ISSN 2349-6193
Impact Factor (PIF): 2.243

IJESMR
International Journal OF Engineering Sciences & Management Research

ASSESSMENT OF ENERGY CONSERVATION PRACTICES IN RESIDENTIAL & COMMERCIAL BUILDINGS IN INDIA AND OPPORTUNITIES FOR IMPROVEMENT

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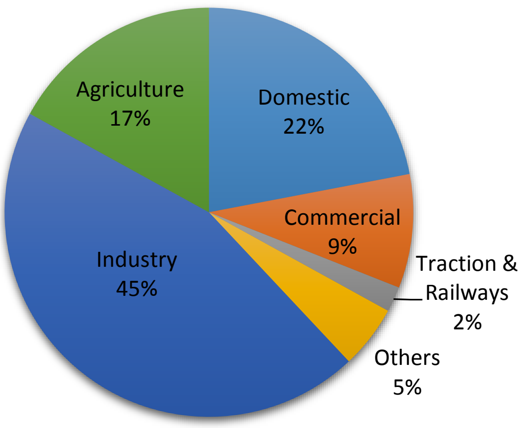
Keywords: Energy, energy conservation, residential buildings, commercial buildings, EC Act, ECBC, Bureau of Energy Efficiency.

ABSTRACT
The chief function of a building is to provide comfortable indoor environment to the occupants. Thus, the focus of energy conservation practices is to optimize energy performance of a building and reducing dependence on energy guzzling electromagnetic devices without compromising comfort of inhabitants. Energy consumption in a building is mainly in Heating, Ventilation, Air conditioning (HVAC), lighting, lifts, water pumps, running domestic appliances, operating electronic gadgets and due to losses in local transmission. The building energy consumption which is mainly in form of electricity is ever increasing and with rapid urbanization, it is bound to accelerate to unprecedented levels unless corrective measures are taken to reduce dependence on exhaustible energy sources.

This paper provides insight on energy consumption pattern and energy conservation techniques practiced in commercial & residential buildings in India. It discusses opportunities for improving energy efficiency in buildings through improvement in building design, low energy intensity equipment selection and integration of renewable energy sources with conventional sources.

BACKGROUND
Energy is essential for leading a decent quality of life and with fast paced growth of Indian economy dependence on electric power is bound to increase. During 2011-12 the estimated electricity consumption in India was 7,72,603 GWh, a massive increase from 43,724 GWh during 1970-71. Out of this domestic sector accounted for 22.01% and commercial sector 8.97% [1]. Both residential and commercial building energy use are on rise, the key factors that may be attributed to this are electrification, urbanization, industrialization, increased demand for comfort levels, growth in GDP, improved standard of living thus more time spent inside buildings. The overall sector-wise distribution of consumption of electricity during 2011-12 is as shown below:



Source: Energy Statistics, 2013, Central Statistics Office, Ministry of Statistics & program implementation

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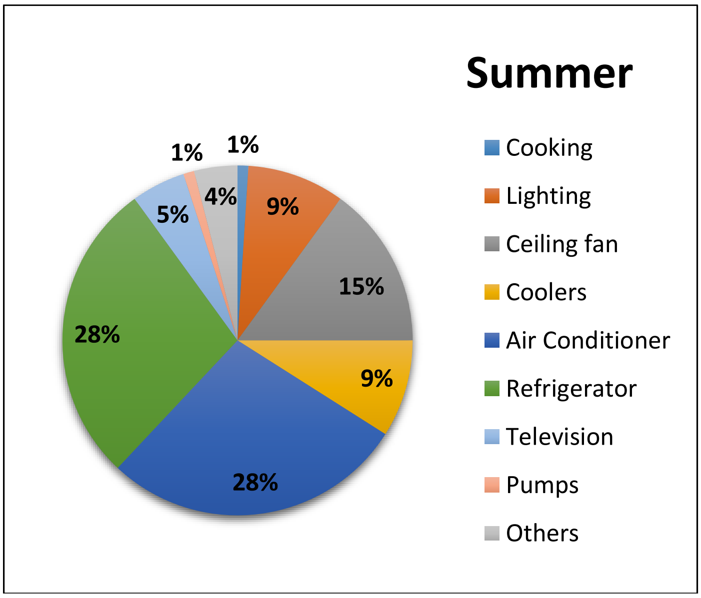
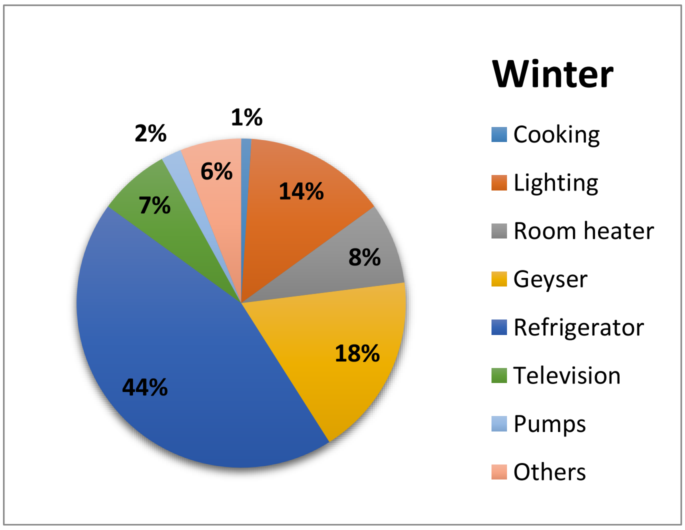
The amount and end energy use in a building depends mainly on three factors i.e. quality of life of inhabitants, climate and nature of building use.

Manisha et al., 2007 stated seasonal differences in energy demand in Delhi. The break up of end-uses electricity consumption for residential sector in Delhi is as shown below:





Source: Manisha et al., 2007

As far as commercial buildings are concerned, as per CPWD (2004) electricity consumption in commercial sector in India is highest for lighting i.e. 60% of the total electricity consumed, followed by 32% for space conditioning, and 8% for refrigeration. It is pertinent to mention here that electricity consumption varies with space conditioning needs, for example in a fully air conditioned office building, about 60% of the total electricity consumption is towards air conditioning followed by lighting (20%) [2].

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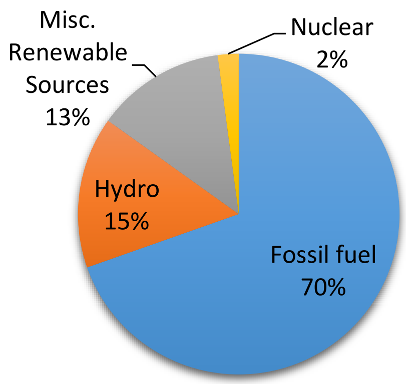
The energy consumption in a building is predominantly in form of electricity. As per Ministry of Power, main source of electricity generation is fossil fuel (69.6 %), followed by hydro (15.3 %), miscellaneous renewable sources (13 %) and nuclear fuel (2.1 %) [3]. Thus, major share of electricity generation comes from fossil fuels which contribute to increased levels of carbon dioxide emissions in the atmosphere.



Fuel	MW	%age
Total Thermal	**1,91,264**	**69.6**
Coal	167,208	60.8
Gas	23,062	8.4
Oil	994	0.4
Hydro (Renewable)	41,997	15.3
Renewable Energy Sources (Wind Energy, Small Hydro Project , Biomass Gasifier, Biomass Power, Urban & Industrial Waste Power)	35,777	13.0
Nuclear	5,780	2.1
Total	**2,74,818**	

Source: Ministry of Power, Govt. of India

ENERGY CONSERVATION PRACTICES IN BUILDING SECTOR

'Energy saved is energy produced', Energy Conservation Act (EC Act) was notified in 2001 for providing legal and institutional framework for efficient use of energy and its conservation. Bureau of Energy Efficiency (BEE) was set up under EC Act on 1st March 2002 as the statutory body at the central level to institutionalize energy efficiency services and reduce energy intensity of Indian economy. Its functions include standards & labeling of equipment & appliances, energy conservation building codes for commercial buildings, energy consumption norms for energy intensive industries, research & development, testing & certification, providing financial assistance, awareness drives, energy audit etc.

Bureau of Energy Efficiency (BEE), has developed specific policies and strategies to reduce energy consumption from buildings. It comprises of improving energy performance with regard to household lighting, labeling of appliances, Heating Ventilation Air Conditioning (HVAC) requirements, etc. As per Ministry of Power, the target of energy savings against these schemes during the XI plan period was kept 10,000 MW of avoided generation capacity.

Some of the prominent steps taken by BEE are discussed in detail below,

- Energy Conservation Building Code

The Energy Conservation Building Code (ECBC) was launched by Ministry of Power on 27th May 2007 to improve energy efficiency in building sector which consumes upto 22.1% of total electricity generation in India.

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ECBC is on voluntary basis and sets minimum energy standards for new commercial buildings having a connected load of 100kW or contract demand of 120 KVA and above. Also, to promote awareness and acceptability for energy saving schemes BEE has developed a voluntary Star Rating program for buildings based on energy consumption by a building with respect to area occupied. Also, star rating schemes have been implemented for day use office buildings, BPOs, shopping malls and hospitals [4].

In addition to above, ECBC in pursuant to National Building Code, 2005 has provided design norms for following,

1. Building envelope- roof assembly, opaque wall assembly and vertical fenestrations U-factor and insulation R- value requirements based on climate zones of India
2. Lighting system- Values of illuminance for common activities such as 300-700 Lux for general offices, libraries 200-500 Lux, laboratories 300-750 Lux, stores 100-200 Lux, canteen 150- 300Lux etc. Also, interior lighting power allowance e.g. office 10.8 W/m^2, Theater 17.2 W/m^2, education institute 12.9 W/m^2, gym 11.8 W/m^2, dining 17.2 W/m^2, etc.
3. Energy performance norms for unitary air conditioning equipments, chillers, heating pump heating mode, ductwork insulations, maximum allowable losses of 11, 22KV transformers, recommended specific fuel consumption of DG sets

S No.	Electricity generating capacity	Type of fuel used	Specific fuel consumptions (lit/kWh)
1.	200	HSD	0.325
2.	292	LDO	0.335
3.	400	HSD	0.334
4.	480	LDO	0.334
5.	800	HSD	0.29
6.	880	LDO	0.307
7.	920	LDO	0.297

- **Standards & labeling**

Standards and labeling program for equipment and appliances was started in 2006 to display energy performance labels on high energy consuming equipments & appliances and set down minimum energy performance standards. The objective of the scheme was to provide the consumer with a learned choice about the energy consumption and cost saving potential of the marketed product. The scheme covers 19 appliances, they are Room Air Conditioners, Fluorescent Tube Lights, Frost Free Refrigerators, Distribution Transformers, Induction Motors, Direct Cool Refrigerator, electric storage type geyser, Ceiling fans, Color TVs, Agricultural pump sets, LPG stoves, Washing machine, Laptops, ballast, floor standing ACs, office automation products, Diesel Generating sets & Diesel operating pump sets. Out of these Room Air Conditioners, Fluorescent Tube Lights, Frost Free Refrigerators and Distribution Transformers are notified under mandatory labeling from 7th January, 2010, remaining appliances are under voluntary labeling [5].

The energy efficiency labeling programs are focused on promoting reduction in the energy consumption of appliance without weakening its performance. It provides a competitive edge to energy efficient appliances as a result of which, least-efficient equipments are removed from the market and more efficient products are encouraged.

- **Award, Awareness program and Training**

Apart from star rating schemes and energy savings certificates BEE conducts awareness programs and trainings for promoting energy efficient practices such as national education training program for standard & labeling, energy conservation award, etc. Also, BEE has initiated Bachat Lamp Yojana (BLY) scheme is to provide Energy Efficient Compact Fluorescent Lamps (CFLs) at the same cost i.e. Rs.15, as of Incandescent Bulbs.

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OPPORTUNITIES FOR ENERGY CONSERVATION IN A BUILDING

The primary function of a building is to provide comfortable indoor environment. Hence, the energy conservation activities in a building are focused on ensuring optimum energy performance and yet provide desirable thermal and visual comfort.

Traditionally buildings were built to harness maximum advantage of climate and its surrounding. However, the modern buildings require electromechanical devices such as HVAC, lighting systems etc. which consume huge amount of energy to provide indoor comfort to the inhabitants. Hence, it is essential to achieve comfortable indoor conditions with minimal dependence upon electromechanical devices. In pursuant to this goal, following steps may be considered to optimize energy performance of a building without compromising comfort of the occupants:

1. Incorporating energy-efficient equipments for heating, cooling, ventilation, lighting, activities etc.
2. Integrating renewable energy with conventional energy systems
3. Using solar passive techniques while designing the building

Subsequent discussion is focused on energy conservations options based on fundamentals mentioned above with regard to design concept, low energy strategies and available energy efficient technologies.

(i) **Heating and/or (ii)** cooling requirements of a building depend on climatic zone in which it falls. India is divided into following five major climatic zones,

Sl. No.	**Climate Zone**	**Mean monthly maximum temperature (^{0}C)**	**Mean monthly relative humidity percentage**
i)	Hot-dry	Above 30	Below 55
ii)	Warm-humid	Above 30 Above 25	Above 55
iii)	Temperature	Between 25-30	Above 75
iv)	Cold	Below 25	Below 75
v)	Composite	-	All values

Source: National Building Code, 2005, Part 8

Depending on climate zone, comfortable conditions inside a building can be achieved either by resisting heat gain & promoting heat loss or resisting heat loss & promoting heat gain or resist heat gain in summers & resist heat loss in winters and accordingly appropriate measures can be taken to optimize energy performance of a building.

For example, Delhi falls under composite climate region; hence the building design should resist heat gain in summers and resist heat loss in winters. Also, it should promote heat loss in summer and monsoon months. Hence, passive strategies and design features that may be considered for buildings in Delhi are low surface to volume ratio, correct orientation, providing buffer zones (verandas and balconies) to protect the building mass from direct exposure to solar radiation, providing shading (overhangs, louvers and trees), increase external surface reflectivity through light color of building envelope, plantation of trees and water bodies for evaporative cooling etc. In winter months, thermal resistance and thermal capacity may be achieved through insulating roof, walls and designing thick walls.

(iii) Ventilation

Ventilation of indoor spaces is essential to control indoor air quality and achieve thermal comfort. Natural ventilation should be encouraged in a building design through proper location of openings, cross ventilation, chimneys, wind towers etc. The minimum fresh air requirement in a mechanically ventilated or air conditioned space is set by National Building Code (NBC), which is tabulated below for some common areas:

ISSN 2349-6193
Impact Factor (PIF): 2.243

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(iv) Lighting

Lighting constitutes a key component of energy consumption in buildings. In a fully air conditioning office in India, lighting constitutes 20% of total energy consumption. Energy consumption in lighting can significantly be reduced by good lighting design strategies, such as use of efficient lighting equipments, uniform light distribution, use of occupancy sensory, timers, photocells, daylight integration, effective maintenance of lamps, luminaries & control gears, lighter finish of ceiling, walls & furnishings, glare reduction, good lamp coloration, reducing wastage, etc.

A small step towards energy conservation can go a long way, this is illustrated through an example below which compares luminous and electrical efficiencies of three types of lamps, incandescent bulb (1000W), compact fluorescent lamp (25 W) and LED (5.4 W).

We consider a general office of area 500m^2 with range of service luminance as 300-700 Lux (NBC, 2005). The

SI. No.	Application	Estimated Maximum Occupancy (Persons/100m^2)	Outdoor Air Requirement	
			l/s/Person	l/s/m^2
1.	Commercial dry cleaner	30	15	-
2.	Kitchen (cooking)	20	8	-
3.	Office space	7	10	-
4.	Public restrooms, l/s/we or urinal	-	25	-
5.	Elevators	-	-	5.0
6.	Stadium spectator areas	150	8	-
7.	Auditorium	150	8	
8.	Classrooms	50	8	
9.	Hospital operating rooms	20	15	

lighting power allowance for general office is 10.8w/m$^{2.}$ Hence, the total power allowance for lighting is 5400 watt.

The efficacy of incandescent bulb (1000W) is 18 Lm/W, whereas compact fluorescent lamp (25 W) is 80 Lm/w. Hence for lighting office area of 500 m^2 with maximum power allowance of 5400 Watt, CFL would produce illuminance of 4,32,000 Lm compared to incandescent lamp 97,200 Lm i.e. CFL of 25 W would light the same space 4.4 times higher than incandescent bulb of 1000W.

If we assume that average office service illuminance requirement is 500 Lux i.e. 500 Lm/m$^{2.}$ Then for 500 m^2 office area 2,50,000 Lm is required. Based on this, it is estimated that 25 W CFL lighting will require 6250 KW power to produce same lighting effect as incandescent bulb which would require 250000 KW i.e. 40 times more power consumption.

Similarly, for a 5.4 Watt LED, luminous efficacy is as high as 101.9 Lm/m^2 hence it will provide illuminance of 5, 50, 260 Lm for power consumption of 1350 KW i.e. 4.62 times less than CFL and 185 times less than incandescent bulb. The above calculated results are tabulated below:

Type of lighting source	Wattage	Luminous Efficacy (Lm/W)*	Illuminance for allowable power consumption of 5400W (Lm)	Illuminance ratio	Power consumed for producing 2,50,000 Lm (KW)	Power consumption ratio
Incandescent	1000 W	18	97,200	1	2,50,000	185

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bulb						
CFL	25 W	80	4,32,000	4.44	6,250	4.62
LED	5.4 W	101.9	5, 50, 260	5.66	1350	1

**NBC, 2005*

CONCLUSION

The energy conservation activities in a building should focused on ensuring optimum energy performance and yet provide desirable thermal and visual comfort. The buildings should be designed to harness maximum advantage of climate and its surrounding to reduce dependence upon electromechanical devices. Energy-efficient equipments should be incorporated for heating, cooling, ventilation, lighting, operating electronic devices etc. Renewable energy sources needs to be integrating with conventional energy systems and solar passive techniques should be used while building designing

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