A LANDSCAPE ANALYSIS OF SUSTAINABLE, CIRCULAR HOUSING SOLUTIONS IN INDIA

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E4C Fellow:
Sudhamayee Pochiraju, India

This research is in collaboration with:
Habitat for Humanity
habitatindia.org

Project Advisors and Collaborators:
Anoop Nambiar, Country Director (India)**;**
Shyam Chander Kunagaran, Senior Market Systems Specialist (India)
Deepak Visvanathan, Senior Technical Advisor (India); **Juan Pablo Vargas**, Senior Advisor, Innovation, Entrepreneurship, and Markets Systems, Applied Innovation (Costa Rica);
Jennifer Oomen, Director, Applied Innovation, Terwilliger Center for Innovation and Shelter (Netherlands)

E4C Program Management Team:
Mariela Machado, Senior Program Manager; **Erin Peiffer**, Research Manager; **Marilynn Holguín Clover**, Program Coordinator; **Jonathan Kemp**, Program Specialist; **Carolina Rojas**, Program Associate

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Executive Summary

The construction industry is one of the largest industries that contributes to global pollution. The Sustainable Development Goals (SDG), specifically SDG 11: Sustainable Cities and Communities, demonstrate how important sustainable construction is and why it should be promoted in the materials and processes used. This research report details a landscape analysis of sustainable housing solutions in India. As India is a large and heterogeneous country, this research used a case study approach through desk research and interviews with experts to identify new sustainable construction solutions which were then benchmarked against national institutional guidelines and policies on sustainable construction.

The benchmarking framework was used to identify where solutions addressed various sustainability considerations. From the solutions benchmarked, there appears to be positive growth towards promoting environmentally friendly materials that are also price competitive in the market. All the products reviewed are currently strengthening their supply chains by using local resources, making the manufacturing more efficient than conventional methods, and ensuring operational efficiency, in addition to maintaining price competitiveness.

Additionally, there appears to be a positive policy push to support pilot projects and relevant seminars, but there is still a lack of awareness among users and fraternity for promotion of these new materials. Being a part of the schedule of rates, approval from various standards and testing organizations to enter the mainstream construction value chain still remains a challenge. Further support such as lowering the goods and services tax, increasing incentives and access to funding, as well showcasing new solutions at large events can help users become familiar with these new materials.

Overall, there is a positive step being taken by various private stakeholders to come up with materials that are sustainable across various parameters, but there is still a long way to go for them to completely replace the conventional materials through the adoption of the masses.

Habitat for Humanity supports various aspects related to affordable housing, such as the promotion of appropriate technologies in the construction sector. Identifying case studies of organizations that are working towards sustainable construction solutions can play a huge role in promoting affordable and green housing in the future. The case studies identified in this research provide tangible examples of how organizations within India are working towards a more sustainable construction sector for the benefit of all.

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Introduction

There is a pressing need for a development model where there is optimum utilization of resources to combat climate change. With a growing population, rapid urbanization, climate and environmental change, there is a need to make a shift towards a circular economy where the resources are reused rather than being thrown away at the end of their lifecycle.[1]

In India, the construction industry is one of the largest sectors that employs a large number of people after agriculture as it employs more than 45million people[2]. Being one of the largest employment generating sectors, it also accounts for nearly 38% of total global energy-related CO2 emissions.[3] As a way to reduce these carbon emissions, bringing the circular economy into mainstream construction, in the form of materials or processes, can be one of the methods to mitigate the negative environmental impact and move towards sustainable development in the construction industry.

The term sustainability has many definitions making it difficult to succinctly define. For this report, sustainability is conceptualized as three pillars: social, economic and environmental. Aspects such as community, livelihood creation, adaptability to context, and fulfilling the desired needs of the users are covered in social sustainability. For economic sustainability, livelihood creation, affordability, access to funding, and efficient supply chain are studied. Local availability of resources, efficient supply chain, carbon emissions, and scalability are some of the aspects that are considered under environmental sustainability.

The aim of this study was to complete a landscape analysis of trends, enablers, and barriers to innovation of sustainable solutions for, or applicable to, housing in India. India is a diverse country, where the definition of sustainability can drastically change with geographical location and context. Hence, case studies were selected to highlight current solutions in India and the challenges and opportunities they face within the scope of study. Though the intention is not to comment on the overall sustainability of the construction industry of India, an attempt is made within this scope to identify the general barriers and opportunities.

Methodology

The figure below summarizes the methodology used for this report. Desk research was conducted to understand definitions of sustainability as stated by various important institutions such as The National Building Code, Indian Green Building Council, Building Materials and Technology Promotion Council, and the Center for Science and Environment. From this desk research, criteria were identified for benchmarking sustainable solutions identified through case studies. Interviews were then conducted with multiple diverse organizations to understand their sustainable construction solutions and any challenges or opportunities they are currently facing. All the data was then consolidated from the desk research and qualitative interviews to identify the barriers and opportunities in promoting sustainability in the construction industry.

[1] Niti Aayog, Government Driving Transition from Linear to Circular Economy, 2021
[2] Goel, A., Ganesh, L. S., and Kaur, A. (2021). Sustainability assessment of construction practices in India using inductive content analysis of research literature. International Journal of Construction Management, 21(8), 802-817
[3] United Nations Environment Programme, 2019 Global Status Report for Building and Construction Section, 2019

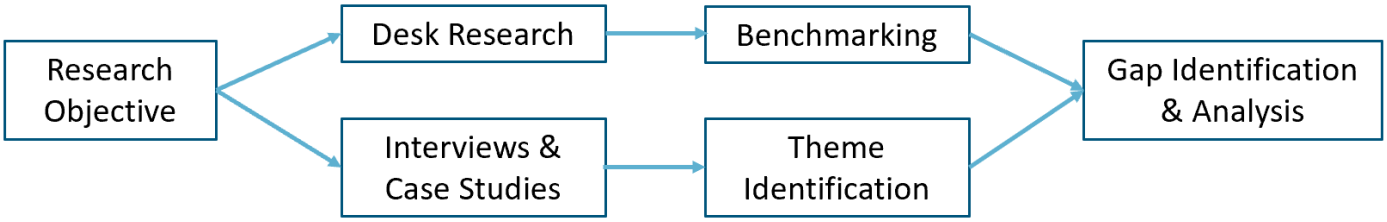

Figure 1. Methodology

Desk Research

To establish the benchmarking criteria for sustainable housing solutions, reports from four institutions in India were selected including the National Building Code (NBC), India Green Building Council (IGBC), Building Materials and Technology Promotion Council (BMTPC), and the Center for Science and Environment (CSE). The institutions chosen play different roles, but all promote sustainability measures in regular construction practices in India. The NBC provides mandates to be followed before constructing any building; the IGBC gives certifications to benchmark sustainable construction; and BMTPC promotes sustainable practices that can be used before building any structure. The guidelines set by NBC and BMTPC, if followed, can provide significant results for promoting sustainability in construction while CSE provides overall awareness, research, and advocacy for reference for any stakeholder to practice sustainable construction.

There are many factors along with material and technology through which sustainability is achieved. It can be through form, massing, site development, landscape, lighting, water, and more. Once all these factors are holistically considered, sustainable design of buildings is possible. This research focuses specifically on sustainable materials and technology.

The National Building Code

The National Building Code (NBC) is a mandate that has to be followed while constructing any built form. Chapter 11 of NBC particularly focuses on sustainability and ensuring it is considered during the planning, design, construction, operation and maintenance of buildings. According to the NBC, a sustainable building is anything that meets "specified building performance requirements", key terminology of which is presented in Table 1, as specified in the sustainability chapter of NBC, "while minimizing disturbance to the environment and improving the functioning of local, regional and global ecosystems both during and after the construction and specified service life".[4]

Life Cycle Assessment (LCA) of materials is also encouraged in NBC so that the environmental impact at every stage of the life cycle is analyzed, from raw material sourcing to process, manufacturing, finishing, installation, maintenance, operation, and demolition. At every step, it is important to note what material contributes to the environment. There are certain aspects brought in focus while assessing the LCA such as – embodied energy, resource reuse, 3Rs, natural, biodegradable, indigenous, renewable, compliant with clean water and clean air, low ozone depletion potential etc.[5]

[4] Bureau of Indian Standards, National Building Code of India, Chapter 11, Section 10.2 Sustainable Buildings,, 2016
[5] Bureau of Indian Standards, National Building Code of India, Chapter 11, 2016

Some examples of materials that may be considered more sustainable alternatives include options such as "the use of pozzolans and other mineral admixtures for cement replacement in cement concrete and other cement matrix products", burnt clay bricks and tiles, cob walls, stone, timber, and bamboo.[6] For materials traditionally considered less sustainable, such as plastics and metals, the NBC provides recommendations to maximize sustainability.

The identified terminologies in the sustainability chapter of NBC are shown below in Table 1. These considerations were used in the benchmarking framework to establish considerations for sustainable solutions.

Table 1. Terminologies related to sustainability in the National Building Code

Aspects of Sustainability that can be achieved through Technology	
Utilization of waste (e.g., agricultural or industrial)	Adaptable to local climate
Utilization of local resources	Reduced embodied energy
Cost effective	Reduced operational energy
Environmentally friendly	Optimized vernacular design and processes

Indian Green Building Council

The IGBC provides affordable, green building rating systems addressing different green features that can be part of a building such as site measures, water conservation, energy conservation, material conservation, indoor air quality, innovation, and design process.[7]

As this study majorly focuses on materials and technology as means to reduce carbon footprint, Table 2 shows the material conservation criteria as established by the IGBC.

Table 2. Terminologies related to material conservation in the Indian Green Building Council

Important Aspects of Sustainability that can be achieved through Materials Conservation	
Waste Management	Materials with Recycled Content
Handling Construction Waste	Appropriate Technologies
Use of Local Materials	Alternate Construction Materials

While the NBC provides mandates for building and sustainability, the IGBC provides guidelines to receive credits and star ratings to certify building sustainability. NBC promotes certain areas where a sustainable approach can be taken whereas IGBC works as an additional guide to be followed to qualify any building to be sustainable. Due to this interlinkage it is interesting to see that if the areas that NBC provide guidelines on are followed, a building is automatically given a higher star rating by IGBC. Getting a certification from IGBC itself is a trademark in the market.

[6] Bureau of Indian Standards, National Building Code of India, Chapter 11, Section 9.2 Materials and Recommended Sustainable Alternatives, 2016
[7] India Green Building Council, Green Building & Sustainable Architecture in India, About IBGC, n.d.

Center for Science & Environment

CSE is a public interest and research organization that aims to create awareness on environmental problems and provide sustainable solutions. Most of the research conducted at CSE consists of solving environmental problems through solutions based on the core values of CSE. CSE engages in multiple activities including awareness programmes, research and advocacy, education and training through a knowledge portal, and pollution monitoring.[8]

To increase the sustainability of a product, it is important to reduce the use of virgin materials, reduce the energy and carbon footprint of materials, ensure it results in less pollution, and minimize waste without compromising on the project's economic viability and overall comfort, safety, and other requirements of the occupants. CSE came up with an analysis based on Multi-Attribute Evaluation Methodology for Selection of Emerging Housing Technologies, adding sub-attributes to those stated by BMTPC. [9]

BMTPC was set up as an apex body, and they act as a common platform between the central and state government, and private stakeholders to come together and promote appropriate technologies. BMTPC is mandated to resource-efficient, climate resistant, disaster resistant construction practices. They have networks with academic and research organizations, public and private sector, NGO's, foreign institutions, among others. [10]

Table 3 given below shows the attributes added by CSE to what BMTPC states. All of the institutions mentioned below play a key role in setting the guidelines for sustainable construction practices in India. These criteria provide a baseline for assessing building sustainability in India. Hence, these terminologies are set as benchmarks to define sustainability for each of the case studies selected in the upcoming sections.

[8] Center for Science and Environment, About CSE, n.d.
[9] Center for Science and Environment, Optimizing the Third Skin, 2020
[10] Building Materials and Technology Promotion Council, BMTPC, n.d.

Table 3. Attributes added to BMTPC table by CSE

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

Case Studies: Sustainable & Affordable Housing Solutions

The study has been conducted to understand barriers to promote sustainability into mainstream construction. Due to limitations of time, the scope is limited to the number of case studies chosen. The intent is to try to understand sustainability barriers on the basis of case studies selected and the desk research done. The case studies include institutions, private organizations, new startups, all from different domains working on different product development and technology developments. The attempt is made to cover case studies from very different backgrounds so that a holistic idea towards sustainability in construction can be understood.

Bio-Bricks[11]

Bio-Bricks are one sustainable and affordable housing solution in India that are currently in the prototyping stage. Developed by Dr. Priyabrata Rautray of IIT Hyderabad with the motto "more than sustainability", they utilize waste generated after harvests to create bricks which can be used for construction. This solution capitalizes on the large volume of post-harvest waste that doesn't hold any commercial viability in creating bricks which are less expensive than existing alternatives in the market. While most of the products today use agricultural waste as an additive, this product uses 80-85% agricultural waste. The product performance is also better as it has high thermal resistance and with additives such as lime, it is also fire resistant. The strength of the bricks can be improved through the incorporation of cement. Due to porosity of the product, it regulates humidity which is a positive aspect for constructing in the coastal areas. At the stage of demolishing, the product is completely decomposable.

The materials used for Bio-Bricks cost between one-third to one-half of conventional materials. The target market for this solution is for builders where these bricks can be used as the filler material. While this product does not seek to compete with conventional bricks, the designers hope to use their Bio-Bricks to introduce a new material into traditional construction methods in rural areas. As this material can be used for roofs and walls. The aim is to develop housing construction with a single material.

People can also be trained to use these materials themselves. New machines are also being developed to make bricks on site where there is agro waste. In the future, the goal is to have one central unit for 4-5 villages where there can be a central machine to convert agro waste to bricks. These bricks can then create a market in the rural areas for local construction, more like a cooperative model.

Figure 2. A prototype made out of bio bricks[12]

There has been a lot of effort with regard to policy professionals, educational institutions for financial support to promote this product. There is support to incorporate this product in the schedule of rates[13] provided lab testing, LCA and other tests done to convince all the parameters. Hence, the product is still at the prototype stage, once the tests are conducted, there is a possibility to draw traction from various financial sources.

Green Jams Infrastructures LLP[14]

GreenJams is an award-winning CleanTech Social Enterprise decarbonizing the built environment. The products created under Green Jams include agrocrete, BINDR and hemp bloc (see Figure 3). The founder of Green Jams,

[11] Interview with Ar. Priyabrata Rautray, PhD scholar at IIT Hyderabad, Design Department, January 2022
[12] Express Web Desk, India's first building made of bio-bricks at IIT-Hyderabad is a great example of 'wealth from waste', 2021
[13] Schedule of rates can include "a list in a contract setting out the staff, labour and plant hire rates the contractor will use for pricing cost reimbursable instructed daywork". - Design Buildings, Schedule of Rates for Construction, n.d.
[14] Interview with Mr. Tarun Jami, Founder of Green Jams, January 2022

Mr.Tarun Jami defines sustainability as slow utilization of resources so that there is less pressure on existing resources. It was stated that it is not important that every chain is circular but it is important to create effective linear chains also. The company's focus was initially on hemp Crete which is fire resistant and is carbon negative but was deemed unfavorable for the Indian construction industry due to difficulty accessing hemp. Then the focus shifted to new product development with focus on value chain and understanding the market. The availability of crop residue in the country and burning this residue is a problem which is suited to be the most effective resource to focus on.

The manufacturing units are set up in rurban or rural areas where there is availability of crop residue. The target market is for both rural and urban markets. Each manufacturing unit can target 600 acres of cultivable land and convert the crop residue to a value added product. It is a product that has a lot of demand in the market, the issues that need to be solved are from the supply side, managing the crop residue and setting up manufacturing units. Agro Crete can eliminate the use of concrete and steel at least for G and G+1 structures, though no changes can be made in the slab. While the hollow area in the brick is increased, the material itself is strong. Agrocrete uses 60% crop residue by volume and the remaining 40% is industrial waste such as fly ash and slag. There is no use of cement and lime.

The standout point for the product that is developed is the cost which has resulted in 12 million blocks in the enquiry as the product is resulting in 50% less construction cost. It is not about the cost of the product itself but also other costs such as reduction in labor costs, consistent mortar joints, fine finishing, lighter weight, better workability etc. The agrocrete block developed is a load bearing block, depending on the design it can also be used as a filler material. The product achieves western class insulation and good acoustic insulation. The focus is on open markets and also offer large volumes to builders where it is a filler material. There has been a lot of effort put to develop a community with architects and designers to create awareness.

Operational efficiency of a built structure is highly dependent on the design but agrocrete can be used to achieve this. Thermal comfort from agro Crete eliminates the need to use any other insulating material; the durability is high where the blocks gain strength over time. Overall, the performance of the blocks have been proven to be effective and there is a positive response from the users. These blocks are like a carbon capture mechanism where a material that would have burnt is now a value added product.

The founder stated that there is a need to get the Environmental Product Declarations (EPD) certifications and other important certifications indicating a negative carbon footprint which can help in gaining more customers even though it is a patented product.

Figure 3. Agrocrete, Bindr and Hemp Bloc developed by Green Jams[15]

[15] Green Jams, n.d.

Strawcture Eco[16]

Strawcture Eco believes that waste from one industry can serve as a raw material for another. To embrace this resource utilization and waste reduction, they have created a value chain of building materials. The main product created by Strawcture Eco are agri bio panels which are agri fiber panels made with 90% straw and other adhesives that are compressed at high temperature and pressure (see Figure 4). According to the founder, straw as a material is very similar to wood and has the potential to be a substitute in building materials. It has the potential to give thermal and acoustic comfort and also has more silica content and is more fire retardant than wood. Due to these features, straw composites can be converted into a more palatable form for commercial purposes, modular panels that can reduce the time of construction is one example of a solution with high market potential.

The product is only made of three materials: 90% agri fiber from various sources, 5% moisture, and 5% binder. It is tested for toxicity and volatile organic compounds (VOC) emission and the product has the lowest VOC emission compared to any other materials in the market, promising better air quality. It has no negative impact at the demolition stage as well. It improves the overall interior environment. There is zero amount of water used during installation and only 5% water used in the manufacturing process which is a significant impact as manufacturing usually consumes significant amounts of water.

For manufacturing in the south, the products will have more focus on coconut than crop residue; in the east focus will be on bamboo. As such, locally available material can be used to ensure the most efficient local supply chain. For sustainability, the raw material used by Strawcture Eco is locally sourced (within 100 km) which is made possible due to straw availability throughout the country. Once the product is made, the intent is also to provide a market in the nearby areas, so the entire supply chain is as local as possible. Local sourcing of the raw material also reduces the cost for transportation and potential impacts on the environment. Decentralized micro-manufacturing units are one way to minimize the carbon footprint of this solution, and in the long term, there is hope to employ this as a highly scalable model.

Every product that is launched by Strawcture Eco aims to be competitive with existing products in the market regarding cost and quality. Additionally, to target small projects, Strawcture Eco aims to establish a traditional distribution market network to ensure the product is within the reach of architects and designers. Architects and designers have found the texture of the product samples attractive. All the technical aspects such as termite proof, moisture proof, fireproof, and price competitiveness are met to further convince stakeholders in using the new material. Strawcture Eco aims to develop products that are durable, sustainable, and affordable which is the reason for customer satisfaction and retention.

One challenge Strawcture Eco faces is ensuring that architects and designers are aware of their products and that their solution is differentiated from the competition. Multiple certifications and LCA have been done to prove that this product's performance will be much better at the operational level and also has a negative carbon footprint when compared to any other material is another challenge. LCA helps to understand the entire supply chain value and not only the end product.

There is currently a policy push for the product. Recently a Covid hospital was completed with the bio panels which was a government project. Though there is a need to further lower the goods and service tax to promote these agri bio panels on a larger scale, the customer satisfaction and retention has been high which gives hope

[16] Interview with Ms.Shruti Pandey, Founder of Strawcture Eco, January 2022

for the dealer to also stock the Strawcture Eco products. The aim is to showcase the product in major attention seeking projects so that the product is visible and gains traction for further support.

Figure 4. Agri Bio Panel developed by Strawcture Eco[17]

Saltech Design Labs[18]

Saltech created circularity by deploying advanced closed-loop recycling technology to extract maximum value out of waste and improve the value chain. The patented process transforms single-use plastics, construction and demolition waste, and industrial minerals/aggregate/fly ash wastes into high-value alternative composite building materials. The company's focus was to understand waste management, the waste disposal at home, and how it ends up in the landfill. It was seen that, even if the waste is segregated at home, it is mixed outside the house which is a result of weak monitoring. In contrast, metal never goes to waste because there is a monetary value and also there is a solid framework to recycle the metal to gain that monetary value. Similarly, if a monetary value is put on the recycled plastic, the demand for the material goes up and automatically plastic is segregated to be able to recycle it. The final recycled material describes the monetary value over the entire value chain. This understanding resulted in focusing on two components, 1) post-consumer waste that is plastic and 2) industrial waste such as fly ash.

Figure 5. Process followed by Saltech Design Labs to convert waste to usable products[19]

[17] Strawcture Eco, n.d.
[18] Interview with Mr. Adithya Shukla, Founder of Saltech Design Labs, January 2022
[19] Recycler India - Saltech Design Labs Private Limited, n.d.

Industries don't have technology to recycle the waste and for post-consumer waste, it is a combination of multiple types of plastic together which is a heterogeneous waste. This is where the company aimed to create a solution to create products which could be used as building materials. The main agenda was to use this huge quantum of waste generated, recycle it and create a product that can have high market demand where there is otherwise no value added to the entire linear supply chain. The quantum of material used is high in building materials, thus the target for using the recycled waste products in the construction industry was set as the vision.

The product was positioned such that it is competitive with the conventional material with a focus on road pavement and walling materials. At the time of disposal/post usage, the products are again recyclable with the same technology. The market for these products is very regional; buyers rely on local manufacturers within a 100 km radius. The product cost is lowered by using waste material and eliminating the processing steps such as sorting and washing. The other way cost is reduced is by focusing on the waste that doesn't have a supply chain established such as low density plastic.

Waste is a very locally driven business, where it has to be manufactured locally and also consumed locally. With the support of the ministry of urban affairs, the product was acknowledged due to their waste mitigation strategy and product performance. While the price was competitive, another incentive to government project consumers was to manufacture locally and to consume locally. To target these consumers, decentralized scaling is planned for the future. Waste is generated in a fragmented manner in different geographies, so setting up multiple manufacturing units with the technology developed by Saltech makes it replicable and scalable.

Government stakeholders such as those in public infrastructure are target consumers for Saltech. Both those in procurement and consumers are government stakeholders so, the focus is on Business to Business and Business to Government. Once used, the consumer sees a benefit in the installation, landing and transportation cost, and the LCA shows how durable the product is. Repeat orders from the users further justify the product performance.

Once the supply and the technology is scaled, new markets can be tapped into. The product is competitive, in performance, transportation cost, and waste absorption. Overall, the product positioning in the commodity market is very important and Saltech is expecting to get the positioning right.

Tvasta Construction[20]

The use of materials in the construction process plays a major role in contributing to the world's carbon emissions. The cement industry alone contributes to 10% of this. Tvasta created a concrete 3D printing technology for the construction industry that aims to increase the efficiency from the construction process, during transportation, and after construction during the operation phase. A 3D printed house prototype by Tvasta can be seen in Figure 6.

[20] Interview with Mr. Aditya, Founder of Tvasta, January 2022

Figure 6. 3D printed house prototype by Tvasta[21]

Through this technology, the amount of materials, including cement, is reduced, as the walls are hollow. Currently for a medium and a premium structure, Tvasta matches the conventional building cost but saves on the time of construction and cost of labor. Tvasta owns the technology end to end. While their focus is to develop the execution capacity, there is some competition from big companies.

Tvatsa has received recognition from the government through startup awards and customers have responded positively as the built structure meets or exceeds expectations while looking like conventionally built structures. Additionally, the structures have good thermal insulation capacity and consume less energy in its lifetime. The design of the building supports energy efficiency during the operating phase and the technology has the capacity to go up to an eight story structure.

Janaadhar[22]

Janaadhar aims to create high-quality, affordable homes that are rich in amenities and low on financial stress while incorporating sustainability into conventional housing. This solution takes into consideration all of the features from the IGBC sustainable and affordable housing framework with regard to green and efficient energy without compromising on cost which is needed for rapid scaling.

According to Ms.Shikha Parakh, precast technologies were suitable for incorporating affordable and sustainable features into their buildings. Precast reduces waste as it utilizes resources efficiently, is made in a factory resulting in water saving, and utilizes concrete more efficiently overall. This method is able to attain the same strength while using less concrete. All these characteristics improve sustainability in the long run or in the operational phase while keeping the cost in control. Figure 7 shows one of Janaadhar's complete projects.

[21] Tvasta, Projects, n.d.
[22] Interview with Ms.Shikha Parakh, General Manager Janaadhar, January 2022

Figure 7. Completed project by Janaadhar using PreCast services[23]

Once a manufacturing set up is established, multiple projects can be done in the unit. Business to business is targeted where customisation is done according to the room design and with elements such as walls, slabs and staircases that are manufactured centrally. Large developers cater to self-projects whereas Janaadhar is focusing on self as well as outside projects for manufacturing building elements. According to Janaadhar, the building has a better finish, better lifecycle cost, and better energy efficiency during occupancy.

One challenge that they currently face is convincing the client that the experience of a precast method is better than a conventional building. Currently central manufacturing is not implemented at a large scale, but once the manufacturing reaches its optimum capacity, the model can turn profitable.

ECO STP[24]

ECO STP's (sewage treatment plant) patented technology treats sewage in a decentralized, self sustainable way in underground chambers without requiring power, chemicals or human intervention. Using biomimicry, regenerative innovation inspired by nature, ECO STP utilizes functional principles and strategies of microorganisms and ecosystems found in a cow's stomach.

According to Mr. Tharun, founder and CEO of ECO STP, the intent was to treat waste without requiring power or chemicals, compared to conventional methods which are resource intensive. They are able to accomplish this through anaerobic digestion in which anaerobic bacteria and wastewater treats sewage waste. Additionally, this method doesn't require air to handle smell from the waste. The execution Model of Eco STP can be seen in Figure 8.

The wastewater treated also goes through a root zone, or certain plant species, to further treat the water. There is no segregation as all water, including the waste water, washing machine water, and bathroom water, comes to the chamber. After going across multiple chambers, clean water is produced. Sludge accumulation requires cleaning once every two years. The treated water can then be reused for cleaning and flushing toilets. Research is ongoing to provide water quality suitable for bathing or even drinking.

[23] Janaadhar, Services, n.d.
[24] Interview with Mr. Tharun Kumar, Founder and CEO of ECO STP, January 2022

ECO STP is a private company that claims that every standard is met and the functionality of the system is perfect and has proven to be most effective when compared to any other competitor in the market, which are mostly government launched systems. Full design customization can be done for any client. Local materials and local labor can be used to build it further promoting sustainability. ECO STP provides support during execution and annual maintenance.

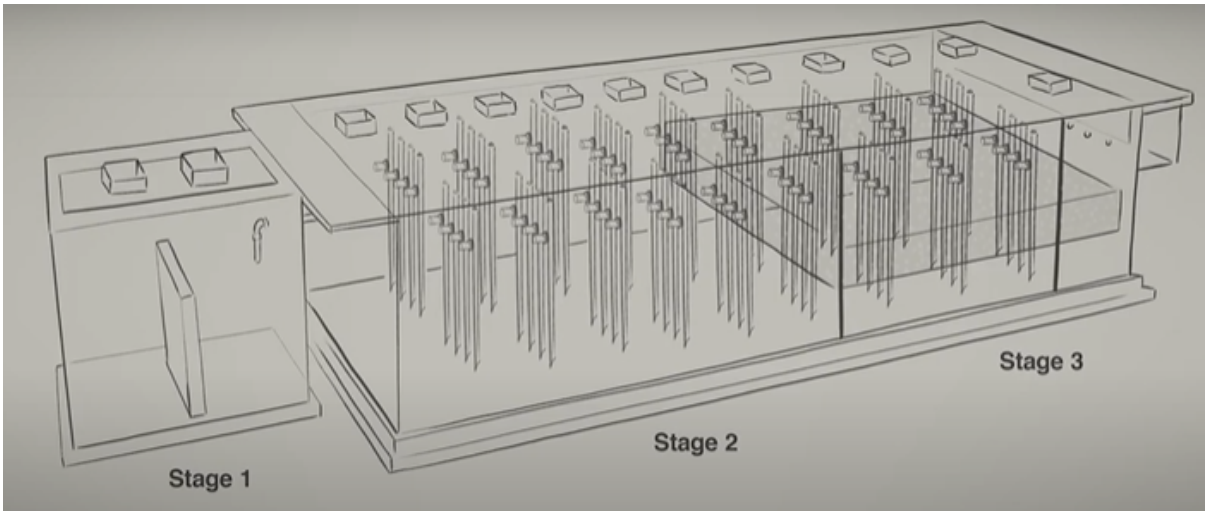

Figure 8. ECO STP Execution Model[25]

Capital cost of the ECO STP is 20% more than the conventional STP (the civil cost per Kl is Rs.50000) but the operational cost is less (Rs.2/Kl compared to Rs.16/18 per Kl for a conventional setup). The target market is business to business where the main customers are new developers, group housing, and also commercial buildings.

Adopting a new technology is a challenge as it needs education and awareness. This is one challenge ECO STP face. While they have multiple clients across the country, they are not yet at scale. It is mandatory, according to the pollution control board, to have an STP but most of the clients either don't follow it or directly put it in the septic tank.

The technology conforms to six SDGs and there is a lot of research done by ECO STP to show how effective the technology is. According to Mr. Tharun Kumar, there should be a mandate from the regulatory authorities to promote this technology, but currently STP are not mandatory.

Ex Dalmia Cement[26]

Ex Dalmia Cement is a manufacturer of cement. Two main areas of research that are ongoing in this space related to sustainability include energy and materials. Currently, there are many alternative fuels that are being promoted in the cement industry (PET coke, American coal, etc.) to reduce CO2 emissions, improve process efficiency, and reduce cost. To reduce dependence on coal, there is additional interest in finding alternative options which can be more environmentally friendly, make the process more energy efficient and at the same time provide satisfactory results. If coal is replaced as the fuel source, manufacturing processes will need to be

[25] ECO STP, n.d.
[26] Interview with Mr. Ramanathan, Ex Dalmia Cement, January 2022

updated for compatibility. Heating is a critical component in manufacturing and with the introduction to PET coke, the cost is expected to decrease while being more environmentally friendly.

Cement has a composition of clinker (97%) and gypsum (3%). Resources such as clinker can be preserved if replaced with industrial waste materials such as fly ash. For example, blended cement (Portland Pozzolana Cement (PPC), Portland slag cement) reduces clinker to 50%. The quality of fly ash is critical to maintain pozzolanic quality, but PPC has better performance. The promotion of PPC is also one of the methods to save the resource and reduce CO2 emissions by reducing the amount of limestone required.

While bigger companies and experts are now promoting PPC, government projects are still using ordinary portland cement. As ordinary Portland cement and PPC look similar, there is currently insufficient monitoring to identify the cement used. Currently, there is a lack of awareness as PPC and its advantages with regard to environmental benefits, cost, and resource efficiency.

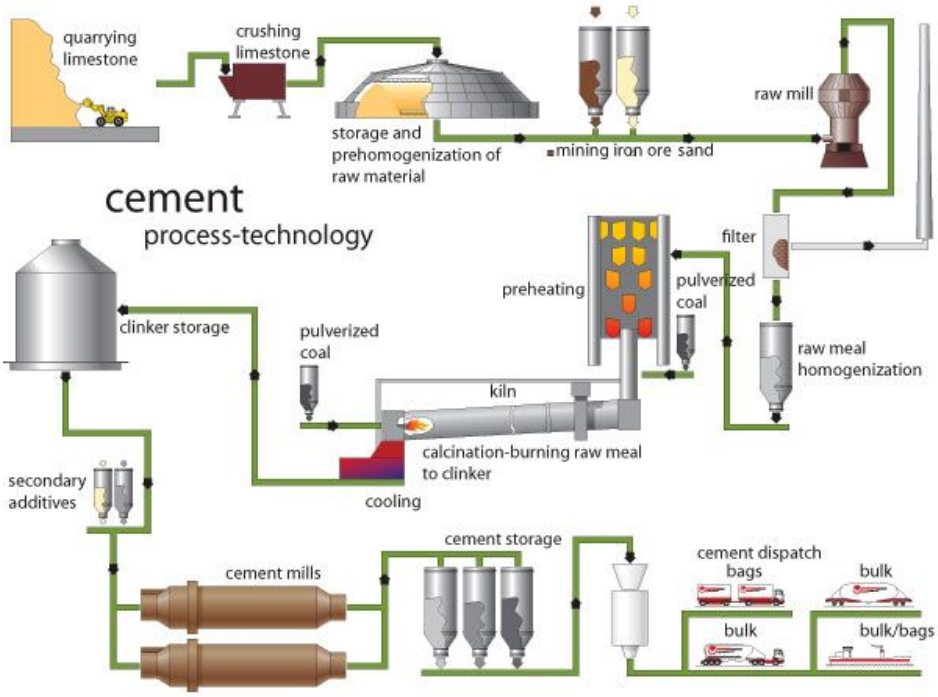

Figure 9. Cement manufacturing Process[27]

BMTPC[28]

In order to bridge the gap between research and development and large-scale application of new building material technologies, the Ministry of Urban Development, Government of India established the Building Materials And Technology Promotion Council (BMTPC) in July 1990. As stated by the executive director at BMTPC, Dr. Shailesh Agrawal, sustainability is the need of the hour, whether it is about materials, technologies or day to day activities, but every person has a very different perspective on sustainability.

For architects, NBC has a special chapter to provide an overall framework of sustainability to reduce environmental impact. One important aspect from this chapter is resource efficiency with regard to the use of local materials, waste minimization, waste reuse (circular economy), and reduced dependency on fossil fuels.

[27] Construction Cost, Cement Production Process, n.d.
[28] Interview with Mr.Shailesh Agrawal, Executive Director, BMTPC, January 2022

Additionally, embodied energy of every material used in the construction process is very critical. Things such as occupant health from exposure to volatile organic compound (VOC) emissions should be avoided in the materials used and promoted.

Policies to promote sustainability already exist, and there is a commitment for reducing carbon footprints in construction and promoting a circular economy. It is the responsibility of the fraternity, architects, designers, and construction professionals to bring awareness at the design stage and to ensure implementation on the ground to support the creation of a market for sustainable materials and methods. Additionally, it is the architect's responsibility to reduce HVAC load or consider more sustainable wastewater treatment methods.

There is active work from BMTPC to promote different technologies, innovations, and resource efficiency methods. Major changes such as the rejection of concrete or cement is not required. Instead there should be a focus on resource efficiency. It is a step in the right direction if the resources used are reduced through the addition of industrial waste, according to Mr. Shailesh Agrawal.

Guidelines at the state level provide frameworks for architects for design layouts, proper light and ventilation, among other considerations. While education and awareness around lifecycle cost are being promoted, there is still a need for stronger research and execution. It is no longer sufficient to only consider initial costs of construction. Demolition cost, which is often overlooked, should be included in planning as well as a sustainable practice.

CSD[29]

The Center for Science and Environment (CSE) is a public interest research and advocacy organization based in New Delhi, India. CSE researches, lobbies for, and communicates the urgency of development that is both sustainable and equitable. As stated by Mr. Sugeet Grover, Program Officer at CSE, sustainability can be defined as minimizing the amount of resource consumed and waste generated, maximizing the lifecycle of any material, reducing the negative impact of a material on an occupant, along with the promotion of a more circular economy. From his perspective, it is still not being promoted at a scale, not only in India but anywhere else in the world too.

While there is a need for awareness and consciousness around sustainable materials and processes, the technologies promoted by BMTPC for housing typologies do not clearly define the criteria to qualify a certain material as 'sustainable', and there are no solid frameworks to qualify any material as sustainable. To address this gap, "Optimizing the Third Skin", a research document released by CSE, provides guidelines to qualify any material as 'sustainable' where various aspects such as resource efficiency, thermal comfort, recyclability, and renewability are analyzed. Stronger policy mandates are required to promote sustainable materials to increase market demand.

C40 Cities[30]

C40 is a network of mayors of nearly 100 world-leading cities collaborating to deliver the urgent action needed right now to confront the climate crisis. As stated by Ms. Shruti Narayan, Regional Director for South and West Asia of C40 Cities, green financing, or how money can be used to improve sustainable development, is an

[29] Interview with Mr. Sugeet Grover, Program Officer at CSE, February 2022
[30] Interview with Ms. Shruti Narayan, Regional Director, South and West Asia, C40 Cities, February 2022

important aspect to promote sustainability. Financial support can come in many different forms including micro credit or incentives.

While multiple methods, materials, and technologies are being developed to promote sustainability, these solutions should be profitable in the long term. Subsidies are just one solution that can support this shift. Tax benefits for products and technologies with low embodied energy or adopting the schedule of rates are other methods adopted by the government to support promising sustainable solutions. The Ministry of Housing has held discussions involving private stakeholders to identify these technologies as well. Despite this, technologies should be efficient enough so that they can be sustained without requiring subsidies or incentives in the long run.

According to Ms. Shruti Narayan, if a new technology or product is replacing a conventional one, it should be scalable. This includes establishing supply chains and fool proof business plans that are capable of functioning at full capacity to meet demand. Market demand should be one of the first considerations before drafting further plans, and the overall shift to the green economy will only happen is a solution becomes mainstream or if the ecosystem becomes fully established. Once the trajectory is mapped and if it is believed that the new materials or technology will be successful in the future, other frameworks such as tax benefits, incentives, subsidies, and pilot projects, will then be given to encourage and bring them into limelight.

Results

This section provides a consolidated view of the important themes identified across the desk research and case studies. The themes identified from the interviews conducted with institutions such as BMTPC, CSE and Green Financing and from literature from NBC and IGBC are used as benchmarks to identify areas of sustainability addressed across the identified case studies. The case studies range from technology to materials to methodologies with different approaches to achieving sustainability.

It is important to note that the color coding is only an indication to see the overall framework and get a broad understanding about sustainability across different case studies. This does not give a concrete answer to sustainability in the construction industry in India. Taking the scope into consideration, the case studies chosen are only used to broadly showcase what are the challenges or the ‘push’ or ‘pull’ areas when it comes to promoting sustainability. Each institution and literature source identified various parameters, which at times overlap. The table lists these parameters after removing duplicity.

The color coding in the table below signify:

1. Red – the process to achieve the following parameter might be planned in the future but currently the process has not yet been started.
2. Yellow - the process to achieve the following parameter might be slow but it is in process of achieving that parameter.
3. Green – the parameter has been already achieved to a certain extent and proven successful.
4. White – the parameter might not be applicable in the case study.

The color coding done in the Table 4 below signifies the progress of each case study towards social, economic and environmental sustainability.

Table 4. Case Studies Progress Towards Different Types of Sustainability

Case Studies	Social Sustainability	Environmental Sustainability	Economic Sustainability
Eco Brick			
Green Jams			
Strawcture Eco			
Saltech			
Tvasta			
Janaadhar			
Eco STP			
Cement Manufacturing			

Tables 5 and 6 have case studies selected on the Y-axis and the terminologies identified from desk research on the X-axis. The themes identified from the case studies tables above have been used to assess sustainability across the table.

Table 5. Case Studies following the definitions of terminologies identified in desk research of NBC & IGBC

Case Studies	NBC								IGBC		
	Agr./ Industrial Waste	Use of local materials	Cost Effective	Envr. Friendly	Adapt. to Climate	Reduced Embodied Energy	Reduced Operational Energy	Vernacular Design	Waste Mgmt.	Appropriate Tech.	Appropriate Materials
Eco Brick											
Green Jams											
Strawcture Eco											
Saltech											
Tvasta											
Janaadhar											
Eco STP											
Cement Manufacturing											

Table 6. Case Studies following the definitions of terminologies identified in desk research of BMTPC, CSE & Green Finance

Case Studies	BMTPC				CSE	Green Finance			
	Health of Occupants	Policy Support	LCA	Reduced Carbon Footprint	Awareness	Market Demand	Economic Stability	Proven Concept	Tax Benefits/ Incentives etc.
Eco Brick									
Green Jams									
Strawcture Eco									
Saltech									
Tvasta									
Janaadhar									
Eco STP									
Cement Manufacturing									

A summary of the results from this research are captured in Figure 10 at a high level across the construction value chain.

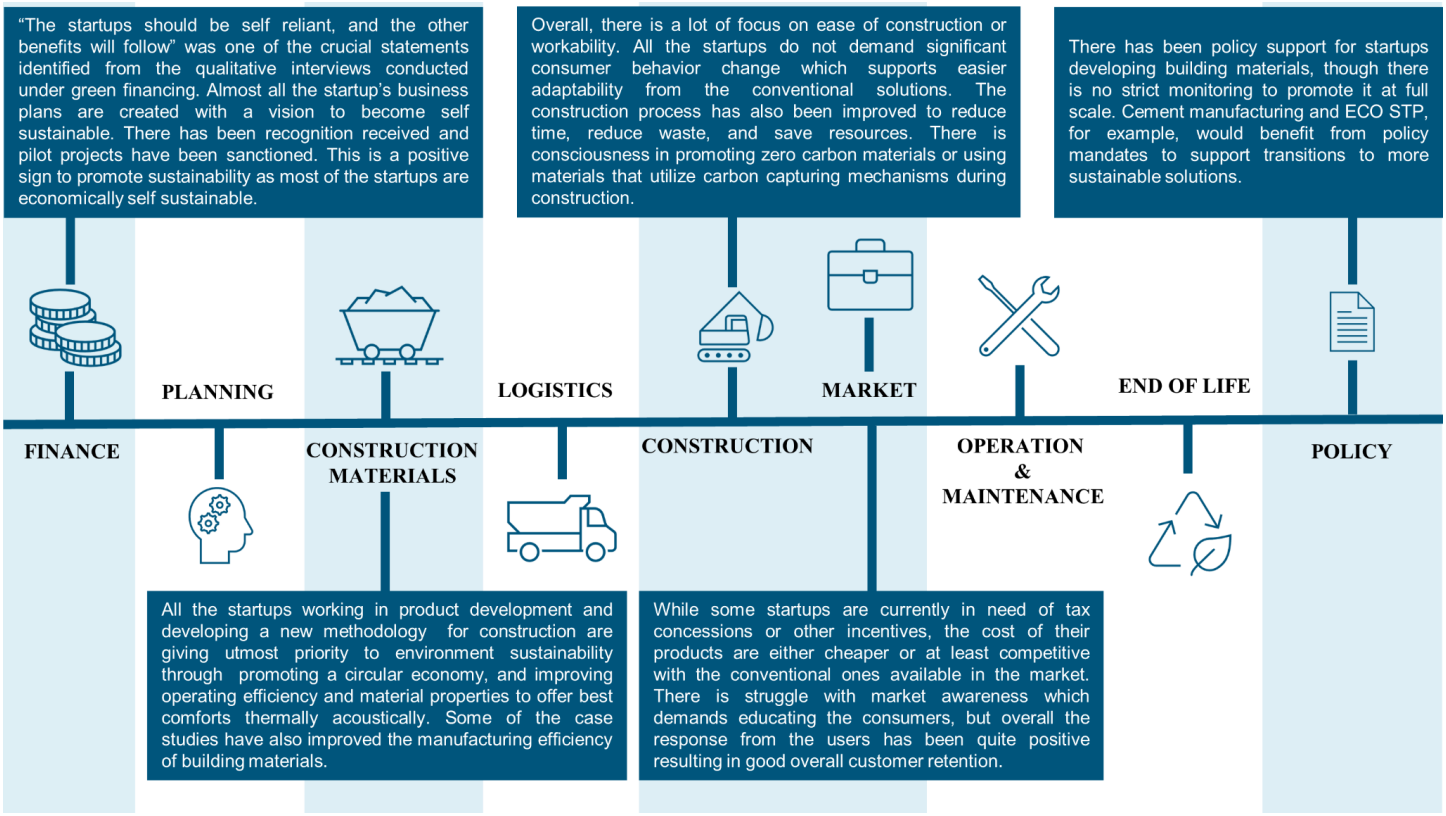

Figure 10. Sustainability in the construction value chain

Recommendations

Supporting the shift to sustainable construction and housing, per the vision of Habitat for Humanity, is necessary yet challenging. New construction materials or processes must fulfill a number of criteria to be both sustainable and successful in the market. These criteria include composition, manufacturing, performance, cost, and product awareness, among others. The case studies identified for this research show that there is a lot of enthusiasm in developing sustainable construction materials and processes that are competitive with longstanding conventional alternatives.

From this research, behavioral change and increased awareness may be required to adopt new materials or processes in construction as the conventional alternatives are considered to be more safe on a large scale. To promote this, multiple stakeholders such as colleges, institutions and organizations, and the government need to build awareness for students, architects, and other stakeholders. There is a need for building awareness starting at the collegiate level where students are sensitized towards green building materials and techniques. Architects and stakeholders involved in the construction industry can also support by being proactive in their promotion of green building materials and techniques within their own practices.

Even if there is a policy support for incentives, one major gap that still exists is that of rigorous testing and approval. One reason innovations in materials and building solutions are unable to enter the market is due lack of robust materials testing, material property insights, trials for strength, durability and performance. Despite this

apparent need, there are no linkages or an institutional network which can approve the material at different stages and bring it into the market at par with the existing conventional ones. This results in a struggling and a slow process for any new material to enter into the market. It is recommended that testing and certification bodies develop higher capacity for mechanical and civil engineering related material testing and certification, fire safety, cyclic and endurance testing, and toxicity to human health.

Currently, monitoring and evaluation of sustainable construction is a weakness. While there may be documents stating that certain materials need to be used for building, there is a lack of monitoring to ensure it is actually implemented. If monitoring is strengthened, strict mandates can ensure follow through on the ground. Additionally, there is a need for evaluation for buildings that use green materials and processes. Evaluation reports assessing performance and costing during the time of occupancy can provide additional awareness to occupants for upcoming construction projects.

As seen in Table 3 with the BMTPC and CSE sub-attributes, criteria should be clearly defined to qualify a certain material as sustainable. There needs to be a detailed framework covering all aspects of social, environmental and economic sustainability along with sub-attributes to qualify or grade a material on its sustainability. Additionally, strong policy mandates to ensure the sector considers sustainability in projects is lacking. New policies can help support startups that are trying to promote a circular economy by adding economic value to waste and ensuring building materials are considerate of carbon emissions.

Any new house that is constructed should serve as a pilot to highlight all the green and sustainable materials and techniques that were incorporated while constructing it. It is highly recommended for big institutions like Habitat for Humanity to document such prototypes where the identity of the materials and techniques, and cost and performance parameters are promoted. If such institutions highlight prototypes using new materials and techniques it can garner attention and awareness at a much larger scale allowing for increased consumer awareness of the novel environmentally sustainable solutions without requiring significant policy intervention.

As seen in Table 5 and 6, upcoming startups are working hard to address circularity, performance, and cost, but consumer recognition takes time. While immediate acceptance from the policy side to test and incorporate in the schedule of rates might be a slow and a tedious process, more immediate results can be attained through for-profit organizations and influential institutions that promote these new materials and techniques.

Conclusion

The construction industry, as a large contributor to climate change, must start moving towards more sustainable practices that take into consideration the three pillars of sustainability: society, economy, and environment. SDG 11, Sustainable Cities and Communities, provides a unifying agenda in support of this vision. Due to the difficulty in disrupting existing supply chains, ample research and development are ongoing to explore sustainable solutions for the construction value chain. This research explored various sustainable construction solutions specific to India.

Given the size and heterogeneity of India, is it difficult to assess the current state of sustainable construction across the country when availability of resources, construction methods, and geographical conditions, among others, change within a few kilometers. As such, this research used a case study approach through desk research and interviews with experts to identify new sustainable construction solutions which were then benchmarked against national institutional guidelines and policies on sustainable construction.

From this research, several challenges to sustainable construction solutions were identified. New materials need multiple certifications and evaluation to pass tests such as durability and performance. Additionally, the process to get involved in the schedule of rates or become recognized by the Bureau of Indian Standards remains a challenge impeding adoption of more sustainable practices. There is a need for policy changes, as highlighted through the cement manufacturing and ECO STP case studies, along with strong mandates and enforced monitoring during implementation. As mentioned in an interview with BMTPC, there is a need for increased awareness on sustainable materials and processes for widespread adoption as these solutions appear to be market competitive but lacking sufficient visibility. Government sponsored events and pilot studies can help to generate this awareness and expedite the adoption of sustainable solutions

Despite these challenges, there are many positive changes taking place in sustainable construction solutions. The result of this research shows that there appears to be positive growth towards promoting environmentally friendly materials that are also price competitive in the market. Progress has been made towards changing existing processes such as in the case of cement manufacturing. Most of the start-ups interviewed are economically sustainable and have established robust supply chains. It is interesting to note that most of the case studies identified did not require any extreme behavioral changes as customers have shown positive attitudes towards the products which is optimistic for the sector. The products or services launched by the startups have received positive response from the consumers, but in India, sustainable promotion has not reached a stage where there can be mass adoption. Even though there is a positive response from the consumers, for high scale adaptability, the entire fraternity should be sensitized.

Habitat for Humanity supports various aspects related to affordable housing, such as the promotion of appropriate technologies in the construction sector. Identifying case studies of organizations that are working towards sustainable construction solutions can play a huge role in promoting affordable and green housing in the future. The case studies identified in this research provide tangible examples of how organizations within India are working towards a more sustainable construction sector for the benefit of all.

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