ACHIEVING RESOURCE SYNERGIES FOR A RAPIDLY URBANISING INDIA

A PRODUCTION OF HOUSING

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Published at

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Research Supported by

HEINRICH BÖLL STIFTUNG

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ABSTRACT

The aim of the paper is to understand the resource implications of growth and upcoming natural resource conflicts and constraints, with a focus on the construction sector in urban India. The paper explores the desired transformations to redefine the development pathway of the country. Further, this paper identifies the opportunities to build synergies in order to do more, do different and/or do better.

ACKNOWLEDGEMENT

This paper was supported by the Heinrich Böll Foundation under "Transforming the Development Paradigm-II" Programme.

We take this opportunity to thank our colleagues of the urban programme at Development Alternatives. We specially thank D Varsha for her contribution and efforts in the research support for this project.

We specially acknowledge the work on resource efficiencies in construction materials with GIZ and the work on housing policies of five states governments in collaboration with IPE Global. This work has supported the data, research and analysis of this paper.

Without the insights, feedback and contribution of the aforesaid individuals, this paper would not have been possible, although any errors are our own and should not tarnish the reputations of these esteemed persons.

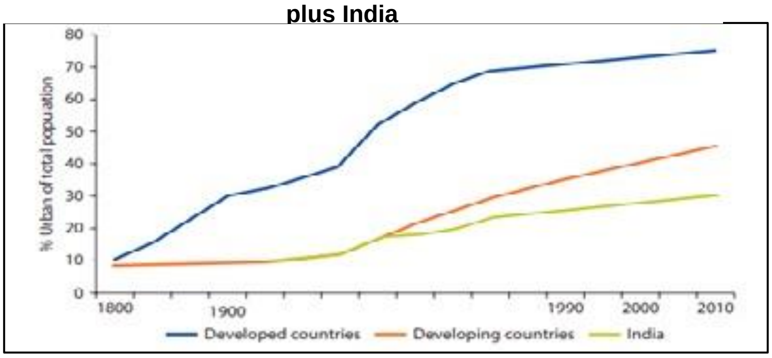
1. INTRODUCTION

Key Message: Over the last few decades India has witnessed a shift towards increasing urbanisation. This rapid growth has increased the need for shelter, food, energy etc. leading to extensive consumption of resources such as land, water, soil, sand etc.

Development of any individual, community or region may find correlation with the kind and amount of natural resources available. The global demand for various goods and services is increasing and consumption and production patterns are resonating unsustainability (The Indo-German Environment Partnership Programme, 2013). However, the natural resource basket around the world remains finite. Unsustainable patterns of resource consumption can already be seen in developed countries, and the developing countries are mirroring similar trends in order to provide appropriate living standards to their citizens (The Indo-German Environment Partnership Programme, 2013)[1]. Consequently, the growth pattern in developing countries has been rapid and the challenges of natural resource depletion like increase in resource prices and increased price volatility could be most severe in these countries. Furthermore, it will disproportionately harm the well-being and resilience of the communities.

An outcome of economic growth is almost always urbanisation, and competently managed urbanisation can fuel further growth, innovation and welfare (ODI, 2015). Currently more than half of the world's population reside in urban areas and it is estimated that approximately two-third of the population will be urban by 2050 (UNDESA, 2014). Africa and South Asia, where city growth rates have been the highest, will contribute 90% to the future urban population growth (Venables, 2015). Urban spaces in developing countries are growing faster than their developed world counterparts and are increasingly vulnerable to various social and ecological impacts such as poverty, climate change, degrading ecosystem, *et cetera*.

Figure 1: Urbanisation in Developed and Developing Countries plus India



Since 1951, India has experienced a slow yet relentless territorial and demographic restructuration towards urban. The rate of urbanisation increased to 2.38% (2010-2015), with 32.7% urban population (CIA, 2013). Yet, the sheer absolute population totals implied by

[1] The appropriateness of living standards is defined in a country's own context. The social/cultural/climatic context is not usually considered while defining it. While a clear definition on appropriate living standards don't exist, basic thresholds for housing defined by the Government of India is considered for the purpose of this paper.

Source: **(World Bank, 2013)**

these rates of urbanisation result in massive urban growth. Currently, 377.1 million people reside in Indian cities. This population is expected to continue to rise year after year, with more than 50% of the country urbanised by 2050 (UNDESA, 2014). The magnitude of urbanisation and growing urban population has been characterised by growing gaps between employment demand and opportunities, increasing shortage of urban services and facilities, such as housing, sanitation, health services, *et cetera*, all of which are accessible to a limited share of urban population (Aluko, 2010). Furthermore, as the conurbations in the country are growing, they are leaving behind a disproportionately larger footprint through ravaged nature in and around these expanding cities (Rajashekariah, 2011).

The urban current housing deficit in India is pegged at 18.78 million units (MHUPA, 2012) estimated to increase to 38 million units by 2030 (Sankhe, et al., 2010). Construction of basic and core infrastructure currently demands vast amount of land and depends on natural resources like sand and soil to produce building materials. The source of this soil and sand is through arable land and through river beds respectively. The same land and soil is necessary cultivate food, while rampant extraction of sand impacts ecological flows of rivers leading to deleterious consequences.

With the Government of India's plan for 'Housing for All by 2022' – 20 million houses in 4041 statutory towns and other missions for urban transformation in 500 cities, the natural resource implications of this would be abundant. It has already been estimated that the amount of land required to fulfil the urban housing need by 2022 would be around 1.7 to 2.0 lakh hectare (KPMG, 2014). Simultaneously, in one state itself about 16.5 million m^3 of soil (90% procured from arable land and 10% from river beds) per year is used to make red bricks (Development Alternatives, 2012). It is necessary to understand that lasting and holistic economic and social development can only be achieved if it is supported by a secure foundation of natural capital (UNEP, 2015). Thus the critical question remains whether India can provide these urban transformations to raise the standard of living of people without degrading the ecosystem and exploiting the finite natural resources.

In response, this paper aims to bring forth the argument that the key to the addressing the challenges of natural resource depletion lies in managing resources sustainably. This can be achieved through decoupling resource use and environmental impacts from economic growth. Resource synergetic pathways for urbanisation do exist and they can reduce environmental burdens thereby decouple resource consumption and economic growth. The objective of the paper is to guide key stakeholders; especially government and industry, develop well thought out strategies that would ensure the resource synergies are promoted and adopted in this accelerated movement towards urbanisation.

The paper attempts to address the following questions;

- India is urbanising at a rapid pace. This will translate into an increasing demand for basic needs[2] like housing, food, water, etc. which are directly correlated to natural resource consumption patterns. What are the resource conflicts arising due to this rapid urban development in India?

[2] There is no single universally accepted definition of basic needs. In simplest terms, it can be explained as a list of things which are required by human beings to survive e.g. food, shelter, housing etc.

- The natural resource basket is finite and while moving on the development pathway there will be conflicts and constraints across regions and sectors for these resources. How can these constraints be mitigated in an urban landscape?
- Resource synergetic options exist and can create win-win situations. These isolated examples have the potential of being scaled up and scaled out. What role do agents of change play in driving the resource synergetic pathway of urbanisation and ensuring it is promoted and adopted?

Following this introduction, Section 2 highlights the possibility to build resource synergies across various sectors and applications. It also elucidates the links between global dialogues and national agenda in order to achieve a resource synergetic urban environment. Its highlights are encompassed in a liveable city within the current resource constrained landscape. Section 3 analyses the various resources needed to sustain the housing sector and highlights synergies that can be built across sectors for critical resources. It studies how resources such as land and those used as building materials are pitted against other applications. Case studies indicate the drivers or obstacles for a sustainable city. Section 4 brings forth approaches that may be adopted and propagated to address the impending resource issues. It highlights the principles that will guide the transition towards adopting a resource synergetic urban landscape. This section essentially looks to answer what can be done and what should be done to achieve the aforementioned pathway. Finally section 5 highlights the key agents of change who (will) play a critical role in transitioning from the current paradigm of development to a resource synergetic pathway.

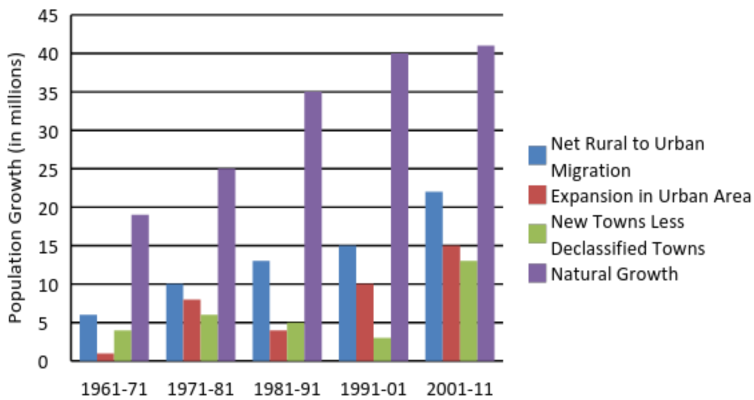
2. CONSTRUCTION FOR URBANISATION: A RESOURCES PERSPECTIVE

Key Message: To meet the increasing demands for housing in urban India, the construction sector will intensify its production thus fuelling resource consumption. The national and global agendas provide the opportunity to adopt resource synergetic pathways and must complement each other and run symbiotically. However, concrete instruments and implementation mechanisms to ensure this, are still weak.

2.1. Urbanisation in India

The Indian economy has been rapid growth trajectory since 1990s. This movement has brought with it an increased trend of urbanisation. The urban population increased from 286 million in 2001 to 377 million in 2011 (Planning Commission, 2012) and it is estimated that there will be an addition of more than 400 million people by 2050 (UNDESA, 2014). Urbanisation is a process that brings with it temporal, spatial and sectoral changes in the demographic, social, economic, technological and environmental aspects of a society (Davis, 1965). Natural increase, net rural-urban classification and rural-to-urban migration are the prominent components of urban population growth (Sivaramakrishnan, Kundu, & Singh, 2011). In India, even though natural growth of population in urban areas represents major cog of urban population growth; reclassification of towns/cities and net rural to urban migration have increased significantly over the years (refer figure 1) (Sivaramakrishnan, Kundu, & Singh, 2011).

Figure 2: Components of Urban Population Growth



Source: **(Sivaramakrishnan, Kundu, & Singh, 2011)**

With the expansion of urban areas and reclassification of towns, there has been a rapid growth of small cities and towns at a national level – an increase from 5,161 in 2001 to 7,935 in 2011 (Planning Commission, 2012). It is estimated that by 2030 India will have 68 cities with a population of more than one million, 13 cities with more than 4 million people and 6 megacities with populations of 10 million or more (Sankhe, et al., 2010). The increase in urban agglomerations and clusters has created various positive reinforcements in India;

- Economic Growth – The urbanisation level increased at a rate of 2.1% points during 1991 to 2001 while the economy grew at 6% per annum, whereas from 2001 to 2011 as the urbanisation level increased at a rate of 3.3%, the economy grew at 8% per annum (Ahluwalia, 2011)

- Reduction in Rural Poverty – From 1983 to1999, on an average, increase in urban population by 200,000 contributed to a decrease in rural poverty in the same district by 1.3 to 2.6 per cent points, mainly due to urban-rural economic linkages (Cali, 2013).
- Access to Opportunities – Urban areas present an investment potential that eventually provides better access to opportunities of housing, healthcare, transportation, education and recreation.

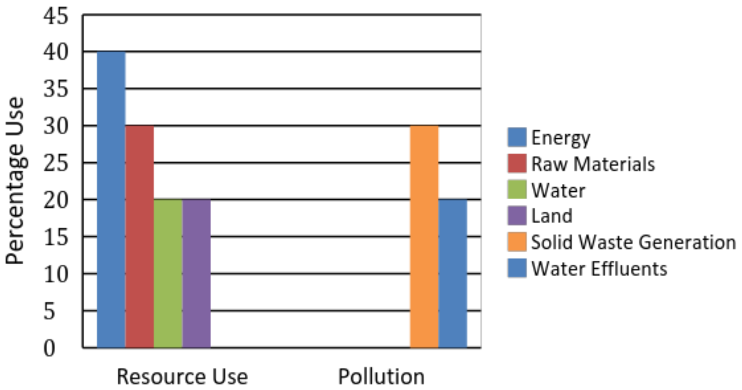
However, the urbanisation process has occurred rapidly but haphazardly vis-à-vis environmental planning. It has brought India to the forefront of an enormous socio-economic shift without adequate thought and planning for defining its environmental future. It has also led to the desperate clamour for more (better and bigger?) urban housing, increasing the housing demand and causing a frenzy of construction. Construction sector has two key segments:

I. Buildings including residential, commercial, institutional and industrial facilities; and[3]
II. Infrastructure projects such as road, rail, dams, canals, airports, power systems, telecommunication systems, urban infrastructure including water supply, sewerage, and drainage and rural infrastructure.

About two-third, i.e., 70% of India's building stock required by 2030 is yet to be built (NRDC-ASCI, 2012). The built up area demand for residential area is expected to increase four fold from 1,514 million sq.m. to 6,487 million sq.m. in the time span of 2005 to 2030 (Climate Works Foundation, 2010).

The housing sector has backward and forward linkages with as many as 260 industries, thereby boosting the economy (Rao, 2015). It is also the second largest employer after agriculture. It has a varied workforce right from construction workers to supervisors, contractors and material manufactures/suppliers.

Figure 3: Resource Use and Pollution by Buildings



Source: **(Roychowdhury, 2011)**

[3] The paper focuses on the impacts on resource use by the construction and use of buildings

However this sector is also responsible for consuming a whole range of materials that influences the resource footprint (Roychowdhury, 2011). Construction sector is a resource and energy intensive sector. Worldwide, the construction sector accounts for over 30 – 40% of the material flows (UNEP SBCI, 2009). India's construction sector is the second largest consumer of materials in the world, accounting for around 20% of all material demand (SERI, 2012). It accounts for 30% of national electricity consumption and 24% of national greenhouse gas emissions (Parikh, 2011) where cement, bricks, steel and lime accounts for 80% of the emission (Reddy, 2003). Roughly, the sector also uses 40–45% of steel, 85% of paint, 65–70% of glass, and considerable amounts of output from automotive, mining and excavation equipment industries (Planning Commission, 2012). Further, the construction of buildings alone utilises 20% of land and water each, whilst accounting for 30% of solid waste generation and 20% of water effluents (refer figure 2) (Roychowdhury, 2011). However, it is important to note that the impacts of resource consumption are not limited to a specific geographical area. Resource constraints have the potential to impact different geographies and socio-economic sections of the society.

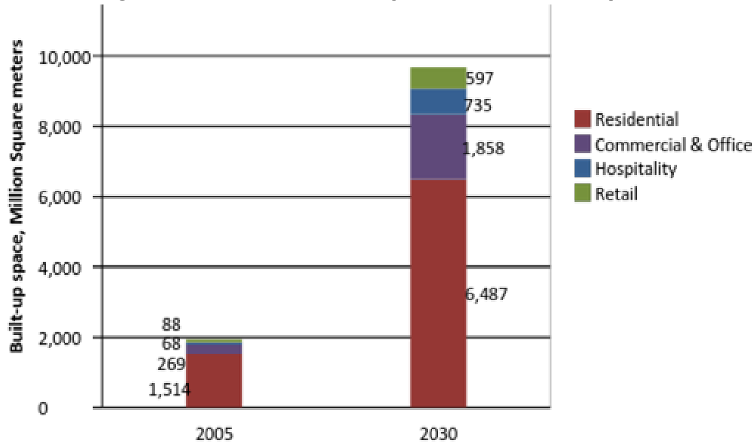
2.2. The Sector Focus

As discussed earlier in section one, there exists a housing shortage of around 19 million units in India currently, comprising of congested houses, obsolescent houses, *kutcha* houses and homelessness (MHUPA, 2012) and with the growing urban population, the affordable housing shortage is estimated to reach 38 million units by 2030 (Sankhe, et al., 2010). The existence of 'shelter poverty' due to the massive housing shortage in India is manifesting itself in the form of mushrooming of slums and pavement dwellers. Therefore development of housing projects in order to provide citizens with the basic amenity of houses is one of the greatest necessities of urban India today.

The National Government as of July 2015 announced 3 urban transformation missions that aim to revive and rejuvenate India's urban landscape. The 3 missions – Smart City, Atal Mission for Urban Transformation and Rejuvenation (AMRUT) and Housing for All by 2022 (Urban) target at 100 cities, 500 cities and 4041 statutory town respectively. The housing mission, where majority of the construction is most likely to occur, seeks to build 20 million housing unit for the Economically Weaker Sections (EWS) and Low Income Groups (LIG) over a period of 7 years, while the other two missions aim to provide core and basic infrastructure for enhanced quality of life. AMRUT aims to ensure that basic services such as water supply, sewerage facilities, septage management, transport facilities *et cetera* are provided to each household. Smart Cities Mission also looks at the applications of 'smart' solutions like access to basic services, solid waste management, transport facilities and others in a city (Ministry of Urban Development, 2015). The task at stake is enormous and the government aims to leverage on public-private partnerships to generate the funds required to fulfil the mission.

The built up area of Indian cities is expected to expand exponentially with the new construction to be several fold more than the current size of construction (refer Figure 3). As discussed in section one, it is estimated that around 1.7 to 2.0 lakh hectare of land will be required to fulfil the urban housing need alone by 2022 (KPMG, 2014). Further, construction phase of a building has significant raw material footprints, including the consumption of minerals (sand, gravel), cement, steel, bricks, aggregates, and energy use – largely

Figure 4: Demand and Projections for Built-Up Area



Source: **(Climate Works Foundation, 2010)**

depending on the size and design of a housing unit. For instance, India's proven limestone reserves will only last until 2028 taking into account future prospects for cement demand (The Indo-German Environment Partnership Programme, 2013). City development and growth would impact food security as urban areas would swallow more arable land and producing building material would place higher demands on the ecosystem[4]. The environmental impacts are expected to worsen with increasing urbanisation and housing demand. Resource implications of construction of houses goes beyond the needs and confines of urban areas, as construction is spreading in peri-urban areas and transport corridors. Such demands and requirements of natural resources such as land, minerals *et cetera* by the housing sector and quite possibly by other sectors like agriculture, industries, infrastructure *et cetera* have not been taken into consideration by the national government in the urban transformation missions.

2.3. Synergising National and Global Agendas

Urban spaces and the subsequent impacts of urbanisation are high on the global sustainability agenda. Urban areas are centres of economic and social activities. They are *change makers* (UNDP, 2012) but struggle to accommodate the rising population and address various multidimensional challenges of urban development (Sankhe, *et al*., 2010). They currently fail to decouple economic development from resource use. The current trends would leave the people and planet vulnerable to environment degradation.

The global environment has adopted a new set of goals and targets to end poverty, protect the planet and ensuring prosperity of all. The set of 17 goals and 169 targets constitute the global agenda of sustainable development. The aim behind setting these goals is to capture synergies in delivering interconnected goals of environmental, economic and social wellbeing and to strengthen the commitment towards overall sustainable development (German Development Institute, 2013). Resource requirements are linked to several goals. 12 out of 17 goals promote human development through sustainable use of natural resources. 10 goals can be achieved only by improving the consumption patterns and efficiencies of resources like land, water and energy (UNEP IRP, 2015). Recognising that cities are diverse in terms of their size, structure, spatial form, economy, wealth, local

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[4] As said by Prof K.T. Ravindran at ***trialogue*2047** – Resource Efficient Smart Cities on 29th January 2015

resources availability and ecological impact, the Sustainable Development Goals (SDGs) has a specific goal *'Making Cities and Human Settlements Inclusive, Safe, Resilient and Sustainable'*. Further the goal on *"Sustainable Consumption and Production"* implies not just consuming or producing lesser goods and services, but also adopting alternate consumption and production patterns that are less resource intensive (Thakur, 2015).

The three national missions to transform the urban landscape looked at through the lens of SDGs enable achieving the national and global targets. The synergies between the two agendas are formed organically whilst aiming to achieve quantitative targets such as access to affordable housing and basic services to all (Target 11.1 of SDG and Housing for All Mission), reducing per capita environmental impacts by waste management (Target 11.6 of SDG and AMRUT/Smart City Mission), assistance for sustainable and resilient buildings using local materials (Target 11.c of SDG and AMRUT/Smart City Mission). However dwelling deeper into the national agendas lays out the fact that there lacks a perspective towards ensuring that the basic services are provided within the capacity of the natural capital.

The SDGs present a base or platform whereby linking the environment and development in a unified sustainable development agenda, safeguarding Earth's natural capital and simultaneously ensuring human wellbeing. Synergising the universal goals with national missions for development, with time-bound quantified indicators that echo resource efficiency will help achieve the ambitious yet worthy goals and targets. However, as pointed out earlier, the Indian national missions look at providing essential benefits to communities and economic development at the value of nature. Therefore it becomes critical to explicitly recognise and achieve resource synergies across various sectors for human wellbeing and safeguarding the natural ecosystem.

3. ADDRESSING NATURAL RESOURCES

Key Message: The Indian construction sector that supports the need for housing is on the verge of becoming the largest consumer of materials in the world. Many of these materials are critical due to its limited stock and conflicting demands from various sectors and regions.

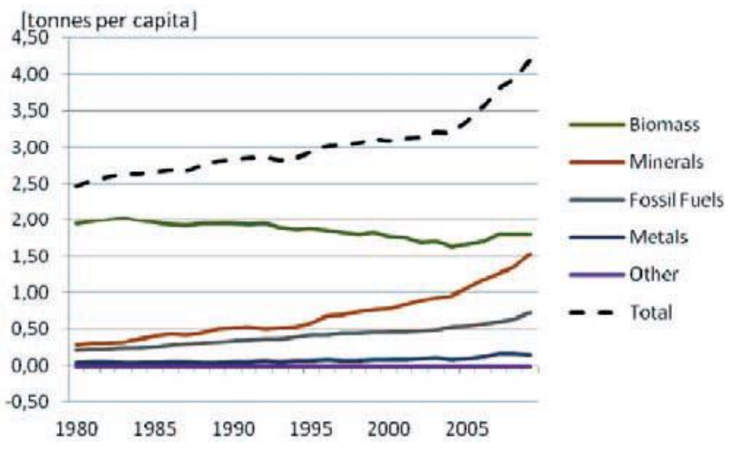
3.1. Resource Consumption

The continuous urban growth is going to swallow additional land and consume more building material to sustain this growth. This is going to place higher demands on the ecosystem and resource base. The urban building sector is the end user of energy, water and various materials and contributes to the resource footprint of cities. The overall constructed area in 2005 estimated to be around 21 billion sq. ft., is expected to grow 5 times to reach 104 billion sq. ft. by 2030 (Roychowdhury, 2011). Most of this construction is expected to be in the residential sector, demanding 63% of built up space. The production of housing is a complex ecosystem involving consumption of natural resources such as raw materials for producing building materials; water and energy both in embodied and operational phases of construction and land to build on. This sector also contributes enormously to the production of waste and emissions.

Since the past few decades the material consumption of emerging economies has seen an upward trend. Their material consumption doubled in the last 2 decades from around 10 billion tonnes in 1985 to almost 21 billion tonnes in 2005 (Dittrich, Giljum, Lutter, Polzin, & Bringezu, 2011). With large populations to cater to in India, the demand for materials has increased significantly.

India has been one of 5 largest consumers of materials in absolute terms since 1980. Its Domestic Material Consumption (DMC) has increased from 2.4 tonnes per capita in 1980 to 4.2 tonnes per capita in 2009 (Dittrich, Giljum, Lutter, Polzin, & Bringezu, 2011). Figure 6 showcases the increasing trend in per capita material consumption of India from 1980 to

Figure 5: Per Capita Consumption of Materials in India, 1980-2009



Source: **(The Indo-German Environment Partnership Programme, 2013)**

2009. While it is indicative that total consumption of materials has been increasing over the years, the consumption of minerals has increased the most during the same time period. It thus becomes absolutely essential to understand how critical the resources are and which resource administer a need to be consumed judiciously. Further consumption of construction materials like cement and steel, bricks and tiles, sands and aggregates *et cetera* is growing at the rate of 9.8% annually, accounting for nearly two third of costs (Planning Commission, 2012).

3.2. Understanding Criticality

With the urbanisation phenomenon in the country on an upward slope, the pressure to fulfil the basic needs is also increasing. Production of housing supported by the construction sector will require more of finite natural resources. In order to ensure that the planet is not irreversibly damaged, assessing the criticality of resources on the basis of the triple bottom line, i.e., economic, social and environmental viability helps understand the conflicts that may arise across various sectors like construction, agriculture, industries, ecological flow.

A framework was developed by GIZ and Development Alternatives (2015) that was applied to various natural resources, specifically raw materials to assess their criticality and identify the key resources that would need to be addressed to form resource synergies (Refer table 1). The parameters for assessment were as follows,

- Scarcity of the resource; both physical and economic
- Cost of the material and the transit / carriage
- Environmental impact due to extraction and production
- Embodied energy i.e. energy consumed while extraction, production and transport
- Supply risk i.e. political, physical, cultural, legal etc.
- Reuse and recyclability potential; secondary uses

Table 1.A: Criticality Framework for Raw Materials

Parameters → Resource ↓	Scarcity	Cost	Environmental Impact	Embodied Energy	Supply Risk	Lack of Recyclability	Opportunity Cost
Soil	**	*	***	***	**	***	***
Iron	*	**	***	***	*	*	*
Limestone	*	*	***	***	*	***	**
Sand	***	***	***	***	***	***	***
Stone	**	*	***	**	**	***	***
Marble/Granite	*	*	***	**	*	***	**
Copper	*	**	***	***	*	*	*
Bauxite (Aluminium)	*	**	***	***	*	*	*
Petroleum (PVC)	*	*	***	**	*	*	*
Silica (Glass)	*	**	***	**	*	*	*
Wood	**	**	***	**	**	**	*

Source: **(Development Alternatives, 2015)**

Sand and soil were identified as the most critical resources. This was primarily due to the associated scarcity of the resource as against the projected demand thus enhancing their supply risk. Another key distinguishing factor was the lack of reuse/recyclability potential especially compared to other resources. Thus we look at these resources in more detail.

3.2.1. Sand

Sand, a critical resource for construction, contributed 16.5% to the value of minor minerals in 2014-2015 (Ltd, 2011). In 2009-2010, India ranked 12th in sand and gravel production; 2.28 million tonnes silica sand was produced (Shrivastava, M Suchitra, Aghor, & Chakravartty, 2012). About 62% of the total sand production was from 15 silica sand mines and two associated mines that also produce other minor minerals (Indian Bureau of Mines, 2010). With majority of utilisation of sand during plastering and concreting, the demand for sand is expected to reach 1430 million tonnes by 2020 (Freedonia Group, 2013). This demand for sand continues to increase with rapid urbanisation. Excessive in-stream sand mining causes the degradation of rivers, lowering the stream bottom causing the deepening of rivers and estuaries, and the enlargement of river mouths and coastal inlets. Compounded by the effect of sea level rise, excessive sand mining is a threat to adjacent infrastructure as well (Anon., 2004). Depletion of groundwater, lesser availability of water for industrial, agricultural and drinking purposes, destruction of agricultural land, loss of employment to farm workers, threat to livelihoods and damage to roads and bridges are some of the main impacts of excessive sand mining (Saviour, 2012).

3.2.2. Soil

Soil is used in brick production, contributing 5.2% to the value of minor minerals in 2014-2015 (Ministry of Mines, 2015). As the world's 2nd largest brick producer, India annually produces around 200 billion bricks by utilising 350 million tons of top soil (Development Alternatives, 2012). One sq. ft. of carpet area with clay brick walling consumes 25.5 kg of topsoil (Autoclaved Aerated Concrete, 2011). Fertile topsoil is extracted heavily for brick production, denuding approximately 1.75 lakh sq. km. lands yearly. Unfortunately, brick kilns are mostly situated on fertile agricultural land, as there is a need for silt clay loam to silt clay soils with good drainage conditions. Urbanisation and the requirement of brick manufacturers have resulted in change in land use pattern as good agricultural land has been turned into agriculturally unproductive land. Topsoil used in brick-making have a high fertility status and their opportunity cost is also high especially when the soil/brick-earth is removed from river basins with intensive agricultural production. The removal of topsoil has direct impact on agricultural crop production via reduced fertility status of soils (Kathuria & Balasubramanian, 2013). As a result the productivity of land decreases, paving the way land and social conflicts due to increased food security concerns.

This framework was adapted to assess the criticality of water, energy and land as well. The parameters for assessment were as follows;

- Economic and physical scarcity; constraints of supply versus demand
- Environmental impact during extraction and/or production; embodied energy
- Social and cultural issues
- Conflict of use with other sectors and/or regions

- Alternative approaches available for resource efficiency

Table 1.B: Criticality Framework for Resources

Parameters→ Resources ↓	Constraints	Economic Assessment	Environmental Impact	Social Aspect	Conflicts	Alternate Available
Water	***	***	**	**	***	**
Energy	**	***	**	**	***	**
Land	***	***	**	***	***	**

Adapted From: **(Development Alternatives, 2015)**

3.2.3. Water

Another key resource in the construction sector is water, both in terms of consumption and waste. Water is consumed in huge quantities along the entire production cycle of a building – i.e., foundation laying, brick-soaking, masonry, curing, concreting, whitewashing, roofs and flooring laying *et cetera* (CSE, 2012). All these techniques demand the use of building materials and/or raw materials. Table 2 highlights the embedded water in a typical building material.

Table 2: Embedded Water in Materials

Building Material	Unit	Embedded Water (litres)
Concrete	1 kg	2000
Steel	1 kg	40
Aluminium	1 kg	88
Plastics	1 kg	185
Brick	1 cumec	300-714

Source: **(CSE, 2012)**

About 10-20% of the total volume of brick and concrete used in a building is water. It is used primarily in concrete mix for hydration of cement, thus the quality and quantity of water is critical as contaminated or excessive water can affect the lifespan of the building (Ramachandran, 2004). Curing and mixing of concrete are the most water intensive phases in the building construction process (BIS, 2005). A large part of the water used in building can be attributed to the operational phase, directly related to the lifestyle of occupants. In India 135 litre per capita per day of water is consumed for operational reasons, with highest consumption for bathing, flushing and washing (CSE, 2012). Further, leakages in old fixtures and due to aging, waning, faulty washers/handles, high pressure or corrosion leads to water loss of approximately 26,000 litres annually.

Agriculture receives the greater share of the annual water allocation in India, receiving about 80% of India's utilisable water according to the Union Ministry of Water Resources (MoWR) and the industrial sector is the 2nd highest user of water after agriculture (CSE, 2004). Further, over 80% of the domestic water supply in India is dependent on groundwater. The potential of most river basins is being exploited beyond 50% and several basins are considered to be water scarce. With demand for water rampant across various sectors, fresh water availability has dropped from 5,177 m^3 in 1951 to 1,820m^3 in 2001 (CSE, 2004). The consumption patterns of water across various sectors and regions are inefficient, leading to increasing scarcity of water. The conflicts over water are bound to increase given that water is finite and there is a lack of alternate available.

3.2.4. Energy

Construction is the fastest growing sector in India that consumes huge amount of energy. In order to manufacture building materials, this sector accounts for about 20-25% of India's total energy demand obtained by the use of conventional energy sources (P Mithra, Kuriakose, & Unnithan, 2015) and contributes to about 24% of total GHG emissions in the country (Parekh, Panda, Ganesh-Kumar, & Singh, 2009). Materials like cement, aggregate, concrete, building blocks, etc. are used in huge quantities by a building, thus being the major contributors of a building's embodied energy. Table 3 highlights embodied energy value of a few building materials, both conventional and alternate (P Mithra, Kuriakose, & Unnithan, 2015).

Table 3: Embodied Energy of Building Materials

Material	Embodied Energy (MJ/kg)
Solid Concrete Blocks	0.424
Hollow Concrete Blocks	0.564
Laterite Blocks	0.032
Burnt Clay Bricks	0.813
RMC M25	1.304
Paving Tiles	1.005
Aggregate (20mm)	0.209
Aggregate (6mm)	0.279
M Sand	0.105
Quarry Dust	0.167
OPC	7.36
PPC	4.09

Source: **(P Mithra, Kuriakose, & Unnithan, 2015)**

Energy consumption in buildings varies according to the building material as well as direct use of energy during building construction and operations phases. The direct use of energy in residential building operations is rather diverse, consuming about 116 billion units with fans and lights accounting for 34% and 28% of the consumption respectively (Roychowdhury, 2011). The commercial energy supply in India is largely dependent on fossil fuels. Coal, oil and natural gas oil accounted for 91.74% of the total primary commercial energy supply in 2011 (TERI, 2012). Furthermore while electricity is high quality, clean and efficient fuel used widely across every segment of the economy and society, the power sector causes substantial material and energy losses and pollution in the process of its generation, transmission and distribution. The total energy loss as a share of throughput energy in the electricity industry in 2009 was of the order of 78.5% (Sengupta, 2013). Besides the construction sector, industrial and agriculture sector accounts for a large share in total energy consumption. This need for energy by several sectors increases the possibility of conflicts amongst sectors along with contributing heavily to carbon emission.

3.2.5. Land

With increasing urbanisation, the land required to sustain the urban population's need for housing would increase. India has a land mass of around 1.8 million sq. km; however only 3% of this land mass has been mapped geo-physically (The Indo-German Environment Partnership Programme, 2013) and 30% of the urban population occupies only 2.3% of the geographical area (KPMG, 2014). As mentioned previously, estimates reveal that in order to fulfil the housing demand by 2022, there would be a requirement of about 1.7 to 2.0 lakh hectare of land (KPMG, 2014). With land being limited in urban spaces, the allocation of land across sectors becomes difficult. The need to fulfil all the basic needs of citizen – shelter, food, clothing *et cetera*, makes lands the most critical resources as it lays the foundation for all the sectors.

Based on both the criticality frameworks sand and soil emerged as key raw materials that need to be consumed with precaution as they have an impact along the triple bottom line and simultaneously have an alternate available. Besides these two raw materials, resources like water, energy and land also emerged critical due to high supply versus demand constraints as well as need from other sectors and regions. However, the criticality of these resources vary with agro climatic region, time, and technology and construction practices. Converting the criticality of these resources in different regions in monetary terms will also be helpful in devising mitigation strategies for future.

Options and approaches for improving resource efficiency in sectors and mitigating the pressure on resources exist. Some of the approaches include decoupling resource use from economic growth, circular economies, integrated waste management strategies, and resource substitution among others. Some of these approaches have been explained in the next section.

4. ALTERNATIVE APPROACHES

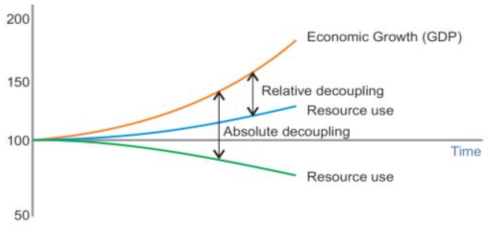
For overcoming resource conflicts across various sectors and regions developing resource substitutions and/or synergies is critical. Material consumption and subsequent natural resource extraction will increase, as the country continues to urbanise and as its vast population increasingly adopts higher-consumption lifestyles. The conventional methods of construction have been resource and energy intensive, leading to high levels of environmental degradation. However, over the years many resource synergetic options and approaches have been developed and have the potential of creating win-win situations.

These approaches promote the concept of ***Decoupling***, i.e., the discontinuance of "economic goods" from the "environmental bads". There are two types of decoupling; relative and absolute decoupling. Relative decoupling relates to "doing more with less" to reduce adverse environmental impacts while achieving higher economic activity. Absolute decoupling relates to the reduction of direct inputs such as material and energy to achieve higher economic output (Anastasiou, 2014).

Figure 7: Circular Economy

Source: **http://www.circle-economy.com/**

Figure 6: Decoupling



Source: **Raworth, 2014**

Another concept that resonates in these approaches is that of ***Circular Economy***, which suggests that the relationships between input, product and waste can be closed so that they are in a reformative state. It is similar to the concept of ***Cradle to Cradle***, which recirculates a lot of industrial production theories. The ideal state for a circular economy takes waste from factories and makes them valuable inputs for other processes and products are repaired, recycled, reused or upgraded instead of thrown away (Domenech, 2014).

These notions can be translated into the following approaches that leverage on resource synergies

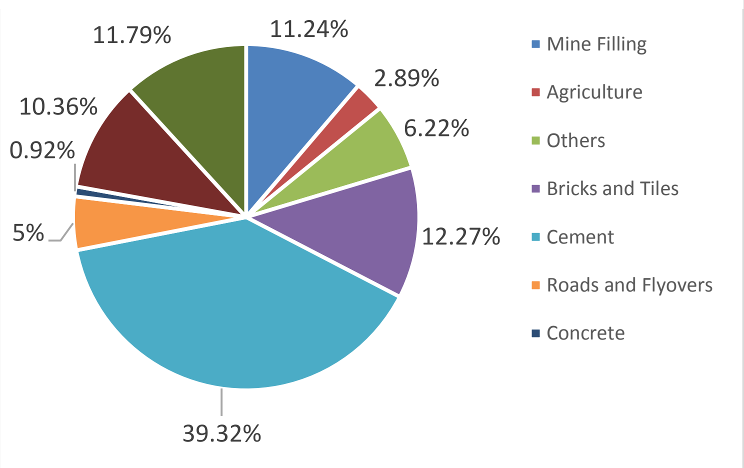
- Creating more with less
- Minimising impact on environment
- Transforming waste into resources

4.1. Resource Substitutions

There exists possibility of using fewer resources and in many cases replacing them entirely in production processes by resource substitution. The alternative approach of resource substitution ensures that the same properties as the original raw materials are maintained. If substitution possibilities are high enough, it may be optimal to suspend the extraction of a resource and adopt a production process that is sustainable – depending more heavily on renewable rather than non-renewable resources. Innovative technologies have been developed and tested that save the finite natural resources at both production and consumption ends.

In the context of depleting natural sand resources and increasing environmental concerns there are various options that substitute the use of natural river sand. Engineers and specialists developed the innovation of manufactured sand (M-sand), robot silica or sand, stone crusher dust, treated and sieved silt removed from reservoirs as well as dams besides sand from other water bodies to minimise the use of river sand (The Hindu, 2012). These are all viable alternatives as they have stable properties making it far stronger than natural sand. The cubical shape of the particles help make concrete more cohesive, perfect gradation ensures fewer voids and increases the compressive strength (The Hindu, 2013). Having balanced physical and chemical properties with no seasonal fluctuations, the alternative sand is appropriate for constructing durable buildings as well. The alternative sand is economically viable as it costs 40% lesser than natural sand and technically reliable and feasible as it as it has more clay content (The Hindu, 2013). However there is need for better pricing and taxation of sand extraction (UNEP, 2014)so that alternative approaches can be mainstreamed and promoted. In India, particularly in Bangalore and Mumbai now, almost 80 to 90% projects are being developed with M-sand, though limited to concrete, as certain properties do not qualify for plastering work. The demand for and availability of M-Sand in particular is excellent as from only 4 to 5 plants across the country there are about 1000 plant currently (Material Advantage, 2011).

Figure 8: Utilisation of Fly Ash



Source: **(Central Electricity Authority, 2014)**

Another resource that is facing severe environmental degradation is topsoil. With increasing conflicts with other sectors and region, it is somewhat imperative to adopt a substitution mechanism for topsoil. About 20 billion cubic feet of topsoil can be saved annually if the 140,000 red brick kilns shift over to using fly ash – a thermal power plant waste (residue of coal) along with reducing the amount of carbon emissions (The Hans India, 2015). As a result of the increased energy requirements of the country, fly ash generation in the country has increased massively. A 99.31 percent increase has been observed from 1947 to 2012-13 (Development Alternatives, 2015). Utilisation of fly ash in brick making will aid in the proper disposal and management of fly ash in the country. It reduces the topsoil requirement for land filling/ brick manufacturing and saves agricultural land (BMTPC, n.d.). Fly ash bricks, made in accordance with the Bureau of Indian Standards (BIS) codes and standards are 100% reliable and long lasting than normal red clay bricks. Fly ash bricks are lightweight building material with high compressive strength up to 35-350 kg/cm^2 and low absorption of heat and less porous, absorbing very little water (BIS, 2002). The strength of the bricks depends on the ratio of the raw materials. In the year 2010-2011, 131 million tons of fly ash was generated of which only 73 million tons was utilised (The Hans India, 2015). It is particularly suited for use in the construction sector with 39% of fly ash used for cement production in 2013-14 and 12% in the brick sector (Refer Figure 8). Following the notification of the Ministry of Environment, Forests and Climate Change on fly ash, if 20% of it is used for brick and tile manufacturing, approximately 23 billion bricks can be produced in the country, replacing 12% of red bricks[5].

Reuse of Construction and Demolition Waste in India

India generates huge quantities of C&D waste each year. 530 million tonnes was estimated to be generated in 2013 (CSE, 2014). However, the rate of generation of waste has increased over the years with the growth in construction sector. With India poised to become the third largest construction sector by 2018, the generation of waste is bound to increase creating problems for its management, it also presents a tremendous opportunity to promote its reuse in the construction sector.

Delhi has a pioneer in the processing and reuse of C&D waste. In collaboration with the Municipal Corporation of Delhi, a pilot project was developed by IL&FS Environmental Infrastructure & Services Ltd (IEISL) in 2010. 2000 tonnes per day of waste is collected from three designated zones of Delhi - Karolbagh, Sadar - Paharganj and City and transported to the processing facility. Aggregates are produced which are converted to Ready Mix Concrete (RMC), pavement blocks, kerbstones and concrete bricks. Another processing facility with a capacity of 500 tonnes per day has been commissioned at Shastri Park, New Delhi.

A similar initiative has been taken by the Ahmedabad Municipal Corporation. It became the second ULB after Delhi to install and operate a C&D waste recycling unit with a processing capacity of 1000 tonnes per day. This project is running on a PPP basis with Ahmedabad Enviro Projects Ltd. (AEP) since June 2014, where C&D waste is processed and recycled into aggregates. These aggregates are used to prepare finished products including paver blocks, kerbstones, concrete tiles, prefabricated structures etc. The success achieved by Delhi and Ahmedabad can be replicated in other cities as well.

Source: (Development Alternatives, 2015)

Both these approaches, though at a considerable nascent stage in terms of the potential, promote the concept of circular economy, i.e., reintegrating waste into the production system. Integrating construction and demolition (C&D) waste by reusing the processed sand and soil is another way of promoting resource substitution.

[5]Based on calculations by DA

4.2. Resource Efficiency

Resource efficiency represents an opportunity to address unsustainable pathways and help transition towards an environment that protects finite resources. By enabling the design and production of low-impact products and services, resource efficiency provides human/social wellbeing along with respecting the ecological carrying capacity of the earth. UNEP defines *resource efficiency* from a life cycle and value chain perspective – reducing the total environmental impact of production and consumption of goods and services, from raw material extraction to final use and disposal (UNEP, n.d.).

Although the Indian government does not have a consolidated approach at the apex level to promote resource efficiency, it has adopted various policy initiatives to promote the sustainable use of resources. One of the most commendable policies is the Fly Ash Notification (S.O. 763 (E)) issued by the Ministry of Environment, Forests and Climate Change (MoEF&CC) in 1999. It was further amended in 2003, 2007 and 2009. It placed restrictions on the excavation of top soil for manufacture of bricks and promotes the utilisation of fly ash for the same. According to it, all construction agencies within a radius of 100 k.m. from a coal or lignite based thermal power plant shall use only fly ash based products for construction. In line with the MoEF&CC notification, some states like Odisha, Bihar, Madhya Pradesh also promote the use of fly ash bricks in government construction around thermal power plants. Draft Municipal Solid Waste Management Rules 2015 encourages the use of recycled C&D waste products such as concrete, manufactured sand, paving blocks etc. in non-structural applications. The Sustainable Sand Mining Management Guidelines encourage the use of renewable and recycled materials like quarry dust, incinerator ash and manufactured sand (m-sand) as sand substitutes. The National Building Code (NBC) 2005 dealt with several aspects of resource conservation through appropriate design, usage and practices with regard to building materials, construction technologies, and building and plumbing services. A new chapter (Part 11) was added to the National Building Code 2005 titled 'Approach to Sustainability' looks at the life cycle concerns of building materials and advocates the use of low carbon and resource efficient sustainable alternatives. Formulation of standards for suitable alternatives by the Bureau of Indian Standards and their inclusion in the Schedule of Rates also encourages their use in public construction.

Given that buildings are among the largest resource consumers and producers in the economy, several initiatives and tools worldwide are aimed at improving its efficiency and at reducing the environmental impacts of buildings. Various tools, particularly rating mechanisms to address the water consumption and energy emission impact of builds have been developed. Internationally – BREEAM (Building Research Establishments Environmental Assessment Method) in UK, CASBEE (Comprehensive Assessment System for Building Environmental Efficiency) in Japan; and LEED (Leadership in Energy and Environmental Design) in the United States have taken a step towards accounting energy consumed during construction and operational phases.

In India, to enable the construction industry environmentally sensitive, CII-Sohrabji Godrej Green Business Centre established a tool called the Indian Green Building Council (IGBC) that encourages, builders, developers, owners, architects and consultants to design & construct green buildings, thereby enhancing the economic and environmental performance of buildings. TERI has also developed an India-specific rating system named GRIHA (Green Rating for Integrated Habitat Assessment), which was adopted as the national rating system for green or resource efficient buildings by the Government of India in 2007. GRIHA is a tool that facilitates the design, construction, and operation of green buildings, complying with which can reduce the energy consumption of a regular office building by 30%–50% (The Indo-German Environment Partnership Programme, 2013). Currently, 675 projects have been registered with GRIHA with a footprint of 25 million sq. m.

The Government of India also launched The Energy Conservation Building Code (ECBC) by the Ministry of Power as a step towards promoting energy efficiency in the building sector. However, unlike other rating systems, enforcement of ECBC has been made mandatory across the country.

Complying by these ratings and guidelines promotes water efficiency during construction. Projects that comply with GRIHA guidelines and benchmarks have registered the following improvements in performance:

- 35% reduction in quantity of potable water required
- 35% reduction in amount of waste water generated
- 15% of treated waste water used for various applications (in new buildings) (UNEP, 2012)

Besides these rating systems, there are a number of appropriate technologies especially in the brick and cement industry that have been invented and developed that ensure the energy emissions are substantially reduced. For example, the brick industry of the country mostly employs conventional techniques such as clamps and Fixed Chimney Bull's Trench Kilns (FCBTKs). These conventional technologies are highly energy intensive and resource inefficient, consuming about 35 million tonnes of coal per year (Lalchandani and Maithel, 2013) and emitting 41.6 million tonnes of CO_2 (DA, 2012). Further, adopting the use of alternate materials such as blended cements can reduce CO_2 emissions. Blended cement utilises industrial by products like fly ash, slag, and silica fume as raw material. Current concrete construction practices routinely replace up to 30% or more of the Portland cement with blended materials, the most common replacement materials being fly ash. Limestone Calcined Clay Cement (LC^3), a new type of cement that reduces CO_2 emissions by up to 30% is another way of advocating energy efficiency. The major innovation in LC^3 is that it combines the use of abundantly available low-grade kaolinite clay and 15% of limestone, with no reduction in mechanical performance. Further it is an economically viable option as it uses existing equipment, reduces clinker content and optimises the synergy between already known chemical systems.

A step towards resource efficiency can be taken by deisgning environmentally friendly building. One classic example of this is the Development Alternatives Building in New Delhi. The building replaced virgin material by using secondary raw material like fly ash and stone dust thereby reducing embodied energy by 30%. Promoting the concept of circular economy it reused the soil recovered from earlier demolished structure to make compressed earth blocks. Smart architectural designing and adopting vernacular spatial configurations save the operational energy as well. Finally, the indoor temperature range of 18^0 to 30^0 celsius, to reduce ecological footprint and innovative concepts likerain water harvesting and waste water treatment plants have been set up on site to reduce the water footprint.

In addition precast RC Planks and Joint Systems for roofing were prepared onsite, reducing cost of the construction upto 20% as well as reducing the consumption of materials. To optimize the material resources for finishing no ceiling plaster is applied and exposed brick work style is practiced with a coat of silicon treatment for imparting damp resistance and water proofing.

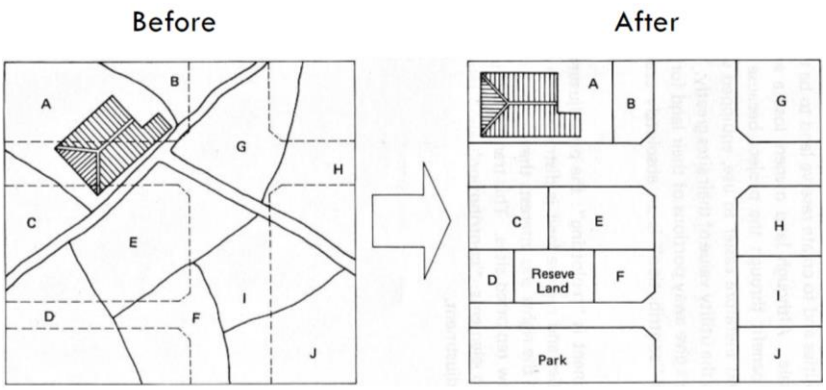
The Development Alternatives building is an example how construction of buildings can be decoupled from resource use through adoption of resource saving strategies and technologies. Such strategies have also been used in some social housing projects. The mass housing project in Bawana, Delhi is one such example. 4348 houses were constructed by Delhi State Industrial & Infrastructure Development Corporation Ltd (DSIIDC). Resource efficient materials like modular perforated clay bricks, cement fly ash sand bricks and precast planks and joists and ferrocement shelves have been used in the construction. The precast planks and joists roofing systems saved 14% steel, 27% concrete and 20% in overall costs of roofing besides savings in time.

There is a positive movement that is enabling and environment of decoupling and resource efficiency. This approach is synonymus with resource productivity and ensures multiple benefits ranging across technical, monetary, social, cultural *et cetera.* However, it is still at a nascent stage wherein support from the governement is required in order scale-up these approaches.

4.3. Multiple Use

The provision of land for housing is a key aspect of government action on housing. It can be done in several ways, and policy choices must depend on local conditions, but in one form or another, making land available is the key to improving the housing conditions of slum dwellers.Make publicly owned land available and increasing the domain to obtain private land are increasingly important given the shortage of land in urban spaces.

Figure 9: Land Pooling in Japan



Source: **(MAPC-LILP, 2011)**

The developers are increasingly going vertical to maximise their space utilisation however realty projects require horizontal development such as township projects, industrial corridors *et cetera* but face the challenge of acquiring land. Engaging and not marginalising the property owners is critical. Land pooling is an option whereby land assembly process is used for developing and redeveloping real estate. Through this process property owners work with local government or developers to reconfigure parcels for more optimal development and redevelopment in such a way number of private parcels can be put to common ownership and later reallocated to a new highest and best use (MAPC-LILP, 2011). Land pooling helps facilitate land acquisition for urban development by speeding up the development process and allow existing landowners to share the wealth generated from urban development. Figure 10 highlights an example of land pooling in Tokyo, Japan.

In India, the very first practice of land pooling was put into practice for Jamalpur area in Gujarat in 1917. This practice, extensively used in Gujarat allows land-pooling authorities to develop commonly pooled land without necessarily acquiring it. The process is a joint venture process between local/metropolitan authority and landowners, redistribute it as plots among themselves after the planning process and share the development cost. In Ahmedabad in Gujarat, 10000 hectares of land has been developed under the concept of land pooling and is being implemented all over Gujarat. Another successful example is that of the Magarpatta Township Development and Construction Company Limited (MTDCCL), where more 400 acres of land belonging to over 100 farmer families was pooled to create an integrated township (Accommodation Times New Service, 2014). The concept of land pooling is increasingly being taken up by other states in the country as well.

Another approach to ensure productivity of land is Mixed Land Use. This involves a range of complementary land uses that are located together in a balanced mix – residential development, shops, employment community and recreation. The approach promotes alternative forms of transportation such as public transport, walking and cycling that resonate sustainability (Healthy Spaces & Places, 2011). It blends a combination of residential, commercial, cultural, institutional, or industrial uses, integrating the physical and functional aspects. In India, Master Plan of Delhi (2001) allows mixed use in residential areas through retail shops, professional offices, nursing homes, banks, non-polluting household industries *et cetera* with fixed criteria/FAR specifications (DDA, 2006).

There is evidence of change towards a more resource synergetic urban development that is echoes in the above-mentioned approaches, however they are still nascent and isolated. These approaches are in consensus with the triple bottom line, balancing the economic, social and environmental viabilities. The offer a win-win solution, for example, adopting resource efficient approaches ensure that lesser inputs for more output – increasing resource productivity or multiple-use increases the value of assets. However adopting these practices on a large scale is complex as it involves various stakeholders with diverse vested interest leading to conflicts. Thus there are agents of change who can trigger this change and promoting scaling up and out of these approaches.

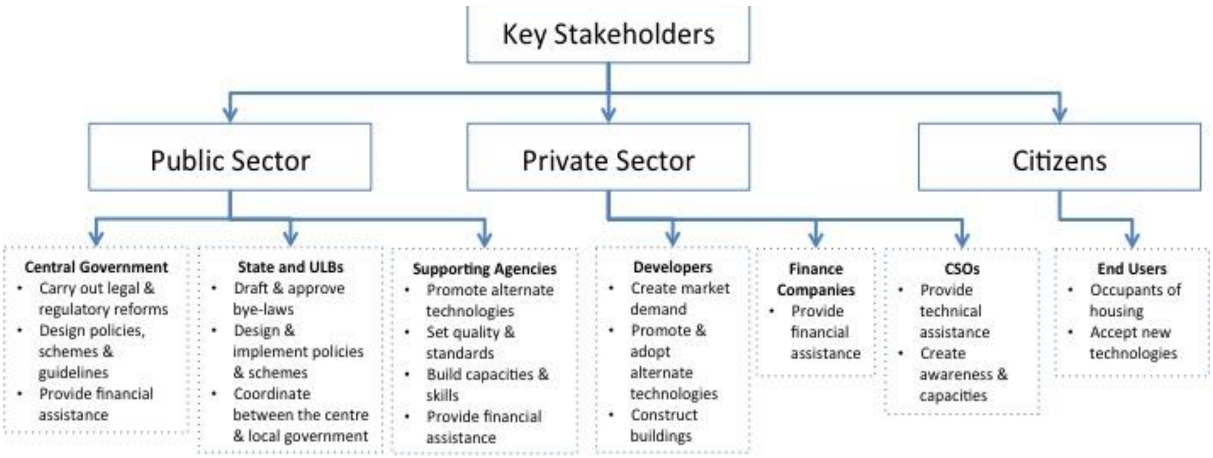
5. AGENTS OF CHANGE

Key Message: In order to mainstream the resource synergetic transitions into the policy and planning systems for urban development, specific and critical role has to be played by 3 key stakeholders; public sector, private sector and citizens.

Sustainable urbanisation entails developing perspectives at a regional level as regions are defined not only by geographic contiguity, but also by their economic, social and ecological connections and are overlapped by transportation systems, energy supply structure, water supply mechanisms, etc. In India, the thrust of demographic and economic growth is now increasingly prominent in small and medium towns. Realising the overlapping nature of urban spaces across regions and sectors, it becomes imperative to identify the role various stakeholders play in promoting the resource synergetic approaches that exist.

Planning as defined by Marcuse (Marcuse, 2006) is setting the framework for social and economic policies designed to improve the lives of people, is comprehensive if the actions of the government, private entities and the citizens are coordinated to be mutually reinforcing and not conflicting. The government traditionally plays the role of carry out legal and regulatory reforms, designing policies/schemes and providing fiscal concessions. Further they aim to create an enabling environment to ensure that the delivery mechanism of housing is strong. However it has been identified that in order to meet housing goals and implementing alternate resource synergetic approaches the government should encourage, orient and if necessary, supervise the private sector (Henshaw, 2010). This is increasingly seen in India private sector participation integral to policy frame. Furthermore, community/citizen participation to strengthen the acceptance of resource synergetic technologies is vital. Figure 10 summarises the role played by various stakeholders for the movement towards adopting resource synergetic options.

Figure 10: Role of Key Stakeholders



5.1. Public Sector

The public sector, comprising of governments at the central, state and local levels as well as supporting agencies such as Bureau of Indian Standards (BIS), Building Materials & Technology Promotion Council (BMTPC), Housing and Urban Development Corporation Limited (HUDCO) *et cetera* play a critical role in ensuring that the aforementioned approaches and strategies can be implemented at a large-scale level. It is critical to approach the public sector role in a decentralised, bottom-up manner to ensure that the policies and schemes designed are holistic and comprehensive. Involving all the stakeholders (refer figure 9) in the planning stage therefore is imperative. Division of tasks within the public sector domain may need the following structuring;

- Central Government
  The central Government's main function is to translate resource conflicts into policies that are appropriate for all stakeholders. They approve policies/schemes that have been designed through a decentralised mechanism. Providing financial assistance (incentives, benefits, etc.) and allocating funds to the state and local level governments and to various supporting agencies to carry forward their role of implementation is a key role that the central government would have to undertake. Furthermore, to ensure that there is a universal mechanism of implementation setting overarching guidelines to abide by would have to be done by the Central Government. An important criterion in these guidelines would be the inclusion of metrics and frameworks for assessing resource criticality in a region.

  Jawaharlal Nehru National Urban Renewal Mission (JnNURM) was a massive city-modernisation scheme launched by the Government of India under Ministry of Urban Development, envisaged to improve the quality of life and infrastructure in cities. The mission was carried out in a decentralised manner with the state level conducting urban planning, water supply and sanitation from the states to cities, as well as the enactment of laws for community participation and public disclosure. At the municipal level, they include the adoption of modern accounting systems, e-government, improvements in property tax collection, better cost recovery for water supply, sanitation and solid waste management, and targeting of investments of the poor.
- State and Urban Local Bodies
  The State and Urban Local Bodies (ULBs) would need to advocate that the set guidelines are met with. Setting bye-laws and regulations that make the application of these guidelines necessary would be needed. This would be undertaken at the state or local level in order to ensure that the bye-laws and regulations are contextualised to the needs of the regions. There is a distinction between the state level government and local level government. The state level government would essentially translate and contextualise the policies/schemes designed by the central government to the state level while the local bodies would adapt this to the needs of the local level. The urban local bodies implement schemes as well as create an enabling environment for practising resource synergetic approaches by proposing it in the policy or by driving the market.

- Supporting Agencies
  There are various supporting agencies that have been set by the government that are critical in the implementation mechanisms of resource synergetic approaches. While currently there may be some overlapping in the functioning of some of the agencies, it is imperative to have directive that strengthen the role of these institutional systems. Supporting agencies are the bedrock of ensuring implementation occurs swiftly. They would promote the appropriate technologies and advocate the use of resource

synergetic approaches. Further the supporting agencies would be the knowledge hubs that impart training and capacity building curriculums and ensure skill building of the workforce. Setting codes and standards for quality assurance would be done by the supporting agencies. The supporting agencies streamline the research and technical know-how into codes and standards or provide the necessary financial incentives to promote resource synergetic approaches. NHB and HUDCO provide financial assistance; CRRI, CBRI, BMTPC, DST *et cetera* provide technical assistance and BIS helps set codes and standards.

5.2. Private Sector

The private sector comprising essentially of the developers, financing companies and the civil society organisation have an increasing role in the housing sector now. They are the sector that would readily accept changes in technologies; resource use *et cetera* if provided with appropriate incentives, benefits *et cetera.* The government has to create a supporting environment for the private sector to be involved in the housing needs of the country. Setting up partnerships with the private sector to collaboratively ensure quality delivery housing is imperative. The Central policy has included private sector through the concept of PPP and craving out a stipulated role for the private sector in the 3 national missions.

- Developers
  The developers form the foundation by creating the market demand for resource synergetic options and accepting the alternate approaches. Enticed to use resource synergetic approaches, adopt appropriate technologies and build capacities through incentives, subsidies, benefits *et cetera* by the government; the developers would be able to scale up and mainstream alternate approaches across the life-cycle of housing. The developers supply the market and thereby influence and drive the demand for resource synergetic approaches.

- Financing Companies
  The inadequate acceptance of resource efficient solutions emerges from the fact that financing options for the developers are poor and it is complicated due to the small size of loan demanded by most developers, entrepreneurs, etc. Strengthening the financing options for both the producers and consumers of resource synergetic solutions is imperative through innovative models. A decentralised mechanism that provides support along entire ecosystem through incentives, subsidies, benefits, etc. would need to be developed. This would create an impetus to the market and allow a holistic environment for accepting and demanding loans. Since the 1980s, the financing companies have mainstreamed various financing options to the high and medium incomes group, however affordable housing financing still remains weak.

- Civil Society Organisations

5.3. Civil Society Organisations

The civil society organisations are largest promoters of resource synergetic approaches. They perform the role of conducting extensive research and generating awareness regarding alternate approaches. Through various functions such as conducting workshops, consultations, interaction with public and private sector player *et cetera,* CSOs play a role in disseminating knowledge and technical know-hows to a wider audience. A critical step that would need to be taken would be to develop partnerships with these organisations to advocate their findings.

5.4. Citizens

The citizens are the most important stakeholders in the entire housing ecosystem. Involving their desires and needs in the planning and implementation mechanism is critical. Community participation does not occur by chance but has to be embedded in the implementation mechanism and have to be at an acceptable level to other stakeholders. It is vital to build capacities of the citizens and generate awareness amongst them to fully integrate them in the implementation mechanism. Citizens are the tools through which local level influence can be directed to project design, influencing public policies and choices, and holding public institutions accountable for the goods and services they provide (Thwala & Aigbavboa, 2011).

6. Conclusion

The growth of Indian construction sector has been fuelled by the emerging wave of urbanisation in the last decade and increasing housing and infrastructure needs. It is poised to become the world's third largest construction sector by 2018. This can be roughly translated to a five times increase in the floor area by 2030. These growth trends have created huge demand for infrastructure, housing, and other goods and services leading to larger pressure on finite resources. The resource constraint and conflict factors that were raised (i.e. raw materials, energy, and water) are exacerbated by broader global changes such as rapid urbanisation and changes in economy and fuelled by climate change effects. However, urban areas have the potential of delivering cost-effective policy responses to ensure resource synergies as they are the hubs of innovation that can promote clean energy systems, spatial development and waste management strategies.

Synergies between different resources must be identified to overcome resource conflicts across different sectors and regions. The traditional methods of construction have been resource and energy intensive, leading to high levels of environmental degradation. However, over the years many resource-synergetic options and approaches have been developed and have the potential of mitigating the pressure on natural resources by decoupling. Some of the approaches include resource substitution, multiple uses, use of secondary raw materials among others. Yet there is limited spontaneous adoption of these options and approaches beyond the isolated oasis of good practices. However, these approaches have the potential to be scaled up.

However adopting these approaches on a large scale is complex as it involves various stakeholders. Therefore, multi-stakeholder action is required to achieve this transition. It is essential to define the roles and responsibilities of all the relevant stakeholders to scale-up these approaches. It is also essential to customise them to different regions, context and scenarios.

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