



Decoding India's First Net Zero Energy Showroom

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Abstract

A large percentage of most countries' energy demand goes to power its buildings. Urbanization will only increase building constructions and, in turn, cause an increase in energy demand. Designing buildings that are self-sustained is, therefore, logical and very important. A building that can satisfy its own energy needs, by generating the energy it requires, is called a Net Zero Energy Building and The Puma Sustainable Store at Bangalore is the first such designed showroom in developing India.

This building incorporates a lot of sustainable features in architectural and engineering design: recycled steel in concrete and locally designed porotherm blocks made from waste silt are used in construction; high performance glazing, recycled bamboo, earth air tunnel for free cooling to reduced air conditioning load by 10.3%, 30%-40% reduction in lighting power density, natural daylight achieving illuminance levels of minimum 270 lux in 75% of the interior spaces, CFD techniques to determine optimised diffuser locations for the under floor air distribution system, etc. are some of the concepts incorporated in this project. Water is recycled in a sewerage treatment plant and reused for landscaping and flushing requirements. CO₂ concentration-dependent demand control ventilation system is used to keep the air quality in check. Solar photo-voltaic panels are installed to generate the energy required to operate the building. The designed annual energy consumed by the ground, first and mezzanine floor was determined to be 41,895 kWh. The energy generated by the

solar photo-voltaic was designed to be 42,000 kWh per year. The energy demand of the building was then calculated to be 37.62 kWh/m²-yr.

Keywords

Sustainability, Zero Energy, Recycle & Reuse, Renewable Energy, CFD

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Satish Iyengar completed his engineering in M&E in 1978 and masters in business management from Mumbai. He was a management trainee in Crompton Greaves before he joined Voltas, where he worked in Mumbai and Bangalore. He started Services Consultants in 1988 specializing in MEP, IBMS and sustainability services consultancy, which he still heads. He is also associated with Index Workshop Inc. He is a founding member and Chapter President Emeritus of ISHRAE Bangalore Chapter, and was thrice Co-chairman of ACREX. He is a past National President of ISHRAE. He is a member of ASHRAE, Electrical Consultants Association and Indian Plumbing Association.

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Introduction

The world's energy demand is growing rapidly and this is raising concerns over the exhaustion of existing energy resources, environmental impacts like ozone layer depletion, global warming, climate change, etc. People in developing economies have started to move to urban cities from rural villages to seek better comforts of living. This natural and unrestricted movement of people into cities will only increase the demand for new buildings and the energy necessary to operate them. Research claims that India is the fourth largest energy consumer in the world, trailing only the United States, China, and Russia (Curtis, Lohman, Medcalf, Powell, & Rajagopalan, 2011). With rapid urbanization in India, there is an unprecedented demand for construction of buildings, which account for more than 30% of India's total electricity consumption (Kapur, Khosla, & Mehta, 2009). Considering current growth trends, research by EIA forecast that emerging economies will soon reach energy demands of developed economies in the next 5-10 years. It is, therefore, more important than ever that buildings today are made more energy efficient and self-sustained in their construction and operation. The rise of pollution levels in cities has forced designers to think about the quality of air supplied to their buildings. Buildings are, therefore, tending to be designed air conditioned nowadays. Research shows that about 50% of the building energy consumption and 20% of total energy demand in the USA is accounted for by air conditioning systems (Pérez-Lombard, Ortiz, & Pout, 2008). With such a precedent, it becomes all the more important to focus on construction techniques adopted in developing economies. If buildings can be built in a more efficient and self-sustained manner, it will help create a better urban environment. Encouraging the construction of Net Zero Energy type of buildings can therefore help reduce the massive impacts energy grids may face in developing economies.

Background

Urbanization in India grew by 10.7% from 1970 to 2005 (Mohan & Dasgupta, 2005). With a near consistent 8% rise in annual energy consumption in the residential and commercial sectors, the overall energy consumption of buildings in India has seen an increase from a low of 14% in the 1970s to nearly 33% in 2004–2005 (Huang & Deringer, 2007). Estimates predict that more than 70% of India would become urban by the end of this century (Chaturvedi, Eom, Clarke, & Shukla, 2012). The same research also claims that more than 45% of the total final energy in India was consumed by the building sector in 2005 with HVAC systems using 50%, lighting using 15% and appliances using 10% of the energy demand. Another research shows that air conditioning systems consume 57% of energy in office buildings, followed by lighting (19%), lifts and pumps (18%) and other equipment (6%) (Saidur, 2009).

The Government of India's Energy Conservation Building Code (ECBC) initiative aims to counter this unstructured spring in building construction. The ECBC is currently voluntary, which has resulted in its slow adoption. However, the country wide lack

of information and awareness about the economic benefits that energy efficiency can provide is the real reason. Additionally, the lack of skilled expertise to employ these efficient methods adds to the disinterest. Efficient technologies also have a higher upfront cost, which deters investors seeking to make nearer-term economic returns. The building owners who undertake the expenditure do not usually benefit from lower energy bills that are accrued by tenants paying utility bills.

In this project, we use an array of energy efficient technologies. The problem of air conditioning the building at lower operational costs is solved by using an earth air tunnel. Soil temperature at a depth of about 12' or more stays fairly constant throughout the year, and it is approximately equal to the average annual ambient air temperature. The ground can, therefore, be used as a heat sink for cooling in the summer. For Bangalore, the temperature at 12' is around 24 °C and it is constant throughout the year, which makes the use of such a system possible.

Design Methodology

Architecture

Building Shell

The walls of the building are made of porotherm blocks with a U-value of 0.021 W/m-K. These blocks are made from the waste acquired from de-silting of lakes in Kunigal. The lakes, which are the only source of water for the surrounding villages are de-silted every year by the government in order to increase the water table. In addition to providing thermal and acoustic insulation, the blocks are lightweight, so are structurally advantageous. The steel used in the construction is of recycled nature. The building uses over-deck extruded polystyrene insulation (XPS) with concrete slabs to achieve an overall U-value of 0.012 W/m-K, eliminating solar insolation from the roof. The glazing used for the entrance façade has a U-value of 0.072W/m-K, SHGC of 0.52 and VLT of 0.6. Other façades have a U-value of 0.094W/m-K, SHGC of 0.24 and VLT of 0.22. The first floor of the building is made with a recyclable suspended volume, which can be plugged and unplugged from the building shell. The front canopies have BIPV (Building Integrated Photo-Voltaic) panels that generate electricity, while allowing natural light into the plaza.

Material

The paints used in the building are low VOC emitting paints. The false ceiling is made from bamboo composites and is recyclable. The furniture used in the building is made from composite wood. The composite wood specified does not use adhesives with added urea and formaldehyde, which are hazardous to health. All adhesives and sealants used are low VOC emitting materials. All doors and windows are made from UPVC and Aluminium. There is minimum use of hardwood.

Air Conditioning

Earth Air Tunnel (EAT)

A combination of the EAT and a chiller is the design which will be used to air condition the interior space through an Under Floor Air Distribution (UFAD) network. The mechanical cooling only turns on, if required, during peak summers when the EAT's ground temperature

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is above the average ambient. Even during the operation of the chiller, the EAT provides pre cooled ventilation air. The design is such that the system overall provides for a room temperature of 25.5°C in peak summers, i.e. when the ambient is 36°C. The room temperature is maintained at 24°C when the ambient is 10°C-13°C in winters. The UFAD system provides for a stack effect cooling of the interior space, as typically only 8' of height from the ground needs to be cooled. The warmer air is exhausted through extractors in the roof creating a continuous draft. The EAT system uses a VFD driven centrifugal fan in combination with VAV boxes to achieve optimum ventilation rates, which are controlled based on room CO₂ concentration levels. The VAVs modulate the zone pre cooled fresh air quantity based on CO₂ sensor signals. The VFD, in turn, modulates the fan motor frequency based on the demand from zones.

Chiller

A water cooled Variable Refrigerant Volume (VRV) system with a COP of 4.1 is used as the backup chiller in the air conditioning system. The chiller is operated only when the ambient ground temperature goes beyond 25°C. The system rejects heat depending on the ambient wet bulb temperature rather than the dry bulb temperature, so the refrigerant can be cooled to a lower temperature. This results in a better system COP. 30% more outside air than ASHRAE Standard 62.1-2004 has been considered for fresh air ventilation requirements. The quantity of fresh air is modulated based on the CO₂ concentration levels in the space to maintain indoor air quality. Eco friendly refrigerant R410C is used instead of R134A. A natural draft FRP cooling tower, which is locally designed is used to reduce spillage and power consumption. It is used as a heat sink for the chiller unit.

Water and Lighting

All recycled water will be treated to tertiary standards using a sewerage treatment plant and reused for flushing, landscaping and as make up water for the condenser units. Low water consuming and dual flushes are used for urinals and water closets. Most of the run-off water from the ground and terrace is collected in a rain water harvesting tank, treated and reused. The total design water requirement for the building is estimated to be 13 kl/day and the grey water treatment capacity is designed to be 6 kl/day.

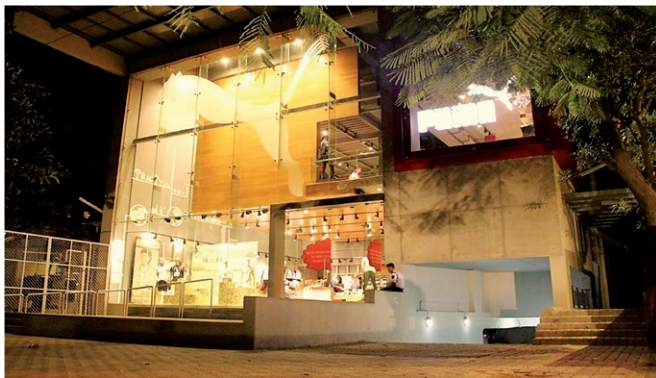


Photo 1: The lit building frontage at night

More than 90% of interior spaces have direct views to natural daylight. 75% of the interior space achieves daylight illuminance levels of minimum 270 lux and a maximum illuminance level of

5,400 lux, thus minimizing artificial lighting. Occupancy sensors are provided to control lighting in unoccupied interior spaces, car parking areas and toilets. Product focussed LED lighting has been specified in retail areas. The Lighting Power Densities (LPD) in all areas have been designed to reduce by almost 30–40% than specified in ASHRAE/ISENA Standard 90.1-2004 without affecting lighting comfort. The overall design LPD achieved in the foreground, mezzanine and first floor is 6.77 W/m². Table 1 shows the LPD considered in various spaces.

CFD

A CFD model was set up to determine the diffuser locations in the interior space. The flow solver model was assigned to incompressible flow with backward Euler time integration. Increment control was set to 1.0 and K-Omega turbulence model was assigned with a prandtl number of 0.85. All walls were assigned the logarithmic Y-Plus condition and the ground was assigned as In-Vis flow. The outlet pressure was assigned to 20 Pascal. The fluid was assigned as air with 1.17 kg/m³ density and viscosity of 1.8 x 10⁻⁵ kg/m-s. The specific heat capacity was set to 1006 J/kg°C and thermal conductivity to 0.022 W/m°C. The fluid heat transfer was assigned a floatability of 0.1* temperature for a dynamically varying profile in conjugation with the diffusion of the fluid. A nodal integration algorithm was assigned to the fluid domain and the computational model was put into an implicit fractional step solver. The meshing was done using a grid size of 0.01 at the inlet and outlet lines, and surfaces with a transition size of 0.1 to a boundary limit of 1000.

LEED

This project has received LEED platinum rating from the Indian Green Building Council. The project has been designed to obtain 26 points in the Sustainable Sites domain with points to be earned in site selection, community connectivity, public transport access, storm water design, heat island effect, light pollution, etc. The project is designed to earn 10 points in Water Use and Efficiency for achieving 50% reduction in water use for landscaping, using of a water treatment plant and reduction in water use by 40% for the building. Optimizing energy performance by 24%, use of renewable energy, refrigerant management, etc. is expected to earn a total of 35 points in the Energy and Atmosphere domain. Electric car charging ports and bicycle parking have also been provided. The Materials and Resources domain has been designed to earn 14 points as 75% of the construction and waste were managed, 10% of materials used were with recycled content, 20% of the materials used were of regional origin – 10% of which were sourced within 400km radius, and 50% of the wood based materials used were certified with FSC.

Daylight illuminance achievements for interior spaces, pollutant control, thermal comfort design and verification, optimization using CFD methods, low VOC emitting materials used for flooring, wood products, paints, adhesives and sealants; increased ventilation, IEQ and monitoring of CO₂ concentrations every 1000 ft² etc. may

Table 1: LPD values considered in different areas

Area	LPD (W/m ²)
Retail Space	4.98
Lobby	4.68
Passage	10.27
Toilet	7.61

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earn the Indoor Air Quality domain 15 points. Innovation in Design for using an earth air tunnel, green education, 100% parking under cover and 30% regional materials used may earn 6 more points. Water efficient landscaping, optimized energy performance, enhanced commissioning and innovative wastewater treatment and reuse may earn 4 more points. The project was designed to earn 110 points overall with the minimum requirement for platinum rated buildings being above 80.

Results & Discussion

Water Conservation

Table 2 shows the design water recycling balance by the use of STP and water cooled chiller system.

Table 2: Design water recycling balance to show zero discharge

Use	kl/day
MBR type STP @ full load	6
Sewage water discharge @ full load	4.9-5
Make up water for cooling tower	2
Toilet flushing @ full load	2.5
Gardening and landscaping	0.4
Total water recycled by STP	4.9

Using this technique we can achieve zero discharge at full load, as all the water recycled by the STP is reused in the building. However, during monsoons and cloudy days, there will be a

discharge of 2 kl/day, which could be compensated by higher consumption during the summer months.

Air Conditioning

A water cooled inverter VRV system is the design and is used to achieve high COPs. The COP at 100% load is 4.4 and at 60% load is 5.0. Variable speed indoor units are used to provide a demand based supply of ventilation to individual zones. Table 3 shows the energy use reduction achieved due to the use of EAT.

Table 3: Designed EAT energy reduction calculation

Ambient temperature (°C)	Annual operation hours	Temperature difference assumed (°C)	Outlet temperature from EAT assumed (°C)	Sensible cooling load by EAT (Btu/h)	Power Reduction @ COP of 3.6	Energy reduction by EAT (kWh)
36	120	10	26	68040	5.54	664
34	270	9	25	61236	4.98	1345
32	270	7	25	47628	3.88	1046
30	270	5	25	34020	2.77	747
28	360	4	24	27216	2.21	797
26	840	2	24	13608	1.11	930

Total reduction in energy consumption due to EAT was calculated to be 5,529 kWh, which includes 683 kWh of energy used to run the EAT fan.

CFD

CFD methods were used to determine the temperature and velocity profiles in the interior spaces of the building. The diffuser locations and design were modified to achieve thermal comfort requirements as per ASHRAE Standard 62.1-2004 and ASHRAE Standard 55-2004. A sample temperature and velocity profile for one of the sections of the interiors is shown in Figure 1 and 2.

Temperature Profiles

CFD simulations were carried out for the already designed diffuser locations to realise the thermal comfort levels. The temperature range was set to 24°C–26°C. Figure 1 shows the temperature profiles for the ground floor of the building at three different heights from the ground. The information was used to modify diffuser locations accordingly to achieve the required thermal comfort.

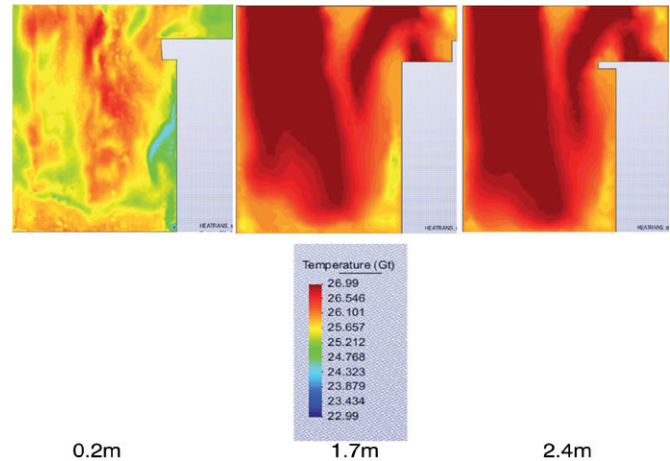


Figure 1: Temperature profile for ground floor

Velocity Profiles

Air velocity values were determined to check if they were in the acceptable range of 0.1 m/s– 0.3 m/s in the occupant zone. Figure 2 shows the velocity profile for the ground floor of the building at different heights.

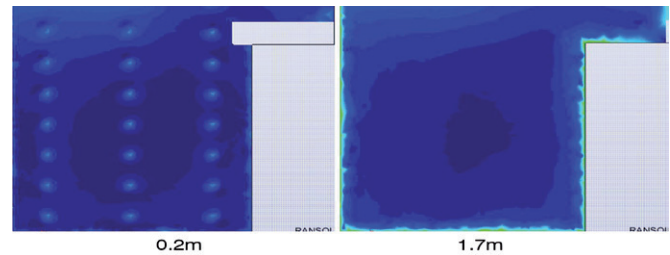


Figure 2: Velocity profile for ground floor

Energy



Photo 2: The three levels of the building

The building has an area of 1113.5 m² comprising of the retail store on the ground, mezzanine and first floor. Table 4 shows the energy consumed in the building and the energy generated by the solar photo voltaic system. The final energy consumption includes all plug loads including computers, printers, machines, lifts, etc. The

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energy consumption of the building is calculated to be 37.62 kWh/m²-yr.

Conclusion

The results show that with conscious effort, an energy efficient building can be realised easily. The building discussed here achieved Net Positive Energy in design. The way to achieve Net Zero Energy is to first reduce the energy needs of the

building by employing energy efficient technologies and second, to generate the small amount of energy that the building requires. We demonstrated that, without compromising thermal comfort or indoor air quality, a building can operate efficiently consuming only 37.65 kWh /m² of energy annually in design. This value of energy consumption is very low, when compared even to existing Zero Energy Buildings across the world. We believe that this research would be able to pave the way for further designs in developing economies to follow such an approach and achieve Zero Energy Operations.

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Special Mention

- This paper was presented at the 12th Asia Pacific Conference on the Built Environment (APCBE) 2013 in Manila, Philippines. References can be made to the conference proceedings.
- This project also won the 8th Bry-Air Award during March 2013 in Mumbai and The Emerson Cup 2013 in Chennai.
- Special thanks to Meghana Dutta and her team for their help and contribution.

Table 4: Calculated energy consumption and production in the building

Description	Energy Consumed / Produced
Base energy consumption	46741 kWh/yr.
Energy consumption reduction by EAT	4846 kWh/yr.
Final energy consumption	41895 kWh/yr.
Solar photo voltaic module rating	28 kW
Total sunlight hours for energy generation (annual)	1500
Total Energy generated 28 X 1500	42000 kWh/yr.

