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Assessing Acceptability Criteria of Building Technologies to Design Appropriate Housing Schemes by Government of India for Economically Weaker Section

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ABSTRACT

In accordance with the Census of India 2011, significant improvement in quality of housing has been observed with increased number of people opting for buildings of permanent nature i.e. with permanent materials for walls, roof and floor rather than temporary materials like thatch, grass, bamboo, mud etc. This has resulted into increased consumption of permanent building materials which are energy intensive. This will enhance cost of construction and increase GHG emission for production and transportation of those materials.

In the United Nations Framework Convention on Climate Change held at Paris in 2015 it was agreed that each country shall communicate a nationally determined contribution every five years and they shall be responsible for its emission level as set out in the agreement. In recognition to the Paris Agreement, India declared a voluntary goal of reducing the emissions intensity of its Gross Domestic Product (GDP) by 20-25%, over 2005 levels, by 2020 [1].

In the Government Schemes for housing for poor, it has been observed that mainly top-down approach for selection of materials and technologies are adopted that sometimes do not meet with the requirement and acceptability of users and do not give cognizance to GHG emission reduction from construction sector and therefore these schemes fail to deliver a sustainable built environment.

As majority of the dwellings are owned by people belonging to Economically Weaker Section, their affordability also plays a vital role in selection of materials, technology and method of construction. Therefore to adopt appropriate construction technologies in Government schemes for housing for poor, a systematic study of users' perception need to be carried out, which has to be cross-linked with the Government's commitment on GHG emission reduction in international forum.

This study assessed the appropriate technologies, through survey and analysis, for Government's housing schemes that will reduce GHG emission without any extra burden to the state exchequer.

Keywords: Housing Schemes for poor in India; Users' perception; Experts' opinion; Appropriate construction technologies; Reduction of GHG emission; Cost-effectiveness.

INTRODUCTION

United Nations is working relentlessly to bring out policies to reduce Greenhouse Gas (GHG) emission from human activities to control adverse effects of climate change. Following the United Nations Framework Convention on Climate Change held at Paris in 2015. India declared a voluntary goal of reducing the emissions intensity of its Gross Domestic Product (GDP) by 20-25%, over 2005 levels, by 2020.

The construction sector in India emits about 17% of the total annual emission of CO_2 at present. In pursuance to the commitment of the Government of "Housing for All by 2022", to meet the housing shortage, the Pradhan Mantri Awas Yojana envisages construction of 20 million permanent houses, out of which 10 million with minimum plinth area of 25 sq.m. will be built in rural areas within 2019. The latest guidelines of the scheme, while stressed on fund allocation, utilization, selection of beneficiaries etc., remained silent on technologies, which should have been in tandem with the 'National Mission on Sustainable Habitat' that states that efforts will be taken to make habitat sustainable through improvement of energy efficiency in buildings.

Although India has diverse traditions of rural housing practiced by local communities across its geographies, state response is limited to poorly-designed standardized housing solutions with persistent use of inefficient technology due to path dependence.

Reddy and Jagadish [2] recommended that 'Use of energy efficient alternative building technologies can result in considerable reduction in the embodied energy of the buildings'. Khosla et al [3] while discussing improved low-carbon technology deployment in developing countries recommended that technology development and transfer collaboration should be made on a 'need-driven' approach. To reduce embodied GHG reduction, Sengupta [4] suggested that cost-effective construction technologies using common building materials, which can be easily handled by existing technical manpower, would be acceptable to common people and at the same time will help in reduction of GHG emission. Janda and Parag [5] suggested that two essential elements for a successful transition are an actor's agency and capacity and they are influenced by technical, institutional, financial, political, social, and psychological factors. The question is how to break into the technological, behavioural and institutional lock-in to arrive at appropriate building technologies which will get users' acceptance and at the same time ensure reduction of GHG emission from housing sector without putting any additional burden on the state exchequer.

The paper dwells upon the following issues

- The state of inappropriateness of conventional building technologies in governmental rural housing schemes for the economically weaker section (EWS) of population in India in terms of government's commitment on GHG emission reduction.
- User perception of the EWS population in India in terms of the attributes like capital cost, safety and durability, availability of building materials & workmen and life cycle cost in opting for specific technologies in government sponsored or self-built housing.
- Experts' opinion about attributes to appropriate building technologies for EWS in terms of government's commitment on GHG emission reduction and other relevant attributes.
- Based on inquiry into these issues the paper outlines policy prescriptions to overcome the technological, institutional and behavioural lock-in to enable a transformative change for facilitating India's building stock under government schemes to move towards a cost-effective and low carbon trajectory.

The study has been conducted in Pan India mode across diverse climatic zones in the country through sample survey among 382 people belonging to different income group and 37 small houses representing traditional and different alternative technologies. Techniques such as multi-criteria decision making using Visual PROMETHEE and Delphi technique were used for different purpose during the study.

REVIEW OF RELEVANT LITERATURE AND RESEARCH WORKS

Review of Government Schemes for Housing for poor

Since independence in 1947, India is plagued with housing shortage. It has always been an important agenda for the Government of India since then as the country was following a socialistic outlook and housing sector was considered as a visible output where development is easily visible and also as a way of boosting national economy by enhancement of industrial production and creation of livelihood opportunities in informal sector. This sector is another major sector, growth of which is directly proportional to the economic upliftment, population growth and increase of purchasing power of common people in developing countries like India.

Due to large scale migration after the partition of country, shortage of housing in urban areas was tremendous and government had to formulate schemes like Subsidised Housing Scheme for Industrial Workers in 1952, Low Income Group Housing Scheme in 1954, Middle Income Group Housing Scheme in 1959 and Slum Clearance and Improvement Scheme in 1956. These schemes continued for few years. In rural areas to fulfill the need for rural housing and tackling housing shortage particularly for the poorest, Indira Awaas Yojana (lAY) was launched during 1985-86 as a sub-scheme of Rural Landless Employment Guarantee Programme (RLEGP). IAY, thereafter, continued as a sub-scheme of Jawahar Rozgar Yojana (JRY) since its launch in April, 1989. Initially the scheme was for families of Scheduled Cast, Scheduled Tribe and bonded labourers in Below Poverty Level (BPL) category. From 1993-94, the scope of lAY was extended to cover all BPL families in the rural areas. IAY was de-linked from JRY and made an independent scheme with effect from 1st January 1996. Some of the features of IAY scheme are a) assistance for construction of a new house, (b) upgradation of dilapidated houses and (c) use of appropriate building technologies using local materials considering the geo-climatic factors and socio-cultural issues. In urban areas, Valmiki Ambedkar Awas Yojna for weaker sections of society was launched in 2001 followed by Basic Services of Urban Poor (BSUP) in 2005 and Rajiv Awas Yojna in 2013 with a vision of "Slum free India" and permanent house of carpet area between 21-27 sq.m for slum dwellers.

Pradhan Mantri Awas Yojana (Urban) of Government of India has also been launched in 2015 [6] to provide a 'pucca house' (permanent house) for every family in urban cities within 2022. This scheme will supports construction of houses up to 30 sq.m carpet area, which are to be designed and constructed to meet the requirements of structural safety against earthquake, flood, cyclone, landslides etc. conforming to the National Building Code and other relevant Bureau of Indian Standards (BIS) codes. Central Assistance at the rate of Rs.1.5 lakh (1 lakh = 0.1 million) per EWS house would be available for all EWS houses in such projects. Though the scheme has elaborately discussed about implementation mechanism and financing part, there was little mention about the technologies that will be affordable and sustainable for the poor except mentioning that "A Technology Sub-Mission under the Mission would be set up to facilitate adoption of modern, innovative and green technologies and building material for faster and quality construction of houses. Technology Sub-Mission will also facilitate preparation and adoption of layout designs and building plans suitable for various geo-climatic zones. It will also assist States/ Cities in deploying disaster resistant and environment friendly technologies."

Pradhan Mantri Awas Yojana (Rural), November 2016 [7] aims at providing a 'pucca house' (permanent house) to all houseless people and those living in 'kutcha' (temporary) and dilapidated houses, by 2022. The house has to be 'pucca' in the sense that it should be able to withstand normal wear and tear due to usages and natural forces including climatic conditions, with reasonable maintenance, for at least 30 years. It should have roof of permanent material and its walls should be capable of withstanding local climatic conditions and need to be plastered when the outer surface of the walls is erodible. Minimum size of the house is 25 sq.m. and Central Assistance of Rs.1.20 lakhs in plains and Rs.1.30 lakhs in hilly regions and difficult areas will be provided to each beneficiary.

Though the scheme gives detailed guidelines on implementation, financing and other formalities, it has not dealt with the technology options for sustainable housing except briefly mentioning some keywords like 'locally relevant house type designs', 'cost saving construction technologies' and 'availability of construction materials and sufficient number of trained masons'. It envisaged setting-up of one National Technical Support Agency (NTSA) who will provide technical supports including training for planning, designing and construction of houses.

In none of the above major Government Schemes for housing, acceptability and affordability of users on technologies and building typologies were given any cognizance. Therefore, in many cases, the buildings were left unfinished or cost of construction was escalated. The aspect of GHG emission reduction from constructions under these schemes were never taken into consideration, though in the 'National Mission on Sustainable Habitat' [8] it has been stated that efforts will be taken to make habitat sustainable through improvement of energy efficiency in buildings

According to Ugwu, et al., [9] the process of translating national strategic sustainability objectives into concrete action at micro levels is a difficult task. While current sustainability initiatives, strategies, framework and processes focus on wider national aspirations and strategic objectives, they are noticeably weak in addressing micro-level integrated decision-making.

Godfaurd, et al [10] opined that careful selection of sustainable building materials has been identified as the easiest way for designers to begin incorporating sustainable principles in building project.

The most important task in meeting the sustainability objectives at the planning and design stage of a housing scheme is selection of appropriate building materials and technologies to be used in the scheme after careful study of the existing typologies. From the studied literature, the exact details of building typologies of EWS could not be assessed. Therefore, a pan-India survey was conducted to assess the building materials and technologies of EWS in rural areas and especially those dwellings which were constructed under any housing scheme of the government. The outcome of the survey has been reported later.

Reviewing Assessment Methodology of Perception of Users on Selection of Building Materials and Technology

There are not many scholarly articles available in journals, which deals with users' perception for appropriate technologies and materials for their own buildings especially users from economically weaker sections. An extensive search has resulted into few articles which have been considered for this study.Florez et al [11] has also mentioned that In addition to environmental factors, market demand is also a factor considered for the achievement of sustainability goals (in construction sector).Lurie and Mason [12] opined that market preferences may be determined using an instrument to validate consumer's preferences of product sustainability. Preferences are measured through visual features and the metaphysical aspects of products and help capture subjective characteristics. In the opinion of Dammann and Elle [13], subjective characteristics associated with sustainable products include low raw material consumption and buildability, Glavic and Lukman [14] also expressed the same opinion. They observed that sustainable products are products that are socially and creatively rewarding, that are available in a continuing renewing manner, are highly satisfying to the user, and are successful in the market. Ljungberg [15] mentioned that low repair requirement and highly prolonged lifetime and satisfaction of the users play crucial role in determination of sustainability of a product. The criterion for optimizing sustainability in products considers not only environmental impacts, economic impacts, and customer requirements but also market demand, he opined. Akadiri and Olomolaiye [16] carried out a questionnaire survey of UK architects and designers to assess the relative importance of the criteria, with "aesthetics", "maintainability" and "energy saving" the three top criteria considered for building materials selection. Factor analysis was applied to identify the underlying structure among these criteria and aggregate them into six independent assessment factors of "environmental impact", "resource efficiency", "waste minimization", "life cycle cost", "social benefit", and "performance capability". Braganca et al [17] opined that the sustainability of a building depends on the decisions taken by a number of actors in the construction process: owners, managers, designers, firms, etc. The pace of actions towards sustainable application depends on the awareness, knowledge as well as an understanding of the consequences of individual actions. The selection of building materials is one of several factors that can impact the sustainability of a project, opined Nassar, et al [18]. Treloar, et al [19] mentioned that an appropriate choice of materials for a design process plays an important role during the life cycle of a building. According to Ofori, et al [20] understanding the environmental issues surrounding the extraction of raw materials, the manufacture of construction materials, and their effects in use, is important to ensure sustainability.

It is needless to mention that success of a technology depends upon acceptance of common man. In all the above studies it appears that, perception of users i.e. of the actual inhabitants of the buildings, especially people belonging to EWS, has not been considered and analysed. But they are the prime market force and their role in selection of building design and materials is of prime importance to achieve sustainability of the technologies and meeting the objective of national strategic sustainability.Therefore, a nation-wide sample survey was carried out at different climatic zones of India to assess the perception of common people belonging to EWS. The feedbacks were analysed with Multi-criteria Decision Support system to arrive at the hierarchy of acceptability criteria of users. Opinion of experts like Engineers, Builders, Architects and Environmentalists were also obtained and analysed with Delphi technique to assess thet appropriateness of building materials and technologies for housing of EWS in different government schemes.

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METHODOLOGIES

Scope of the Study

This study, by taking stock of prevailing building technologies and materials, using primary survey among the users especially from EWS in rural areas and also by obtaining experts' opinion has tried to formulate some policy prescriptionson technologies and materials for construction of small residential houses under different Government Schemes of Housing in rural India or self-financing houses of EWS which will also cater to the country's commitment at international level on GHG emission reduction.

Taking stock of prevailing building technologies for EWS in India

According to a SP 7: 2005 of Bureau of Indian Standards [21], the country may be divided into five major climatic zones as mentioned in Table 1 and shown in the Figure 1.

Table 1: Climatic zones in India and cities/ towns falling under those zones

Climate	**Mean monthly Maximum temperature (oC)**	**Relative humidity (%)**	**Cities / Towns falling under the zones**
Hot and Dry	>30	<55	Ahmadabad, Nagpur
Warm and Humid	>30 >25	>55 >75	Kolkata, Mumbai, Chennai, Vishakhapatnam, Jamshedpur, Guwahati, Thiruvananthapuram, Mangalore, Bhubaneswar, Agartala, Port Blair
Temperate	25-30	<75	Shillong, Bengaluru
Cold	<25	All values	Shimla, Nainital
Composite	This applies, when six months or more do not fall within any of the above categories		Delhi, Jabalpur, Bikaner, Patna, Chandigarh, Hyderabad, Nagpur

[Source: SP 7: 2005]

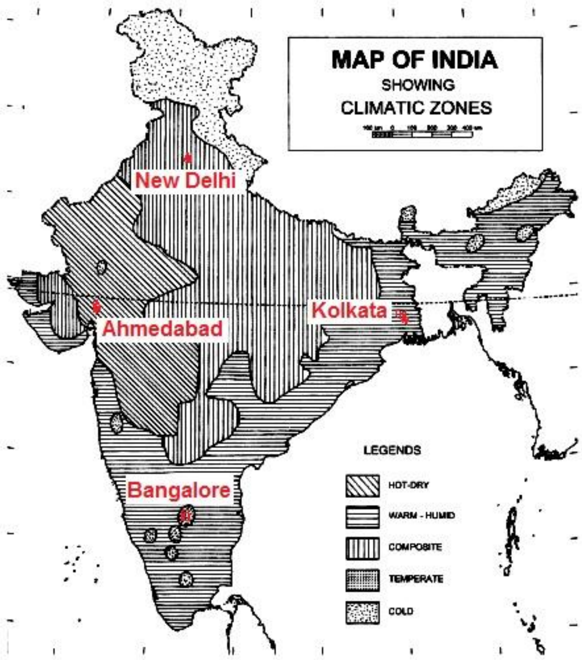

Figure 1: Climatic zones of India
[Source: SP 7: 2005]

A total 37 numbers of small sized residential buildings of about 20 sq.m. in area belonging to people mostly from EWS mostly in rural and suburban areas at different climatic zones of India were studied. Some of the buildings were constructed under different schemes of government also. The buildings were selected based on the following criteria:

a) Area of buildings: Nearly 20 sq.m. in single storey, which is the minimum area for construction of buildings at rural areas under Government schemes,

b) Climatic zones: Four climatic zones. As zone designated as 'Cold' has very limited area in India, it has not been taken into account,

c) Economic Condition of the owners: Mostly EWS, LIG / MIG as more than 90% of housing shortage belongs to these categories,

d) Occupancy: Approx. 5, which is the average family size in India,

e) Building Materials: Permanent and / or Semi-permanent type as temporary structures do not conform to any code / specification.

The covered area of the building, type of building envelops, economic condition of the family, climatic zone and location have been summarized and mentioned in Table 2.

Table 2: Surveyed residential typology – covered area, income group, materials and technology, location and climatic zone

Building typology	Area (sq.m.)	Income level of family	Material and technology for external wall	Material and technology for roof	Location	Climatic zone
RB1	20.20	EWS	Masonry wall 125 thick both side non plastered	RCC roof 100 thick – no plaster	Mircha Village, Patna, Bihar	Composite
RB2	24.32	EWS	Hollow concrete block wall 200 thick both side plastered	CGI sheet sloped roof	Port Blair, Andaman & Nicobor Islands	Warm and Humid
RB3	31.50	LIG	Masonry wall 250 thick both side plastered	RCC roof 110 thick	Kadapa, Andhra Pradesh	Composite
RB4	25.90	EWS	Hollow Concrete Block wall 200 thick inside plastered	Country tiled sloped roof in wooden frame	Kakkad Village, Kozhikode, Kerala	Warm and Humid
RB5	22.31	EWS	Masonry wall 125 thick both side plastered	GI sheet sloped roof in wooden frame	Mircha Village, Patna, Bihar	Composite
RB6	22.31	EWS	Masonry wall 125 thick both side plastered	RCC roof 110 thick	Arjunkhedi Village, Bhopal, Madhya Pradesh	Composite
RB7	24.75	EWS	Masonry wall 250 thick both side plastered	RCC roof 110 thick	Port Blair, Andaman & Nicobor Islands	Warm and Humid
RB8	21.00	EWS	Masonry wall 125 thick both side plastered	RCC roof 110 thick	Arjunkhedi Village, Bhopal, Madhya Pradesh	Composite
RB9	22.31	EWS	Masonry wall 125 thick both side plastered	RCC roof 100 thick	Mirzapur Village, Patna, Bihar	Composite
RB10	17.58	EWS	Masonry wall 125 thick both side plastered	Asbestos roof in wooden frame	Mirzapur Village, Patna, Bihar	Composite
RB11	43.56	MIG	Masonry wall 125 thick both side plastered	RCC roof 100 thick underside plastered	Bagral Gaon, Uttarakhand	Cold
RB12	18.90	EWS	Hollow concrete blok wall 200 thick both side non plastered	Asbestos roof in wooden frame	Port Blair, Andaman & Nicobor Islands	Warm and Humid
RB13	22.31	EWS	Masonry wall 125 thick both side non plastered	Asbestos roof in wooden frame	Subhalo Village, Khurdah, Odisha	Warm and Humid
RB14	24.75	EWS	Masonry rat trap bond wall 250 thick both side non plastered	RCC filler slab roof 110 thick	Baruipur, West Bengal	Warm and Humid

RB15	43.87	LIG	Masonry wall 250 thick both side plastered	RCC roof 110 thick underside plastered	Brahmandihi, Birbhum, West Bengal	Warm and Humid
RB16	24.44	EWS	Masonry wall 125 thick both side plastered	Country tiled sloped roof in wooden frame	Mirzapur Village, Patna, Bihar	Composite
RB17	22.31	EWS	Masonry wall 125 thick both side plastered	Asbestos sheet roof in wooden frame	Dadpally, Rangareddy, Telangana	Composite
RB18	55.25	MIG	Masonry wall 250 thick both side plastered	RCC roof 110 thick plastered	Dadpally, Rangareddy, Telangana	Composite
RB19	31.50	LIG	Masonry wall 250 thick both side plastered	RCC roof 110 thick plastered	Trichur, Kerala	Warm and Humid
RB20	46.75	MIG	Masonry rat-trap bond wall 250 thick inside plastered	RCC filler slab roof 110 thick plastered	Madhyamgram, West Bengal	Warm and Humid
RB21	34.30	MIG	Masonry rat-trap bond wall 250 thick inside plastered	RCC filler slab roof 110 thick plastered	Budge Budge, West Bengal	Warm and Humid
RB22	37.00	MIG	Masonry rat-trap bond wall 250 thick inside plastered	RCC filler slab roof 110 thick plastered	Maheshtala, West Bengal	Warm and Humid
RB23	27.55	MIG	Laterite block 200thick wall	Country tile sloped roof in wooden frame	Kozhikode, Kerala	Warm and Humid
RB24	25.05	LIG	Laterite block 200thick wall	CGI sheet sloped roof in wooden frame	Kozhikode, Kerala	Warm and Humid
RB25	21.94	EWS	Masonry 125 th wall both side plastered	asbestos sheet sloped roof in steel frame	Topsia, Kolkata, West Bengal	Warm and Humid
RB26	22.95	EWS	Masonry 125 th wall both side plastered	Country tiled sloped roof in wooden frame	Mangalore, Karnataka	Warm and Humid
RB27	21.00	LIG	Masonry 125 th wall both side plastered	CGI sheet sloped roof in wooden frame	Dhariathal Village, Tripura	Warm and Humid
RB28	21.00	EWS	Masonry 125 th wall both side plastered	RCC roof 110 thick plastered	Siruganatham, Tiruchirapally	Warm and Humid
RB29	21.00	EWS	Masonry 125 th wall both side plastered	Country tiled sloped roof in wooden frame	Badathepalli Village, Hosur, Tamilnadu	Warm and Humid
RB30	22.34	EWS	Masonry 125 th wall both side plastered	CGI sheet sloped roof in wooden frame	Sonahatu Village, Jharkhand	Composite

RB31	22.75	LIG	Masonry wall 250 thick both side plastered	RCC roof 110 thick plastered	Golida Village, Rajkot, Gujarat	Hot and Dry
RB32	19.25	LIG	Masonry wall 250 thick both side plastered	RCC roof 110 thick plastered	Raigunj Town, West Bengal	Warm and Humid
RB33	17.16	EWS	Laterite block wall 200 thick one side plastered	asbestos sheet sloped roof in wooden frame	Mangalore, Karnataka	Warm and Humid
RB34	21.80	EWS	Masonry 125 th wall both side plastered	asbestos sheet sloped roof in wooden frame	Khashpur, Patna, Bihar	Composite
RB35	31.92	LIG	Hollow concrete brick wall 200 thick both side plastered	asbestos sheet sloped roof in wooden frame	Mundur, Pallakad, Kerala	Temperate
RB36	18.42	EWS	Masonry 125 th wall both side plastered	Country tiled sloped roof in wooden frame	Kanchanpur, Purulia, West Bengal	Warm and Humid
RB37	50.02	MIG	Masonry 125 th wall both side plastered	Country tiled sloped roof in wooden frame	Fajalpur, Gujarat	Hot and Dry

Table 3: Predominant building materials for construction of building envelope for small residential buildings of permanent in nature belonging to EWS

Wall	Ceiling	Door/Window/Roof frame
• Burnt Clay Brick • Hollow Concrete Block • Laterite Block • Cement-Sand Plaster	• Reinforced Cement Concrete • Burnt clay tiles • Corrugated Asbestos Cement sheet • Corrugated Galvanised Iron sheet • Corrugated Aluminium Sheet • Wooden frame • Cement-Sand Plaster	• Wood • Steel • 3mm thick glass pane

From the survey of building typology, though information are inadequate considering the vast population of the country of India and various type of materials used for construction of building at different parts of the country, the materials those have been found as predominant building materials for construction of building envelope for small residential buildings of permanent in nature belonging to EWS have been summarized in Table 3.

Assessment of perception of users on selection of building materials and technology

There is no systematic study to assess the perception of users in India in different climatic zones for selection of building materials and technologies for their own residential houses. Therefore it was determined to carry out a sample survey in different climatic zones in the country.

The sampling frame that was adopted for the selection of the sample was the population of India (1320million). In order to determine a suitable size for the sample, the following formula derived by Czaja and Blair [22] and Creative Research Systems [23] was applied:

$$ss = \{z^2 \times p(1- p)\} / c^2$$

where: *ss* =sample size, *z* = standardised variable, *p* = percentage picking a choice, expressed as a decimal, *c* = confidence interval, expressed as a decimal

In most other research of such kind, a confidence level of 95% was assumed by Munn and Drever, [24] and Creative Research Systems, [23]. For 95% confidence level (i.e. significance level of $\alpha = 0.05$), $z = 1.96$. Based on the need to find a balance between the level of precision, resources available and usefulness of the findings,Maisel and Persell[25] suggested a confidence interval (*c*) of ±5%, which was also assumed for this study. According to Czaja and Blair [22], when determining the sample size for a given level of accuracy, the worst case percentage picking a choice (*p*) should be assumed. This is given as 50% or 0.5. Based on these assumptions, the sample size was computed as follows:

$$ss = \{1.96^2 \times 0.5(1 - 0.5)\} / 0.05^2 = 384.16$$

Therefore the required sample size for the questionnaire survey is 384 persons.

However, the figure requires a further correction for finite populations. The formula for this is given by Czaja and Blair [22] as:

$$ss_{new} = ss / \{1+ (ss - 1) / pop\}, \text{ where pop = population}$$

Considering approximate population of India as 1320 million as in 2017,

$$ss_{new} = 384.16 / \{1+ (384.16 - 1) / 1320000000\} = 384.16$$

So the sample size still remains approximately 384.

Based on the calculated sample size a total number of 396 persons at different climatic zones were interviewed through direct interaction either by the author or his associates. India is a country of widely-varying economic and literacy level of people and different languages of communication in different zones. Due to communication barrier between the interviewer and interviewee, out of the 396 samples, 14 were found to be non-responsive or improper.

The sample survey has been carried out in different regions of the country and among different cross-section of people based on 1 to 5 scale. The questionnaire was kept very simple considering the educational background and level of understanding of the people belonging to EWS and only the following aspects were included for a quick response:

- Safety,
- Cost of Construction,
- Indoor Comfort,
- Maintenance Cost of Building,
- Building Materials Availability,
- Building Artisan Availability,
- Aesthetics,
- Power Consumption during occupancy.

'Reduction of GHG emission' was initially kept in consideration. But from preliminary responses it was observedthata majority of respondents, who are mostly semi-literate, are not at all aware or concerned about the same. Therefore for their understanding the item was changed to 'power consumption during occupancy' as it will indirectly transform to GHG emission from operational energy uses.

The scale chosen is as follows:

Top Priority	Vital	Should be	May be considered	Not so important
5	4	3	2	1

The summary has been compiled in Table 4.

Table 4: Number of people at different climatic zones surveyed during sample survey

Place	Climatic zone	HIG/MIG	LIG	EWS	TOTAL
Agartala	Warm and Humid	3	7	25	35
Ahmedabad	Hot and Dry	5	5	7	17
Bengaluru	Temperate	3	3	13	19
Bhubaneswar	Warm and Humid	2	4	18	24
Jabalpur	Composite	3	3	7	13
Mumbai	Warm and Humid	1	4	13	18
Port Blair	Warm and Humid	0	7	11	18
Nagpur	Hot and Dry	0	0	2	2
Patna	Composite	3	8	17	28
Bikaner	Hot and Dry	2	2	2	6
Chandigarh	Composite	1	2	4	7
Chennai	Warm and Humid	1	3	8	12
Hyderabad	Composite	3	6	14	23
Kolkata	Warm and Humid	12	30	45	87
Nainital	Cold	2	6	14	22
New Delhi	Composite	6	12	27	45
Trivandrum	Warm and Humid	0	1	5	6
TOTAL		**47**	**103**	**232**	**382**

The data obtained during survey to study perception of users for choice of building materials and technologies were analysed using Visual PROMETHEE – a tool for analysis using Analytical Hierarchical Process (AHP). The Preference Ranking Organization Method for Enrichment of Evaluations and its descriptive complement geometrical analysis for interactive aid are better known as the PROMETHEE and GAIA methods.

Based on mathematics and sociology, the PROMETHEE and GAIA method was developed at the beginning of the 1980s and has been extensively studied and refined since then. Rather than pointing out a "right" decision, the PROMETHEE and GAIA method helps decision makers find the alternative that best suits their goal and their understanding of the problem. It provides a comprehensive and rational framework for structuring a decision problem, identifying and quantifying its conflicts and synergies, clusters of actions, and highlights the main alternatives and the structured reasoning behind.

PROMETHEE & GAIA is most useful where groups of people are working on complex problems, especially those with several multi-criteria, involving a lot of human perceptions and judgments, whose decisions have long-term impact. It has unique advantages when important elements of the decision are difficult to quantify or compare.

The results of the analysis are provided in Figures 2 to 5.

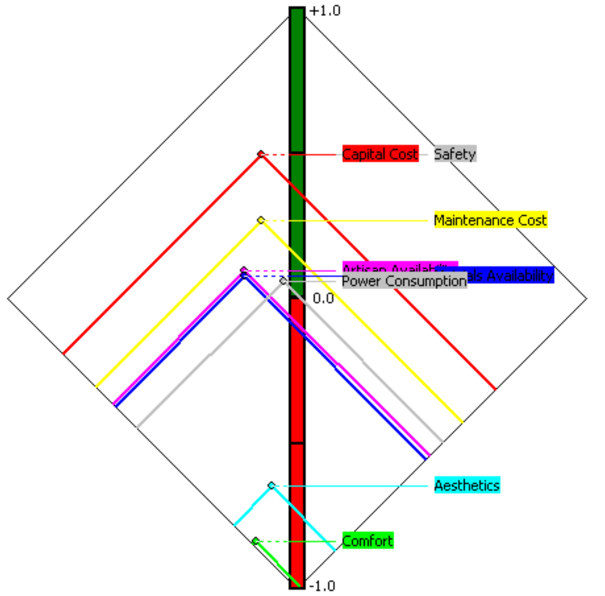

Figure 2: Perception Matrix of users in EWS for choice of building materials and technologies

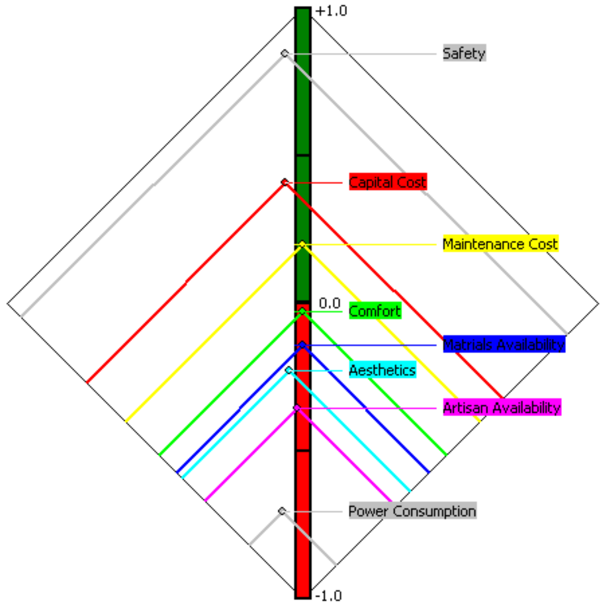

Figure 3: Perception Matrix of users in LIG for choice of building materials and technologies

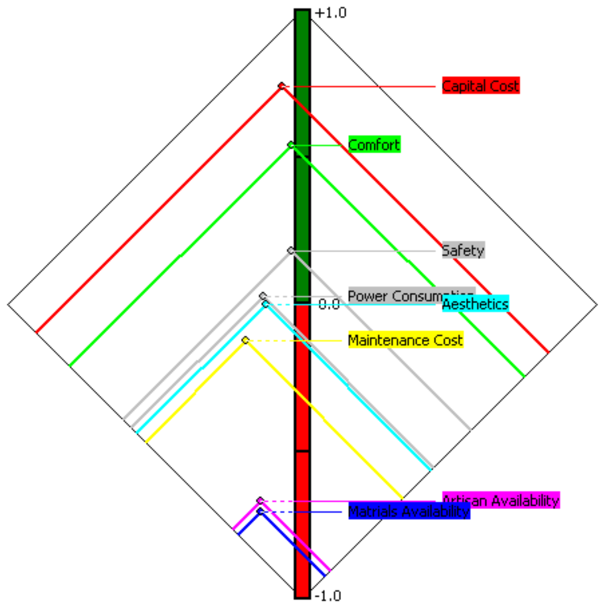

Figure 4: Perception Matrix of users in HIG/MIG for choice of building materials and technologies

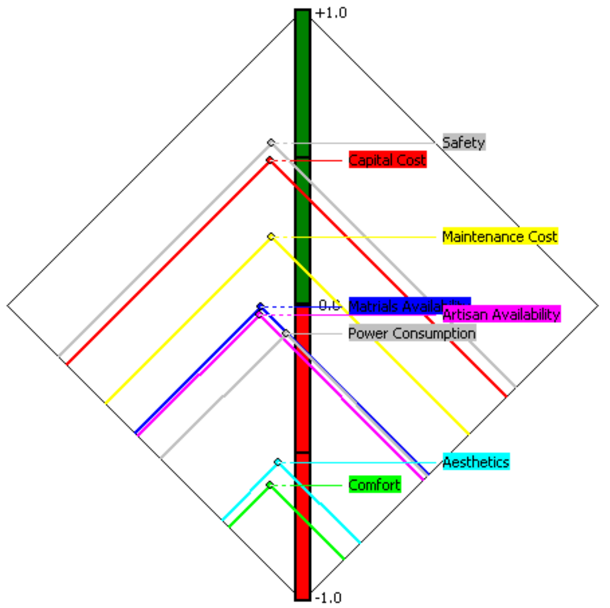

Figure 5: Perception Matrix of all users for choice of building materials and technologies

From the Figures 2 to 5, the preferential ranking of different criteria governing the choice of building materials and technologies as analysed has been mentioned in Table 5.

Table 5: Preferential ranking of different criteria governing the choice of building materials and technologies

Factors	Preference			
	HIG/ MIG	**LIG**	**EWS**	**Combined**
Safety	6	8	7	8
Capital Cost	8	7	8	7
Maintenance Cost of Building	3	6	6	6
Building Materials Availability	1	4	4	5
Building Artisan Availability	2	2	5	4
Power Consumption during occupancy	4	1	3	3
Aesthetics	5	3	2	2
Comfort	7	5	1	1

From Table 5, it may be inferred that the primary three criteria of selection of building material and technology by people belonging to LIG and EWS are Safety, Cost of Construction and Maintenance cost. The materials and workmen for building construction should be available locally also, as those have also got implication on the cost aspect of construction. People belonging to EWS do not have any idea or choice on aesthetics and comfort of the buildings as getting a safe and low-cost permanent shelter is the primary objective for them

Experts consultation for prioritisation of use of building technologies using Delphi Technique

While from the sample survey the priorities of users could be identified which will be the determining factor for designing Government schemes for housing for the poor, another important aspect, viz. the India Government's commitment at international level on reduction of GHG emission was not touched upon due to reasons explained before.

Now a set of indicators could be shortlisted through surveying and analysis of results. With such multiple criteria, multiple technologies, weights of criteria seem to complicate the problems. Investigation of the criteria and attributes that would determine the most appropriate building construction technologies that would help in reduction of GHG emission, AHP methodology may be used. AHP was found to be an effective tool in controlling the fuzziness of the data involved in choosing the most preferred decision variables. For this experts in relevant fields were consulted. Rather using random samples that are representative of target population, a panel of 'experts' were consulted for reaching a consensus using Delphi technique. Consensus reached using the Delphi technique does not mean that the correct answer has been found but rather that the experts have come to an agreement on the issue or issues under exploration.

A number of Academic Persons and Professionals were contacted all over the country and following five members, as mentioned in Table 6, have agreed to contribute in the study (names have not been disclosed as a condition of Delphi study).

Table 6: Details of academic persons and professionals participated in Delphi study

Sl.	Qualification	Present Position	Experience in years.	Expertise
1	Architectural Engineer	Town Planner	26	Planning
2	Civil Engineer	Proprietor	30	Construction business
3	Civil Engineer	Professor	28	Academic
4	Architect	Consultant	26	Planning & construction
5	Civil Engineer	Superintending Engineer	31	Construction
6	Environmental Engineer	Consultant	30	Environmental impact assessment
7	Electrical Engineer	Associate Professor	20	Academic, energy auditor

The Delphi panel members were provided with the results obtained by Survey, Analysis & LCA results and was requested to select the appropriateness factor based on those results.

The survey question to them was as follows:

The Government of India is committed to reduce GHG Emission of the country and at the same time to provide shelter to every shelter-less people by constructing disaster-resistant permanent housing to Economically Weaker Section in rural and urban areas at affordable cost with locally available materials. The analysis of the result of nation-wide survey and the LCA results of five types of combinations of residential houses are enclosed. Those indicate Cost of Construction of the Building Envelope vis-à-vis GHG emission from construction and operational purpose over a span of 25 years from those buildings. You are requested to take part in a two stage Delphi survey to provide your opinion to determine the Critical Factors for selection of appropriate building technology.

The following matrix of Critical Factors for assessing Appropriate Technology was proposed to them:

Cost effectiveness	Disaster resistance	Roof and wall with permanent material (termed as permanent material in analysis)	Quantity of GHG emission (termed as GHG emission in analysis)	Availability of materials and workmen at site (termed as Mat. Workmen in analysis)

Following grading scale of importance was proposed:

Grading	Very Low	Low	Medium	High	Very High
Marking	1	3	5	7	9

The experts agreed to the Critical Factors and Grading Scale. The responses obtained in phase 1 were as follows:

Respondent	Cost effectiveness	Disaster resistance	Roof and wall with permanent material	Quantity of GHG emission	Availability of materials and workmen at site
1. Architectural Engineer	9	5	7	3	1
2. Civil Engineer (Construction Business)	3	7	9	1	5
3. Civil Engineer (Academic)	9	5	3	7	1
4. Architect (Consultant – Planning & Construction)	9	3	7	5	1
5. Civil Engineer (Construction)	3	7	9	5	1
6. Environmental Engineer (Consultant – EIA Specialist)	3	7	5	9	1
7. Electrical Engineer (Academic – Energy Auditor)	5	3	7	9	1

The opinions obtained from the experts were analysed using Visual PROMETHEE and the Priority Matrix of Critical Factors for assessing Appropriate Technology is produced in Figure 6.

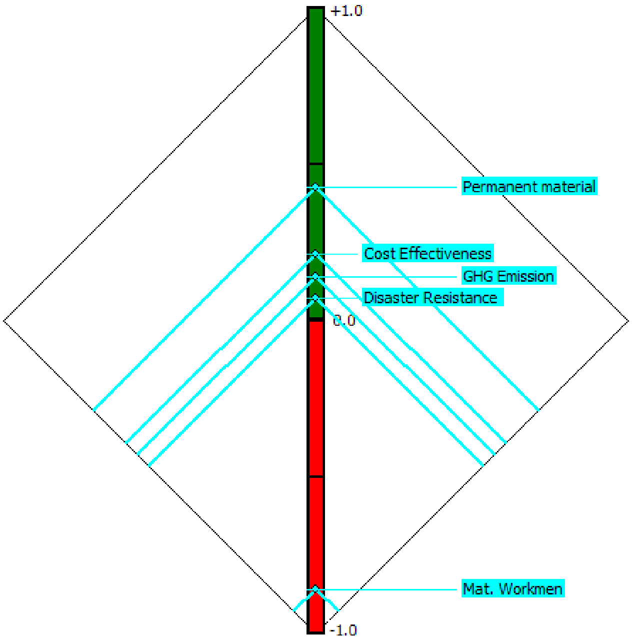

Figure 6: Priority Matrix of Critical Factors for assessing Appropriate Technology after Phase 1 of Delphi study

From the obtained result, the factors governing the choice of building technologies and materials are categorized according to their priority ranking as:

(i) Roof and wall with permanent material,

(ii) Cost effectiveness,

(iii) Quantity of GHG emission,

(iv) Disaster resistance capacity of the building,

(v) Availability of materials and workmen at site.

The results were placed before the experts once again for a second round of opinion with the following survey question:

The report of Government of India and UNDP Disaster Risk Management Programme has clarified that "during flood, houses built with mud, unburnt brick and mud mortar become vulnerable due to their loss of strength in submerged condition during flood and houses made from light weight materials like G.I. or other metal sheets or grass, leaves, bamboo etc. easily float away as soon due to uprooting of their holding down ports by the flowing water. Buildings with lighter materials such as metal sheets and bio-mass materials are not much affected during earthquakes, but can be blown away under the high winds. But those constructed using heavy materials will be totally destroyed under earthquake conditions endangering life and property.

The superstructure walls must be made stable under earthquake as well as high wind conditions. Also if the inundation level rises, the wall material should not become soft and dissolve under water. For heavy materials earthquake safety will require use of special reinforcing details for stability as per relevant code.

The houses in the flood prone areas should be made with flat horizontal roofs which could be used as the shelter by the family during flood.

The following responses were obtained in phase 2:

Also, the National Building Code 2005 [21] has prescribed that the load-bearing walls of a building with weak mortar must be at least one brick thick.

Based on the recommendations of UNDP Disaster Risk Management Programme and National Building Code the factors were again placed before the experts for reassessment and assigning weightage against each key factor so that the total weightage by each expert becomes 100. The experts agreed to take part in the second phase and the process of assignment of weightage to the Critical Factors.

	Cost effectiveness	**Disaster resistance**	**Roof and wall with permanent material**	**Quantity of GHG emission**	**Availability of materials and workmen at site**
Rank in Phase 1	**2**	**4**	**1**	**3**	**5**
Architectural Engineer	15%	25%	25%	25%	10%
Civil Engineer (Construction business)	15%	25%	25%	20%	15%
Civil Engineer (Academic)	15%	25%	25%	25%	10%
Architect (Consultant – Planning & Construction)	20%	20%	20%	20%	20%
Civil Engineer (Construction)	10%	25%	25%	25%	15%
Environmental Engineer (Consultant – EIA specialist)	10%	25%	25%	30%	10%
Electrical Engineer (Academic – Energy Auditor)	15%	20%	20%	30%	15%

The responses were analysed with Visual PROMETHEE and the result is produced in Figure 7.

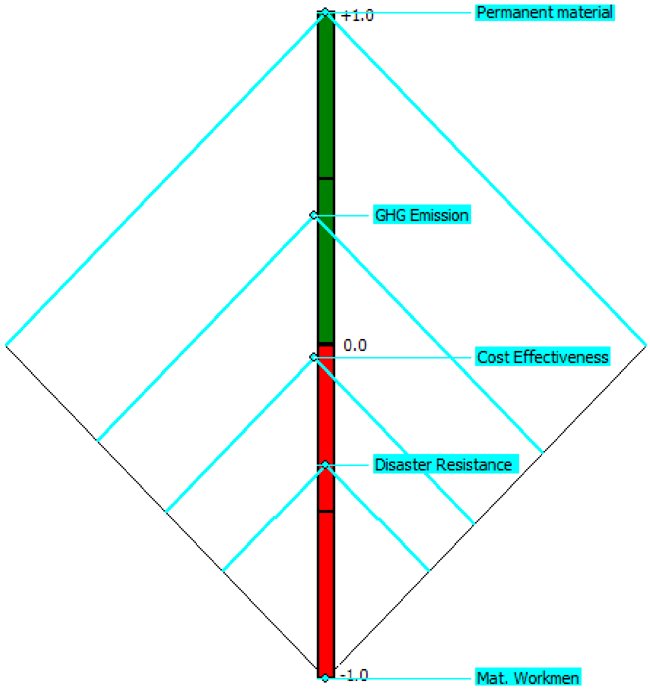

Figure 7: Priority matrix of critical factors for assessing appropriate technology after phase 2 of Delphi study

After two round of consultation with experts in different fields associated with building and energy, the prioratisation matrix for selection of building technologies for EWS for construction of building envelop is constructed as

<u>Criteria</u>	<u>Priority Ranking</u>
Roof & Wall with Permanent material	1
Quantity GHG Emission	2
Cost Effectiveness	3
Disaster Resistance	4
Availability of materials and workmen at site	5

The results were forwarded to the panel of experts and they agreed to the results provided all provisions of codes and practices are followed while constructing the buildings. This is to be noted that consensus reached using the Delphi technique does not mean that the correct answer has been found but rather that the experts have come to an agreement on the issue or issues under exploration.

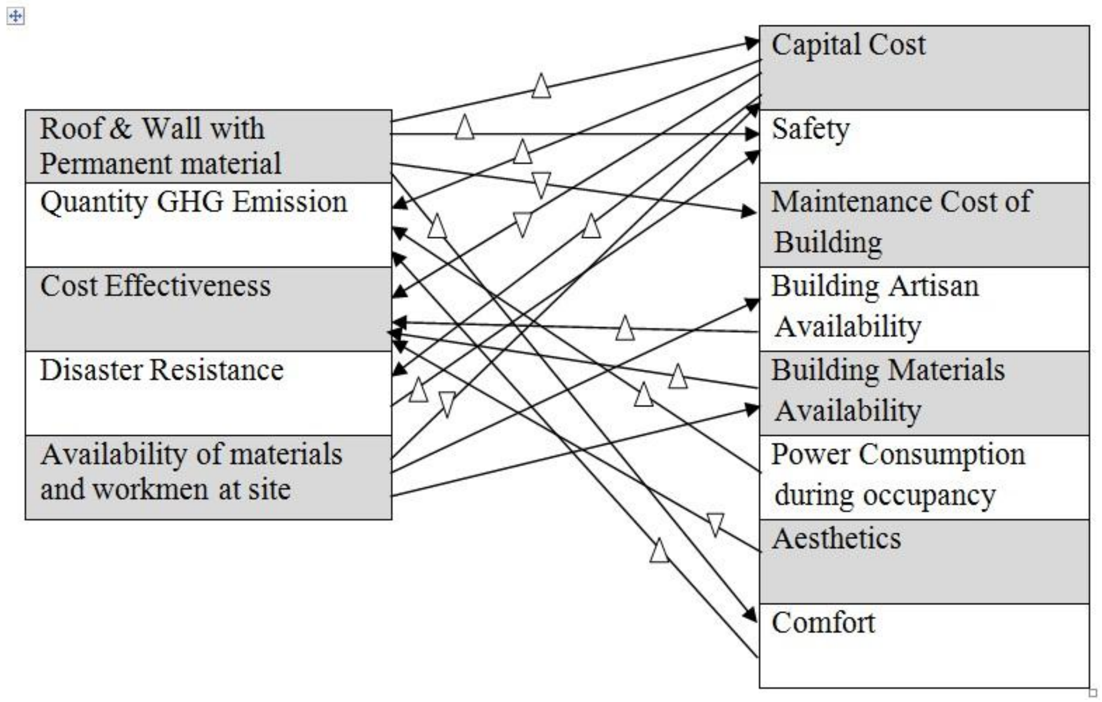

Figure 8: Correlation between attributes

Correlating users perception and experts' opinion

The best building technologies for construction of dwellings for EWS are those which meet both Users' Perception and Experts' Priority. Figure 8 shows the direct or indirect correlation between the two sets of attributes. It may be observed that selection of appropriate technologies for housing for EWS will be a complicated procedure as Construction of permanent dwelling, while ensuring safety and comfort, may increase capital cost, GHG emission but will decrease maintenance cost. To reduce GHG emission it is necessary to reduce use of building materials of high embodied energy and enhance comfort of users which will ensure low power consumption during occupancy. Easy availability of building materials and workmen near the site will enhance cost-effectiveness of the construction. Ensuring a better aesthetic façade may affect the cost-effectiveness.

CONCLUSION

From the study and analysis in this article, it may be observed that the users of Economically Weaker Section and the Experts have converged to provide high priority to safe construction using permanent building materials and cost-effectiveness of construction. Though the experts stressed upon GHG emission reduction as a part of national mission, that aspect was not properly explained to the users and therefore no feedback could be obtained from them. GHG emission from buildings occurs mainly from two accounts viz. embodied energy and operational energy. Thormark [26] has studied the effect of material choice on the total energy need of a building. Total energy need in the life cycle of a building consists of operational and embodied energy and numerous studies at international level have revealed that during an assumed life span of 50 years of a building; in low-energy buildings embodied energy can be 40-60% of total energy use. Praseeda, et al. [27] have studied embodied and operational energy requirement of urban residential buildings in India and found that share of Operational Energy and Embodied Energy in Life Cycle Energy greatly depends upon the types of materials used in construction and extent of space conditioning adopted.

It has been observed, while carrying out the survey, that to reduce cost of construction of buildings belonging to EWS and keep it within the budgetary provision of government schemes, improper materials or technologies are sometimes used without considering the general safety factors and flouting the codes of practices. In some cases, thickness of wall envelope is reduced and materials of high are used conductivity in roofing to curtail cost of construction of the buildings. This leads to increase in operational energy consumption of such buildings.

Residential buildings belonging to EWS in India do not possess any artificial heating or cooling equipment except simple room heater or ceiling mounted circulating fans to provide maximum comfort without much power consumption. Therefore, while planning and designing the buildings of people belonging to EWS, along with cost-effectiveness and affordability, the aspect of indoor comfort should also be taken care of, which will in turn reduce the operational energy demand of the building.

Based on the analysis of this study and considering the basic essence of 'Sustainability' of National Building Code 2016 [28]; engineers, architects and policy makers should chose the best possible solution for providing shelter for the EWS at an affordable cost which are capable to reduce the GHG emission from construction sector as a part of commitment of India at global level.

To ensure reduction of GHG emission from construction activity related to construction of residential buildings for EWS, particularly through any government schemes, the following points may be considered:

- Before planning for construction of permanent houses for Economically Weaker Section, the policy makers, planners, engineers and architects should emphasise on reduction of GHG emission from this sector of building construction,
- Based on the site conditions, materials availability, availability of fund for construction and other relevant factors, technologies for buildings should be selected taking into account of cost-effectiveness, low embodied energy and low thermal conductivity of building envelope,
- A compendium of cost-effective eco-friendly construction technologies using locally available building materials should be prepared at government level and a proper Schedule of Rates and Specifications is to be generated,
- Persons connected with construction of small residential buildings i.e. workmen, local-level engineers, architects and users are to be sensitised about the technologies which will not only reduce cost but also will help in GHG emission out of it. The cost-effectiveness coupled with easy availability of materials will act as a market force for adoption of the technologies,
- Respective government departments have to undertake awareness generation programmes among the users, training of masons, creation of pool of architects and engineers, establishment of building guidance centres etc. for popularization of different Cost-effective Eco-friendly building construction technologies,
- The policy makers of the country should also be made aware of the efficacy of adoption of Cost-effective Eco-friendly building construction technologies as mentioned as it would not only reduce the cost but also enhance comfort level of the users and reduce GHG emission from building construction sector.

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(ii) The Institution of Engineers (India).

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