



International Journal of Emerging Technologies in Computational and Applied Sciences (IJETCAS)

www.iasir.net

THERMAL COMFORT AND ENERGY EFFICIENCY IN INDIAN COMMERCIAL BUILDINGS

Ramesh S P^a, M Imran Khan^b

^aResearch scholar, Mech. Engg. Dept. JMI, faculty of Engg & Technology, New Delhi

^bProfessor, Mech. Engg. Dept. JMI, faculty of Engg & Technology, New Delhi

ABSTRACT: Engineers involved in design and construction and specifying buildings are today facing the challenge of anticipating and designing for uncertain, rapidly changing, climatic conditions. Passive energy solutions offer great opportunity in hot climates, especially in developing countries with rapid growth rates for floor space and air conditioning utilization. Passive technologies that reduce heat gain include cool roofs, reflective wall coatings, low-e glass, window films, radiant barriers, exterior shading, exterior and interior insulations, and ventilation techniques that remove inside heat gain from people and equipments. With comprehensive passive design, many buildings may never need air conditioning or the installed air conditioning capacity can greatly be reduced. This paper discusses and proposes opportunities in minimizing thrust on active technologies and look for more alternates in buildings resulting in reduced energy consumption and minimizing green house gas emission (GHG).

Keywords: Passive technology, heat gain, air conditioning, passive design, GHG.

I. INTRODUCTION

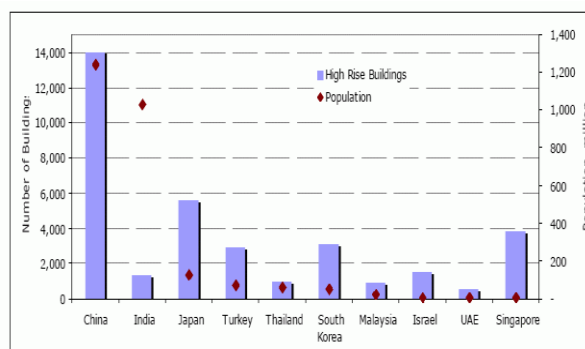
Realty sector has been the front runner of the ever growing economy of the developed and developing world. Multidimensional growth also brings in its share of risks and challenges in terms of large energy demand in managing the comfort of occupants. 15%-20% of world's primary energy and 40% of total energy is consumed in buildings [1] in developed and developing countries. This large share of energy consumption is mainly due to comfort cooling (50%) and lighting (32%), can be mitigated by proper decisions during design and planning of the building. With the increased awareness of energy consumption as well as the environmental impact of building operations, architects, designers and planners are required to place vital consideration on sustainability and energy performance of the building. To ensure most of those considerations, reflected in the building performance, critical design decisions should be made by all the stakeholders during the design development stage.

India is the fifth largest energy consumer in the world, after the United States, UK, China, and Russia. Despite a slowing economy, India's energy demand continues to rise [2]. India and China are considered as the fastest developing economies in south Asia. China has already surpassed India in many sectors, including energy and construction. Though per capita energy consumption in India is relatively low, ever increasing population, urbanization, growth of IT sector, demand for stable comfort condition by younger generation resulted in large scale energy demand in the building sector which is the highest compared to industry and transportation sector [3]. Another reason for increased demand for comfort in building is due to development of air tight buildings. Crudely following the developed countries mistakes for direct solutions will simply raise Indian comfort expectations to levels that require sizeable energy inputs, without substantially improving overall occupant comfort, satisfaction and productivity makes no sense.

II. GROWTH OF REALTY SECTOR AND ENERGY CONSUMPTION IN INDIA

Growth story of Indian realty sector started with IT service sector emerging as booster for economy during 1998, has witnessed unprecedented growth till now and the trend is expected to continue. Overall commercial floor space is projected to grow at 7% per annum till 2030 and office floor space is expected to grow at the rate of 12% per year during 2030[4]. The demand for Grade A office space has been increasing very fast in India, from 4.3 million m² in 2006 to 5.2 million m² in 2007. To date, the term "Grade A office" in India refers to buildings with central air conditioning designed for closed indoor temperature control and 100% power backup on-site [4].

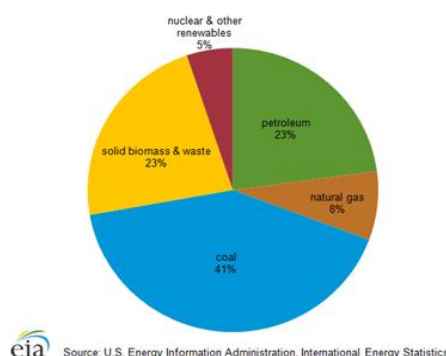
As per the International Energy Agency (IEA) reports, the realty sector is the largest consumer of energy (169 Mtoei or 47%). between 1995 and 2005 (IEA 2007). While most of this is incurred in the residential sector (93% in 2005), energy consumption by the commercial building sector seems to increase rather sharply over coming decades as the sector experiences economic transformation. Currently India has noticeable number of high-rise buildings in line with all the other active construction countries across Asia (See Figure 1). This infers a very high growth potential in building construction in the future to accompany a phenomenal growth in India's economy.



Source: Emporis, 2007; Note: High-rise buildings are those taller than 20 m (68 feet)

Figure 1: High rise buildings and population for future construction countries across Asia [5].

With more than 80% of the construction is yet to come up by 2030, building sector in India is set to consume more than 40% of total energy [5]. Energy consumption in buildings is generally used for building services like HVAC, lighting, fans and pumps and security, see figure2. and figure.3 India's GHG emission is also alarming and amounting to equal percentage of energy consumption. Before India's building sector can fulfill the CO₂ abatement potential it has been earmarked for, it is imperative for new build projects to eschew the energy-intensive designs that characterized western commercial buildings of the 20th century. By following the high-carbon development pathways of warm/hot climate cities such as Singapore and Dubai, the rapid expansion of Grade A, air-conditioned office buildings are a key contributor to India's soaring demand for electricity over coming years [6].



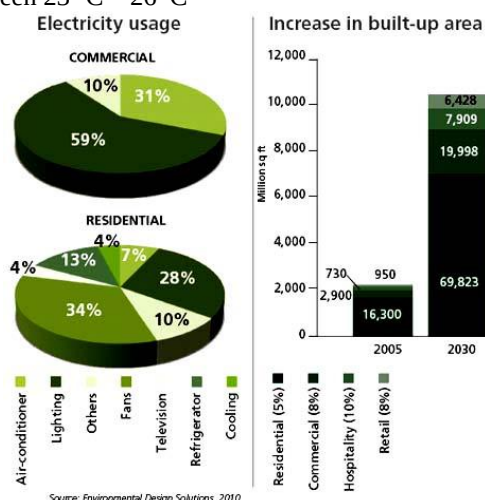
cia

Source: U.S. Energy Information Administration, International Energy Statistics

Figure.2. Total Energy consumption in India, 2011

III. BUILDING STANDARDS FOLLOWED IN INDIA

In India, buildings are designed based on the National Building Code (NBC) (BIS 2005) that stipulates two ranges of inside design conditions that are uniformly set for air-conditioned office buildings regardless of their climatic location across the country. The NBC follow stringent prescriptions of ASHRAE standards with summer temperature falling between 23⁰ C – 26⁰ C



Source: Environmental Design Solutions, 2010

Figure. 3. Energy consumption pattern and increase in built up area in Residential and commercial buildings in India

with relative humidity range of 50-60% and winter conditions between 21-23°C with relative humidity not to be less than 40% [7]. Separately the NBC provides guidelines (see Part 8 Section 1) for designing natural ventilation which pertain to building orientation, air flow rates, opening sizes and shading while noting that the “Tropical Summer Index after Sharma and Ali, 1986 (*TSI*) of a person lies between 25°C and 30°C with optimum condition at 27.5°C.

During 2007, Indian government through the Bureau of Energy Efficiency (BEE -2007) and subsequently revised during 2009 introduced Energy Conservation building Code (ECBC) which was an adaptive comfort model (ASHRAE, 2004) taking care of building envelope, orientation and energy consuming equipments like HVAC, fans and water pumping motors . However there are no recommendations of ECBC on recommended temperature and humidity conditions for air conditioned buildings [8].

Building sector in India has been recognized as one of the prominent energy consuming sector in recent times (ECBC 2007). Until then, building sector either emulated from west for any standard to follow. As an example office buildings used to be designed to operate at $22.5 \pm 1^{\circ}\text{C}$ to meet the stringent “Class A” comfort specifications articulated in documents such as the international Standardization Organization’s comfort standard (ISO, 2005) and ASHRAE 55 guidelines for air conditioned building i.e. follow the worst of the west [9].

IV. LOW ENERGY ARCHITECTURE IN INDIA

Concept of low energy architecture is nothing new to Indian construction industry. Passive architecture has been adopted centuries ago to keep the inside building within acceptable comfort level. Construction of zero energy architecture has to begin at the very initial stages of design with the use of “five elements of earth“. From orientation of the building to selection of low energy material through design and construction can make the building comfortable and environment friendly to live in. However with the urbanization, availability of space in cities is limited and very expensive to adopt passive architecture. This limitation has forced us to go for vertical architecture with air tight envelopes [10, 11, 12]. Obviously these buildings call for heating ventilation and air conditioning (HVAC) to keep the space inside within comfortable limit. Use of low energy architecture along with active cooling (missed mode) can keep the condition inside the building envelope comfortable with reduced energy usage. There are a number of built examples of low energy architecture in India such as Torrent Research Centre at Ahmadabad, Institute of Health Management Research at Jaipur, TERI University at New Delhi, TERI offices at Bangalore, Auroville buildings at Pondicherry, Centre for Environment Education at Ahmadabad, Centre for Development Studies at Trivandrum, to name just a few. Environmental control in these buildings is designed and achieved through passive methods, sometimes in conjunction with alternate low energy cooling systems which do not rely on refrigerant cooling and in other cases in a mixed mode of operation where supplementary air conditioning is used only when conditions ride outside the acceptable comfort level. [13]. Another concept to reduce energy bill without compromising on comfort is to have individual comfort control according to his needs. That is the adaptive concept places the building occupant in charge of creating indoor thermal comfort by exercising a variety of adaptive opportunities such as operable windows, instead of depending on energy-intensive HVAC for comfort. Buildings relying on natural ventilation are now permitted and encouraged by *Standard 55*’s linkage of the acceptable range of indoor comfort temperature limits to outdoor weather and climate. Warmer the external climatic context of the building – the warmer the indoor comfort range permitted under the North America’s comfort standard (ASHRAE, 2004).

V. ENERGY EFFICIENCY IN THE BUILDINGS SECTOR

Urbanization is happening at the fastest rates in emerging economies. For example, more than half the world’s current population live in Asia, and 28 percent of those people will move from rural to urban areas by 2050 (70 percent of the world’s population) see figure 2.

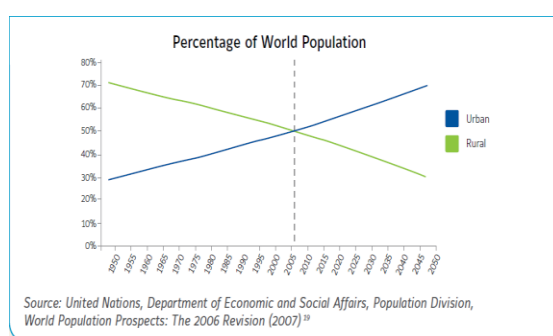


Figure 4. Pace of Urbanization

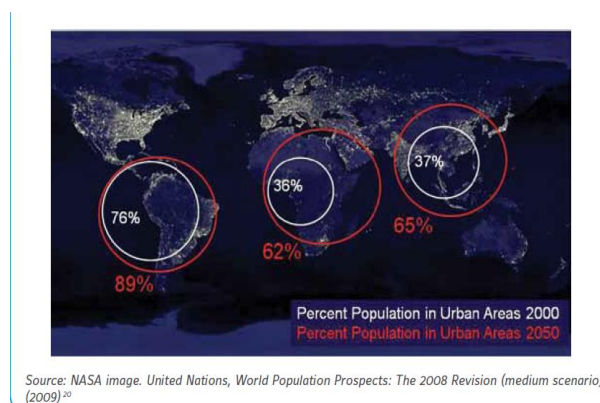


Figure 5. Percentage growth in urban areas 2000-2050. Source; IEA 2007

India's current percentage of urban population is approximately 30% [14]. If studies from developed nations are to be believed India's urban population percentage is likely to stabilize at 60% of the total population. It is projected that India's urban population would grow to about 73 million in 2021 and 820 million by 2051, as against only 285 million in 2001. This further highlights the kind of demand that is expected in the residential and commercial sectors in India. Buildings form the fabric of these rapidly growing urban landscapes. Sustainable development objectives can only be met by increasing the energy and resource efficiency of existing and new buildings, aligning economic, social, and environmental objectives. Energy consumption in buildings sector amounts to 15–20% of the total national energy consumption in developed and developing countries. More than 40% of the total energy in buildings goes into comfort cooling and heating alone (HVAC). Hence buildings sector offers more potential for cost-effective greenhouse gas emissions reductions than any other major abatement category [15]. Buildings use large quantities of raw materials, including energy, water and construction materials, competing with other sectors of the economy for these scarce resources. The environmental impact of the built environment can be minimized with energy efficient buildings. Building energy performance is directly related to the design of the building envelope (insulation, roofing, windows, etc.) and components within it, such as lighting, appliances, and heating, ventilating, and air conditioning (HVAC) systems. Many energy-efficient building technologies are widely available today and can reduce carbon emissions at a low or negative net cost. According to one estimate, available technologies could reduce projected energy use in buildings 41% by 2050, thereby avoiding 11.5 giga tonnes (Gt) of CO₂, or roughly 40% of current global fossil CO₂ emissions (IEA 2009a).

Energy conservation refers to using less while energy efficiency means using the same efficiently. Efficiency frees up valuable capital for other strategic investments in economic progress. Reduced electricity use in efficient buildings can slow down the need to invest in electricity supply, helping liberating funds for other national objectives. Also, reduced electricity use in efficient buildings can be a strategy to help improve overall electric grid reliability. For example, increasing the local renewable energy in the electric grid is an important complement to energy efficiency.

Efficiency would also reduce exposure to volatile fossil fuel prices. Reduced dependence on fossil fuels (the source of most energy and electricity) directly improves the balance of trade of fossil-fuel importing countries, helping to protect those countries from international fluctuations in energy prices. Efficiency improvement in buildings (equipments) calls for capital investment during the initial stages, may be for retrofits, control systems etc., The same can be recovered in days to come y way of saving energy over the rest of the life of the equipment. Hence efficiency is not one time program, instead a way of life for occupants who will enjoy the benefits at a very nominal price with an environment friendly attitude.

VI. GHG EMISSIONS FROM THE BUILDINGS SECTOR

Buildings sector energy efficiency should be a cornerstone of any effort to reduce global emissions contributing to climate change. Building sector consumes more than 40% of global energy. This energy use is currently responsible for a substantial share of global carbon dioxide (CO₂) emissions [16]. Understanding global variations in energy use patterns in buildings can strengthen strategies for mitigating those emissions. In 2004, buildings accounted about 25% of global CO₂ emissions or 8.6 gigatonnes (Gt)—a figure projected to grow to 11.1 Gt by 2020 (IPCC 2007). As Figure 1 suggests, the magnitude and composition of energy use by residential and commercial buildings vary significantly by region of the globe, as influenced by climate, economic development, regulation, culture, and other factors.

VII. NEED OF ENERGY EFFICIENT BUILDINGS

Buildings these days have “clean” unshaded and extensive glazed and sealed windows and deep floor plates, complete with mini power stations capable of 100% generation in case of an electrical blackout. The appeal of such buildings appears to be driven by

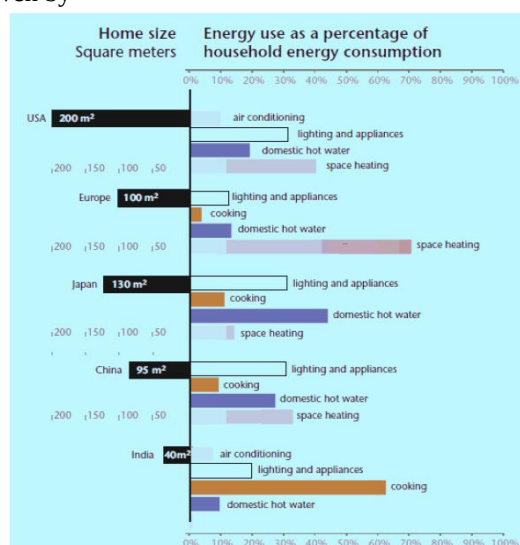


Figure 6. Energy consumption pattern in Indian household. Source: WBCSD 2009

perceptions of image and appearance [17]. An information sheet by developer DLF (2004) while acknowledging the cost and energy consequences of glass attributes its extensive use to “the influx of MNCs [multinational companies]” and the need “to be in line with the latest trends in the architecture as well as the market requirements for contemporary looking structures”

With industrialization/ urbanization demand for energy is increasing fast day by day and is likely to increase. The building sector being one of the largest consumers of energy, has gained prominence over the past few decades. Worldwide over 50% of total global energy is used in heating, cooling and lighting of building while 5% energy is used in building construction. In India, energy used for air conditioning of commercial buildings accounts for 32% of the total energy consumption in the commercial sector in 1995 while 60% goes into lighting. Energy consumption patterns can be substantially reduced by energy conserving measures, particularly during the initial phase of building design [5]. Space heating load can be reduced by about 50%, when economically-viable insulating measures are applied to the building envelopes, i.e. to ceiling and walls. Currently Indian building’s energy intensity is 200 kWh per sq. meter This can be reduced to 120 kWh per sq. meter by the application of energy efficient building techniques, saving up to 60% can be achieved (Source : TERI & BEE, Govt. of India presentations) [18].

Role of energy efficient building Energy efficient, sustainable buildings can help align economic development, social and environmental goals. Design, construction and renovation of buildings are large contributors to GDP and employment, making the transition to energy efficient, sustainable buildings a crucial component of the green economy. Increasing energy productivity through measures like building efficiency has the potential to slow the growth of energy demand in developing countries by more than half by 2020. The environmental impact of buildings can be reduced through design, siting decisions, materials selection, energy and water use, and waste management [19]. Energy efficient buildings contribute to better indoor and outdoor air quality with benefits to human health and productivity, as well as enhanced comfort for improved quality of living. In addition to this, investing in energy efficient infrastructure today can deliver significant cost savings over the lives of the buildings. Higher-quality buildings can aid to achieving other economic development goals by providing high-quality, comfortable spaces that increase worker productivity.

VIII. ENERGY EFFICIENCY TECHNOLOGY PLAN

With a population of 1.2 billion people and one of the fastest-growing economies in the world, India is experiencing a rising demand for energy to cater to its economic activities. This growth has presented a challenge to the energy infrastructure, as evidenced by some of the statistics from the Central Electricity Authority’s Load Generation Balance Report (LGBR) 2010-2011. This assessment of the country’s anticipated electric power supply and demand for that period found that, nationwide, available energy is projected to fall 10.6% short of overall needs, and energy supplied during peak periods will fall 12.1% short of demand. This projected imbalance between supply and demand foretells a major reliability problem and an uncertain climate

for consumers and businesses in need of power. In addition, India's raising greenhouse gas emissions has led to increase in energy scrutiny of the country's energy system. According to the International Energy Agency (IEA), India's emissions are expected to nearly triple between 2007 and 2030, growing from 4.5% of the world's emissions today to 8.5% over the next two decades.

One of the main drivers for this increase in energy use and carbon generation is the growth in building stock expected over the coming decades. Based on forecasts of building construction, it is estimated that about 80% of the floor space that will exist in India in 2030, is yet to be built [20]. This trend stands in stark contrast to developed economies like the United States, where new construction is expected to proceed at a much more gradual pace and represent a much smaller percentage of overall floor space. As in other rapidly developing economies, Indian buildings will continue to demand more energy to fuel greater productivity and a more comfortable standard of living. Exploding construction raises the specter of significantly higher greenhouse gas emissions and an increasing strain on the energy system; but it also presents a significant opportunity to implement efficiency in new buildings, where it is the least costly. Increase in efficiency will also come with a price, which can be offset by the energy saving it offers. However, the payback period will decide whether to go for it and to what extent.

The Government of India institutionalized a national effort to increase efficiency with the release of the Energy Conservation Act in 2001. In addition to authorizing the Central and State Governments to mandate energy efficiency, this legislation created the Bureau of Energy Efficiency (BEE) – formally established in 2002 – and authorized it to support energy efficiency at the national level. The BEE provides research and support for national policy and drives communication initiatives promoting energy efficiency.

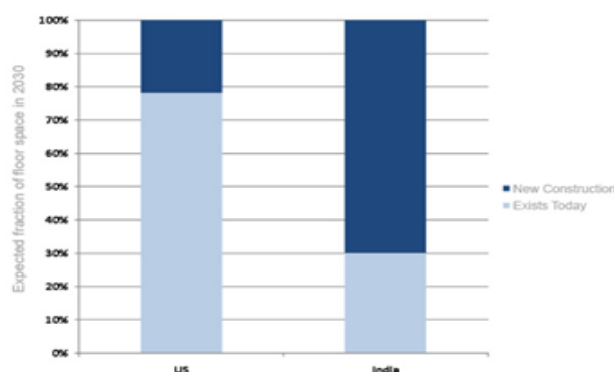


Figure. 7 projected building space in 2030

(Source: Report from Institute for building efficiency, December 2012)

IX. PROPOSED APPROACH TO MINIMIZE THE ENERGY CONSUMPTION

India has five climatic conditions spread across the country and time period. On an average, India falls in tropical region having warm temperature throughout the year. Comfort indoor environmental control can be achieved by adopting passive technologies and Adoptive control technology. Few environmental control strategies that can be adopted in buildings are;

1. Naturally ventilated with no active heating or cooling systems (other than ceiling fans). These passive buildings designed in accordance with traditional climate-responsive bioclimatic principles.
2. Mixed-mode buildings, wherein naturally ventilated buildings with supplementary air-conditioning to manage discomfort in extreme weather conditions.
3. Design of contemporary buildings by extensive use of low energy envelope materials (notably unshaded glass), fully sealed facades, and intensive air-conditioning.
4. Energy efficient air-conditioned buildings or contemporary office buildings where there is a clear energy efficient design intent.
5. Mixed mode green buildings which operate in passive mode (natural ventilation) for a substantial period of the climatic year, but integrate compressor-based air conditioning for use during weather extremes.

In Japan during 2011 studies revealed that occupant's space temp was temperature was found to be 27.2°C. Thermal acceptability was as high as 89%. PMV always significantly overestimated the sensation owing to a wide range of adaptations by the people. As indoor air speeds were low, need for ceiling fans was suggested. In 50% of the environments the indoor temperature was more than the 28°C limit. This setting of thermostat to 28°C during summer and 20°C during winter resulted in large energy saving for Japan.

On similar lines there are two schools of thoughts as far as comfort requirements in buildings are concerned. First being fixed temperature approach (FTA 23°C), which is centuries old, in which comfort has a narrow band of temperature 23±1°C. To meet this, active systems like HVAC have to be used and hence high energy consumption and GHG emission. This approach has a narrow band width which is not only difficult to achieve but demands efficient control systems.

While larger band widths like in adaptive controls gives the occupant to decide his comfort level while minimizing energy consumption. Adaptive comfort system calls for additional capital investment towards control systems which can be justified by low payback period. Hence adaptive control method holds key for optimized energy consumption in buildings and hence GHG mitigation.

X. CONCLUSIONS

With rising energy costs and serious concerns about global warming, energy conservation sustainability measures in buildings must evolve as a way of life in developing countries. Opportunity exists today to align rising energy demand and urbanization trends with sustainable development goals by making buildings more energy efficient to help this world to mitigate greenhouse gas emission. Adoption of passive design and adoptive control methods are simple and effective to achieve sustainability. The role of ECBC is vital as a resourceful candidate in bringing awareness and implementing in the right direction. The resource efficiency of efficient buildings can help cities and countries to challenge energy crisis leading to continued economic development goals while meeting social and environmental goals.

REFERENCES

- [1] IEA (International Energy Agency) (2008) Towards a Sustainable Energy Future, IEA programme of work on climate change, clean energy and sustainable development
- [2] McKinsey & Company Environmental and Energy Sustainability: An Approach for India, August 2009, McKinsey & Company, New Delhi
- [3] Thomas, L., Buildings for Strategic Advantage -Lessons from post- occupancy studies of low energy architecture in India. Proceedings of the World Renewable Energy Congress 2006 (WREC IX), A.A.M.Sayigh, Ed., Florence, Italy, August 19-25, 2006. Elsevier.
- [4] Thomas L. et.al “Air Conditioning, Comfort and Energy in India’s Commercial building Sector, 9-11” April 2010. London: Network for Comfort and Energy Use in Buildings, <http://nceub.org.uk>
- [5] BEE. Energy Conservation Building Code 2007. Revised Version May 2008. Bureau of Energy Efficiency. New Delhi
- [6] Kumar S, Kapoor R, Rawal R, Seth S, Walia A.. Developing Energy conservation building Code Implementation Strategy in India. Proceedings of ACEE Summer Study on Energy Efficiency in Buildings, Pacific Grove, CA, August 2010.
- [7] UNDP 2011. Proposed Project Document for CEO Endorsement. India: IND Energy efficiency Improvements in Commercial Buildings - under the Programmatic Framework for Energy Efficiency in India. January 2011
- [8] Ankur Tulsyan et al., Potential of energy savings through implementation of Energy Conservation Building Code in Jaipur city, India, Energy and Buildings, 2013, vol. 58 p. 123–130
- [9] BEE. 2007. Energy Conservation Building Code 2007. Revised Version May 2008. Bureau of Energy Efficiency. New Delhi.
- [10] BCAP,. Commercial Building Energy Codes-Usability and Compliance Methods, 2008, Developed by Building Codes Assistance Project
- [11] Lall A.B Towards an urban level perspective plan for controlling energy demand in buildings. Sustainable Habitat Synergies Conference, New Delhi. March 2005
- [12] Madhavi Indraganti , Ryoza Ooka, Hom B. Rijal, Thermal comfort in offices in summer, Building and Environment, 2013, vol. 61 p114-132
- [13] CBRE-AMCHAM. Energy Efficiency Improvements in Buildings project cumment, Indian Real Estate Overview, UNDP/GEF, BEE, Government of India, 2011
- [14] 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
- [15] McKinsey Global Institute. India’s urban awakening: Building inclusive cities, sustaining economic growth, , April 2010
- [16] IGBC, “LEED India <http://www.igbc.in/igbc/read.jsp?req=LEED%20India> (Viewed on October 6, 2007)
- [17] Kibert, C.. Establishing principles and a model for sustainable construction. (1994), Proceedings of the First International Conference on Sustainable Construction, Tampa, FL.
- [18] Kibert, C.J.. Sustainable Construction – Green Building Design and Delivery. (2005),1st Ed., John Wiley, New Jersey.
- [19] Majumdar, M Energy-efficient buildings in India. (2001),Tata Energy Research Institute, MNES, New Delhi
- [20] Landman, M, “Breaking through the barriers to sustainable building: Insights from building professionals on government initiatives to promote environmentally sound practices.” (1999), Department of Urban and Environmental Policy, Tufts University, Medford, MA.