

An Unperceived Unsustainable Predicament: Zero-Energy to High-Energy Rural Habitation Transitions

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ABSTRACT: Progressive countries like India and China house nearly 1/3rd of total humanity, each with nearly 70% of predominant rural population. While the urban (and industrial) sectors in these countries are primarily responsible for most of the energy consumption (and CO₂ emissions) and pollution, the extent of such contributions from rural habitations is unclear.

Thus far, rural habitations have adopted climate-responsive building practices relying on local resources (with minimum embodied energy) and energy (for comfort and quality of life). These habitations, many of which can actually be called zero-energy, hold potential answers to enable transition from high-energy urban habitations to zero/low energy habitations. With increasing access to modern amenities (television, mobile phones, internet), rural habitations now aspire for a quality of life (and habitation) akin to urban areas. These aspirations are resulting in transitions from local-resource dependent habitations' to non-local resource based high-energy urban-style habitations.

This paper discusses one such transition-study in the context of a tribal village in West Bengal (India). These transitions are resulting in the habitations becoming increasingly unsuited to the local climatic conditions with increasing discomfort, ill-health, CO₂ emissions and environmental disruption. An attempt has also been made to simulate the like consequences of such transitions in India. Preliminary results and discussions of this study have been presented in this paper.

Keywords: urban and rural, habitations, sustainable habitations, CO₂ emissions, zero-energy, modelling and simulation

1. INTRODUCTION

Buildings alone are responsible for nearly 40% of energy use (and consequent CO₂ contribution) in most countries. In India and China the perceived contribution of buildings' to total emissions is in excess of 15% each [1]. The authors' contend that these values do not represent the entire

spectrum of buildings, viz., *urban and rural*, but is rather limited primarily to urban (and industrial) settlements. WBCSD also states that 'Rural versus Urban attributes are important' [1]. The scope of this paper is limited to habitations alone, both urban and rural.

With increasing awareness on energy efficient low-embodied energy buildings,

urban habitations are in a transition towards green buildings, albeit reluctantly. Rural habitations, in India and China have thus far lived off the land with very negligible demands on energy and process-materials for sustenance. But, with the booming economy, increased affordability and exposure to urban lifestyles, the aspirations of rural habitations is akin to middle-income urbanites (Fig. 1). As habitations respond to the aspirations of its inhabitants [2], a transition is evident from traditional local-materials based buildings to urban non-local high-process material based buildings, viz., *zero-energy to high-energy*. It is important to note that India and China, both carry a rural population of nearly 1.7 billion accounting for nearly 70% of total population. With a swelling housing shortage of (1991) 18.5 million in India [3], carrying urban aspirations, the demands (and consequences) of the entire building industry is likely to result in an unperceived unsustainable predicament. This paper raises this debate, with a case-study of a tribal habitation in transition. It concludes with preliminary results of a simulation model.



Figure 1: Rural India matches urban spending pattern (News Clip: The Times of India, Feb 2, 2008)

2. SUSTAINABLE HABITATIONS

Sustainable habitations comprise living-environments with an ability to sustain a healthy society indefinitely (over generations). A living environment

comprises the built- and natural-environment. The nature of systemic interactions between the built- and natural-environments determines the state of the environment that sustains life (and there by sustainability) [4]. The Hannover 2000 Principles lists a comprehensive ideology for a sustainable living environment.

Given the diversity in living environments, viz., climate, geography, cultures, perceptions, etc., it is however clear that there are no universal solutions for a sustainable habitation. But, it is nevertheless accepted that all habitations, however small or large, must contribute to global sustainability at large.

Recent ideologies of a sustainable habitation, though currently limited to the urban settlements, are zero-energy and low-carbon/ecological footprint habitations. Zero-energy in the context of modern buildings represent buildings that generate and satisfy their own energy requirements. On the other hand zero-energy in the context of tribal habitations requires no energy, whatsoever, at all. Carbon/ecological footprint is an assessment of the global environmental (geographical) coverage attributed to habitation resource and energy demands. Another current approach to a sustainable living is *The 100-Mile Diet* [5] wherein the community resolves to sustain on food available within 100 miles of their habitation. This is primarily to reduce the fuel consumption involved in transporting exotic consumables from distant places.

There are five modes of energy consumption attributed to buildings, viz., embodied energy, energy for transport (grey energy), energy for construction (induced energy), energy for O & M, and finally energy for the demolition and recycling/disposal [6]. India and China are among the six countries identified by the World Bank as the largest emitters of CO₂, with India's contribution being 5%.

2.2 Sustainability Assessment

Assessing sustainability is crucial to evaluate the state of a habitation and also to determine the direction of progress. An integrated approach is crucial. The sustainability of habitations can be evaluated through the shelters that comprise them. Shelters evolve in response to the community's (behavioural) needs and the local environment (and climate). Changing needs of the community result in alterations reflected as transitions in the shelters. An integrated sustainability assessment of these habitation-transitions can be studied through three broad parameters:

1. Comfort and Climate-responsiveness
2. Environmental impact
3. Integrated socio-environmental life-cycle study

Each of these parameters are generic and can involve complex analysis and evaluation of indicators.

2.3 India – Urban vs. Rural

The following table illustrates the life-style traits characterizing urban vs. rural habitations in India. In the context of this paper, it must however be stressed that these are lifestyle traits associated with shelters' and associated activities in a habitation.

Table 1: Urban vs. Rural shelter traits

Trait	Urban	Rural
Population	33 %	67%
Income	surplus	meager
Construction and materials	mechanised and exotic high-process materials	local skills and local resources
Affordability	very high	low
Leisure	sedentary – high-energy	active - outdoor
Earnings in life	very high	low
CO ₂ /ecological footprint	very high	negligible
Community integrity	fragmented	inclusive

Given the extreme diversity in the nature of habitations in India, the traits mentioned in the above table have only been evaluated on a subjective scale. A more objective (measureable) evaluation can be part of a much larger research study.

3. URBAN TRANSITIONS

Globally, urban habitations consume excessively high energy, water, food and other resources. Consequently they are also chiefly responsible for the socio-economic disparity, ill-health, pollution and environmental disruption globally. Buildings alone account for in-excess of 40% of resource-use, including energy (and CO₂ emissions). Progress, which a decade back was assessed, based on the quantity of cement consumption is currently an indicator of contribution to global warming.

Green buildings are the new paradigm, with energy efficiency, low-embodied energy, low-carbon building materials and environmental conducive designs being the new mantra. The WBCSD identifies buildings as one of the five main users of energy where megatrends are needed to transform energy efficiency to reduce CO₂ emissions.

While there is significant awareness in this direction, there is a reluctant adoption of green buildings (India: 64% Aware; 13% Consider; 5% Involve) [1]. The number of green buildings with USGBC's LEED rating in India is still in single digits.

4. RURAL TRANSITIONS

Rural habitations account for nearly 70% of India's population, with an increasing housing shortage of 18.5 million [3]. Rural habitations have predominantly evolved over time adopting local-materials and skills in response to prevalent climatic and environmental conditions. Most settlements are scattered and until the past few decades lacked grid-power supply and hence were sustaining on local energy sources, primarily

firewood. The building materials adopted required very little processing and the actual construction was a community-involved activity. With the booming economy, increased affordability and increasing exposure to urban lifestyles', both in India and China, the average rural household now earns for an urban-like lifestyle. This has also been reinforced by government housing programmes which specify adoption of cement and steel intensive construction. Such practices dissuade the use of local materials and skills. Further, government supported schemes of subsidised (often free) power supply and widespread distribution of TV sets is also strengthening the earning for an urban-like lifestyle. In response to this, rural (and tribal) habitations are now exhibiting a strong transition towards urban-like high-process material dependent, climatically un-responsive shelters (thereby further increasing the demand for power to provide for building comfort).

The extent of the resulting impact of these transitions on global CO₂ contribution and resource consumption still remains unperceived. The following sections discuss a case-study of a transition in a tribal village in West-Bengal and results of a simulation model to forecast the nature of CO₂ contributions attributed to urban and rural transitions.

5. MODERN RURAL TRANSITIONS

This section presents an integrated sustainability assessment into earthen dwellings in a tribal village *Banskuti* in west Medinipur district in west-Bengal, India. These earthen structures have evolved over generations in response to local climatic and environmental conditions. All the building materials used are locally procured, which include thatch, earth and bamboo (Fig. 2). The shelters exhibited ideal passive-solar adaptations to extreme climates, exhibiting little variations in indoor temperature even as external temperatures fluctuated significantly (winters reaching as low as 3°C

and summers a scorching 45°C). The shelters' were studied for their climatic-responsiveness, comfort and clothing, ecological footprint and integrated life-cycle assessment [7].



Figure 2: Traditional Two-Storied Tribal Shelter (earthen walls, thatch roof)

The average monthly income of a single family average Rs. 1,500 – 2,500 (1 \$ USD = 42 Rs.). 80 % of the tribal community is involved in agriculture. Other economic activities include fishing, basket-weaving and making plates from Sal leaves.

Over the past decade transitions in their shelters attributed to improved economic viability is apparent, primarily in the building materials adopted (form still remaining the same). The transitions can be observed in three progressive phases, viz., Phase 1 involves the replacement of traditional thatch roof by either a corrugated asbestos or tin roof (Fig. 3); Phase 2 involves adoption of burnt-brick (procured from nearby town) wall with mud mortar replacing the traditional earthen walls (Fig. 4); Phase 3 involves a total transition into burnt-brick walls with cement mortar and corrugated tin roof (Fig. 5). Thus far significant alterations in the basic form of the shelter have not been observed, though that is expected to be the next phase. Monto et. al [7] provides a more detailed documentation of this study.



Figure 3: Transition Phase 1: tribal shelter with tin roof (replacing thatch roof)



Figure 4: Transition Phase 2: tribal shelter with burnt-brick walls in mud mortar (replacing earthen walls)



Figure 5: Transition Phase 3: tribal shelter with burnt-brick walls in cement mortar and tin roof (replacing earthen walls and thatch roof)

The resulting alteration in life-cycle assessment and ecological footprint resulting from such transitions is presented in Table 2 below.

Table 2: Life-cycle Assessment between traditional shelters and modern transitions

Env. Impact	Units	Traditional Habitation	Transition Phase 3
Acidification	Mg H+	0.00E+00	7.12E+05
Air	microDALY	0.00E+00	2.97E+02
Pollutants			
Global warming	g CO ₂	0.00E+00	2.09E+06
Smog	g NO _x	0.00E+00	8.22E+03
Ecological footprint	Global hectares	5.00E-01	1.30E+00

Besides, a unanimous response of increasing discomfort, both during winters and summers, the tribal community is still inclined towards further effecting modern (unsustainable) transitions.

6. SIMULATION AND FORECASTING

A simulation model has been developed to forecast the impact of urban and rural transitions in habitations on the CO₂ emissions in India. The variables considered for the simulation included the behavioural traits [both in urban and rural habitations towards their preference for low-energy shelters, conventional urban (high-energy) shelters] affordability and economic boom, number of low-carbon shelters, number of conventional shelters, current CO₂ emissions, resource scarcity, rising oil-prices, threat of climate-change and environmental destruction.

The simulation-model has been developed using Cross Impact Analysis, a powerful systems forecasting tool, wherein a system is characterised into sub-systems, entities and variables. System interactions are effected by entities through their variables and captured in the Cross Impact Analysis as pair-wise direct interactions [8].

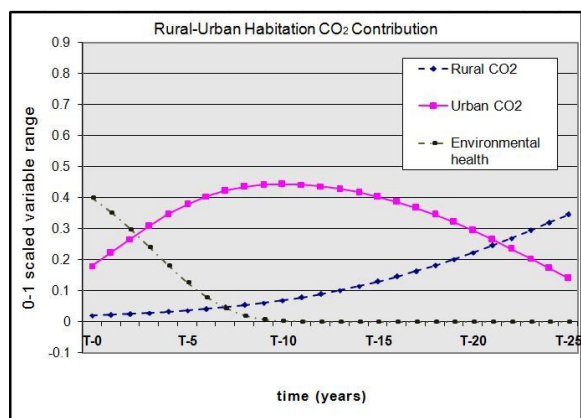


Figure 6: Simulation result – rural vs. urban habitation CO₂ contribution

Figure 6 illustrates a preliminary result of the model-simulation for base-case scenario. It is possible to discern the unsustainable predicament that is likely to occur, i.e., in a little over the next two decades, despite the eventual reduction in urban CO₂ emissions due to wide-spread adoption of low-energy building practises, rural CO₂ contribution attributed to modern transitions is likely to exceed urban CO₂ contributions. In our strife to make urban transitions sustainable, the unsustainable predicament in rural habitations may remain unperceived.

7. CONCLUSION

The paper attempts to draw attention to an unperceived unsustainable predicament attributed to modern transitions in rural habitations. Current high levels of CO₂ emissions can be attributed primarily to urban habitations. While these are resulting in urban transitions towards low-energy green buildings, the same may not hold true for rural habitations. Rural habitations comprising nearly 70% of India's population, originally zero-energy, are now aspiring for an urban-like lifestyle. This can effect a slow but momentous increase in CO₂ emissions that can surpass urban emissions in a little over two decades. Preliminary results of a simulation-model indicate this likely predicament. The paper

attempts to draw global attention towards transitions occurring in a significant portion of rural habitations, that if unchecked, can make all low-energy green efforts in urban areas superfluous.

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