India's First Modern Net Zero Energy Building

By Ashish Rakheja
Chief Operating Officer
Spectral Services Consultants Pvt. Ltd., Noida, UP

Amongst the many challenges that humankind is facing, resource exhaustion, waste disposal and Green House Gas (GHG) emissions are common concerns across the globe. Our present rate of exploitation of Earth's finite resources is highly unsustainable and the widespread consequences include alarming trends of global warming, threat of climate change, extinction of cohabiting species as well as several others. The prime cause for this destruction includes over-reliance on non-renewable resources for energy needs, consumerist lifestyles, over population, insensitive attitude to other living forms, lack of awareness towards life cycle approach, etc. There is now a crying need for adopting a sustainable form of development that focuses on harmonizing life-styles with available natural resources without compromising growth trends. Since buildings across the world consume nearly 40% energy, the construction industry shoulders a major responsibility in adopting a sustainable approach. Sustainability in construction through energy efficient fixtures and systems, use of rapidly renewable building materials and efficient resource management through BIM (Building Information Modeling) can reduce the carbon footprint to promote an environment-friendly growth.

As the world is shifting gears to a higher level of sustainability, India too has responded by joining the elite group of countries that can boast of a "Net Zero Energy Building".

The Eco Commercial Building (ECB) by Bayer is a proud new benchmark in India that employs the latest technologies and simulation tools to provide a peek into future buildings.

From High Performance to a Net Zero Energy Building

A high performance building design takes into consideration all the component and sub-systems along with their potential interaction and impact on occupants. This integrated design approach requires that site selection, planning, aesthetics, equipment choice, material selection, construction, commissioning and long-term operation / maintenance remains the focus of designers from the beginning of the project. Developing a high

About the Author

Ashish Rakheja is a mechanical engineer from REC, Allahabad and an M Tech from IIT, New Delhi. He has been working with Spectral for 16 years and heads a large team of engineers working on various projects all over India. He teaches at the School of Planning and Architecture, Guru Gobind Singh University and Vastu Kala Academy, New Delhi. He is vice chairman, technical committee of IGBC, a certified LEED India trainer and has been involved in the design of 8 green buildings of which 7 were rated LEED-Platinum by USGBC. He is a member of ASHRAE, NFPA and past national president of ISHRAE.

performance building thus mandates close collaboration between owners, architects, engineers, contractors and operation team.

Net Zero Energy Buildings (NZEBs) require additional efforts on the part of design team to cross the barrier of space constraint and install on-site renewable power generation to meet the cumulative annual energy demand of the building. This is the easier said than done. Since most Indian cities do not have potential for wind power generation, solar power generation is the only viable option. However, lack of adequate space (either roof or external greens) for mounting solar power panels in a building significantly limits the on-site power generation capability. Hence, the only methodology to construct a Net Zero Energy Building is to match the annual cumulative power demand with the energy produced by the on-site solar panels. This requires innovative design solutions, optimization of design and coordinated team effort, as the objective has to be achieved without affecting the functionality of the building as well as lifestyles.

Some of the yardsticks followed for defining Net Zero Energy Buildings are as follows:

Net Zero Site Energy

The building produces at least as much energy as it uses in a year, when accounted for at the site. The measurement time frame is annual.

Net Zero Source Energy

The building produces at least as much energy as it uses in a year, when accounted for at the source. Source energy refers to the primary energy required to generate and deliver the energy to the site.

Net Zero Energy Emissions

The building produces at least as much emission-free renewable energy as it uses from emission-producing energy sources annually. Carbon, NOx, and SOx are emissions that NZEBs offset.

The Eco Commercial Building (ECB) has tried to achieve the Net

Photo 1: A front view of the Bayer building

Photo 2: Natural day lighting in the building

Zero Site Energy capability as transmission losses in India are large and it is difficult to define the emissions from the fuel sources.

Role of Air Conditioning in a Net Zero Energy Building

HVAC systems contribute towards nearly 60% annual electricity bills of a conventional building. Thus the prime focus of a Net Zero Energy Building is on optimizing the air conditioning system design. Following parameters are important to be evaluated in a building design for achieving the lowest AC load:

- Building envelope design.
- Climate responsive façade concepts.
- Efficient glazing selection with balance between low thermal conductivity and shading coefficient.
- Building structure's thermal mass and insulation materials.
- Lighting and day lighting controls.
- Strategies for natural ventilation.
- Energy recovery opportunities.
- HVAC system equipment selection at highest full load and part load efficiency points.
- Operational strategies.

In addition, a whole-building design approach that integrates the building performance with occupant comfort considering life cycle impacts of the entire HVAC&R system enhances the performance of buildings. In addition, Energy Management Systems (EMS) and Building Automation Systems (BAS) further increase the energy efficiency capability, thereby giving facility managers the information to make better decisions during building operations.

All the above capabilities are the focus of design for the Eco Commercial Building (ECB).

Project Description

The eco commercial building in Greater Noida is a Net Zero Energy project under the Bayer Climate Program initiative launched in 2007. The building is primarily meant for day use with a built-up area of 9,600 sq ft spread over ground and first floor and consisting of work stations, cabins, meeting rooms, support areas, etc.

Project Highlights

The project has several firsts to its credit and brings India into the select league of countries that can boast of Net Zero Energy Building. Several innovative design features and demonstrative future technologies set the stage for going *beyond green buildings*. Some of the highlights of the project include:

- First Net Zero Energy Building in India and South East Asia.
- Upto 41% savings in primary energy utilization (compared with a standard building in India) through high performance heat insulation, improved protection against sunlight and the use of further energy saving technologies associated with the electrical power supply system/building management system.
- 100% solar and thus emission-free on-site energy generation through the use of a 57 kW photovoltaic system spread over a total surface area of approximately 492 m^2.
- 24-hour autonomous operation of the building, independent of the electrical grid through the use of a battery back-up.
- Employing Chilled Beams for convective cooling thereby eliminating fan energy from the system.
- Zero Water Discharge whereby the entire sewage generated on-site is recycled and treated water is used for makeup in cooling towers, flushing and landscaping.
- Zero heating energy requirement (despite low ambient conditions in winter) and thus no need for a heating system.
- The project, with the help of onsite photovoltaic electricity generation, saves 100 % in energy costs over the LEED® mandated ASHRAE 90.1-2004 baseline.
- The project aim included achieving maximum points under LEED India rating system and be counted amongst the "greenest in world".

Environmental Footprint of ECB

ECB in its quest to achieve the Net Zero Energy objective has targeted to optimize performance of all the energy consuming equipment/ fixtures in the building thereby turning into an efficient entity. *Table 1* depicts the annual energy consumption reduction (kWh) and equivalent impact on emission of greenhouse gases (kg). Through advanced energy simulation tools, it is predicted that the annual energy consumption of the Eco Commercial building is 54,801 kWh and an on-site generation capability of 88,900 kWh.

Table 1: Reduction in annual energy consumption

Parameters	Conventional Building	ECB Net Zero Building
Annual energy consumed (kWh/yr)	2,82,014	12,215
Carbon emitted (kg/yr)	2,28,431	9,894
Cooling load (sq ft/ton)	250	605
Electric load (W/sq ft)	10.65	2.25
Pollution (equivalent cars on road)	68	3
Pollution (acres of forest deforested)	2.21	0.1

When compared to an ASHRAE established baseline, this translates into emission reduction of approximately 1,07,572 kg of green house gases. In terms of sustainability equivalencies, this is same as preventing emissions generated by 32 passenger cars in a year. This is also the same amount of green house gases that would be sequestered by about 2 acres of forest. Hence the efficiency measures in the building are equivalent to taking 32 cars off roads or preserving two acres of forest from deforestation.

ECB Envelope Design

In a similar internal-load dominated building, carefully selected fenestration designs have the potential to reduce lighting and HVAC costs by 10%-40%. To explore this potential, evaluation of

Table 2: Lighting and HVAC load reduction by carefully selected fenestration design

S. No	Parameter	Performance	Comment
1.	Walls	U-value- 0.04 Btu/hr ft²°F	Insulation thickness of 75 mm thick polyurethane foam sandwiched externally.
2.	Roof	U-value-0.03 Btu/hr ft²°F	Insulation thickness of 75 mm thick polyurethane foam laid over-deck integrated with water proofing and additional 50 mm thick mineral wool.
3.	Glazing in reception	U-Value : 0.27 Btu/hr ft²°F SC : 0.31 VLT : 50%	High performance large glass in façade.
4.	Glazing in other orientations	U-Value : 0.24 Btu/hr ft²°F SC : 0.31 VLT : 49%	High performance.

continued on page 86

continued from page 84

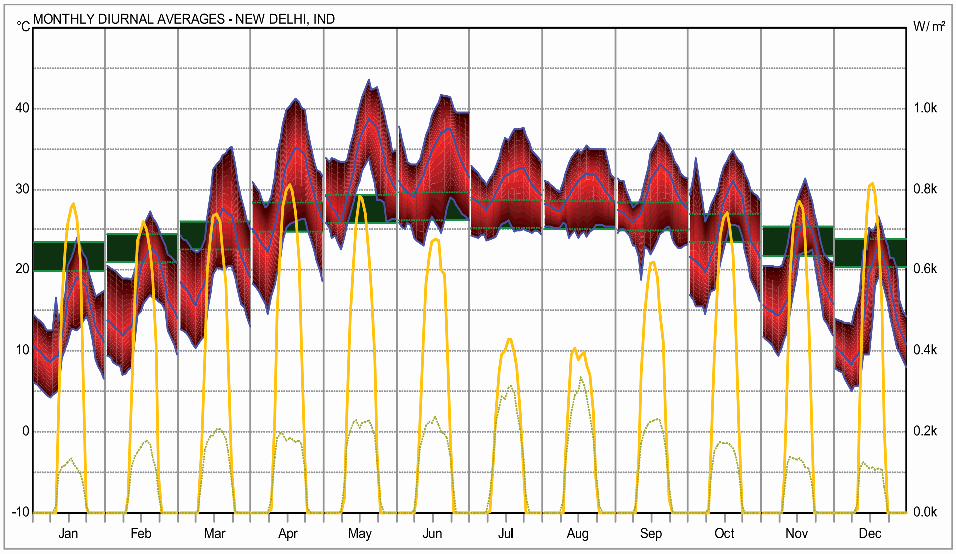

Figure 1: Monthly temperature and solar radiation for Delhi

a building envelope design was carried out to analyze its effect on cooling loads and day-lighting. Through several iterations, following envelope specifications yielded optimized cost effective result with short payback. (See *Table 2*)

A comparison of the envelope design against conventional design practice is presented in *Table 3* wherein the Overall Heat Transfer Coefficients of Building Envelope (in W/m²°C) are listed out.

Table 3: Overall heat transfer coefficient of building envelope

Parameter	Conventional Building	Eco Commercial Building
Wall	1.8	0.22
Roof	0.56	0.16
Glass	3.2	1.5

In the exterior wall construction, the insulation materials are: 150 mm thick Autoclaved Aerated Concrete (AAC), Fly Ash block work and 75 mm thick Polyurethane Foam (PUF). For the roof, the materials are 75 mm thick PUF Insulation, 75mm Fly Ash and 100 mm thick Mineral Wool. In addition, a Window Wall Ratio (WWR) of 30% ensured maximum day-lighting potential with minimum solar heat gains. Incorporation of these aspects minimized the energy demand and operating power as well as reduced the size and cost of HVAC system needed to maintain adequate building pressurization, good indoor air quality and a comfortable thermal environment for building occupants.

Outdoor & Indoor Design Conditions

ISHRAE weather data file 'WeDCo' was referred for creating year round AC load profile to size the equipment. A conventional building in Delhi is designed for peak ambient conditions, which are specified in hand-books and design guide. (See *Table 4*)

On the contrary, in design of a high performance building, it is important to evaluate year round building performance for equipment selection and also study the impact of other natural phenomenon like wind speed, solar orientation etc. for optimizing performance.

Breaking free of traditional practice of low internal temperatures, following indoor design conditions were adopted for the project. (See *Table 5*).

Table 4: Ambient design conditions

Summer	Dry Bulb Temperature	43.3°C (110°F)
	Coincident Mean Wet Bulb Temperature	23.8°C (75°F)
Monsoon	Coincident Mean Dry Bulb Temperature	35°C (95°F)
	Wet Bulb Temperature	28.4°C (83°F)
Winter	Dry Bulb Temperature	6°C (43°F)
	Wet Bulb Temperature	5.2°C (41°F)

Table 5: Indoor design conditions

Dry bulb temperature	24 + 1°C
Relative humidity	Not exceeding 55 %
Dust filtration efficiency	Combination of MERV 8, Pre Filter & MERV 13 Bag Filter

Mechanical ventilation standards adopted for various areas are as follows:

- Toilets : 10 ACPH exhaust
- Plant room spaces : 20 ACPH exhaust

Lighting Design

Since ECB is a day use building, the main effort revolves around maximizing day-lighting in all occupied spaces. Using simulation softwares like Radiance and DIALux, the impact of various shading devices over windows for ensuring soft glare free light in the space was studied. The main objective of the design exercise

continued on page 88

continued from page 86

was to avoid the use of blinds/curtains on windows without compromising on visual comfort of occupants.

Consequently, to cater to the cloudy days and late evening office operations, a high quality energy efficient lighting system was designed that utilized lighting controls for maximize day-lighting effect.

Figure 2: Lighting fixtures

The selection of energy efficient fixtures and ballast alone helped in cutting down operational costs (for lighting only) by 37%. The other benefits include enhanced lighting quality in space, and also a healthy and productive work environment.

Further lighting equipment selection was based on a balance between the requirements of the design and an effort to limit the number of fixture types and lamp selection in order to have reasonable maintenance inventories. Lamp selection was based on efficacy (lumens per watt), color temperature, color rendering index, life, lumen maintenance, availability, switching, dimming capability and cost. Combination of T5 linear fluorescent and compact fluorescent lamps were considered as excellent choices for ECB because they are energy efficient, have good color rendering properties, long life, ready availability, easy controllable and affordable. High frequency electronic ballasts were installed because they reduced eye strain and fatigue due to excess lighting levels.

The project achieved following distinction in lighting design:

- Approximately 90% of total regularly occupied spaces in the building have a minimum daylight factor of 2%.

Photo 3: Chilled beam in the office space

- The benefits from day lighting were further maximized by using occupancy sensors in normally unoccupied areas like stores, toilets, mechanical rooms, etc. to minimize misuse.
- All lighting fixtures are provided with high efficiency digital dimmable ballasts linked to daylight sensors which cut-off artificial lighting during daytime and are programmed to gradually build it up as dusk approaches. This too ensures minimum internal heat gain in the space and reduced AC load.
- Lighting Power Density (LPD) of 0.67 W/ sqft is achieved in all occupied spaces, which is approximately one third of the conventional practice of 2 W/sqft.

Energy Modeling

It is conventional practice to compute air conditioning loads using peak ambient conditions that occur either 0.4% or 1% of the times in a year. This leads to over sized equipment selection, which introduces inefficiency in the system due to part load operation most time of the year. For ECB, sophisticated computer simulation tools namely Ecotect and Energy Plus were employed to create year round AC load profile that helped in better understanding of operating conditions.

Building thermal performance calculations were made for two primary reasons: to size and select mechanical equipment and to predict the performance of each component that contributed to heat gain in the space. After several iterations, the final breakdown of space sensible and latent loads achieved is as follows:

> The careful planning of passive and active design features helped the project in achieving, for a built-up area of 9,600 sft, total diversified AC load of 15 TR. Thus the project achieved an astounding 650 sft/TR

Further comparison was made with ASHRAE 90.1-2004 defined parameters (for base case) to study the benefit of each strategy.

Dedicated Outdoor Air System (DOAS) and Demand Control Ventilation

As a design strategy, the sensible and room latent heat gains were computed separately. Dedicated Outdoor Air System (DOAS) was selected for the project to cater to the entire latent load in the building. Dry outdoor ventilation air supplied through an externally mounted air handling unit dehumidified the air before supplying to occupied space. This dry outdoor air also acts as primary air to the chilled beams.

In accordance with LEED requirement, the design ventilation rate of 30% additional outdoor air over the benchmark set by

continued on page 90

continued from page 88

Photo 4: Installation of chilled beam

ASHRAE Standard 62.1-2004 has been adopted to enhance the Indoor Air Quality within the building and provide occupant comfort.

Air quality is monitored inside the entire building with the help of CO_2 sensors located 1.8 m above the floor level in various spaces. These provide an audible alarm to the operator when the difference between outdoor and indoor CO_2 levels exceed 530 ppm.

DOAS also has a heat recovery section to provide a way of recovering waste energy from building exhaust. Dehumidified cold exhaust air from toilets and space is collected in each service core, which enters one side of the rotating Heat Wheel thereby chilling the wheel and drying the desiccant coating. This cool and dry part of the wheel then rotates into the outdoor air stream where it absorbs heat and gains humidity from the incoming ventilation air before it is cooled to room temperature in AHU room. The Energy Recovery Wheel helped to reduce the ventilation AC load by 80%, thereby minimizing operating energy as well as the size of air conditioning equipment.

Active Chilled Beams

Since the building had a tightly sealed envelope, Chilled Beams were selected as a means for achieving cooling in the space. The advantages include cutting down operation cost due to saving in AHU fan energy and simultaneous reduction in chiller energy as the beams are selected to receive incoming chilled water from water chilling machines at 15°C as against the conventional practice of 7°C. Based on indoor design conditions of 24°C & 55% RH, the room dew point temperature is at 14°C and chilled water is thus supplied at a temperature 1°C higher (at 15°C) in order to avoid any condensation on the surface.

In addition, dry fresh air is injected into the Chilled Beams (after passing through a dedicated outdoor air system) thereby enhancing the sensible load handling capability and minimizing the number of beams inside.

Precaution was also taken to minimize ingress of hot humid air in to the space from outside by providing double doors at the entrance with an air lock. Additionally, a drip tray is provided under the beams in the reception area to minimize the possibility of condensation in this space.

Motor Selection

All motors used in the air conditioning system are of premium efficiency and meet the criteria of ASHRAE Standard 90.1 – 2004. This helps in reducing operational energy as most electricity gets converted into useful power with little heat loss.

Variable Frequency Drives

Extensive use of variable frequency drives on AHU motors, cooling tower motors, pumps and ventilation equipment helped in increasing operational efficiency even during part load conditions which are encountered most part of the year in any building thereby reducing annual electricity bill.

Increasing Operation Efficiency

It is common knowledge that despite superior standards of design solutions and exposure to new technologies and products, there is a significant gap in the quality of execution due to poorly trained labor and conventional operation methodology. ASHRAE recommended commissioning methodology was adopted for the project wherein services of a Third Party Commissioning Agent & Energy Auditor were employed which carried out the following:

- Design Phase Commissioning that provided early inputs for incorporation of successful monitoring mechanism to facilitate Operation & Maintenance (O&M) staff.
- Construction Phase Commissioning to overview the proper implementation of M&E systems.
- Acceptance Phase Commissioning wherein contractors were required to demonstrate the operation of equipment as per design intent.
- Occupancy Phase commissioning wherein the focus is on proper operation of the systems by the O&M staff.
- Continuous Commissioning, which will be done at later stages to verify operational methods and equipment performance through periodic audit process.

Energy meters have been installed to monitor equipment performance wherein data is continuously logged. This data is compared to the baseline data to determine the savings. A daily and weekly comparison of the consumption is carried out

continued on page 92

continued from page 90

and the monthly consumption of the whole building, as well as the individual consumption of HVAC, lighting and other related areas are compared with the monthly baseline consumption figures provided through Energy Modeling.

The following metering arrangement is provided:

- Main incoming power supply
- Chillers
- Internal lighting consumption
- External lighting consumption
- Air handling units
- Water supply system
- Sewage treatment plant
- Solar PV system

Renewable Energy Source (Solar PV)

Active solar technologies are employed on the project to convert solar energy into usable direct light and heat, cause air-movement for ventilation and further store energy for future use. The project uses Crystalline Silicon Grid Connected Solar System by Moser Baer Photo Voltaic Ltd. The capacity of grid connected solar photovoltaic system is 57 KWp and approximate energy generation of the system will be 88.9 MWh/year. This system has been designed using 210 Wp crystalline silicon modules and has considered the 24° tilt angle and 23° azimuth angle. The total covered surface area is about 592 m^2 and is set up on the building roof. This kind of solar technology has no moving parts to wear out, provides non-polluting energy and is quiet.

ECB: A Leader in Sustainability

Situated in an industrial estate pre-developed by Greater Noida Industrial Development Authority (GNIDA), ECB is surrounded by densely populated residential area. The site is well connected by public transport and has chalked out a comprehensive transport management plan to ensure that most occupants do not drive to work.

Photo 5: Solar PV on terrace

To achieve maximum water efficiency, entire building has been designed to achieve zero discharge status as 100% of wastewater is treated on site to tertiary standards and used for flushing, landscape and air conditioning make up. A Sewage Treatment Plant of 3 KLD based on Sequential Batch Reactor Technology has been installed onsite.

In addition, the project team has made considerable efforts in selection of material like adhesives, paints and coatings, flooring systems, composite wood and agrifiber products that are recyclable, regional and low VOC producing.

Lastly, an elaborate erosion and sedimentation plan during pre-construction stage and careful construction waste management ensured that the building does not choke the city storm water drains and also reduced the pressure on landfill areas.

Conclusion

As construction practices across the world continue to evolve and strive towards a higher sustainability platform, India has a golden opportunity to carve out its place by building responsibly. India has to its credit several efficient buildings from the past like Taj Mahal, forts, palaces and monuments which boast of harnessing natural resources through a climate conscious design. However, this knowledge was lost to west-influenced construction in the last two decades. Several European nations and other developed countries are now promoting and adopting renewable energy sources. Societies like ASHRAE have set a goal to promote Net Zero Energy Buildings and drive equipment efficiencies to achieve this target by year 2020. Air conditioning systems and engineers will continue to play an important role towards the goal of reducing reliance on city grid power. These technologies and research work are available to Indian engineers and there is a need to convert them into buildable, indigenous, cost effective techniques.

The Bayer Eco Commercial Building is yet another step towards achieving the goal of a "Green India".

The Project Team

An integrated project delivery approach has been adopted on this project by the entire project team comprising of:

- *Owner: Bayer Material Science*
- *Architect & Interior Designers: Sankalpan Architects Pvt. Ltd.*
- *MEP & Sustainability Consultants: Spectral Services Consultants Pvt. Ltd*
- *Contractors and Project Managers: Shobha Developers*