of the exterior wall (in mm)					
Shotcrete	EPS	Shotcrete			Steel Lattice
35	57	35			-

Physical attributes of the external wall	
Width	127 mm
Mass	173 Kg/m^2
U-value	0.503 W/m^2 K
Imported Component	Panel is imported from Mexico, Shotcreting is done on site
Steel Needed	4 kg/sq.m.







Recyclability component:
Concrete and Steel both are difficult to recycle.

Economic Viability in affordable housing:
Government will have to reduce duties if it has to be used for mass housing.

Structural safety:

Special equipment requirements:
Shotcrete machine

Labor used while working with technology:
Labor can work on site after a few hours of being trained

Notes:

Widely used in Post-disaster rehabilitation programs (Kerala had used the technology post 2018 floods)
No certification in India is available for Rapid-Panels.
Testing at a government recognized institutions is capital intensive which in turn discourages vendors to avail certification.

Production Penetrability:

Name
QuickBuild 3D Panels

Manufacturer
Beardsell Ltd, Chennai

Description of Technology
In quick build 3 D Panel system, the panels consist of fire-resistant grade insulated polystyrene core, two engineered layers of Galvanized Steel Mesh and galvanized steel trusses. The steel trusses are pierced through the polystyrene core and welded to the outer layer sheets of Galvanized steel mesh.
The wall panel is placed in position and a structural plaster is applied to both sides. The wall panel receives its strength and rigidity from the diagonal cross wires welded to the welded-wire fabric on each side. This combination produces a truss behavior, which provides rigidity and shear terms for a full composite behavior.

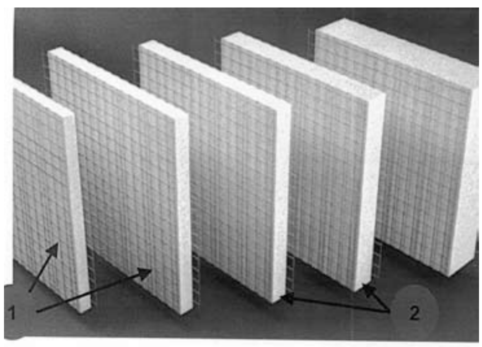
Advantages
EPS used is of zero-toxicity (food grade).
Monolithic structure has earthquake resistant properties.
Steel used is galvanized which prevents rusting and increases its life.
It offers 1.5 times more longevity than conventional structure.
Up to 10-20% components are recycled.
Fly ash is used in the concrete.
Beams can be avoided till a certain span when used as a roof slab.

Challenges
Steel used in the construction is imported from China because of quality issues in India.
Thermal bridges formed within the panels that would increase the thermal transmittance of assembly.

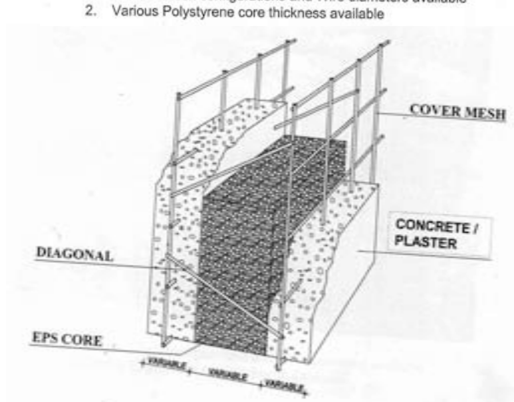
Components of the exterior wall (in mm)

Shotcrete	EPS	Shotcrete			Steel Lattice
35	50	35			-

Physical attributes of the external wall	
Width	120 mm
Mass	174.4 Kg/m^2
U-value	0.61 W/m^2 K
Imported Component	Steel imported from China
Steel Needed	4 kg/sq.m.



1. Various Mesh configurations and Wire diameters available
2. Various Polystyrene core thickness available



Recyclability component:
Concrete and Steel both are difficult to recycle.

Economic Viability in affordable housing:
Price can range from Rs. 700-1200 / sq.m.

Structural safety:

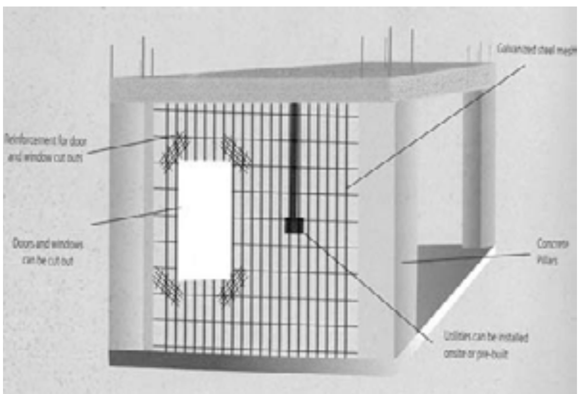
Special equipment requirements:
Shotcrete machine is required.

Labor used while working with technology:
Beardsell has an organized training system that trains executive engineers who in turn need to train the engineers, contractors and labor before work can be executed at site.

Notes:

Weak recognition of the technology by state government for mass housing.
It works as a load bearing technology up to G+2, beyond that it will require a frame structure.

Production Penetrability: Production is well spread out across India in cities of Bangalore, Pune, Hyderabad, Delhi and Chennai



Name
SRPL – Waffle-Crete Technology

Manufacturer
Shaival Reality Pvt. Ltd. Ahmedabad

Description of Technology
Waffle-Crete Building System consists of large, structural, ribbed panels of reinforced precast concrete, bolted together and the joints between the panels are caulked to form the walls, floor and pitched or flat roofs of buildings.

Advantages
There is a reduction in labor cost.
35% reduced construction time
Steel requirement is reduced if roof and wall both use this technology.
Columns and beams are avoided.
Shuttering cost is avoided.
Plastering can be avoided.
On site material wastage is reduced.
Technology can be used anywhere.

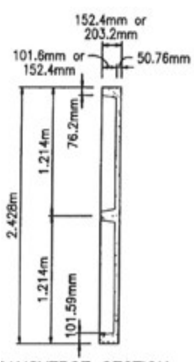
Challenges
The services are unconcealed.
Thermal transmittance is very high however insulation can be added for extra cost.
A structure higher than G+3 is yet to be built.
Only standard sizes available, custom sizes need to be specially made.

Components of the exterior wall (in mm)
RCC
152mm ribs with 51mm slab

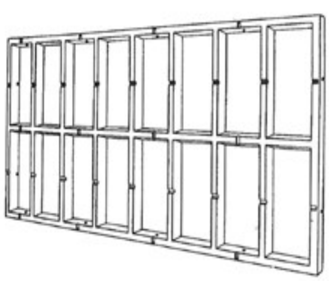
Alternate exterior wall (in mm)		
RCC	Glass Wool	Gypsum Board
152mm ribs with 51mm slab	100mm	

Physical attributes of the external wall	
Width	152 mm
Mass	168 Kg/m^2
U-value	5 W/m^2 K
Imported Component	None
Steel Needed	1.25 kg/sq.ft.

Physical attributes of the internal wall	
Width	152 mm
Mass	168 Kg/m^2
U-value	5 W/m^2 K
Imported Component	None
Steel Needed	1.25 kg/sq.ft.



RANSVERSE SECTION


WALL PANEL – 2.438m height

Recyclability component:
Reinforced Cement Concrete cannot be recycled with ease.

Economic Viability in affordable housing:
Projects in Gujarat are being done for mass affordable housing

Structural safety:

Special equipment requirements:
Surface Vibrator needed, Ready Mix Concrete Machine needed, Weigh Batcher needed

Labor used while working with technology:
15-20% reduction in labor

Notes:

Architecturally, it would be difficult to deal with the coves that are formed inside or outside.
The U-Vaue of such a material would be very high as the effective thickness of concrete is only 56mm in the non ribs area.
Local unskilled labors can be trained in a few days for the use of the technology.

Production Penetrability: Can be manufactured anywhere where the equipment can reach.

Name
AAC blocks and panels being used in Industrialized 3-S system

Manufacturer
Siporex, BG Shirke road, Pune

Description of Technology
In the system, precast dense concrete hollow column shell of appropriate sizes are used in combination with precast dense concrete rectangular / 'T' shape / 'L' Shape beams with light weight reinforced autoclaved cellular concrete/Precast RCC slabs for floors and roofs. Autoclaved Aerated Concrete (AAC) slabs can be used as floor / roof slabs as well as for walls.

Advantages
The walling requires no cranes hence can be used for smaller scale projects.
AAC blocks or panels are lightweight and hence structural and transportation load gets reduced.
Less joints in AAC masonry compared to burnt bricks reduces requirement of water.
AAC has a very low U-Value.
Reduced plaster as compared to burnt brick.
Variable thicknesses are available.
The blocks are dimensionally correct.

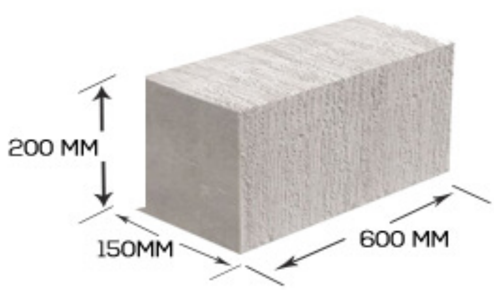
Challenges
Laying the AAC blocks take more time and labor as compared to other non conventional technologies.
AAC panels are faster but use steel reinforcement which is a high embodied energy material.
Predominantly used in non load bearing structures.
Large amount of waste produced at production units which goes to landfills.

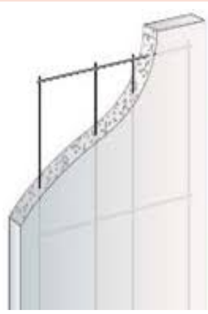
Components of the exterior wall of AAC block (in mm)		
Plaster	Autoclaved Aerated Concrete block	Plaster
10	125, 150	10

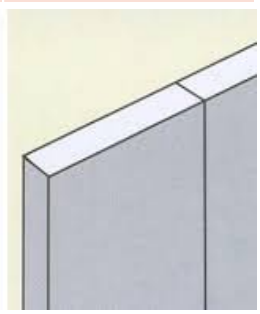
Components of the exterior wall of AAC panel (in mm)		
Plaster	Autoclaved Aerated Concrete panel	Plaster
10	100, 125	10

Physical attributes of the external wall	
Width	170 mm
Mass	125.24 Kg/m^2
U-value	0.87 W/m^2 K
Imported Component	None
Steel Needed	None

Physical attributes of the internal wall	
Width	125 mm
Mass	110 Kg/m^2
U-value	1 W/m^2 K
Imported Component	None
Steel Needed	Yes (in Panel)







Recyclability component:
Major component in AAC is fly ash (waste product) and later the bricks can be reused as a replacement for sand in screed.

Structural safety: These are mostly used in non-structural application as infill walls or partition walls. Reinforced AAC panels are designed to withstand wind loads up-to 200 kg/m².

Economic Viability in affordable housing:
It is lighter than red bricks due to which dead load on the building is decreased and less reinforcement is required. Due to smoother finish, the requirement for plaster is also reduced

Special equipment requirements:
No special equipment needed.

Labor used while working with technology: The labor needed for AAC is lower than conventional red bricks.

Notes:
The technology is primarily used for non- load bearing construction.
The handling and application of the blocks is slightly different than red bricks therefore the labor must be provided some training.
The blocks can be cut into different dimensions providing an array of design options.

Production Penetrability: Manufacturing takes place in many places in North India and this technology is becoming popular alternate for red bricks.

Name
Walltec Hollowcore Concrete Panel

Manufacturer
B.N. Precast Pvt. Ltd. Ahmedabad

Description of Technology
Extruded non-load bearing concrete hollowcore wall panels manufactured in fully automated machines. Walltec wall panels are factory produced using light weight concrete made of river sand, crushed stone aggregate, light weight aggregate and Ordinary Portland cement.

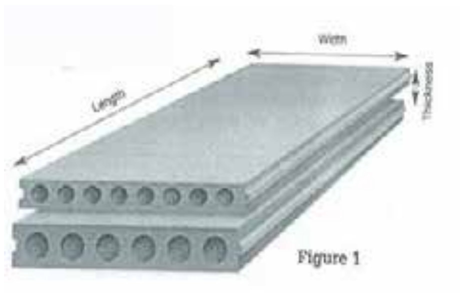
Advantages
Faster Construction with strict time frame.
Wastage is minimized due to prefabrication.
Shuttering cost is avoided.
Plastering can be avoided.
Damaged panels can be recycled into aggregates for further panels.
No curing onsite needed hence less water consumption.

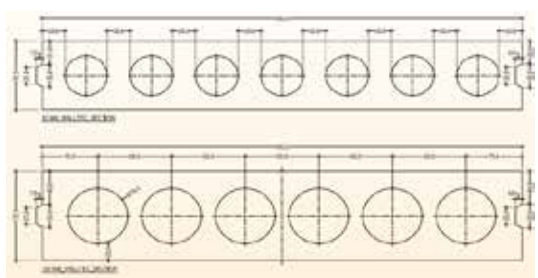
Challenges
Cranes are needed for installing panels.
Difficult to be used for external walls as scaffolding would be required on outside.
Bills are not paid on time in government projects so incentive of working fast goes away.
Co-ordination issues occur when used in conjunction with other technologies.

Components of the exterior wall (in mm)
RCC
120mm thick with 74mm dia. voids

Components of the interior wall (in mm)
RCC
92mm thick with 53mm dia. voids

Physical attributes of the external wall	
Width	92-120 mm
Mass	140-170 Kg/m^2
U-value	2.5 W/m^2 K
Imported Component	Equipment
Steel Needed	None





Recyclability component:
Aggregates from stone, concrete, bricks or AAC can be reused into the panels.

Recycled component used: The technology can use bricks, AAC, stones as aggregate for manufacturing the panel.

Labor used while working with technology:
Trained labor required during manufacture.

Economic Viability in affordable housing:

Special equipment requirements:
Special equipment from Finland or China are imported for manufacturing of panels.
The panel installation requires cranes to be used which is not feasible in a small project.

Notes:
Walltec panels are best used if the entire construction uses precast members.
The technology hasn't been used for exterior walls much as it becomes difficult to fit a precast member into a cast-in-situ construction due to defects of a cast in situ construction.
A crane is required for panels installation and hence a small project is not feasible.

Production Penetrability: The technology is being manufactured by B.N.Precast only near Ahmedabad and hence the transportation is only feasible around 200Kms of the manufacturing site unless more plants are setup.

Name
Compressed stabilized Earth Blocks (CSEB)

Manufacturer
Aureka, Auroville, Tamil Nadu

Description of Technology
These are blocks that are made from a mix of soil (gravel, sand, silt and clay), cement and water. This mix is placed in a steel pressing machine (manual/automatic) where it is compressed to form a block of a desired dimension. Later, these blocks are stacked together and cured until they are ready to be used.

Advantages
Significant reduction in transportation requirements as soil is locally available as compared to other technology.
Production and usage requires little training.
Block finish is better than red bricks hence plaster is avoided.
CO_2 emissions and embodied energy 4 times lower than red bricks as the blocks are not burnt in a kiln.
Soil does not react with cement hence maintaining its soil characteristics.

Challenges
Requires careful handling and storage until the block is ready.
Time intensive to produce the blocks.

Components of the exterior wall (in mm)		
Plaster	CSEB	Plaster
-	220-240	-

Physical attributes of a load bearing wall	
Width	240 mm
Mass	408 Kg/m^2
U-value	2.47 W/m^2 K
Imported Component	None
Steel Needed	None

Physical attributes of a partition wall	
Width	90 mm
Mass	153 Kg/m^2
U-value	3.88 W/m^2 K
Imported Component	None
Steel Needed	None

Recyclability component:
More than 90% of the brick content is soil which can be recycled back to earth.

Structural safety: The blocks can be used to build as high as 4 storey as a load bearing structure and can be designed for earthquake prone areas.

Economic Viability in affordable housing:
A 32 % reduction in cost per sq.m of plinth area in a 4 storey load bearing structure, compared to conventional red bricks, can be achieved.

Special equipment requirements:
Manual/automatic machine for compressing the soil-cement mixture.

Labor used while working with technology:
850 (240x240x90) blocks can be produced by 7 laborers in a full day manually.

Notes:

The technology can provide employment opportunities for semi-skilled labor.
For faster production, blocks can be manufactured before-hand or an automatic machine be used for faster block production.
There is a societal perception that unburnt soil blocks are low-quality building material.

Production Penetrability: The manufacturing can be set up on the site-itself with enough space for staking and curing.

ANNEXURE 2:

HOUSING STOCK AND COMMON INFRASTRUCTURE AND UTILITIES

Overall, PMAY will have to align in a more integrated manner with other regulations to maximize resource savings and improve quality of life in housing and the larger habitat. While PMAY notification provides for minimum compliance, state governments have the potential to take further steps by stringent provisioning in resource conservation and sufficiency. For instance, Environmental Impact Assessment Notification, 2006 is a key regulatory tool of the Central government to reduce the impact of new constructions on environmental resources.

WATER MANAGEMENT

Telangana is geographically located in a rain-shadow area, which faces frequent droughts. In Siddipet, Sangareddy, Ranga Reddy, Rajanna Sricilla, Nalgonda and Nagar Kurnool districts the water table has fallen down to 20 m below ground.[15] These are also the districts where the housing demand is the highest. Urban areas including the Greater Hyderabad Metropolitan region have periodically faced water supply shortages during peak summer. Under such a scenario, the state needs to prioritize use of alternative sources like rainwater and recycled wastewater and reduce dependence on potable water for other needs.

The state has taken measures such as mandating rainwater harvesting in plots with 300 m^2 area and above and 6 cum. storage for every 100 m^2 of rooftop space. A 10 per cent rebate on property tax is also offered to install rainwater harvesting structures, according to the State Building Rules, 2012. Under the 2BHK scheme, projects in urban areas (GHMC and other municipalities) also have provisions for on-site wastewater treatment using conventional sewage treatment plants (STPs).

ENERGY MANAGEMENT

Power generation in Telangana is dominated by thermal energy. Of the current installed capacity of 16,302.91 MW, only 23 per cent comes from renewable energy (mostly solar), 15 per cent from hydel energy and a very small per cent from other sources such as nuclear and biogas.[16] Telangana is not a power-rich state. Further, distribution companies (discoms) in the state recorded a debt of Rs 11,897 crore in September 2015. Nodal agencies for electrification in the 2BHK scheme projects are Telangana State Northern Power Distribution Company Limited (TSNPDCL) and Telangana State Southern Power Distribution Company Limited (TSSPDCL).

Telangana has recognized the significance of solar energy and the potential to increase its penetration in buildings. Telangana Solar Policy, 2015 provides many incentives on taxes and duties vis-à-vis solar power. A Residential Rooftop Solar Policy, 2018 provides 30 per cent subsidy from Ministry of New and Renewable Energy and 30 per cent from the state government. State Building Rules also provide a 10 per cent rebate on property tax on use of solar water heaters and solar-powered street lighting. Solar-powered LED lamps for street lighting have been installed at many affordable housing projects, such as those in Ahmedguda (GHMC) and Eravalli (rural).

A calculation reveals as much as 15 per cent of electricity demand in the 2BHK scheme projects can be met from on-site solar energy generation, while other projects (under PMAY-urban and GHMC) have a ground coverage of 20–40 per cent; for instance, D. Pochampally, a GHMC project, wherein about 30 per cent of the site area is covered by blocks, has yielded a potential to meet 15 per cent of the site's electricity demand through solar power.

Computation of solar energy generation potential

Rooftop area = 9957.90 m^2
60 per cent of roof top area = 5,974 m^2
Solar PV that can be accommodated (@12 $m^2$for 1 KWp) = 5,974/12 = 497.8 KWp
Dwelling units = 1,620
Load per unit = 2 KWh
Total connected load in site = 3,240 KWh
Per cent of total connected load that can be met by solar = 497.8/3,240 = **15**

Many states have mandated the use of solar rooftop under their affordable housing schemes, especially where land is provided by the government. Gujarat, for instance, is prioritizing at least 5 per cent of connected load to be met by rooftop generated solar energy. Renewable Energy Service Companies (RESCO) are offering competitive prices including establishment, operation and maintenance costs for solar power plants. Latest auctions conducted by Solar Energy Council of India saw solar power tariffs settle between Rs 2.44 and Rs 6.20 per unit, which is lower than conventional power tariff.[17] On-site solar power generation is an area with tremendous scope in Telangana.

SOLID WASTE MANAGEMENT

Municipal collection efficiency is 70–90 per cent in major metro cities and below 50 per cent in small cities. Of this incomplete collection, only 10 per cent goes for treatment and a remarkable 90 per cent is dumped in landfills without any treatment.[18] The consequence is that municipal bodies are running out of landfill sites. In addition, the absence of scientific and safe disposal poses a great threat to the health and wellbeing of the rapidly increasing number of city inhabitants as well as the environment.

The 2BHK scheme places a need for an organized system for scientific collection, transportation, treatment and disposal of about 561,232 kg of solid waste generated every day. Solid Waste Management Rules, 2016 mandate a three-way segregation and the Environmental Impact Notification encourages on-site treatment of organic waste using natural techniques. However, municipal bodies are yet to adopt the rules and ensure their effective implementation. For instance, GHMC distributed 44 lakh bins to segregate dry and wet waste in households and yet only 27per cent of waste was found to be segregated.

Much stronger efforts need to be put in for efficient and effective waste management. A calculation reveals that on-site treatment of organic waste using non-mechanized methods requires less than 5 per cent of unpaved or green space and a miniscule of the site area. Financial requirement is only towards payment of daily wages to manual labourers to ensure segregation of waste and look after composting. In order to comply with the provisions of EIA Notification, especially in larger projects, the state needs to work on how to ensure these requisites in site layouts.

On-site solid waste treatment potential

Area under tot-lots and green area = 2,805.21 m^2
Dwelling units = 1,620
Organic waste generation in a day (@ 400 g per capita per day) = 2,592 kg waste generation during one compost cycle = 2592 x 45 = 116,640 kg
Amount of waste to be treated after compaction = 11,6640/1.5 = 77,760 kg
Volume of waste to be treated (@ 500 g / cum) = 155.52 cum
Area required for pit composting (depth of pit = 1.2 m) = **129.16 m^2**

AFFORDABILITY TO OPERATE AND MAINTAIN COMMON INFRASTRUCTURE

According to the 2BHK scheme guidelines, operation and maintenance (O&M) of common infrastructure and utilities such as water supply system, sewage treatment plants and lighting in common areas is to be conducted by the beneficiaries. This includes contribution of costs. GHMC has provided commercial areas in their projects to facilitate some of the recurring O&M costs through commercial rent for beneficiaries. However, O&M costs will peak after a few years when the infrastructure demands intensive investments. For instance, an STP requires recapitalization in about 20 years and a diesel generator in 10 years. Concerns arise whether these costs will render O&M of the infrastructure unaffordable for the beneficiaries. This cost can be significantly reduced by prioritizing recycle and reuse of water and switching to low-cost and nature-based solutions for wastewater treatment, or switching to renewable energy, for instance. Therefore, there is a need for states to look into cost-effective solutions for all common infrastructure and utilities.

REFERENCES

1. Available at *https://beeindia.gov.in/sites/default/files/Flyer_22nd%20Jan.pdf*, as accessed on 12 May 2020

2. Rajan Rawal and Yash Shukla 2014. *Residential Buildings In India: Energy Use Projections And Savings Potentials,* Global Buildings Performance Network (GBPN). Available at *http://www.gbpn.org/sites/default/files/08.%20INDIA%20Baseline_TR_low.pdf, as accessed on* 12 May 2020

3. Available at http://iess2047.gov.in/pathways/primary_energy_overview_chart, as accessed on 12 May 2020

4. *Socio Economic Outlook 2018*, Government of Telangana. Available at h*ttps://tsdps.telangana.gov.in/downloads/Socio-Economic-Outlook-2018.pdf*, as accessed on 12 May 2020

5. *GO MS No.10, 15 October 2015:Guidelines for implementation of 2bedroom housing programme*, Government of Telangana. Available at *https://2bhk.telangana.gov.in/getInfo.do?key=unspecified&id=4&type=2*, as accessed on 12 May 2020

6. Maddy Deekshith 2018. 'Telangana hikes steel price for 2BHK project', *Deccan Chronicle.* Available at *https://www.deccanchronicle.com/nation/current-affairs/170218/telangana-hikes-steel-price-for-2bhk-project.html* as accessed on 12 May 2020

7. *G.O.Ms.No.3-Industries & commerce (Mines-I) Department-Dated:08 January 2015*: *Mines & Minerals - Regulation Of Sand Mining - New Sand Mining Policy, 2014 – Formulation Of Telangana State Sand Mining Rules – 2015 (Tssmr-2015) – Orders – Issued*, Government Of Telangana. Available at *https://2bhk.telangana.gov.in/getInfo.do?key=unspecified&id=4&type=2*, as accessed on 12 May 2020

8. *G.O.RT.No.178-Housing (RH&C-A1) Department- 2 November 2016: Housing Department-TSHCL-Procurement of cement by the TSHCL for implementation of WSHP under 2BHK for three years-Finalization of Rates-orders-Issued,* Government of Telangana. Available at *https://2bhk.telangana.gov.in/getInfo.do?key=unspecified&id=4&type=2*, as accessed on 12 May 2020

9. *G.O.Ms.No. 168, 7 April 2012*, Government of Andhra Pradesh. Available at *https://hmda.gov.in/Gos/168.PDF*, as accessed on 12 May 2020

10. *Multi-Attribute Evaluation Methodology for Selection of Emerging Housing Technologies,* Building Material and Technology Promotion Council, Ministry of Housing & Urban Poverty Alleviation Government of India. Available at *http://www.bmtpc.org/DataFiles/Content/Multi_Attribute_Booklet.pdf*, as accessed on 12 May 2020

11. *Eco Niwas Samhita 2018 (Energy Conservation Building Code for Residential Buildings) Part I: Building Envelope*, Bureau of Energy Efficiency. Available at https://www.beeindia.gov.in/sites/default/files/ECBC_BOOK_Web.pdf, as accessed on 12 May 2020

12. *National Building Code of India 2016*, Bureau of Indian Standards, New Delhi

13. *Ibid.*

14. *Ibid.*

15. Available at *http://gwd.telangana.gov.in/open_record_view.php?ID=141*, as accessed on 12 May 2020

16. *Telangana State Power Statistics Report -Statement A*, Transmission Corporation of Telangana Limited. Available at https://www.tstransco.in/index.php/power-statistics-report/statement-a, as accessed on 12 May 2020

17. Kaavya Chandrasekaran 2018. 'Solar tariffs once again hit all-time low of Rs. 2.44 a unit at SECI auction', *Economic Times*. Available at *https://economictimes.indiatimes.com/industry/energy/power/solar-tariffs-once-again-hit-all-time-low-of-rs-244-a-unit-at-seci-auction/articleshow/64834531.cms*, as accessed on 12 May 2020

18. SilpaKaza,Lisa C.Yao, Pernaz Bhada-Tata and Frank Van Woerden 2018*. What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050,* World Bank Group, Washington, DC. Available at *https://openknowledge.worldbank.org/handle/10986/30317*, as accessed on 12 May 2020.

Housing for all has for long been the dream of India's economically deprived sections, particularly in urban areas, where the problem is the most acute. Not surprisingly, it has also been a battle cry of successive Central governments. Pradhan Mantri Awas Yojana (PMAY) is the latest iteration of this policy desire to provide everyone a shelter.

But how do we marry the need to provide affordable housing to India's teaming millions at speed while achieving the thermal comfort goals as scribed in the India Cooling Action Plan? How do we bend the energy consumption curve of the built sector in the country downwards? How do we ensure that these dwelling spaces are liveable and environmentally sustainable?

Centre for Science and Environment did an in-depth analysis of a few affordable housing projects in Telangana to find answers to these questions.

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