Case Study: India's First Net-Zero Energy Building- Indira Paryavaran Bhavan

Rati Khandelwal, Ravindra Kumar Jain, Mukesh Kumar Gupta

Abstract— In the current scenario of microclimate change and ecological crumbling, sustainable approaches should be implemented to maintain the ecological balance and reduce carbon footprint. In the field of sustainability, net-zero energy building design concepts have grabbed attention due to clean energy deployment, energy security, economic growth, and environmental sustainability. Since numerous advantages are associated with the implementation of NZEB, many architects, design professionals, builders contributed to new design concepts in new buildings. Amongst those new buildings, Indira Paryavaran Bhawan is an iconic building and a great example in the field of sustainability located in New Delhi, India (composite climate zone). This research paper elaborates on the case study of Indira Paryavaran Bhawan from various green building and NZEBs norms perspective. Numerous key points of this building have been discussed in this research paper that will be helpful for professionals from a different field.

Index Terms Building Design Strategies, Composite Climate, Energy Efficiency, Net Metering, Net Zero, Renewable Energy Sustainability, Solar Panel

1 INTRODUCTION

India is facing intimidating challenges in meeting its energy needs. If India continues with a sustained growth rate of 8% per annum, its primary energy supply will need to grow by 3 to 4 times, and electricity generation capacity/ supply by 5 to 6 times compared to 2003-04. It is estimated that by 2031-32, the country's power generation capacity of 800,000 MW would be required as against the installed capacity of 160,000 MW inclusive of all captive plants in 2006-07. It has been estimated that the country is currently facing an electricity shortage of 9.9% and a peak demand shortage of 16.6%. Domestic and commercial sectors account for approximately one-third of total electricity consumption and these sectors are likely to consume around 37% of electricity in 2020-21.[1]

Building sector energy consumption continues to increase, the primary reason is that new buildings are constructed faster than old ones are retired. [2] Per capita energy consumption has increased in India due to the improved urban living standards and advanced means of energy consumption from households to the industrial sector. [3]

The Indian building sector consists predominately of the residential and the commercial sector like building the city of Chicago Nearly, 700 - 900 million sqm of commercial and residential space is projected to be built each year until 2030.[4]

Buildings are also prime generators of Green House Gases (GHG), thus posing a threat to the environment. This is an alarming issue and hence it is necessary to develop energy-efficient buildings that would facilitate minimization of energy consumption and reduces GHG.[12]

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Most recently in India, increased efforts to advance energy efficiency in buildings have been incorporated in various policies such as Energy Conservation Building Codes (ECBC) for commercial buildings. Additionally, the government seeks to explore unconventional energy resources and a big push to a wide uptake of solar energy [5]

Electricity in buildings is used to provide a variety of services such as thermal comfort (space heating and cooling), lighting, and water heating and electrical appliances.[6] Energy-efficient buildings, green buildings, and high performing buildings such as NZEBs have the potential to provide long term solutions to the challenging situation regarding future energy demand. India has gradually started to introduce energy efficiency solutions in its building sector with several tools and strategies, and by supporting green building market growth in India with prevalent green building certification t

ools. If this is to be successful, these efforts must be improved or scaled to realize the potential for energy savings in proportion to the exponential rise in the building sector in India. Therefore, India's building sector must be supported by strong policies and packages that include multiple facets of development and scaling of energy efficiency and integration of renewable technologies in both new and existing buildings [7]

The worldwide CO2 emission mitigation efforts, the growing energy resource shortage, dependence on fossil fuels, and the fact that buildings are responsible for a large share of the world's primary energy use drives research towards new building concepts, in particular NZEBs. This concept has received increasing attention in recent years, since growing numbers of stakeholders globally are attempting to reduce the energy consumption, operating costs, and embracing targets to diminish energy footprints from their building's stocks. The latest and perhaps the most ambitious of these efforts relate to the development and evolvement of NZEBs.

NZEBs are commonly understood as highly energy-efficient buildings that use, over a year, renewable energy technology to produce the same amount of energy they consume.[8]

Therefore, the NZEB approach in a country can differ depending on the climate, the resources for (green) electricity in the grid, the heating and cooling grid infrastructures.[9] To meet energy demands of building long term strategy needed which can increase energy efficiency levels and use of renewable energy resources. The main target is new buildings by using the energy conservation measures in construction, to make energy-efficient buildings or NZEBs.[8]

Net-zero energy buildings do not exist in isolation. Despite the multiple definitions of net-zero building. [10] The wording "net-zero" implies interaction with a surrounding energy grid. It is expected that the accounting of the selected metric (e.g., primary energy) over a relatively long period (typically a year), will yield a net balance close to zero [11] Designing of an NZEB typically requires successful integration and optimization of several architectural concepts and strategies such as building orientation concerning sun path, natural ventilation, solar shading, day-lighting, solar heat gains, thermal comfort as well as the deployment of well-proven insulation practices, energy-efficient glazing, air conditioning, and lighting systems, and incorporation of renewable energy technologies for on-site power generation. [1]

Green buildings or NZEBs are not yet a very common phenomenon in India, but policymakers, architects, and builders are increasingly identifying their benefits and pushing for them.[8] The Government at the Central as well as at the State level putting efforts towards integration of energy efficiency and renewable energy at the design stage of the buildings.[1]

a set of following key initiatives have been undertaken in India to spur NZEB market uptake: (i) NZEB portal and industry alliance, (ii) NZEB demonstration projects, (iii) Net Zero certification.[8]

2 INDIA'S FIRST NET ZERO ENERGY BUILDING: INDIRA PARYAVARAN BHAWAN

This is a project of the ministry of environment and forests for the construction of new office buildings at Aliganj, Jor Bagh Road, New Delhi. The project has been designed to make the net-zero energy building. First in government sector targeted for both ratings of green building (5 STAR GRIHA LEED India Platinum) The building has won awards such as the Adarsh/GRIHA of MNRE for ideal illustration of Integration of Renewable Energy Technologies. This new office building has been constructed in a composite zone. This building sets revolutionary change into conventional building design.

The building has been designed by CPWD by using an integrated design approach with the help of multi-disciplinary fields experts like Architect, Electric Consultant, HVAC Consultant, Plumbing Consultant, Green Building Consultant, Commissioning Authority, Landscape Consultant, Structure Consultant, and other project team members.

The project team emphasized on the energy conservation measure at every step of building design and construction for reducing energy demand by using passive design strategies by providing windows with shadings which again provide adequate natural light with that landscape to reduce ambient temperature and for outdoor greenery access with that energy-efficient active systems.

All the possible energy-efficient and conservation practices were adopted to lessen the energy load of the building and the remaining demand load was met by an onsite solar PV System of 930 kW capacity to make the building Net Zero Energy building.

Fig. 1: Indira Paryvaran Bhawan view

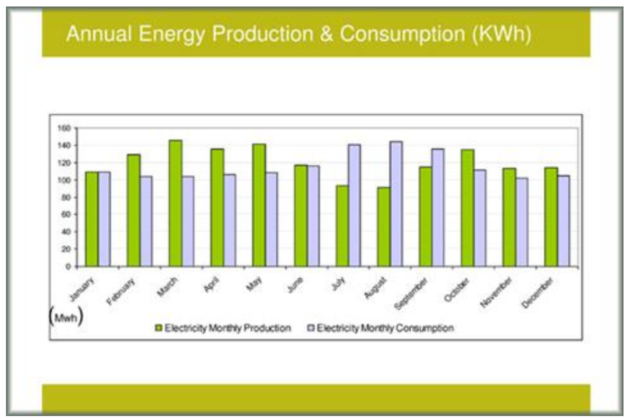

Fig. 2: Annual energy production and consumption graph

The energy consumption of Indira Paryavaran Bhawan is 67.3% less in comparison to the GRIHA benchmark. The project adopted numerous green building concepts for occupants' wellbeing and eco-friendly approaches like water conservation and rainwater harvesting.

The building orientation set in the manner that it favors optimum solar access and shading. Two blocks facing north-south direction have been arranged parallelly having a linear open court in the middle. Building front is a wider setback so that it can protect tree lines for occupant's outdoor view access.

Fig. 3: Final design view of North-South blocks orientation and courtyard

Authorities have got permission to cut 46 trees but only 19 trees were cut, and 11 trees were planted to make up for it. Native plants/trees were planted, and sprinklers and drip irrigation provided to reduce further water requirement. Local ecology was preserved as much as possible to maintain cooler microclimatic. Hard green spaces provided to elevate the greenery.

Onsite STP with FAB/MBBR technology constructed to recycle the total water amount to create zero wastewater. Water consumption has been reduced by 64% by providing water-efficient fixtures.
Building top, courtyard, and edges fully covered by the Solar PV panels which gives shading and create a cooler microclimate. Onsite solar energy capacity provides sufficient energy to meet the demand capacity of the building which plays an essential role to make the building Net Zero Energy Building. This is the first govt. building in the country to achieve this landmark and one of the very few full-fledged multifunctional office buildings in the world to do so on a tight urban site.

Fig. 4: Onsite installed Solar PV Panels

Effective ventilation provided by orientating the building N-S and by optimum integration with nature which has been obtained by separating different blocks with connecting corridors and by providing a huge central courtyard.

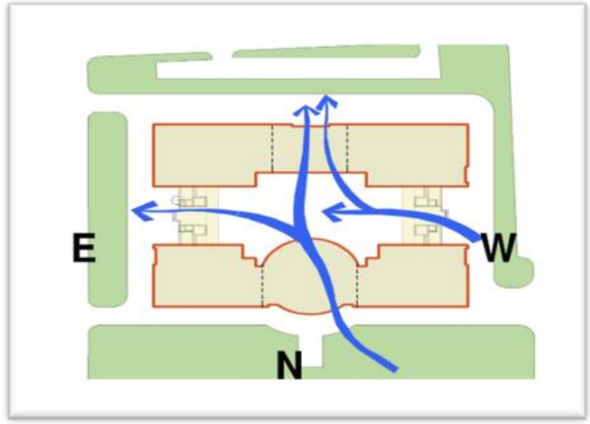

Fig.5: Effective ventilation pattern due to building design

2.1 DESIGN FEATURE OF INDIRA PARYAVARAN BHAWAN:

Building design plays a vital role in the energy consumption of the building. Indira Paryavaran Bhawan was designed in three stages by using an integrated design approach. All three stages -Passive design, Active design, and Renewable Design, elaborated below which helped in achieving the net-zero energy consumption of buildings. Detailed submission guidelines can be found on the author resources Web pages. Author resource guidelines are specific to each journal, so please be sure to refer to the correct journal when seeking

2.2 Passive Design Strategies:

Passive design out-turn when a building is designed and simply works "on its own". Passive design strategies based upon climate considerations attempt to control comfort by the orientation of the building envelope (plan, section) to control airflow. Apart from this Passive design strategies uses materials to control heat, optimizes the use of free solar energy, maximizes the use of free ventilation for cooling, and uses shade- it can be natural or architectural, to control heat gain. Indira Paryavaran Bhawan is in Delhi which comes under the composite zone, on this basis following passive design strategies implemented by the project team.

- **Orientation:** The building is north-south oriented, which is favorable for effective ventilation. Two separate blocks connected through corridors for optimum integration with nature and a huge central courtyard provided which again helps in better air circulation and provides skylight also. The courtyard has been provided with natural vegetation which reduces surrounding temperature, enhances air movement thus by cool air is preserved and hot air escapes easily and provides a green view. Orientation minimizes heat ingress. Window to wall ratio of the building is optimum according to the energy conservation benchmark.
- **Landscaping:** Greater than 50% area outside the building is covered with plantation especially native plants that have been planted to reduce water consumption. Circulation roads and pathways are softly paved to enable groundwater recharge

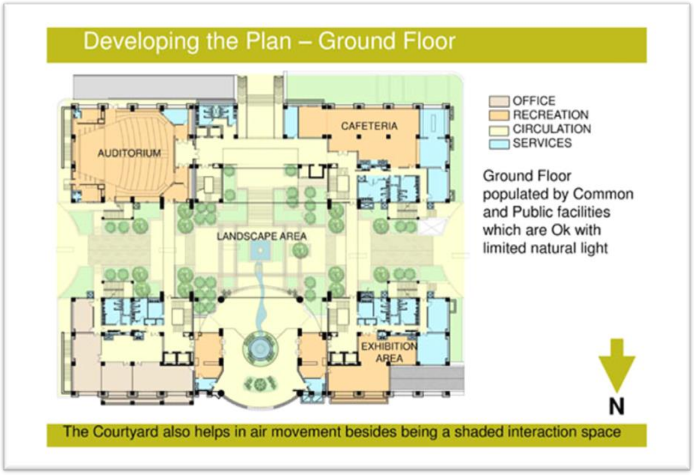

Fig. 6: Landscape designing of the courtyard

• **Ventilation:** Courtyard in the center of the building helps in air movement as natural ventilation happens due to the stack effect. Windows and jaalis add to cross ventilation.

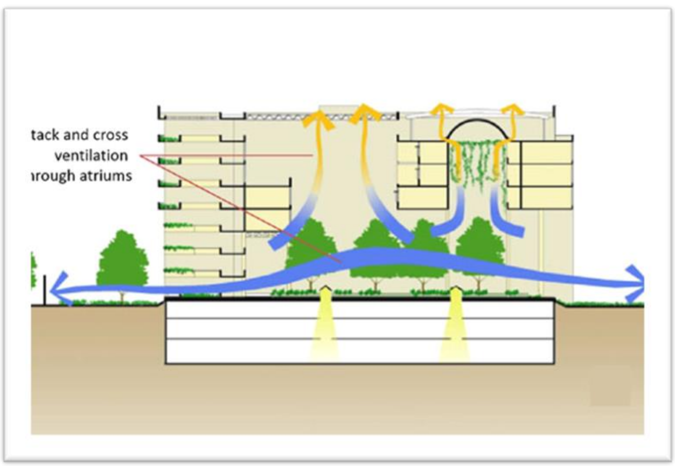

Fig. 7: Ventilation through the courtyard

• **Daylighting:** The courtyard provided with skylight which provides indoor natural sunlight. 75% of building floor space is provided with adequate daylight, consequently reducing dependence on artificial sources for lighting.

• **Building** Envelope and Fenestration: Building Envelope Optimized, rock wool insulation used. The window uses high-efficiency low heat transmittance index double glazed glass of U-Value 0.049 W/m2K, VLT 0.59, SHGC 0.32. The hermetically sealed uPVC windows reduce incoming heat. Use of high reflectance terrace tiles (Cool roofs) or heat ingress, high strength, hardwearing.

• **Materials** and construction techniques: Building constructed with the use of low embodied energy and a recycled content-based product like AAC blocks with fly ash, fly ash-based plaster & mortar. The building has been constructed by providing local stone flooring, bamboo jute composite doors, frames, and flooring. These products are of low embodied energy. High-efficiency glass, high VLT, low SHGC & Low U-value, optimized by appropriate shading which helps in energy efficiency. Light shelves have been provided for diffused sunlight. Stone and Ferro cement jaalis used.

2.3 Active Design Strategies:

The active design uses appliances and technologies to modify the state of the building, create comfort and energy, ie. Fans, pumps, etc. This is the main part where much of the energy conservation can be done.

• Lighting Design: Building provided with an energy-efficient lighting system that uses a lux level sensor to optimize the operation of artificial lighting. The total lighting power density of the building is LPD = 5 W/m2 which is much more efficient than Energy Conservation Building Code benchmarks. Installed integrated photovoltaic (BIPV) provides energy to the remaining lighting load.

• Optimized Energy Systems / HVAC system: Building used chilled beam system to meet 160 TR of air conditioning load. The use of a chilled beam system lessens energy use by 50 % in comparison to a conventional system by saving AHU/FCU fan power consumption by approximately 50 kW. Chilled water is supplied at 16° C and the return temperature is 20° C. This system is used from second to the sixth floor in the building. Water-cooled chillers and double skin air handling units fitted equipped with variable frequency drivers (VFD) which reduces energy consumption on variable load. Chilled water pumping system, cooling tower fans, and AHUs use VFD. All HVAC equipment controlled & monitored through an integrated building management system. Sensible & latent heat energy recovery wheel used to precool fresh supply air from toilet exhaust air. Room temperature is maintained at 26 ±1 ° C which is again a brilliant step towards energy conservation. more efficient than ECBC requirements.

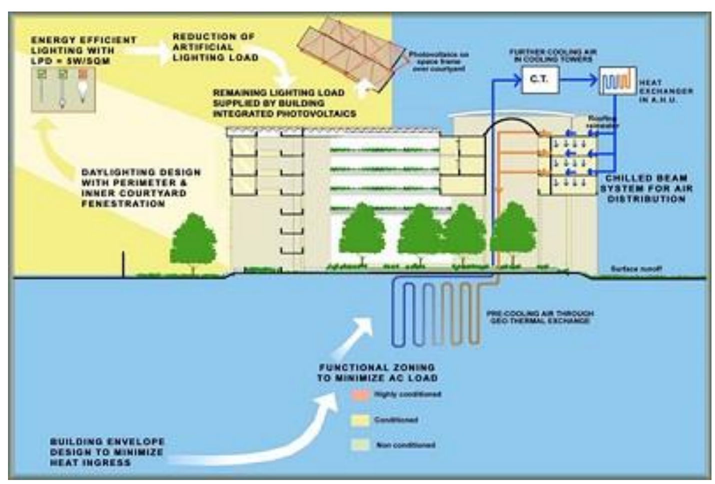

Fig. 8: Energy saving active design strategies (all in one)

The building used functional zoning to reduce air conditioning loads. With the chilled beams, drain pans are provided to drain out condensed water droplets. The overall HVAC load of the building is 40 m2/TR, which is 50%.

- Geothermal Heat Exchange System: Geothermal system has been set up to meet the cooling requirement of the building which consists of 180 vertical bores to the depth of 80 meters with a minimum of 3 meters distant all over building premises. By the use of a Geothermal system, 160 TR of heat rejection is achieved without the use of a cooling tower. Each bore has an HDPE U-Loop pipe having 32mm outer diameter, connected to the condenser water pipe system in the central air conditioning plant room. Each U-loop grouted with Bentonite Slurry and one U-Loop has 0.9 TR heat rejection capacity.

2.4 Renewable Energy:

The Indira Paryavarn Bhawan met the energy demand with the green and clean energy solution, Efficient Solar PV systems. The building has a solar PV system installed in a 6000 m2 area of 930 kW capacity. The total area covered by the panel is 4650 m2 by 2844 solar panels which generate 14.3 lakh unit annually which is huge in amount.

This is the first govt. building in the country to achieve the landmark of net-zero energy building and one of the very few full-fledged multifunctional office buildings in the world to do so on a tight urban site.

3 Acknowledgement:

Ministry of Environment and Forest has established the remarkable net zero energy building with the help of integrated approach by the impaccable involvement of efficient architect and design professionals. Ar. Deependra Prasshad has designed the building by aiding sustainability norms, passive design strategies according to the composite climate zone. The building was constructed by Central Public Works Department (CPWD) efficiently with the inclusion of energy efficiency measures and efficient on site renewable energy system.

4 Conclusion

The case study discloses that Indira Paryavarn Bhawan first govt. building in the country to achieve the landmark of net-zero energy building which has an annual energy consumption of 14.21 Lakh kWh met with equivalent annual energy generation of 14.3 lakh kWh from Solar BIPV installed on-site and one of the very few full-fledged multifunctional office buildings in the world to do so on a tight urban site. Being the highest green-rated building in the country, the project serves as a shining example of high performing government buildings. This building will play the role model of sustainability and will guide the architects, MEP consultants, builders to implement green norms in upcoming buildings construction. The design parameters adopted in the building will enlighten the academician and professional for defining the design criteria of net-zero energy buildings in composite climate conditions.

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