

Transforming Educational Campuses into Net Zero Labs

Sub theme: Goal 11 – Sustainable Cities and Communities

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Abstract

This paper explores the transformative potential of educational campuses as living laboratories for achieving Net Zero carbon emissions, in alignment with Sustainable Development Goal 11 (Sustainable Cities and Communities) and India's commitment to Net Zero by 2070. University campuses, with their vibrant communities and diverse resources, present unique opportunities to model and implement sustainability practices.

Focusing on passive design strategies, sustainable materials, and climate-resilient construction techniques, the study investigates how campuses can lead the way in sustainable development. Passive design approaches, such as optimizing building orientation, thermal insulation, and natural lighting, are explored to minimize energy consumption. The use of sustainable materials like recycled steel, fly ash concrete, and carbon-sequestering timber is emphasized, alongside modular and prefabricated construction methods to reduce waste. Climate-resilient strategies, including flood and heat mitigation measures and disaster-ready designs, are presented as essential components for adapting campuses to environmental challenges.

The study employs a qualitative methodology, combining live and digital case studies of global and Indian campuses, including IIM Udaipur, CEPT University, Centre for Science and Environment (CSE) Building, New Delhi, Global), Avasara Academy Lavale, Pune as well as study of global examples like Monash University in Australia, form the cornerstone of this research to identify effective Net Zero strategies. Findings highlight innovative practices like passive design strategies, Sustainable Materials and Construction and Resilience to Climate Change offering actionable insights for transforming campuses into sustainable models.

Challenges such as financial constraints, Lack of Technical Expertise, behavioral resistance and Material Availability are also examined, with proposed solutions emphasizing policy support, stakeholder engagement, and public-private partnerships. By becoming Net Zero Labs, educational institutions not only instill sustainable values in their communities but also significantly contribute to national and global climate goals.

This paper concludes by outlining scalable strategies for campuses to act as catalysts for broader socio-economic and environmental change, demonstrating their pivotal role in shaping a sustainable future.

Keywords

Net Zero Campuses; Sustainable Development; Passive Design Strategies; Climate-Resilient Infrastructure; Sustainable Materials

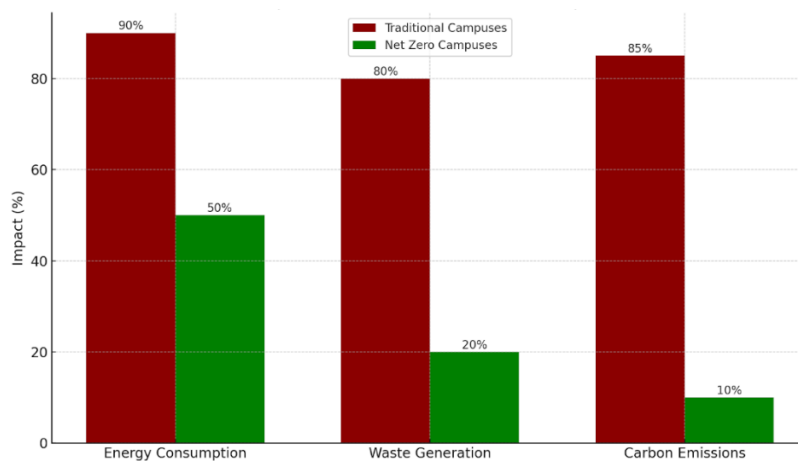
1. Introduction

The accelerating impacts of climate change have heightened the urgency for transitioning toward sustainable and carbon-neutral solutions. In response, governments across the globe are actively reshaping policies and development strategies to align with Net Zero objectives, aimed at mitigating global warming and its adverse effects. India, recognizing its pivotal role in addressing this global challenge, has pledged to achieve Net Zero carbon emissions by 2070, prioritizing innovation, resource efficiency, and inclusive community participation. In this context, educational campuses emerge as powerful platforms for experimentation and innovation. These campuses, functioning as microcosms of urban systems, host diverse populations, extensive research capabilities, and substantial infrastructure, making them ideal environments for developing, testing, and implementing Net Zero strategies.

1.1 Problem Statement

Despite their immense potential, many educational campuses continue to operate using outdated infrastructure and unsustainable practices. High levels of energy consumption, inefficient use of resources, and a lack of strategic planning for sustainability exacerbate environmental challenges, including significant carbon emissions and waste generation. Such conventional approaches sharply contrast with the global movement toward sustainability. However, the inherent characteristics of campuses, such as their ability to pilot innovative solutions and influence large communities, position them uniquely as ideal settings for advancing scalable and replicable sustainable practices.

Figure 1 Comparison between Traditional vs Net Zero Campuses



Source: Energy.gov

1.2 Research Gap

While numerous global examples demonstrate the feasibility and benefits of sustainable campuses, Indian educational institutions encounter distinct challenges. Limited financial resources, insufficient technical expertise, and fragmented policy support frequently hinder the adoption of sustainable practices. Moreover, there is a notable absence of research focused on developing scalable and context-specific frameworks tailored to the Indian landscape. Bridging this gap necessitates the development of localized strategies that integrate sustainable design principles, eco-friendly materials, and innovative approaches into campus infrastructure and operations.

1.3 Objectives

This study seeks to investigate and propose actionable strategies for transforming educational campuses into Net Zero Labs, focusing on three critical dimensions:

1. Implementing passive design strategies to optimize energy efficiency.
2. Utilizing sustainable materials and construction techniques to minimize environmental impacts.
3. Enhancing resilience to climate change through adaptive design and planning measures.

1.4 Research Statement

Educational campuses hold significant potential to spearhead the transition toward sustainability and Net Zero objectives. By embracing innovative design methodologies, adopting low-carbon materials, and integrating climate resilience into their planning processes, these campuses can effectively reduce their environmental footprint. Furthermore, these initiatives align with India's commitment to achieving Net Zero and serve as replicable models for sustainable development on both national and global scales.

2. Methodology

2.1 Research Approach

The study adopts a qualitative research methodology to explore strategies for transforming educational campuses into Net Zero Labs. This approach is particularly suited for gaining an in-depth understanding of existing practices, identifying challenges, and uncovering innovative solutions. By analyzing real-world examples and leveraging insights from subject matter experts, the research focuses on developing practical strategies and tailored adjustments to address contextual needs effectively.

2.2 Data Collection

The research integrates both primary and secondary data sources. Primary data is gathered through site visits and detailed case studies of Indian campuses, such as IIM Udaipur, CEPT University, and the Centre for Science and Environment (CSE) Building in New Delhi. These examples are complemented by digital studies of global campuses, including Stanford University and Monash University. Secondary data is sourced from peer-reviewed academic journals, government policy documents, and reports from sustainability organizations. This

combined approach ensures a robust and comprehensive analysis of strategies that can guide the transition to sustainable campus environments.

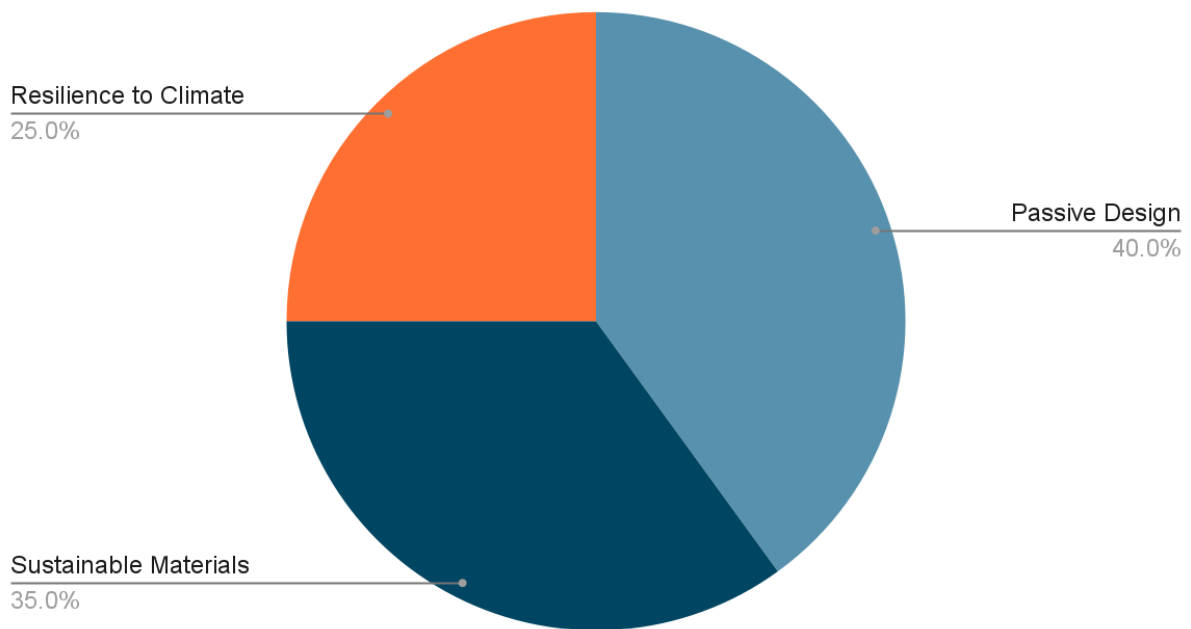
2.3 Analysis Framework

The analysis is structured around three foundational pillars of sustainable campus transformation:

1. **Passive Design Strategies:** Investigating methods to enhance natural lighting, ventilation, and energy efficiency while minimizing resource consumption.
2. **Sustainable Materials and Construction Techniques:** Assessing the use of low-carbon, durable, and locally appropriate materials to reduce environmental impact.
3. **Resilience to Climate Change:** Exploring adaptive strategies to mitigate risks associated with climate variability and extreme weather events.

Figure 2 Focus of Analysis

Focus of Analysis



2.4 Case Study Evaluation

Case studies are systematically reviewed to extract best practices and innovative solutions for each of the above categories. The comparative analysis emphasizes the following:

- Effectiveness in reducing carbon emissions.

- Practicality and feasibility of implementation.
- Adaptability to Indian conditions and contexts.

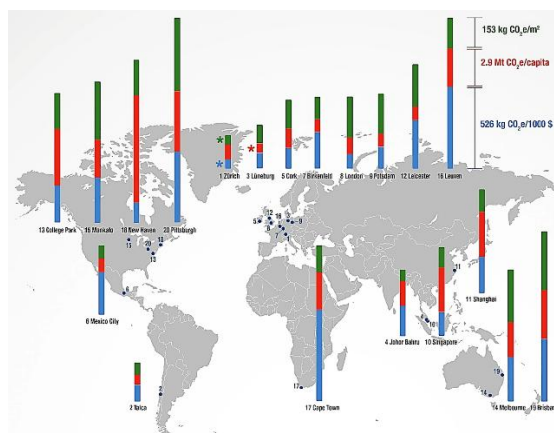
By synthesizing insights from diverse sources, the study develops a structured framework aimed at creating comprehensive roadmaps for transforming educational campuses into living laboratories that exemplify Net Zero innovation and sustainability.

3. Literature Review

3.1 Net Zero initiatives globally and in India for educational campuses

Across the globe, universities are implementing various strategies to reach net-zero carbon targets on their campuses. As major consumers of energy worldwide, universities have considerable economic and environmental impacts. Universities are increasingly re-evaluating their approaches and methods to improve the promotion of effective and sustainable energy use throughout their campuses. Indeed, campus-like environments provide a naturally favorable setting for collaboration and innovation. Many universities have reduced their carbon emissions by implementing advanced energy-monitoring systems and utilizing renewable energy sources. Calls for net-zero emissions are no longer limited to national commitments as the effects of climate change grow more apparent. Universities have the unique opportunity to develop operational emission-reduction plans and foster local awareness, climate research, and action within their communities.

Figure 3 Carbon foot printing of universities worldwide



Source: Environmental Sciences Europe

3.2 Policy and Strategic Movements

Net Zero University Campus" as part of the U75 national movement

India made history on February 20, 2024, when the Green TERRE Foundation, in collaboration with AICTE (Ministry of Education) and IIT Guwahati India, hosted the fourth regional workshop for "Net Zero University Campus" as part of the U75 national movement. Then, India became the first nation in the world to lead the push for carbon neutrality on campuses of educational institutions in all four regions of the country: Pune University in the west, SRMIST University in the south, Delhi University in the north, and IIT Guwahati in the

east. The conference concluded that net zero initiatives ought to have the ability to influence not just the campus but also the local communities, as well as the future homes and workplaces of students. Other universities should have free access to the data produced by 75 universities during their journey to Net Zero in order to make their campuses carbon neutral. With this kind of data access, 75 universities across 75 nations may achieve net zero. Universities are urged by SCCN to begin localising and implementing Net Zero and the SDGs on their campuses. Technical support would be given to universities for baseline surveys, creating a plan to achieve the goals, and implementing digital tools to track and measure results. On their path to become carbon neutral and putting the road map to become a carbon neutral campus into action, SCCN would present guidelines created at each step.

SDSN Net Zero on Campus Initiative Toolkit

The SDSN (Sustainable Development Solutions Network) has created the Net Zero on Campus Initiative in partnership with the Climateworks Centre, Monash University, Second Nature, and the EAUC in response to the growing global university net-zero commitments. They've together compiled a guide and online toolkit to establish new communities of practice and assist colleges and institutions in expediting their plans for climate action. Resources and case studies useful for "institutions of different geographies, scales, and levels of decarbonisation to account for their various needs and challenges" are included in an online toolkit that goes with the guide. The report outlines actionable initiatives that campuses can implement regarding energy, transportation, facilities, waste management, recycling, and procurement, as well as programs that reach outside of campus operations. By doing this, it acts as a practical "toolbox" for sustainability and facility managers at higher education institutions, and showcases approaches to empower students to instigate change.

3.3 Role of Universities in Advancing SDGs

The SDSN (Sustainable Development Solutions Network) has created the Net Zero on Campus Initiative in partnership with the Climateworks Centre, Monash University, Second Nature, and the EAUC in response to the growing global university net-zero commitments. They've together compiled a guide and online toolkit to establish new communities of practice and assist colleges and institutions in expediting their plans for climate action.

1.4 Case Studies



*Figure 4*CEPT University Campus, Ahmedabad & Avasara Academy, Pune

Table 1 Observations and analysis of Educational Campuses

Educational Institutes studied	Three foundational pillars of sustainable campus transformation		
	Passive Design Strategies	Sustainable Materials and Construction Techniques	Resilience to Climate Change
<i>IIM Udaipur</i>	Use of optimal building orientation to improve daylighting and natural ventilation. Usage of shading devices and thermal insulation for minimizing the need of artificial cooling.	Stone and other locally accessible materials are widely used, reducing embodied carbon. A focus on energy-efficient building methods in order to meet environmental objectives.	To reduce the risk of floods in the semi-arid area, water management techniques such as rainwater collection and effective drainage are used.
CEPT University, Ahmedabad	Usage of energy-efficient HVAC and lighting technologies. The building was designed with sun shading and fenestrations that minimize heat gain.	Utilizing fly ash bricks and CSEBs results in a reduced environmental impact. Materials are chosen according to their local availability and longevity.	CEPT integrates landscaping featuring drought-resistant plants and bioswales for efficient water management, boosting the campus's adaptability to climate changes.
Centre for Science and Environment (CSE) Building, New Delhi	The structure features solar shading and strategically placed windows to minimize heat gain, and it also incorporates energy-efficient lighting and HVAC systems.	Elements such as recycled steel and concrete made with fly ash help in lowering embodied carbon. Modular building reduces waste.	Green roofs and rainwater collection systems are used to address urban heat island effects and effectively manage storm water.
Avasara Academy, Lavale, Pune	The school buildings are designed to harness prevailing winds for natural airflow. Overhangs and shading features decrease solar heat absorption while enhancing natural illumination.	Materials such as stone and brick sourced locally are utilized, along with energy-efficient building methods that reduce environmental effects.	Being in a rural area, water security is guaranteed by integrating systems such as rainwater harvesting and wastewater recycling.
Global Example- Monash University, Australia	The Woodside Building features enhanced orientation and natural light access, leading to a notable reduction in energy use.	Sustainable wood and pre-manufactured parts are utilized to reduce waste and embodied carbon.	Green roofs and rainwater collection systems boost thermal efficiency and strengthen flood resistance, adjusting to rising climate variability.

4. Results and Discussion

The findings of this study emphasize the diverse strategies implemented to transform educational campuses into Net Zero Labs. By incorporating passive design principles, leveraging sustainable materials, and integrating climate-resilient planning into construction, these campuses establish benchmarks for sustainable development. Indian case studies demonstrate the potential for local adaptation of global strategies, while international examples provide aspirational practices to guide further innovation. By addressing barriers such as funding limitations, technical knowledge gaps, and material availability, these initiatives underscore how institutional commitment and innovative design can foster transformative change, advancing both national and global climate goals.

4.1 Passive Design Strategies

Passive design strategies play a pivotal role in reducing energy demands and enhancing the environmental efficiency of educational campuses.

Building Orientation and Natural Ventilation: Indian campuses such as IIM Udaipur and Avasara Academy in Pune exemplify how optimal building orientation can harness prevailing winds to enhance natural ventilation. The incorporation of overhangs, shading devices, and courtyards reduces direct solar heat gain while facilitating air circulation. Similarly, Monash University in Australia employs optimized building orientation to minimize reliance on artificial cooling systems, highlighting the universal applicability of these techniques.

Figure 5 IIM Udaipur & Avasara Pune, Campus



Daylighting and Thermal Insulation: The Centre for Science and Environment (CSE) Building in New Delhi utilizes advanced fenestration designs and solar shading methods to maximize daylighting while minimizing heat ingress. At CEPT University, building envelopes are designed with materials that improve insulation, significantly reducing the energy required for heating and cooling. These efforts demonstrate how passive design can align with sustainability goals while ensuring thermal comfort for occupants.

Figure 6 CSE, Delhi & CEPT Campus



Shading and Landscaping: CEPT University integrates shaded walkways and drought-resistant landscaping to mitigate urban heat island effects and enhance thermal comfort. Globally, Monash University's green roofs serve as an additional layer of insulation and thermal regulation, showcasing a scalable model for campuses worldwide.

Figure 7 CEPT & Monash University Campus



4.2 Sustainable Materials and Construction

The adoption of sustainable materials is critical to achieving Net Zero objectives in campus development.

Figure 8 CSEB Bricks, Fly Ash Concrete and Timber



Innovative Materials: Indian campuses lead in the use of low-carbon and recycled materials. IIM Udaipur employs locally sourced stone, minimizing embodied carbon, while CEPT University utilizes fly ash bricks and Compressed Stabilized Earth Blocks (CSEBs), reducing environmental impact. The CSE Building in New Delhi incorporates recycled steel and fly ash concrete, and Monash University employs sustainable timber and prefabricated components to enhance efficiency.

Modular and Prefabricated Construction: Modular construction methods, as demonstrated by the CSE Building, minimize waste and reduce on-site labor. Monash University showcases the scalability of prefabricated materials, which are adaptable to changing needs while maintaining durability and sustainability.

Carbon-Sequestering Materials: Materials like sustainably sourced timber, which reduce emissions while offering improved lifecycle sustainability, are increasingly being utilized. The integration of such materials in global examples highlights their potential for replication in Indian contexts.

4.3 Resilience to Climate Change

Addressing climate variability and extreme weather events requires robust resilience measures tailored to specific challenges.

Flood and Water Management: IIM Udaipur employs advanced drainage systems and rainwater harvesting to mitigate flood risks in semi-arid regions. Similarly, CEPT University uses bioswales and water-sensitive landscaping to manage stormwater, ensuring water security on campus.

Heat Mitigation: The CSE Building in New Delhi combats urban heat island effects with green roofs and reflective surfaces. At CEPT University, landscaping strategies featuring drought-tolerant plants help reduce heat stress while preserving green cover.

Disaster-Ready Designs: Avasara Academy in Pune incorporates water recycling systems to conserve resources, ensuring resilience in rural environments. On a global scale, Monash University employs disaster-resilient construction and adaptive design techniques, offering a blueprint for campuses to prepare for future climatic uncertainties.

By tackling challenges such as resource constraints, knowledge gaps, and material availability, these campuses exemplify how institutional commitment, innovative design, and sustainability-focused policies can drive meaningful change. These efforts align with national and global climate objectives, serving as replicable models for broader societal transformation.

4.4 Impact Assessment: Estimate potential environmental, financial and socio-economic benefits.

Category	Aspect	Benefits	Examples
Environmental	Carbon Emissions Reduction	Lower greenhouse gas emissions through passive design and sustainable materials	Use of fly ash concrete and recycled materials at CEPT University, Ahmedabad
	Waste Reduction	Modular construction minimizes onsite waste	Modular building techniques at CSE Building, New Delhi

	Resource Efficiency	Rainwater harvesting and efficient energy systems reduce resource consumption	IIM Udaipur's rainwater harvesting system
Socio-Economic	Skill Development and Employment	Boost in green jobs and skills development in sustainable construction	Incorporation of energy-efficient technologies at Avasara Academy, Pune
	Educational Opportunities	Hands-on learning in sustainability and real-world applications for students	CEPT University's climate-resilient construction modules
	Community Awareness and Impact	Localized sustainable solutions inspire community participation	Monash University's outreach programs and initiatives
Financial	Capital Investment Reduction	Decreased construction costs through modular and prefabricated methods	Prefabricated sustainable timber components at Monash University
	Operational Savings	Significant long-term cost savings in energy and water use	Energy-efficient HVAC and water systems at CSE Building, New Delhi
	Revenue Generation Opportunities	Monetizing sustainability through carbon credits or renewable energy sales	Solar energy generation surplus exported to grids by Net Zero campuses

5. Conclusion

5.1 Summary

This study highlights the transformative role of educational campuses as Net Zero Labs, emphasizing their potential to serve as exemplars of sustainability. By incorporating passive design principles, leveraging sustainable materials, and embedding climate-resilient strategies, campuses can significantly reduce their environmental footprint. Simultaneously, these efforts drive socio-economic benefits, such as community engagement, skill development, and long-term cost savings.

5.2 Call to Action

To realize the vision of Net Zero campuses, it is imperative for policymakers, academic institutions, and design professionals to adopt sustainability as a foundational principle. Governments should introduce incentives, such as grants and subsidies, to encourage the development of sustainable campus infrastructure. Institutions must proactively seek collaborations and funding opportunities to address resource constraints and technical gaps. Architects and planners hold a key responsibility in transforming these aspirations into practical, scalable, and efficient designs, enabling widespread adoption and long-term impact.

5.3 Future Scope

Future research should focus on integrating advanced technologies to enhance the effectiveness of Net Zero initiatives. Artificial intelligence (AI) has the potential to optimize energy consumption through intelligent management systems, while Internet of Things (IoT) devices can provide real-time monitoring of environmental and operational performance. Longitudinal studies are also essential to evaluate the socio-economic impacts of Net Zero campuses, offering valuable insights for refining strategies and ensuring alignment with global sustainability goals.

Additionally, exploring the role of renewable energy integration, innovative materials, and policy frameworks in achieving Net Zero objectives can provide actionable recommendations for scaling these efforts. By addressing these dimensions, future research can contribute to building a robust roadmap for sustainable campus development, reinforcing the pivotal role of educational institutions in driving climate action and fostering a sustainable future.

6. Recommendation

Category	Recomondation
Campus Administrators	• Integrate Passive Design Strategies • Adopt Sustainable Materials • Enhance Climate Resilience • Foster Sustainability Education
Policy Frameworks	• Incentivize Net Zero Initiatives • Establish Standardized Guidelines • Promote Green Skills Training
Partnerships	• Collaboration with Government, NGOs and Community
Financial Recommendations	• Resource Mobilization • Long-Term Investment Planning

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