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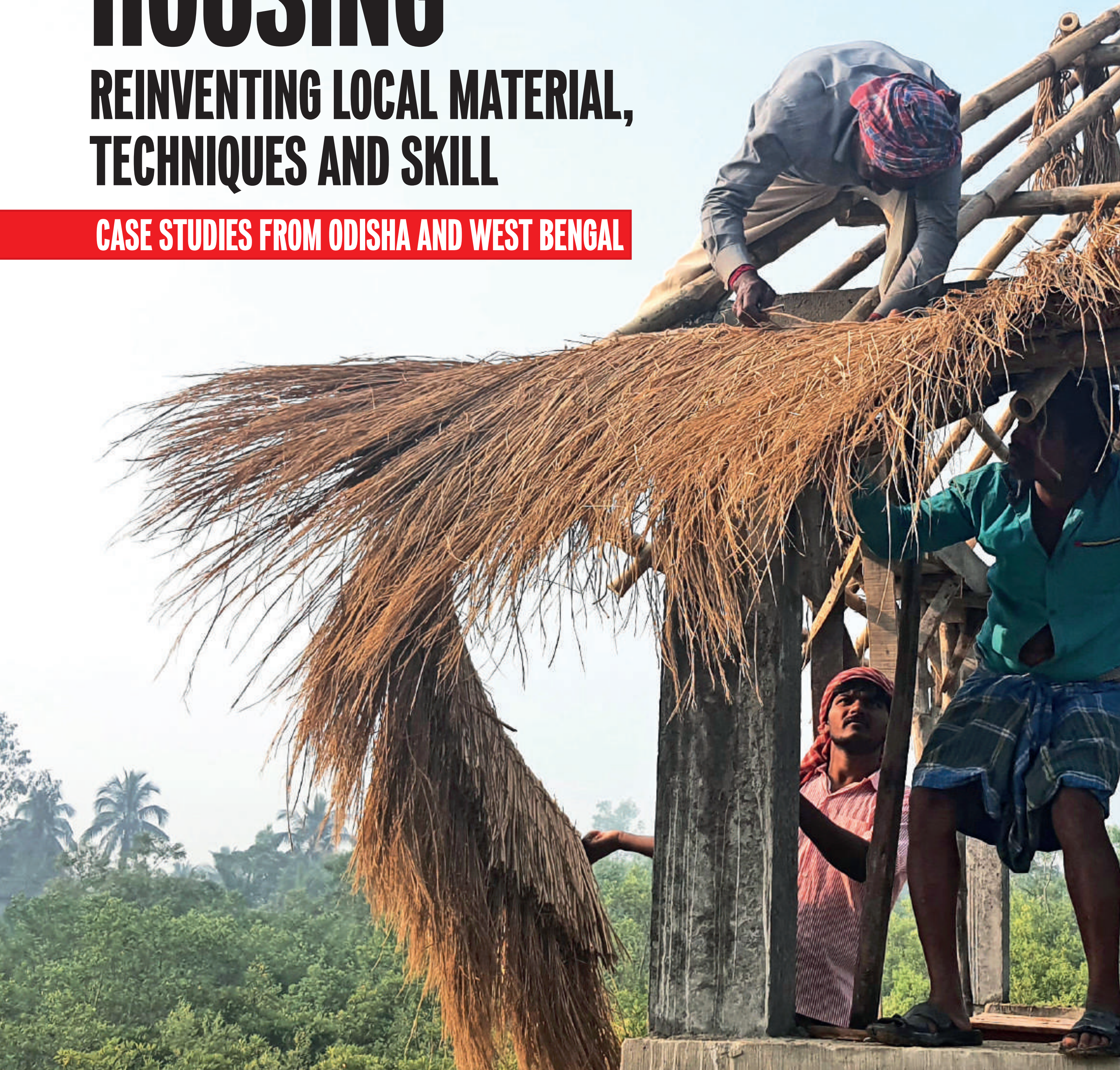
REINVENTING LOCAL MATERIAL, TECHNIQUES AND SKILL

CASE STUDIES FROM ODISHA AND WEST BENGAL



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India's stated ambition of meeting its goal of net-zero carbon emissions by 2070 and reducing the emissions intensity of its gross domestic product (GDP) by 45 per cent by 2030 can have significant bearing on the mitigation strategies designed for the building-construction sector. According to the estimates of the Bureau of Energy Efficiency, India's building sector accounts for nearly 40 per cent of its energy consumption and is growing by 8 per cent annually. The International Energy Agency's (IEA's) *World Energy Outlook 2021* states that India is set to more than double its building space over the next two decades, with 70 per cent of new construction in urban areas. Further, it estimates that rising appliance ownership and demand for cooling can nearly triple the share of electricity in residential energy use.[1]

The material intensity of the building sector in terms of demand for steel, aluminium, glass, cement, bricks, concrete etc. is also among the highest. These materials use enormous amounts of energy for production, extraction and transport that increase the embodied energy of material and the overall energy intensity of buildings. In fact, the share of steel used in the building sector is also the highest among all sectors in India—as much as 40 per cent.[2] Steel is one of the most energy-intensive materials.

This sector requires aggressive strategies to reduce embodied and operational energy. Several policies and policy instruments are evolving to improve energy efficiency and energy savings in new buildings, commercial as well as residential. These aim to improve building envelope design, choice of materials based on their insulation properties and heat gain potential, appliance efficiency, and application of passive architectural design and renewable energy.

Among these interventions, one of the most challenging areas is material choice and application. At one level, material choice is governed by insulation properties to reduce heat gain through building envelope; at another, steps are needed to reduce use of material with high embodied energy. Norms and information on performance and cost curves have to mature further to influence these decisions and choices.

Judicious material selection for mass construction remains a challenge. This is getting more complex with the rapid infusion of new-generation precast and prefab construction technologies in the urban mass-housing sector. These technologies are attractive for the construction industry as they allow fast-paced construction. Even though they are more expensive than conventional technologies, they are preferred to save time, labour costs and other associated costs.

Currently, uptake of these materials and techniques in the mass housing sector is tied to Pradhan Mantri Awaas Yojana-Urban (PMAY-U), which aims to provide housing for all by 2022. In fact, the 2019 Global Housing Technology Challenge of the Ministry of Housing and Urban Affairs (MoHUA) aims to mainstream innovative walling technologies in the affordable-housing sector in urban areas.

This is driving a shift towards walling materials and technologies such as monolithic concrete construction in urban mass housing. There are concerns that if these materials are adopted without adequate passive architectural design, the built structures may become more carbon intensive.

A Centre for Science and Environment (CSE) assessment shows that the application of prefab materials is often not combined with architectural strategies or thermal massing to reduce the thermal load on buildings in affordable mass housing. This undermines the thermal comfort conditions inside the buildings and increases use of energy-intensive mechanical cooling.

CSE's analysis also revealed that the walls of these houses heat up twice as fast as those with conventional burnt clay brick walls. Unregulated penetration of such materials without the requirement of thermal comfort can deter the goal of the India Cooling Action Plan 2019, which is to provide thermal comfort for all.

What about self-built housing and material transformation?

While a lot is being said about the need for assessing the heat-gain and insulation properties of materials and embodied energy to inform urban mass housing and institutional buildings to guide the construction industry, there is very little conversation around the potential and opportunity of transforming material penetration in self-built housing, the principle source of housing supply in India. This is the key focus of this study.

There is a vast area of self-built housing in urban, peri-urban and rural areas. Currently, Pradhan Mantri Awaas Yojana (Urban) (PMAY-U) and Grameen

(PMAY-G) are the flagship programmes for provision of affordable housing in urban and rural areas. Among all their verticals, the majority of PMAY beneficiaries are in the self-built housing vertical—nearly 60 per cent of new PMAY houses in urban areas and 100 per cent in rural and peri-urban areas are under PMAY-G. Multitudes of home owners are building their own houses in different income categories.

The Pradhan Mantri Awaas Yojana-Grameen (PMAY-G) scheme, which supports self-built housing in rural and peri-urban areas, was launched in 2016 to provide by 2022 pucca housing with basic amenities to the houseless and those living in dilapidated dwellings.[3] The scheme restructures the provisions of Indira Awaas Yojana and focuses on those living below the poverty line (BPL). A house of minimum 25 sq. m is provided under the scheme, with fiscal support of Rs 1.20 lakh in plain areas and Rs 1.30 lakh in hilly areas and in difficult terrains.

As on July 15, 2022, the scheme targeted construction of 27 million houses and has received sanctions for 24.3 million houses. Of this, about 18.8 million units have been completed. Over 3 trillion houses have been allocated to beneficiaries under the scheme, with over Rs 247 billion of the sanctioned amount utilized in making the houses so far.

While self-built housing in urban areas is predictably and predominantly brick-and-mortar structures, those in peri-urban and rural areas are steadily shifting from traditional materials and techniques to brick-and-mortar structures. This shift is accelerated by funding support for housing schemes that is tied with the narrow definition of pucca houses. Funding for self-construction is available for only brick-and-mortar structures and not those built with traditional materials and techniques.

This has become a case of missed opportunities as this approach combined with aspirational factors is eliminating locally available sustainable materials such as bamboo, stone, and wattle and daub. But there can be considerable scope for material substitution and reduction of material intensity if the construction sector and policies draw upon time-tested traditional materials and local techniques and skills to combine with concrete structures to reduce the environmental and carbon footprint of buildings.

The policy needs to enable communities to exercise that choice as well as promote fusion and a hybrid approach of combining the traditional and contemporary and adapting traditional materials and techniques. Dominant traditional materials and techniques include wattle and daub, cob-based walls, stone-based walls (random rubble), bhunga roofs, kathkuni and dhajji diwari structures and an array of walling and roofing technologies that utilize local materials and local skills to construct houses.

But, currently, these traditional materials are dismissed as “kutcha” and are associated with only low-income families. This has blocked the opportunity to reinvent these materials for fusion and hybridization with modern conventional techniques to maximize energy and environmental gains.

Notably, self-constructed housing allows and offers more flexible choices of material, techniques and design to retain and reinvent traditional and locally available materials and locally evolved techniques within a specific climatic context. It is possible to combine these with the contemporary material and techniques of self-constructed housing to reduce material and carbon intensity of the structures while strengthening the foundational structures. Local know-how and materials can provide more efficient ways of resisting climatic stress and even extreme weather events like cyclones and earthquakes. These technologies are also circular in nature as they utilize locally available materials, generate less waste and utilize waste. This cannot be ignored at a time when India is facing a daunting carbon-reduction target by 2030.

Even though rural and peri-urban housing are the repository of local material and associated techniques and intergenerational skills to nurture them, these are also disappearing rapidly due to lack of patronage. These built structures and designs have evolved within the context of local ecosystem, ecology and culture that have enhanced adaptive thermal comfort and resisted local climatic stress. Very little effort has been made to understand and document these materials and techniques and assess the potential of their adoption and integration with modern buildings to leverage the sustainability potential of these material and techniques.

Currently, this reinvention of dying wisdom is confined to a few progressive architects who have taken the initiative to assess local material and techniques and have experimented to create hybrid forms to combine them with contemporary techniques. But there is no policy response to explore and assess their potential application in new self-built housing and provide support.

The livelihood connect: Another reason for the importance of fusion of old and new building technologies for sustainable and climate-resilient built structures is to ensure a just transition in the building sector. The construction industry is a labour-intensive sector, with considerable potential for job generation. The housing sector plays a crucial role due to its forward and backward economic linkages. According to a study by the National Council of Applied Economic Research, it accounts for 6.8 per cent of the employment in the country. The share of informal employment to total employment in residential construction alone is the second highest among all sectors, next only to agriculture. Further, for every investment of Rs 1 lakh in the residential construction sector, 4.06 new jobs are created. Efforts need to be made towards sustainable housing while keeping green jobs as the central focus.

Yet, the modern building technologies that are being adopted in urban mass housing, for instance, are labour displacing. Therefore, it is important to ensure that the green building movement ensures job creation and livelihood security across the urban and rural landscape. Traditional technologies that are skill intensive are an opportunity to ensure that jobs are created around new construction.

It is necessary to understand how reinvention and promotion of local techniques and knowledge can strengthen the local livelihood base to provide more economic security while nurturing sustainable practices. This aspect had come to the forefront during the migrant crisis triggered by the corona virus 2 (SARS-CoV-2) pandemic. There were reports of massive job losses in the construction industry. The sudden shock of job loss in cities led to waves of reverse migration back in villages that were also reeling under a livelihood crisis.

According to World Bank estimates, nearly 40 million migrant workers (inter- and intra-state) were affected by the lockdown in India.[4] States such as Odisha, West Bengal, Uttar Pradesh, Bihar and Jharkhand bore the brunt of reverse migration. For instance, just Ganjam district in Odisha received 2 lakh workers back from Surat during the lockdown.[5] Such unprecedented reverse migration also increased the need for housing in rural and peri-urban areas.

In the context of livelihood and housing crisis in villages during the pandemic, CSE explored the following question: Can local building techniques and skills become a means of strengthening local livelihood systems, absorb the labour force and at the same time help to reinvent local skills and material for adoption in new buildings to make them sustainable and thermally comfortable? This would meet the needs of just transition as well as help chart pathways to low-carbon and locally appropriate built structures that can inform and support modern buildings.

If done with conscious policy focus, local knowledge and skills can be integrated with modern housing policy of the government while strengthening local community-based livelihoods. Currently, self-construction that dominates the housing sector lacks guidance and clear direction on how to build to respond to local climatic conditions and adopt climate-appropriate materials, techniques and skills while creating jobs and improving livability conditions of the poor. This has to define the opportunity for green recovery in the housing sector.

Housing policies and schemes especially for rural and peri-urban housing can be more explicit about realizing the potential of local techniques and skills in creating local jobs and secure livelihoods. Currently, the PMAY-G scheme, designed with a focus on self-construction, entitles beneficiaries to 90–95 person days of unskilled labour from MGNREGS. The scheme encourages leveraging of other schemes to support the development of self-built houses such as availing of funds under Swachh Bharat Mission to construct a toilet in their house.

The scheme also recognizes the shortage of skilled masons to deliver quality houses. To address this, the National Technical Support Agency has been set up and several training and certification programmes have been rolled out by state governments. A compendium of house design typologies, including disaster-resilience features—*Pahal: Prakriti Hunar Lokvidya*—is also being promoted to guide construction under the scheme.[6] Comprising nearly 130 designs for 10 states, it has was developed collaboratively, with government officials, engineers, local architects, masons and rural communities involved.

All housing schemes and most of the skill centres in states are, however, oriented towards brick-and-mortar technologies and have not integrated application of local material, techniques and skills. But there is a small whiff of change in which the Building Materials and Construction Technologies (BMTPC) along with CSIR–Central Building Research Institute (CBRI) has developed a compendium that acknowledges that in the face of depleting natural resources, climate change, green-house gas (GHG) emissions and energy scarcity it is not feasible to continue to use conventional brick, mortar and cast-in-situ RCC construction. The document targets the construction of individual houses for low-rise to mid-rise structures and lists 66 technologies for floor and/or roof construction, wall construction, foundation technologies, system-level technologies, services and materials. It has taken cognizance of traditional technologies such as random rubble masonry, kath kuni and dhajji diwari "bamboo-strip walling". In fact, bamboo-strip walling has been highlighted for its labour intensity and potential to generate local employment. Each of these systems is explained in detail along with technical specifications, tools and equipment, salient features, cost, sustainability and economic aspects, material requirements, limitations, market linkages, structural drawings/detailing and relevant standards and references. The compendium also mentions the geo-climatic suitability of these technologies. About 13 demonstration centres spread across the country have to some extent integrated various walling and roofing techniques using traditional and neo-sustainable construction materials and/or techniques.

These small steps need to be leveraged further to build skills and employment around the traditional and hybrid technologies.

There are several skill-building and livelihood schemes and programmes of the government, including Deen-Dayal Upadhyaya Gram Kaushal Yojana, Pradhan Mantri Kaushal Vikas Yojana, National Rural Livelihoods Mission and its state adaptations such as Anandadhara in West Bengal and the Odisha Livelihoods Mission in Odisha. All these can be leveraged for green recovery and skilling through promotion of climate-appropriate houses and skills.

This study aims to address the compelling questions around possible integration of traditional and contemporary technologies to reduce material and carbon intensity of self-built structures and the potential to maximize employment generation from this fusion, especially in rural and peri-urban areas. This report assesses how communities are building houses in the rural hinterlands and how their knowledge repository and skill sets can inform modern construction in the self-built housing sector in rural, peri-urban and even urban areas.

Spotlight on Odisha and West Bengal: This report takes a case study approach. It focuses on the states of Odisha and West Bengal, which faced the brunt of reverse migration during the pandemic. These states registered a demand of 1.8 million and 3.4 million housing units under PMAY-G respectively.[7]

According to Census 2011, nearly 83 per cent of the population in Odisha and 68 per cent in West Bengal live in rural areas. Both these states are also highly vulnerable to extreme weather events such as super-cyclonic storms, extreme heat, heavy rainfall and floods. In 2020, for instance, according to the Odisha State Disaster Management Authority, Cyclone Amphan affected as many as 44.45 lakh people in 9,838 villages and 22 urban local bodies. The cyclone also directly led to livelihood loss for 5,040 craftsmen, damaged 10,725 hectare of agricultural land and/or crop and affected those associated with or are dependent on livestock, poultry and fisheries.

This study revisits some housing schemes for rural and peri-urban areas in Odisha adn West Bengal, including self-constructed housing in urban areas, for uptake of climate-appropriate local housing material and techniques for co-benefits of low-carbon trajectory and circularity. While infusion of modern materials and techniques in the traditional built form is inevitable, it is also necessary to assess the potential of adaptation and integration for sustainability of buildings.

Methodology

This study was carried out in West Bengal and Odisha to understand the scope, prevalence and nature of traditional building technologies and extent of infusion of new and alternative materials in the local market. It also identified skilling and livelihood programmes and opportunities that can integrate traditional technologies. It has also mapped the initiatives of the architects who adopted traditional techniques and material in modern buildings to demonstrate how this can be done.

To identify materials in the self-built housing sector, data from Census 2011 and PMAY housing—which provided a list of materials currently used in the self-built housing sector—was accessed. Further, the documentation and reports on traditional construction technologies have been reviewed to map the region-wise application of the technologies.

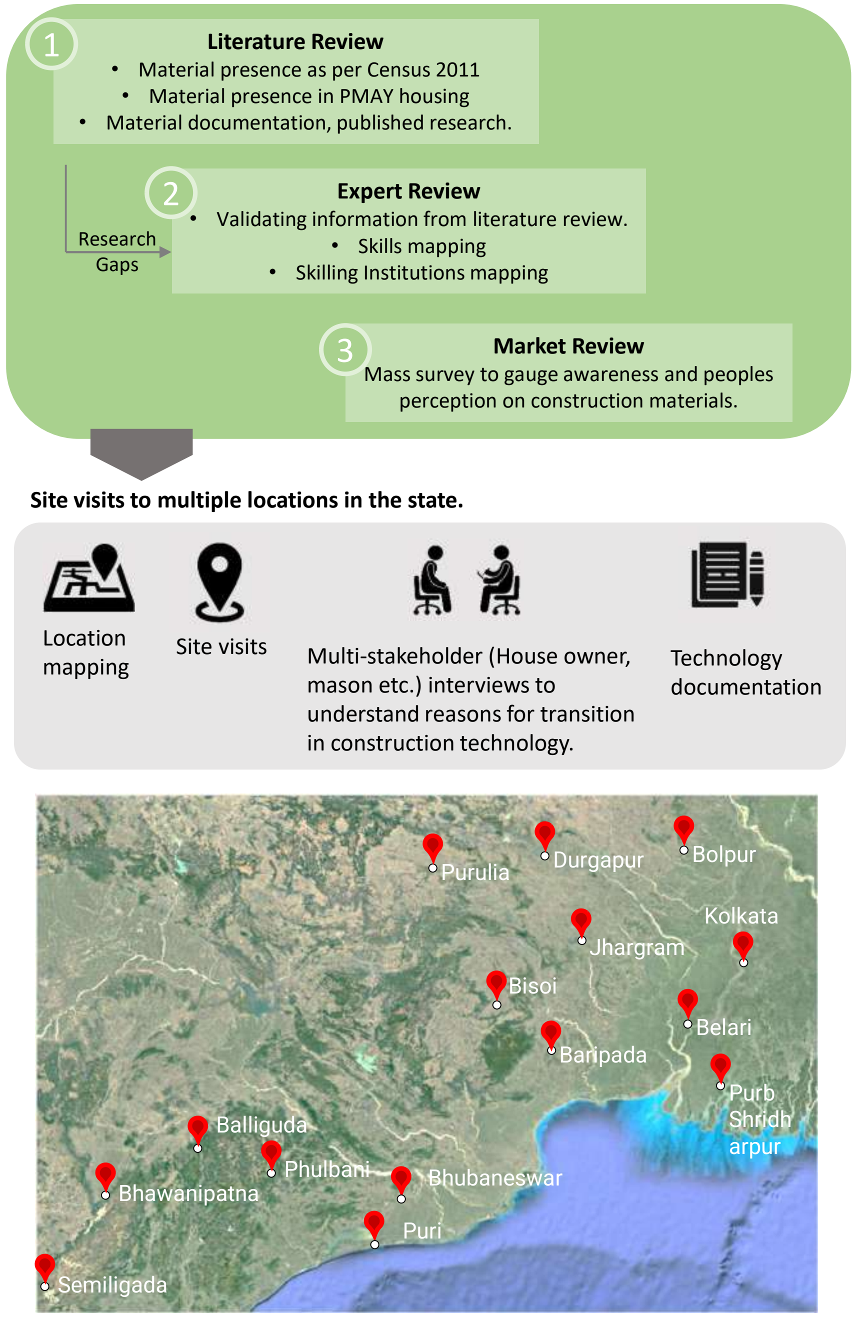
Research gaps in this review were discussed with sectoral experts using the Delphi technique. The experts were provided with a form containing a list of materials and/or technologies. They had to write the skills required for construction material and/or technology to be applied corresponding to each item, and how the skill is acquired. In addition, the experts validated the findings of the literature review that had been carried out.

The third step comprised rolling out a mass survey form to understand the market penetration of traditional materials, building techniques and ways of acquiring skills. The survey indicated great need to inform choice of materials based on different climates, locations, cost, aesthetics, etc.

Based on this three-stage exercise, the following three main components were identified and mapped:

- Locations where traditional construction technologies exist;
- Current skilling and livelihood programmes, their officials and offices; and
- Institutions carrying out skilling courses and their representatives.

Figure 1: Methodology for the research



West Bengal

- Purb Shridharpur
- Kolkata
- Bolpur
- Belari (Uluberia)
- Durgapur
- Purulia
- Jhargram

Odisha

- Baripada
- Bisoi
- Bhubaneshwar
- Puri
- Semiligada
- Bhawanipatna
- Bolangir
- Phulbani

The fourth step involved field investigations in targeted villages and peri-urban areas to assess the on-ground application and local skill sets, and interact with the homeowners, masons, builders and local architects to understand the transition in these materials and the reasons for this shift.
In all, close to 50 rural locations were covered during the study. Multiple mediums for documentation were utilized, including physical interviews, group discussions, photographs and videos. Additionally, resource mapping of locally available building materials was carried out and a region-wise compendium of these technologies created.

In the second phase of field investigation, the skilling schemes and centres were investigated. Officials of the skilling and livelihood programmes were contacted and interviewed to understand the potential of schemes for generating green jobs in the construction sector. Further, key institutions conducting construction- related skilling courses were consulted for an understanding of the curriculum followed.

CSE also conducted a deep-dive assessment of materials used in construction, resources used in preparing the materials, availability and location of materials, availability of masons and labour (semi-skilled and unskilled) and construction costs. Interviews with homeowners, masons, semi-skilled and unskilled labour, architects and developers were conducted. The assessment also encapsulates the economics related to traditional materials and housing in rural Odisha and West Bengal. Field investigations were carried out in Jhargram, Purulia, Paschim Bardhaman districts and Sundarbans in West Bengal and Koraput, Kalahandi, Kandhamal, Mayurbhanj and Puri districts of Odisha (see *Figure 1: Methodology for the research*). Within these districts, nearly 24 villages in Odisha and 19 villages in West Bengal were visited. These locations were identified based on literature review and interviews conducted with identified experts.

The study reviewed projects of a select group of architects who have started building hybrid structures and promoting blending of local and mainstream systems in the two states. These projects successfully demonstrate how blending is possible in contemporary houses in both rural and urban settings in locally appropriate ways.

For the purpose of this study, clear definitions were set to identify and classify the materials used in the walls of housing. These categories are:

- *Local/traditional*: Local materials—usually climate responsive and sourced locally from nearby sites—and/or techniques—e.g. cob wall, thatched roof and wattle daub—traditionally used in a region. Any construction material or technique with improved or innovative application which reduces resource consumption

Figure 2: Methodology for mapping of skilling and livelihood programmes

Mapping skilling and livelihood programmes and schemes active in state.

Identifying schemes with construction related skilling

Interviews with officials to explore potential of schemes for generating green-jobs in construction sector.

Meeting personnel from key institutions involved in the implementation of skilling programmes.

Curriculum mapping

Sieving construction related courses

Interviews to understand reasons for the current curriculum.

- Capturing the transition in construction technologies and the reasons from inhabitant perspective.
- Capturing market forces and levers governing this transition.
- Understanding the kind of construction skills the new generation of masons are adopting.
- Role played by government housing schemes in construction material adoption.
- Role played by livelihood schemes and institutes in providing construction related skilling to masons

Output

- A compendium of traditional construction materials being used in the region.
- Sectoral guidance strategies to generate livelihood opportunities for local labour force in the self-built housing sector.

Source: CSE

in comparison with conventional market practice, including rammed earth, compressed stabilized earthen blocks (CSEB), filler slabs and rat-trap bond.

- *Mainstream conventional*: Most frequently used construction technologies, including red brick walls, burnt clay brick, fly-ash bricks, concrete columns and reinforced cement concrete (RCC) floors. Materials are not sourced locally. Most skilling schemes and courses related to construction profess this technology.
- *Alternative new mainstream material*: Modern or new age materials and/or techniques promoted by organizations such as the Building Material and Technology Promotion Council (BMTPC) as alternatives to conventional materials, including monolithic concrete technologies and EPS (expanded polystyrene) concrete-based technologies. The components are largely factory-made and the construction process is known to boost the pace of construction.
- *Blended approach in hybrid mode*: Hybrid techniques of construction borrow elements from both modern construction practices (conventional and alternative) and local-material-based (traditional and neo-sustainable) technologies. These techniques thus incorporate durability and stability along with resource-prudent practices.

To reinforce the findings of the literature review, a perception survey was conducted with experts from Odisha and West Bengal. The experts include academicians, practising architects and social workers who have on-ground experience or expertise in the subject from the two states. They validated the finding of the literature and provided information on construction materials and techniques that were not covered by the literature review.

The questionnaire shared with the experts focused on self-built housing in both states. Information regarding the following was sought:

- Construction materials and techniques in the states;
- Skills associated with each of the materials and techniques identified;
- Ways of acquiring skills—formal learning centres, ancestral knowledge, informal institutions, and experience gained from exposure to other regions;
- Materials- and/or technology-promoting agencies, e.g. BMTPC;
- Name of demonstration centres and projects in the respective states which can be visited to observe the constructions materials or techniques listed; and
- Mapping the presence of materials (at the district level) such that the regional presence can be understood to establish a relationship between the climate and the materials and/or techniques.

Nineteen experts were reached for the survey of which ten duly filled questionnaires were received.

Highlights of key findings

Trend in material use in all households in rural areas of Odisha and West Bengal shows predominant use of local material: According to Census 2011, grass, thatch, bamboo, wood, mud, etc. are still the dominant building materials in Odisha. About 33.9 per cent of the total households in the state use these materials, followed by concrete (23 per cent) and handmade tiles (22.8 per cent). While use of grass, thatch and bamboo is considerable in West Bengal, new materials, including galvanized iron, asbestos and metal sheets, are also becoming prominent.

Traditional material and techniques are widespread and commonly applied in local climatic context: Traditional materials—including mud, bamboo, other materials such as wattle and daub in which the wood or bamboo wattle is placed between two layers of daub to make walls, cob walls made of sand, clay and straw, rat-trap bond, laterite block walls and compressed stabilized earth blocks—applied in varying combinations. For roofing, traditional materials and techniques include country tiles with timber understructure, thatch roof, kadi baraga, funicular shells and filler slabs. Additionally, in West Bengal, other techniques, including bamboo attu, brick arches, and ekra wall, have been seen. Terracotta flat tiles with timber under structure is a common roofing technique in West Bengal.

Diverse skill sets have evolved in the region: Time-tested knowledge—including techniques around the use of bamboo, timber and other local wood, their harvesting time, the process of seasoning it, knowhow about knots, ties and joineries and method of treating the bamboo and wood—has evolved in the region. Mud-based technologies require knowledge relating to proportions of mud, filler material and water, consistency of the mixture, drying time for mud, finishing on the external side and protection from weather conditions. Similarly, for stone, mud and clay bricks and blocks, techniques related to curing period, dressing, plastering methods and mortar requirements have evolved.

Specialized expertise relating to the rat-trap bond, which requires understanding of the quantum of mortar to be used, has evolved. This workmanship needs to be properly mapped and nurtured and integrated with modern skill-building programmes. If neglected a valuable resource base and skill will disappear.

Local communities recognize the importance of traditional roof and walling technologies for thermal comfort and livability Some common roofing and walling techniques include cob walls and using sand for strength, clay for binding material and straw for tensile strength. Thatched roofs and wattle and daub walls add to the structural stability of the walls. Generous use of soil provides thermal comfort as this acts as a thermal “battery” to absorb heat during daytime. The higher the thermal mass, the better the thermal comfort.

These traditional technologies are valued for climate responsiveness, providing protection from extreme heat or cold and improved performance with regard to thermal comfort. Further, dwelling units that use these technologies are largely naturally ventilated, and with some use of fans encourage and promote more adaptive thermal comfort. Those who live in houses that employ traditional materials or technologies recognize this function, which reduces the need for cooling appliances and keeps electricity bills lower.

Traditional techniques and material are affordable: The materials are largely sourced from the surroundings and labour from the neighbourhoods. Social cohesiveness among the people in these rural communities plays a role in facilitating the materials and labour required as evidenced in community-oriented self-built housing in several parts of rural Odisha such as Semiliguda, Bisoi, Baripada and in places such as Purulia and Jhargram in West Bengal.

Availability and easy access to local building materials and skills sustain local interest: Technologies that are largely sourced from local vegetation, agricultural waste, soil and stone are available locally and sometime within a radius of 1 km. In Semiliguda, Jhargram, Purba Sridharpur and Puri, adjacent agricultural land is the source for soil and thatch. Bamboo used in wattle and daub technology also come from nearby forests in Belari, Jhargram, Bhawanipatna and Baripada. Proximity to the resource base minimizes or eliminates transport costs and minimizes embedded energy. Notably, local craftsman and masons are nurturing this practice and knowledge.

Women as repositories of traditional techniques and skills: In most of the settlements visited, the construction and upkeep of the house was seen to be done largely by the women of the house. Sourcing and processing of materials as well as walling, plastering and flooring was all done by women. Men helped with roofing.

Mothers teach their daughters these skills and daughters in turn pass it on to the next generation. Family skill reduces the need for hiring outside labour. Also, as the community comes together as and when required to build the houses, the supply of labour for building these houses increases.

This chain of family-based transmission of knowledge is, however, being disrupted by the intrusion of new materials and techniques. This may lead to exponential loss of knowledge and skills for traditional technologies. This reinforces the need to document and preserve these dying technologies that embody traditional wisdom and skills on climate-appropriate housing.

Under the current policy framework formal self-built housing is transiting to new material: Data on PMAY-G, available for nine states and 69 projects, shows that the majority of the units are load-bearing structures (55 per cent) followed by RCC frame structures (39 per cent) and ekra walls (6 per cent). The walling materials in these load-bearing structures are largely red brick (55 per cent), fly-ash bricks (19 per cent), sandstone (16 per cent), laterite blocks (5 per cent) and fly ash brick–red brick combination (5 per cent).

It is natural that with expanding urban influence and changing aspirations the preference for built structures, techniques and materials will also change. Increasingly, communities are moving towards bricks-and-mortar structures and materials like burnt-clay and fly-ash bricks. This trend is industry-led. The materials are homogeneous in nature as their components cannot be changed to their original form after being processed.

New technology requires less labour as compared to traditional techniques and provides fewer opportunities for livelihood. More complex technologies such as monolithic concrete walling and EPS-based walling are taking over. These are highly resource-intensive, carbon-emitting and non-recyclable and have high embodied energy. They are also labour-displacing technologies. If this trend continues traditional material and techniques will become obsolete.

Challenges associated with traditional technologies: Traditional technologies need more maintenance and are less durable than cement structures. For instance, cob walls develop cracks over time due to exposure to heat and daub plaster breaks or chips in heavy rain and floods, exposing the bamboo or wooden reinforcements within the wattle and daub walls. Many of the settlements are located in flood- or cyclone-prone regions, which necessitates additional maintenance and increases costs. But in Bisoi and Baripada, soil can still be acquired from nearby lands while all other building materials have to be bought from the market.

The stereotypical description of "kutcha" housing works against the sustainability of traditional techniques and materials: According to Census 2011, a pucca house is defined as one whose walls and roof is made of permanent materials, i.e. the walls may use stones (duly packed with lime or cement mortar), galvanized iron (GI), metal, asbestos sheets, burnt bricks, cement bricks or concrete. The roof may be made of machine-made tiles, cement tiles, burnt bricks, cement bricks, stones, slate, GI, metal, asbestos sheets or concrete. Kutcha houses are defined as those with walls and roof made of materials that have to be replaced frequently. Walls may be made from any one of the following temporary materials: grass, unburnt bricks, bamboos, mud, grass, reeds, thatch, plastic, polythene, loosely packed stone, etc.

This attribution of "temporary" and "permanent" materials undervalues traditional technologies so that it is perceived as "underdeveloped" and for the poor. Conventional modern materials are seen as "developed" and for the affluent, and that defines the aspiration. This works against local technologies and discounts that a fusion with modern applications is possible.

Policy definition of pucca house is eroding local material and skills: Housing policies promote non-traditional construction materials through construction of *pucca ghar*. A pucca ghar is defined as one that utilizes burnt bricks, fly-ash bricks, reinforced cement concrete, reinforced brick concrete and other such non-traditional materials that are usually industrial products.

According to the requirements, the houses must last for a minimum of 30 years for it to be called a pucca house. Government housing schemes such as PMAY-G provide monetary benefit of up to Rs 1.3 lakh for the beneficiary for building a house and it is tied to construction of a pucca house. This reduces the demand for traditional construction technologies. Prospective home owners are therefore condition bound and cannot exercise the choice for local materials and technique. This approach is generates a rich–poor divide.

Skilling schemes and programmes do not recognize traditional skills and craftsmanship that work with local material: The guiding principle used to understand skills is the following definition stated by the National Sample Survey Organization (NSSO): "A person holding a certificate/ diploma on an appropriate subject will be considered to possess the specified skill along with persons who have acquired the said skill without any such certificate/ diploma or even without attending any institution."

Though the definition is inclusive of people who have acquired skill without any certification, it does not help as there is no validation or consideration for traditional building technologies and techniques through a certified course or acknowledgement as a subject. The skilling courses only teach brick-and mortar-related courses. Hence a mason trained in these technologies is not "certified" as skilled. The “unskilled” status of a local mason with knowledge of traditional techniques has contributed to their wages being considerably lower than their counterparts skilled in brick-and-mortar construction. It is necessary to assess these gaps and influence the skilling and livelihood schemes to incorporate the wealth of knowledge on traditional building material and construction. The curriculum of construction-based courses followed in the states is controlled centrally by agencies such as the Directorate General of Training (DGT) and the respective Sector Skill Councils. The curriculum remains the same throughout the country. It does not incorporate diverse knowledge sets and innovation and nor teach relevant local construction technologies. Ultimately, the skilling and innovation potential of these technologies and workforce in these material technologies need to be assessed.

Absence of policy interest and market pressures has stymied innovation in traditional construction among local communities: In several parts of Odisha and West Bengal, communities that are most vulnerable to climatic stress and extreme weather events depend on traditional construction techniques and material. There is no formal system or policy support to enable innovation in their application to build climate resilience, durability and safety of structures. However, communities find their own ways to resist climatic stress. Local craftsmen find ways to increase durability of self-constructed houses. For instance, fishermen communities along the Puri coast use nets to cover thatched roofs and tie them for reinforcement against high winds. In the Sundarbans, communities are developing hybrid systems in which precast concrete posts are used in place of bamboo poles for reinforcement against strong cyclonic winds. This also helps reduce overall maintenance requirements.

Threatened local ecosystems and ecologies are reducing availability of local building materials sourced from nature and increasing costs: Urbanization and erosion of green cover have led to loss of local vegetation. Micro markets and local economies that nurture traditional building materials have declined. Diversity of agriculture waste has reduced due to the increasing trend toward monoculture. Change in cultivation patterns and crop varieties has eliminated certain crop varieties whose waste was used in construction. For example, roof thatches were in the past made from a variety of rice called Dhudheshwar. But the new variants of cultivated rice are Aman, Aush, Boro, which produce straw that is less resilient to rain and wind. New straw is increasing maintenance costs.

Loss of circularity: A material like thatch is a byproduct of farming. As roofing moves away from traditional thatch systems, farmers lose the “value” of thatch.

The material is considered just “waste” and is burnt in the open, leading to toxic air pollution.

Encouraging trend towards integration of local techniques and material in modern self-built housing: Several architects and local communities have taken the lead in incorporating elements of both traditional and non-traditional construction techniques and materials in contemporary architecture. Although this is not common so far in the conventional mainstream construction sector, a group of progressive architects are demonstrating and validating the potential application of local techniques and materials in the blended or hybrid mode. There is also an emerging trend in which brick-and-mortar houses, built through the government schemes, are extending living spaces and/or building second homes. In such cases, the residents opt to retain the traditional portion of the house for thermal comfort during summer. Traditional technologies such as cob, adobe etc. absorb heat during the day. This thermal massing is also evident in stone-wall technologies.

Initiatives to mainstream fusion techniques: CSE’s research has documented the work of multiple building practitioners that have blended the two approaches to combine the durability and stability of modern technologies with benefits of better thermal comfort, lower material intensity and more employment opportunities of traditional technologies. Currently, hybrid models have not received much support from the market or government policies.

The focus of architects in Odisha and West Bengal—in areas such as the Sundarbans, Bolpur, Baruipur, Kalyani etc.—is on a combination of burnt brick, concrete columns, wattle and daub walls and mud flooring. Concrete columns provide structural stability while wattle and daub walls act as fillers between them. Walls incorporate modern services such as electric fixtures and have good insulation and sound-absorbing properties. These structures utilize concrete columns and beams while infill walls utilize adobe bricks made on-site. The manufacturing of adobe bricks utilizes local labour and material, saves transportation cost, and is significantly less energy intensive than red bricks. They provides good thermal mass. A few courses of red brick are used at the base of the wall as this area is more susceptible to water splashes. The walls are finished with mud plaster. Timber from talwood (the local term for wood from the date palm tree) is used to make the floor to avoid RCC slabs. In Bolpur, the local tradition of triangular window frames is incorporated to avoid RCC lintels.

Examples from Bolpur show that the ground and first floor of structures have RCC columns and beams while the topmost floor is entirely a mud structure with wooden columns. The structure uses sun-dried adobe bricks that contain soil, water, lime and human hair (sourced from local barbers). The bricks are used for external and internal walls and mud plaster is used in finishing the walls. RCC slabs are used only in bathrooms and corridors and the filler slab technique, which saves concrete while making the structure lighter, is used.

The village of Purba Sridharpur in the Sundarbans Delta region, which is prone to frequent floods and cyclones, also has three houses built with local modified materials. A combination of bamboo, rope, precast concrete posts, mud daub, bamboo mats, clay tiles and wooden frames were used to make these structures. Mud daub is used for flooring and on the upper level, spread over bamboo reinforcement. The use of precast concrete posts for structural frameworks serves as a durable alternative to the traditional bamboo and/or wooden framework. Bamboo poles, joined together with steel rods and nylon threads are used to make the roofing frameworks, lintels, support columns and beams. The roofing is done with clay tiles and rice thatch. The rice thatch has panels to be replaced periodically as they get damaged in the heavy rains and winds, but the materials required are locally available and renewable.

Architects have built these structures with local labour. Local residents were trained in the construction techniques, which built local capacity for self-built housing. A non-traditional thatching technique for making thatch panels was also taught to the local women. This hybrid approach that has reinterpreted and created a combination of technologies provides resilience to these structures against frequent extreme climatic events in the region. The use of precast concrete posts has become a common sight in the region as it provides long-term durability and resistance against extreme and frequent rains, floods and winds.

Employability of traditional masons and artisans

CSE visited villages around Durgapur, Jhargram and Purulia in West Bengal and Baripada, Bisoi, Puri coast, Bhawanipatna, Phulbani, Baliguda and Semiliguda in Odisha, and looked into the employability of masons in traditional and non-traditional technologies and techniques. Interviews and focus group discussions revealed that 72–75 per cent of the workers found employment within a radius of 10 km from their home in brick-and-mortar construction projects. A much smaller percentage of labour had to travel beyond 10 km to find employment.

Masons skilled in fusion technologies are rare, and the few that exist are closely associated with architects and/or building designers who focus on hybrid technologies. Since the demand for such projects is less, they must travel longer distances for employability in their niche skill set. We traced the work of two architects that work with hybrid technologies and the masons associated with them to understand how widespread their projects were.

Inadequate policy attention: The guidelines and norms for building material and techniques—which predictably focus on modern material and new alternative technologies applied in mass housing—include the Multi-Attribute Evaluation Methodology for Selection of Emerging Housing Technologies developed by the Building Materials and Technology Promotion Council (BMTPC) for mass housing projects to specify mandatory and desirable attributes for selecting alternative technologies for all state agencies; Global Housing Technology Challenge for identifying and adopting of technological advances in low-cost housing; and BMTPC's *Compendium of Prospective Emerging Technologies for Mass Housing* (2017, 2018 and 2021). The guidelines are designed to facilitate informed choices of different innovative construction practices for mass housing schemes. They focus on the latest materials, their specifications, construction methodologies and projects. BMTPC has added more technologies since its third compendium but these are more relevant for the mass housing self-built housing sector or beneficiary-led construction.

Nascent stage of official documentation of traditional technologies:
The 2021 *Compendium on Building Technologies*, a joint publication by CSIR-Central Building Research Institute, Roorkee and BMTPC, enlisted 66 existing technologies in the following categories: floor/roof construction technologies, roof-construction technologies, wall-construction technologies, foundation construction technologies, system-level technologies, services and materials. The publication focused on the construction of individual houses for low-rise to mid-rise structures and includes traditional and neo-sustainable technologies such as rammed earth, compressed earth, kath kuni wall etc.

Also, the 2021 *Compendium of Indigenous Innovative Building Materials and Construction Technologies* lists 73 technologies and focuses on owner-driven single- or double-storied houses that are self-constructed or made by local masons or artisans. The document acknowledges the importance of technology-generating local employment opportunities and lists this as a feature under various technologies.

Skill development policies and promotion of construction materials and buildings techniques have not integrated local knowledge and material: There are several skill development programmes and institutions at the Central and the state levels, including Pradhan Mantri Kaushal Vikas Yojana (PMKVY), Deen Dayal Upadhyaya–Gram Kaushal Yojana (DDU-GKY), Deendayal Antyodaya Yojana–National Rural Livelihood Mission (DAY-NRLM) and others that fund skilling centres. Visits to several skilling centres in Odisha and West Bengal show that short-term courses play a major role in skilling trainees even in the remotest areas of the states. The Directorate General Training (DGT) decides the curriculum and syllabus; the curriculum for short-term courses is defined by the respective Sector Skill Councils. None of the skilling centres visited conduct courses on indigenous construction technologies. The course Mason General covers construction of masonry structures with brick or block, plastering of masonry surfaces and RCC structure, waterproofing work for structures using cementitious materials, random rubble masonry and IPS or tremix flooring works. Employment post completion of the course is the responsibility of the skilling centre and many centres have tied up with builders or construction companies to absorb their trainees. Not including indigenous skills and materials in course curriculum is clearly a lost opportunity as this neither helps strengthen the local requirements of self-built housing in rural and peri-urban areas nor does it foster integration of the local skills and material in modern self-built housing.

The way forward

Integration of local building materials, techniques and skills with mainstream technologies for self-built housing in rural, peri-urban areas as well as urban areas can give multiple co-benefits. It can reduce material intensity, environmental footprint, create climate-appropriate shelters and improve thermal comfort while improving the structural safety and durability of self-built structures that are the primary source of housing in India.

Yet, the potential application of these technologies in hybrid mode has not been well understood or recognized to draw policy attention. The misplaced emphasis on pucca housing—with local material overlooked as kutcha or temporary—and elevating the status of concrete structures has caused substantial damage. It has detracted attention from the opportunities of blending traditional knowledge with the contemporary to create more sustainable structures.

As a result, local knowledge, techniques and materials have been steadily eroded. Locally appropriate and sustainable techniques that have the potential to be integrated with modern and contemporary applications to reduce the environmental footprint of built structures are ignored in the new housing policy targeted at self-built housing in rural and peri-urban areas. Further, the progressive and voluntary steps that a select group of architects are taking to validate and integrate local techniques and material in modern self-built housing have not found adequate attention and policy support to formalize the efforts to create an institutional and regulatory framework for their uptake in modern structures.

This is not only destroying local systems and the material base but also the livelihood systems and skill base around them. The pandemic-led migrant crisis has reinforced the need for mapping local livelihood options in rural and peri-urban economies. The building sector is crucial as it has one of the largest carbon and environmental footprints and is a difficult sector to contain. As self-built housing is the largest source of housing supply in India across urban and rural areas, it is necessary to assess the emerging hybrid approaches for deeper infusion of local and sustainable techniques and material to prevent more lock-in of more unsustainable material.

Housing schemes need to recognize and incentivize hybrid approaches and fusion of local technologies and material: Government housing schemes such as PMAY-G and its state counterparts need to internalize and incentivize traditional and hybrid technologies in new self-built housing for the co-benefits linked with thermal comfort, climate-appropriateness and circularity. This will provide a wider choice to beneficiaries to integrate several sustainability features in new houses or new extensions. Government schemes need to remove stereotyping of kutcha and pucca houses based on material application and allow more fusion of the two technologies.

It is now necessary to include traditional and local techniques and material within the scope of the housing policy and financing for self-built housing in rural, peri-urban and even urban areas, where a new clientele base seeking fusion technologies is slowly emerging. This will also be more cost effective. Local evidence shows that the capital cost of a house using traditional technologies is considerably lowered.

Provide guidelines, norms, and certify traditional and fusion technologies: The biggest roadblock for mainstreaming of traditional and fusion technologies is the lack of testing and certification of these technologies. While scientific literature has proven the benefits of thermal comfort and disaster resilience of most of these technologies, the absence of standards and tested evidences has prevented their uptake in the market. These technologies need to be evaluated for their performance on thermal comfort and disaster resilience. Based on this technical evaluation, traditional and fusion technologies and the skills related to it need to be certified. Some initiatives such as those pioneered by organizations like Hunnarshala in Gujarat have already begun to generate more data and evidence on these technologies. This need to be taken forward at a scale.

Zoning according to geo-climatic conditions for climate-appropriate guidance on hybrid and traditional construction: A state may have several climatic zones, with varied exposure to disaster and climate vulnerability. For instance, Odisha has a coastline that is frequented by high-speed winds and cyclones as also hilly forest areas with different vulnerabilities. Similarly, West Bengal has a highly eco-sensitive Sundarbans region that is battered by frequent cyclones and storm surges as also the hill districts of Darjeeling and Kalimpong. To address these variabilities, states need to zone their areas and guide choices of construction technology and materials that are suitable for a particular zone. Vulnerability mapping will be crucial in order to provide an appropriate response.

The reinvention of technologies has to address climate-resilient structures: The Odisha Urban Housing Mission highlighted the reconstruction process after Cyclones Phailin and Fani and underscored the importance of disaster-resilient construction and need for skilling local masons despite the problem of aspirational conflicts among beneficiaries. Odisha has reinvented the hybrid approach for cyclone rehabilitation. Their shelter schemes have used modern technologies for structural systems, such as a concrete foundations and raised plinths with protection, while using traditional techniques such as four-way sloped roofs that proved to be more disaster resilient. This housing scheme offers the opportunity for fusion technologies for which the government adopted a toolkit with prototype designs for making transit homes. Experts also point out that even building typologies need to be reinvented in highly vulnerable areas, and may require at least one disaster-resilient room.

Update schedule of rates for formal adoption of these materials: The states need to include traditional and hybrid technologies and the materials used in their schedule of rates for procurement. This will push uptake and mainstream these technologies in the construction sector.

Skill-development programmes and skilling centres need to integrate local technologies: The focus has to be on technologies that utilize locally available materials and skills and are responsive to the local climate and cultural context. To do this, a repository of region-specific construction technologies derived from local materials that perform well in terms of climate sensitivity and thermal comfort must be prepared. This compendium has to define the scope of its application in hybrid mode. The Central Building Research Institute (CBRI) at Roorkee, Uttarakhand, has taken note of this. Such initiatives need to be taken forward as part of the housing policy.

Skill-development programmes and skilling centres need to integrate local technologies: The focus has to be on technologies that utilize locally available materials and skills and are responsive to the local climate and cultural context. For this, a repository of region-specific construction technologies derived from local materials that are tested and perform well in terms of climate sensitivity and thermal comfort must be prepared.

To provide transit houses to beneficiaries after cyclone Phailin hit Odisha in 2013, the Urban Housing Development Mission, government of Odisha, developed guidance on houses that are disaster resilient and use local material and labour. Such initiatives need to be taken forward as part of the housing policy. Certification of these technologies will play an instrumental role in increasing uptake and aligning skilling efforts towards.

Skilling schemes and institutions to recognize hybrid technologies to diversify livelihood options in the sector needed: The curriculum in institutions needs to be designed to include local techniques and materials to build the knowledge base and build new skills in the sector. Local labourers and masons who are otherwise exiting to brick-and-mortar and concrete technologies need to be trained in hybrid technologies through skilling centres. To do this, certification of skill on traditional and hybrid technologies is crucial. Once masons are certified, statutory bodies such as the West Bengal State Council of Technical and Vocational Education and Skill Development can roll out skilling programmes on these technologies. This is needed to make future building stock climate responsive, especially in areas that are especially vulnerable to climatic stress and need appropriately designed buildings rooted in local resources. It is also needed to catalyse more local innovation and normalize use of locally developed climate-sensitive hybrid technologies.

Promote micro industries and local economies that process local building materials and agricultural waste to build the supply chain: This is in line with the objectives of the United Nations Sustainable Development Goal 12—titled "responsible consumption and production"—and principles of circular economy. Setups like state tribal museums and technology demonstration centres play an instrumental role in such efforts. A strong co-benefit of this approach is the absorbing of agricultural waste that otherwise may be burnt and cause a range of environmental problems. Circular use of material in the building sector can help address this problem.

Innovation and demonstration centres are needed to promote hybrid technologies: Funding strategy and policies need to support hybrid approaches and local technologies in contemporary modern self-built houses in both rural and urban situations. The experiments and initiatives of several architects that are already underway for both rural and urban clientele need to be supported and mainstreamed. Several projects have already demonstrated how the combination of traditional and new technologies can work efficiently while improving thermal comfort, durability and cost effectiveness. Innovative use of conventional materials such as burnt-clay bricks, cement and concrete, along with the new material, can provide a range of solutions for sustainability. In fact, such hybrid techniques need to be included in the schedule of rates. The state schedule of rates must incorporate region-specific hybrid and traditional technologies as well as materials used under them. This will push uptake and mainstream these technologies in the construction sector.

Promotion of local material can strengthen conservation of local ecology and promote circularity to reuse waste material or agricultural waste: The ecological resource base that sustains building material such as wood, timber, bamboo and thatch is under stress due to environmental degradation and developmental impacts. If a supply chain can be developed to sustain a market in innovative self-built housing based on the fusion principle, it will create pressure to conserve and rejuvenate the ecological base. Also, conversion of agricultural waste into building material such as thatch can prevent burning of this waste, which contributes enormously to air pollution. Overall, rejuvenation of the ecological base, reduction in environmental and carbon footprint of built environment and greater sustainability of self-built housing has co-benefits while also strengthening the livelihood base.

SECTION 1: Profiling material and skills of built structures in rural areas

This study, conducted in the states of Odisha and West Bengal, has the following two objectives:

1. To understand local building materials and techniques used in different climatic conditions and ecosystems and the way they are used by local communities; and

2. To examine how these time-tested locally sustainable and low-carbon techniques and strategies can be mainstreamed into contemporary self-built houses in rural, peri-urban and even urban areas. While this can provide locally appropriate and climate-sensitive solutions with minimal environmental footprint, it can also be a source of local livelihood in local construction.

The compelling reason for this investigation was also the pandemic-led migrant crisis that exposed the fragile economy and weak employment base in rural and urban areas. The local base of employment is under stress in several sectors, particularly in the local building sector. Traditional techniques are disappearing and reducing the demand for local skills, affecting local masons and other labour, who have migrated for jobs to urban centres and transited to mainstream technologies in the building construction sector.

Given that building construction will remain the most carbon-intensive sector, this is a matter of concern. The use of mainstream materials with high embodied energy due to their extraction, manufacture, long transportation from the place of origin and heat gain through the building elicits increasing demand for cooling as well as the heat island effect. Mainstream approaches have also reduced the use of passive architectural techniques of shading, ventilation and daylighting. This trend especially in mass housing is making mainstream construction approaches more carbon intensive.

It is therefore necessary to understand what is possible in the sector of self-built housing that is more influenced by individual decisions and choices. The possibilities are immense in rural and peri-urban areas where a fusion approach can be adopted to integrate the sustainability features of local architectural and construction traditions and knowledge of local-material use with mainstream material and design approaches. This is possible in new construction of self-funded and government-funded houses as well as in incremental extension of existing houses.

Against this backdrop, the Centre for Science and Environment (CSE) conducted this assessment to understand the construction materials and techniques and local skills native to Odisha and West Bengal. The assessment is based on field investigation, including a series of interviews conducted with practising architects, academicians, skilling centres, local masons and community leaders. It also includes a review of the literature on construction materials, techniques and local skills in West Bengal and Odisha, including reports published by governmental and non-governmental organizations, governmental schemes and missions. Data available from Census of India records on material use in households has also been reviewed.

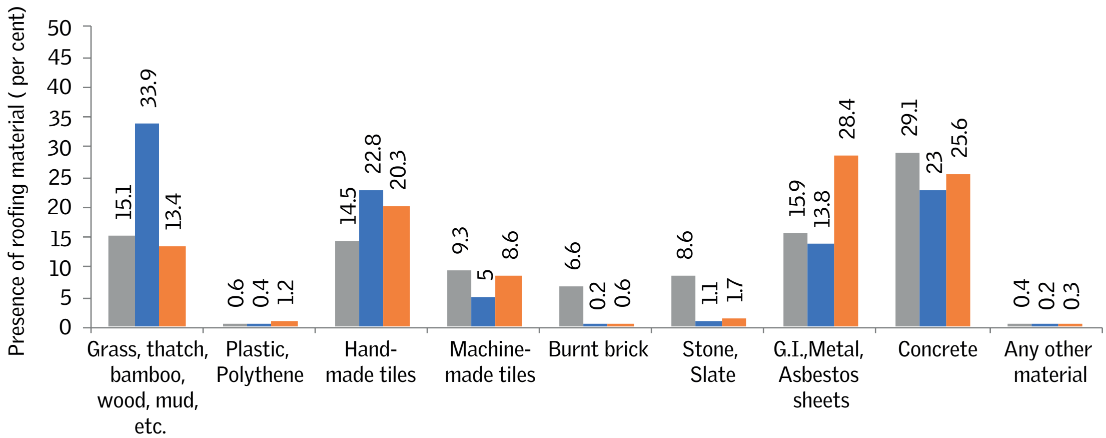
The assessment brought out the following critical trends in the local building construction sector:

Trend in material use in rural households: The Census of India records the predominant material used for roofs and walls in states. According to Census 2011, grass, thatch, bamboo, wood and mud are the dominant building materials in Odisha—about 33.9 per cent of the total households use them—followed by concrete (23 per cent) and hand-made tiles (22.8 per cent). In contrast, in West Bengal, galvanized iron, asbestos and metal sheets are dominant—28.4 per cent of the households use them—followed by concrete (25.8 per cent) and handmade tiles (20.3 per cent) (see *Graph 1: Material usage in roofs in West Bengal and Odisha*).

For walling, burnt brick is predominantly used as the primary material in Odisha (44.1 per cent), followed by mud or unburnt brick (29.1 per cent) and grass, thatch and bamboo (18.1 per cent). In West Bengal, mud or unburnt brick is primarily used (47 per cent) followed by burnt brick (36.7 per cent) and grass, thatch, bamboo (6 per cent) (see *Graph 2: Material usage in walls in Odisha and West Bengal*). Given the dominance of rural and peri-urban households in these states, mud, unburnt brick and grass, thatch and bamboo dominate material use.

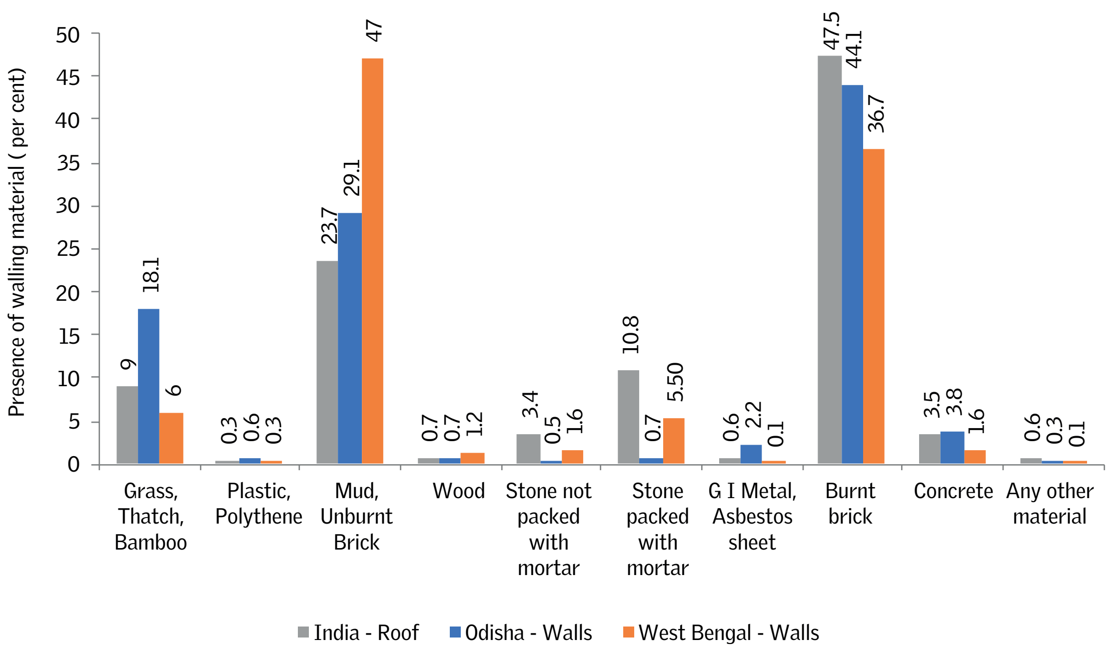
For Pradhan Mantri Awas Yojana-Grameen (PMAY-G), data on materials is available for nine states and 69 projects as of July 2021 in a series known as *Gaon Vikas ki Ore* on the PMAY-G website. The majority of the units are load-bearing

Graph 1: Material usage in roofs in West Bengal and Odisha



Source: CSE study

Graph 2: Material usage in walls in Odisha and West Bengal



Source: CSE study

structures (55 per cent) followed by RCC frame structures (39 per cent) and ekra wall (6 per cent). The materials in these load-bearing structures can be further divided into five categories. About 55 per cent of the walling comprises red brick, 19 per cent fly-ash bricks, 16 per cent sandstone and 5 per cent each laterite blocks and fly-ash brick-red brick combination.

Profiling material use in districts of Odisha and West Bengal

Existing published literature on material presence and interviews with experts indicate an array of materials and building techniques in use. Materials are divided into three categories: traditional, neo-sustainable and alternative mainstream. The tentative locations of the materials have also been mapped based on their availability (see *Map 1: Districts of Odisha with presence of the identified materials* and *Map 2: Districts of West Bengal with presence of identified materials*).

CSE conducted a literature review to understand region-specific construction materials and techniques in the native climatic and topographical conditions of Odisha and West Bengal (see *Table 1: Construction materials and techniques validated for Odisha* and *Table 2: Construction materials and techniques validated for West Bengal*). Based on the literature survey, expert interactions and experts' perception survey, the regional material and technology presence was mapped for the self-built housing sector. This review reveals nine types of roofs and seven types of walling material and/or technologies in Odisha and five types walling material and/or technologies and five types of roofs in West Bengal.

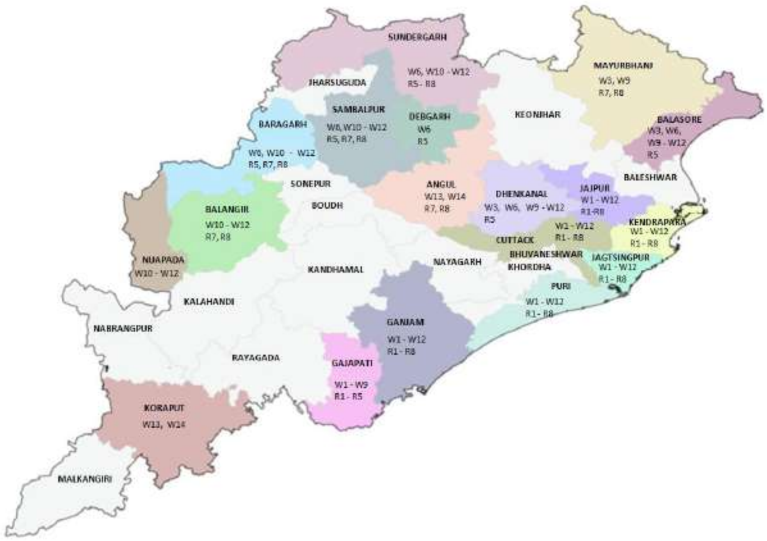
Table 1: Construction materials and techniques validated for Odisha

S. no.	Category	Material or technique validated
WALLING MATERIALS OR TECHNIQUES		
1	Traditional	Wattle and daub
2	Traditional	Cob wall
3	Traditional	Laterite block
4	Neo-sustainable	Rat-trap bond
5	Neo-sustainable	Compressed stabilized earth blocks
ROOFING MATERIALS OR TECHNIQUES		
1	Traditional	Country tiles with timber under structure
2	Traditional	Thatch roof
3	Traditional	Kadi baraga
4	Neo-sustainable	Funicular shells
5	Neo-sustainable	Filler slab

Map 1: Districts of Odisha with presence of the identified materials as per expert review

LABEL	WALL TECHNOLOGIES	CLASSIFICATION
W1	WATTLE AND DAUB	TRADITIONAL
W2	COB BASED WALLS	TRADITIONAL
W3	LATERITE BLOCKS	TRADITIONAL
W4	BAMBOO ATTU	TRADITIONAL
W5	WOODEN ATTU	TRADITIONAL
W6	ADOBE BRICKS	TRADITIONAL
W7	SUN DRIED BRICKS	TRADITIONAL
W8	BAMBOO POSTS AND MATTED PALM LEAVES AS WALLS	TRADITIONAL
W9	KHONDALITE BLOCK	TRADITIONAL
W10	RAT-TRAP BOND	NEO - SUSTAINABLE
W11	RAMMED EARTH	NEO - SUSTAINABLE
W12	CSE BLOCK	NEO - SUSTAINABLE
W13	FLY ASH BRICKS	NEO - SUSTAINABLE
W14	AAC BLOCK	NEO - SUSTAINABLE

LABEL	ROOF TECHNOLOGIES	TRADITIONAL
R1	DOUBLE ROOF	TRADITIONAL
R2	GABLE ROOFS - TIMBER AND BAMBOO	TRADITIONAL
R3	THATCH ROOF	TRADITIONAL
R4	KADI BARANGA	TRADITIONAL
R5	COUNTRY TILES	TRADITIONAL
R6	FERROCEMENT ROOFING CHANNELS	NEO - SUSTAINABLE
R7	PLANK AND JOIST	NEO - SUSTAINABLE
R8	FILLER SLAB	NEO - SUSTAINABLE



Map 2: Districts of West Bengal with presence of identified materials as per expert review

LABEL	WALL TECHNOLOGIES	CLASSIFICATION
W1	WATTLE AND DAUB	TRADITIONAL
W2	COB BASED WALLS	TRADITIONAL
W3	BAMBOO ATTU	TRADITIONAL
W4	WOODEN ATTU	TRADITIONAL
W5	SUN DRIED BRICKS	TRADITIONAL
W6	EKRA WALL	TRADITIONAL
W7	BAMBOO POSTS AND MATTED PALM LEAVES AS WALLS	TRADITIONAL
W8	RAT-TRAP BOND	NEO - SUSTAINABLE
LABEL	ROOF TECHNOLOGIES	TRADITIONAL
R1	GABLE ROOF	TRADITIONAL
R2	THATCH ROOF	TRADITIONAL
R3	KADI BARANGA	TRADITIONAL
R4	COUNTRY TILES	TRADITIONAL
R5	TERRACOTTA TILES	TRADITIONAL
R6	EKRA ROOF	TRADITIONAL

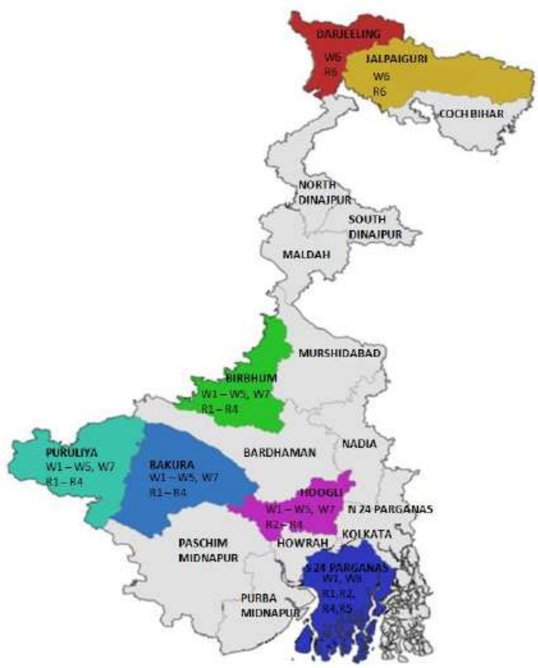


Table 2: Construction materials and techniques validated for West Bengal

S. no.	Category	Material or technique validated
WALLING MATERIALS/TECHNIQUES		
1	Traditional	Wattle and daub
2	Traditional	Cob wall
3	Traditional	Bamboo attu
4	Traditional	Brick arches
5	Traditional	Ekra wall
6	Neo-sustainable	Rat-trap bond
ROOFING MATERIALS OR TECHNIQUES		
1	Traditional	Thatch roof
2	Traditional	Terracotta flat tiles with timber under structure
3	Traditional	Kadi baraga
4	Traditional	Country tiles
5	Traditional	Ekra roof

The changing landscape of walling technologies

Traditional walling technologies in Odisha and West Bengal have for centuries protected households from the hot and humid weather typical of these states. The CSE field investigation revealed that cob-based walls, wattle and daub and stone masonry are the most commonly used technologies in rural areas. Such technologies are a product of years of evolution and wisdom that combine sourcing of materials from the vicinity and identifying construction techniques and shaping them together to respond to the native climate.

As a result, each material used in these technologies plays a different role. Cob walls, for instance, are made of sand, clay and straw. While sand adds strength, clay acts as a binding material and straw brings tensile strength. Similarly, thatched roofs—made with wooden and bamboo reinforcements layered with thatch bundles or panels—as well as wattle and daub, in which the wood or bamboo wattle placed between two layers of daub, add structural stability to walls. Generous use of soil has made these technologies capable of providing thermal comfort. Soil-based walls act as a thermal "battery" that absorbs heat during the day and keeps interiors cool. This heat-absorbing property of a material is called "thermal mass". The higher the thermal mass, the better the thermal comfort. This property also applies to walling that uses stone.

Despite several co-benefits associated with traditional technologies, walling materials have predictably seen a transition to materials such as burnt-clay brick and fly-ash bricks. These materials are homogeneous in nature as their components are irreversible to their original form after being processed. In comparison with traditional technologies, these conventional technologies provide less thermal comfort to the occupant as gathered from the field investigation. On the other hand, industry-led changes in mainstream material use require less labour as compared to their traditional predecessors. Hence their manufacturing and implementation provide fewer livelihood opportunities.

The emerging practice brings back non-homogeneous materials but this time with more complex technologies such as monolithic concrete walling and EPS-based walling. These technologies are highly resource-intensive, carbon emitting and non-recyclable, with high embodied energy. Also, their manufacturing and implementation require less labour and but more heavy equipment. With high need for engineering inputs, these technologies take away livelihood opportunities in local areas. They are also making traditional skills and techniques obsolete.

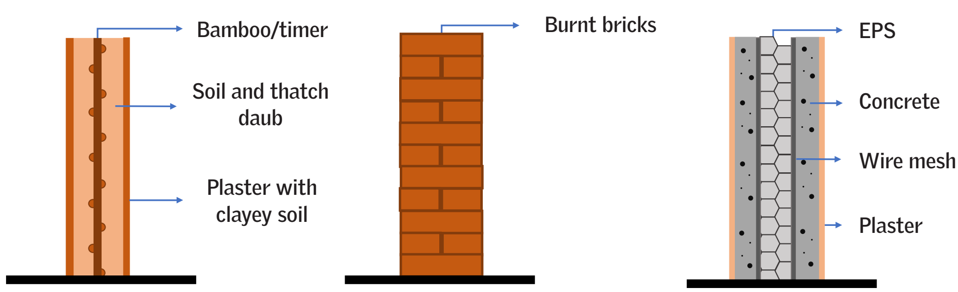
Traditional technologies still exist despite the infusion of different technologies in the market due to its several co-benefits. For many years, traditional walling technologies have helped people withstand the hot and humid climate of West Bengal and Odisha. Economic factors also contribute to the prevalence of these technologies. This section describes these factors.

What currently influences demand for traditional technologies?

The following factors contribute to traditional technologies being favoured in rural communities.

Climate responsiveness: Traditional technologies have been tested and tweaked over generations to respond to local geo-climatic conditions. Protection from

Figure 4: Transition from non-homogeneous to homogeneous to non-homogeneous materials



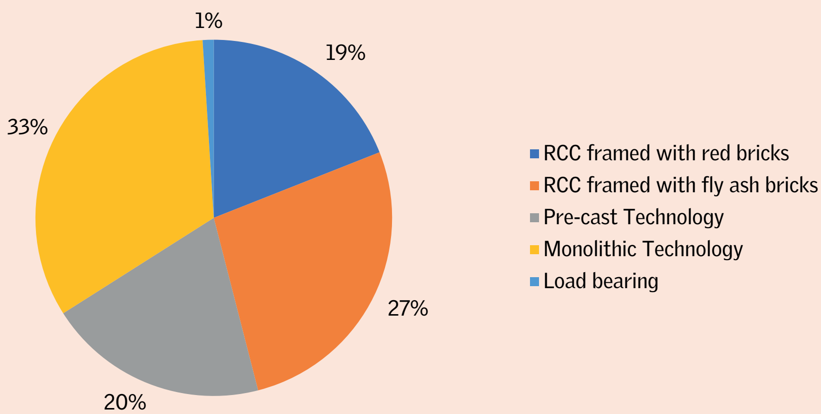
Source: CSE

TREND IN MATERIAL USE IN URBAN HOUSEHOLDS—PMAY-U

As per data submitted by different states and Union Territories to the Central Sanctioning and Monitoring Committee (CSMC) under PMAY, CSE studied about 128 projects for their materials.

Under the affordable housing in partnership (AHP) vertical of PMAY-U, monolithic technology dominates (at 33 per cent) walling techniques within the sample (see *Graph 3: Construction materials and technologies used in PMAY-U [AHP]*). This is followed by the reinforced concrete cement (RCC) frame structure with fly-ash bricks (27 per cent) and RCC frame structures with red bricks (20 per cent) and precast technology (19 per cent).

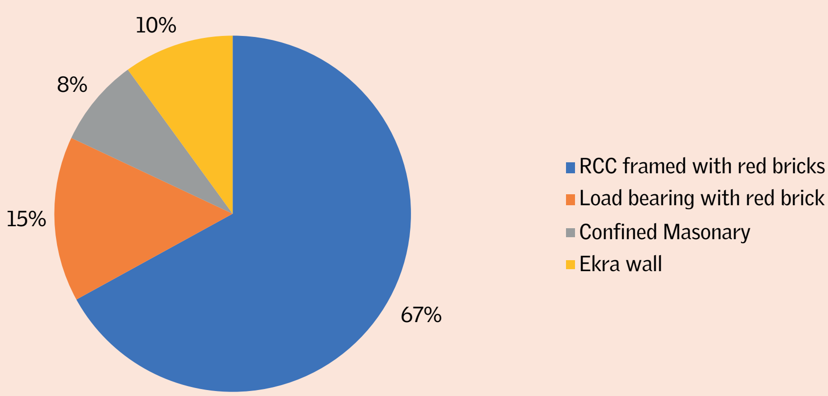
Graph 3: Construction materials and technologies used in PMAY-U (AHP)



Source: CSE study

In the beneficiary-led construction (BLC) vertical of the PMAY-U, RCC frame structures with red bricks dominate, with 67 per cent of the units using this in the sample size of 115 projects (see *Graph 4: Construction materials and technologies used in PMAY-U [BLC]*). This includes load-bearing structures with red bricks (15 per cent), ekra wall (10 per cent) and confined masonry (8 per cent).

Graph 4: Construction materials and technologies used in PMAY-U (BLC)



Source: CSE study

extreme heat or cold is a fundamental function of dwellings made with traditional technologies and are perceived to perform well for thermal comfort. These dwelling units are largely naturally ventilated with some use of fans that encourage and promote more adaptive thermal comfort. Occupants recognize and understand this function. The use of traditional technologies reduces the need for cooling appliances and keeps electricity bills lower. Aspects of the built structure can be oriented and designed as needed to withstand weather events such as cyclones and floods.

Affordable construction: Dwellings made with traditional technologies are relatively inexpensive. Aspects requiring monetary inputs include labour and materials that are available locally. Material is mainly sourced from the surroundings and labour is available in the neighbourhood. For instance, soil and clayey soil—generally the main component of traditional walling—is usually taken from the owner's land and/or from nearby areas such as farmlands or riverbanks. Wood from local vegetation or from forests is collected, treated and used for trade and construction.

Community mobilization of labour and resource: Social cohesiveness in rural communities also facilitates the availability of materials and labour required

Residents of Semiliguda village in Odisha come together for the construction of a new house in their locality

PHOTO BY: HARIKRISHNAN

from the villages. People from one locality get involved in making all the houses in the vicinity. This collaborative practice of self-construction is a community tradition witnessed in Semiliguda, Bisoi, Baripada in rural Odisha and in Purulia and Jhargram in West Bengal. People from different families in the villages come together to contribute labour for the construction of houses.

Supply factors in favour of traditional technologies

Availability of and easy access to local building materials: The advantage of traditional technologies is that the material supply chain is nearly entirely local. They are sourced from local vegetation, agricultural waste, soil and stone. Most of these materials are available locally and sometimes within a radius of not more than 1 km as observed during the field investigation. For instance, rural settlements of Semiliguda, Jhargram, Purba Sridharpur and Puri are most often adjacent to agricultural land, which makes availability of soil and thatch abundant. Bamboo used in wattle and daub technology—used in Belari, Jhargram, Bhawanipatna and Baripada—also comes from forests nearby. In hilly areas such as Lulung village in Baripada, Purulia and Phulbani, stones are widely available. Close availability of materials eliminates associated transportation costs, which is a huge component in the cost of conventional and alternative technologies. Such easy access and availability add to the attraction of traditional technologies.

Availability of skilled labour and role of women: In most settlements in Odisha, the construction and upkeep of homes is done largely by the women of the house. Sourcing of materials and processing, walling, plastering and flooring is all done by women. Men contribute with roofing. Mothers teach their daughters these skills and they pass it on to the next generation. As the skills are available at home, the need to hire masons is obviated. Communities coming together for construction also improves the supply of labour for houses.

The interviews conducted with experts for this assessment also revealed that ancestral knowledge is the primary source of acquiring skills around traditional technologies. Therefore, if a few members of one generation do not teach and train the next generation due to penetration of conventional materials, an exponential loss of knowledge and skills for traditional technologies results. This reinforces the need to document and preserve dying technologies that embody traditional wisdom and skills on climate-appropriate housing.

Terrain and type of housing: Financially vulnerable low-income communities tend more to live in less connected and/or disaster-prone zones than financially stable middle- and high-income communities. Most urban centres are located in

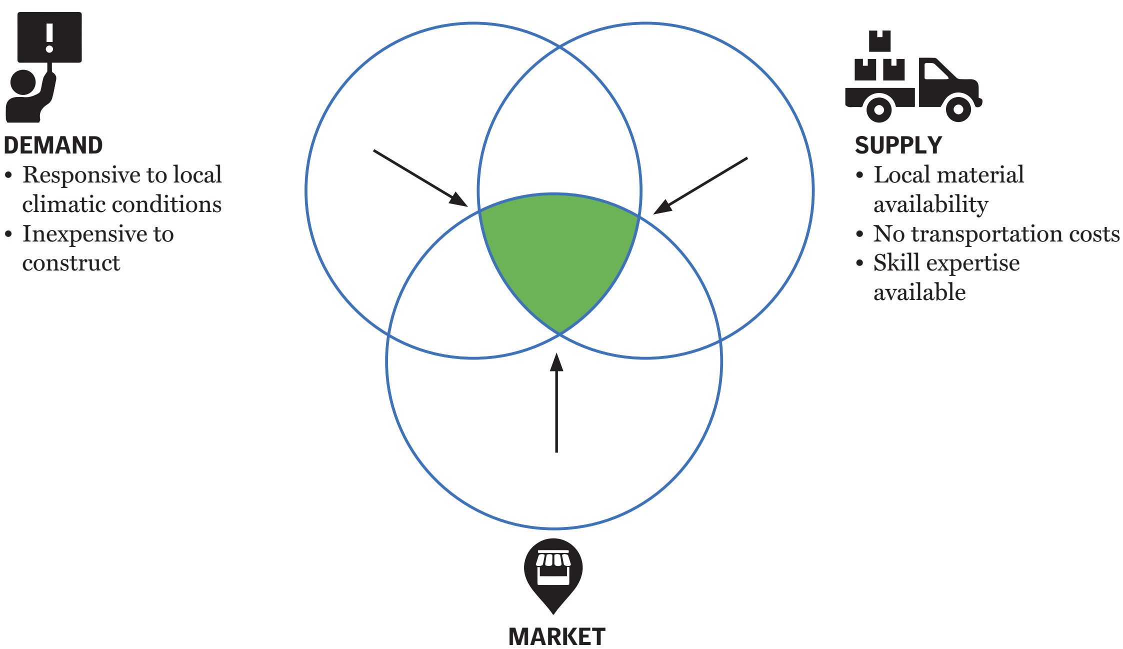
House and bamboo trees in Durgapur

House at Hathichada in the hilly forests of Bisoi

House in Tandaghar in the coastal plains of Puri

House in the mountainous forests of Purulia, West Bengal

Figure 5: Market dynamics in the past—factors that made traditional construction desirable



the plains and are well connected to national and state transport networks. Ease of accessibility and transportation helps in the further reach and use of non-traditional building materials such as brick, mortar and asbestos.

The presence of non-traditional housing is seen more in the plains than in other geographic zones. Maintenance required in these areas is also less as they are less prone to extreme weather events, unlike the coasts, which face cyclones. The coasts are mostly occupied by farmers and daily wage labourers, who have to constantly renew and maintain their homes.

What is working against traditional technologies?

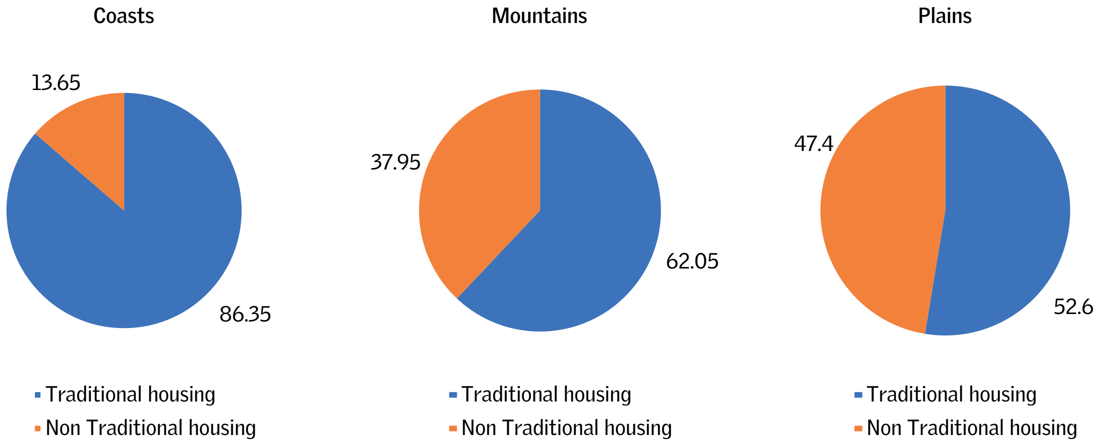
Rural areas are using more modern and fast-paced walling technologies, eclipsing the benefits of traditional technologies. Further, this transition from traditional technologies is disrupting the local market and pushing beneficiaries towards expensive, climate-inappropriate, resource-intensive and high embodied-energy materials. With the influx of modern conventional technologies, the odds are against traditional technologies.

Traditional technologies are more maintenance intensive: Traditional structures are less durable than cement structures. They undergo wear and tear and require periodic maintenance. For instance, cob walls develop cracks due to exposure to heat over time and daub plaster breaks or chips in heavy rains and floods, exposing the bamboo or wooden reinforcements within wattle and daub walls. Many settlements are located in flood-prone areas and periodic maintenance of houses has become part of the daily lives of people.

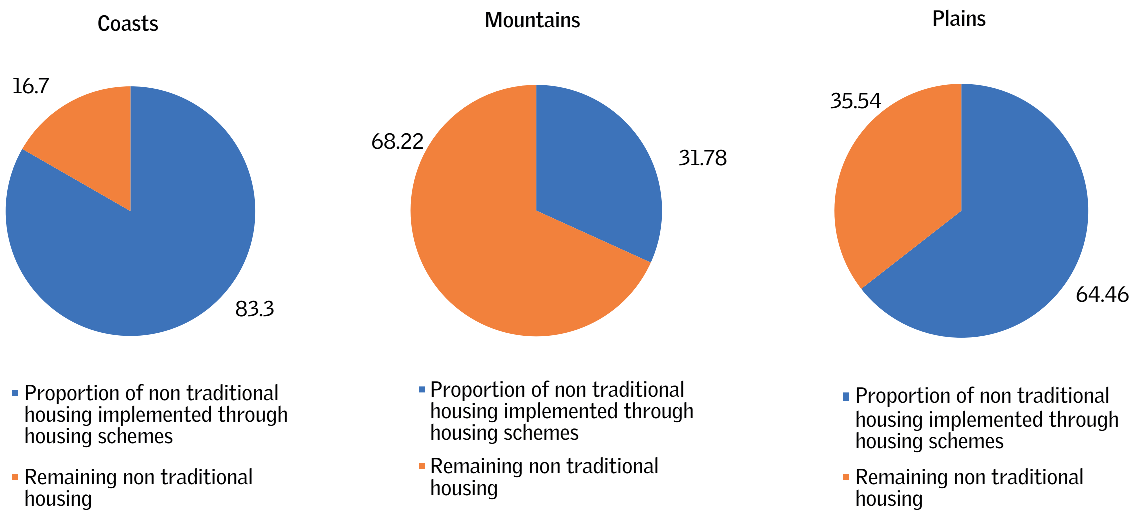
The increasing occurrence and intensity of extreme-weather events—largely cyclones and floods in this region—heighten the need for maintenance. This is even more so for villages in and around coastal areas such as Puri and Purba Sridharpur in the Sunderbans as they witness frequent cyclones. Water levels rise to about five feet from ground level and damage walls of shelters even when most of the structures are built on elevated plinths created to prevent the impact of the floodwater. Houses previously required annual or semiannual maintenance, but now require at least three to four rounds of maintenance due to increasing extreme-weather events. For instance, 2021 witnessed Yaas, Jawad and Gulab cyclones, which caused substantial damage in coastal areas.

Since most of the walls are traditionally constructed using soil-based technologies—they are made in layers, with each layer taking a day or two in the sun to dry—the walls of a dwelling can take up to 10–20 days to construct. This is a time-

Graph 5: Material usage of traditional and non-traditional construction in surveyed villages with different topographies



Graph 6: Proportion of government-implemented housing in surveyed villages with different topographies



consuming process. Moreover, in case of heavy rains, the walls are vulnerable to damage. Cracks also form over time and require maintenance close to every rainy season. For these reasons, some residents have started to shift to conventional materials such as red-brick walls.

The common thatch roof requires maintenance at least once every year. This is a time-consuming and expensive exercise. On average it takes one day to remove an

PHOTO BY: SUGEET GROVER

The level of water rise during floods in Purba Sridharpur, Sundarbans

PHOTO BY: SOURAV JANA

Buildings are constructed next to waterbodies in Purba Sridharpur as livelihoods depend on the waterbodies.

PHOTO BY: SOURAV JANA

The base of wattle and daub walls cracked open due to the frequent floods in Purba Sridharpur

PHOTO BY: HARIKRISHNAN

Fishing nets are used over roof thatches to provide resistance to wind in Gundalba, Puri

existing thatch (with two to three workers) and two to three days to put up a new one. In spite of most residents admitting that the thatch roof keeps their dwellings cooler, maintenance works out to be expensive. Metal sheets and asbestos sheets provide simpler solutions as maintenance reduces significantly.

The shift to columns is less than to roof and walls, but areas that experience frequent flooding have shifted to either precast concrete columns (in the Sunderbans region) or red-brick columns (in Belari-Uluberia).

Increase in maintenance requirements means increased need of time, energy and money. High-speed winds, floods and cyclones damage both roof and walls. Blowing away of thatch panels and tiles are direct damage. Indirect damage includes deteriorating quality of materials due to changing climate. For instance, thatch—a byproduct of locally cultivated rice—in Purba Sridharpur is witnessing reduced durability due to rising episodes of heatwaves.

As per our field investigation, the annual maintenance cost of a 300–400 square foot house made with traditional technology is Rs 8,000–12,000 at the time of repair. The cost has increased in the last few years and varies from region to region, depending on how much material can be locally sourced. For instance, in Bisoi and Baripada, soil can still be acquired from nearby lands while all other building materials have to be bought from the market. Material available locally is also reducing.

Stereotyping of kutcha houses: Another factor working against traditional technologies is their stereotyping as kutcha houses, which are perceived as inferior and make pucca houses aspirational. Census 2011 defines a pucca house as one whose walls and roof are made of permanent materials, namely, stones (duly packed with lime or cement mortar), galvanized iron (GI), metal, asbestos sheets, burnt bricks, cement bricks or concrete. The roof may be made with machine-made tiles, cement tiles, burnt bricks, cement bricks, stones, slate, GI, metal, asbestos sheets or concrete. Kutcha houses are defined as houses in which both the walls and roof are made of materials that have to be replaced frequently. Walls may be made from any one of the following temporary materials: grass, unburnt bricks, bamboo, mud, grass, reeds, thatch, plastic, polythene, loose packed stone, etc.

This classification of "temporary" and "permanent" materials imply that traditional technologies are "underdeveloped" and conventional modern materials are "developed". These two categories have come to be associated with socioeconomic status—"high-income" status is associated with modern conventional materials and "low-income" status with traditional technologies of the rural communities. Conventional building materials are used more in less disaster-prone areas.

SECTION 2: The policy muddle—kutcha versus pucca

Housing policies favour only pucca houses and not integration: The multiple housing schemes and policies of the Government of India, including Pradhan Mantri Awas Yojana and state schemes such as Bangla Awas Yojana in West Bengal and Biju Pakka Ghar Yojana and Nirman Shramik Pucca Ghar in Odisha, have not integrated traditional materials and techniques within their scope.

According to the administrative development frameworks and systems in place, a house must last for a minimum of 30 years for it to be called a pucca house. The schemes provide monetary benefit of up to Rs 1.3 lakh for beneficiaries for building a house. One of the conditions, however, is that the construction should be "pucca"—funding is allotted for pucca construction. A homeowner is thus forced to use non-traditional technologies, leading to a decrease in the demand for traditional construction technologies. Policies are thus promoting non-traditional construction materials

A pucca ghar is one that utilizes burnt bricks, fly-ash bricks, reinforced cement concrete, reinforced brick concrete and other such non-traditional materials which usually are industrial products. A kutcha ghar is defined as one utilizing traditional materials such as unburnt bricks, bamboo, soil, grass, reeds etc.

In the past, there was almost no construction that could be defined as pucca in the region. All buildings were made of traditional building materials. Now 22.2 per cent, roughly two out of 10 built units in the villages of Phulbani, Bhawanipatna, Semiliguda and Baliguda in Odisha are pucca houses. In Durgapur, Jhargram and Purulia in West Bengal, 31.4 per cent—roughly three in 10—are pucca houses.

Policies and schemes are thus catalysing the transition of materials without a guide on how non-traditional and traditional housing can be integrated.

Sociocultural factors (aspirational notion): More than 75 per cent of the people from about 160 interviews and surveys in the visited locations aspired for or preferred modern construction technologies due to the elevated status symbol associated with a pucca ghar. Also, the monetary benefits and distinction between kutcha and pucca by the development authorities and treatment of traditional material as non-durable have changed people's perceptions.

Non-recognition of traditional skills and techniques under skilling schemes a barrier: The guiding principle for understanding skills in the National Sample Survey Organization (NSSO) is the following: *"Any marketable expertise, however acquired, irrespective of whether marketed or not, and whether the intention is to market it or not, is considered as skill. Thus, a person holding a certificate/diploma on an appropriate subject will be considered to possess the specified skill along with persons who have acquired the said skill without any such certificate/diploma or even without attending any institution. When a person has acquired skill in more than one trade, the skill in which he is more (most) proficient is considered as his skill."*

This definition is inclusive of people who acquire skills without any certification. But since there has been no validation nor consideration for traditional building technologies and techniques as a certified course or acknowledged as a subject, the demand for it has never increased.

Both Odisha and West Bengal have robust skilling schemes. However, the skilling courses only teach brick-and-mortar-related courses. Hence a mason trained in traditional technologies is not "certified" as skilled. Courses only certify modern-building construction skills. The reduction in demand and the "unskilled" status of masons trained in traditional technologies has contributed to their wages being considerably lower than their counterparts skilled in brick-and-mortar construction. It is necessary to assess the gaps and influence these skilling and livelihood schemes so as to incorporate the wealth of knowledge on traditional building material and construction.

Traditional construction techniques were once household knowledge, and thus an easily accessible and cheap workforce. As they are not acknowledged as relevant, these techniques are losing their value and getting lost.

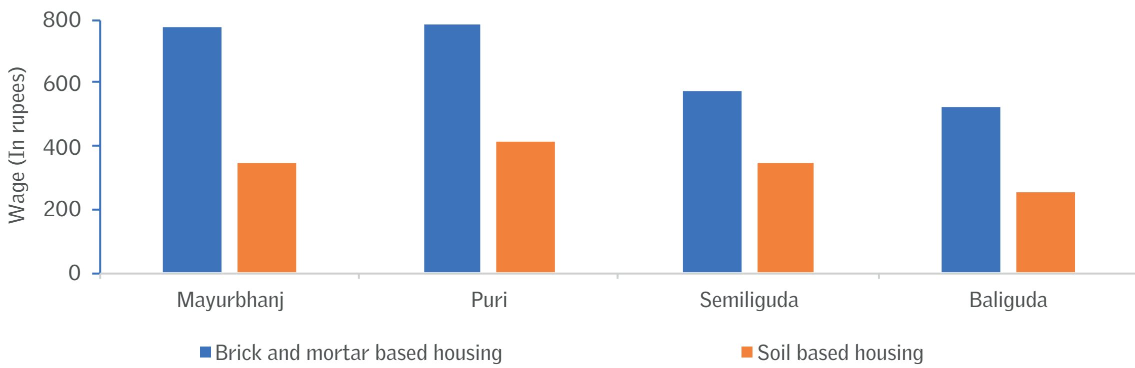
Neglect stymies in innovation in traditional construction: Several institutes in the country—including the Centre for Sustainable Technologies, Central Building Research Institute (CBRI) and Rajiv Gandhi Rural Technology Park—do formal research on traditional construction methodologies, techniques and solutions for gaps and weaknesses.

The curriculum of construction-based courses in the states is controlled Centrally by agencies such as Directorate General Training (DGT) and the respective Sector Skill Councils. The curriculum remains the same throughout the country, without integration of the wealth of traditional and innovation knowledge. The states do not teach these relevant local construction technologies. The skilling and innovation potential of these technologies and workforce in these material technologies need to be assessed.

Skill migration to modern technologies: As opportunities for masons in local traditional construction is dwindling, other factors are pulling them to non-traditional construction sectors. Even better wages linked with traditional technologies are lower than those associated with modern technologies. Moreover, traditional building materials such as bamboo, soil and thatch are being driven out of the market. Skilled labour who deal with these materials have lost their livelihood.

CSE investigated the daily wages of masons involved in traditional (soil-based) and non-traditional (brick-and-mortar-based) housing. Masons involved in non-traditional construction techniques were seen to earn almost double of those

Graph 7: Comparison of daily wages of masons in Odisha



Graph 8: Comparison of daily wages of masons in West Bengal

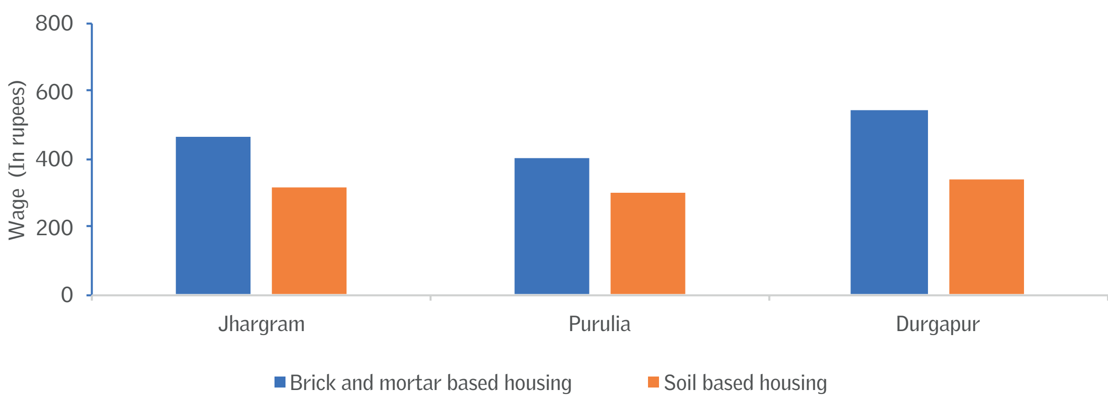
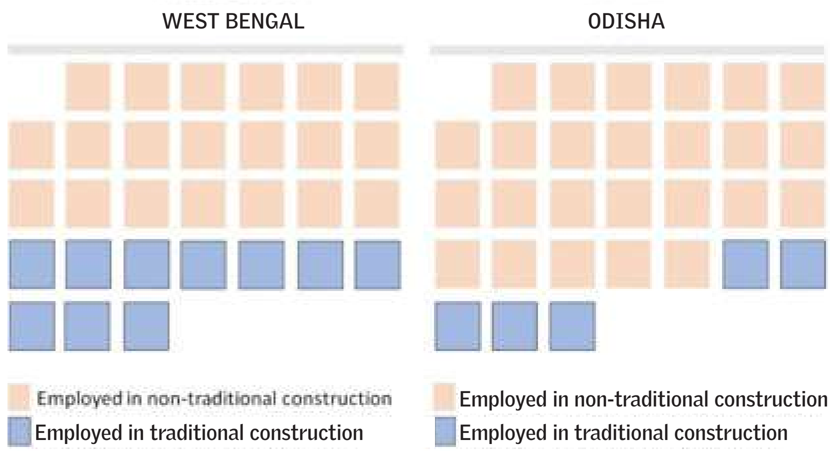


Figure 6: Number of days a mason skilled in traditional and non-traditional construction gets employment



involved in traditional construction techniques in Odisha. The difference was less stark in West Bengal where masons skilled in traditional technologies earned about one-third less than their counterparts.

CSE visited the villages around Durgapur, Jhargram, Purulia (in West Bengal), Baripada, Bisoi, Puri coast, Bhawanipatna, Phulbani, Baliguda and Semiliguda (in Odisha) and investigated the employability of masons in traditional and non-traditional technologies and techniques.

Most masons were found to be working in both traditional and non-traditional technologies. They, however, found employment for an overwhelming number in non-traditional technology projects. On average, these masons spent 20–25 days employed in brick-and-mortar construction and five to 10 days in traditional technology construction.

Regular stable income in non-traditional construction combined with the fact that such work is available from nearby areas contributes to the preference for non-traditional construction. This trend was evident in most of the villages surveyed. Only masons who worked in locations that are not well connected geographically have to travel far to find work.

Reduced availability of resources and increased cost of building material: With increasing neglect of traditional technologies and materials and increased development and environmental degradation, the local resource base that produces key building materials, including bamboo, grasses and timber, are depleting. The micro markets and local economies that nurture traditional building materials have also reduced. This resource stress is also escalating the cost of such materials.

Notably, with the change in cultivation patterns and crop varieties, certain crop varieties have been eliminated, impacting the quality of thatch. For example, waste straw from Dhudheshwar, a variety of rice, was favoured for thatch roofs. But this is being replaced by new variants of cultivated rice—Aman, Aush and Boro—which produce straw that is apparently less resilient against rain and wind. This increases the maintenance cost of roof structures made of new straw.

It is evident from the surveys that the cost of procuring natural materials has increased significantly. The price of several materials such as curved and flat tiles have increased by about five to eight times, while the remaining materials—such as soil, stones, bamboo and timber—which previously cost almost nothing have become heavily commercialized.

This also brings out the symbiotic relationship between built structures and health of an ecosystem. To support local traditional practices and resource base, strong conservation methods and sustainable harvesting of resources are critical.

Graph 9: Comparison of costs of local building material

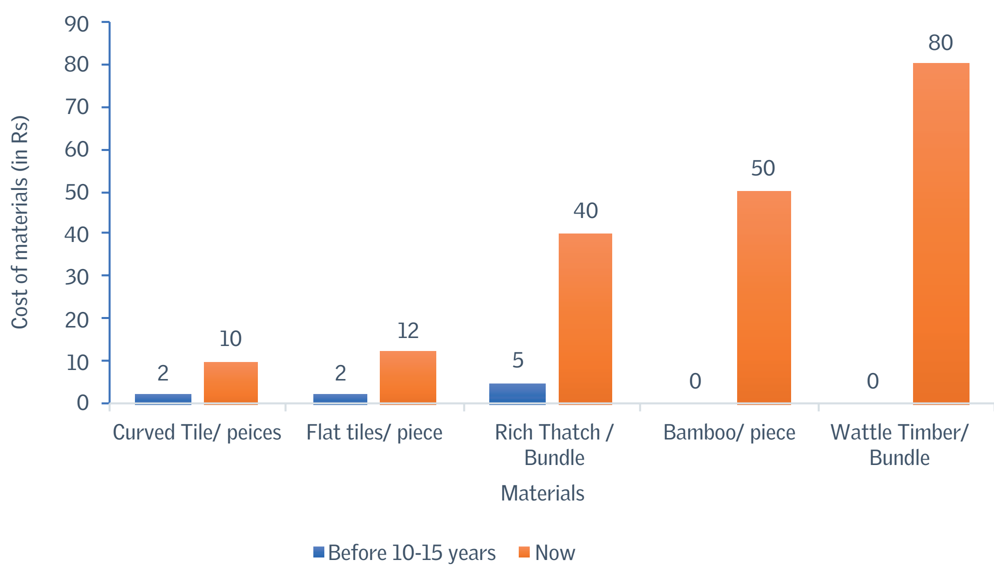
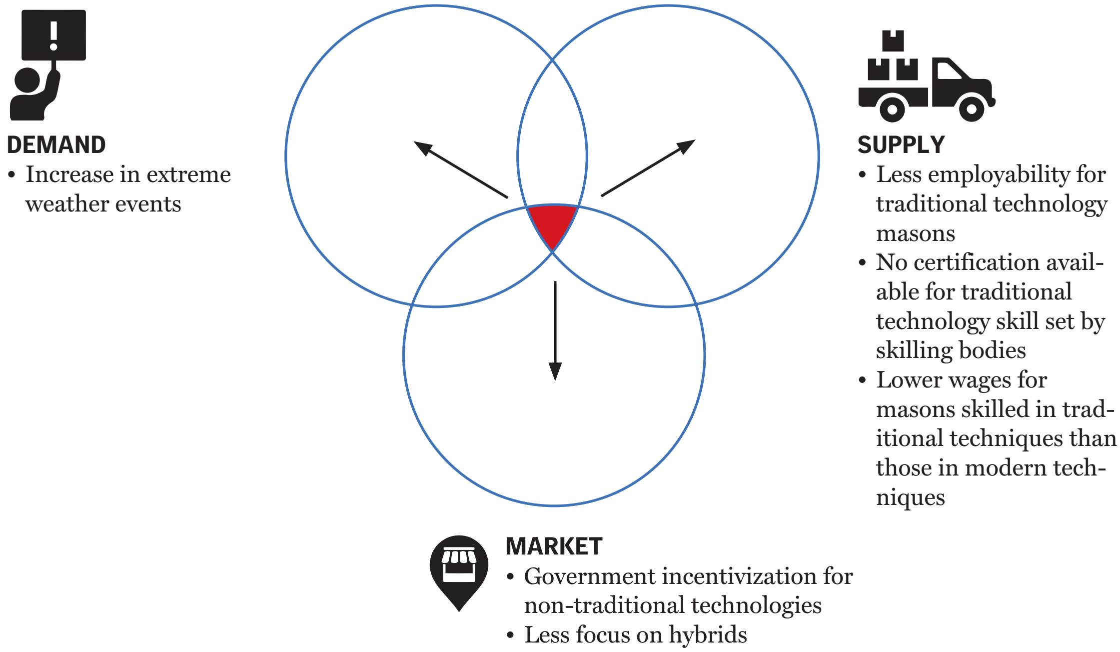


Figure 7: Market dynamics—factors contributing to decreasing application of traditional construction



Changing microeconomic ecosystems

The shift to conventional technologies is not just a shift for material and workforce but of an entire microeconomic ecosystem dependent on traditional construction. For example, the process of using thatch for roofing panels involves collection, husking, dusting and drying of agricultural waste before it is woven into roof panels. At every stage, labour is involved. Consequently every stage is a microeconomic activity that employs many people (see *Figure 8: Disruption of local economies due to non-traditional construction*).

Timber and stone are sourced from forests and hills, treated and used locally to make shelters. In the case of soil-based technologies, such as mud daub and clay for making tiles, local labour is employed for the collection and preparation of mixtures. Modern construction on the other hand is energy-intensive, and reduces jobs, triggers migration and erodes sustainable practices, including circularity.

SOURCING OF TRADITIONAL CONSTRUCTION MATERIAL

Building materials for construction of traditional housing are sourced from nearby areas. These materials are responsive to climate as they are sourced from natural components that are a byproduct of the environment of the biosphere.

Rice thatch from agricultural waste: Thatch used for constructions are a byproduct of cultivated rice that is processed, sun-dried and made into bundles of straw.

Clayey soil: Clayey soil, found in riverine alluvial plains, is one of the most used materials for construction of walls and flooring. It is usually sourced from farmlands or nearby areas with high presence of clayey soil.

Neem, sal and other local varieties of wood: Wood is used mainly for the construction of elements such as columns, beams and roof frameworks. It is also used for making door and window frames and panels. Neem and sal are most commonly used. Other types of native wood are also used, such date palm and mango wood sourced from surrounding forests.

Bamboo: Bamboo poles are used mainly for making roof frameworks. Bamboo was previously used for making partitions, wattle in wall construction and even doors in some cases but its use has reduced. Bamboo varieties of different thicknesses are cultivated and used for various purposes.

Random rubble: The highlands close to the Kandhamal Range are rich in natural stones. Stones are abundant on the surface or with minimum topsoil excavation. Rubble and other natural stones is found along the highlands.

Coconut and date farming: The agricultural byproducts of coconut and date farming—timber and thatch—are processed and used for construction. The timber is used for support and frameworks and the thatch for roofing.

Pinewood, acacia: Pinewood, acacia and jheong trees (a variety of pine found along the coast) are found in the region. The wood is used to make columns, rafters and purlins and is even used in wattle and daub construction.

Laterite: Laterite mining is legally prohibited in the area but is still used in the region. It is mainly used for plinths and columns. Laterite blocks in the region cost around Rs 60–70 per piece.

Figure 8: Disruption of local economies due to non-traditional construction

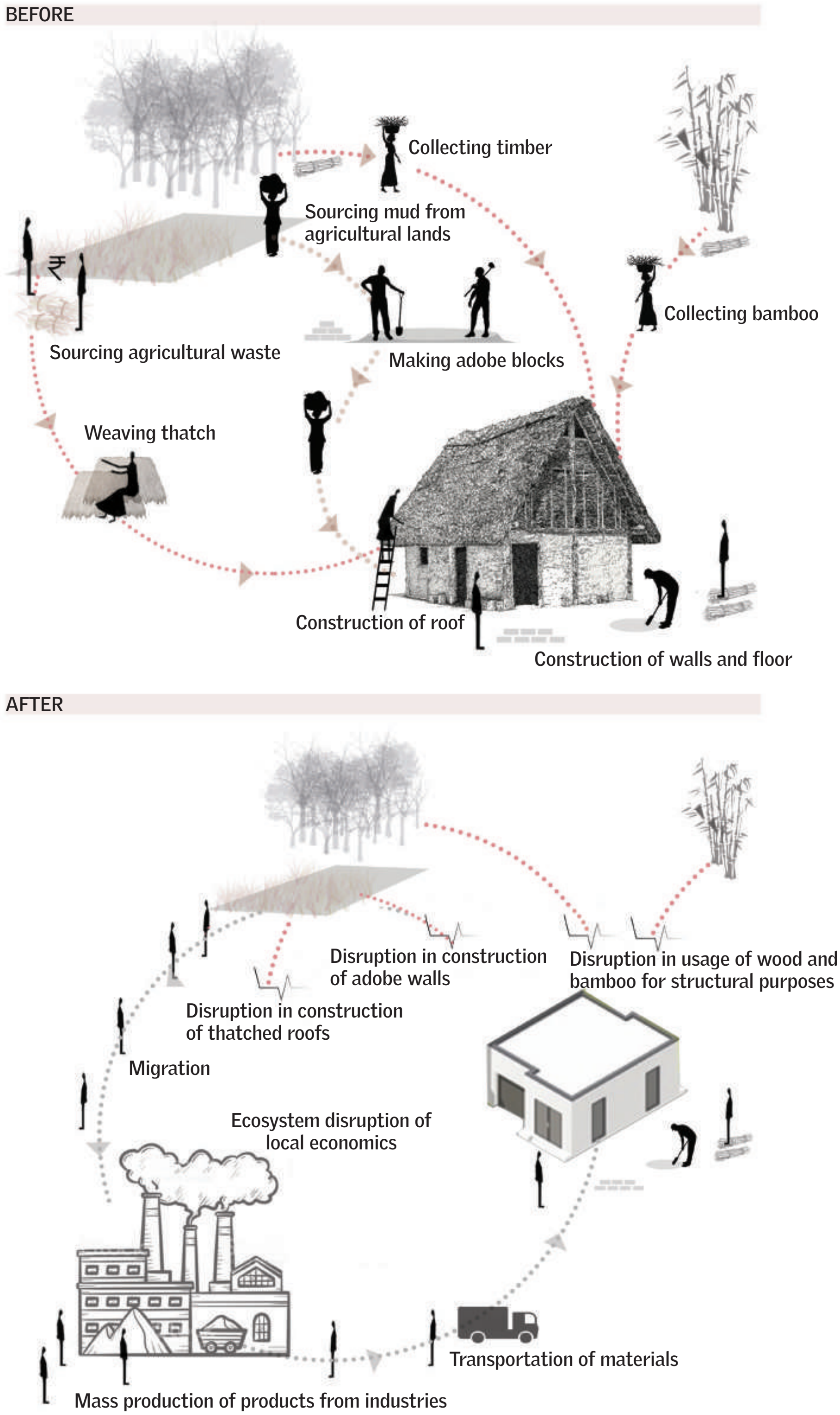
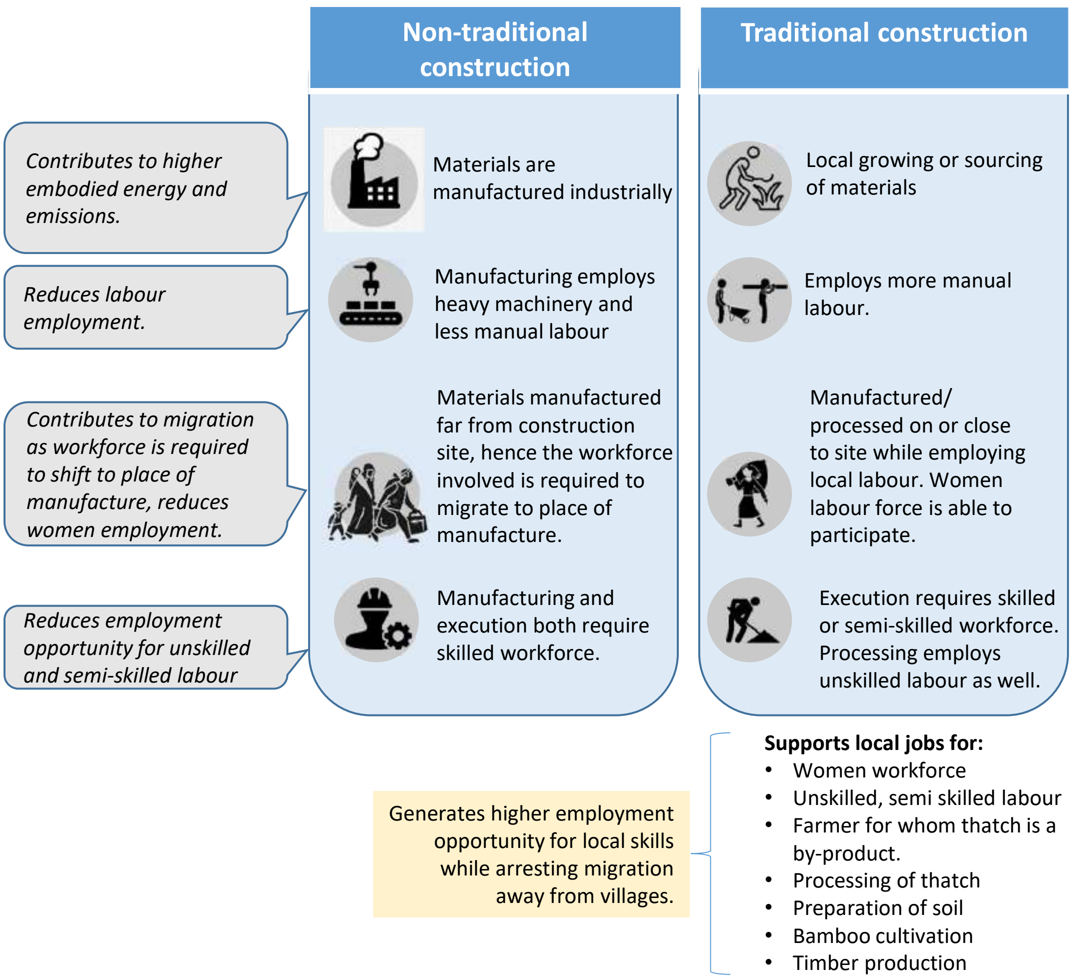


Figure 9: Characteristics of traditional and non-traditional construction



Source: CSE

Local factors for increased pace of transition from traditional to conventional technologies	Location
The regions are primarily rural and have a large economically vulnerable population who depend on government housing schemes. Most of the transition is through the housing schemes, which incentivize modern construction technologies and materials.	Baripada Balliguda Bhawanipatna Jhargram Semiliguda
With the development of the Durgapur Steel Plant (DSP) under the Steel Authority of India (SAIL) in 1959, many infrastructure facilities like toilets and resettlement villages were set up. This triggered a shift from local building materials and techniques to modern construction methods.	Durgapur
Many local types of vegetation such as tal (palmyra) have changed in their pattern of growth as high winds bend the trees because of which the trees cannot be used for making runners. So grass found growing naturally in the region is depleting.	Bolpur
The region is closer to Kolkata and has a high presence of state government schemes for affordable housing. These schemes are triggering transition to conventional technologies.	Belari-Uluberia
These regions are located on the coast and are vulnerable to cyclones, torrential rains and floods. In recent years, the frequency and intensity of weather events has increased, which ultimately force the houses to undergo maintenance and even reconstruction multiple times in a year, ultimately resulting in high maintenance costs.	Purba Sridharpur Puri
The region is predominantly occupied by tribal communities. Construction techniques have been inherited as household knowledge. Legal reservations of land accorded by the state forest department have prevented sourcing of materials such as timber and stone from the forests. This has limited their access to some of the construction materials from the forests.	Purulia Bisoi Phulbani

SECTION 3: Learning from the ground: Case studies

Several case studies of traditional technologies were carried out in districts across West Bengal and Odisha. Details are available in the e-compendium on local material and technologies.

The following is snapshots of current practices in building techniques and how techniques are undergoing transformation due to infusion of new technologies and materials as well as hybridization.

West Bengal

The Sundarbans is one of the most eco-sensitive zones, highly vulnerable to extreme weather events and impact of climate change. Building techniques here have evolved in the context of its mangrove ecosystem. Mangrove vegetation is found locally and is mostly used as wattle in wall construction. The mangrove cover is gradually declining—and trees are not replanted to maintain the balance with harvesting. Local bamboo is cultivated and used for making roof structures and wattle in wall construction. It is sourced from other areas too as the local supply doesn't meet the demand in the region.

Bricks for walls are cut in a parallelogram shape from the clayey agricultural soil and put out to dry, after which they are layered in courses. This type of technique is rarely found in the region now and only a few houses remain. The kadi (timber or bamboo beam) and baraga (timber or bamboo rafter) are applied for flat-roof construction used as intermediate floors. The final flooring could be made with a mixture of soil and thatch or even with bricks in some cases. Local rice-thatch is processed and prepared for roofing. The thatch work requires periodic maintenance from wear and tear.

Wattle and daub wall in Purba Sridharpur

Sun-dried bricks, Purba Sridharpur

Kadi baraga roof

Thatched roof in Purba Sridharpur

Increasingly renovation and reconstruction, however, are beginning to use precast concrete columns as the most common "transition material", with many old constructions preferring a hybrid system. This combines precast reinforced cement concrete (RCC) columns and wattle and daub walls. The roofing is replacing traditional thatch with tiled roofs, concrete, asbestos and galvanized iron sheets. The wattle and daub walls are being replaced by brick walls.

Transition technologies—galvanized iron roof

Concrete structures—houses transitioning to brick

A hybrid of concrete pillars with wattle-and-daub walls

Brick walls with thatch roof in Purb Sridharpur

The height of flood waters and impact of flooding on houses near Purba Sridharpur

Impact of flooding on wattle and daub walls

The increase in the frequency of cyclones, floods and storms has contributed to the shift towards conventional techniques, which require less maintenance. One can find multiple points of distribution for building materials like asbestos, bricks, cement, bricks and precast columns in towns roughly 10–15 km from the village of Purba Sridharpur.

Households living in close proximity to the river are seen to in general belong to poorer communities and depend largely on fishing for their livelihood. More affluent households live further from the river. Households near the river get more affected by floods. Their daub walls get washed off, exposing the wattle. Affluent households use more roof tiles. Houses in Purba Sridharpur are vulnerable to regular flooding two to four times in a year, resulting in flooding till about 900 mm above the plinth for up to 48 hours and necessitating regular maintenance. People are adapting by raising the height of buildings above flood level.

Rural settlements are thus finding ways to increase durability of their self-constructed houses. For instance, in coastal areas in both states alternative technologies are used for resistance against heavy winds. Fisherman communities along the Puri coast use nets to cover and tie thatched roofs for reinforcement. In the Sundarbans, precast concrete posts are used in place of bamboo poles for reinforcement as the latter is incapable of resisting the strong cyclonic winds that frequently affect the area. This also helps in reducing the need for maintenance. Frequent maintenance implies increased labour cost. Overall, the need and cost of maintenance has increased significantly, creating a market environment suitable for alternative durable building materials and technology that requires less maintenance.

Local skills

CSE met several traditionally skilled masons in the area who had mastered the the local techniques. The masons demonstrated the technique of making floor and roofs with traditional building materials.

In Purba Sridharpur, in the Sundarbans, mason Joy Mondal demonstrated the flooring technique. The basic components for flooring include clayey soil, cow dung and water. All three components are abundantly available in the Sundarbans region. The proportion of cow dung and soil depends on local materials and requires judgement by the person who lays the floor, but the rest of the process is fairly simple and does not require skilled labour. Maintenance depends on usage of the space and footfall. The more the footfall, especially with footwear, the more the maintenance needed.

Clayey soil, cow dung and water is mixed thoroughly (in this case in a proportion of 1:2:2) so that it becomes homogeneous. The mixture should be in a clayey state so that it can be spread over.

The soil–dung mixture is carried by hand and placed in small mounds on the floor. Water is sprinkled over it to maintain its moisture and prevent it from getting solidified.

The soil–dung mounds are placed at roughly equal distances in a grid, so that they can be distributed evenly. The mixture is then flattened onto the ground and plastered thoroughly with hand. The floor is left to dry for two to three days.

The raw material for making thatch panels is sourced from locally cultivated rice. Neelima Halder, a resident of Purba Sridharpur, demonstrated how thatch panels are fabricated. The grass is cut at about 20 cm from the ground. The straw bundles

Mason making a mud-cow dung floor

Mud–cow dung floor

Neelima Halder, a resident of Purba Sridharpur, demonstrating how thatch panels are made

Thatch panels

Masons putting up thatch panels for roofing

are eventually placed perpendicularly to two split bamboos and slid in between them. The bamboo bundle is folded back along the inside of the split bamboo member and tucked into it. Locally made ropes are used to tie the rice thatch to the split bamboos. The worker holds the thatch straight—with the leg—and ties the rope tight to keep it from coming off. The panels are eventually stacked and protected from heavy rainfall. They are periodically made and distributed, depending on local need. Simple tools—saw, machete and needle—are used.

Similarly, in Bolpur in Birbhum district, West Bengal, local builders use material from their ecosystem. Sandy and coarse soil is used for making cob walls—unlike the wattle and daub technique that utilizes wood or bamboo for the walls—for dwellings in the region. Tal gachh (palm tree), sor grass (a local variety of grass), elephant grass and thatch from rice are part of local vegetation that are used in traditional construction in the region.

Techniques have been developed for using these materials. For layered mud walls (cob walls), a wet-soil mixture is placed in layers. The proportions and composition of the mixture can include clay, sand, thatch etc. Each layer requires about a day to dry. Bundles of locally available sor grass are used for making intermediate floors,

A typical mud house in Bolpur

Layered mud walls in Bolpur

Flooring members made out of bundles of sor grass in Bolpur

Bamboo and wood used for intermediate flooring in Bolpur

which is then layered with mud and thatch fibres as the final finish. Tal wood is used as the runner which spans the room and bamboo or wooden members are used above this. The mud and thatch mixture acts as the final finishing layer.

For cob walls, soil and water are mixed thoroughly using foot work to make the mixture homogeneous. The mason decides whether the mixture needs more thatch, sand or clay on the basis of local soil conditions. Once the mixture is ready, the mason picks up a handful of the soil mixture, which should be in a semi-solid state. The soil mixture is placed on top of the previous layer of soil. A ladder may be needed for this step. The mixture is then hand moulded to roughly fit the width of the wall. A bamboo stick is used on the sides of the wall to smoothen the surfaces. The wall is then left to dry before another layer is applied.

Small sections of bamboo are used as lintels above the windows to transfer the load of the wall above the window void. The wooden frame around a triangular window essentially eliminates the need for a lintel, with the frame itself transferring the load to the walls.

Bamboo lintel in cob-wall construction

A wooden frame for triangular windows eliminates the requirement for a lintel

Material and technology transition observed in a house in Bolpur

New materials used in hybrid modes are being adoption in this region. Cemented plinths, metal sheet roofs, concrete lintels and brick walls are added to traditionally built dwellings.

In Jhargram, West Bengal, wooden members used for support run along the span of the room and bamboo is laid on top of them. Soil and thatch are made into a homogeneous mixture and used as the finishing layer on top.

Wooden beams crossing the span of the room with bamboo laid on top

Concrete houses built under the housing scheme Pradhan Mantri Awas Yojana (PMAY) in Jhargram, West Bengal

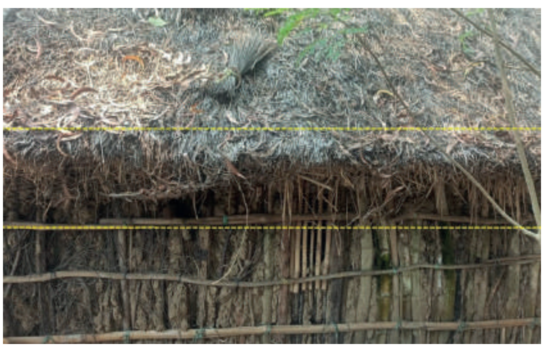
Odisha

Snapshots of local material and building techniques in Odisha bear out the intrinsic link with the local ecosystem and resource base.

In Puri, for instance, pine groves near the sea, rice and coconut cultivation and laterite stone have nurtured local architecture. Laterite mining is legally prohibited in the area now but is still used in the region for plinths and columns. Pinewood, acacia and jheong trees are found in the region and their wood is used to make columns, rafters, purlins and even used in wattle-and-daub construction. The agricultural byproducts of coconut and rice farming, timber and thatch respectively are processed and used for construction. The timber is used for supports and frameworks and thatch for roofing. Soil from the riverbanks and agricultural lands is used for making cob-based walls.

Innovating to become climate resilient

Given the risk of extreme climatic events like storm and cyclones in the region, local builders tie thatch roofs with fishing nets above them. Fishing nets are tied to the end of the rafters over the thatched roofs.



Thatched roof with fishing nets layered over it

Fishing nets tied over roof structures

Dwellings with pitched roofs that have increased slopes and longer sides which are aligned with the direction of the wind.

The roof is also made with an increased hip angle. Orientation of the built structures with the longer side of the building along the direction of the wind is another noticeable adaptation to the wind pattern in the region. These techniques help in providing a certain degree of wind resistance.

Building with increased slope of roof is a common feature in most of the traditional housing in the coastal region. In this transitional phase, most buildings are being upgraded in stages, with the transition being in roofs as it is the most affected building element from the frequent strong winds.

The walls are made of local wood panels and the edges are sealed with a mud mixture made out of clayey soil and water. The walls are about 5–10 cm thick. Very few houses that remain in the area use this technology.

Villages in the highlands, such as Lulung and Kakarpani near the Similipal mountain range, have an abundance of natural stone as well as local vegetation such as bamboo, neem and sal.

As per Odisha State Disaster Management Authority, the region lies in the low damage risk zone II seismic zone. But the region experiences flooding once every one or two years along the riverine edges.

Laterite stone is used in the region for the construction of plinths and columns. Mining is banned in the region, but use of laterite blocks persists. Wood from neem and sal and other trees are used for making structural members such as columns, beams and under structures for the roof. Different varieties of local bamboo of varying thicknesses are cultivated and used for purposes such as roof structures, wattle in wall construction and understructure of thatch roofs. Woven mats made from local grass and rice thatches are used as screens. They also act as envelopes for extended spaces such as verandas and storerooms.

Local bamboo is used as wattle while soil is used as daub. Walls are roughly 15 cm thick. This type of construction requires periodic maintenance as the mud daub cracks in the summer heat and gets dislodged by floods. A variation of the same, with local wood used in place of wattle, is found in the region. This technology and its variations were observed in both Bisoi and Baripada.

Adoption of non-vernacular building materials in renovations and new constructions in and around the Puri coast

In Balliguda, Odisha, wood panel walls are used with mud plaster

Cob walls

Mud brick coursework and laterite columns in Baripada, highlands of Simlipal

Slat stone coursework:

Mats woven from thatch

Modern construction with brick and mud mortar

SECTION 4: Fusion approach to integrate local techniques and material in contemporary houses

It is encouraging that, despite the odds, several architects and local communities have come forward to incorporate elements of both traditional and non-traditional construction techniques and material. This fusion is not common yet in the conventional mainstream construction sector. But it has opened up the opportunity for the integration and hybridization through the process of fusion.

There is an emerging trend in which brick-and-mortar houses built under government schemes are extending living spaces by adding a room to existing structures. In several such cases, the residents prefer the traditional portion of the house to remain to improve thermal comfort especially during summer. Traditional technologies such as soil-based walls (cob, adobe etc.) act as a thermal “battery” that absorbs heat during the daytime to keep occupants cool. The property of a material to absorb heat is its thermal mass. The approach of thermal massing is evident in the use of stone-based wall technologies. It is especially useful for the “affordable housing” self-built category, which relies more on natural ventilation and effective use of windows. The absorbed heat in the walls is released during the night when the ambient air temperature drops significantly compared to daytime temperature. This property of the dwellings to keep the interiors cool during sweltering heat also reduces use of appliances and homeowners’ energy bills.

The following projects studied by CSE in the region used fusion technologies:

Classroom prototype in the Free Residential School by Laurent Fournier, Kolkata, West Bengal

The building utilizes a combination of burnt brick, concrete columns, walls made of wattle and daub and mud flooring. The concrete columns provide structural stability while the wattle and daub walls act as fillers between them. The walls incorporate modern services such as electric fixtures within them and have good insulation and sound absorbing properties which are needed in a classroom requirement.

Wall construction in Free Residential School, Joka, Kolkata

Modern electric services being inserted in bamboo wall construction

Unnamed house by Bidyut Roy, Bolpur, West Bengal

This building in Bolpur follows a similar philosophy. The structure utilizes concrete columns and beams while the infill walls utilize adobe bricks that have been made on-site. The manufacture of adobe bricks utilizes local labour and material, saves transportation cost, and is significantly less energy-intensive than red bricks. It provides good thermal mass that contributes to improving thermal comfort. A few courses of red brick are used at the base of the wall as this area is more prone to water splashes. The walls are finished with mud plaster.

The understructure of the floor uses timber from tal wood and is topped with a wooden flooring, thus avoiding RCC slabs. The building uses triangular window frames that also avoid RCC lintels. This technique originates from the triangular windows in villages in the Bolpur region.

There are more examples of such creative application. The ground and first floors of the structure have RCC columns and beams while the topmost floor is entirely a soil structure with wooden columns. The structure uses sun-dried adobe bricks that contain soil, water, lime (5 per cent), human hair (sourced from local barbers)

Unnamed house by Bidyut Roy, Bolpur, West Bengal

Adobe brick infill wall in portal structures

Mud-plastered walls

Wood and concrete structural framework

The ceiling of the Mud House, Bolpur

Inner walls of the Mud House

Corridor in the Mud House

and chemicals to keep rodents and termites away. These bricks are used for external and internal walls and mud plaster for finishing the walls.

RCC slabs are only used in the bathrooms and corridors. The filler slab technique, which saves on the quantity of concrete needed while also making the structure lighter, is used. The building has been standing for seven years and its requirement for maintenance has decreased.

Three demonstration houses have been created in Purba Sridharpur village in the Sundarbans delta region, which is prone to frequent floods and cyclones that have increased in frequency. The project comprises three houses that are built with hybrid building elements and act as a repository of various technologies that can be applied in the region. Local materials are mainly used. The houses are designed to be more resilient to flooding and cyclones.

PHOTO BY: SOURAV JANA

Housing prototypes by Blue Planet, a consortium of architects, designers, students and engineers

PHOTO BY: SUGEET GROVER

Housing prototypes demonstrating different construction technologies and materials

The first house uses precast concrete posts pegged into the ground, providing the structure with stability and bracing the bamboo structure to the ground. The rest of the structure mainly uses bamboo walls with bamboo–mud flooring.

The second house is load-bearing and uses Hydraform blocks sourced from about 80 km away from the village. The understructure of the roof uses bamboo and the final roof is made from locally sourced reused terracotta flat tiles. High winds damage flat terracotta tiles and is the main reason for their decrease use. Bricks placed over the tiles as ridges keep the tiles from getting damaged and flying off.

The third house also uses precast RCC posts placed in a tripod form, which makes the structures more earthquake resilient. The intermediate floor uses the shallow dome technology which reduces the need for steel and concrete in the structure. The walls are made from wattle-and-daub technology with mud-lime plaster.

Innovation in thatch panels

The thatch roof requires special mention. Local materials such as rice thatch are used for the covering and bamboo as the understructure. The technique of creating this roof has been modified slightly from the traditional one. In this modified

PHOTO BY: SOURAV JANA

House prototype 2 uses Hydraform blocks and flat terracotta tiles

PHOTO BY: SOURAV JANA

House prototype 3 uses wattle-and-daub construction and thatch for the roof

PHOTO BY: SUGEET GROVER

Thatch panels made of split bamboo and rice straw construction technique, panels are pre-made on the ground, denser thatch is used and additional knots are added during the process of tying the thatch with the bamboo runners. This increases the life of the thatch roof, reduces maintenance and makes the roof more resilient to winds and heavy rains.

Local labour was trained in making of these panels, eventually building capacity in a new technique for the region while utilizing locally available materials. The traditional way of building required labour to climb the roof understructure to place the thatch—this discouraged the women labour from participating in the process. However, as thatch panels are now made on the ground, women are able to participate in the process. This technique has been adopted throughout the region. This innovation in thatch panel production was inspired by a technique used in Indonesia and is a perfect example of how experimentation and cross-learning can bring new life into usage of traditional materials while generating more livelihood opportunities.

Local women engaged in making thatch panels

Guest house by Udit Mittal, Qx Design Studio, Purba Sridharpur, West Bengal

This guest house is another example of hybridization using local building materials. It was constructed completely with local labour and materials from nearby areas. Precast concrete posts were used to make the foundation, and ferrocement was used in constructing the staircase.

The structure above the ground was made with bamboo poles, fasteners, nylon threads, local ropes and bendable wires. The understructure of the roof is made from bamboo over which thatch is placed.

Mainstreaming fusion techniques

In spite of these advantages, the market jumped from traditional technologies directly to modern technologies. The stability and durability provided by modern material that drive these choices cannot be ignored. One possible solution is to adopt a "hybrid" system that combines the advantages of both approaches of construction.

CSE's research has documented multiple building practitioners whose work has combined the two technologies. This hybrid leverages the advantages of the two approaches and combines the durability and stability of modern technologies with

Stage 1: Making of foundations with precast concrete poles

PHOTO BY: SOURAV JANA

Stage 2: A layer of chicken mesh is used to make the reinforcement for staircases.

PHOTO BY: SOURAV JANA

Roof made from bamboo and rice thatch in Purba Sridharpur, Sunderbans

Figure 10: Market jump from traditional to modern, skipping the hybrid

TRADITIONAL
- Better adapted to local climate conditions in providing user comfort.
- Employs local materials and capital expenditure to construct house is less.
- Provides better employment opportunities than modern construction systems.

HYBRID
- Combines the durability and stability of modern technologies with benefits of better thermal comfort and more employment opportunities of traditional technologies.

MODERN
- Do not necessarily perform on thermal comfort parameters.
- Provide better stability and less maintenance than traditional systems.
- Materials are often industrial based and hence provide less opportunity for employment.

benefits of better thermal comfort, lower material intensity and more employment opportunities of traditional technologies.

One way to do this is by having framed structures but using technologies such as cob, adobe blocks, wattle and daub etc. as infill materials. In this approach, sturdier materials form the outer skin of the building that deals with the harsh weather events while the infill walls, intermediate floors etc. still employ local materials, ultimately making the overall construction cheaper.

Currently, hybrid models have not received much support from the market or government policies. The housing schemes do not consider them, and the skilling centres have not included them into their curriculum. The latter is a missed opportunity as including hybrid or fusion construction technology in the curriculum can bring forth innovative solutions to combine modern and traditional technologies.

The market also reflects the relative isolation of emerging hybrid projects with fusion of technologies. Masons trained in brick or mortar construction, on the other hand, get work within 5–10 km of their dwelling.

Employability of traditional masons and artisans

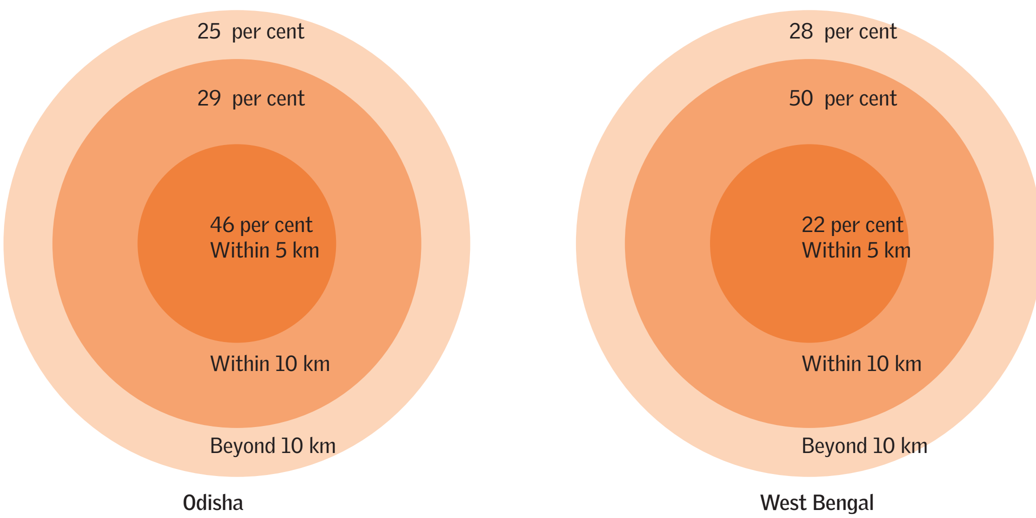
CSE visited villages around Durgapur, Jhargram and Purulia in West Bengal and Baripada, Bisoi, Puri coast, Bhawanipatna, Phulbani, Baliguda and Semiliguda in Odisha, and investigated the employability of masons in traditional and non-traditional technologies and techniques. Interviews and focus group discussions revealed that 72–75 per cent of the workers found employment within a radius of 10 km from their home in brick-and-mortar construction projects. A much smaller percentage of labour had to travel beyond 10 km to find employment.

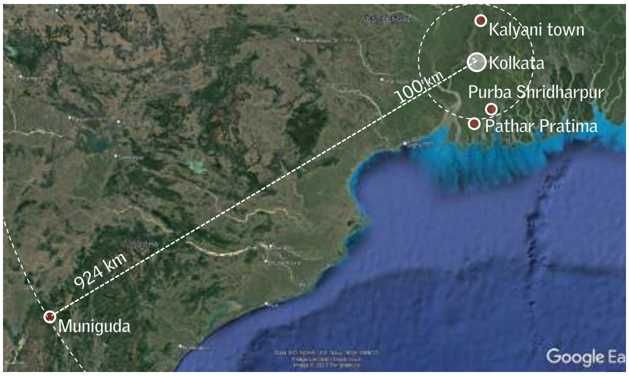
Masons skilled in fusion technologies are rare, and the few that exist are closely associated with architects or building designers who focus on hybrid technologies. Since the demand for such projects is less, they must travel longer distances for employability in their niche skill set. We traced the work of two architects that work with hybrid technologies and the masons associated with them to understand how widespread their projects were.

Building new skills around fusion technology

As architects are experimenting with the fusion approach, a new skill set is also emerging in the region.

Figure 11: Commuting distance for local masons to find stable work in the modern construction sector in Odisha and West Bengal





The demand for projects utilizing fusion technologies is limited because of which the architect and associated masons need to travel further. Left: Distance to architect Laurent Frontier's projects; right: distance to architect Udit Mittal's projects

Laurent Fournier promotes shallow dome architecture to achieve lower material intensity and energy use and reduce the environmental footprint of built structures. He has designed two houses—one in Kalyani municipality of West Bengal and the other in Baruipur suburb near Kolkata—with shallow dome in cement mortar, with steel ties embedded in concrete. Any type of brick can be used—regular red clay, fly ash or cement brick—to make shallow domes. The domes can be made with wood-less shuttering made of mud and temporarily rented steel girders or without any shuttering. Shallow domes do not have steel reinforcement except for the tie with minimal concrete for protection. This reduces the economic and environmental costs of shuttering and overall material intensity of the structure.

A similar shallow dome technique has been applied in the three-storey Baruipur house, which also has mud walls with reinforced concrete frames. Walls are made of bamboo and lime-stabilized mud. The roof is a bamboo frame with thatch. The flooring is made of stone.

While making these houses in urban and peri-urban setting, a local pool of skilled masons were trained to apply such fusion technique. This has created a new skill set in the region. This demonstration also has the potential to create a new clientele base in an urban setting. The fact that such applications have started in urban middle-class houses shows that there is an opportunity to take forward the fusion technique for sustainability.

This initiative needs to be taken forward to generate more knowledge and validated scientific data on the local craft, techniques and material to build confidence and bring popularity. In other parts of the country, institutions such as Hunnarshala founded by Sandip Virmani and Kiran Vaghela in Bhuj, Gujarat have emerged.

A mason constructing a shallow dome using bricks

Left and right: A three-storey house in Bariupur which are testing and validating local techniques from different ecosystems and cultures. This includes application of cement stabilized and unstabilized earth, stone, thatch-stabilized rammed earth, recycled country tiles for roofing, compressed stabilized earth block, shallow domes and recycled and waste wood. This helps to provide validated information for people to select technologies in contemporary buildings.

SECTION 5: Are policies addressing traditional technologies?

Currently, housing policies, guidelines and norms on building material and techniques focus predictably on modern material and new alternative technologies for mass housing. Examples include Multi-Attribute Evaluation Methodology for Selection of Emerging Housing Technologies developed by Building Materials and Construction Technologies (BMTPC) to respond to the challenge of evaluation and selection of alternative construction technologies for mass housing projects. It includes mandatory and desirable attributes to be considered for selection of alternative technologies to serve as a useful tool for performance appraisal of emerging technologies for all state agencies in selecting emerging technologies for their future projects in an objective manner.

Further, the Ministry of Housing and Urban Affairs conceptualized a Global Housing Technology Challenge-India platform for the identification and adoption of technological advances to rapidly deliver low-cost housing that meets stringent environmental, societal, quality and economic standards in the housing construction sector in a holistic manner. In April 2017, BMTPC published the second edition of *Compendium of Prospective Emerging Technologies for Mass Housing*. The third (2018) edition contains details of the 24 new emerging technologies evaluated and recommended by BMTPC that will help user agencies make informed choices of different innovative construction practices and incorporate speed, safety and sustainability in the construction sector, which could be utilized for mass housing schemes.

The 2021 *Compendium of Innovative Emerging Technologies* prepared as part of the Global Housing Technology Challenge provides concise information on 54 technologies. These technologies were shortlisted by the Technical Evaluation Committee (TEC) set up by MoHUA. It provides information about their application in real projects in India and abroad and also provides contact details of technology providers.

Further, Light House Projects (LHPs) are model housing projects built with shortlisted alternative technology suitable to the geoclimatic and hazard conditions of a region to demonstrate and deliver ready-to-move-in houses with speed, economy and improved quality of construction in a sustainable manner. These projects shall serve as live laboratories for all stakeholders, including research and development (R&D). Stakeholders can register themselves as "technograhis" and visit these pilot projects. In fact the course NAVARITIH (New, Affordable, Validated, Research Innovation Technologies for Indian Housing) is offered jointly by the School of Planning and Architecture, New Delhi and Building Materials and Technology Promotion Council (BMTPC), Ministry of Housing and Urban Affairs, New Delhi to familiarize professionals with the latest materials, their specifications, construction methodologies and projects, and where these technologies have been used so that they can be used in day-to-day practices. Thus, technically there is no policy or regulatory framework for integrating traditional material and techniques with new construction of mass housing.

In 2021, however, the joint CSIR-Central Building Research Institute (CSIR-CBRI), Roorkee and BMTPC publication *Compendium of Building Technologies*, which targets construction of individual houses for low-rise to mid-rise structures, enlisted 66 existing technologies in the categories of: floor/roof construction technologies, roof construction technologies, wall construction technologies, foundation construction technologies, system-level technologies, services and materials. The compendium includes traditional and neo-sustainable technologies such as rammed earth, compressed earth, kath kuni wall etc.

Also, the 2021 *Compendium of Indigenous Innovative Building Materials and Construction Technologies*, which lists 73 technologies, focusses on owner-driven single- or double-storey houses on the land available with the beneficiaries and is self-constructed or made by local masons and/or artisans. The document acknowledges the importance of a technology generating local employment opportunities and lists this as a feature under various technologies.

BMTPC has added more technologies since its third compendium. However, the applicability of an overwhelming majority of these technologies is in the mass housing scenario and they are found to be not applicable for the self-built housing sector (beneficiary-led construction) which contributes to more than 60 per cent of the housing sanctioned under PMAY. As an example, the most widely used on-ground technology amongst the ones promoted by BMTPC is the monolithic concrete technology which is only feasible if the same design is repeated hundreds of times as in mass housing.

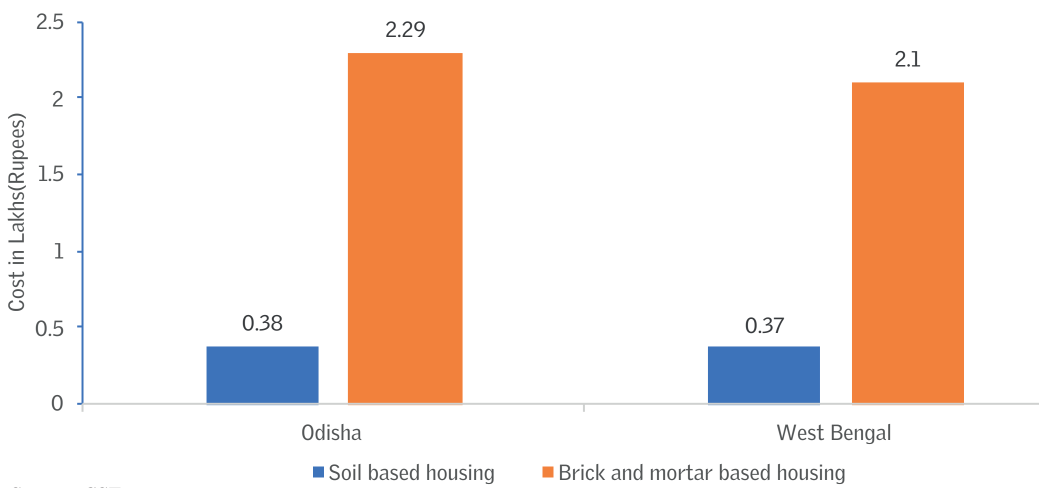
It is now necessary to include traditional and local techniques and material within the scope of the housing policy and financing for self-built housing in rural, peri-

Table 2: Comparison of capital involved in the construction, operation and maintenance of traditional and non-traditional housing

	Conventional house (~260 sq.ft)	Traditional house (~260 sq.ft)
Approximate capital cost for construction (Rs)	~230,000	~38,000
Maintenance per year (Rs)	Less than 1000	8,000–12,000
Support by government scheme	1,30,000	Nil
Operational cost	Relatively high due to requirement of fans, refrigerators etc.	Low due to traditional houses being more climate appropriate.

Source: CSE

Graph 10: Comparison of capital cost for construction in Odisha and West Bengal



Source: CSE

urban and even urban areas, where a new clientele base seeking fusion technologies is slowly emerging. It will also be more cost effective. Illustratively, local evidence shows that the capital cost of a house using traditional technologies is considerably lowered. The average capital investment required for the construction of a 260-square-foot brick-and-mortar house is about Rs 2–2.5 lakh, with minimal annual maintenance. The cost of constructing soil-based housing averages Rs 37,000–38,000, with an average annual maintenance of Rs 8,000–10,000, which varies from location to location, depending on weathering and accessibility to natural resources. The capital cost of brick and mortar-based housing is almost five times more than that of soil-based housing. The average cost incurred in each state is derived from the mean of data collected from visited study locations in each of them.

SECTION 6: Integrating traditional skills and techniques in formal skill-building programmes

This study has also reviewed the existing skilling programmes and skill centres in Odisha and West Bengal to understand if the curriculum is integrating the requirements of local skills and material.

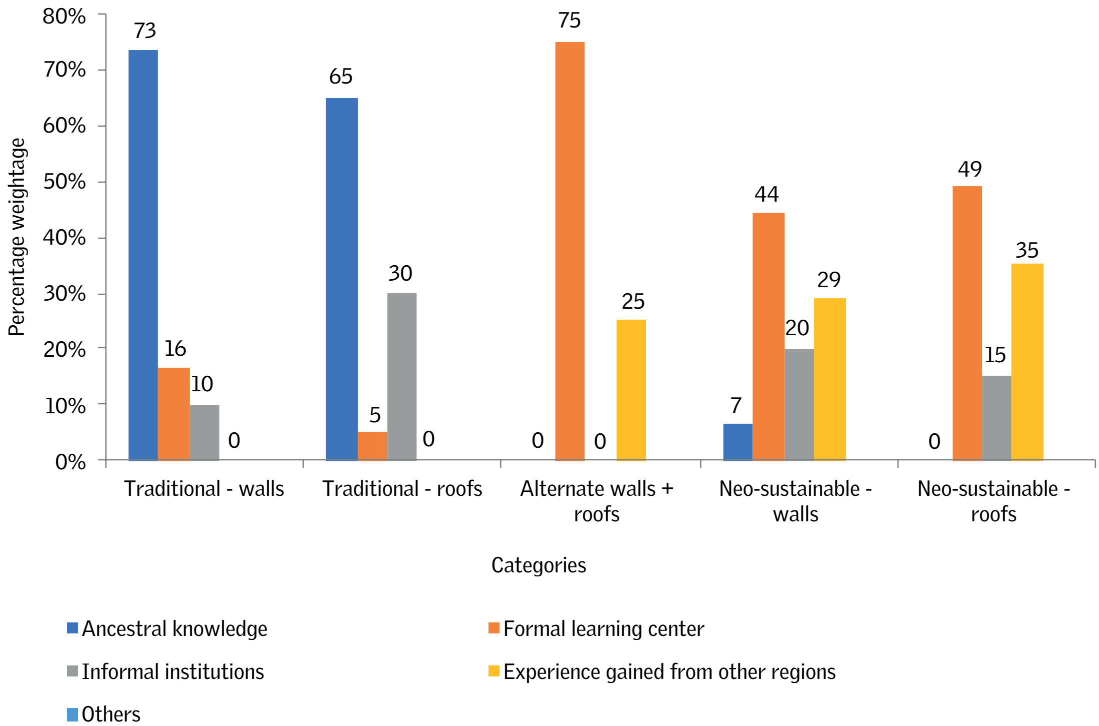
A survey was carried out to understand the perceptions. After the survey, participants identified the associated skills for each of the construction materials and/or techniques, they were asked to choose the ways of acquiring the skills. Five options were provided in the survey questionnaire—ancestral knowledge, formal learning centres, informal institutions, experience gained from exposure to other regions, and others (where they had the option to specify).

The survey revealed that skills to construct walls using traditional construction materials or techniques were acquired mainly through ancestral knowledge (73 per cent of the respondents) (see *Graph 11: Perception of experts on ways of acquiring skills*). The intricacies associated with wall constructions using traditional materials or techniques such as the mathematical calculations, vertical alignment of wall, ideal height up to which the wall can be raised on each day of construction, mix proportions and composition etc. are most often passed on from one generation to another.

Formal learning centres such as Industrial Training Institution (ITI), local NGOs, building/demonstration centres, etc. provide formal training related to various construction techniques.

In the case of construction of roofs using traditional materials and/or techniques, 65 per cent of the experts suggested that the skill was largely acquired from ancestors. Around 30 per cent of the experts stated that construction of traditional roofs can be learned in informal ways, such as associating with a senior mason at work. This is because roof construction mainly depends on understanding installation techniques for rafters and purlins. Once this is learned, placing of thatch, tiles or any other roofing material is a fairly simple process.

Graph 11: Perception of experts on ways of acquiring skills



Source: CSE

In the case of alternative and neo-sustainable construction materials and techniques used to construct walls and roofs, formal learning centres play a crucial role followed by experience gained from exposure to other regions. This is because these materials and techniques have evolved over time and need to be taught.

Institutional mapping for skills, livelihoods and promotion of construction materials and buildings techniques

The Government of India has launched several schemes for skilling and livelihood that have been adapted by states for implementation. This section provides a brief overview of these schemes and their state counterparts.

CSE conducted interviews with representatives of skilling centres that conduct courses pertaining to construction. The purpose was to understand the process followed, funding and curriculum. None of the skilling centres visited taught any courses related to indigenous technologies. The curriculum in the ITIs is controlled by the Directorate General Training (DGT) while the curriculum for short-term courses taught in the skilling centres is defined by the respective Sector Skill Councils.

Pradhan Mantri Kaushal Vikas Yojana (PMKVY)
This is the flagship scheme of the Ministry of Skill Development and Entrepreneurship (MSDE) implemented by the National Skill Development Council (NSDC). So far over 65 lakh youths have been skilled in the Recognition Prior Learning (RPL) category out of which more than 5.4 million candidates have been certified. Over 6.7 million candidates have been skilled in short-term courses of which over 2.3 million candidates have been placed successfully.[8]

Deen Deaya Upadhayaya-Gram Kaushal Yojana (DDU-GKY)
Launched by the Ministry of Rural Development (MoRD) in 2014, DDU-GKY is part of the National Rural Livelihood Mission (NRLM) tasked with providing livelihoods to rural youths in the 15–35-year age group from poor families. The scheme aims to ensure sustainable livelihoods to over 26 lakh individuals. As of September 2021, around 1.1 million people have been successfully trained out of which over 0.6 million have been placed.[9]

Deendayal Antyodaya Yojana-National Rural Livelihood Mission (DAY-NRLM)
Conceived by the Ministry of Rural Development (MoRD) in 2010, DAY-NRLM is a Centrally sponsored scheme, with the Central (60 per cent) and state governments (40 per cent) jointly funding the projects. It aims to provide effective and efficient institutional platforms to enable the unemployed rural poor to increase their household income by means of sustainable livelihood enhancements and better access to financial services.

Skilling schemes in Odisha

Several institutions are working to improve housing, skill and livelihoods as well as to uplift vulnerable population. This section provides a brief overview of the government and private institutions actively involved in the sectors of housing, skill building and livelihoods in Odisha.

Odisha Skill Development Authority (OSDA)
OSDA was conceptualized in May 2016 to provide direction to the various skill development initiatives of the Odisha government. It also brought together several other organizations—governmental and non-governmental—that would dedicatedly engage in skill development. Affiliated institutions offer several courses in the construction sector, such as 2D and 3D drafting with AutoCAD, shuttering and scaffolding, bar bending, mason work, etc. The duration of these courses range from one and a half months to three years, most of the courses are for three to six months. Matric-passed as well as non-matric candidates are eligible.

Odisha Rural Development and Marketing Society

The Panchayati Raj and Drinking Water Department of the Odisha government created the Odisha Rural Development and Marketing Society (ORMAS) in 1991 to create different marketing channels for rural producers so as to promote sustainable livelihood through adoption of appropriate rural technologies and skill building. At the state level, ORMAS partners with relevant ministries and their agencies such as research organizations, apex training institutes, academician (universities, academic institutes) and media (print and electronic). At the district level, it partners with district-level training institutes, vocational training centres, non-governmental organization (NGOs) and international NGOs (INGOs). At the grassroots, it works with the value-chain-based associations, implementing partners, facilitating partners, private sectors, civil societies, NGOs, etc.

Odisha Livelihoods Mission

In 2006, the government of Odisha implemented various poverty-reduction programmes in the state. It was the first state in the country to implement the National Rural Livelihoods Mission (NRLM). The Odisha Livelihoods Mission (OLM) is an autonomous society under the Mission Shakti Department, Government of Odisha. It currently implements both NRLM and its project. Two programmes—Rural Self Employment Institutes (RSETI) and Project Life—are under this mission and work towards providing livelihoods through skilling in the construction sector.

Scheduled Castes and Scheduled Tribes Research Training Institute (SCSTRTI)

SCSTRTI came into existence in 1952 (its name has changed several times since then). The main objective for setting up the institute was to conduct studies on the problems of tribal communities in Odisha and to serve as a centre for providing data and advisory services to the government on the problems of the Scheduled Tribes and the Scheduled Castes. SCSTRTI currently works across several themes, including research, publications, data analysis, trainings and capacity building, etc. This institute also builds demonstration houses of the tribal people across the state and holds an annual exhibition to display life-size tribal houses made in situ in the Adivasi Mela at Bhubaneswar.

Aside from government institutions, several national and international think tanks and research organizations are working in Odisha for skill building, livelihoods and climate responsive development in varying capacities (see *Table 3: Nature of work of institutions in Odisha*). While the majority of these organizations are capacity-building and technical advisories, a few—such as BMTPC, UNDP, Gram Vikas and SEEDS India—have worked or are working in project management

Table 3: Nature of work of institutions in Odisha

S. no.	Actors	Research and evaluation	Capacity building and training	Technical advisory	Technology transfer	Finance facilitation	Implementation	Project management and consultancy	Disaster risk mitigation	Post-disaster rehabilitation
1	CSIR-CBRI									
2	BMTPC									
3	DA									
4	HUDCO									
5	UNDP									
6	Gram Vikas									
7	SEEDS India									
	Working in Odisha									
	Scope of organizations									

Source: CSE

and consultancy. HUDCO and Gram Vikas are involved in financing, while CSIR-CBRI and BMTPC work towards technology transfer, with a focus on disaster resilience and post-disaster rehabilitation.

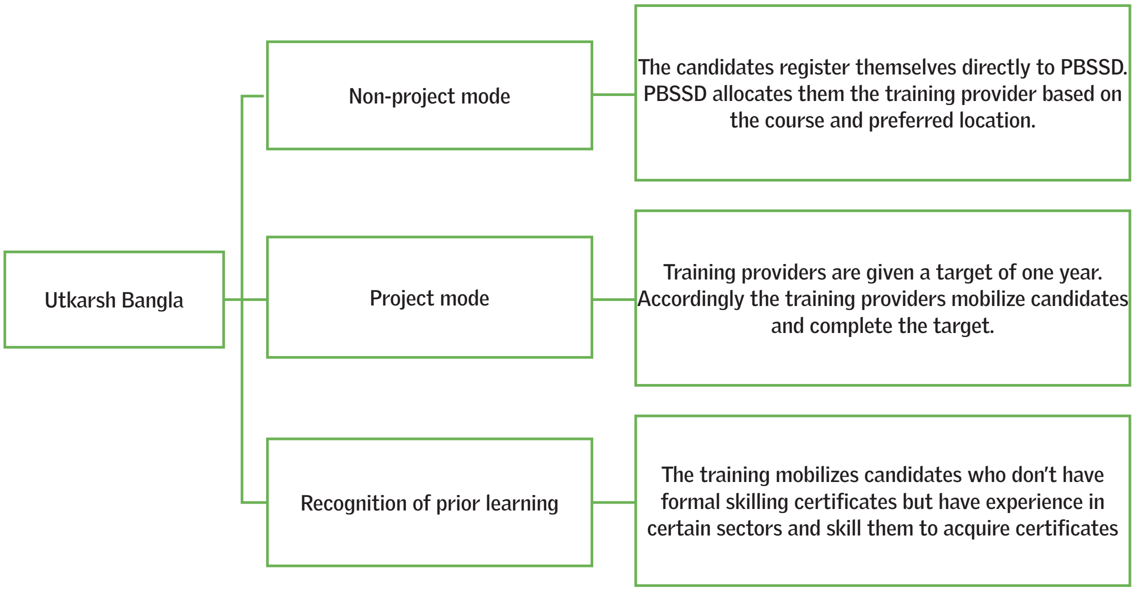
While implementing any policy changes in the sector, these institutions should be consulted owing to their experience in the state.

Skilling schemes in West Bengal

Due to the high vulnerability risk of West Bengal, the state has long focussed on affordable housing. Other focus areas are disaster-resilient housing, disaster-risk reduction and post-disaster rehabilitation.

West Bengal State Council of Technical and Vocational Education and Skill Development (WBSCTVESD)

WBSCTVESD came into existence in 1996 and has been operational under the Technical Education, Trainings and Skill Development Department of the government of West Bengal. It is responsible for administering and examining vocational courses in the state. The courses are offered from various affiliated institutions such as higher secondary and secondary schools and polytechnic colleges across West Bengal. Some institutions that have vocational courses related to the construction sector and class 12-passed students are eligible for them.

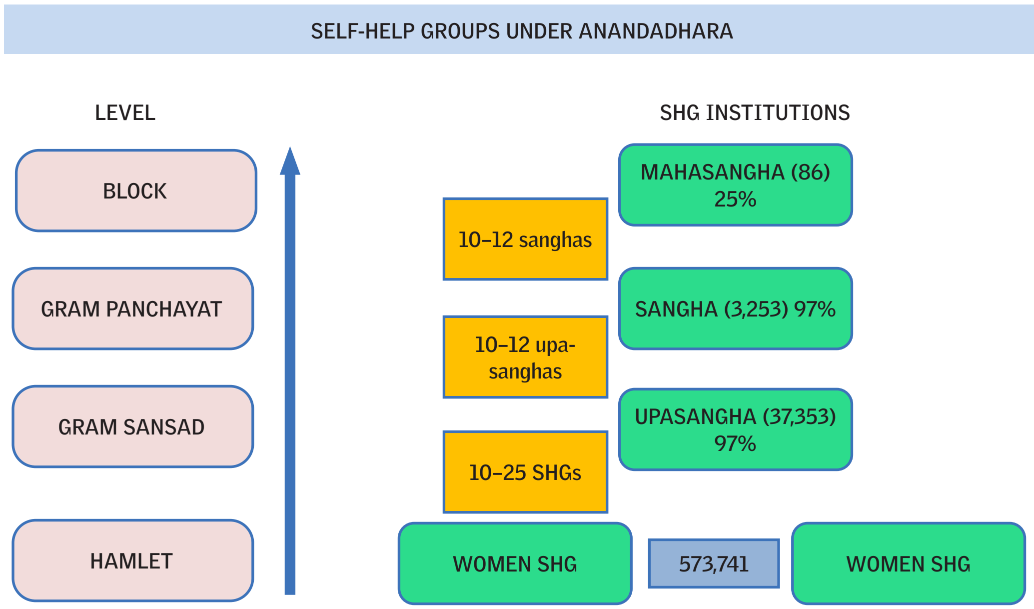


Utkarsh Bangla-Paschim Banga Society for Skill Development

Under the same department of the government of West Bengal, the Utkarsh Bangla-Paschim Banga Society for Skill Development (PBSSD) was launched in 2016 for placement linked short-term skill trainings across West Bengal. So far, over 3 lakh candidates per year have been trained under PBSSD since its inception. As per the latest data from their website, 23 districts in West Bengal have 54 training providers training people on courses related the construction sector. Individuals are specifically trained to become surveyors, masons or draughtsman and in the fields of scaffolding and wall construction. Individuals who have are matric passed and non-matric (minimum class 5 passed) are eligible to enroll for the training courses. The duration of these courses ranges from two to six months.

Anandadhara—West Bengal State Rural Livelihood Mission

In 2012, NRLM was launched as Anandadhara in West Bengal. The agenda was to mobilize the rural poor and vulnerable into self-managed federated institutions and support them for livelihood collectives. The programme is funded jointly by the government of West Bengal and the Ministry of Rural Development (MoRD). The target groups are women over 18 years of age, who are organized in self-help groups (SHGs). These SHGs and their networks are strengthened through capacity building, financial inclusion, access to institutional credit and skill development for taking up different livelihoods options, supported with provisions of technological as well as marketing support.



Source: Anandadhara

The scheme largely institutionalizes SHGs and enables implementation of government initiatives. Some of the projects include solid waste management, fisheries, handcrafted products (sold in rural haats), organic farming, focus on value addition, branding, packaging of non-farm products among others.

Regional Directorates of Skill Development and Entrepreneurship (RDSDE) and National Skill Development Council

Two Central government institutions—Regional Directorates of Skill Development and Entrepreneurship (RDSDE) and National Skill Development Council (NSDC)—have state offices in both Odisha and West Bengal. Both organizations work towards conducting trainings and capacity-building programmes for skill-building.

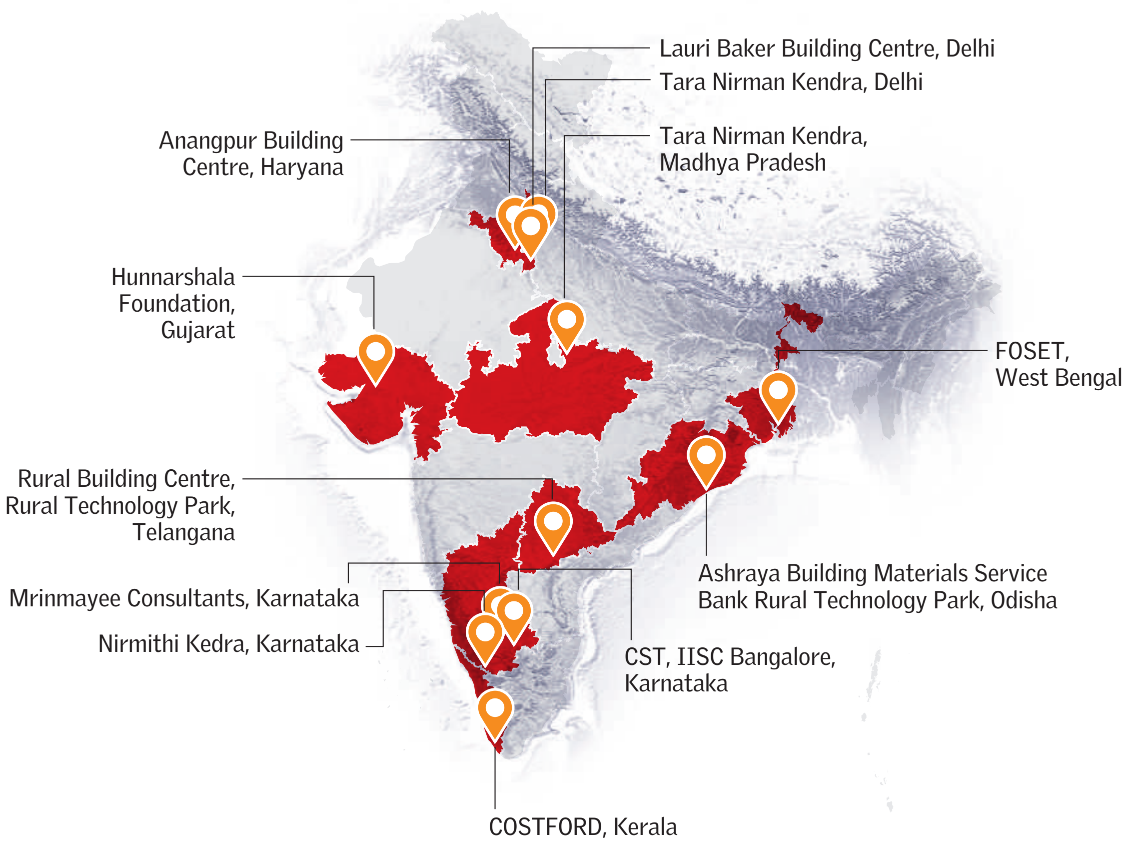
RDSDE ensures a steady flow of skilled workers in different trades for domestic industry to raise industrial production quantitatively and qualitatively by systematic training. It also aims to reduce unemployment among educated youth by providing them with employable skills, and nurture a technical and industrial attitude in the minds of the younger generation. Subsectors under the construction sector—such as construction and maintenance of buildings (including houses); setting of tiles, marble, bricks, glass and stone; and painting and decorating work for constructions—are widely covered in the apprenticeship scheme.

NSDC was incorporated in 2008 and aims to promote skill development by catalysing creation of large, quality and for-profit vocational institutions. The organization also provides funding to build scalable and profitable vocational training initiatives. It acts as a catalyst in skill development by providing funding to enterprises, companies and organizations that provide skill training. Specific to the housing sector, several courses are hosted by the various institutions affiliated with NSDC. The duration of these courses ranges from three months to three years—the three-month courses are the most frequent. Matric passed (or non-matric with minimum class 5 passed) are eligible for the courses.

Location of demonstration centres across India

Based on the survey and discussions with experts, 13 demonstration centres were identified with various walling and roofing techniques using traditional and neo-sustainable construction materials and/or techniques (see *Map 3: Technology demonstration centres in India).*

Map 3: Technology demonstration centres in India



Skilling centres in Odisha

Tarini Education Trust:
Till the end of 2019, the centre ran three-month courses on subjects such as plumbing, housekeeping, bar bending, mason and carpentry. It trained nearly 4,500 people in 2016–19 but the courses were disrupted during the Covid pandemic. Currently only courses related to safety operations are being conducted. The training centre needs to ensure minimum employability of 70–80 per cent of those who have completed the training otherwise they have to pay an associated fine. The curriculum followed is set by Sector Skill Council and there is no scope for customization of the curriculum to local conditions.

Construction course by Tarini Education Trust

Source: Tarini Education Trust

Asmacs Skill Development Ltd (ASDL)
Asmacs Skill Development Ltd (ASDL) runs training in courses pertaining to mason general, electrician, bar bending etc. The eligibility and duration for each course is different. While masonry and bar bending are three-month courses—participants who have not passed class 10 are also eligible—electrician is a six-month course, and only participants who have passed class 10 are eligible to apply.

The skilling centre provides trainees with meals, uniforms and hostel facilities. Funding is provided through Deen Dayal Upadhyaya Grameen Kaushalya Yojana (DDUGKY) and ORMAS. It is divided into four stages and linked with post-course placement. For example, ASDL can incur a fine if 70 per cent of their students do not get placement post completion of course. Each batch has roughly 30–35 students. The curriculum is decided by the Sector Skill Council (SSC) under the National Skill Development Council (NSDC).

Construction course by ASDL in progress

Source: ASDL

Skilling centres in West Bengal

IL&FS Skills Development Corporation, PMKK Berhampur:
This centre had initially started with courses related to masonry, bar bender etc. but has discontinued these courses as aspirations of the youth are not what they were when the centre started. Another reason cited by the centre was that skills like masonry work are not in demand from these formal training centres but are passed on from previous generations. The centre is run under the Utkarsh Bangla scheme.

Khakurdah Samannay Society:
This centre carries out mason general training, which lasts around four months (six days a week), with around 60 people trained at a time. The curriculum includes brickwork, plastering, concrete work, bar bending as well as casting of beams, footing, columns, foundation etc. Participants are required to meet a basic qualification to attend the course and trainees receive Rs 50 per hour as stipend. Khaukurdah Samannay Society has tied up with two local builders—Sardar Enterprise and Hasan Enterprise—to absorb some trained masons. The courses are run under the Utkarsh Bangla Scheme.

Construction course by Khakurdaha Samannay Society in progress

Source: Khakurdaha Samannay Society

Durgo Cultural Associate:

This centre has 12 or 13 centres but only one in South 24 Parganas has courses related to masonry. The mason general and assistant mason general are roughly 350-hour courses and take around three months to complete. The target for the number of people to be trained, based on the infrastructure and size of the training centre, is provided by the Paschim Banga Society for Skill Development. Employment of trainees graduating from the centre is the responsibility of the training centre.

ITI Howrah Homes:

This institute conducted a course called Broad Based Basic Training, which included multiple aspects of construction, including masonry. The employability of such courses, however, was found to be limited. The centre currently conducts one- to two-year-long courses related to sheet metal worker, welder, plumber, electrician, fitter, turner etc. All ITIs have the same course curriculum and examination, and the certificate is provided by the Directorate General Training.

Takeaways from visits to skilling centres

- Skilling centres conducting short-term courses play a major role in skilling of trainees even in the remotest areas of the states.
- The skilling centres visited (apart from Industrial Training Institutes) were funded by a combination of state-level livelihood schemes (ORMAS, Utkarsh Banga etc.) and Central schemes (Deen Dayal Upadhyaya Grameen Kaushalya Yojana, Pradhan Mantri Kaushal Vikas Yojana).
- The Industrial Training Institutes can be government or privately run, but the curriculum is decided by the Directorate General Training (DGT). The syllabus of a course taught in ITI remains the same throughout the country and the certificate issued also remains the same.
- Of all the skilling centres visited, none conducted courses that taught indigenous construction technologies.

Classroom for courses at ITI Howrah Homes

Source: CSE

- The curriculum for short-term courses taught in the skilling centres is defined by the respective Sector Skill Councils. The curriculum of many of the construction-related courses is defined by the Construction Skill Development Council of India.

  A course such as Mason general covers the following topics:
  - o Constructing masonry structures using bricks or blocks;
  - o Executing plaster on internal and external surfaces of masonry and RCC structures;
  - o Carrying out waterproofing work for structures using cementitious materials;
  - o Building structures using random rubble masonry; and
  - o Carrying out Indian patent stone (IPS)/Tremix flooring works.
- The curriculum remains the same throughout the country. Skilling centres thus cannot incorporate the indigenous knowledge of a region into the curriculum. The curriculum followed in ITIs is decided by DGT while the curriculum of short-term skilling courses is decided by the respective Sector Skill Councils.
- Employment post completion of course is the responsibility of the skilling centre. Failing to achieve employment for a minimum percentage (as defined by the skilling scheme) of trainees can lead to a financial loss for the skilling centre. For this reason, many centres have tied up with builders and/or construction companies to absorb their trainees.

Lack of focus on skill building on traditional techniques and material

Skilling centres and curriculum related to the construction sector have not integrated local and traditional techniques and materials for skill building.

Reforms to include local and traditional techniques and materials in skilling centres is necessary in view of the emerging trend towards fusion technology. Several architects have adopted a hybrid approach for self-built houses not only in rural areas but also for urban clientele. Including local and traditional techniques and materials in skilling centres can enrich local construction techniques and create livelihood opportunities.

Mapping of available skills in the sector, discussions with local craftsmen and masons and experts survey have highlighted the need for developing high levels of skills for this segment of housing. Masons working with these materials need to have knowledge of requisite skills. The curriculum needs to be enriched from this perspective.

- For techniques that involve the use of bamboo, timber or any other local wood, it is essential that masons are aware of the age of bamboo or wood and understand the process of seasoning it. Knowledge about knots, ties and joineries are also essential.
- Work related to bamboo and timber is subjected to seasonal suitability. Hence, sequencing of the work plays a crucial role.
- In the case of mud, it is important to gauge the proportions of the mud, filler material and water. Consistency of the mixture obtained after mixing all the three components is key.
- Other important aspects include drying time for mud, finishing on the external side to protect from the weather conditions etc.
- For stone, mud or clay bricks and blocks, knowledge about their curing period, dressing techniques, plastering methods, mortar requirements etc. is essential.
- A few experts highlighted that while working with neo-sustainable techniques such as rat-trap bond, one has to be skilled enough to understand the quantum of mortar to be used. It was stated that in some cases the cavities between the bricks were filled due to the excessive use of mortar which defeated the whole purpose of wall construction using rat-trap-bond technique.
- A good level of workmanship while using the neo-sustainable and alternative materials for construction is necessary.

SECTION 7: The way forward

Integration of local building materials, techniques and skills with mainstream technologies for self-built housing in rural and peri-urban areas can give multiple co-benefits. It can reduce the environmental footprint, create climate-appropriate shelters and improve thermal comfort while improving the structural safety and durability of self-built structures, which is the primary source of housing supply in India.

But the potential application of these technologies in hybrid mode has not been recognized or well understood to draw policy attention. Misplaced emphasis on pucca housing while ignoring local material as kutcha and temporary and elevating the status of the concrete structures has caused significant damage. It has detracted attention from the opportunities of blending traditional knowledge with the contemporary to create more sustainable structures.

As a result, there has been a steady erosion of local knowledge, technique and material. Locally appropriate and sustainable techniques that have the potential to be integrated with modern and contemporary applications to reduce the environmental footprint of built structures are being ignored in the new housing policy targeted at self-built housing in rural and peri-urban areas.

Further, the progressive and voluntary steps that a select group of architects are taking to validate and integrate local techniques and materials in modern self-built housing have not found adequate attention and policy support to formalize such efforts to create institutional and regulatory framework for their uptake in modern structures.

This is not only destroying local systems and the material base but also the livelihood systems and skill base around them. The pandemic-led migrant crisis reinforced the need to map out local livelihood options in rural and peri-urban economies. The building sector is a hard-to-abate sector, with one of the largest carbon and environmental footprints. As self-built housing is the largest source of housing supply in India across urban and rural areas, it is necessary to assess the emerging hybrid approaches for deeper infusion of local and sustainable techniques and material to prevent more lock-in of more unsustainable material.

Housing schemes need to recognize and incentivize hybrid approaches and fusion of local technologies and material: Government housing schemes such as Pradhan Mantri Awaas Yojana-Grameen (PMAY-G) and its state counterparts need to internalize and incentivize traditional and hybrid technologies in new self-built housing for the several co-benefits linked with thermal comfort, climate-appropriateness and circularity. This will provide beneficiaries with a wider choice to integrate several sustainability features in new houses or new extensions. Government schemes need to remove stereotyping of kutcha and pucca houses based on material application and allow more fusion of the two technologies.

It is necessary to include traditional and local techniques and materials within the scope of the housing policy and financing for self-built housing in rural, peri-urban and even urban areas, where a new clientele base seeking fusion technologies is slowly emerging. Fusion and traditional technologies will also be more cost effective—local evidence shows that the capital cost of a house using traditional technologies is considerably lower.

Guidelines and norms should be provided and traditional and fusion technologies certified: The biggest roadblock for mainstreaming of traditional and fusion technologies is the lack of testing and certification of these technologies. While scientific literature has proven the thermal comfort and disaster resilience benefits of most of these technologies, absence of standards and tested evidences have prevented their uptake in the market. These technologies need to be evaluated for their performance on thermal comfort and disaster resilience. Based on this technical evaluation, traditional and fusion technologies and the skills related to it need to be certified. Initiatives such as those pioneered by organizations like Hunnarshala in Gujarat have already begun to generate more data and evidence on these technologies. This need to be taken forward at a scale.

Zoning according to geo-climatic conditions for climate appropriate guidance on hybrid and traditional construction: A state may have several climatic zones with varied exposure to disaster and climate vulnerability. For instance, Odisha has a coastline that is frequented by high speed winds and cyclones while it also has hilly forest areas with different kind of vulnerability. Similarly, West Bengal has a highly eco-sensitive Sundarbans region that is battered by frequent cyclones and storm surges as well as the hill districts of Darjeeling and Kalimpong. To address this variability, states need to zone their areas and guide choices of construction technology and materials that are suitable for a particular zone. Vulnerability mapping is crucial to providing an appropriate response.

Reinvention of technologies must address climate-resilient structures: The Odisha Urban Housing Mission has highlighted the reconstruction process after Cyclone Phailin and Fani and underscored the importance of disaster-resilient construction and need for skilling of local masons despite the aspirational conflicts among beneficiaries. Odisha has reinvented the hybrid approach for cyclone rehabilitation. Their shelter schemes have used modern technologies for structural systems such as a concrete foundation and raised plinth with protection, while using traditional techniques such as four-way sloped roofs, which have proved to be more disaster resilient. There is an opportunity for fusion technologies and prototype designs within this housing scheme that has toolkit that the government adopted for making transit homes. Experts also point out that even building typologies need to be reinvented in highly vulnerable areas that may require at least one disaster-resilient room.

Update schedule of rates for formal adoption of these materials: The states need to include traditional and hybrid technologies and materials used in their schedule of rates for procurement. This will push uptake and mainstream these technologies in the construction sector.

Skill-development programmes and skilling centres need to integrate local technologies: The focus has to be on technologies that utilize locally available materials and skills and are responsive to the local climate and cultural context. To do this, a repository of region-specific construction technologies derived from local materials that perform well in terms of climate sensitivity and thermal comfort must be prepared. This compendium has to define the scope of its application in hybrid mode. The Central Building Research Institute (CBRI) has taken note of this. Such initiatives need to be taken forward as part of the housing policy.

Skill-development programmes and skilling centres need to integrate local technologies: The focus should be on technologies that utilize locally available materials and skills and are responsive to the local climate and cultural context. For this, a repository of region-specific construction technologies derived from local materials that are tested and perform well in terms of climate sensitivity and thermal comfort must be prepared. This repository should define the scope of its application in hybrid mode. CBRI has taken note of this. For instance, Odisha in its Urban Housing Mission developed guidance on houses that are disaster resilient and use local material and labour. This was done to provide transit houses to beneficiaries after cyclone Phailin hit the state in 2013. Such initiatives need to be taken forward as part of the housing policy. Certification of these technologies will be instrumental in increasing uptake and aligning skilling efforts.

Need skilling schemes and institutions to recognize hybrid technologies to diversify livelihood options in the sector: Curriculum in institutions needs to be designed to include local techniques and materials to build the knowledge base and build new skills in the sector. Local labourers and masons who are otherwise exiting to brick-and-mortar and concrete technologies need to be trained in hybrid technologies through skilling centres. To do this, certification of skill on traditional and hybrid technologies is crucial. Once masons are certified on traditional and hybrid technologies, statutory bodies such as the West Bengal State Council of Technical and Vocational Education and Skill Development can roll out skilling programmes on these technologies. This is needed to make future building stock climate responsive, especially in areas that are particularly vulnerable to climatic stress and need appropriately designed buildings rooted in local resources. It is also needed to catalyse more local innovation and normalize use of locally developed climate-sensitive hybrid technologies.

Micro industries and local economies that process local building materials and agricultural waste to build the supply chain should be promoted: This is in line with the objectives of the United Nations Sustainable Development Goal 12—titled "responsible consumption and production"—and principles of circular economy. Setups like state tribal museums and technology demonstration centres play an instrumental role in such efforts. A strong co-benefit of this approach is the absorbing of agricultural waste that otherwise may be burnt and cause a range of environmental problems. Circular use of material in the building sector can help address this problem.

Innovation and demonstration centres are needed to promote hybrid technologies: Funding strategy and policies need to support hybrid approaches and local technologies in contemporary modern self-built houses in both rural and urban situations. Experiments and initiatives of architects that are underway for both rural and urban clientele need to be supported and mainstreamed. Several projects have already demonstrated how the combination of traditional and new technologies can work efficiently while improving thermal comfort, durability and cost effectiveness. Innovative use of conventional materials such as burnt-clay bricks, cement and concrete, along with the new materials, can provide a range of solutions for sustainability. In fact, such hybrid techniques need to be included in the schedule of rates. The state schedule of rates must incorporate region-specific hybrid and traditional technologies as well as materials used under them. This will push uptake and mainstream these technologies in the construction sector.

Livelihood schemes need to include local buildings based on local technologies to create jobs: There are several institutional and non-institutional livelihood programmes at the national and state level. This assessment reveals that these programmes do not have livelihood support linked with the use of local technologies and material in the construction sector. To initiate this, certification of masons trained in use of traditional technologies is needed.

Promotion of local material can strengthen conservation of local ecology and promote circularity to reuse waste material or agricultural waste: The ecological resource base that sustains building materials such as wood, timber, bamboo, thatch is under stress due to environmental degradation and developmental impacts. If the supply chain can be developed to sustain a market in innovative self-built housing based on the fusion principle, this will create pressure to conserve and rejuvenate the ecological base. Also, conversion of agricultural waste into building material like thatch can prevent burning of this waste that contributes enormously to air pollution. Overall, there will be a co-benefit of rejuvenation of ecological base, reduction in environmental and carbon footprint of built environment and greater sustainability of self-built housing while strengthening the livelihood base.

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Rural communities in India primarily use local materials and construction techniques to build their homes. This ensures thermal comfort in high and low temperatures and leads to efficient use of resources, strengthening the local livelihood base and sustaining the local economy. Currently, however, there is no ecosystem that internalizes these practices and contributes to India's thermally comfortable housing goals.

CSE has identified the gaps in the housing, materials, skilling and livelihood framework through field investigations and a deep dive into the policies in Odisha and West Bengal. This report describes how to build an ecosystem that mainstreams climate-appropriate materials and promotes local economies that support material and skill innovation, with a focus on the self-built housing segment.

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