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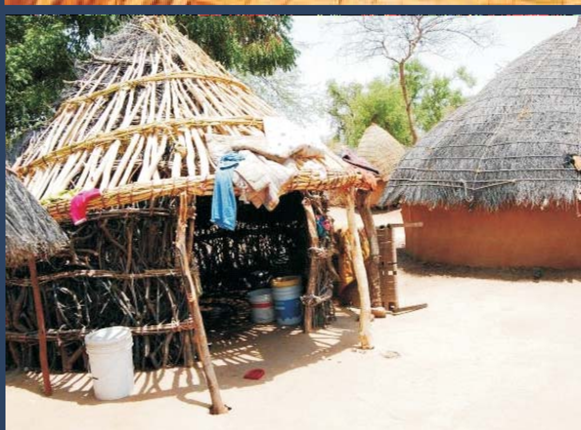

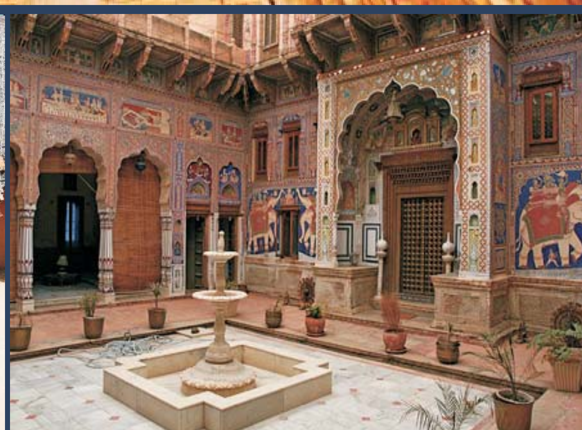

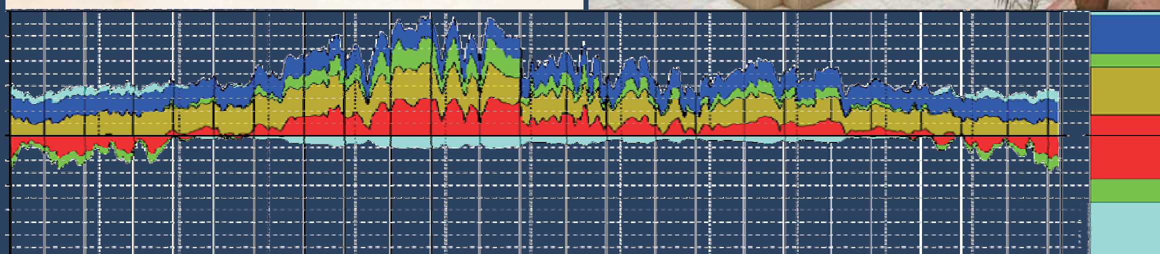

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Global Housing Challenge: A Case Study of CO_2 Emissions in India

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Abstract

The world today faces a housing crisis with nearly a third of world population living in inadequate housing. A large proportion of this shortage is concentrated in developing world. India has an existing shortage of 49 million housing units. Meeting housing requirement would mean that India would have to construct six million housing units for next 15 years. This has implications for sustainability of use of natural resources. Present paper estimates yearly building material requirements for construction of six million housing units. Moreover, if present trend in construction technologies and use of building material continues, the scale of proposed housing construction activity would add 77 million tonnes of carbon dioxide emission each year. Low carbon housing materials and techniques can reduce the emissions, as demonstrated in this paper, by as much as 61 %.

Key Words

Housing Needs, Building Materials, CO_2 Emissions, Low Carbon Housing, India

Introduction

Adequate housing is necessary for social welfare as it provides protection from weather, place to bring up families and a place to work. However, 828 million or about a third of urban population living in developing countries in 2010 were either living in poor housing conditions (slums) or were homeless (UNHABITAT, 2012). The situation is precarious when we look at the regional distribution. The percentage share of people who live in poor housing conditions out of the total regional population in Sub-Saharan Africa is about 72 % in 2001, in Asia-Pacific about 43 %, Latin America and Caribbean about 32 %, Middle East/North Africa about 30 % (Struyk and Gidding, 2009). Though the share of slums in total population is decreasing, the absolute number is still growing (UNHABITAT, 2012).

Housing conditions in cities in developing countries who cannot afford formal housing vary substantially from well-constructed houses with durable materials with many amenities (although still not legal) to decrepit shacks in slums built of wood, mud and scrap materials (Struyk and Gidding, 2009). Overcrowding is another issue particularly in cities of the developing world. In some of the poorer cities of Africa and Asia, more than 40 % population lives in housing of insufficient living space (Struyk and Gidding, 2009).

Inadequate housing is also a serious problem in rural areas, though less addressed in policy debate. In 1995, the UNCHS report on "Improving rural shelter in developing countries" highlighted that many countries do not have explicit rural housing policies and many national housing policies cover only urban housing assuming that there is no significant problem in rural areas and that the rural households will continue to address their housing needs without government involvement (UNCHS, 1995). The situation continues to be the same and most of the focus including of the United Nation's Millennium Development Goals (target 11 of MDG is to improve the urban slum conditions for 100 million people by 2020) is on urban housing.

Given that about three billion people in developing countries live in rural areas (UN, 2008), improving housing condition in rural people cannot be ignored. Most of the houses in rural areas are built using non-durable building materials including biomass, mud, plastic sheets. In India alone 60 % of rural houses (80 million units) in 2001 were constructed using non-durable or a combination of durable and non-durable building materials (MoRD, 2007). These houses are unsafe and vulnerable to floods, storms, cyclone and so on, important in the context of current debate on climate change. The vulnerability of residents in such houses is compounded by the fact that a large proportion of such houses are concentrated in the rural areas, with poor access to infrastructure for help and communication compared to urban areas. Moreover, households incomes in rural areas are generally lower than in the urban areas. With seasonal unemployment and uncertain and fluctuating incomes many households find it difficult to upgrade their homes to proper housing (built using durable building materials). Poor housing conditions and lower household incomes in rural areas compared to urban have implications for the social and environmental sustainability of rural communities.

Poor housing conditions in urban and rural areas are also associated with poor access to basic services such as water and sanitation. However, according to UNHABITAT (2005), rural housing conditions as expressed by access to safe drinking water, sanitation and electricity are worse than urban housing conditions in almost all the countries in developing world. While poor housing often has also poor access to basic services, even middle class may not have adequate basic services, mainly due to inadequate infrastructure and public investment. in Sub-Saharan Africa, where 72 % of the population lives in poor conditions, about 42 % of population lacks access to water connection (either in the house or through public stand post) and 69 % do not have access to adequate sanitation facilities. In all the regions, the situation is far worse in rural areas than in urban areas.

Consequences of poor housing conditions and lack of basic services are severe. One indicator, health of resident children, indicates that children living in slums have high mortality rate and very high incidence of diseases. For example in Kenya while the mortality rate among under five years old children is 112 per thousand births at the national level, the rate is 151 per thousand births in slums. In some slums the mortality rate is as high as 254 (UNHABITAT, 2005). Lack of access to sanitation facilities and safe water sources is the defining feature of slums, sometimes supplemented by absence of waste collection systems, electricity supply, surfaced roads and footpaths, street lighting and rainwater drainage (UNHABITAT, 2003).

Future demographic trends will have two important features: much of the new household formation would happen in developing world and a large proportion would be in cities. As projected in Fig-1, of the 536 million new households that would add to the world during 2010-25, 464 million would be in developing world. The disaggregated statistics by countries on new household formation indicate that China and India together would dominate the scene. Between 2010 and 2025, China would add 92 million households and India would add 41 million households (Fig-2). Urbanisation in developing world is exacerbating the housing crisis further. Based on the projected incremental urban population between 2010 and 2030 and already accumulated shortage arising from rehousing needs of households living in slums, UNHABITAT (2012) estimates that there is an urgent need of 2.25 billion housing units. This means that over next two decades, 60,000 housing units would have to be built daily.

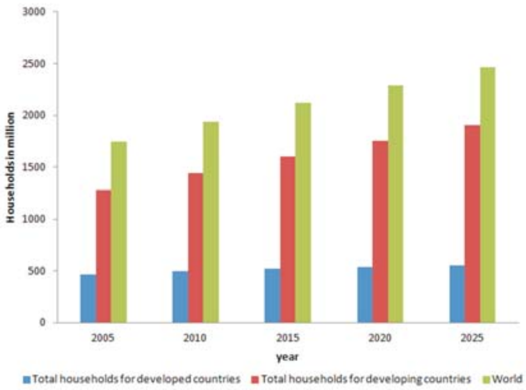

Fig-1: Projected new households
Source: Compiled by IRADe, from UN-HABITAT, 2005.

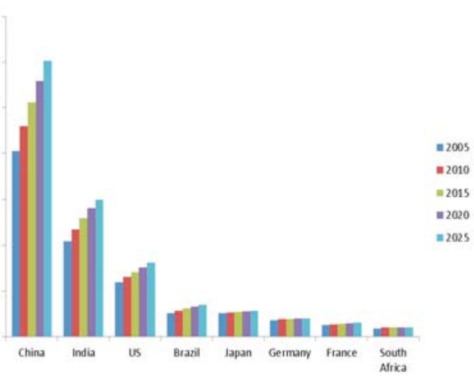

Fig-2: Trend of Households of some countries in the world: 2005 to 2025
Source: Compiled by IRADe, from UN-HABITAT, 2005

Housing is also an important link between society and environment. The relationship between housing and environment is two-way. On one hand, housing is exposed to variety of environmental impacts and hazards including those associated with natural disaster and climate change. Climate change in future may further increase vulnerability of households living in houses constructed using non-durable materials compared to those living in durable housing, as durable houses are more likely to withstand the impact of flooding or droughts. On the other hand, housing construction and operation itself consumes large amount of natural resources – land, energy, water, building materials – while producing land, water and air pollution (UNHABITAT, 2012). Fig-3 presents the share of residential sector in total carbon dioxide emissions attributable to fuel combustion in top ten emitting countries. The figure indicates that the share of emissions from residential sector in top three emitting countries (China, US and India) is between 4-6% of the total emissions. It may be highlighted here that these emissions are attributable to operational activities of residences – lighting, cooling, heating, etc. Fig-3 does not include emissions during construction of houses and due to the use of materials in construction which have high embodied energy. House construction activity using durable materials such as bricks, cement, steel, tiles, refractories, etc., contributes substantially to the carbon dioxide emissions due to high energy intensity of these building materials. The contribution of house construction activity to overall emissions could be substantial depending on the level of construction activity in a country. Parikh et al. (2009) estimate for India that in meeting the final demand for construction, the carbon dioxide emitted contributes to about 24% of total carbon dioxide emissions in the country. A large part of the construction activity is housing. The share of house construction in overall construction activity in India is around 60% (Tiwari, 2001).

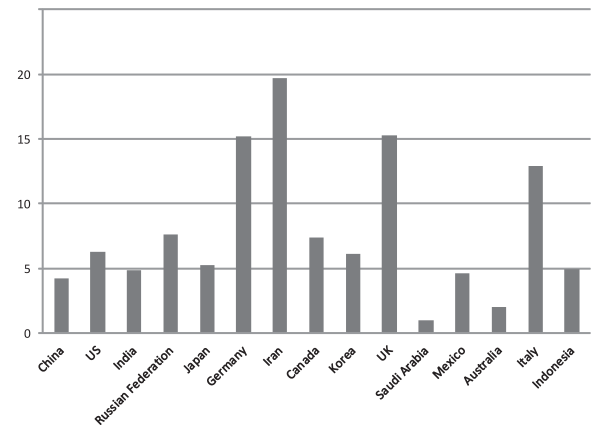

Fig-3: Share of residential sector in total carbon dioxide emissions from fuel consumption (2009)
Source: Based on data from IEA.

This paper analyses the energy and building material requirements associated with house construction activity and associated carbon dioxide emissions during construction with India as a case. The paper demonstrates the importance of choice of technology in determining the level of emissions. By analysing low carbon technologies, present paper demonstrates that there is huge potential for reduction in carbon dioxide emissions during construction activity. As mentioned earlier, while the sustainability in the use of resources, such as energy and water, is equally important during operation of housing during its life, it has not been dealt with in this paper. Furthermore, the energy and building material requirements have been estimated for India based on commonly used construction practices for durable housing and to sustain a level of housing construction activity that will meet the enormous construction needs (as projected later). Recent statistics from Census of India 2011 indicate that during 2001 – 2011 total of 65 million houses were added where 35 million and 30 million were in rural and urban areas respectively. Even so, the gap of housing persists not only in terms of quantity but also quality. Though there has been some policy debate in India on meeting the shortage of housing in the urban areas (see for example the report by Task Force on Housing for the Eleventh Five Year Plan or even programme like the Rajiv Awas Yojana) as well as rural areas (through programme Indira Awas Yojana), the impact in meeting the housing needs has been small. While the importance of providing shelter for all cannot be understated, another important issue that has been generally ignored in policy debates in India is the large proportion of dwelling units, particularly in rural areas, that are built using non-durable materials (also called *kutcha* housing). Out of the total stock of 246 million houses in India, 115 million are constructed using non-durable or informal materials including biomass, mud, plastic sheets. Replacing informal houses with durable housing, though necessary, has CO_2 implications.

Following are the three objectives of this paper in the context of India: (i) to analyse the current trends in house construction activity, (ii) to project future house construction requirements, and (iii) the resource requirements for meeting construction needs. The construction needs, as discussed later, include the replacement requirements of non-durable houses and also the construction of new houses to meet the shortage arising from new household formation and population growth. In addition to roof over head, a house provides basic services especially water, sanitation and electricity. The construction of basic services will also consume resources and have carbon implications. However, this paper limits itself to estimation of resource requirements for housing structures that would be constructed to meet housing needs and does not calculate resource requirements for providing basic services that will also be part of housing development. Choices that households make with regard to the structure of housing construction are a function of their financial resources. Estimation of available financial resources, though important for future housing choices, is not the focus of present paper.

While the analysis of house construction activity has been conducted for India, it could easily be expanded to other countries. The main reason for not generalising the results to other countries is that there are local practices which may differentiate countries in their use of building materials and construction techniques and may cause some differences in the estimate of carbon dioxide and building material requirements. However, it could be asserted that in all countries opportunities exist to reduce the use of energy intensive materials and hence carbon dioxide emissions.

The rest of the paper is structured as follows: Section 2 presents an overview of the housing situation in India. Section 3 constructs a scenario for housing construction needs which includes the conversion of housing units built using non-durable materials to durable materials and new construction of housing units to meet the shortage. Section 4 briefly presents the methodology and assumptions employed in the estimation of resource required. Section 5 and 6 discuss the results and section 7 concludes the discussion.

Trends in Housing in India

Projected housing construction needs would depend on the requirements for new housing due to new household formation and the replacement needs of non-durable and poor quality houses. This section presents an overview of demographic trends and housing condition in India. The next section would present the projected housing needs.

Households and housing stock

The number of households in India has grown from 100 million in 1971 to 246 million in 2011. The average household size is about 4.9. (Fig-4). During this period, the growth in number of urban households has been faster than rural households. The number of households in urban India has grown 3.8 times, while rural area has seen a growth of 2.1 times.

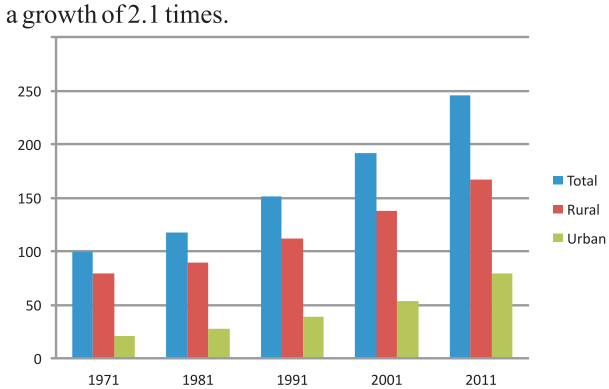

Fig-4: Number of households in India
Source: Compiled by IRADe, 1971, 1981, 1991 and 2001.

The census also revealed that nearly 131 million of the 246 million houses are of durable category *pucca*, 102 million semi-durable *semi-pucca* and 13 million non-durable *kutcha* (Fig-5). What is interesting, however, is that the % share of semi-durable houses in total increased to 41 % during 2011 from 30 % in 2001, while the share of non-durable housing reduced from 18 % to 5.3 % during the same period. The share of durable homes has increased from about 51 in 2001 to 53 % in 2011. In absolute terms, while the total number of houses increased by 54 million units during 2001-11, the durable and semi-durable houses have increased by 76 million units. An inference that can be drawn from this trend is that households may have adopted incremental approach to upgrade their homes as there is a reduction of 22 million non-durable homes while semi-durable homes have increased by 44 million during 2001-11.

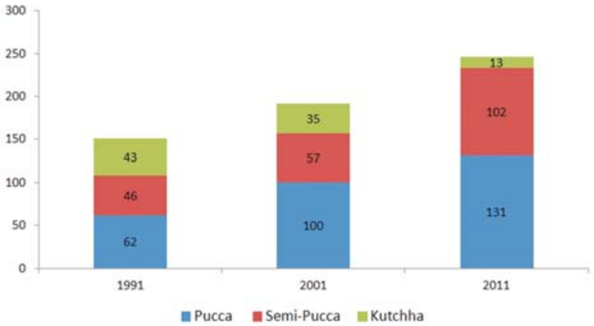

Fig-5: Structural types of houses (million)
Source: Compiled by IRADe, 1991, 2001 and 2011

Qualitatively also the dwelling units have exhibited significant improvements. Though the use of non-durable building materials still dominates the construction of dwelling units (Fig-6, 7 and 8), the proportion of durable building materials has gone up significantly during 2001-2011. The proportion of houses with non-durable roofs in total has come down from 22% in 2001 to 15% in 2011. The proportion of houses with non-durable walls was 33% in 2011 compared to 42% in 2001. The flooring for 47% of houses was made of non-durable material in 2011 compared to 57% in 2001.

Housing conditions

Census does not collect information on housing condition but according to a survey conducted by NSSO (2010) nearly a third of non-durable housing units are unserviceable and in immediate need of redevelopment. The non-durable housing units have an economic dimension too. Nearly a quarter of households in rural areas in the bottom 40 % of economic strata on the basis of monthly per capita expenditure (MPCE), live in non-durable housing units. In urban areas, most of the dwellers in non-durable housing units belong to the bottom 40 % class on the basis of MPCE.

Another indicator that reflects housing condition is the age of the building. Age as an indicator needs to be interpreted cautiously as a well maintained building could last longer. As per the NSSO (2010), about 26 % of owned housing units are more than 20 years of age. The survey also indicates that about 15 % of housing units required major repairs. In addition, about 47 % housing units required minor repairs. In effect, 62 % housing units are in need of major or minor repairs.

The quality and condition of a housing unit is also

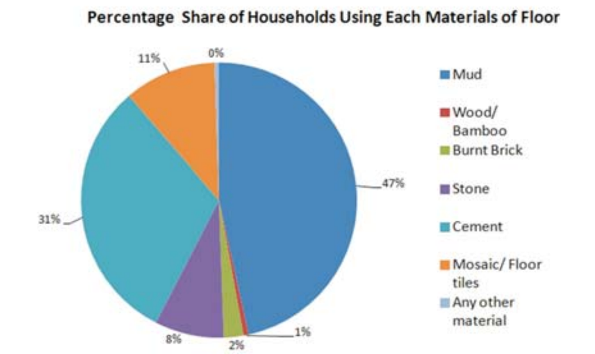

Fig-6: Building materials used in construction of floor (2011)
Source:Compiled by IRADe, 2011

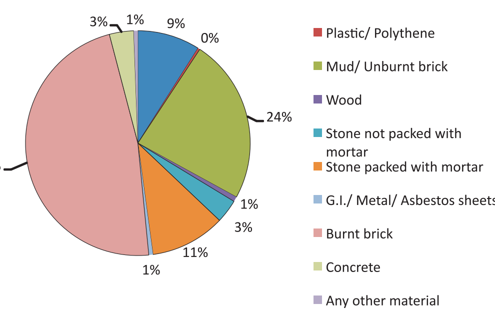

Fig-7: Building materials used in construction of walls (2011)
Source: Compiled by IRADe, 2011

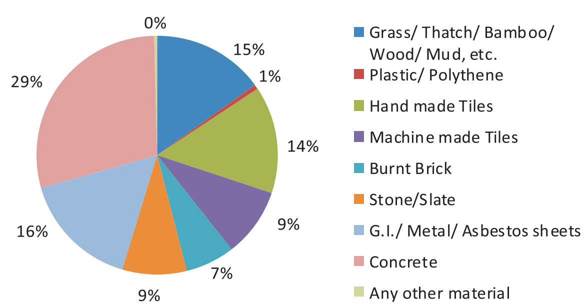

Fig-8: Percentage Share of Houses Using Each Materials of Roof (2011)
Source: Compiled by IRADe, 2011

reflected in the amenities that the unit has. As per NSSO (2010), about 60 % of households either had no access to drainage system or had at best non-durable drainage. The situation is starker in rural areas where three quarter households do not have access to drainage or have non-durable drainage system. The informality in the availability of amenities is linked to the informality in the type of housing units, which are both connected to affordability and government policy or lack of it.

This is further confirmed if we look at the nature of construction that is taking place. According to NSSO (2010), 57.2 % of construction of new housing units or improvements in existing housing units was either using non-durable or a combination of non-durable and durable building materials. While most of the construction in urban areas was using durable materials, 63 % of construction in rural areas was using non-durable or a combination of non-durable and durable building materials. The financing of construction in rural areas was mainly through own labour and own financial resources.

The above review indicates that the scale of housing problem in India is large as a sizeable problem of houses are non-durable with poor amenities and majority of households who own these houses are in lower income brackets with lack of financial ability to upgrade them.

Need for Housing Construction

The need for housing construction arises from the following: (i) replacement of non-durable housing units to durable (ii) replacement of semi-durable housing units to durable (iii) new housing needs.

We estimate the construction needs for 2011 using the methodology for estimation of housing shortage used by the Task Force on Urban Housing for the Eleventh Five Year Plan and the Task Force on Rural Housing for the Eleventh Five Year Plan as the basis (MoUR, 2008; MoUD, 2008). Existing housing shortage has three components: replacement needs of non-durable housing, needs to address overcrowding or congestion in existing housing units, and needs arising for replacement of obsolescent stock. Congestion factor has been defined in the Task Force for Eleventh Five Year Plan (for urban and rural housing) as the percentage of households in which at least one couple is not having a separate room to live in. This includes the households in which couples are sharing the room with 10+ age member of the household. The congestion factor in rural India is 6.5% and in urban India is 19.11%, implying that 6.5% households in rural and 19.11% in urban are facing housing congestion problems.

Obsolescence factor is defined as the percentage of households living in the dwelling units having age 40-80 years and that are in bad condition and percentage of households living in all structures aged 80+ years, irrespective of condition of structure. The obsolescence factor for rural India is 4.3% and in urban India is 3.6%.

With 2011 as the base year, estimates for construction requirements are presented in Table-1.

Table-1 indicates that the construction needs in India in 2011 was around 49 million housing units. This estimate does not include vast majority of semi-durable houses, which also would need up-gradation/replacement to withstand impact of climate change. The number of semi-durable houses in India is about 113 million housing units. Adding the two together the total construction need is for about 162 million housing units (Table-2).

Table-1: Housing construction needs in India (2011)

Factors taken for assessing housing shortage	Calculation	Rural housing shortage (million)	Urban housing shortage (million)
Number of non-durable houses in 2011		10	3
Shortage due to congestion	Congestion factor x number of households	10.86	1 5.09
Shortage due to obsolescence in 2011	Obsolescence factor x number of households	7.18	2.84
Total		28.04	20.93
Total housing shortage (urban + rural): 48.97 ~ 49 million units			

Table-2: Construction need for dwelling units in India 2011

Components	Housing units (million)
House Construction needs (Table-1)	49
Replacement/Up-gradation of semi-durable housing units	113
Total	162

The construction needs in Table-2 require careful interpretation. The need for construction more than triples if we add the replacement/up-gradation of semi-durable houses to the construction needs arising from shortage, replacement of semi-durable houses by durable, replacing obsolescent houses and meeting the additional housing requirements to ease housing unit congestion. Meeting the construction needs estimated in Table-1 may take precedence over the replacement/up-gradation needs of semi-durable housing units if available resources and finance become a constraint. The construction needs of 49 million durable housing units plus new requirements arising from population growth and new household formation over next fifteen years (2011-25) is an achievable task given that 31 million durable housing units were added during 2001-11 and 38 million during 1991-2001.

Methodology for Resource Estimation

The estimation of resources up to 2025 (2011-25) focuses on meeting the construction needs of 49 million units plus additional requirements arising due to population growth and new household formation. The new housing requirement is about 41 million units arising from the formation of new households as presented in Fig-2. The up-gradation needs of semi-durable housing units have been assumed to take place after next fifteen years once all non-durable housing units have been converted to durable and new construction needs have been met. Hence, it is assumed that over next 15 years a total of 90 million housing units would be required.

Two assumptions have been made to allow us to estimate the resource requirements. First, we assume that the housing construction activity would progress in a way that the conversion of present construction needs for housing units and the incremental needs for additional housing would be met over fifteen years (2011-25). The total requirement for construction of housing units during 2011-25 is projected in Table-3. Considerations for obsolescence are not necessary here as we are assuming that the whole stock of semi-durable housing would also need gradual replacement after 2025.

Table-3: Construction needs for houses during 2011-25

Components	Housing units (million)
House construction backlog (2011)	49
Additional house construction requirement (2011-25)	41
Total	90
Yearly construction requirement	6.0

How doable is the yearly construction requirement? As discussed earlier, during 2001-11 about 31 million durable houses were added to the stock. The average annual addition was about 3 million durable housing units. During 2001-11, the rate of addition to housing stock went up but a large addition was in terms of semi-durable housing. With policy impetus such as Rajiv Awas Yojana particularly for low income housing, it may be possible to double the construction of housing units yearly over the next fifteen years.

The second assumption is regarding the size of the dwelling unit. Table-4 presents the distribution of households according to the number of rooms. The proportion of each type of house that would be constructed is assumed according to Table-4.

Table-4: Distribution of households according to rooms in 2011

Number of Rooms	Percentage of households
1	41.06
2	31.71
3	14.63
4	7.32
5 or more	5.28

Source: Our calculations based on Census 2011

The share of each type of housing units, out of 6 million units yearly, is assumed to be the same in proportion as in Table-3. The size of each room is assumed as 3.5mx3.5mx3.14m. The carpet area of 1 room dwelling unit based on the assumption of the size of room is about 136 square feet. A dwelling unit is assumed to be combination of such rooms. These rooms could be living room, bedrooms, kitchen, bathroom, toilet, etc., but no distinction is made here. The analysis in this paper is looking at the construction of structural frames of walls without specifically focusing on the intended use of space. Further the analysis does not account for doors and windows as standardisation of these elements of housing units for different houses in not possible. This room can exist anywhere in the building structure of up to three floors. Up to three floors, the minimum thickness of walls is one brick under certain conditions. Beyond this level, the minimum thickness of wall increases. However, in normal construction practices the walls beyond the third floor are rarely load bearing. Generally, a framework of columns and beams is constructed which is load bearing and the space in between is filled with non-load bearing walls. With this assumption, the specification of the room considered is reasonable.

An optimisation model proposed by Tiwari et al. (1999) has been used to estimate the building material requirements. Construction of a building consists of construction in following stages: stage 1 - foundation bed under load bearing wall; stage 2 - foundation bed under partition wall; stage 3 - foundation for load bearing wall; stage 4 - foundation for partition wall; stage 5 - wall construction; stage 6 - partition wall construction; stage 7 - roof construction; stage 8 - flooring; stage 9 - external plastering; stage 10 - internal plastering. The output of construction activity is a house. Various combinations of technologies can be used at different stages, mentioned above, to build the same house.

Tiwari et al. (1999) model identifies technologies at different stages (viz., foundation, floor, walls, roof, plastering) of construction from a range of technological alternatives present before a developer for each stage to meet the output levels required at each stage of construction of a room. However, to simplify this paper takes the set of technologies that are commonly employed for durable construction as given in Table-5.

Table-5: Choice of techniques at for stages of construction

Stages	Techniques
Foundation bed under load bearing wall	1:4:8 Cement Concrete
Foundation bed under partition wall	1:4:8 Cement Concrete
Foundation for load bearing wall	1:1:8 Cement, sand, lime brickwork
Foundation for partition wall	1:6 cement, coarse sand brickwork
Load bearing wall	1:6 cement, coarse sand brickwork
Partition wall	1:6 cement, coarse sand brickwork
Roof	1:3:6 RCC balanced
Floor	40mm 1:2:4 cement concrete floor
Internal Plastering	12mm 1:6 cement mortar
External Plastering	12mm 1:6 cement mortar

The optimisation model has cost minimisation as its objective function and has a number of constraints. There are resource constraints which restrict the choice of techniques based on availability of building materials. The availability of building materials is further constrained by availability of raw materials that are used to produce them. Besides resource availability, there are structural design constraints which restrict the combination of technologies at different stages. Raw materials include fuel (electricity, coal), limestone, gypsum, etc. which are required in the production of cement, bricks, lime, steel, etc. which can be either directly used in construction or can be used in manufacturing of concrete blocks, which are used in building construction. In this model, different technical specifications that provide the same outputs (a house with a combination of functional room of the size defined earlier) are considered. The levels of resources and production activities are determined so that the overall cost of construction of the specified house is the minimum. For the purpose of present paper we have adopted the set of common technologies that result from the optimisation process.

Results and Discussion

Table-6 presents the resource requirements and associated carbon dioxide emissions for construction of one room as estimated using Tiwari et al. (1999) model for techniques presented in Table-5.

Table-6: Resource requirements and carbon dioxide emissions for the construction of one room

CO_2 Emission (tonnes)	6.25
Cement (tonnes)	2.20
Bricks (thousand)	6.02
Coarse sand (cu-m)	5.71
Fine sand (cu-m)	1.64
Stone aggregate (cu-m)	5.49
Unslaked lime (hundred Kg)	0.22
Steel (Kg)	66.39

Now we run a full-fledged Tiwari et al. (1999) model for the construction of 6 million houses required annually, with the set of technologies as described in Table-5 and under the assumption regarding the size distribution of housing units as presented in Table-4. The yearly material requirements and associated carbon dioxide emissions are presented in Table-7.

Table-7: Material Requirements for Conventional Construction of 6 Million Houses

Cement (Million tonnes)	27.3
Bricks (Billion)	73.7
Coarse sand (Million cu-m)	69.9
Fine sand (Million cu-m)	20.1
Stone aggregate (Million cu-m)	67.2
Unslaked lime (Million tonnes)	2.7
Steel (Million tonnes)	0.81
CO_2 Emission (Million tonnes)	76.5

Another factor that constrains the housing activity is the domestic output of building materials. Availability of building materials and appropriate technology is crucial to the growth of housing. The total production of key building materials like cement and steel indicate that these would not pose constraint in achieving the annual target of 6 million housing units.

Low Carbon Building Technologies

Earlier section presents estimates for resource requirements and associated carbon dioxide emissions for constructing 6 million houses every year for next fifteen years using commonly prevalent 'durable' housing construction technologies. This section explores alternative technologies that can be used for construction of 'durable' housing and are low carbon technologies. Tiwari et al. (1996) conducted an extensive analysis analysing low carbon technologies and argued that these technologies are not only low carbon but are also cost effective. Table-8 presents a set of technologies based on Tiwari et al. (1996) for various stages of house construction. These technologies use less of cement, steel and burnt bricks, the three building materials that have highest embodied energy.

Comparing Tables 7 and 9 indicate that using low carbon technologies can reduce carbon dioxide emissions by 61 %. This is because the consumption of cement reduces by 47 % in low carbon case than in common practices. Consumption of burnt bricks reduces by 82 % in low carbon case compared to common practices. Steel consumption too can be reduced substantially. Overall, using low carbon technologies can reduce carbon footprint without compromising the durability of buildings.

Table-8: Low carbon house construction technologies

Stages	Techniques
Foundation bed under load bearing wall	1:4:8 Cement Concrete
Foundation bed under partition wall	1:4:8 Cement Concrete
Foundation for load bearing wall	1:1:8 Cement, sand, lime brickwork
Foundation for partition wall	1:6 cement, sand, lime brickwork
Load bearing wall	1:4:8 cement, flyash, sand mud blocks
Partition wall	1:4:8 cement, flyash, sand mud blocks
Roof	Filler slab with Mangalore tiles
Floor	40mm 1:2:4 cement concrete floor
Internal Plastering	12mm 1:6 cement mortar
External Plastering	12mm 1:6 cement mortar

Source: Tiwari, et al., 1996.

Table-9: Material requirements for constructing 6 million houses using low carbon techniques

Resources	Quantities
Cement (Million tonnes)	14.6
Bricks (Billion)	13.1
Coarse sand (Million cu-m)	42.2
Fine sand (Million cu-m)	17.5
Stone aggregate (Million cu-m)	24.1
Unslaked lime(Million tonnes)	3.06
Steel (Million tonnes)	0.09
Flyash (Million cu-m)	13.1
Mudblocks (Billion)	50.1
Mangalore tiles (Billion)	0.73
CO_2 Emission (Million tonnes)	29.6

Conclusion

Providing adequate and good quality housing for all is a major challenge that the world is facing today. The problem is far more acute in developing world where slums are burgeoning. Going forward two demographic trends would dominate the world: (i) Demographic trends where joint families split into two to three nuclear families, or married couples live separately from their parents, may also add to the need of additional housing. Therefore, a large proportion of new household formation would happen in developing world and (ii) increasing proportion of new households would be added in the cities. This does not mean that housing problem in rural areas is not as acute. These are the regions where quality of housing poses major challenge as houses made from 'non-durable' materials dominate housing stock in rural areas. Poor housing is also associated with poor basic services – water and sanitation – with serious negative implications for health and quality of life. According to an estimate by UNHABITAT (2012) the world would need 2.25 billion new houses by 2030 to address housing requirements.

The requirement of new housing construction globally is magnanimous. Expected construction activity over the next two decades would pose challenge for the use of resources and carbon dioxide emission due to embodied energy in commonly used building materials. A major part (almost 40% of global housing construction) of the house construction activity would take place in India.

The paper also reviews changes in the housing situation in India using the recent census data (2011). Poor quality, over-crowding and lack of basic services dominate housing situation in urban and rural areas. India would need about 6 million new houses every year for next 15 years to meet the shortage posed by new demand and replacement needs of poor quality housing.

The scale of housing construction activity would be large as it would require doubling the present level of house construction in India. This would require that natural resources are used sustainably. The estimates in this paper indicate that about 27 million tonnes of cement, 74 billion bricks and 0.8 million tonnes of steel would be required every year. These building materials are energy intensive, which has implication for carbon dioxide emissions. The proposed house construction activity in India, even assuming modest type of one-room housing for poor, would contribute 77 million tonnes of carbon dioxide emissions every year.

The discussion in this paper opens up a debate regarding what are the challenge of providing adequate housing for all and how to meet them in a sustainable way. This paper also demonstrates that using alternative building materials and designs could help reduce the carbon burden by as much as 61 %. These materials would need to be explored further so that housing requirements could be met in most sustainable way.

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