Energy Efficiency in Residential Buildings in Mumbai, India

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Abstract

We are currently in a situation where the economy is crunching and energy is getting more expensive by the day. A lot of effort is being made to switch to renewable sources of energy and use it to power the grid. Extensive investment and research is being made and we can expect a complete change in paradigm over the next decade. But immediate strategies are required now to bring down our energy consumption and meet the current needs. In the United States the federal agencies were required to reduce building energy consumption per square foot by 30% in 2005 and 35% in 2010, both relative to 1985. This executive order was passed after detailed analysis and studies carried out by Federal Energy Management Program (FEMP) to identify cost-effective energy efficiency measures that should be implemented in these structures.

This paper has conducted a study on a high rise residential construction in the metropolitan city of Mumbai in India. The energy consuming appliances and fixtures in a typical residential unit in the city are identified and then replaced with the accessible technologies using renewable energy and energy efficient fixtures. The study has targeted changes that can be carried out by a single homeowner for his/her apartment in a multistoried building. A comparison between the existing energy consumption and that computed with the modifications presents a clearer picture as to whether 30% efficiency can be achieved in an existing residential building in the heart of Mumbai, India. The results further open up the different paths that can be adopted by the government for establishing benchmarks for increasing energy efficiency of high rise residential constructions by merely educating homeowners and the end users.

Introduction

A study conducted by Energy Information Administration and U.S. Department of Energy indicates that there is a visible trend across the globe wherein the growth rate in total energy consumption has been greater than the population growth rate. In the developed countries the energy consumption growth rate is only marginally higher compared to the population growth rate. For example, in USA, energy consumption is projected to grow at 1.3% while the population growth rate is projected to grow at 0.8%. In contrast, in developing countries like India population growth rate is expected to grow at 1.3% while the energy consumption rate is

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expected to grow at 4.3%. This trend would strain the energy sector to a large extent. The construction industry in India is growing at a rapid pace and the rate of growth is 10 % as compared to the world average of 5.2%. Hence energy efficiency in the building sector assumes tremendous importance.

In the United States the government has made huge investments in terms of time and money for increasing the efficiency of federal buildings. The Executive order 13123 that went into effect in June 2000 established a goal of 35% reduction in energy consumption per square foot in all of the federal facilities by 2010 with respect to the 1985 baseline (Register 1999). In order to achieve the benchmark of 35% the SAVEnergy audits were sponsored by FEMP to conduct studies on the federal buildings and identify measures for increasing the energy efficiency. The audits developed the information based on extrapolation from a sampling of buildings and put forth the estimates of cost effective energy savings and the corresponding investment required (Brown and Dirks 2001). But it has been estimated that O&M programs targeting energy efficiency can save 5% to 20% on energy bills without a significant capital investment (PECI 1999). The interesting aspect to this is that in July 2004 FEMP, released the Operations & Maintenance Best Practices, A Guide to Achieving Operational Efficiency. The guide clearly advocates the use of low cost and no-cost O&M measures as the first energy saving measures that should be considered. Some of the reasons mentioned are low cost, easy installations, early paybacks and faster implementation as they do not require design time, bid preparation, evaluation and response as against the capital projects (Sullivan, Pugh et al. 2004).

Leadership in Energy and Environmental Design (LEED) established by the USGBC in 1998 has grown to be a popular and accepted energy assessment tool across wide sections of the industry. USGBC and LEED have played a primary role in promoting Green buildings and Sustainable energy designs in the United States and in many international locations too. There are other Energy rating programs like Building Research Establishment Environmental Assessment method (BREEAM) and Green Building Tool used in U.K, BASIX in Australia and HQE2R in France (Kibert 2008). The LEED certification program is gradually gaining popularity across the world. In India the Indian Green Building Council (IGBC) has released bridged versions of LEED-NC (New Construction) and LEED-CS (Core and Shell). 'LEED India' rating which considers local Indian codes and standards is in an advanced stage of development. The built up area of LEED certified buildings in India have risen from a humble 20,000 square feet in 2003 to 10 million square feet in 2006. Such Green Buildings consume 40 -50% less energy and 20 -30% less water as compared to a conventional building (Srinivas 2007). As of yet IGBC has not released LEED-EB for existing buildings. The paper accepts the dominance of LEED in energy efficient buildings. At the same time an attempt is being made to understand the efficiency that can be achieved in an existing building with minimal cost effective changes.

In Mumbai, the financial capital of India, the power demand has soared above the supply of 2100 MW to 2750 MW. The city's deficit of 650 MW is being bridged by purchasing power from surplus, wherever available in the country at a rate of nearly (US) 21cents per KWh of electricity

Earlier this year, the Maharashtra Electricity Regulatory Commission (MERC) had given its consent to power companies to procure surplus power from other regions, to meet the deficit in Mumbai, at a premium and pass on the average price to the consumers. The power crisis has been plaguing other urban areas of Maharashtra for quite some time now. They have been

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enduring load shedding to shield Mumbai from a power deficit. It was only in April 2005 that the MERC issued a landmark order for a more equitable distribution of energy conservation efforts. The order decreed that consumers using over 500 kWh of electricity in a month would be charged an additional [US] 2 cents for every kWh consumed in excess of 80% of their consumption in the corresponding period of the previous year. The MERC also began to aggressively pursue other measures such as imposing a ban on illumination of hoardings during peak hours, stepping up purchase of power from the northeastern grid, and promoting captive power generation for industrial use (Forum 2008). The measures adopted have been stern but not as effective as required.

In India, the Ministry of Non-Conventional Energy sources have been implementing comprehensive programs for the development and utilization of various renewable energy sources in the country. India is implementing one of the world's largest programs in renewable energy. The country ranks second in the world in biogas utilization and fifth in wind power and photovoltaic production. Renewable sources already contribute to about 5% of the total power generating capacity in the country (MNRE 2007).

The National Electricity Policy of 2005 in India aims at achieving the following objectives: (MNRE 2007)

1. Access to Electricity- available for all households in the next five years.
2. Availability of Power- demand to be fully met by 2012. Energy and peak shortages to be overcome and spinning reserve to be available.
3. Supply of reliable and quality power of specified standards in an efficient manner and at reasonable rates.
4. Per capita availability of electricity to be increased to over 1000 units by 2012.
5. Minimum lifeline consumption of 1unit/household/day as a merit good by 2012.
6. Financial turnaround and commercial viability of electricity sector.
7. Protection of Consumers interest.

This research evaluates the energy efficiency that can be achieved by targeting homeowners in an existing residential building in Mumbai, India by carrying out simple and effective changes in electricity consuming fixtures and appliances.

Research Methodology

The proposed research proceeded as suggested below

- A typical multistoried residential building is identified in the heart of the metropolitan city of Mumbai.
- Based on well established energy prices and other parameters the total energy consumption for a single unit in the same is computed.
- Modifications and retrofits of the relatively more effective and performance oriented components are applied onto this building and the corresponding decrease in energy consumption is calculated.
- The measures of efficiency achieved by the above methods are evaluated.

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Base Case- A Residential Building in Mumbai

For the purpose of this study a residential building (Figure 2, Table-1) is selected in Andheri suburb of Mumbai, India. The author's residence having been in the same building for 5 years in the past, the familiarity with the layout, the flat, the appliances and the other features play a major role in making some assumptions for the paper. Reliance Energy is the Electricity supplier in this part of the city and so the billing systems and the rate of electricity per unit used in the paper follows the same method as that of the provider.

Location	Lokhandwala Complex, Andheri (w), Mumbai 400053
Orientation	Longer face –NS and Shorter face-EW
No. Of Flats	56 flats
Area per Flat	560 square feet –built up
Construction materials	R.C.C framework Walls: Hollow Blocks Floors: Mosaic tiles on Concrete Slab Window Glazing: Single Pane (u-value= 0.75)
Year Of Construction	1985

Table 1: Information of a typical multistoried residential building in Mumbai, India

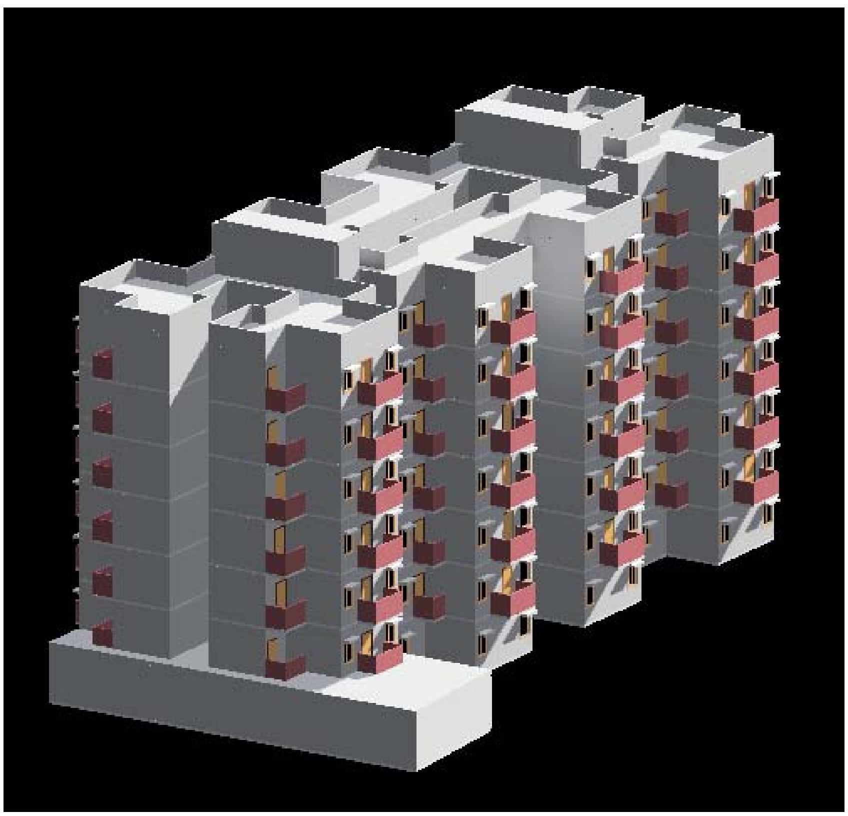

Figure 2: A typical multistoried residential building in Mumbai, India (Revit Architecture Software)

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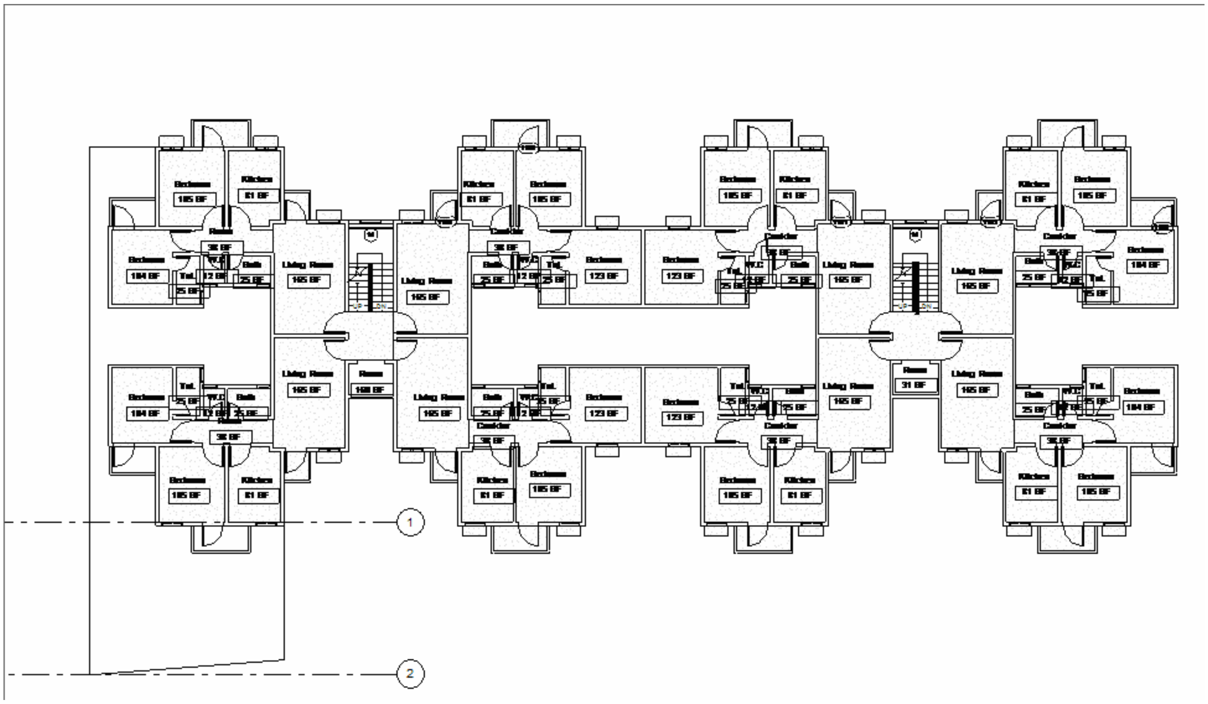

Figure 3: Floor Plan of the multistoried residential building.

Based on the familiarity with the average Indian residential units and specifically this building a list of all the major electricity consuming appliances for a single unit are made. As per the findings of the SAVEnergy audits lighting was found to have the maximum energy saving potential further followed by cooling systems, ventilation and controls, building envelope, service hot water and heating systems.

The Mumbai climate belongs to the warm and humid zone. And so as the temperatures are not excessive, there is practically no requirement for heating as temperatures do not normally fall below 20 º C. During summers the temperatures may rise to 35 º C and so there is a relatively small requirement for cooling during summer. Each room in the flat has day lighting and so use of lights is restricted to evenings and later. Based on all these factors we can safely assess the time requirement for most of the electricity consuming appliances. We will assume that the equipments are used uniformly throughout the year. Table 2 below calculates the current consumption of electricity for one month in the single apartment and Figure 4 below graphically depicts the consumption of each appliance.

Energy Efficient Technologies

Having established our base case with a single two bedroom- hall- kitchen flat consuming 637.8 units, we went ahead and studied the accessible and established technologies for achieving energy efficiency. Although there is a lot of information on passive design features the paper will not delve into these as they are applicable to new constructions and any kind of attempt to incorporate them into existing buildings would prove to be expensive and not worthwhile. The following list brings together a selective combination of the efficient technologies under the categories of lighting, exterior envelope, cooling systems, hot water and ventilation.

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Equipment and Appliances	Approx. Load(Watts)	No. of Equipments	Average hours/day	Approx. Units/Month
Tube lights	40	8	4	38.4
Lamps	60	4	2	14.4
Fan	60	5	12	108
T.V	200	1	12	72
Music System	200	1	5	30
Water heater/Geyser	1000	2	1	60
A.C 1.5ton	1500	3	1	135
Mixer/Grinder	200	1	1	6
Washing Machine	700	1	2	42
Electric Iron	600	1	1	18
Refrigerator	200	1	8	48
Exhaust Fan	150	4	1	18
Computer	200	1	8	48
				637.8

Table 2: Current Consumption of Electricity

Note: 1Unit=1000Watts per Hour
Approx Units per Month=
(Approx. Load x No. Of Equipments x Average hours per day x 30)/ 1000

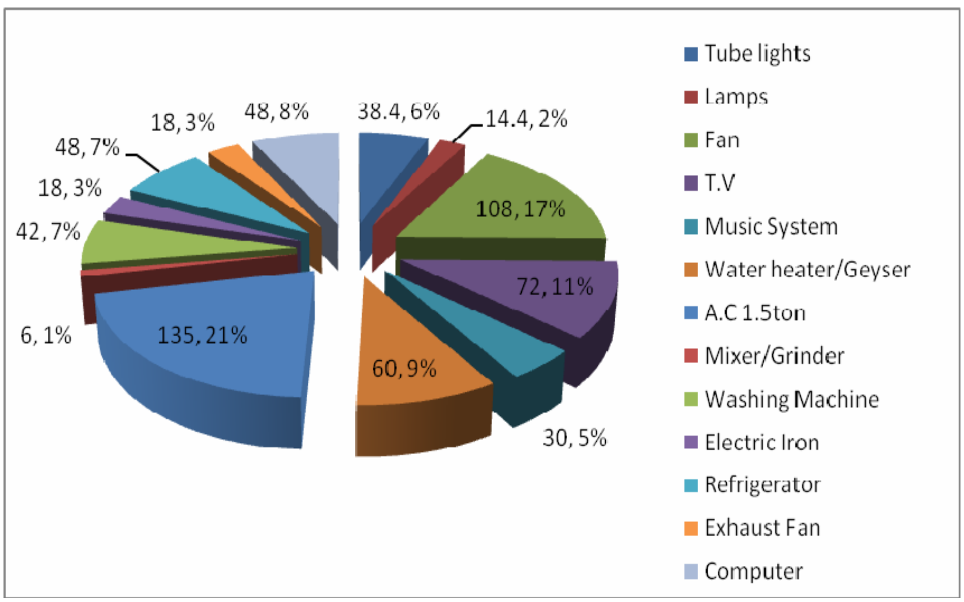

Figure 4: Pie- Diagram of Current Consumption of Electricity

Lighting: Using fluorescent tubes and energy efficient compact fluorescent lights (CFLs) in fixtures throughout the home improves energy efficiency. Fluorescent lamps are much more efficient than incandescent (standard) bulbs and last about 4 to 10 times longer. Today's CFLs

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offer brightness and color rendition that is comparable to incandescent lights. Although fluorescent and compact fluorescent lamps cost a bit more than incandescent bulbs, they pay for themselves by saving energy over their lifetime. CFL fixtures are now available that feature dimmers and operate much like incandescent fixtures. Using new lighting technologies can reduce lighting energy use in a home by 50% to 75%. For efficient lighting the following changes have been advocated by DOE

Common 40-watt and 75-watt lamps can be replaced with energy-saving lamps of 34 watts and 60 watts, respectively. Energy-saving lamps for less-common fluorescent fixtures are also available. If you need to replace the ballasts in your fluorescent fixtures, consider using one of the improved varieties. These fluorescent ballasts, called improved electromagnetic ballasts and electronic ballasts, raise the efficiency of the fixture 12%–30%.

Hot Water systems: Flat Plate solar Collector- This system consists of a flat plate solar collector, a storage tank kept at a height behind the collector and connecting pipes. The system is generally installed on the roof or on the open ground with the collector facing the sun and connected to a continuous water supply. The collector comprises of copper tubes welded to copper sheets, both coated with highly absorbing black coating, with a toughened glass sheet on top and insulating material on the back. The entire assembly is placed in a flat box. In certain models, evacuated glass tubes are used instead of copper and a separate glass sheet and the insulating box are not required in this case. Flat-plate collectors heat the circulating fluid to a temperature considerably less than that of the boiling point of water and are best suited to applications where the demand temperature is 30-70°C (86-158°F) and/or for applications that require heat during the winter months.

Most domestic solar water heaters are provided with electrical backup. Electrical heating elements are usually placed in the storage tank and can be switched on during cloudy days. The smallest solar water heater available has a capacity of 100 liters per day which is sufficient for a family of 4 or 5 members. It costs 15,000 to 18,000 INR or approx. 300 to 350 USD. In India soft loans are available at an interest rate of 5% for non-commercial users and 7% for commercial organizations. Indian Renewable Energy Development Agency (IREDA) provides loans for up to 80% of the system cost, to be repaid over 6 years including one year of moratorium. The latest information for the same may be obtained from the MNES website. The capacity range of these systems is between 100-500 liters of hot water per day.(MNRE 2008)

SPV lighting systems: SPV lighting systems are becoming popular in both the rural and the urban areas of the country. In rural areas SPV lighting systems are being used in the form of portable lanterns, home lighting systems with one or more fixed lamps and street lighting systems. Applications in urban areas include glow-sign display systems on the streets, traffic signaling, message display systems based on light emitting diodes (LED's) and systems to illuminate advertisement hoardings (MNRE 2007).

Energy Star Rated Equipments: A wide range of Energy Star rated products are available which fall under the various categories of appliances, home envelope, heating and cooling and home electronics.(DOE 2005) The appliances are 30% more efficient than their counterparts. A mass awakening among the end users regarding all these products is required. As many of these

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appliances are selected by the owner for more reasons than just efficiency a calculation with Energy Star rated appliances may not paint a realistic and possible picture for achieving energy efficiency.

Modification to the Base Case

Based on the literature reviews and the established and available technologies we can carry out changes in the lighting fixtures, hot water supply systems and cooling systems. Table 3 gives a list of the changes with the corresponding changes in consumption and the investment required for the same. These are the areas with major energy saving potential and easily accessible replacement technologies. The table 3 below recalculates the electricity consumption in the single apartment in the building after making the modifications in certain appliances and fixtures.

Existing Appliances and fixtures	Notes	Approx. Load (Watts)	No. Of Equipments	Avg. hours/day	Approx. Units/ month	Investment
Tube Lights	Energy saving lamps 35 W and Electronic ballast	34 with 12% efficiency= 30	8	4	28.8	2500 INR
Fluorescents-40W						51 USD
Lamps	850 lumens equivalent to 60W incandescent	14	4	2	3.36	1560 INR
Incandescent						32 USD
Fans	same	60	5	12	108	
T.V	same	200	1	12	72	
Music Systems	same	200	1	5	30	
Water Heater	Solar Water Heaters	0	1	Limited quantity	0	18000INR
						350 USD
A.C- 1.5T	Energy Efficient A.C	1000	3	1	90	12250 INR
						250 USD
Mixer/Grinder	same	200	1	1	6	
Washing Machine	same	200	1	2	12	
Electric Iron	same	600	1	1	18	
Refrigerator	same	200	1	8	48	
Exhaust fan	same	150	4	1	18	
Computer	same	200	1	8	48	
					482.16	34,310 INR
						700 USD

Table 3: Modification to the Base Case

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Calculations:

With the rate of Rs. 5.75 per unit we have a monthly saving of

(637.8 x 5.75) – (482.16 x 5.75) = 155.64 x 5.75 = 895 INR

This would give an annual savings of 778.2 x 12 = 10740 INR

The investment would pay back in 3.19 years. An efficiency of 24.40% is achieved.

Conclusions

The energy efficiency that is achieved by targeting homeowners and making certain changes in lighting, hot water system and air-conditioning systems in an existing residential building is 24.40%. This requires an investment of 34,300 INR or 700 USD and it gives as payback in 3.19 years.

Energy Star rated appliances ensure a very good percentage of energy efficiency as compared to their counterparts. But as most of these appliances are selected by the homeowner for reasons other than energy efficiency, the best way to make the most of these specifications is by ensuring that the market is flooded with a great variety of these appliances, inducing homeowners to invest in them.

The efficiency of 24.40% that is obtained by making some very simple changes in the existing scenario of a unit in the multistoried building gives us a very valuable guideline. Based on the total number of similar households in the city, the total savings that can be achieved in the electricity consumption can be approximated as follows (Table 4).

Total number of households (size 5) (2001 Census Suburban Mumbai District)	Savings per unit per month	% of homeowners accepting modification	Total savings in Electricity in suburban Mumbai district per month(MW)
1,838,426 x 50/100 (Assuming 50% pucca houses)= 919,213	155.64kWh	25%	35,766 MW
		50%	71,533 MW
		80%	114,450 MW
		100%	143,066 MW

Table 4: Total savings that can be achieved

From the above table we can see that even if 25% of the households apply the modifications suggested in the paper then the city would consume at least 35,766 MW less electricity. However it is very important that an actual reduction in the electricity consumption of the homeowner is achieved and the usage of the remaining appliances does not increase with the comfort feeling that we have reduced the consumption in certain areas.

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