TOWARDS SUSTAINABLE TOMORROW: EXPLORING ENERGY EFFICIENCY OF MALLS IN DELHI

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Abstract: The rapid growth of population and economic development has put severe stress on the natural resources, infrastructure and environment of the country. Malls are the new generation window to the country's commercial activity. They are in the luxury mode by spending extravagantly on facilities and services. The study was an effort to explore the energy resources used for facilities and services in selected malls and also assess the experience of comfort level of employees working in the malls as well as customers visiting the malls.

The results of the study highlighted that maximum power was consumed by HVAC (Heating, Ventilation and Air Conditioning) systems and motors used for pumping water followed by escalators and elevators as compared to energy used by lighting system and security services. Carbon emissions were alarming from each mall as the minimum emissions per day were 8032.12kg to a maximum of 44097.46 kg per day. As regards energy efficiency rating on the parameters of GRIHA developed by TERI, none of the selected malls could obtain minimum score of 50 to be qualified as green structure even though couple of them adopted water recharge pits to ensure zero discharge of waste and rainwater into municipal drainage. In some of the malls the HVAC and the lighting systems were switched off manually when not in use. However, the effort was insignificant. A substantial percentage of respondents i.e., the mall employees and the customers reported discomfort due to heaviness in eyes and high illumination levels.

There is a need to design and build such structures on sound concepts of energy efficiency and apply suitable retrofit options to existing buildings to minimize energy consumption and environmental pollution.

Keywords: Sustainability, Energy Efficiency, Energy Security, Energy Conservation, Green Buildings.

INTRODUCTION

The rapid growth of population and economic developments has put severe stress on the natural resources, infrastructure and environment of the country. Large scale and pervasive nature of energy related activities have made the greatest impact on the environment, the world over. If the current pattern of energy production, distribution and consumption continues, the resources could be exhausted much faster, environmental degradation accelerated and progress of the country could slow down dramatically. Therefore the need is to reconsider the ways in which energy is used and refashion the ways of life**.** World Bank emphasizes (<http:// www.worldenergyoutlook.org/> accessed on 4 December 2007) that energy security based on energy efficiency is one of the major concerns of developing countries for sound energy management. The fundamental goal of energy management and conservation is to produce goods and services at the maximum energy efficiency, least cost and least adverse environmental impact. Good energy management can lead to reduction in pollution particularly the carbon-di-oxide levels (CADDET, 1995).

Considering the vast potential of energy savings and benefits of energy efficiency, the Government of India enacted the Energy Conservation Act, 2001 (retrieved from www.Delhi transco.gov.in on 21 August 2007). The Act provides for the legal framework, institutional arrangement and a regulatory mechanism at the central and state level to embark upon energy efficiency drive in the country. The Energy Conservation Act 2001 (cited in Govt. Of NCT of Delhi plan document, 2007) empowers the central and the state Governments to implement various measures for improving energy efficiency. These measures are expected to lead to widespread market development through better standards for the appliances and equipment, energy efficiency labeling, mandatory energy audits, awareness and training, financial and fiscal incentives. Under the provision of the Act, Bureau of Energy Efficiency (BEE) has been established to institutionalize and promote energy efficiency services to improve its delivery mechanisms. A report of National Development Council Committee on power (cited in Sharma, 2007) indicates the power consumption levels (refer to figure 1) and saving potentials in the industrial, agricultural, domestic and commercial sectors in India.

Energy is used in non-residential buildings for a variety of purposes other than heating and cooling like for lighting, movement of people and goods, ventilation, computers, office machines, etc.

Alternative fuels and technologies are already available at reasonable cost. UN Millennium Project recommends that there is a need to reduce use of biomass for cooking by 2015 to switch to other cleaner fuels. This would have an insignificant impact on world oil demand and the equipment cost (<www.environment.gov.au> accessed on 5 June 2007).

The Green Building movement in India is a step towards minimizing the negative impact of construction activity on the environment. In the light of this, TERI (The Energy and Resources Institute) has been deeply committed to every aspect of sustainable development, took upon itself the responsibility of acting as a driving force to popularize green buildings by developing a tool for measuring and rating a building's environmental performance in the context of India's varied climate and building practices (Kumar & Tyagi, 2002). This tool by its qualitative and quantitative assessment criteria, would be able to 'rate' a building on the degree of its 'greenness'. The rating would be applied to new and existing building stock of varied functions – commercial, institutional and residential (retrieved from <www.teriin.org> on 2 August 2007).

This approach results in reduction in operating costs like energy and water, besides several intangible benefits. Some of the salient features of a Green Building are: (a) Minimal disturbance to landscapes and site condition (b) Use of recycled and environmental friendly building materials (c) Use of non-toxic and recycled/recyclable materials (d) Efficient use of water and water recycling (e) Use of energy efficient and eco-friendly equipment (f) Use of renewable energy (g) Indoor air quality for human safety and comfort (h) Effective controls and building management systems

A Green Building can have tremendous benefits, both tangible and intangible. The immediate and most tangible benefit is in the reduction in operating energy and water costs right from day one, during the entire life cycle of the building. The energy savings could range from 25 to 40% depending on the extent of green specifications (retrieved from <www.itcwelcomegroup .com> on 21 July 2007). Other tangible savings would be reduction in first costs and enhanced asset value. Intangible benefits of Green Buildings include increasing productivity of occupants' health, safety benefits and a green corporate image (Majumdar, 2004). Several Corporate are now seeing Green Building Rating as a tool to enhance marketability. People are attracted towards a green building due to three top reasons often cited by those occupying these buildings.

Operational Savings

Green buildings consume at least 40-50% less energy and 20-30% less water vis-à-vis a conventional building. This comes at an incremental cost of about 5-8%. The incremental cost gets paid back in 3-5 years time.

Daylight and views

Daylight and views provides connection to the exterior environment. This has a soothing effect on the mind. Various studies prove that the productivity of people who have access to day lighting and views is at least 12-15 % higher.

Air Quality

Green buildings are always fresh and healthy. The green buildings use interior materials with low Volatile Organic Compound (VOC) emissions.

METHODOLOGY

The study was conducted in 5 malls located in the West zone of National capital Delhi. Questionnaire and Interview Schedule were prepared to do the case profile of energy consumption pattern in the malls and comfort of customers and employees in the malls. TERI's Green Energy Rating Scale referred as **'*GRIHA*' (Green Rating for Integrated Habitat Assessment)** was used to find out the energy-efficiency and eco-friendliness of built structure of the mall.

The study was conducted in 3 phases: (a) Phase 1- Interview with key facility personnel (public relation officer, facilities manager and administrative officer) (b) Phase 2- Facility tour for energy consumption and identification of energy efficient methods. (c) Phase 3- Comfort of employees and customers in the mall.

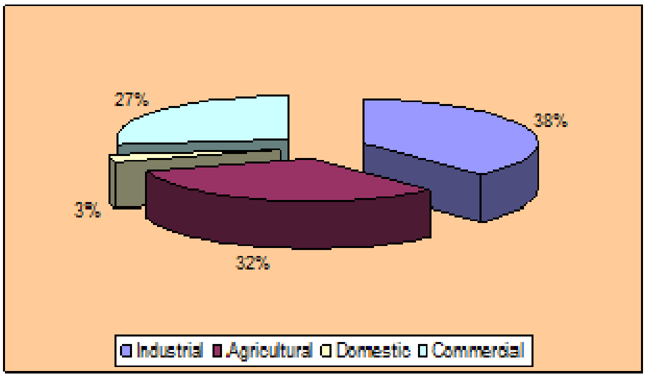

Figure 1: Sector-Wise Electricity Consumption in India

Table 1: Building profile of the selected malls

Building Profile	**Mall 1**	**Mall 2**	**Mall 3**	**Mall 4**	**Mall 5**
Building operation hours	14	12	12	12	14
Built-up area(indoor) sq.ft	1,30,000	1,32,000	**3,50,000**	1,32,000	65,000
Total built-up area (in sq.ft. outdoor + indoor)	138,000	137,000	**5,50,000**	1,40,000	70,000
Electricity consumption/square feet (KW)	3.94	4.6	2.4	3.8	3.4
Approximate number of employees in the building	102	105	150	120	97
Electricity supply information					
Monthly electricity tariff	20,00,000	22,00,000	**47,00,000**	21,00,000	12,00,000
Sanctioned load(KW)	2471	2750	**3870**	2600	1250

Table 2: Energy cost of various facilities and their ratio to the total energy consumption

Facilities and Services	**Mall 1**		**Mall 2**		**Mall 3**		**Mall 4**		**Mall 5**	
	Energy Cost	**%**	**Energy Cost**	**%**	**Energy Cost**	**%**	**Energy Cost**	**%**	**Energy Cost**	**%**
Motors	67012.8	**13**	42669.6	**7**	97704	**7**	21638.4	**4**	9328.8	**4**
Lighting Systems	10998	**2**	12352.8	**2**	19294.8	**2**	11163.6	**2**	6526.8	**3**
HVAC Systems	348930	**64**	478710	**75**	1062045	**80**	380187	**70**	**203220**	**84**
Plumbing System	11232	**2**	15120	**2**	22830	**2**	21000	**4**	3888	**2**
Miscellaneous	105588	**19**	92520	**14**	121050	**9**	108000	**20**	18000	**7**
Total Energy Consumed(Kwh)	**543763.8**		**641372.4**		**1322923.8**		**541986**		**240963.6**	
Total Energy Consumed (Kwh / sq.ft.)	**3.94**		**4.6**		**2.4**		**3.8**		**3.4**	

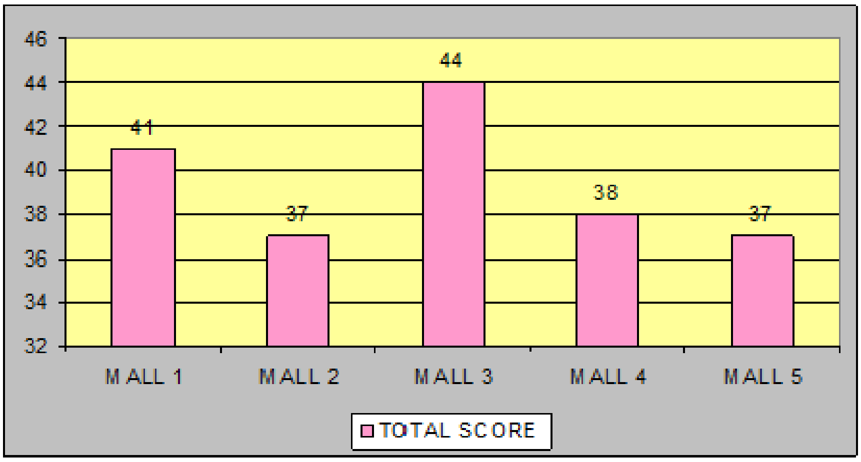

Figure 2: Scores of Selected Malls on the criterion of TERI's *GRIHA*- Green Rating

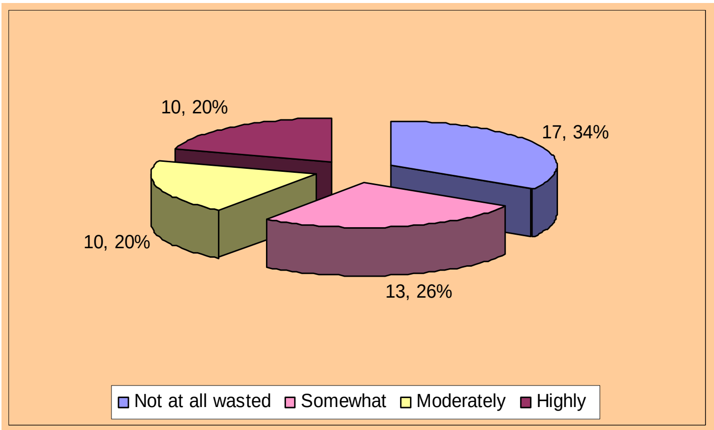

Figure 3a: Energy usage for lighting as perceived by customers

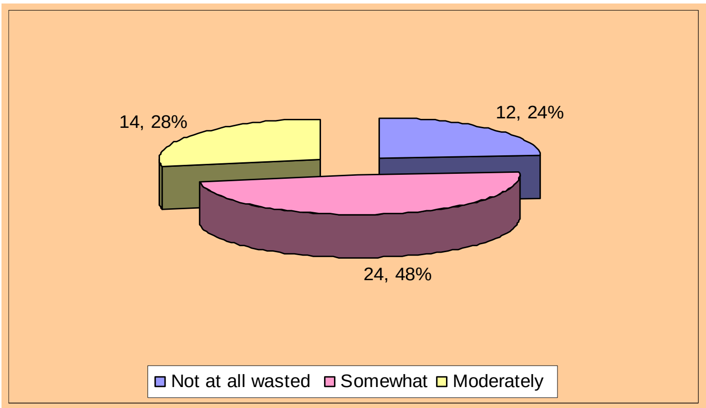

Figure 3b: Energy usage for lighting as perceived by employees

RESULTS AND DISCUSSIONS

General profile of the malls

The 5 malls selected for the study were located in the west zone of Delhi referred to as, Mall 1, Mall 2, Mall 3, Mall 4 and Mall 5. The area of the malls ranged from 65000 square feet to 550000 square feet. Sanctioned load ranged from 1250 KV-3870 KV. The monthly electricity tariff varied from Rs.1200000/- to Rs.4700000/-. Malls were operational for 12-14 hours every day. Number of employees managing the maintenance of malls ranged from 97 to 150 persons per mall.

Facilities and services available in the malls

Various facilities and services used in selected malls included motors, HVAC system, lighting system, plumbing system, escalators, elevators, CCTV, rain-water harvesting, waste water management, parking, security and safety.

Power supply information

The monthly electricity tariff varied from Rs.12,00,000/- to Rs.47,00,000/-. Table no.1 shows that the mall with more area had higher sanctioned load, i.e., 3870 KV and subsequently higher monthly electricity tariff, i.e, Rs.47,00,000/-. Each mall had a different amount of sanctioned load which ranged from 1250 KV to 3870 KV.

The other 3 malls were quite similar in relation to the total built-up area as well as the sanctioned load and monthly electricity tariff. The analysis of the electricity consumption/square feet (i.e., KW/month) revealed for two of the malls that the electricity consumption was not in accordance to the total built-up area. The fact that Mall 3 was the biggest mall amongst all the five malls whereas it had the least electricity consumption per square foot, i.e., 2.4 KW/ square foot while the Mall 2 consumed 4.6 KW/square foot. When comparing the power consumption of malls with similar area it showed excessive consumption. All the malls were operational for 12 to 14 hours every day. A large fleet of facility personnel were involved in maintenance of malls, it ranged from 97 to 150 persons per mall.

Energy cost of various facilities and total energy consumption

It was found that motors used for various purposes like ventilation (exhaust fans), air-conditioning, flushing and water transfer (pump-sets) etc. also consumed substantial amount of energy (4-13%). Second last being plumbing system which included different pump-sets meant for transfer of treated water, soft water, flushing water and sump pumps (water suction) to prevent basement flooding. It was observed that HVAC system was contributing maximum to the total energy consumption as compared to other heads. In malls where there were cinema halls for which A/C thermostat had to be maintained at a lower temperature as compared to other areas and hence consumed more energy. Lighting systems including different type light sources such as CFL (**Compact fluorescent lamp**), fluorescent tube lights and sodium lamps consumed the least amount of energy (2-3%) of the total energy consumption.

Observation of table 2 reveals that energy consumption was highest for HVAC system (64-84%) followed by miscellaneous facilities like, elevators, escalators and security equipments like CCTV (Closed Circuit Televisions) and food court services. The power consumption by these facilities ranged from 7-20%. The malls consuming less energy for miscellaneous facilities had not installed CCTV for security services.

Carbon emissions and energy consumption for various facilities and services

Maximum energy in all the malls was consumed by HVAC systems and motors, followed by escalators and elevators Energy consumed by HVAC system and motors was highest in all the malls, followed by escalators and elevators while share of energy used by lighting system, plumbing systems and security services was comparatively low. Rain-water harvesting was only practiced by Mall 1 and Mall 3.

Carbon emissions were alarming from each mall as the minimum emissions per day were 8032.12kgs to a maximum of 44097.46kgs per day. Carbon emissions as well as power consumption per square foot were highest by the HVAC system of Mall 5 as it had more cinema halls.

If we go by the predictions that real estate will further boom in the coming years - that means more buildings and malls will come up in the near future. If we continue to build in the same fashion by ignoring the concern for saving the ecology we could be sure of severely impacting the living conditions. Climate change would become more prominent.

Energy Efficiency Rating by *GRIHA*- Green Rating Scale

None of the selected malls could achieve a minimum score of 50 (out of maximum 100) on the 32 criterion of *GRIHA* to be qualified as Green Building (refer to figure 2). Mall 3, largest of all five scored the maximum.

Findings indicated that malls were energy guzzlers and also emitted large amounts of carbon compounds in the atmosphere. They were hardly making appropriate efforts towards self-sufficient, energy efficient and sustainable environment. As regards the norms or benchmarks set by TERI towards green building design for environmental harmony, they did not follow any of the stated guidelines. The criterions where the malls lost out badly were: (a) Reduced hard paving on site (b) Need to enhance outdoor lighting system efficiency (c) Reduced air pollution during construction (d) Inefficient water use during construction (e) Poor use of renewable energy and low-energy material in interiors (f) Non-renewable energy based hot-water system (g) Inefficient waste segregation (h) Poor storage and disposal of waste (i) Poor resource recovery from waste (j) Lack of use of VOC (Volatile organic compounds) paints/ adhesives/ sealants (k) No effort to minimize ozone depleting substances (l) No efforts to audit energy use and validation (m) Alternative transportation systems not used (n) Poor focus on environmental education (o) No emphasis on company's policy on green supply chain (p) No analysis done assess lifecycle cost

It was interesting to find that all the malls performed well on the following criterions: (a) Preserved and protected landscape during construction (b) Soil conservation (post construction) (c) Design to include existing site features (d) Plan utilities efficiently and optimize on site circulation efficiency. (e) Provide at least minimum level of sanitation / safety facilities for construction workers (f) Reduce landscape water requirement (g) Reduce building water use (h) Optimize building design like use of daylight through windows to reduce conventional energy demand (i) Optimize energy performance of building within specified comfort (j) Utilization of fly ash in building structure (k) Reduced volume, weight and time of construction by adopting efficient technology (like, precast systems, ready-mix concrete, etc.) (l) Water recycle and reuse along with waste water treatment (m) Ensure optimum water quality (n) Acceptable outdoor and indoor noise levels maintained (o) Tobacco and smoke control

The reason for poor scoring on TERI's *GRIHA* could be lack of awareness of the mall management right from pre-construction stage wherein there was no consciousness among the concerned persons to make efforts to incorporate energy efficient components. There is a great need to make people aware of the green building concept so that energy consumption in building could be minimized and the hazardous substances emitted by buildings like, VOC, HCFC (hydro chlorofluorocarbon) and CFC (chlorofluorocarbon) from the HVAC and use of heavy duty motors used for pumping and treating water could be reduced to as far as possible.

Profile of Employees and Customers

Majority of the employees working in the malls were middle level professionals including sales executive customer care associates, HR executives, quality analysts, engineers, estate and facility managers. Majority of them (males as well as females) were in the age-group of 15 to 25 years. Profile of customers visiting the malls varied in terms of their age, sex and occupation.

Comfort Level of Employees and Customers

Comfort level of Employees and Customers was evaluated on 6 parameters - **thermal comfort, adequacy of daylight, visual comfort, experience of glare, experience of heaviness in eyes, and adequacy of water.** Majority of customers and employees felt comfortable within the interior premises of the malls. However, substantial percentage of respondents reported discomfort due to heaviness in eyes and high illumination levels.

Overall comfort of the employees working in the malls and the customers visiting the malls

Comfort level of customers and employees was accessed as moderate to high based on their responses. The frequency distribution of employees and customers revealed that majority of customers (52%) and employees (54%) experienced high comfort. However, a substantial percentage of customers as well as employees reported moderate comfort. They experienced heaviness in eyes due to high illumination levels and too much glare inside the malls. Several studies have reported that pupils constrict at high illumination levels that cause poor visual acuity. Another aspect that did not appease the customers and the employees was poor use of daylight to light up the interiors during the daytime.

The interiors were air-conditioned and to maintain the temperature at lower levels window area was minimized and the atrium though was translucent but did not provide the same comfort to the occupants. All the customers and employees felt thermally comfortable as temperature was maintained at optimum levels i.e., between 18^0C to 21^0C. Those who found it cold tried to compensate by wearing appropriate clothing.

Perception of energy usage by facilities and service by the customers and employees

Energy used for lighting

Majority of the customers as well as the employees felt that either energy was not wasted or very little was wasted for lighting (refer to figures 3a & b). Customers could not appreciate high lighting levels used for display of certain products as it was too high comparing illumination levels practiced in their own surrounding spaces whereas employees found illumination levels of optimum. They understood the significance of lighting for selling the merchandise especially for display of products and to attract the customers to the stores.

Power consumption for lighting in the malls was optimal i.e., 6526.80 KWH to 19294.80 KWH per month. Power consumption for lighting among the other heads was the minimum. Hence contribution to the total carbon emissions by lighting was the least in all the malls, i.e., 2 to 3% of the total power consumption. It was observed that in the malls energy efficient lamps i.e., the CFL, slim fluorescent tubes and LEDs (Light Emitting Diodes) were used for lighting. However, there was some scope of energy efficiency by using more daylight and using new lighting technologies like electronic dimming ballasts, sensors for occupancy driven light like motion or occupancy sensors, time switches and photo sensors.

Energy used for HVAC

Majority of customers as well as employees felt that that a excessive power usage was made for HVAC and they found the wastage to be moderate to high (figures 4 a & b). Most of them found that very low temperature was maintained that even during summer children and old felt quite cold. Therefore it was necessary to use electronic thermostats so that constant temperature could be maintained on a long term sustainable basis. As was also observed air-conditioning used the maximum power which ranged from 203220 to 1062045 KWH per month

It was also found that the carbon emissions from air-conditioning were 64 to 84% of the total power consumption, which was comparatively very high in terms of the carbon emitted by other facilities and services in the malls. Temperature and humidity clock display results showed that in the malls temperature maintained ranged from 18^0C to 23^0C wherein 22 to 23^0C could have been quite comfortable for Indian conditions. It was also found that a mall that was the biggest in size, i.e., Mall 1 consumed a lot of power but at the same time in the smallest of all, i.e., Mall 5, air-conditioning contributed maximum energy costs. This brings out the fact that air-conditioning costs could be reduced up to 50%. This could be done by efficient chiller systems (it would be better to use centrifugal chiller rather than the traditional screw chillers). The use of electronic thermostats so that the temperature could be maintained at 22 to 23^0C would also help to make the system more energy efficient.

As regards the power consumption for artificial ventilation, i.e., electric fans (fresh air fans, exhaust fans, etc.) employed use of heavy duty motors used to operate these equipment in the malls. As most of the motors were on alternative power supply and using 7 to 13% of the total power in the malls, about $1/3^{rd}$ was used for ventilation purpose.

Energy used for vertical movement in the malls

There were 2 to 8 **escalators** in each of the malls. The average power consumption per escalator was 3,600KWH, with the average power consumption for all the escalators ranging from 7,200KWH-28,800KWH per month. Respondents were of the opinion that all escalators need not be operational all the time and it could be sensor driven and used in relation to the use frequency and number. It is necessary for the mall management to conduct research on use pattern of escalators for various spaces, facilities as well as services and use them according to the requirement which will also result in high amount of energy savings.

Observation of vertical movement of the sample showed that larger numbers of customers were traveling by escalators as compared to the **elevators**. While employees preferred elevators to escalators probably because they had to carry materials to different floors of the malls more customers felt that elevators were energy wasters probably because they could not use the elevators much due to long waiting time and limited capacity whereas larger number could access the escalators without any delay. As regards the power consumption, 10,800KWH to 21,600 KWH of power was used per month. Consumption in Mall 3 and 4 was 21,600 KWH hence emitting high amounts of carbon.

The number of elevators in the malls ranged from 3 to 6 in number. It was found that most of them were operational simultaneously and operating even for just one or two passengers. Since, elevators are very significant source of power consumption so care should be taken that they are operational optimally. In order to conserve power, all the elevators need not be operational all the time but as per the usage.

Elevators with new sensor technologies such as photoelectric sensors and highly sensitive devices to judge the distance of the floor to be covered in a visit as well as frequency of stoppage, can help in saving a lot of energy being wasted in the malls.

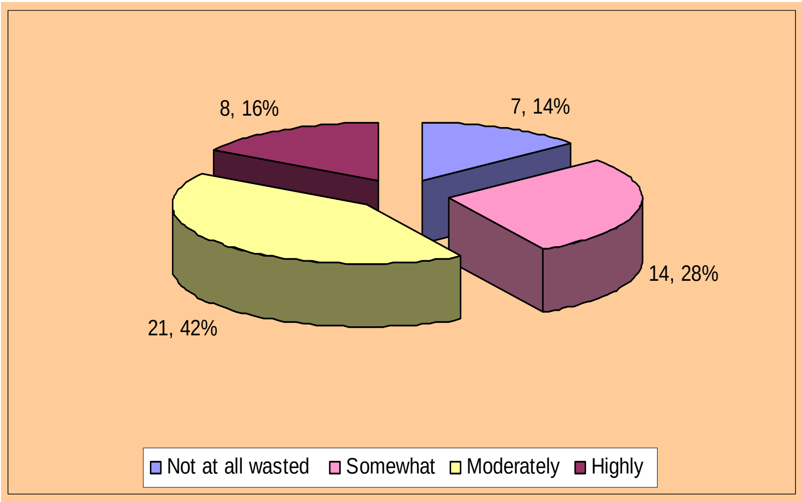

Figure 4a: Energy usage for air- conditioning as perceived by customers

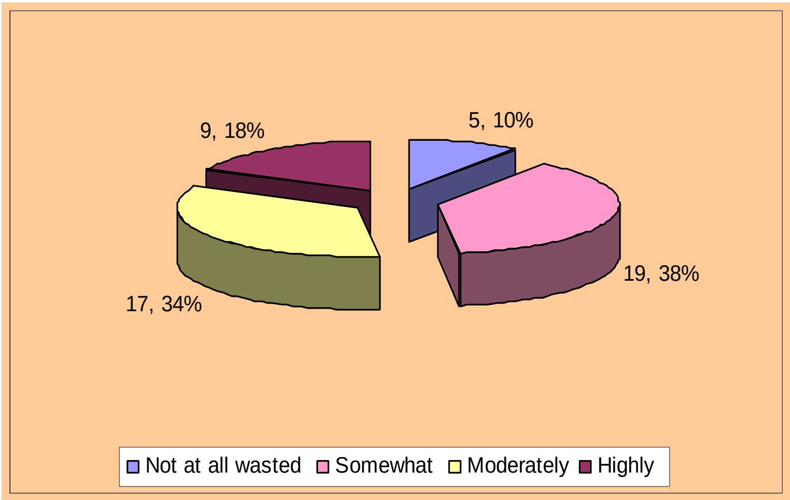

Figure 4b: Energy usage for air-conditioning as perceived by employees

Energy used for water supply system

Number of motors installed ranged from 12 to 22 ranging from 3 to 120 horse power capacity. Water supply system consumed about 3888KWH to 22,830KWH of power per month. Further there were several motors used which consumed 4% to 13% power per month for water pumping for various purposes. A lot of carbon (13%) was also contributed by these systems considering the fact that some of the motors had been re-wounded more than once thereby reducing their energy-efficiency.

It was also observed that a lot of water was consumed for air-conditioning, restrooms and for maintaining other services in the malls. Kitchens were also utilizing a lot of water for cooking and washing. A lot of water was used for cleaning wherein large garden pipes were used for washing indoor and outdoor spaces. a lot of water was wasted while washing the outdoor paving for a cleaner look.

Energy used for safety and security system

Majority of the customers felt that security devices did not involve excessive use of energy while a few felt that energy was being wasted for installation of security devices. Three malls installed CCTV while most of them used smoke detectors for ensuring fire safety.

Power consumption by CCTV revealed that it consumed 1188KWH to 4050KWH power per month in the malls. However, there seemed to be no better and convenient option other than CCTV therefore, most of the commercial buildings made use of CCTV in order to keep track on the security.

CONCLUSION

Malls are in the spent thrift or luxury mode for extravagantly spending on facilities and services. There has to be an intelligent use of various facilities and services so that unnecessary expenditure of energy could be avoided.

The findings of the research also highlight the fact that even though malls were spending so much on power yet they were able to satisfy only three-fourths of the occupants or visitors one-fourths were yet uncomfortable. Therefore, a greater consciousness is required by the builders, architects, designers, town planners and beaurocrats to encourage green practices in building construction so that optimal use of power was made. Several researches and experiments by architects and designers have also shown that better aesthetics could be worked out by practicing green design using local materials and technologies. The right orientation is required by the practitioners using natural materials and procedures. There is need to design and develop the new buildings on sound concepts of efficient use of energy and apply suitable retrofit options to existing buildings to substantially improve energy efficiency, reduce wastage and pollution, recycling and reuse of waste and improve quality and productivity.

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