

Net Zero Energy Building Audit: A Feasibility Study and Retrofit Strategy for Institutional Buildings

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Abstract: *The rapid urbanization and infrastructural development in India have led to a massive surge in energy demand, with buildings accounting for approximately 40% of global CO₂ emissions. To mitigate environmental impact, the transition to Net Zero Energy Buildings (NZEB) has become critical in modern civil engineering. This paper presents a comprehensive Level 2 Energy Audit conducted on the Main Academic Block of Guru Gobind Singh Polytechnic, Nashik, aiming to transform an existing structure into an NZEB. The study utilized a multi-phased methodology involving walk-through and diagnostic audits using tools like thermal imaging and power analyzers to establish a baseline Energy Use Intensity (EUI) of 78 kWh/m²/year. By proposing a combination of civil retrofits (cool roof application, XPS insulation, Low-E window films) and electromechanical upgrades (LED lighting, 5-Star inverter ACs, BLDC fans), the optimized EUI was reduced by 42.3% to 44.97 kWh/m²/year. A 50 kWp grid-tied rooftop solar photovoltaic system was then designed to offset the remaining load. The proposed retrofit achieves a net-zero energy balance with a calculated simple payback period of 3.78 years, proving that NZEB standards are economically and technically viable for existing institutional structures.*

Keywords: Net Zero Energy Building, Energy Audit, EUI, Energy Conservation Measures, Solar PV, Retrofit Strategy

I. INTRODUCTION

India's electricity sector is rapidly expanding, yet it faces challenges like grid instability and the environmental burden of coal-dominated power generation. The building sector is a major contributor, consuming nearly 33% of all generated electricity. Traditionally designed institutional buildings heavily prioritized upfront cost reductions over long-term operational efficiency, resulting in high thermal transmittance and an over-reliance on energy-intensive mechanical cooling. Nashik experiences a composite climate with hot, dry summers exceeding 38°C, making older buildings highly susceptible to massive cooling loads. The NZEB philosophy addresses this through a two-pillar framework: extreme energy efficiency to drastically reduce demand via passive and active strategies, followed by fulfilling the optimized demand through clean, on-site renewable energy generation like rooftop solar PV.

II. PROBLEM STATEMENT

The core problem lies in the excessive energy consumption and high carbon footprint of existing institutional buildings that predate modern Energy Conservation Building Codes (ECBC). The Main Academic Block of Guru Gobind Singh



Polytechnic presents a classic energy efficiency deficit: a poorly insulated thermal envelope, outdated non-inverter air conditioning, and power-hungry fluorescent lighting. The challenge is to assess the feasibility of balancing the structural limitations and budget constraints of a government polytechnic while designing a viable, step-by-step retrofit strategy to achieve a net-zero performance status.

III. METHODOLOGY

The study followed an adapted ASHRAE Level 2 Energy Audit framework tailored for existing institutional buildings in composite climate zones.

A. Diagnostic Audit and Baseline Assessment Initial utility bill disaggregation of 24 months of data revealed an annual baseline consumption of 117,000 kWh. The field diagnostic audit utilized digital lux meters to map lighting levels, thermal imaging cameras to identify heat ingress through the building envelope, and power analyzers to measure the active power of HVAC units. HVAC was identified as the largest consumer at 34.6% of the daily load.

B. Proposed Civil and Architectural Retrofits

To optimize the building's thermal envelope, two primary civil engineering interventions were designed:

Roof Treatment: The application of a 50mm thick Extruded Polystyrene (XPS) rigid insulation board bonded to the RCC roof, covered by a high-albedo elastomeric reflective coating. This reduces the roof U-value from 2.2 W/m²K to 0.55 W/m²K.

Fenestration Optimization: Application of Low-E (Low Emissivity) solar control window films on East and West windows to reduce the Solar Heat Gain Coefficient (SHGC), and the installation of fixed external aluminum horizontal louvers on the South facade.

C. Electrical and Mechanical Upgrades

Energy Conservation Measures (ECMs) were applied to active systems to further reduce load:

Complete replacement of 250 conventional 40W fluorescent tubes with 18W LED batten fixtures.

Upgrading 15 aging non-inverter 1.5-ton ACs to 5-Star BEE-rated Inverter ACs.

Replacing 200 conventional 75W ceiling fans with 28W Brushless DC Motor (BLDC) fans. These combined interventions reduced the optimized annual energy consumption to 67,450 kWh/year.

D. Renewable Energy Integration A 50 kWp Grid-Tied Solar PV system using 93 Monocrystalline PERC (540 Wp) panels was sized to precisely match the optimized annual demand. Connected via a bidirectional net meter to the MSEDCL grid, the system offsets the remaining load, resulting in a net-annual energy consumption of zero.

IV. CONCLUSION

This audit conclusively demonstrates that transforming an older, highly inefficient educational structure into a fully compliant Net Zero Energy Building is both technically sound and financially compelling. By following a "reduce first, generate second" methodology, the building's EUI was drastically lowered from 78 kWh/m²/year to 44.97 kWh/m²/year. The integration of civil retrofits, active mechanical upgrades, and a 50 kWp solar PV system successfully eliminates Rs. 14.04 Lakhs in annual electricity expenditure and avoids 95.94 tonnes of CO₂ emissions annually. With a calculated simple payback period of 3.78 years on a capital investment of Rs. 53.07 Lakhs, this study establishes a scalable blueprint for achieving sustainable infrastructure in technical educational institutions.



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