



**Sustainable Buildings
and Climate Initiative**

Promoting Policies and Practices for Sustainability

THE 'STATE OF PLAY' OF SUSTAINABLE BUILDINGS IN INDIA

UNITED NATIONS ENVIRONMENT PROGRAMME



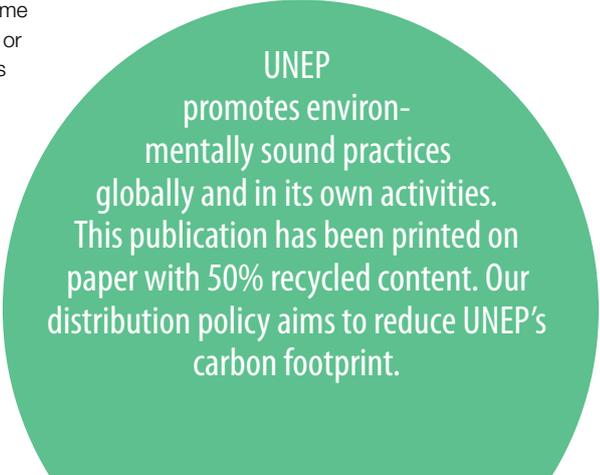
Copyright © United Nations Environment Programme, 2010

This publication may be reproduced in whole or in part and in any form for educational or non-profit purposes without special permission from the copyright holder, provided acknowledgement of the source is made. UNEP would appreciate receiving a copy of any publication that uses this publication as a source.

No use of this publication may be made for resale or for any other commercial purpose whatsoever without prior permission in writing from the United Nations Environment Programme.

Disclaimer

The designations employed and the presentation of the material in this publication do not imply the expression of any opinion whatsoever on the part of the United Nations Environment Programme concerning the legal status of any country, territory, city or area or of its authorities, or concerning delimitation of its frontiers or boundaries. Moreover, the views expressed do not necessarily represent the decision or the stated policy of the United Nations Environment Programme, nor does citing of trade names or commercial processes constitute endorsement.



UNEP
promotes environ-
mentally sound practices
globally and in its own activities.
This publication has been printed on
paper with 50% recycled content. Our
distribution policy aims to reduce UNEP's
carbon footprint.



THE 'STATE OF PLAY' OF SUSTAINABLE BUILDINGS IN INDIA



**UNEP DTIE
Sustainable Consumption &
Production Branch**

15 Rue de Milan
75441 Paris CEDEX 09, France
Tel: +33 1 4437 1450
Fax: +33 1 4437 1474
E-mail: unep.tie@unep.org
www.unep.fr/scp/sun



**Sustainable Buildings
and Climate Initiative**

Promoting Policies and Practices for Sustainability

UNEP SBCI

E-mail: sbci@unep.org
www.unep.org/sbci

Table of Contents

Acknowledgements	3
Executive Summary	3
Vernacular Building	4
Green Building	5
Energy Efficient Building	5
‘State of Play’ of Sustainable Buildings in India*	6
Introduction	7
1. Vernacular Schools of Thought	9
1.1 Mera Wala Green	9
1.2 Sri Aurobindo Society (SAS) School of Thought	14
1.3 Sustainable Communities	16
1.4 Solar Model for Green Buildings	19
1.5 Replication and Way Forward	21
2. Green Buildings	22
2.1 Green Rating for Integrated Habitat Assessment (GRIHA)	23
2.2 Leadership in Energy and Environment Design (LEED)	25
2.3 Replication and way forward	28
3. Energy Efficient Buildings	30
3.1 Energy Conservation Building Code 2007	30
3.2 Energy Star Rating of Office Buildings	32
4. A Way Forward	34
Incorporating Sustainable and Green Building Design Parameters in the Indian Building Sector	34
5. Conclusion	37
6. Notes and References	38

* Note: The ‘State of Play of Sustainable Buildings in India’ section has been prepared by UNEP-SBCI and does not necessarily represent the views of TERI.

About The Energy and Resources Institute (TERI):

A dynamic and flexible organization with a global vision and a local focus, TERI was established in 1974. While in the initial period the focus was mainly on documentation and information dissemination activities, research activities in the fields of energy, environment and sustainable development were initiated towards the end of 1982. The genesis of these activities lay in TERI’s firm belief that efficient utilization of energy, sustainable use of natural resources, large-scale adoption of renewable energy technologies and reduction of all forms of waste would move the process of development towards the goal of sustainability.

All activities in TERI move from formulating local and national level strategies to suggesting global solutions to critical energy and environment-related issues. It is with this purpose that TERI has established regional centres in Bangalore, Goa, and Guwahati, and a presence in Japan, Malaysia, Russia, Africa and the United Arab Emirates. It has also set up affiliate institutes: TERI-NA (The Energy and Resources Institute, North America) Washington DC, USA, and TERI-Europe in London, UK.



Acknowledgements

Author: Ms. Priyanka Kochhar, Associate Fellow and Area Convenor, Centre for Research on Sustainable Building Science, TERI

The author would like to thank Ms. Mili Majumdar, Dr. Hina Zia, Ms. Pooja Shukla, Mr. Apoorv Vij, Mr. Tarun Garg, Ms. Sonam Shah, Mr. Gaurav Shorey from TERI; and Dr. Peter Graham from University of New South Wales for their valuable comments, suggestions and inputs in the research. The author would also like to thank Mr. Dharmender Singh for secretarial assistance. The information presented in the paper emerged from inputs shared by: Abhikram: Mr. Nimesh Patel and Ms. Parul Zaveri; Footprints EARTH: Mr. Yatin Pandya; Jaisem Foundation: Prof. A. R. Jaisem; Good Earth: Mr. Jeeth lype; Sri Aurobindo Society: Mr. Jatin Lad and Ms. Trupti Doshi; Ashok B Lall Architects: Prof. Ashok B Lall; Bureau of Energy Efficiency: Mr. Sanjay Seth; Shri S P Gon Choudhari, Dr. Arvind Krishan

The viewpoints expressed in the paper are of the author and do not necessarily reflect the views of the institute. The author is solely responsible for any inadvertent errors in the paper.

Design / layout: Thad Mermer

Executive Summary

The Indian construction industry is experiencing a fast rate of growth with a sustained increase in gross built-up area of 10%¹ per annum over the last decade. Demand for housing, expansion of organized retail, commercial office spaces by multi-nationals, the setting up of special economic zones (SEZs), are all increasing. This is spurred on by increasing per capita income and standard of living.

Energy consumption and associated greenhouse gas emissions will therefore continue to rise unless actions to direct the construction industry towards sustainable consumption and production are taken urgently.

More positively, the practice of green building is becoming more popular in some sectors. The secretariat of India's bespoke green-building rating scheme Green Rating for Integrated Habitat Assessment (GRIHA) has set a target for five million square meters of built up space to be GRIHA compliant by the end of 2012. Further, the Indian Green Building Council also targets to register ninety three million square meters of built up space with LEED India. While important, this alone will not be enough to mainstream sustainable design and construction practices in India. Achieving this requires:

- Bridging the knowledge gap on sustainable building strategies, which exists at various levels within the industry;
- Enforcing implementation of strategies to encourage adoption of sustainable, green and energy efficient buildings; and
- Conducting research and development on technology for lowering costs.

Support and cooperation between all the players of the sector is required. The immediate actions to be considered include:

- Development of a national platform to project individual efforts and exhibit financial benefits of sustainable buildings;
- Undertaking extensive capacity-building

- at various levels, including construction of demonstration projects across the country;
- Developing a business model to provide a further impetus to initiatives to minimize the detrimental impacts of construction on the environment and society;
- Introducing a green rating for residential developments and directing real estate developers to adopt this; and
- Developing, enforcing and implementing sustainability performance benchmarking for industry sectors.

This report on the 'State of Play' provides a representative understanding of sustainable building activity in India, which has a unique traditional knowledge, and is a developing country in terms of the modern world. The report explains the state of sustainable buildings and construction in India including best practices, successes, barriers and recommendations for further implementation towards mitigation of climate change impacts.

Considering the wide diversity that exists in the building typology across India, issues and concerns range from addressing low cost, low energy buildings to high cost high energy buildings through various income groups and climatic zones of the country. The following report has been structured to address the various schemes (i.e. government codes, strategies, policies vernacular and other institutional schools of thought) that co-exist to direct building construction towards a minimum detrimental impact on the environment. Various case studies have been used to explain the indicators of 'sustainability issues' with an emphasis on life cycle and actual performance of buildings.

Seven case-studies of institutional and residential buildings in three prominent climatic zones of India, namely composite, warm-humid and hot-dry, have also been studied. Based on the good practice compliance of buildings, information received and information available in public domain, the case studies from representative climate zones have been identified for the purpose of this study.

The following four approaches, which have been endorsed by prominent practitioners in the field of

sustainable and green building design, government bodies, government agencies and private bodies for voluntary adoption by relevant stakeholders, have been taken up for discussion in the report:

1. Vernacular schools of thought
2. Green ratings for green buildings
3. The Energy Conservation Building Code (ECBC)
4. Scheme for star rating of office buildings

These four approaches are described through case-studies which are representative of the 'state of play' for sustainable building in India.

VERNACULAR BUILDING

Vernacular schools of building design are deeply embedded in the traditional wisdom that offered beauty and joy to enhance the cultural milieu of India's built environment. As reflected through the various case studies, each project addresses an integrated approach to design with a special emphasis on climatology, solar passive architecture, bio-climatic design and low energy architecture to achieve appropriate human comfort, low-energy low-cost community development, use of recycled municipal/domestic waste as building material; and a financial model that may be implemented for successful promotion of sustainable building design principles respectively.

The following case studies have been used to further explain the vernacular schools of building design that exists in various parts of India.

1. Torrent Research Centre, Ahmedabad to represent the *Mera Wala* green school of thought;
2. *Sharanam*- a purpose-built training centre for rural development, Tamil Nadu to represent the Sri Aurobindo Society school of thought;
3. *Manav Sadhna* Activity Centre, Ahmedabad to reflect the sustainable community school of thought; and
4. Solar Housing Complex (*Rabirashmi Abasan*), Kolkatta to represent a financially sustainable model for green buildings.

The vernacular schools of thought as described through the various case studies, reflect the specific sustainability priorities, which have been established in specific regions of the country. While 'mera wala green' seeks to establish common sense solutions with emphasis on Indian 'needs' from local solutions in terms of material use and traditional wisdom; *Sharanam* emphasizes on adopting an integral approach towards development with a special focus on the socio-economic and skill development dimension.

Manav Sadhna Activity Centre demonstrates that a building can become an economic activity to empower the poor and exhibits a potential for becoming a cottage industry for economic self-reliance. With emphasis on the socio-economic aspects of sustainable building design, this vernacular school of thought reiterates the holistic approach followed for sustainable buildings in India. Taking this a step further, the Solar Housing Complex focuses on the financial aspect of sustainability that may be replicated on a larger scale.

In circumstances where it is not possible to address all aspects of sustainable design, environmental and economic concerns take priority in order to direct building construction towards green design. Green rating of buildings as described below encourages adoption of green design strategies rather than a more holistic sustainability approach.

GREEN BUILDING

There are two prominent green rating systems that co-exist in India. One system, Green Rating for Integrated Habitat Assessment (GRIHA), is the national rating system for the country endorsed by the Ministry of New & Renewable Energy (MNRE), Government of India. Another system, Leadership in Energy and Environment Design (LEED), has been launched by the India Green Building Council (IGBC). The Centre for Environmental Sciences and Engineering at IIT Kanpur, the first GRIHA compliant building of India, and the Institute for Rural Research and Development (IRRAD), Gurgaon, which is a LEED India compliant building have been used as case studies to highlight the nuances of the two green rating systems.

Both green rating systems aim to quantify the environmental, economic and socio-economic benefits of green building design with emphasis on sustainable site planning, optimized energy performance, efficient materials and construction practices, water and waste management strategies; and indoor environmental quality. The rating systems also emphasize life cycle cost analysis so that the client has an option of making informed choices when opting for green technologies which may have an initial incremental cost with acceptable pay back periods.

ENERGY EFFICIENT BUILDING

In case it is not feasible for a given building project to be compliant with the green rating system, energy efficiency is addressed as the next major sustainability parameter to be addressed. The Bureau of Energy Efficiency (BEE) provides an option for new buildings to be compliant with the Energy Conservation Building Code (ECBC), which contributes to significant energy savings through the operation of an efficient building, contributing to CO₂ emission reduction. The Fortis hospital building, which is ECBC compliant, indicates the implications in terms of building specifications and benefits from compliance with the code.

Further, the BEE has also developed a scheme for star rating of existing buildings that meet the energy efficiency benchmarks as established, to further narrow the parameters of sustainability in building design. As discussed in this report, the Reserve Bank of India (RBI) building at Bhuvneshwar has been awarded the first five star rating for being energy efficient.

The report goes on to describe the key barriers and way forward for incorporation of sustainable, green and energy efficient building design parameters in the Indian building sector. It provides an outline of the knowledge gap at various levels, issues pertaining to lack of effective enforcement of policies; and lack of financial incentives, which deter stakeholders from large scale adoption of sustainable design strategies and energy efficient technologies.

‘STATE OF PLAY’ OF SUSTAINABLE BUILDINGS IN INDIA

Sustainability Challenges for the Indian Building Sector

India has one of the fastest growing construction sectors in the world. New construction spending has grown by as much as 10% in the last five years² and built floor area has more than doubled. This increase in construction activity is being driven by rapid urbanization. About 30% of India's 221.1 million households are now in urban areas with the urban population projected to more than double by 2050³.

Demand for commercial building has also increased dramatically, fueled by a boom in the services sector which has been estimated to have added 53% to the value of GDP in 2008 alone. The amount of built office space is projected to increase from approximately 200 million m² in 2009 to 890 million m² by 2030, an increase of more than 70%⁴. (The figure in the Eco-III report is 870 million m²; however these are different from the commercial built up rates projected in the BCC project).

Many new office buildings import typical glass-curtain wall design which increase demand for mechanical cooling in India's predominantly warm climate. Recent studies of the energy performance of commercial buildings in India indicate that energy efficiency is poor by international standards, which has the effect of locking Indian cities in to in-efficient and potentially uncompetitive building stock for decades (TERI in GEA).

Unchecked, greenhouse gas emissions from electricity used in existing buildings alone could increase by 247% by 2050. If the energy-efficiency of new-buildings constructed over the same period are not improved, the total electricity related emissions from buildings could be more than 390% higher than current levels⁵. Green house gas emissions associated with building material

manufacturing are also likely to spike over the next decade, increasing the need to consider lower embodied energy approaches to construction.

Energy demand is also increasing in rural India where programs are underway to bring electricity to the more than 400 million people that lack access to basic energy services. Providing such basic services to all of its citizens will require a 3 to 4 fold increase in primary energy supply and a 5 to 6 fold increase in electricity generation over 2005 capacity by 2030⁶.

Such factors contributed to the building sectors proportion of total national commercial energy consumption rising from 14% in the 1970's to approximately 33% by 2005, an increase in energy use in buildings of approximately 8% per year. Given that 55% of India's electricity is generated from coal-fired power plants, the energy performance of buildings is an increasingly significant factor in national greenhouse gas emissions⁷.

These issues are being addressed by policy makers. As Section 4 describes the new ECBC and BEE programs aim to deliver significant operating energy efficiency gains from India's commercial building sector. Full implementation of the Energy Conservation Building Code for example could reduce energy consumption in new commercial buildings by 25-40%. Further potential energy savings of 25% could be achieved with cost-effective retrofitting of existing commercial buildings⁸.

Indian cities are among the worlds most vulnerable to impacts of climate change. Given 50-60% of Indian's will be living in cities by 2050, the role of buildings in providing climate change adaptation options is fundamental to sustaining prosperity and well-being. A key climate change pressure on the built-environment is the diminishing availability of water for urban areas⁹.

Most Indian cities rely heavily on ground-water for use in buildings. However, ground-water levels in India are projected to have dropped from 1901 m³/

Introduction

person/yr in 2001 to 1401 m³/person/year by 2030 which is well below the international benchmark for water stress of 1700 m³/person/year. Rainwater harvesting and large scale water recycling are not widely implemented in urban areas despite demand for water often outstripping supply. An added drain on urban water supply is the approximately 30% of water wasted each year due to leaking infrastructure. Conversely, there is a need for greatly expanding clean water supply in rural India, where more than 75% of the population does not have access to sanitation^{10/11}.

The rapid growth in India's building sector no doubt presents opportunities for improving the living conditions and livelihoods of millions of people. However, in order to be sustainable the environmental pressures of increased demand for resources coupled with a rapidly changing climate must be addressed.

These issues are now being addressed by policy makers at various levels. However as in most countries there is a huge scope to optimize the effectiveness of policy by encouraging a more holistic life-cycle approach to building. India also has the opportunity to further incorporate unique vernacular building techniques and traditional knowledge to support more sustainable building practices.

The following report on the 'State of Play' provides representative examples of the range of sustainable building activity in India. The report explains the state of sustainable buildings and construction in India including best practices, successes, barriers and recommendations for further implementation towards mitigation of climate change impacts and a transition to more sustainable built environments.

- UNEP SBCI, Paris, July 2010.

Considering the wide diversity that exists in the building typology across India, issues and concerns range from addressing low cost, low energy buildings to high cost high energy buildings through various income groups and climatic zones of the country. The acceptability and understanding of the term sustainable building is applicable to various design frameworks and approaches that have been developed in India.

The following report has been structured to address the various approaches (i.e. government codes, strategies, policies and other vernacular schools of thought) that co-exist to direct building construction towards a minimum detrimental impact on the environment. Various case studies have been used to explain the indicators of 'sustainability issues' with an emphasis on life cycle and actual performance of buildings.

Information for the study was collated after extensive literature survey, discussions with policy makers, receipt of information requested via a survey questionnaire prepared in consultation with subject experts and discussions with architects and users of buildings.

The seven case-study buildings cover six institutional buildings and one residential complex in three prominent climatic zones of India, namely composite, warm-humid and hot-dry.

Composite

- Centre for Environmental Sciences and Engineering Building, at the Indian Institute of Technology (IIT) Kanpur
- Institute of Rural Research and Development, Gurgaon
- Fortis Hospital at Shalimar Bagh, Delhi

Warm-humid

- *Sharanam*- a purpose-built training centre for rural development, Tamil Nadu

- Solar Housing Complex (*Rabirashmi Abasan*), Kolkatta
- Reserve Bank of India, Bhuvneshwar

Hot-dry

- Torrent Research Centre, Ahmedabad

The case studies are representative of various approaches for sustainable, green and energy efficient buildings prevalent in the country. In order to highlight the relevance of sustainable building design in India, each scheme is described and the description followed by an explanation of the case study or detailed description of the building with emphasis on the key sustainability parameters, as applicable.

It is pertinent to note that the various approaches/frameworks, adopted on the basis of key principles and indicators to address the performance of buildings, provide local indicators to the globally established sustainability performance parameters of buildings. Table 2 lists the major issues usually considered in the methods that attempt to assess the sustainability performance of buildings globally. The state of play, via the various approaches, (described in the following section), addresses each of the sustainability performance indicators and compliance with locally established benchmarks to

suitable degrees, thus emphasizing that buildings and construction activity in India are engaging with globally established green and sustainable practices.

It should further be noted that sustainable building activity in India reflects the ethos of the “Habitat Agenda”, the preamble to which states¹³: “Sustainable development of human settlement combines economic development, social

Table 2: Major issues to assess sustainability performance of buildings

Major issues to assess sustainability performance of buildings			
Consumption of non-renewable fuels	GREEN BUILDING	SUSTAINABLE BUILDING	
Water consumption			
Materials consumption			
Land use			
Impacts on site ecology			
Greenhouse gas emissions			
Other atmospheric emissions			
Solid waste / liquid effluents			
Indoor air quality, lighting, acoustics			
Longevity, adaptability, flexibility			
Operations and maintenance			
Social and cultural issues			
Economic considerations			
Urban / planning / transportation issues			

Source: UNEP (2008)¹²

Table 1: Building Case Study Locations, Climate Zone and Type,

Project name	Location (City, State)	Climate zone	Building type
1 Centre for Environmental Sciences and Engineering Building, at the Indian Institute of Technology (IIT) Kanpur	Kanpur, Uttar Pradesh	Composite	Institutional
2 Institute of Rural Research and Development	Gurgaon, Haryana	Composite	Institutional
3 Fortis Hospital at Shalimar Bagh	New Delhi, Delhi	Composite	Commercial
4 Sharanam	Pondicherry, Tamil Nadu	Warm-humid	Institutional
5 Solar Housing Complex (<i>Rabirashmi Abasan</i>)	Kolkatta, West Bengal	Warm-humid	Residential
6 Reserve Bank of India	Bhuvneshwar, Orissa	Warm-humid	Institutional
7 Torrent Research Centre	Ahmedabad, Gujarat	Hot-dry	Institutional

Source: TERI, 2010

1. Vernacular Schools of Thought

development and environmental protection, with full respect for all human rights and fundamental freedoms, including the right to development, and offers a means of achieving the world of greater stability and peace, built on ethical and spiritual vision”.

The timeline in Figure 1 maps the evolution of ‘architecture for sustainability’ in India. This movement is rooted in traditional wisdom that has provided indigenous solutions to each crisis situation that has arisen over time.

The four approaches, namely the vernacular school of thought, green rating for buildings, the ECBC compliance of buildings; and the star rated buildings are extensions to the time line shown in Figure 1, and have been used to capture the current state of play of sustainable buildings in India.

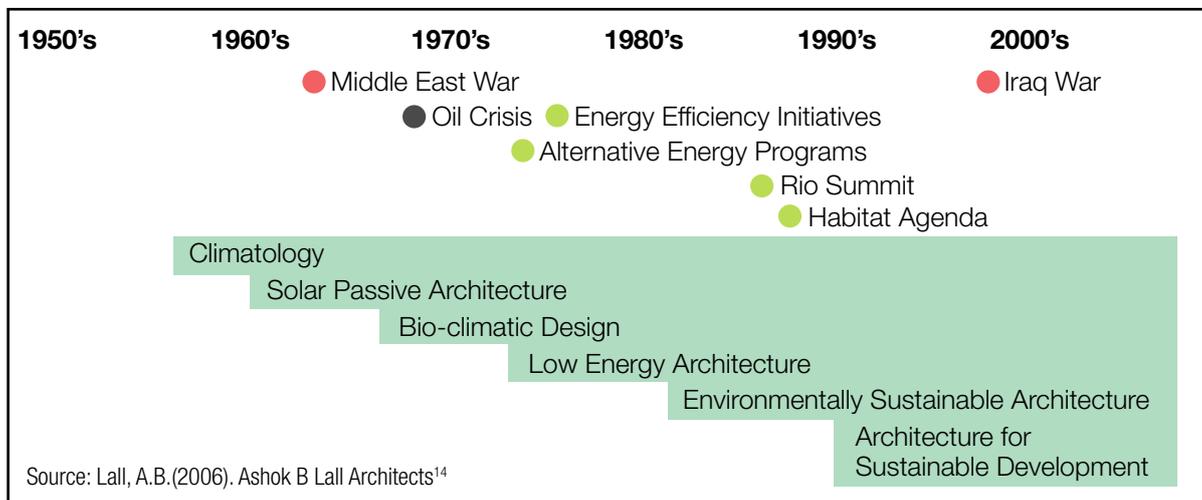
Through vernacular approaches to building design, construction and operation, the built environment evolves to comply with the modern day requirements and functions, while at the same time integrating the climate responsive architecture inherent to India. As is reflected in the following case studies, each project addresses an integrated approach to sustainable design with a special emphasis on climatology, solar passive architecture, bio-climatic design and low energy architecture to achieve appropriate human comfort, use of recycled municipal/domestic waste as building material; and a model solar housing that may be implemented for successful promotion of green building design principles respectively.

‘Green’ building techniques have traditionally been integrated with economic, social and cultural considerations. Thus, vernacular building knowledge has traditionally addressed what we now consider to be ‘sustainability’. The following case studies have been used to further explain the vernacular schools of thought that exist in various parts of the country.

1.1 MERA WALA GREEN

‘Mera Wala¹⁵’ or ‘my kind of green’ attempts to clarify that ‘green’ is only a direction for achieving greater sustainability, and not a recipe in which

Figure 1: Timeline depicting the philosophies and objectives of sustainability



use of identified 'green' products or technologies would result in truly 'green' or 'sustainable' buildings for any context. The school of thought emphasizes that the meanings and understanding of 'sustainable' or 'green' building is open to individual and contextual interpretation, where what may be required in one case or country may not be relevant for another.

In trying to comply with the design strategies and materials appropriate for other countries, India has suffered by creating enormous pressures on its resources. Therefore, it is necessary that any dialogue on 'green' building in India should constitute being 'green' for the various regions and climates of India. Subsequently, '*mera wala green*' seeks to provide a local understanding of sustainability for any building, which includes:

- Defining 'human comfort' required for each building to be suitable in terms of indoor air quality, thermal, visual, and acoustical comfort- and raising minimum standards progressively toward 'sustainability' benchmarks'.
- Ensuring longevity, adaptability and flexibility of any built environment is addressed suitably.
- Maximizing the use of traditional wisdom in design, wherever applicable, since it shall represent knowledge about the long term behaviour of materials, their strengths as well as weaknesses. Use of local materials with low embodied energy shall also reduce associated green house gas emissions.
- Assessing all new technologies for their long term impact in the context of India and its development priorities, before accepting them for use.
- Taking a performance approach for buildings.

Even though the above-mentioned practices have been ingrained in Indian built environment for centuries and have proved to be sustainable, they have been less popular in the current scenario for several reasons.

The approach emphasizes reducing consumption and pursuing an understanding of sustainability that implies:

- Use of low technology innovations, materials and products, which are not 'brand' driven;
- Recognizing 'performance' and not just 'intent' of going 'green' and;
- Necessary use of common knowledge.

However, these goals contrast with increasingly popular approaches, which are perceived to:

- Emphasize the quantification of energy saved;
- Promote high technology innovations, materials and products, which are brand driven;
- Recognize 'intent' rather than 'performance' and;
- Necessitate expert inputs and simulations.

The lack of common definitions for 'green buildings', coupled with the popularity of the term as a mark of currency among architects is increasing the risk of green-wash and could ultimately undermine fundamental changes toward more sustainable practice. However, '*mera wala green*' stresses that the two most important and readily available tools to achieve sustainability in the built environment are the use of common knowledge and common sense; which may be further supplemented progressively with innovations, trial and errors; and scientific decision making, as the context may demand.

Torrent Research Centre (TRC)

The Torrent Research Centre (TRC)¹⁶ at Ahmedabad in Gujarat explores the above school of thought and brings together the use of common knowledge, common sense, innovations, trial and errors; and scientific decision making to arrive at '*mera wala green*', specific to the region and proposed function of the building. The following section provides a brief description of the building features and establishes compliance with the '*mera wala green*' understanding of sustainable buildings in India.

The TRC was completed and occupied in 1997; and has been reported as a unique example for climate responsive design integrating a Passive Downdraft Evaporative Cooling (PDEC) system. The significant characteristics of the building design are that:

- 72% of the central building has achieved human comfort (28-28.5°C as threshold temperature which could be exceeded for a certain number of hours) by using PDEC and;

- The building has been able to establish extremely low levels of energy consumption per square metre.

A number of factors such as client commitment for environmental design, clear goals for environmental performance, an integrated and multidisciplinary team approach for design that is mindful of user needs, and responsive building management during commissioning and operation have influenced the low energy outcomes in the building.

The TRC complex comprises of a range of pharmaceutical research facilities and related support services, housed in a group of buildings. Each

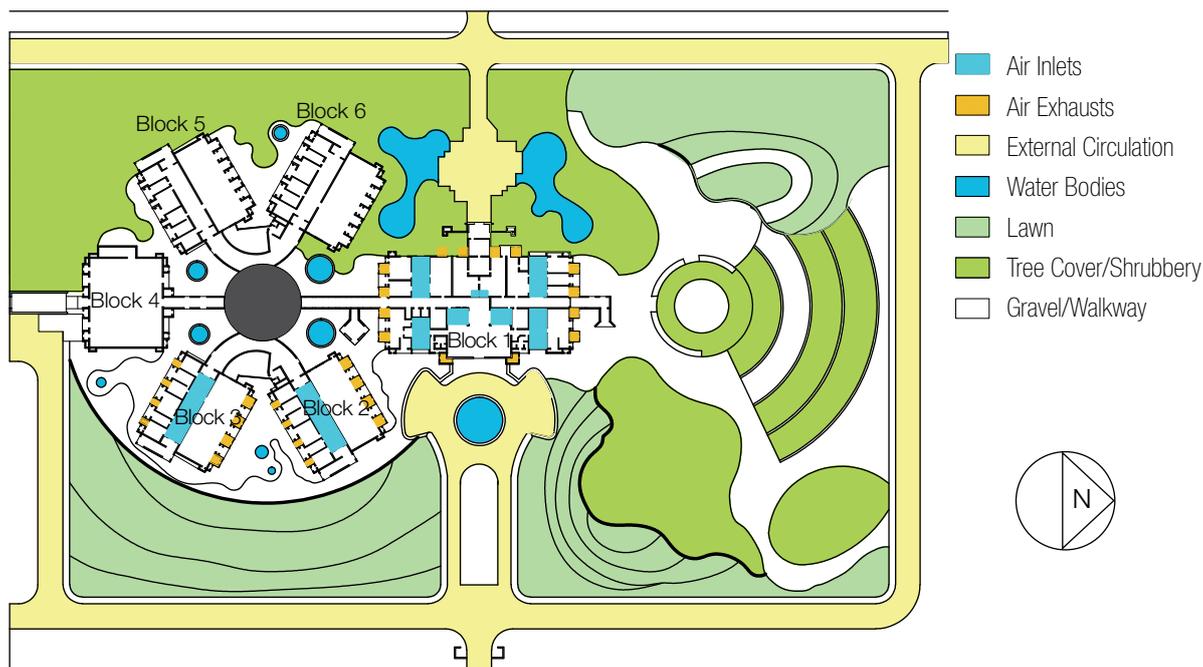
Figure 2: Torrent Research Centre, Ahmedabad



laboratory building has a similar plan, with a wide corridor flanked by deep office spaces and laboratory spaces (Figure 2). Two of the five laboratory buildings are air conditioned, while the other three equipped with the PDEC system. The entire complex covers 22,600 square metre of floor space, of which around 3,200 square metres is air-conditioned.

The overall control of solar heat gain is achieved by judicious design of glazing. The fixed windows are shaded externally, not only in the horizontal plane by overhangs, but also in the vertical plane by the air exhaust towers which project from the façade. The buildings are thermally massive. The reinforced concrete construction framed structure has cavity brick infill walls, plastered inside and out, and hollow concrete blocks filling the roof coffers, also plastered inside, with vermiculite used as an insulating material on both roof and walls. The external surfaces are white and the walls painted with the roof using a china mosaic finish.

The PDEC system is designed to operate under critical climatic conditions during hot-dry season when mid afternoon outside temperatures regularly reach 40°C or more. The PDEC system pipes water through nozzles at a pressure of 50 Pa to produce a fine mist (microniser) at the top



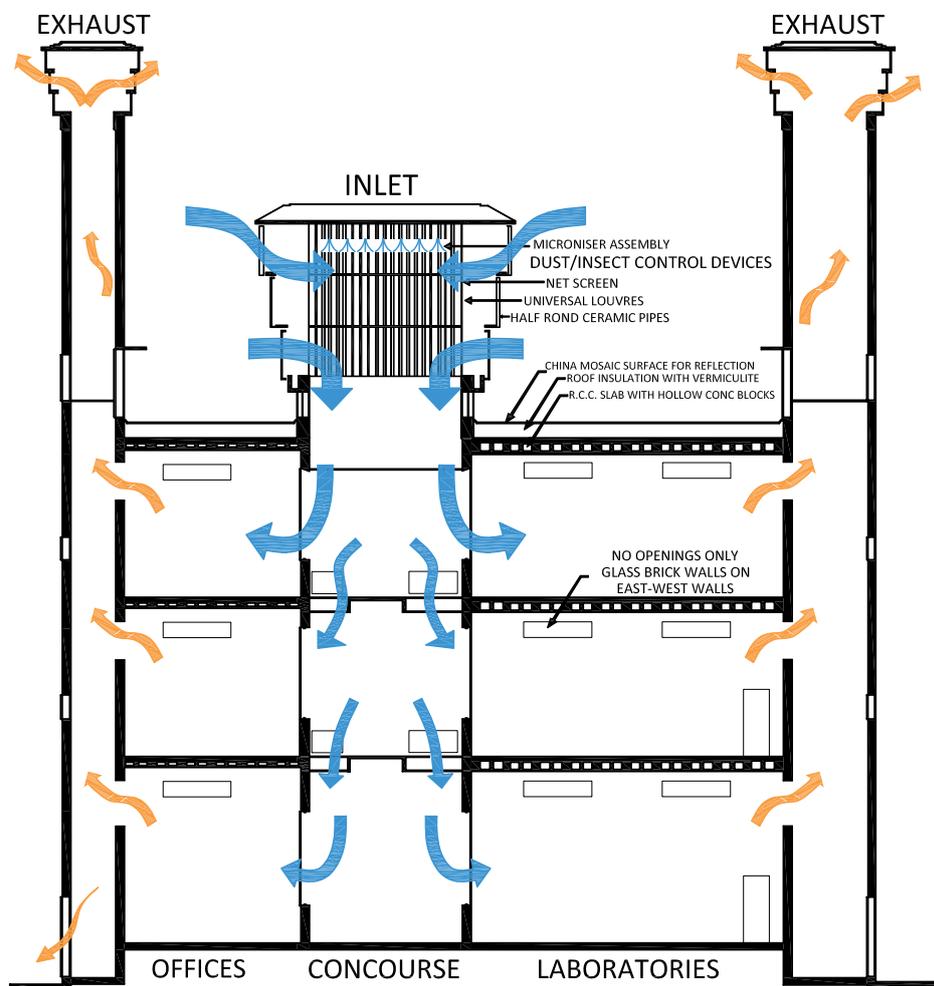
Source: Patel,N.(2007). Panika Team¹⁷

of the three large air intake towers located above the central corridors of each laboratory building. Evaporation of the fine mist serves to cool the air which then descends slowly through the central corridor space via the openings on each side of the walkway (Figure 3a/b). At each level, sets of hopper windows designed to catch the descending flow, can be used to divert some of this cooled air into the adjacent spaces. Having passed through the space, the air may then exit via high level glass louvered openings which connect directly to the perimeter exhaust air

towers. Night time ventilation is also an option during this season.

During the warm humid monsoon season when the use of microniser would be inappropriate, the ceiling fans can be brought into operation to provide additional air movement in the offices and laboratories. In the cooler season the operating strategy is designed to control the ventilation, particularly at night, to minimize heat losses by the users adjusting the hopper windows and louvered openings in their individual spaces to suit their requirements.

Figure 3a: Section of a PDEC system



SECTION
LABORATORY BLOCK
BUILDING 2

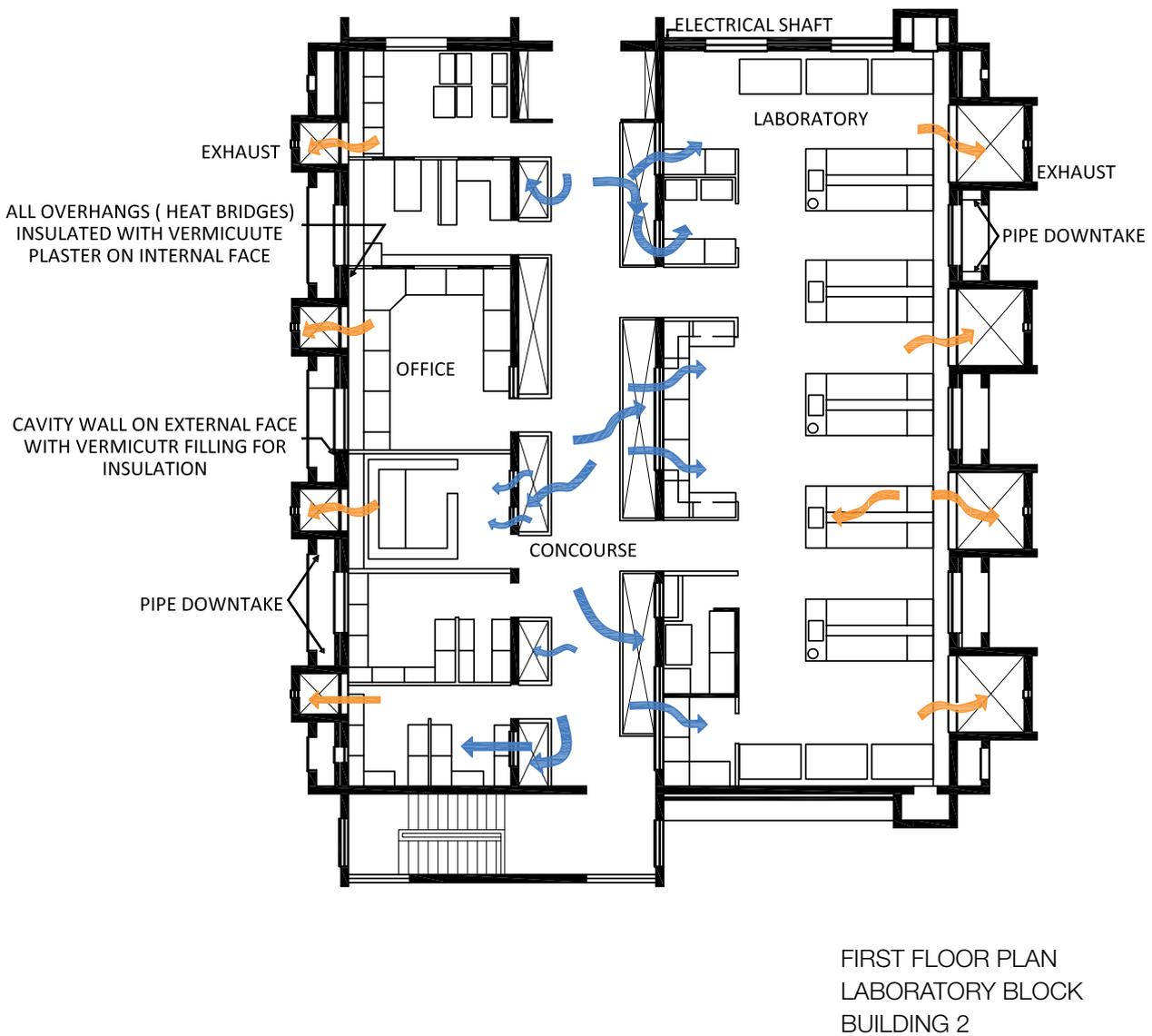
Source: Patel, N. (2007). Panika Team

The implementation of 'mera wala green' principles of defining human comfort, understanding and identifying needs for a long time scenario and maximizing the use of traditional wisdom in design to pursue goals, as described earlier have resulted in significant benefits for the environment, building occupants and clients who have made the capital and operational expenditure investments for the complex.

The results of complying with the 'mera wala green' philosophy have been listed as follows:

- 200 tonnes of air-conditioning load saved;
- Summer temperatures are maintained at 28°-32°C;
- 6 to 9 air changes/hour on different floors in summer, including in a chemical laboratory;
- The temperature fluctuations inside do not exceed 3°-4 °C, over 24 hour period, when outside fluctuations are 14°-17° C;

Figure 3b: Plan of a PDEC system



Source: Patel,N.(2007). Panika Team

- Humidity not allowed to exceed 65-70% in summer;
- Air movement velocity not allowed to exceed 1.5 feet/second;
- The building which was designed for 150 occupants in 1997 accommodated more than 600 users in 2005. The buildings have accommodated 250% additional users, without significant discomfort;
- Everyone using PDEC areas breath 100% fresh air, not re-circulated air;
- It gives healthy financial returns on investment in building costs. The entire cost of the building has been recovered from the electrical savings in 13 years of operations and energy conservation.

The post-occupancy survey of 2004-05, conducted by University of Technology, Sydney, Australia, and Victoria University of Wellington, New Zealand concluded that “the total energy consumption for PDEC and AC combined (includes light, equipment and AC for 2 blocks) for the 6 blocks in 2005 was 647000 kWh”. This averages to 54 kWh per square metre. Clearly the climate responsive approach to buildings such as TRC comprising labs and offices with extended hours of operation in hot dry climate of India, is comparable to available targets for commercial buildings.

In conclusion compliance with and replication of the ‘mere wala green’ school of thought offers an approach to sustainable building which enables:

- Focusing on solutions for India’s local needs;
- Finding local solutions from local resources;
- Finding ways of decreasing our consumption levels;
- Learning from our own traditional wisdom, for simple cost effective solutions;

1.2 SRI AUROBINDO SOCIETY (SAS) SCHOOL OF THOUGHT

Sri Aurobindo Society (SAS)¹⁸ is an international NGO established since 1960, working in multiple fields including health, education, management and rural development. ‘*Sharanam*’, a purpose-built training centre for rural development has adopted an integral approach to green building, which has been described briefly as follows.

Sharanam

Sharanam is designed as training and administrative centre of a larger rural development programme initiated by SAS, in the surrounding villages of Villupuram district, Tamil Nadu. *Sharanam* is the main venue for a variety of programmes in rural development covering a range of topics including rural health and hygiene, sanitation, education, income-generation, teacher training, self-development among women, youth and children facilitated through psychological development.

The principal facilities at *Sharanam* include a multipurpose hall (max. capacity 150), administrative offices, library, computer room, demonstration technologies, stores, kitchen and washrooms. In order to meet the functional requirements which are also in sync with the SAS design philosophy, a unique, inspirational and green building suited to a rural context has been designed to restore the ecological landscape of the site scarred due to illegal mud quarrying. Comfort conditions in an excessively hot and humid climatic zone (summer temperatures touching 40 °C and annual average 70% relative humidity) have been targeted to construct a modern highly-engineered superstructure using earth as the primary building material and minimize use of steel and cement. The *Sharanam* training centre was created not only for, but by local workers who were employed in the construction of their facility.

The design and construction of *Sharanam* embodies an integral approach towards development which encompasses the ecological, climatic, cultural, technological, environmental and socio-economic dimensions. These are outlined in the following paragraphs.

The site, landscape and ecological issues have been addressed by integrating the following activities through the construction process:

- Illegal mud quarrying was stopped to restore the ecological landscape of site.
- Concerted efforts at soil healing through plantation of new indigenous flowering trees nurtured by organic methods, bunding and mulching were undertaken towards revival of a local drip irrigation system has reduced the irrigation water requirement by 75%.
- Water has been conserved through ground water recharge wells, trenches and contour bunds. Surface run-off diverted to a reservoir for re-use in irrigation.
- Top soil from areas demarcated for construction carefully removed and stored separately for use in gardening.
- The entire building has been designed around existing trees and no tree has been cut.

Climatic and cultural response has been addressed in the following way:

- The design of *Sharanam* has been inspired by the careful study of traditional Tamil buildings, namely, temples, Chettinad houses and local vernaculars, which demonstrate a strikingly similar response to the year-round hot and humid climate of Tamil Nadu, i.e. shade from the intense heat and maximum ventilation to combat the high humidity.

Figure 4: Rammed foundations



Source: Lad, J.(2009). Sri Aurobindo Society

- Several solar passive strategies have been employed to achieve thermal comfort in *Sharanam*. Some of them are: building orientation that is perpendicular to the predominant summer breeze, evaporative cooling through water bodies, effective use of piers for funneling breeze, large fenestrations, increased height of the building and roof overhangs for maximising 'stack effect'.

Green building materials and appropriate, innovative technologies have been used. The focus has been to minimize the use of energy intensive and environmentally polluting materials and equipment, and to demonstrate use of environmentally responsive materials and sustainable technologies.

Earth has been used as the primary building material in two ways:

1. Rammed earth foundations: Foundation pits have been precisely dug and the same excavated earth sieved, mixed and rammed to ensure zero wastage of raw material. No soil has been brought from outside (Figure 4).
2. Compressed Stabilised Earth Blocks (CSEBs) have been manufactured with earth from the lowest point on site. Almost 100,000 custom-made CSEBs, stabilized with only 5% cement have been made in nine different sizes for the main superstructure. Soil for these blocks was procured from a small area measuring 9 x 15 x 1.5 m which is integrated into the design as the surface run-off reservoir.

Enormous environmental, structural and cost benefits have been realised using CSEBs manufactured at *Sharanam*. In comparison to the locally available wire cut bricks, the CSEBs are 4 times cheaper, 10 times less polluting, and 3 times as strong and of a far superior quality.¹⁹

The aim has been to design and construct a strong roof, beam, foundation etc. using the least amount of material (e.g. the main roof, which is a segmental vault in earth spans 9.5m and is 42m long). It has been built with 36,850 custom-made CSEBs with the roof thickness reduced to only 9 cm at the key stone. The CSEB masonry uses stabilized

Figure 5: Precision being executed at site



Source: Lad, J.(2009). Sri Aurobindo Society

earth mortar which is 1 mm thick and allows 140 tonne roof to be built using only 33 bags of cement (Figure 5).

Environmental practices and resource management practiced on site include:

- Use of renewable energy in the building design.
- Rain water harvesting including segregation of roof-top and surface run-off with separate storage of roof-top water for potable purposes.
- Recycled and treated waste from green toilets and kitchen used for irrigation.
- Construction methods used ensure zero construction waste.

The integral approach at *Sharanam*, goes beyond providing a ‘green building’ as a finished product that can be quantitatively evaluated through carbon emissions or numbers in energy audits. It is the integral approach towards building *Sharanam*, which includes not only the cultural and climatic context of Tamil Nadu and technological context of sustainability, but also the wider human dimension and the social context of rural development, which has contributed to the ‘greenness’ of *Sharanam*. As such, the project provides a qualitative expression of a process of building that constitutes architecture for sustain-

ability. Here, the act of building is seen as a means of self-development for all concerned.

In addition to demonstrating low environmental impacts the project has been successful in:

- Redefining the role of the architect as a hands-on professional engaging in the wider, inter-disciplinary context of development.
- Instilling the wider values of ‘modernity’ into the process – quality, precision, discipline and organization.
- Eliminating the contractor, which removes the heavy percentage cuts (about 30% generally) taken by brokers and ensures all workers receive their due wage on time since the architects are leading the construction by training local unskilled workers from surrounding villages during the process of construction.
- Skilled local workers e.g. masons, have their skills upgraded and introduced to new techniques and higher standards of work.
- The cost of the unique superstructure is 40% cheaper than conventional reinforced concrete buildings.

1.3 SUSTAINABLE COMMUNITIES

The design philosophy and considerations of the sustainable communities school of thought²⁰ revolve around, and are inspired by, Gandhian principles of enlightenment of the poor and the oppressed, advocacy of sanitation, and education of the poor. It is propagated by *Manav Sadhna*, a non-governmental organisation which follows the philosophy of love all and serve all; and is engaged in constructive humanitarian projects that cut across barriers of class and religion while addressing issues faced by socio-economically neglected segments of society. Non-polluting environment, economic empowerment and affordable built forms are the three key dimensions of this initiative.

Considering that nearly 27.4 million tonnes of waste is produced daily in the urban centres of India, and that cities like Ahmedabad alone produce 2750 metric tonnes²¹ the initiative is an attempt to recycle municipal and domestic waste into building materials.

Manav Sadhna Activity Centre, Ahmedabad

The 'sustainable communities' approach has been applied in the development of the *Manav Sadhna* Activity Centre, which is located amidst the largest squatter settlement of Ahmedabad. The multi purpose activity centre serves as an informal school for young children, provides evening education for adults and serves as a training centre and activity workshop for the manufacturing of craft based products by women and elderly. The campus also includes a dormitory, an administrative unit and an all-religion meditation unit (Figure 6).

The campus is built using components prepared through recycling municipal and domestic waste. This process simultaneously addresses environmental concerns, economic issues and affordable housing. Since municipal waste from the domestic sector is used for producing building components, it helps to reduce waste as pollution.

Through value addition processes of recycling the waste, it provides a means of economic activity as well as a sense of empowerment for the poor. Finally, as the recycled building components are cheaper and of higher quality than the conventional materials, they provide affordable and superior quality building alternatives for the urban poor.

The project also demonstrates that building can become an economic activity that empowers the poor by providing the potential of becoming a cottage industry for economic self-reliance.

The campus is built as a live demonstration for the application of recycled waste as affordable, aesthetically pleasing and efficient building components (Figure 7). Building products manufactured from municipal and domestic waste are used in the walls, roofs slabs, doors and windows. Materials and products were configured to enable construction with simple hand tools.

Figure 6: Panoramic view of the activity centre



Source: Pandya, Y. (2009). Footprints EARTH

Figure 7: Inner partition walls made from vegetable crate wood panelling



Source: Pandya, Y. (2009). Footprints EARTH

There are six types of materials and techniques used in the making of the walls. These include: cement bonded flyash bricks, mould-compressed bricks made from landfill site waste residue, stabilized soil blocks, recycled glass bottles, recycled plastic bottles filled with ash and waste residue, and vegetable crate wood paneling in the inner partition walls (Figure 8).

Figure 8: Window made from vegetable crate wood panelling



Source: Pandya, Y. (2009). Footprints EARTH

Figure 9: Glass bottle roof



Source: Pandya, Y. (2009). Footprints EARTH

Similarly the floor and roof slabs in the activity centre include:

- Filler slab with glass bottles (Figure 9),
- Plastic bottles and bricks stone slab,
- Cement bonded particle board with clay tile cover, and
- Light conduit pipe truss with Galvanised Iron sheet and clay tile roof.

The door panelling uses shredded packaging wrapper and coated paper waste as reinforcement substitute for fiber reinforced plastic (FRP). Vegetable crate wood as a frame and oil tin container as blades make the ventilation louvers in the toilets. Panelled door using vegetable crate wood and oil tin containers for the frame and cladding respectively have been provided in the administrative block office toilet. Flyash and waste residue moulded tiles with inlaid ceramic industry waste as china mosaic (applied during tile moulding itself) is also applied in patches for their demonstration.

All of these products are developed and produced first hand. The products thus produced have been lab tested for their engineered performance and they prove to be economical, environmentally friendly, participatory and aesthetically pleasing solutions and express alternatives to contemporary practices.

This vernacular school of thought also exhibits social, environmental and economic sustainability like the 'Sharanam' as described earlier, however in

reusing and recycling waste material; it gives a new meaning to the understanding and applicability of sustainable habitats.

1.4 SOLAR MODEL FOR GREEN BUILDINGS

India's first Solar Housing Complex²² (*Rabirashmi Abasan*), has been constructed in the New Town area of Kolkatta city in the State of West Bengal. The project has been executed by the West Bengal Renewable Energy Development Agency (WBREDA) with partial support of Ministry of New and Renewable Energy, Government of India and State government agencies.

Solar Housing Complex (*Rabirashmi Abasan*)

This is the first building integrated photo voltaic (BIPV) project in India using the net metering

system of power transfer to grid, implemented under the newly formulated policy guidelines of the West Bengal State Electricity Regulatory Commission (WBERC). The housing complex (Figure 10) comprises twenty five reasonably priced plush bungalows, a community hall and a swimming pool developed on a 7125 square metre plot in New Town Kolkata.

A financially viable model was developed in order to promote energy efficient and renewable energy based housing. Since most projects are owner driven, this is a unique example where the developer community has driven the initiative to showcase that to build green is not expensive.

A public private partnership was established whereby the finances were put together by seeking 50% advance (of the total cost of each house) from independent house owners at the beginning.

Figure 10: Rabirashmi Abasan



Source: Majumdar, M. (2008). TERI

The State and Central governments contributed equivalent of USD 100000²³ out of the total project cost of USD \$2200000 -inclusive of cost of land (which was provided to the government at a 10% discount as is the norm in New Town area).

Key sustainable design parameters

The key principles of green building design such as site planning, energy and water efficiency, use of appropriate materials and good indoor environmental quality have been maintained. Further, principles of sustainable building design have also been addressed by devising suitable economic models for owners of houses and addressing social and cultural requirements by planning for and providing areas and buildings for community activities.

The complex is a unique model in India and has been developed on the concept of 'zero use of conventional electricity'. The following issues have been addressed during the planning, design and construction of the sustainable housing complex.

a. Site planning

- Maximum solar and wind access to individual houses in the hot and humid climate zone of Kolkatta.
- Gravity-based sewerage system to reduce sewerage pumping energy
- Appropriate landscaping to modulate air flows within site, divert air flows to rooms, shade paved areas (to reduce heat island effect)
- Stand alone high mast solar street lights with battery at the top and high power fluorescent lights.
- Battery operated pick-up van.
- Solar PV operated name plate and signage.
- Solar PV operated garden lights.

b. Building envelope and system efficiency

- Passive solar features with swimming pool in South
- Solar Chimney
- Adequate ventilation and natural lighting
- Use of Light Emitting Diodes (LED)/Compact Fluorescent Lamp (CFL) lighting fixtures
- Energy efficient electrical appliances have been installed in the houses and the complex

c. Use of renewable energy

- Outdoor lighting using solar photovoltaic based street lighting. All the 17 streetlights are fitted with solar photovoltaic panels.
- There is a swimming pool heated by solar energy.
- Evacuated tube collector (ETC) based solar water heater of 130 litres per day (lpd) capacity to meet hot water requirements. The small water tank in the solar heater has a thermal insulation which provides round-the-clock hot water supply.
- 2.0 kW roof top solar PV with grid connectivity, metering and stand alone facility for 4 hours operation. Each bungalow has own "power plant" on the rooftop, comprising a solar photovoltaic panel with a capacity of two kilowatts. Household gadgets and electric installations can run on solar power during the day. Post sunset, with the generation dwindling, the system automatically switches to grid supplied electricity.
- The PV system also has an in-built power back-up system, which stores around 3 kilowatts of power. So, in case of an emergency at night, say during power cuts, one can switch to the back-up to harness stored power. An inverter helps the "switchover" post-sunset. All residents have been advised to opt for LEDs and CFLs for lighting.

d. Water efficiency

- Use of pervious paving to maximize groundwater recharge
- Hydro-pneumatic water supply system with 40% less energy consumption.

e. Economic feasibility for the owner

- Each house in the complex was priced ranging from USD 86,000 to USD 90,000 for a built-up space 165 square metres with an open area of 80 square metres. The land area for each house is 200 square metres. Each owner has rights to the land and generates own power for domestic use as well as for feeding the grid.
- Since net metering is being adopted, the users export electricity to the grid and thus fall in the lower consumption (and thereby tariff) slab. The option of net metering can also be used when the house is unoccupied.

f. Social and cultural considerations

- A community centre and a swimming pool have been provided for use by the occupants
- WBREDA is in-charge of general maintenance for the first year while each installation — be it the heater, inverter or solar lights — comes with a five-year guarantee.

g. Urban planning and transportation

- Efficient infrastructure planning by minimized road lengths, aggregate utility corridor
- Consolidated pedestrian and automobile paths
- Centralized car parking
- Use of battery-operated vehicles for intra-site transportation

The vernacular school of thought as described through the various case studies reflects the specific sustainability priorities, which have been established in specific regions of the country. While 'mera wala green' seeks to establish common sense solutions with emphasis on local 'needs' from Indian solutions in terms of material use and traditional wisdom, *Sharanam* adopts an integrated approach towards development with a special focus on the socio-economic and skill-development dimension.

Manav Sadhna Activity Centre demonstrates that a building can become an economic activity to empower the poor and exhibits potential of becoming a cottage industry for economic self-reliance. In its emphasis on the socio-economic

aspects of sustainable building design, the vernacular school of thought iterates the holistic approach followed for sustainable buildings in India. Taking this a step further, the Solar Housing Complex focuses on the sustainability of the project in ways that make a living complex which is affordable for middle class consumers.

In scenarios where it is not possible to address all aspects of sustainable design, environmental and economic concerns take priority in order to direct building construction towards green design. Green rating of buildings as described below encourages adoption of 'green' rather than 'sustainable' design strategies.

1.5 REPLICATION AND WAY FORWARD

The vernacular design and construction techniques follow an integrated approach. However, stresses on land availability, constraints on time for design and construction of buildings, issues of future saleability of space and perceived notions of development, result in adoption of popular models of design and construction that are not climate responsive. Table 3 provides information on the GRIHA recommended energy performance indices for new commercial/ institutional buildings. In comparison with such performance benchmarks, the energy consumption and associated green house gas emissions from the popular models of unsustainable institutional buildings are high (approximately 300 kWh per

Table 3: Energy performance index for air-conditioned/non-air-conditioned buildings in India

Climate classification	EPI day-time occupancy @ 5 days/ week	EPI 24 hours occupancy @ 7 days/ week
Air-conditioned buildings (commercial)		
Moderate	120 kWh/m ² /annum	350 kWh/m ² /annum
Composite / warm and humid/ hot and dry	140 kWh/m ² /annum	450 kWh/m ² /annum
Air-conditioned buildings (residential)		
Composite/ warm and humid/ hot and dry	200 kWh/m ² /annum	
Non-air-conditioned buildings		
Moderate	20 kWh/m ² /annum	85 kWh/m ² /annum
Composite / warm and humid/ hot and dry	25 kWh/m ² /annum	100 kWh/m ² /annum

Notes: kWh/m²/annum - kilowatt hour per square metre per annum; EPI - Energy Performance Index
Source: GRIHA, TERI 2009

2. Green Buildings

square metre) as compared to approximately 150 kWh per square metre commonly achieved in vernacular and energy efficient buildings. Further, the BEE star rating for existing buildings and the Energy Performance Index (EPIs) achieved by new buildings on compliance with ECBC also reflect the range as mentioned above.

In order to expand the acceptability and implementation of the vernacular approach to design and construction of buildings, the following issues need to be addressed:

- Knowledge dissemination and capacity building
- Integration of incentive with initiative;
- Conducive energy pricing;
- Net metering; and
- R&D on integration of renewable energy for multi-storey and high rise residential apartments.

In order to address these issues it is important for the building sector in India to follow a strategy that can:

- Include human resources of the semi skilled and skilled personnel in the growth of construction trades while enhancing knowledge and skill;
- Ensure a wider participation in the economic processes and promote equitable distribution of wealth; and
- Develop efficient utilization of natural and low-process energy materials to meet contemporary demands- as an alternative to the current trend towards high process-energy materials thereby limiting the impact of building production on greenhouse gas (GHG) emissions.

Green buildings in India are defined by the performance criteria used by green building rating schemes. Green rating systems for buildings measure and quantify the environmental performance of a given building. India currently has two local green rating systems for buildings that address indicators and benchmarks for performance issues of global concern. They are:

- Green Rating for Integrated Habitat Assessment (GRIHA); and
- Leadership in Energy and Environment Design (LEED)

Even though green rated building may be environmentally friendly, there exist schools of thought which do not consider rated buildings to be sustainable. However, the prime objective of these green building rating systems in India is to rate buildings based on their meeting or exceeding predefined goals and benchmarks²⁴ on the following broad criteria:

- Sustainable site planning
- Optimized energy performance
- Efficient materials and construction practices
- Water and waste management strategies
- Indoor environmental quality

Rating systems for buildings are popular in India because they enable:

- Quantification of benefits accrued through energy savings, water savings, etc.;
- Decision-making based on life cycle costs;
- Increased motivation for users and owners to fulfil their commitment to the environment;
- Generation of awareness of the need for sustainability through media attention;
- Enhancement of brand image; and
- Stimulation of competition among peers to achieve performance goals.

Both the rating systems are point-based and rate a building based on energy efficiency, water efficiency, material efficiency, and indoor environmental quality. However as discussed below, they differ in their approach to the rating methodology and benchmarks established for various criteria.

2.1 GREEN RATING FOR INTEGRATED HABITAT ASSESSMENT (GRIHA)

It is the national green building rating system for India, endorsed by the Ministry of New and Renewable Energy (MNRE), Government of India (GoI). The rating system acts as an integrating platform for all relevant Indian codes, standards, strategies and policy instruments for buildings directed towards our national priorities. It consolidates and builds upon the National Building Code²⁵ (NBC) 2005, the Energy Conservation Building Code (ECBC) 2007²⁶, the environmental clearance norms and standards mandated for large construction projects by the Ministry of Environment and Forest (MoEF)²⁷, the energy labelling programs for appliances by the BEE, several programs of the MNRE focussed on utilisation of renewable energy sources in buildings; and the priorities set forth by the Ministry of Urban Development (MoUD) on implementation of infrastructure projects in sixty three cities under the Jawarharlal Nehru National Urban Renewal Mission²⁸ (JNNURM).

GRIHA provides a rating of up to five stars for green buildings. Developed for new commercial and residential buildings, the rating system sets benchmarks for air conditioned and non air conditioned buildings in five climatic zones, namely hot-dry, warm-humid, composite, temperate and

cold. A major objective of the rating is to promote passive solar techniques for optimising indoor visual and thermal comfort; where a building is assessed on its predicted performance over the entire life cycle from inception through operation.

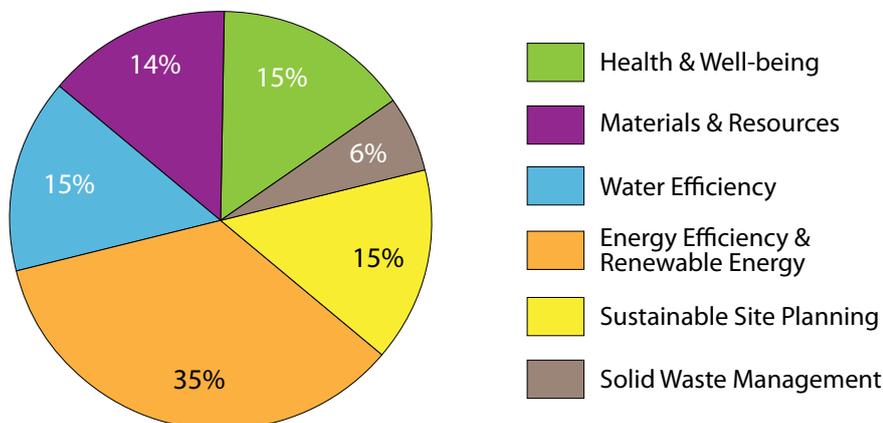
The 11th Five Year Plan (2007-2012) aims to achieve GRIHA compliance for five million square metres built up area, out of which about two million square metres of built up area is registered and GRIHA compliant (as of December 2009).

GRIHA comprises a set of 34 criteria addressing sustainable site planning, optimised energy performance, use of efficient materials and construction practices, integration of water and waste management strategies, indoor environmental quality and; health, comfort and safety of human beings. It is a 100+4 point system where differential weighting is allocated on various criteria (Figure 11). The 4 points for innovation are over and above the 100 points that a project may score for compliance with the benchmarks.

Centre for Environmental Sciences and Engineering at IIT Kanpur

Centre for Environmental Sciences and Engineering at IIT Kanpur (Figure 12) is the first 5 star GRIHA rated building, in which an integrated approach has been adopted to comply with the design, construction and operation guidelines set forth

Figure 11: Weighting of various criteria as per GRIHA



Source: Majumdar, M. (2008). TERI

by the rating system. Quantitative and qualitative measures have been incorporated to achieve and surpass performance benchmarks for key resources such as energy and water through implementation of traditional and vernacular knowledge of architecture along with present day technology.

The building comprises wet labs which are non-air-conditioned spaces on ground floor and dry labs that are air-conditioned spaces on the first floor. Building design and envelope has been optimised through selection of appropriate wall and roof construction and thorough adoption of solar passive measures after studying the sun path analysis to provide shading devices for windows and roof, which shall reduce energy demand to condition the spaces.

All the commitments as described in GRIHA to optimise the system design and to achieve thermal comfort in non air conditioned spaces have been followed. This has resulted in annual energy savings that exceed the performance benchmark for composite climates set by GRIHA. Water conservation measures have been adopted in the building through selection of efficient fixtures and rain water harvesting. The building uses electricity

generated by integrated photovoltaic panels. Rain water is harvested and treated waste water is reused for irrigation. The building is fully compliant with the ECBC. An integrated approach to design of the building has resulted in about 59% energy savings in the building performance.

The base case Energy Performance Index (EPI) of the building was 240 kWh per square metre per annum. The envelope was improved upon by adding ECBC compliant insulation to the external walls and roof. After addressing appropriate orientation and incorporation optimum envelope design, the EPI reduced to 208 kWh per square metre per annum. Next, artificial lighting systems were optimized by reducing the lighting power density of the building from 20 W per square metre to less than 10 W per square metre. T5 tube lights which are high efficiency tube lights and CFL lamps were used. The EPI reduced to 168 kWh per square metre per annum.

After the lighting system was optimized, the efficiency of the HVAC system was improved by selecting more efficient chillers. The EPI further reduced to 133 kWh per square metre per annum. Next the building controls were added

Figure 12: CESE Campus , IIT Kanpur



Source: Tanuja, B.K.(2007). Kanvinde Rai & Chaudhury

to the mechanical systems primarily the HVAC. Building controls manage the operating schedules, temperatures, pumps etc. That is to say that the building control systems turns up or turns down the HVAC system according to the number of users, time of the day, year etc. This allows for less usage of energy when the occupancy of the building is low or temperature outside is moderate or in any such similar condition. This further led to a reduction of 25 kWh per square metre per annum.

And finally a passive Earth Air Tunnel was coupled with the HVAC system. The earth-air tunnel drastically reduces the energy required for conditioning of air by utilizing the thermal properties of earth as a heat exchanger. In the end, the final EPI of the building was 98kWhper square metre per annum, a 59% reduction in energy consumption compared to the initial stage. The final case was fully ECBC compliant and as a result achieved a 5-star rating on the GRIHA rating system.

2.2 LEADERSHIP IN ENERGY AND ENVIRONMENT DESIGN (LEED)

The Indian Green Business Center (IGBC), under the Confederation of Indian industries (CII) is facilitating the LEED rating of the United States Green Building Council (USGBC). Introduction of the LEED Rating system has stimulated innovation within the building materials supply industry. High albedo roofing materials, high performance glass, waterless urinals, fly ash bricks for walls, roof insulation materials, high

CoP (coefficient of performance) chillers and energy simulation services are now being made available in the market.

The IGBC has launched LEED India for Existing Buildings (EB), New Construction (NC), Core and Shell (C&S) and Indian Green Building Council (IGBC) Green Homes, which represent the measurable indicators for global and local concerns in the Indian scenario. Based on the points achieved, the building may be eligible for LEED certified, Silver, Gold or Platinum Rating. Weighting of criteria reflects Indian environmental priorities.

The figure 13 represents the differential weighting given to each criterion under the LEED India NC.

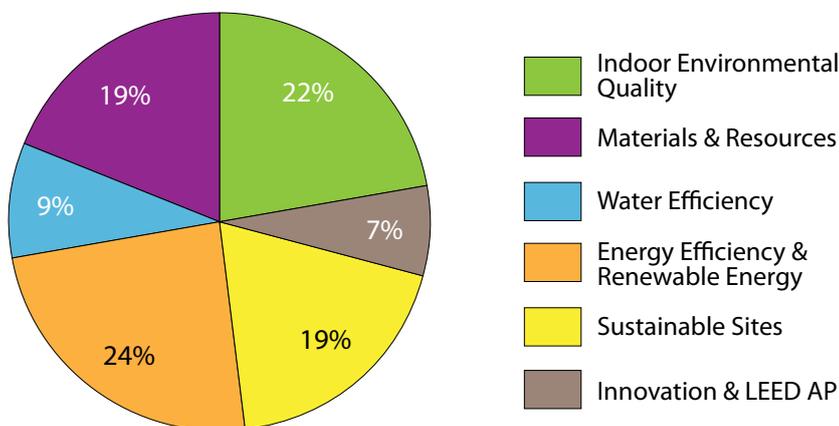
Institute for Rural Research and Development (IRRAD), Gurgaon

The IRRAD building at Gurgaon²⁹ resides among some of the ultra-modern high rises of Gurgaon and meets the standards of the LEED INDIA Green Building Rating System™. Some of the key features of the building are:

- 35 kWp photovoltaic solar panels
- Energy-efficient heating/cooling and lighting
- Waste-water recycling
- Zero water runoff from the site

The IRRAD building provides a model for the application of alternative energy systems at a larger urban scale. The building (Figure 14) has been

Figure 13: Weightage of various criteria as per LEED INDIA NC



Source: Majumdar, M. (2008). TERI



Figure 14: IRAAD Building and Entrance with wooden pergola (above)



Source: Tapia, J. (2009), TERI

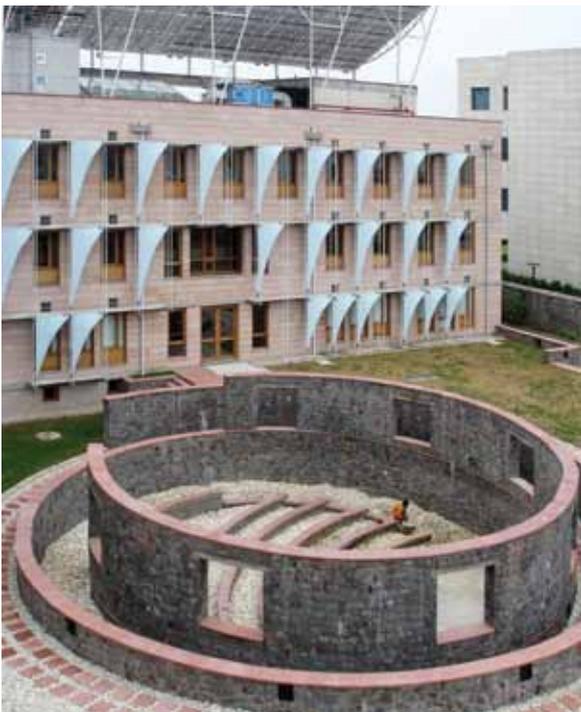
designed as a demonstration of a modern building in which the building's materiality and its spatial qualities are based on energy conserving considerations.

Some of the prominent green design features of the LEED INDIA compliant building are described as follows.

The scarcity of water in the region has been addressed by integration of a large rain water harvesting and storage system into the building and landscape design of the campus. This strategy reduces the demand of treated water supply from utilities water supplier and meets the energy efficiency objective of the HVAC system.

Assuming a throughput of collected rainwater through the tank during the monsoon season to be two full tanks, with an additional full tank being available at the end of the monsoon period, it is estimated that the water supplied to the building by the rainwater collection system will be 1.1 Mega-litres. Considering peak demand for water toward HVAC at 11,000lts/day, the rainwater collection provides for 100 working days of treated fresh water demand.

Figure 15: Amphitheatre acts as the filter bed for with rainwater storage tank below it



Source: Tapia, J. (2009), TERI

Further assuming that the air-conditioning season is restricted between mid March and mid October, the rainwater storage system would effectively take care of approximately half of the demand of water on account of HVAC.

The rain water collection facility is designed (Figure 15) as a central focal element in the landscape garden with a useful outdoor congregation function. This design strategy announces the importance of water conservation for all visitors and users of the building.

In order to minimize embodied energy in construction of the building, a comprehensive strategy to avoid approximately 640 tonnes of CO₂ emissions has been employed. Excavated earth from the basement has been used for manufacturing compressed earth blocks (Figure 16) on site, as substitute for burnt brick and concrete block. Locally available stones have been used (Figure 17) for external cladding/ finishing and flooring, as a substitute for curtain glazing, metallic or ceramic cladding systems. Further, sustainably harvested timber and biomass products have been used as substitutes for aluminium doors and window frames and shutters and aluminium air conditioning grills (Figure 18).

Figure 16: Compressed Earth Block instead of burnt brick



Source: Lall, A.B. (2008). Ashok B Lall Architects

Figure 17: Locally sourced stones in various applications



Source: Lall, A.B. (2008). Ashok B Lall Architects

Figure 18: Wooden air conditioning grilles instead of aluminium



Source: Lall, A.B. (2008). Ashok B Lall Architects

The building is designed to aid thermal comfort and reduce cooling loads inside the building through passive design techniques. The solar PV installation is also integrated into building design to provide thermal comfort passively (Figure 19). Since the installation effectively shades approximately 60% of the roof from the summer sun, it also provides shade over the atrium and the entrance courtyard, while allowing filtered and reflected day light into the courtyard spaces.

The integration of passive design strategies including use of shading has resulted in 9.2% decrease in peak load for the proposed building.

2.3 REPLICATION AND WAY FORWARD

As discussed above, there are two prominent green rating systems that co-exist in India. While Green Rating for Integrated Habitat Assessment (GRIHA) is the national rating system for the country, Leadership in Energy and Environment Design (LEED) has been launched by the India Green Building Council (IGBC). The Centre for

Environmental Sciences and Engineering at IIT Kanpur, the first GRIHA compliant building of India and the Institute for Rural Research and Development (IRRAD), Gurgaon, which is a LEED compliant building have been used as case studies to highlight the nuances of the two green rating systems.

Both green rating systems aim to quantify the environmental, economic and socio-economic benefits of green building design with emphasis on sustainable site planning, optimized energy performance, efficient materials and construction practices, water and waste management strategies; and indoor environmental quality. The rating systems also emphasize life cycle cost analysis so that the client has an option of making informed choices when opting for green technologies which may have an initial incremental cost with acceptable pay back periods.

In order to mainstream compliance with green rating systems, the GRIHA Secretariat has set a target to achieve five million square metres built up space to

be GRIHA compliant by 2012. On the other hand, the IGBC has set a target of registering ninety three square metres of built up space with LEED by 2012. Together, there is 1.56 million square metre commercial built up space³⁰ compliant with both LEED and GRIHA. However, due to split incentives for developers and a perceived notion of high initial incremental costs, the demand for buildings compliant with any green rating requires impetus. Financial incentives in the form of property tax concession or other subsidies from the government would encourage a larger adoption of the rating systems. A strong policy mandate at the local level to enforce compliance is another way that may be adopted for upscaling compliance with GRIHA or LEED rating systems.

In case it is not feasible for a given building project to be compliant with the green rating system, the BEE also provides an option to be compliant with the Energy Conservation Building Code (ECBC) which contributes to significant energy savings through the operation of an efficient building, contributing to GHG emission reduction.

Figure 19: PV panels shading the roof



Source: Lall, A.B. (2008). Ashok B Lall Architects

3. Energy Efficient Buildings

3.1 ENERGY CONSERVATION BUILDING CODE 2007

The Bureau of Energy Efficiency, Government of India, launched the ECBC (Energy Conservation Building Code)³¹ in 2007 for commercial buildings with peak demand in excess of 500 kW or connected load in excess of 600 kVA. Analysis done during the development of the ECBC shows energy savings in the range of 27%–40% in an ECBC-compliant building over a typical commercial building with annual energy consumption of 200 kWh per square metre.

The ECBC sets minimum energy performance standards for the design and construction of large new commercial buildings. It encourages energy-efficient building systems, such as building envelope; lighting; HVAC; water heating; and electric power distribution, within the building facilities while enhancing thermal and visual comfort, and productivity of the occupants.

The objective of the ECBC is to reduce the baseline energy consumption by supporting adoption and implementation of efficiency measures in buildings.

Fortis Hospital at Shalimar Bagh, Delhi

Fortis hospital at Shalimar Bagh³², has been designed as an energy efficient building that complies with the ECBC (Energy Conservation Building Code) and is undergoing TERI GRIHA certification.

The hospital (Figure 20) has been planned as a 500-bed facility that would cover a built up area of 64 400 square metres, comprising cardiology, renal, and gastro intestinal units. Energy efficiency and resource conservation measures have been incorporated in various aspects of the design, construction, and operation of the proposed green building.

The impact on energy savings achieved through ECBC interventions are described briefly as follows. The EPI for the base case (i.e. as designed by the

Figure 20: Image of the ECBC compliant Fortis hospital building at Shalimar Bagh



Source: Sood,P. (2007). FORTIS

architect to begin with) was 605kWh per square metre per annum. By incorporating the envelope optimization recommendations of the ECBC, the EPI reduced by 2% to 593kWh per square metre per annum. The following interventions in the building envelope were incorporated:

- Achieving u-value³³ of 0.69W per square metre K (as compared to 1.98W per square metre of the base case) for external wall by using 200mm autoclaved aerated concrete (AAC) blocks, plastered on both sides;
- Achieving u-value of 0.98W per square metre K (as compared to 2.43W per square metre K of the base case) for roof by using 150mm reinforced cement concrete (RCC), 65mm vermiculite, 100mm brick coba and 25mm tiles; and
- Achieving u-value of 2.8W per square metre K (as compared to 5.7W per square metre K of the base case) with a solar heat gain coefficient (SHGC) 0.46 (reduced to 0.25 by use of external shading) by using double glazed low emissivity glass with a light transmission of 46%.

On a preliminary reduction of the EPI by optimization of the building envelope, a further 21% reduction (cumulative with building envelope optimization) in the EPI was achieved by optimization of artificial lighting. The lighting power density was reduced from 20W per square metre as in the base case to less than 10W per square metre with energy efficient fixtures and lamps to achieve an EPI of 476kWh per square metre per annum.

Further the HVAC chiller efficiency was improved from 1.15KW per TR (air cooled chiller) to 0.61KW per TR (water cooled screw chiller) towards a cumulative EPI reduction by 43%. The EPI reduced to 346 kWh per square metre per annum by incorporation of optimized envelope, lighting and HVAC system.

Integration of controls on the HVAC system, i.e. variable frequency drive on chilled water pumps and air handling units further reduced the EPI to 312 kWh per square metre per annum, achieving a

total of 48% reduction in the EPI of the building.

Replication and way forward

In order to mainstream compliance with ECBC, the BEE has taken several initiatives. Most recently (December 2009), the ECBC shall be mandated in eight states of India, namely, Delhi, Haryana, Maharashtra, Andhra Pradesh, Tamil Nadu, West Bengal, Gujarat and Uttar Pradesh by 2012³⁴. Further, extensive training of architects, engineers and consultants is being undertaken by the BEE across India.

To encourage adherence to ECBC code, the BEE has supported the following activities in Government/Public Sector buildings:

- **Ministry of Health and Family Welfare** – Ministry of Health and Family Welfare is developing six All India Institutes for Medical Sciences (AIIMS) like institutions under the “Pradhan Mantri Swasthya Yojana”(PMSSY) scheme at Bhopal, Jodhpur, Rishikesh, Patna, Bhubanshewar and Raipur. These are being developed as ECBC compliant buildings. BEE is providing assistance to them through their empanelled ECBC expert architects.
- **National Thermal Power Corporation** - BEE is providing assistance to NTPC for their administrative cum lab building of energy technologies at Greater Noida to enable compliance with ECBC. The expert architect is providing suggestions on their existing plans for building envelope, electrical systems, HVAC and lighting to meet with the code requirement to the extent possible.
- **The Government of Delhi** has approved mandatory implementation of ECBC in government buildings/building complexes (new construction) including buildings/building complexes of municipalities/local bodies, boards, corporations, government aided institutions and other autonomous bodies of the city government. Further, the National Mission on Sustainable Habitat, which is a part of the National Action

Plan on Climate Change released by the Prime Minister’s Council on Climate Change, emphasises promotion of energy efficiency in the residential and commercial sectors through the extension of the Energy Conservation Building Code (ECBC), use of energy efficient appliances and creation of mechanisms that would help finance demand side management, providing further impetus to the policy initiative.

3.2 ENERGY STAR RATING OF OFFICE BUILDINGS

In order to accelerate the energy efficiency activities in existing commercial buildings, the

BEE has developed the scheme for star rating of buildings³⁵. The programme is based on actual performance of the building, in terms of specific energy usage (in kWh per square metre per year). Initially, the programme targets warm humid, composite, and hot and dry climatic zones for air-conditioned and non- air-conditioned office buildings. The programme is designed to rate office buildings on a 1-5 star scale, with 5-Star labeled buildings being the most energy efficient. The star rating program for existing buildings will subsequently be extended to other climatic zones and building types. EPI in kWh per square metre per year is considered for rating the building. Bandwidths for EPI for different climatic zones

Tables 4-9: BEE Star Ratings for Office Buildings

BEE Star rating for office buildings more than 50% air conditioned in a built-up area

Climate zone: Composite

EPI (kwh/m ² /year)	Star Label
200-175	1 Star
175-150	2 Star
150-125	3 Star
125-100	4 Star
Below 100	5 Star

Source: Scheme for Star Rating of Office Buildings (2009), Bureau of Energy Efficiency, Ministry of Power, Government of India

Climate zone: Warm and Humid

EPI (kwh/m ² /year)	Star Label
180-155	1 Star
155-130	2 Star
130-105	3 Star
105-80	4 Star
Below 80	5 Star

Source: Scheme for Star Rating of Office Buildings (2009), Bureau of Energy Efficiency, Ministry of Power, Government of India

Climate zone: Hot and Dry

EPI (kwh/m ² /year)	Star Label
190-165	1 Star
165-140	2 Star
140-115	3 Star
115-90	4 Star
Below 90	5 Star

Source: Scheme for Star Rating of Office Buildings (2009), Bureau of Energy Efficiency, Ministry of Power, Government of India

BEE Star rating for office building less than 50% air conditioned in a built-up area

Climate zone: Composite

EPI (kwh/m ² /year)	Star Label
80-70	1 Star
70-60	2 Star
60-50	3 Star
50-40	4 Star
Below 40	5 Star

Source: Scheme for Star Rating of Office Buildings (2009), Bureau of Energy Efficiency, Ministry of Power, Government of India

Climate zone: Warm and Humid

EPI (kwh/m ² /year)	Star Label
85-75	1 Star
75-65	2 Star
65-55	3 Star
55-45	4 Star
Below 45	5 Star

Source: Scheme for Star Rating of Office Buildings (2009), Bureau of Energy Efficiency, Ministry of Power, Government of India

Climate zone: Hot and Dry

EPI (kwh/m ² /year)	Star Label
75-65	1 Star
65-55	2 Star
55-45	3 Star
45-35	4 Star
Below 35	5 Star

Source: Scheme for Star Rating of Office Buildings (2009), Bureau of Energy Efficiency, Ministry of Power, Government of India

have been developed based on percentage air-conditioned space. Key performance issues to be considered in the star rating are presented in Tables 4 through 9.

The Star rating Programme provides public recognition to energy efficient buildings, and creates a “demand side” pull for such buildings. Buildings with a connected load of 500 kW and above are considered for BEE star rating scheme.

Reserve Bank of India (RBI), Bhuvneshwar

The RBI building at Bhuvneshwar, Orissa has been awarded the first BEE Star Rating for office building in India. Since the air conditioned area

of the building is more than 50% and the EPI for the building is 82kWh/m² per year, it lies in the bandwidth of less than 90 kWh/m² per year; hence has been awarded the five star rating. The detailed information as collected for award of rating is appended below (Table 10).

Replication and way forward

The BEE is working towards creating a market for energy efficient buildings through awareness and education. It is planned that an independent agency shall be appointed to evaluate the program impact and process of implementation on a periodic basis.

Table 10: Building Information and Energy Data for RBI, Bhuvneshwar,

Primary Data		Year:	
No.	Item	Value	
1	Connected Load (kW) or Contract Demand (kVA)	937.5 kW	
2	Installed capacity: DG/ GG Sets (kVA or kW)	530 kva	
3	Annual Electricity Consumption, purchased from Utilities (kWh)	1330000	
	Annual Electricity Consumption, through Diesel Generating (DG)/Gas Generating (GG) Set(s) (kWh)	-	
	Total Annual Electricity Consumption, Utilities + DG/GG Sets (kWh)	1330000	
4	Annual Cost of Electricity, purchased from Utilities (Rs.)	5445000	
	b) Annual Cost of Electricity generated through DG/GG Sets (Rs.)	-	
	Total Annual Electricity Cost, Utilities + DG/GG Sets (Rs.)	5445000	
5	Area of the building (exclude parking, lawn, roads, etc.)	a) Built Up Area (square metre)(Excluding Basement Area)	16220
		Conditioned Area(in square metre)	11658
		Conditioned Area(as % of built up area)	
6	Working hours (e.g. day working /24 hour working)	day	
7	Working days/week (e.g. 5/6/7 days per week)	5	
8	Office	Total no. of Employees	519
		Average .no. of Persons at any time in office during office hours	
9	Installed capacity of Air Conditioning System (TR)	610	
10	Installed lighting load (kW) (if available)	75	
12	HSD (or any other fuel oil used, specify)/Gas Consumption in DG/GG Sets (liters/cu. meters) in the year	-	
13	Fuel (e.g. FO, LDO,LPG, NG) used for generating steam/water heating in the year (in appropriate units)	3200 kg	
14	EPI in kWh/m ² per year Energy includes electricity purchased and generated (excluding electricity generated from on-site renewable resources)	82	
15	Star Label applied for	Five Star	

Source: BEE, 2009

4. A Way Forward

INCORPORATING SUSTAINABLE AND GREEN BUILDING DESIGN PARAMETERS IN THE INDIAN BUILDING SECTOR

The following sections provide an overview of key barriers and way forward for incorporation of sustainable and green building design parameters in the Indian building sector. It provides an outline of the knowledge gap at various levels, issues pertaining to lack of effective enforcement of policies; and lack of financial incentives, which deter stakeholders from large scale adoption of sustainable design strategies and energy efficient technologies. New construction in India is currently growing at more than 10%³⁶, and is projected to increase. Therefore, if greenhouse gas emissions and other unsustainable impacts of buildings are to be minimised, the perception that high-tech, energy intensive buildings indicate progress must be challenged.

Even though sustainable habitat and green building design are inherent to each region of India, and reflected in the vernacular design strategies; the process of building design, construction and operation is increasingly influenced by images of buildings designed for the developed world. With the convergence of urbanization, globalization and a rapidly changing and expanding economy, India is experiencing a rapid spurt in building construction across a range of city activities and socio economic spectrum with a direct impact on and increasing consumption of building materials such as glass, cement, metals and ceramics.

For the process of accelerated urban development to be socially and economically sustainable, while curtailing the impact of GHG emissions attributable to buildings, it is important to promote the strategies described in this report. This is preferential to a shift by default to a ready-made global technology and building type. While there is a huge potential to achieve energy efficiency by incorporating passive design, efficient envelope and systems, the current trend in mainstream architecture is not toward such aims.

The materials used in modern day constructions are not only energy intensive in their manufacture, but combined with the sheer scale of construction activity, contribute to increasing GHG emissions. Energy audits conducted by TERI in 2005-06 for buildings in Gurgaon indicate that many existing glass intensive buildings do not respond to the climate and require cooling even in the winter months. In response, the ECBC attempts to restrict gross wall area to window area ratio to a maximum of 60% and has set higher stringency levels for glazing specifications in case if glazing area is increased. Mandatory adoption of ECBC will help circumvent this problem to a large extent. Policy measures that encourage retrofitting of existing poor performing buildings also need to be developed.

Knowledge gaps amongst builders, designers, architects, policy makers, investors and consumers, act as a major impediment to incorporation of sustainable and green building design and construction practices. The construction industry remains unaware of the environmental impacts of its operations and the economic, environmental and health benefits of using green and efficient strategies, products and appliances. Sustainable design and energy efficiency in buildings is not taught as a part of core curriculum in any Indian school of architecture. All architectural and engineering schools and colleges should introduce relevant courses in their curriculum. There is an urgent need for effective and large-scale capacity building and awareness generation programme at all stakeholder levels.³⁷

First Costs: A major barrier to adoption of sustainable principles in building is the general apprehension of high initial cost and lack of life cycle cost approach to carry out cost benefit analysis. With an increasing number of green and efficient buildings in the country, there is a need to have collective information on incremental costs and benefits. This would help in overcoming the perception that efficient, green and sustainable buildings are expensive. All consultants providing services to help design efficient buildings should follow life cycle analysis approaches to motivate stakeholder buy-in.

Technology gaps: Technical difficulties arising for solar water heating installations, e.g. availability of south facing horizontal area, line losses (especially in high rises structures), water wastage, inadequate roof area for high rise apartments to be able to cater to hot water requirements for all the flats, scaling due to hardness of water, etc., need to be addressed by manufacturers and suppliers. Lack of knowledge on available incentives such as subsidies and soft loans, should be addressed through awareness campaigns and programmes.

Awareness: With reference to energy efficient appliances, most consumers are currently unaware about the availability of green products and BEE-labeled products. They are also unaware of the economic, environmental and health benefits of using such green and efficient products or appliances. Since there is a lack of awareness about the lifecycle cost benefits of efficient products, the higher up front cost prevents purchase. Awareness programs should also focus on marketing and increasing highlighting of lifecycle costs and cost-saving potential in efficient products. The economic benefits of BEE-labeled products should be marketed further.

Enforcement and implementation of strategies to encourage adoption of sustainable design strategies in buildings, use of energy efficient products and services are required. Lack of programs for monitoring and verification, policy mandates and incentives, both financial and symbolic, must be addressed to encourage a greater participation from the concerned stakeholders.

State and Central government building and construction projects follow age-old specifications, which need urgent revision to incorporate energy efficiency as a sustainability parameter among others. Although there are regulations, there is absence of a regulatory framework for implementation of energy efficiency in buildings. For example, in the case of environmental clearance of large constructions by state/central environment dept/ministries, implementation and monitoring mechanisms are totally absent. There

should be strong implementation and monitoring protocols developed and implemented through the establishment of independent agencies set up for that purpose.

Mandatory environmental clearance requirements from the central/state environmental appraisal committees for large construction projects also to some extent, demand incorporation of efficiency measures such as solar water heating systems, efficient lighting systems into residential developments. However, enforcement and monitoring protocol should be put in place to ensure effective implementation.

Building by-laws and urban planning by-laws do not address sustainable building solutions. For example, ECBC is not included into National Building Code or in any building code. At the national level, an attempt should be made to integrate the provisions of energy efficiency into the building by-laws.

Further, there is no mandatory requirement for minimum building energy performance. Even though the BEE has already made energy audits mandatory for many government buildings, and has planned to mandate energy audits for all commercial buildings above a certain threshold of connected load, it remains important to develop mechanisms to ensure that the recommendations of the audit are implemented in a stipulated time. Auditing combined with certification of energy performance could work in tandem to ensure implementation of energy efficient systems.

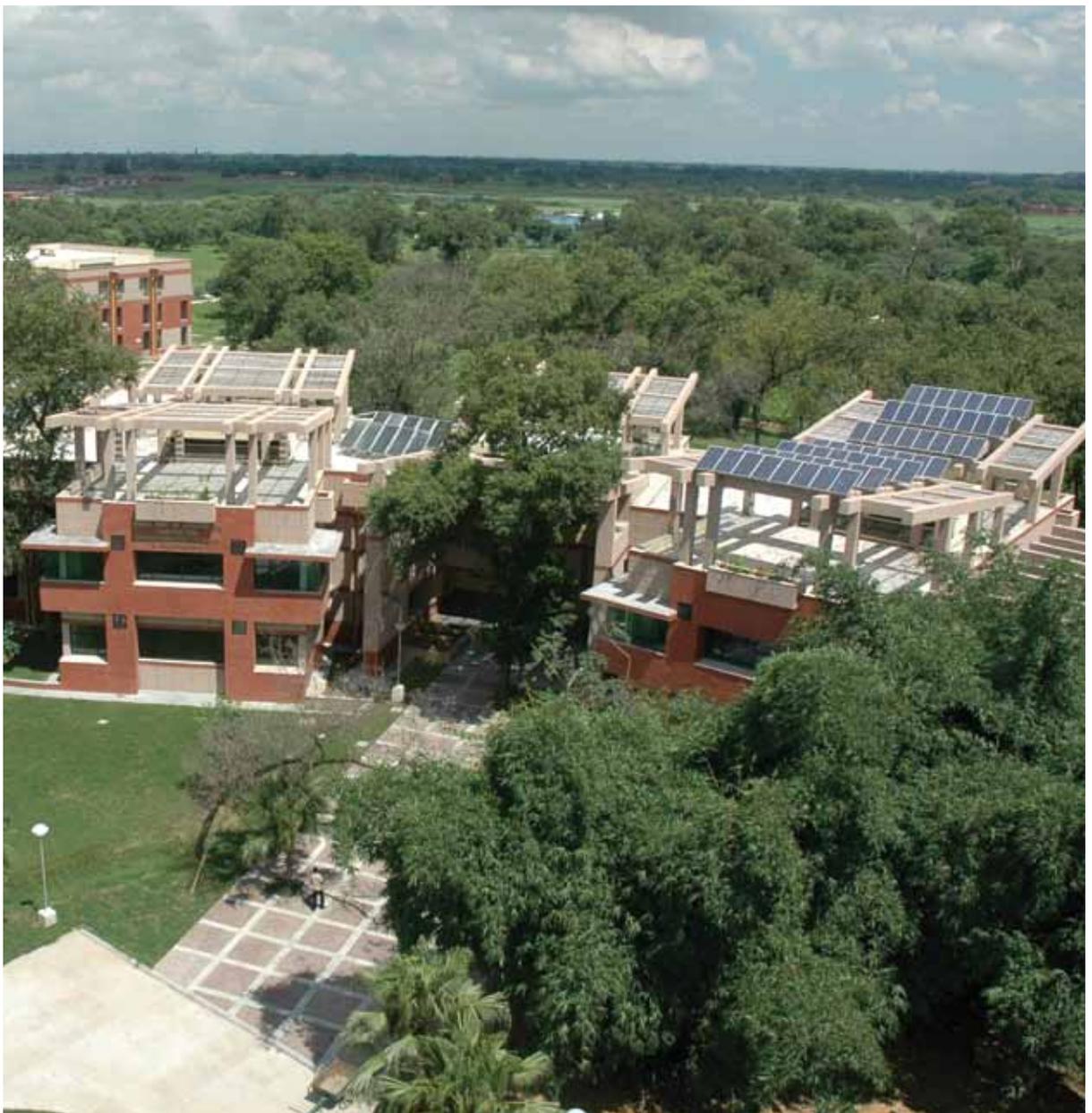
Lack of competitive pricing and financial incentives also act as a barrier to large scale implementation of sustainable building design. The residential sector, which is dominated by apartments and high-rise buildings, is developed by builders and developers. The developers do not benefit directly by incorporating energy efficient/green design features in new developments. As can be seen in various cases, there is an issue of split incentive for developers which needs to be resolved for large scale adoption of green building

design. Thus, with lack of incentives for builders to integrate environmentally friendly features in their construction, the penetration of appropriate technologies is very limited in residential sector.

Financial incentives such as tax breaks could be linked to rated buildings. Since there is absence of financial products to offset incremental costs,

this would provide motivation for users to demand energy efficient buildings and motivate developers to provide answer such demands.

The section above highlights key steps that can be taken up by various stakeholders in order to direct construction towards a minimum detrimental impact on the environment.



5. Conclusion

The 'State of Play' on sustainable buildings in India provides an overview of sustainable, green and energy efficient buildings prevalent in the country. An attempt has been made to describe each approach, followed by an explanation of the case study or detailed description of the building with emphasis on the key sustainability parameters, as applicable, in order to highlight the relevance of core global issues on sustainable building design in India.

The case studies are representative of major climatic zones of India and represent the various approaches to sustainable building being practiced in the country. It is pertinent to note that while regionalism forms an important aspect of the vernacular school of thought, there are standardized benchmarks and codes, in the form of green and energy rating systems, established for adoption across the country.

Each case study describes the building performance with reference to key principles, indicators, core issues and key targets used for defining sustainable building performance in practice, covering a range of issues as applicable. The case studies focus on institutional buildings and a residential development which highlights the financial model being practiced to make the building economically sustainable for the consumer.

Incentives are required to expand the acceptability and implementation the vernacular approach to design and construction of buildings. Conducive energy pricing and net metering could be used as tools to enhance the use of renewable energy which requires further research and development, especially in integration of renewable energy for multi-storey and high rise residential apartments.

The mode of implementation, policy environment, certification, legislation and economic incentives have been described to support the adoption of green and energy rating systems for buildings.

The demand for buildings compliant with any green rating requires impetus due to a perceived notion of high initial incremental costs for green buildings. Financial incentives in the form of property tax concession or other subsidies from the government would encourage a larger adoption of the rating systems. A strong policy mandate at the local level to enforce compliance with GRIHA or LEED rating systems is also required.

In cases where compliance with a green rating system is not feasible, it is possible for the building to be compliant with the Energy Conservation Building Code (ECBC) which contributes to significant energy savings through the operation of an efficient building, contributing to GHG emission reduction.

In order to mainstream compliance with ECBC, the BEE has taken several initiatives.

The way forward will be to bridge the large knowledge gap that exists at various levels, invest in research and development on local design, construction and materials suitable to the country that may be incorporated in modern buildings, and enforce implementation of policy in the building sector. Further, extensive training of architects, engineers and consultants is also being undertaken by the BEE across India.

Additionally, financial incentives will also provide the much required impetus to move away from unsustainable building design and construction practices, which are progressively creeping into practices of building in the cities of India.

6. Notes and References

(Endnotes)

1. Construction Industry Development Council, India. India Country Report, 2005-06; 801, Address: Hemkunt Chambers, 89, Nehru Place, New Delhi 110019
2. UNEP (2007) Buildings & Climate Change UNEP Sustainable Buildings & Climate Initiative, Division of Technology, Industry & Economics, Paris.
3. TERI in-press (2010) Greenhouse Gas Emission Base-lines and Mitigation Potentials from Buildings in India. UNEP Sustainable Buildings & Climate Initiative, Division of Technology, Industry & Economics, Paris.
4. Architectural Curriculum in India. (2008). Background Paper (Draft). Available at: <http://www.eco3.org/downloads/007-Education%20Curriculum/Architecture%20Curriculum%20Background%20Paper.pdf>
5. TERI in-press (2010) Greenhouse Gas Emission Base-lines and Mitigation Potentials from Buildings in India. UNEP Sustainable Buildings & Climate Initiative, Division of Technology, Industry & Economics, Paris.
6. Planning Commission. (2006). Integrated Energy Policy Report of Expert Committee. Government of India, Planning Commission, New Delhi.
7. Hong, W., Chiang, M., Shapiro, R., Clifford, M. (2007) Building Energy Efficiency: Why Green Buildings Are Key to Asia's Future Asia Business Council, Hong Kong.
8. Ibid.
9. Brenkert, A. & Malone, E. (2005) Modeling Vulnerability And Resilience To Climate Change: A Case Study Of India And Indian States in *Climatic Change* 72: 57–102
10. Kumar, R., Sing, R. & Sharma, K. (2007) Water Resources of India in *Current Science*, Vol. 89, No. 5, 10 September
11. Brenkert, A. & Malone, E. (2005) Ibid.
12. UNEP (2008) An international review of sustainable building performance indicators & benchmarks, A technical briefing paper by BRE Global and CSTB for the UNEP Finance Initiative and the Sustainable Buildings & Climate Initiative, Paris May. p10
13. http://ww2.unhabitat.org/declarations/documents/The_Habitat_Agenda.pdf Last accessed on 13th May 2009
14. Lall, A.B. (2006). Development Alternatives World Headquarters: Context [1,2]. Retrieved from <http://www.ashoklallarchitects.com/research/research.htm> Last accessed on 20th May 2009
15. 'Mera Wala Green: Explorations of a design practice using common knowledge and common sense'; presentation made by Nimish Patel, Parul Zaveri & Panika team; for the green Building Congress 2008: Conference on Green Homes organised by Confederation of Indian Industry (CII) at Mumbai in September 2008. Information towards this school of thought was also collected during a telephone interview with Mr. Patel.
16. Thomas, L., Baird G (2007): Post-occupancy evaluation of passive downdraft evaporative cooling and air-conditioned buildings at Torrent Research Centre, Ahmedabad, India
17. Patel, N. (2007), Panika team
18. Information for this project as collected over discussions with the project architects Mr. Jatin Lad and Ms. Trupti Doshi in April 2009. <<http://www.sriarobindosociety.org.in/sharanam/skills.html>> Last accessed on 12th April 2009
19. Research data and laboratory test results verifying these findings are available with Architecture Studio, Sri Aurobindo Society
20. Information for this project collected over discussions with the project architect Mr. Yatin Pandya in April 2009.
21. Pandya, Y. (2008). Recycling Domestic Waste as Building Components-An Environmental, Economic and Aesthetic Imperative. *Manav Sadhna* Activity Centre – Ahmedabad

22. Information for this project is based on telephonic interview with Shri S P Gon Chaudhuri, Managing Director, West Bengal Green Energy Development Corporation Limited and Ms. Mili Majumdar, energy consultant (TERI) to the project on 9th April 2009

23. Rate of conversion used for the calculation:
1USD= Rupees 50

24. Majumdar, M. (2008). An assessment of LEED-India NC and GRIHA Version 1, presented to the Ministry of New and Renewable Energy, Government of India

25. Bureau of Indian Standards (2005), National Building Code, New Delhi.

The Bureau of Indian Standards has developed the National Building Code as a guiding code to be followed by municipalities and development authorities in formulation and adoption of building by-laws. In the latest edition (2005) of the NBC, some aspects of energy conservation and sustainable development have been consistently dealt with in various parts and sections through appropriate design, usage and practices with regard to building materials, construction technologies, and building and plumbing services.

26. Bureau of Energy Efficiency (2007), Energy Conservation Building Code 2007, Ministry of Power, Government of India, New Delhi

27. MoEF has developed a manual on norms and standards for environmental clearance for large construction projects after wide consultation with experts from different disciplines. The manual is used as a technical guideline to assist the project proponents/ stakeholders/ consultants for the preparation of projects to obtain environmental clearance. All new construction projects are appraised on the basis of the manual by both the Environmental Appraisal Committee (EAC) at MoEF and State Environmental Appraisal Committee (SEAC) at the State/ Union Territory level.

The EACs/ SEACs will do the grading of the projects. Platinum (90-100 points), Gold (80-89 points), Silver (60-79 points) and Bronze (40-59 points) grade can be earned, depending on the points achieved. The detailed criteria for gradation and the expected performance standard are provided in the Manual. Accordingly, the concerned regulatory authority indicates the gradation based on merits of the project while according Environmental Clearance. The State Pollutions Control Boards shall verify the compliance of the Environmental Management Plan and the observance of the criteria of gradation by the project proponents.

28. The government launched the JNNURM in 2005-06 covering 63 cities. This was a first of the kind comprehensive urban development policy to assist in urban infrastructure capacity creation through government funding, to support the anticipated rush in urbanization, wherein by 2011, urban areas are expected to contribute about 65% to the gross domestic product (GDP).

29. Information for this project has been collected from Prof. Ashok B Lall

30. Based on information from IGBC and GRIHA Secretariat, a total 1.56 million square metre commercial built up space, equivalent to 0.5% of the total commercial building stock in 2008 is energy efficient and compliant with GRIHA and LEED.

31. Bureau of Energy Efficiency (2007), Energy Conservation Building Code 2007, Ministry of Power, Government of India, New Delhi. Also available at: <http://www.bee-india.nic.in/>

32. TERI-GRIHA rating certifications developed at TERI as the indigenous rating system for India. It has been endorsed by the Ministry of New and Renewable Energy, Government of India (November 2007) and renamed as GRIHA. The Fortis project was registered with TERI much before the establishment of the GRIHA Secretariat and is compliant with the older TERI-GRIHA rating.

33. The U-value (or U-factor), more correctly called the overall heat transfer coefficient, describes how well a building element conducts heat. It measures the rate of heat transfer through a building element over a given area, under standardized conditions.
34. <http://business.rediff.com/report/2009/dec/05/green-code-must-for-buildings-in-eight-states.htm> / Last accessed on 10th December 2009
35. Scheme for Star Rating of Office Buildings (2009). Bureau of Energy Efficiency, Ministry of Power, Government of India. Also available at: <http://www.bee-india.nic.in/ecbc/BEEStarRatingforexistingOfficeBuildings.doc> / Last accessed in March 2009
36. Construction Industry Development Council, India. India Country Report, 2005-06; 801, Address: Hemkunt Chambers, 89, Nehru Place, New Delhi 110019
37. In order to identify the courses on green buildings offered by various architectural and engineering universities across the country (2008-09) for the Ministry of Urban Development, TERI observed that there are 2-3 institutes that have recently initiated programs related to sustainable buildings. These range from full 2 years courses to one semester modules. However, review of the course structure shows that these courses do not cover all aspects related to the subject. In light of the extensive work being undertaken by TERI on the subject of green buildings, TERI has been recognised as the Centre of Excellence on the subject and is currently developing curriculum for post graduate courses on green buildings.

About the Sustainable Buildings and Climate Initiative

Launched in 2006 by the United Nations Environment Program (UNEP), the Sustainable Buildings and Climate Initiative (SBCI), formerly the Sustainable Buildings and Construction Initiative, is a partnership between the private sector, government, non-government and research organizations formed to promote sustainable building and construction globally.



**Sustainable Buildings
and Climate Initiative**

Promoting Policies and Practices for Sustainability

SBCI harnesses UNEP's unique capacity to provide a convening and 'harmonizing' role to present a common voice from the building sector on climate change issues. More specifically UNEP-SBCI aims to:

1. Provide a common platform for and with all building and construction stakeholders to collectively address sustainability issues such as climate change;
2. Establish globally consistent climate-related building performance baselines and metrics for monitoring and reporting practices based on a life cycle approach;
3. Develop tools and strategies for achieving a wide acceptance and adoption of sustainable building practices throughout the world;
4. Implementation - Promote adoption of the above tools & strategies by key stakeholders.

For more information,
see www.unep.org/sbci

About Sustainable United Nations (SUN)

Sustainable United Nations (SUN), is a UNEP initiative that provides support to UN and other organisations to reduce their greenhouse gas emissions and improve their sustainability overall. SUN was established in response to the call from UN Secretary General Ban Ki-Moon at the World Environment Day 2007 (5 June), to all UN agencies, funds and programmes to reduce their carbon footprints and “go green”. This call was echoed in October 2007 in a decision of the UN Chief Executives Board (CEB/2007/2, annex II) to adopt the UN Climate Neutral Strategy, which commits all UN organisations to move towards climate neutrality. SUN is in this context working with the UN Environment Management Group – the UN body coordinating common environmental work within UN – to provide guidance, and develop tools and models for emission reduction within organisations.

SUN operates in synergy with existing initiatives and networks such as the Environment Management Group, the Sustainable Buildings and Construction Initiative, the High Level Committee on Management Procurement Network, the UN Global compact, or the Marrakech Task Force on Sustainable Public Procurement and many others.



For more information, see
www.unep.fr/scp/sun

About the UNEP Division of Technology, Industry and Economics

The UNEP Division of Technology, Industry and Economics (DTIE) helps governments, local authorities and decision-makers in business and industry to develop and implement policies and practices focusing on sustainable development.

The Division works to promote:

- > sustainable consumption and production,
- > the efficient use of renewable energy,
- > adequate management of chemicals,
- > the integration of environmental costs in development policies.

The Office of the Director, located in Paris, coordinates activities through:

- > **The International Environmental Technology Centre** - IETC (Osaka, Shiga), which implements integrated waste, water and disaster management programmes, focusing in particular on Asia.
- > **Sustainable Consumption and Production** (Paris), which promotes sustainable consumption and production patterns as a contribution to human development through global markets.
- > **Chemicals** (Geneva), which catalyzes global actions to bring about the sound management of chemicals and the improvement of chemical safety worldwide.
- > **Energy** (Paris and Nairobi), which fosters energy and transport policies for sustainable development and encourages investment in renewable energy and energy efficiency.
- > **OzonAction** (Paris), which supports the phase-out of ozone depleting substances in developing countries and countries with economies in transition to ensure implementation of the Montreal Protocol.
- > **Economics and Trade** (Geneva), which helps countries to integrate environmental considerations into economic and trade policies, and works with the finance sector to incorporate sustainable development policies.

*UNEP DTIE activities focus on raising awareness,
improving the transfer of knowledge and information,
fostering technological cooperation and partnerships, and
implementing international conventions and agreements.*

For more information,
see **www.unep.fr**

For more information, contact:

UNEP DTIE

**Sustainable Consumption and
Production Branch**

15 Rue de Milan

75441 Paris CEDEX 09

France

Tel: +33 1 4437 1450

Fax: +33 1 4437 1474

E-mail: unep.tie@unep.org

www.unep.fr/scp/sun

www.unep.org

United Nations Environment Programme

P.O. Box 30552 Nairobi, Kenya

Tel.: ++254 (0) 20 762 1234

Fax: ++254 (0) 20 762 3927

Email: unep@unep.org



India has one of the fastest growing construction sectors in the world. New construction spending has grown by as much as 10% in the last five years and built floor area has more than doubled. This increase in construction activity is being driven by rapid urbanization. About 30% of India's 221.1 million households are now in urban areas with the urban population projected to more than double by 2050. This rapid growth in India's building sector no doubt presents opportunities for improving the living conditions and livelihoods of millions of people. However, in order to be sustainable the environmental pressures of increased demand for resources coupled with a rapidly changing climate must be addressed.

This 'State of Play' report provides representative examples of the range of sustainable building activity in India. The report explains the state of sustainable buildings and construction in India including best practices, successes, barriers and recommendations for further implementation towards mitigation of climate change impacts and a transition to more sustainable built environments.