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Net-Zero Energy Campuses in India: Blending Education and Governance for Sustainable and Just Transition

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Abstract: This study addresses the urgent need for comprehensive climate education amid a climate emergency. Human (energy) behaviors are developed from childhood and early adulthood. This study hypothesizes that transcending a nation's net-zero energy ambition can be accomplished through experiential education. An Urban Governance Lab plus nEt-Zero Energy league model is introduced. Various behavioral interventions are designed based on the principles of serious games. Discussions provide rich narratives on how a nation with so many diverse communities can forge a rapid net-zero transition. The blended multi-disciplinary STEM education can drive energy citizenship in campus-like communities. A scenarios-based analysis demonstrating the potential of the proposed model in shaping energy behavior in young citizens leading to net zero is presented. The results from the scenario analysis present optimistic evidence underlining how campus-like communities driven by bottom-up initiatives can realize net-zero ambition beyond hope.

Keywords: behavioral interventions; climate education; league model; net-zero transition; sustainability

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1. Introduction

India has emerged as a frontrunner in the global fight against climate change, with remarkable progress in meeting its mitigation commitments. The country's energy sector, responsible for 73% of greenhouse gas emissions, is leading these efforts. By 2050, India is expected to have around 800 million urban dwellers and at least seven megacities surpassing 10 million people by 2030 [1]. India targets to achieve a per capita consumption of 3000 kWh annually by 2040, with 60% of this demand being met through non-fossil fuel-based sources. However, India's urban population is set to double by 2050, and there is a projected tripled demand for residential electricity [2]. In line with the International Energy Agency's "Net Zero by 2050" mission, numerous initiatives from the government, industry, and academic research have aimed to achieve net-zero emissions in India in recent years.

The government initiatives primarily focus on developing and implementing policies through various building rating systems and codes [3]. For example, the Indian Green Building Council (IGBC) started voluntary ratings of net-zero energy buildings in 2018. It is voluntary in nature to rate net-zero buildings based on energy performance improvements and the usage of renewable energy sources. It gives up to 25 percent weightage to the use of renewable energy in addition to focusing on the energy-efficient design of the buildings. Solar-grid, rooftop solar photovoltaic (PV) systems are a central pillar of government initiatives in Indian, and several studies have been conducted in this area [4,5].

Furthermore, with the support of the Ministry of Power in 2021, the Bureau of Energy Efficiency (BEE) introduced the "Shunya labelling" program as an exclusive certification to promote net-zero and net-positive energy buildings in India [6]. This program aims to recognize the building owners who contribute to fulfilling India's net-zero mission. Under this program, two types of labels have been proposed: Shunya and Shunya+. The Shunya label is awarded to net-zero energy buildings with an Energy Performance Index (EPI) ranging from 10 to 0 kWh/m^2/year. On the other hand, the Shunya+ label is given to net-positive energy buildings, which are either those with an EPI below 0 or buildings that generate more energy than they consume. Figure 1 summarizes key characteristics of several high-energy performance buildings and facilities indicating the prevalence and growth of net-zero energy transition across the nation. The trends analysis suggests that organizations, including private and public offices, residences, educational institutions, and manufacturing industries, have embraced sustainability and adopted climate-sensitive building designs in the past decade. Furthermore, our observations suggest that experiential guided educational tours have been institutionalized by Environmental Design Solutions (EDS) since 2019. Through these initiatives and their potential for integrating more renewable energy sources, India aims to achieve approximately 40% of total electricity through clean energy sources by 2030.

List of HPBs in India	Building Use-Type	Location in India	Area (in m^2)	EPI (kWh/m^2/yr)	(If any) Experiential Activities/Programs
Bhawar Residence	Residence	Chennai, TN	330	0.77	
SIERRA's eFACiLiTY®	Private Office	Coimbatore, TN	2322	56	EDS conducted 1 guided tour on Oct 19, 2019
Lodsi Community Project	Manufacturing facility and Office	Lodsi, UK	929	35	
IIT Jodhpur	University Campus	Jodhpur, RJ	807512	45 (simulated, not measured & verified)	
St. Andrews Boys Hostel Block	Student Dormitory	Gurugram, HR	5572	NA	
St. Andrews Girls Hostel Block	Student Dormitory	Gurugram, HR	2322	NA	
Rajkumari Ratnavati Girls' School	School Campus	Jaisalmer, RJ	35600	NA	
Kalpana Housing	Community Housing	Auroville, TN	5010	NA	
Jaquar Headquarters	Manufacturing facility	Manesar, HR	48000	NA	
Humanscapes	Community Housing	Auroville, TN	1680	NA	
Unnati	Private Office	Noida, UP	3740	60	EDS conducted 1 guided tour on Sept 19, 2019
Avasara Academy	School Campus	Pune, MH	11148	NA	KUDOS conducted 1 guided tour on July 18, 2023
Infosys – Pocharam Campus	Private Office	Hyderabad, TR	27870	75	EDS conducted 1 guided tour on Nov 23, 2019
Indian Green Business Centre (IGBC)	Private Office	Hyderabad, TR	1858	80	
Godrej Plant 13 Annexe	Private Office	Mumbai, MH	24443	75	EDS conducted 1 walking tour on Aug 9, 2019
CEPT, A Living Laboratory	University Campus	Ahmedabad, GJ	498	58	EDS conducted 1 walking tour on Aug 24, 2019
Indira Paryavaran Bhawan, MoEF	Office	New Delhi, ND	9565	44	
Akshay Urja Bhawan, HAREDA, Panchkula, Haryana	Public Office	Panchkula, HR	5100	30	
Eco Commercial Building (ECB) Bayer Material Science	Private Office	Noida, UP	891	72	
Malankara Tea Plantation	Private Factory	Kottayam, KL	NA	NA	
GRIDCO Bhubaneswar	Public Office	Bhubaneshwar, OD	15793	90	
Sun Carrier Omega	Private Office	Bhopal, MP	9888	NA	

Figure 1. An overview of high-performance buildings (HPB) and facilities in India (Source: www.nzeb.in, accessed on 23 August 2023).

Research for net-zero goals focuses on issues related to finance [7], governance [8], policy [9], strategies to minimize energy loss, etc. Some studies have identified key strategies to realize the net-zero mission in India [10], which include engaging with citizens, engaging with the energy sector workforce, pricing carbon, deploying low-cost finance, and going beyond co-benefits. In contrast, others focused on energy consumption reduction, such as developing strategies to enhance energy efficiency in high-rise office buildings [11].

Research has shown that behavioral factors such as social norms, personal norms, emotions, attitudes, trust, and skills significantly influence high-level decision-making related to energy policies [12,13]. Integrating socio-psychological factors into energy policies can lead to more effective and efficient outcomes. For instance, Hong et al. [14] reported that raising awareness among residential end-users and improving behavioral factors through non-monetary intervention strategies can save up to 20% of energy. Wang et al. [15] categorized intervention strategies to shape targets and facilitate behavioral change into positive motivational, coercive, and incentive-based techniques. Stephenson et al. [16] suggested that interactions among material culture, energy practices, and norms are significant factors that shape and reinforce occupants' energy behaviors. According to Hansen [17], studies have demonstrated that exposure to certain types of homes and living spaces during childhood and early adulthood can shape energy consumption behaviors. Dubois et al. [18] emphasized households' significant role in the context of carbon emissions. By inducing changes in attitudes, norms, or practices, it is possible to influence consumption habits, thereby generating incentives for additional voluntary changes to arise [19]. It is important to undertake a systematic approach to gathering qualitative data and analyzing local communities to understand the growing global population's values, ingrained behaviors, and needs and predict their energy practices, needs, and usage.

According to the International Energy Agency's report, "Net Zero by 2050", a combination of efficient energy use, resource efficiency, and changes in behavior is necessary to offset the increasing demand for energy to achieve the goal of net-zero emissions by 2050 [20]. Implementing energy policies that effectively balance economic development with environmental sustainability requires the consideration of socio-psychological factors in decision-making. Hence, India requires a holy grail approach that involves the participatory engagement of urban citizens who can actively contribute to addressing the increasingly complex energy sustainability goals. Thus, it is vital to integrate socio-psychological factors into holistic energy policies to achieve sustainable development goals and address challenges associated with rapid urbanization and industrialization.

2. Existing Models and Framework

The Sustainable Solutions Development Network (SDSN), under the global initiative of the United Nations, offers a guide and toolkit for universities worldwide to race to net zero [21]. It provides guiding principles for each stage of the campus decarbonization journey. The accompanying online toolkit provides examples of resources that can support the planning and implementation of decarbonization efforts across several stages, including energy, mobility, facilities, waste and recycling, procurement, and beyond-campus operations of college and university campuses worldwide.

To assess climate action in Indian cities, the Climate Smart Cities Assessment Framework 2.0 evaluates cities based on 28 indicators across five thematic areas, including Energy and Green Buildings, using a 1 to 5 stars rating system [2]. Another framework exists for net-zero-carbon cities and net-zero buildings. The framework in [22] encompasses the entire lifecycle of buildings, evaluating their potential for self-sufficiency by utilizing local natural resources. The findings from this research indicate that the sustainability assessment is most influenced by two key factors: the building's lifespan and the behaviors of its occupants. The existing research has a framework for sustainability design and decision-making of net-zero buildings [23], which did not consider the behavioral aspects and their impacts and indicated it as a study limitation. Another research with a framework for net-zero carbon building integrates Building Information Modelling and Digital Twins to achieve it [24]. To achieve energy efficiency in urban energy planning, a framework was developed taking into consideration energy, environmental, and social criteria [25].

A recent study on the Indian community establishes a framework centered on a community-oriented energy-analysis approach. It introduces a decision-making framework to assess the feasibility of building retrofit schemes across residential communities. The primary objective of the research was to assess the viability of community solar rooftops, emphasizing the concept of achieving net-zero energy consumption within residential buildings [26]. Another study identifies that relying solely on energy efficiency measures will not suffice to meet carbon emission reduction goals [27]. A framework has been created to chart the elements associated with such buildings to address this necessity. This framework is intended to be a valuable tool for sustainable designers working on new construction projects and retrofitting existing buildings.

2.1. Net Zero at Universities

Worldwide, universities are taking numerous measures to achieve the net-zero carbon goals on their campuses. Universities are undeniably significant energy consumers globally, leading to noteworthy economic and environmental consequences [28]. Universities are progressively reassessing their strategies and techniques to enhance the promotion of efficient and sustainable energy utilization on their campuses [29]. In fact, campus-like communities are naturally conducive environments for co-creation and innovation. Numerous universities have diminished their carbon footprint by incorporating intelligent energy-monitoring systems and harnessing renewable energy sources [30]. Curtin University's Green Wave and Curtin Net Zero projects have focused on exploring how universities could implement strategies for achieving net-zero energy and decarbonization goals while simultaneously fostering stronger community and business partnerships. Massey University partnered with the Building Research Association of New Zealand (BRANZ) with a zero-carbon agenda for building professionals. The educational institution and industry work hand in hand to empower students to become change agents in the industry through their Building Capability to help the Construction Industry Transition to Zero Carbon program, where students work on Zero Carbon projects. Some educational institutions introduce electricity energy-efficiency programs for entire universities, such as the Institut Teknologi Sepuluh Nopember (ITS) in Indonesia, which has implemented the Smart Eco Campus program since 2011, aiming to promote electricity energy efficiency and create a safe environment [31]. The National Energy Conservation and Emissions Reduction Competition for college students is a well-received environmental-social practice in China. It provides a platform for students to showcase their creative inventions and investigations regarding environmental issues. Taking place annually, students form teams and participate voluntarily in the competition. The competition serves as a strong motivation for college students, who dedicate around six months of their spare time to prepare for it. Students actively engage with the community during this period, collect data, identify problems, and explore effective solutions. This student-driven initiative aims to modify college students' behavior to reduce their carbon footprint, benefiting the environment.

To enhance the understanding of energy conservation and foster a culture of energy-saving behavior, it is recommended that long-term environmental education campaigns be implemented across all higher educational institutions based on a study from Kuwait University. This would ensure a continuous and sustained effort in promoting energy conservation knowledge [32]. Introducing ecological footprint calculators as part of a master's course in environmental psychology helped South African university students understand, change, and measure the environmental impacts of their daily activities [33]. Similarly, introducing energy lectures improved the students' attitudes and intentions toward energy-saving behaviors at a Portugal University [34].

In the US, many universities have taken numerous measures, such as sustainability training and self-management techniques, resulting in a boost in participants' efforts to conserve energy. A notable contrast between students' initial energy consumption and their energy consumption after a workshop and training session was observed [35]. In another US campus, staff received training and monthly emails containing a graph summarising their building's energy use during the previous months and were asked to be volunteers for energy interventions, resulting in a significant decline in energy use relative to before intervention [36]. At Otago University in New Zealand, interventions using visual prompts, feedback, and incentives to promote behavior change in relation to electricity usage showcased the effectiveness of utilizing interventions [28].

Universities can broaden their influence by incorporating net-zero and other sustainability principles into their two primary areas of operation: research and education. Such integration and implementation would contribute to developing practical and innovative solutions to address climate change effectively in India. The literature review shows a lack of a framework model for university campuses in India for achieving zero-carbon goals.

2.2. Knowledge Gap and Contributions

There are existing frameworks (e.g., SDSN), models (e.g., Smart Eco Campus program, Green Wave, and Curtin Net Zero), and climate education programs [33–36] that empirically demonstrate the potential to make campus-like communities net-zero energy worldwide. Likewise, in India, accomplishing net-zero goals within the residential communities has been explored [26]. Our literature study presents a clear knowledge gap in this regard. Just and successful governance of net-zero transition in campus-like communities in India requires blending indigenous and global approaches. In this context, our study makes the following contributions to the scientific body of knowledge. Firstly, it proposes new indigenous and creative interventions (tailored appropriately to the Indian context). Secondly, it exemplifies how to blend them appropriately with other socio-behavioral interventions under one framework. Finally, a scenario analysis is presented to test the viability of meeting net-zero energy goals, especially for campus-like communities in India. Furthermore, this study underlines driving the momentum through comprehensive educational outreach and engagement efforts. The goal is to facilitate the widespread adoption of such groundbreaking models across campus-like communities in India.

3. Proposed Model

This study introduces the prototype of an UrbaN Governance Lab plus nEt-Zero Energy (UNGLEE) league model. The proposed model stems from the concept of Energy Citizenship, which attempts to reimagine the role of every urban citizen as an actively engaging agent in the energy transition proposed in [37]. Energy citizenship is a concept that refers to the active engagement of individuals, communities, and organizations in the management, conservation, and generation of energy resources, as well as in the decision-making processes related to energy policy and sustainability. Energy citizenship recognizes that energy is a critical aspect of modern life and that individuals and communities have a role to play in shaping how energy is produced, consumed, and governed. The UNGLEE draws ideas such as gaming, guided walks, competitions such as hackathons, datathons, etc., and blends them to co-create a gourmet of climate derisk interventions and action plans led by young citizens. As the name suggests, UNGLEE (when translated into Hindi) is synonymous with “showing a direction” and shall serve as a reference to how to seed responsible innovation in the minds of young citizens during their tertiary education, allowing the space and time for them to nurture, enabling them to co-develop ideas, pilot and implement net-zero energy interventions/solutions within a campus-like ecosystem, use a digitized data-driven governance platform to monitor their impact over time, and thus validate their efficacy. Studies recommend that universities implement a comprehensive multi-vector approach based on evidence from which the university campus scale benefits. Thus, there is a need to necessitate a deliberate co-evolutionary process based on adaptive governance, utilizing a feedback loop model, advancing participatory action research, and improving the effectiveness of government policies towards zero carbon [38].

UNGLEE is a generic model for transitioning into a realistic net-zero energy future by focusing on the three core principles:

- Digitization of everything, including infrastructure, information, resources, and processes, which are otherwise either unaccounted or accounted for in logbooks/registries;
- Democratization of information leading to actionable insights by relevant stakeholders in various capacities leading towards open innovation and energy citizenship;
- Decarbonization of the built environment.

The proposed model presented in Figure 2 is like the five guiding principles of SDSN: commit, assess and organize, plan and strategize, implement and innovate, and monitor and evaluate.

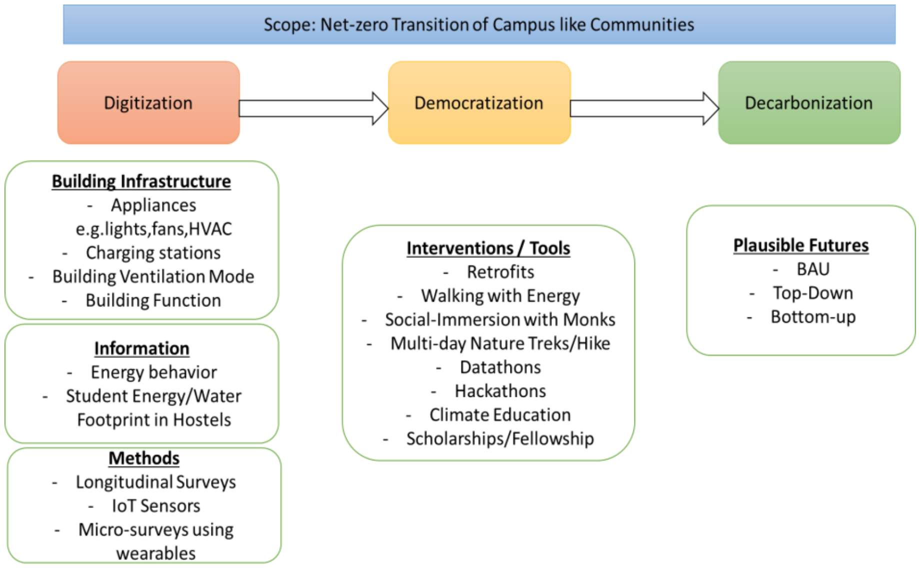

Figure 2. An overview of the proposed UNGLEE model tailored to campus-like communities.

The data-driven, decentralized, participatory approach upon which UNGLEE is built is generic in that it applies across the scale of buildings, communities, and urban areas. For instance, at the building scale, digitizing energy use together with some analytics shall enable categorizing energy consumers and designing intelligent behavioral-change interventions/campaigns in partnership with utility companies to improve energy efficiency by feeding back insights to every household. Likewise, next-generation real estate management firms such as APNAComplex are already digitizing a lot of information at a community level, e.g., apartment complexes in Indian cities. Combining aggregated energy-usage information, for example, at Block A, B, and C levels, can allow them to run digital campaigns combining rewards to motivate change in energy-use behavior among residents in each housing complex block without intruding into individual households' privacy. At the scale of a city, urban local bodies, in partnership with regional schools, can possibly employ students as grassroots-level ambassadors of change in energy behavior amongst households (e.g., in the case of the southwest council in Singapore) to design successful long-term energy transition campaigns. However, in this study, discussions deliberating the application of the proposed model shall consider campus-like communities.

3.1. Digitization

The proposed model described in Figure 2 exemplifies the application details in the context of campus-like communities, which are quite prevalent across the country, including boarding schools, universities, townships, large IT parks, etc. Regarding the digitization phase, certain key information relevant to campus facilities and infrastructure should be digitized as the first step. This includes appliances, on-site renewables, number/type/function/use of buildings (e.g., hostel, faculty housing, lecture theatres, and faculty office), gross foot area, occupancy pattern, other key building design features (e.g., glazed and mechanical ventilation), and key facility management features (e.g., access controls and ventilation modes). In addition to the above, information pertinent to energy usage, user interaction, and energy behavior of occupants (e.g., how much students use energy in hostels and energy-intensive equipment in faculty labs). Typically, information relevant to energy use in the campus community can be easily digitized, collected, and stored through longitudinal surveys, IoT sensors, and micro-surveys via wearables.

The digital energy usage information from multiple sources forms a rich foundation to stimulate the design and implementation of community-driven, engaging behavioral interventions on campuses involving students, faculty members, and staff. It is typically facilitated by a centralized campus estate building management system such as Siemens

Desigo CC or Apogee, which forms one of the key sub-systems for governance in the proposed model. The BMS, together with another high-level analytics engine and application layer, typically constitutes the core of the net-zero energy governance system in the context of the proposed model. These two sub-systems allow the democratization of data, fostering a greater degree of culture of innovation that allows co-creating, piloting, and validating creative and thoughtfully designed behavioral interventions. Data collection can be performed in a number of ways, such as surveys or wearables from people. Building and resource use can be tracked using sensors that serve as the foundation of an IoT network, as they are embedded within physical devices to detect and collect data from the surrounding environment [39]. Smart meters can provide users with important information on energy usage [40].

Another example of digitization is providing cheap smart plugs and energy monitors to students to measure their operational energy consumption as a part of a course on sustainable habitat design at IIT Delhi, India (Figure 3). Energy usage measurement helped the students to know where to prioritize their energy reduction efforts. They were curious about how much energy is wasted in standby mode while we keep laptops, televisions, microwave ovens, etc., connected to the mains. They also experimented with an air conditioner (AC) setpoint with an energy monitor to find out how much energy is saved this way. For a 1.5 ton inverter-based AC, the power consumption for a setpoint of 30 °C vs. 23 °C was 0.8 kW vs. 2.2 kW, respectively, when used in Delhi in September 2023.

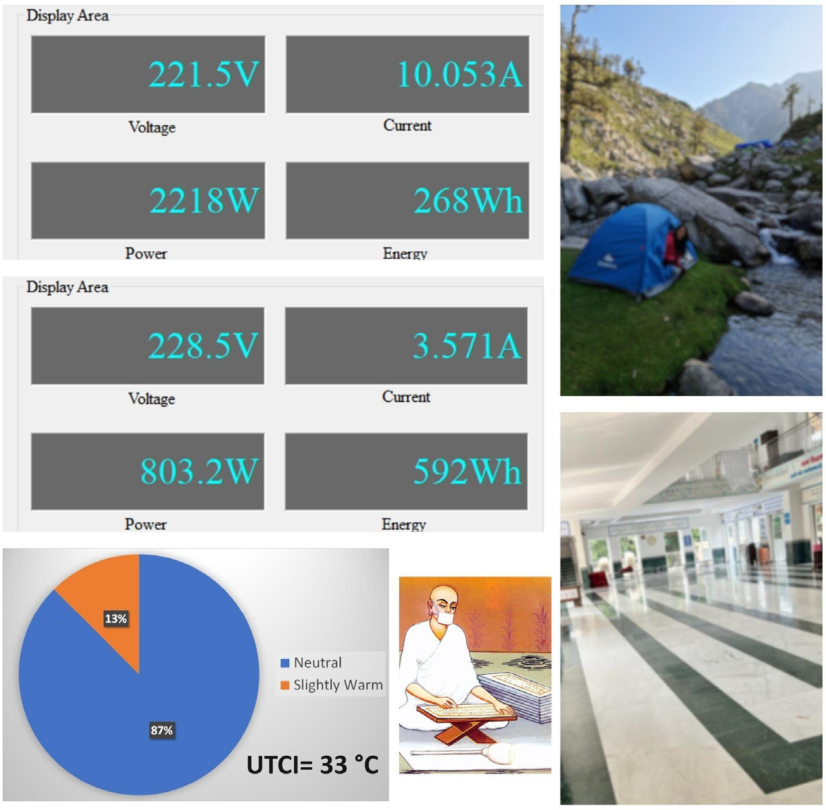

Figure 3. Behavioral interventions helping with climate education: digitization with energy monitors for AC setpoints of 23 °C and 30 °C (**top left**), multi-day trekking to reduce consumption behaviors (**top right**), immersion with Jain monks leading to reduced cooling needs (**bottom left**), Jain monk (**bottom center**), and high window to wall ratio in Jain Sthanak (**bottom right**).

3.2. Interventions

There are several indigenous interventions that can propel university campuses towards zero-carbon goals in India. The examples selected for this study (as presented in Figure 3) are from the literature review, observations, research studies by the authors, and feedback from university students, as explained in this section.

The students of the course on sustainable habitat design at IIT Delhi visited Jain monks who do not use any operational energy. The monks explained how they lead a life in sync with nature and made suggestions for how the students could reduce their energy consumption. Some of the suggested techniques that do not use electricity include sleeping in an airy place, moving to a cooler room in summer, and using a wet cloth for evaporative cooling. The students were asked to fill out a thermal comfort survey while they were there with the monks. The thermal comfort index, UTCI, was in the strong heat stress range with a value of 33 °C, but the majority of the eight students felt a neutral thermal sensation corresponding to a UTCI between 18–26 °C (Figure 3). This could lead to a reduction in their energy consumption behavior for cooling, which is rising rapidly in a warming planet. It is also to be noted that the Jain Sthanak building had a very high window-to-wall ratio to promote cross ventilation. One of the students said that the monk made her realize how altering their lifestyle is possible and can help conserve nature. Some of the other students were also asked if multi-day trekking helped in reducing their carbon footprint. Interestingly, the students who had undergone climate education responded positively, but the other students did not comment about it. Climate education coupled with multi-day trekking could be a behavioral intervention to help students reduce their carbon footprint in fun ways.

Thermal imaging techniques using a FLIR-C5 camera were used to test environmentally friendly and affordable ways to reduce cooling needs in hostel rooms without an AC as a part of a student's design project at IIT Delhi. With the students willing to participate in the experiments, she found that techniques such as taking a shower reduced the skin temperature by about 4 °C (Figure 4). Another zero-energy cooling technique was to touch the person's back directly with the cool floor to cool the body. The thermal image in Figure 4 (center right) shows a skin temperature of 32.2 °C, like the shower case, achieved when the floor cools the back. The floor is an infinite reservoir of cooling, and it can be used until the cooling lasts. The room was naturally ventilated, with no active cooling during this experiment. These techniques show the promise of behavioral interventions to reduce energy consumption through active citizen participation, but experiments with a higher sample size of participants using a longitudinal study should be performed to test the efficacy of these interventions.

It is a well-known fact that animals use similar techniques to stay cool. The buffaloes would spend many hours in the water to escape the summer heat. One of the author's pet dogs preferred to sleep on the floor during summer and even when offered a comfy bed. Indraganti [41] suggests many behavioral adaptations for planet-friendly cooling methods. Drinking cold water, staying in an airy place, and performing less vigorous activities are some behaviors that help to beat the heat in the summertime in India.

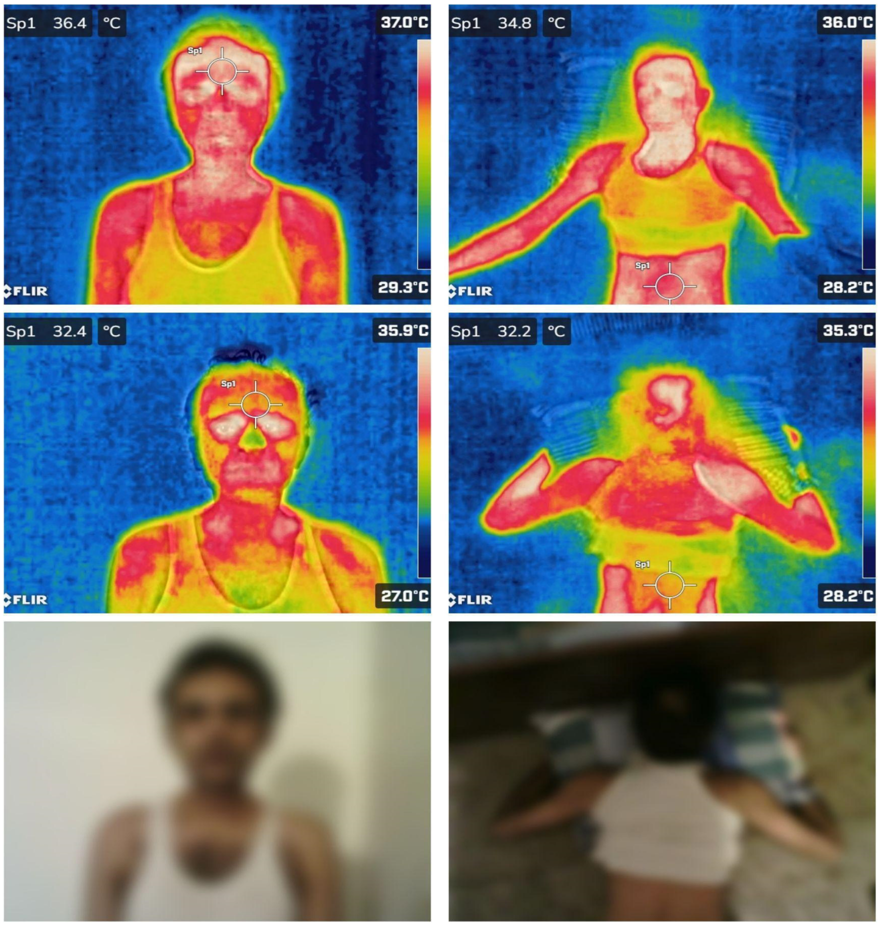

Figure 4. Zero-energy cooling-based behavioral interventions: thermal image before shower (**top left**), thermal image after shower (**center left**), real image (**bottom left**), a thermal image in a supine position on the floor (**top right**), a thermal image in a prone position while back is in touch with the floor to show cooling (**center right**), and real image of the prone position (**bottom**).

Previous studies have shown that experiential learning methods have enhanced engagement and improved students' learning experiences [42]. Similarly, experiential games and activities are blended interventions to reimagine the learning experience to educate and accelerate responsible climate action in a university setting in India. Figures 5 and 6 presents an overview of blended serious games of Building-in-a-Box (BiBo) and a guided walk to Avasara Academy's net-zero energy campus in Pune, introduced as interventions during FLAME Summer School in July 2023. A new interactive board game, BiBo is introduced as an interactive aid to communicate climate emergencies on the building scale [43]. It serves as a simple yet creative artifact to stimulate the thinking of future alternatives, leading to responsible design and behavioral change innovations within complex urban systems inspired by the potential of games as socio-behavioral change agents in society. Recent studies highlight the gap in the penetration of serious games in the AEC industry in Asia, particularly within the energy and built-environment sectors [44]. BiBo is thus uniquely positioned as one of the first games of its kind that aims to promote and enhance innovation in the AEC industry sector across global-south nations (e.g., India) beyond energy and sustainability. It simulates real-world challenges (urbanization, climate action, and technological risks) and constraints (land-use limitations, climate emergencies, and passivity) that the industry faces. It facilitates roleplays that enable participants to think outside the box and explore creative/alternative solutions to complex and intractable (wicked) problems encountered by stakeholders in this industry. The engaging game design encourages creativity, fostering innovation and risk-free exploration. Moreover, it functions as an interactive visioning tool that challenges the status quo (design practices, operations, maintenance, and best practices) prevalent in the industry and allows reimagining future design alternatives more holistically.

Figure 5. (**top**) Building-in-a-Box game board and gameplay introduced in FLAME Summer School in Pune, India (**bottom**) Overview of a guided energy walk to the Avasara net-zero energy campus introduced in FLAME Summer School.

At the university level, institutes such as IIT Bombay have conducted intra-hostel competitions in which the hostels compete to reduce their electricity bills. Solar Decathlon competitions worldwide also make the students compete to design and fabricate net-zero buildings. The students of Team SHUNYA, who participated in Solar Decathlon Europe 2014 [45], felt that they learned more from participating in this 18-month-long competition than their curriculum, highlighting the importance of experiential education, learning by doing, and connecting the curriculum to real-world problem solving. SHUNYA, which means zero in Hindi, is an acronym for "Sustainable Habitats for an Urbanizing Nation by its Young Aspirants".

During a guided walk to the Avasara Academy, participants understood several key design aspects, including choice of materials (such as recycled doors, windows, and fly ash bricks), active energy systems (rooftop photovoltaics), and passive systems (reed bed water recycling and solar chimneys) that contribute to low carbon during the lifecycle of buildings. We collected feedback from participants to determine the efficacy of the blended approach. The feedback showed that all respondents reported an increase in their comprehension of concepts, methods, and applications, including the technology underlying the operations of net-zero energy buildings, where a mean score = 8.875 and SD = 0.83, respectively. Specifically, most respondents (seven responses) acknowledge acquiring new conceptual knowledge about design principles, materials, energy use, and the influence of energy generation on net zero. Specifically, 43% of the survey respondents felt that the guided walk alone provided the knowledge required to understand energy and sustainability concepts in buildings, whereas 57% of respondents felt that the seminar, BiBo gameplay, and guided walks provided greater understanding [43]. Through this study, we show how to create an experiential learning program around net-zero transition and commit to scaling these efforts to accelerate climate action in India. The study hints about replicating this model across the country by aggregating existing information and creating experiential educational programs through partner institutions to build the necessary capacity for scaling.

A recent comprehensive review of gamification has uncovered 118 different theories and derived ten basic principles of gamification [46]. Among them are five principles, namely, clear and relevant goals, immediate feedback, positive reinforcement, guided paths, and simplified user experience, to guide intended behavioral outcomes. Three principles, namely, individual goals, adaptive content, and multiple choices, foster individual relevance. Finally, two principles, namely, social comparison and social norming, enable social interaction and positive social effects.

A systematic review by [44] reviewed 21 serious games employed as engaging mediums for building energy consumption, focusing on the role of energy-consumption awareness-related education in motivating end-users to save energy and make informed decisions to change energy-related behaviors. This study underlines serious games as strategic tools that elicit pro-environmental behavior for energy efficiency related to—environmental education, consumption awareness, and energy efficiency behaviors. Table 1 presents evidence of recent developments in creating experiential programs. Table 2 presents an overview of games classified by building use-type and objective of the game. This study also examines the growth and penetration of serious games in the AEC industry, particularly in Asia, compared to global trends.

Table 1. Summary of activities broadly related to environment, design, and policy.

Experiential Activities/Programs	Country	Context/Game Objective	References
Walking with Energy'—A guided energy walk	Sweden and UK	Energy Citizenship	[47]
Integrated Child Development Services, Kaun Hai Master? Kya Hai Plan?, City for All?	India	Tactical Urbanism	https://www.socialdesigncollab.org/open-source (accessed on 23 August 2023)
Telling Tales	UK	Storytelling to tackle the "wicked problems" of climate change	[48]
Shaping Future, Polity, Unpack Play, Curriculum for 74th Amendment	India	To design better policies using games and simulations.	https://fieldsofview.in/projects/ (accessed on 23 August 2023)
Climate Hackathon	Norway with Microsoft	To develop software solutions for energy consumption problems.	https://climatehackathon.devpost.com/ (accessed on 23 August 2023)
The Climate Change Emergency Hackathon	UK	To explore the use of data to tackle the climate emergency.	https://www.ofgem.gov.uk/publications/climate-change-emergency-hackathon (accessed on 23 August 2023)

Table 2. Summary of serious games related to energy in built environment [44].

Games Title	Building Type	Game Objective
Power Agent	Real House	Change in human behavior
Power Explorer	Real House	
EnerCities	Virtual Cities	
EnergyLife	Real House	
Energy Battle	Dormitory	
Super Delivery	Virtual Cities	
Ghost Hunter	Real House	
eViz	Virtual Apartment	
Do It In The Dark	Dormitory	
Energy Chicken	Real House	
Residence Energy Saving (RES) battle	Virtual house/Virtual Commercial	
Power House	Virtual House	
Social Power	Virtual House	
Greenplay	Real House	
Ringorang	Real House	
Energy Cat	Real House	
Energy Piggy Bank	N/A	
Smarter Households	Real House	
Serena Games	Virtual House	Design and improvisation of the game
Greenify	N/A	
EcoIsland	N/A	

The assessment of retrofitting measures on the energy efficiency performance of the buildings was conducted, and the resulting impact was calculated for an educational building of Kazakh–German University. Their results indicated that minor retrofitting interventions provide energy savings of up to 36.9 kWh/m^2, and in the major scenario, the savings were 77.76 kWh/m^2, reducing up to 82% CO_2 emission [49].

While we discuss how the interventions would lead to people reducing their energy consumption, we also need to relate their impact to the decarbonization goals for the campuses. We should also look at the bigger picture of how the campuses would help the country to transition to net zero faster. Scenario analysis helps us know what would happen if we conducted business as usual (BAU) and the impact of different steps for decarbonizing the world. Reports from the International Energy Agency [20,50] help look at the BAU, exploratory, and normative scenarios to suggest the energy transition paths for the world and the factors that would affect their success in terms of financial investments, uncertainties over technological growth, policies at the governmental level, impact of behavioral interventions, etc. Recently, the Green Terre Foundation launched the U75 initiative to make 75 campuses net zero [51], which the government of India is supporting. It is suggested that all Indian university campuses become net zero by 2030. The campuses are the most forward-looking in the nation, and they can lead the way in terms of R&D and training the future leaders of the nation to propel the nation to achieve its net-zero targets.

3.3. Scenario Analysis

In this section, we present a simple framework to conduct a scenario analysis to understand the impact of different strategies on the decarbonization goals of the campus. Figure 6 provides glimpses of large university campuses in India. There are several factors that will affect the net-zero energy transition of campus-like communities, including:

- Buildings and infrastructure: This includes hostels, faculty and staff housing, faculty and academic staff offices, administrative offices, dining cum-community kitchens, lecture theatres, network equipment, data centers, EV charging stations, renewables, energy storage facilities, and local energy distribution stations;
- Number of students: The students join the academic programs (UG, PG, and PhD) offered on-campus by different academic units;

- Number of faculty and staff: This includes faculty members, academic and administrative staff, and their respective families;
- Operations: This encapsulates factors that affect the energy consumption on campuses, including the schedule of hours of operation (day-long, evening college, remote classes, and fixed length of time per day), flexible workplace culture (work-from-home and fixed/flexible number of office days per week), and space ownership (co-working/dedicated/open-plan offices), among others.

Figure 6. Glimpses of some large university campuses in India. (Starting from **top-left**) BITS Pilani, Rajasthan; IIT Roorkee, Uttarakhand; FLAME University, Maharashtra; IIT Gandhi Nagar, Gujarat; IIM Kozhikode, Kerala; IIT Jodhpur, Rajasthan; IIIT Hyderabad, Telangana; IIT Delhi; Azim Premji University, Karnataka; and LNMIIT Jaipur, Rajasthan.

Campus data from IIT Delhi [52] have been considered a reference for a hypothetical campus for this scenario analysis. The hypothetical campus would be referred to as the "Shunya" campus for this study (Table 3). The electricity consumption for this campus is assumed to be 60 GWh for the year 2022, with 20 GWh coming from renewable sources of solar PV and hydropower purchase. The floor area for the campus buildings has been assumed to increase at a compound annual growth rate of 3% from 2022 to 2047. The gross floor area would roughly double in the next 25 years, as described in Figure 7. The campus administration would manage the energy use in the common area in academic buildings, administrative buildings, and facilities such as hospitals, guest houses, creche, etc. The faculty and the academic staff have been assumed to have control over the energy use in their offices, residences, and labs. The students would have the freedom to manage energy use in hostels, sports fields, and student activity centers. Considering the operational energy, the corresponding Energy Performance Index (EPI) in terms of kWh/sq.m.-year seems to be the highest for faculty offices and labs and lowest for students residing in hostels (refer to Table 4). Most student hostels may not be air-conditioned, leading to lower energy consumption. The administration may pay the energy consumption bills from faculty offices and labs centrally, leading to a higher consumption than required.

Table 3. Shunya campus in numbers.

Item Description	Value
Campus area (in sq.m.)	1,200,000
Forest area on campus (in m^2)	200,000
Number of students	10,000
Number of students residing on campus	7000
Number of faculty and staff	1000
Number of faculty and staff residing on campus with their families	3000
Total campus residents	10,000
Electricity consumption for the year 2022 (in GWh)	60
Electricity supply from Solar PV + Hydropower (in GWh in 2022)	20
Built-up area (in sq.m.)	500,000

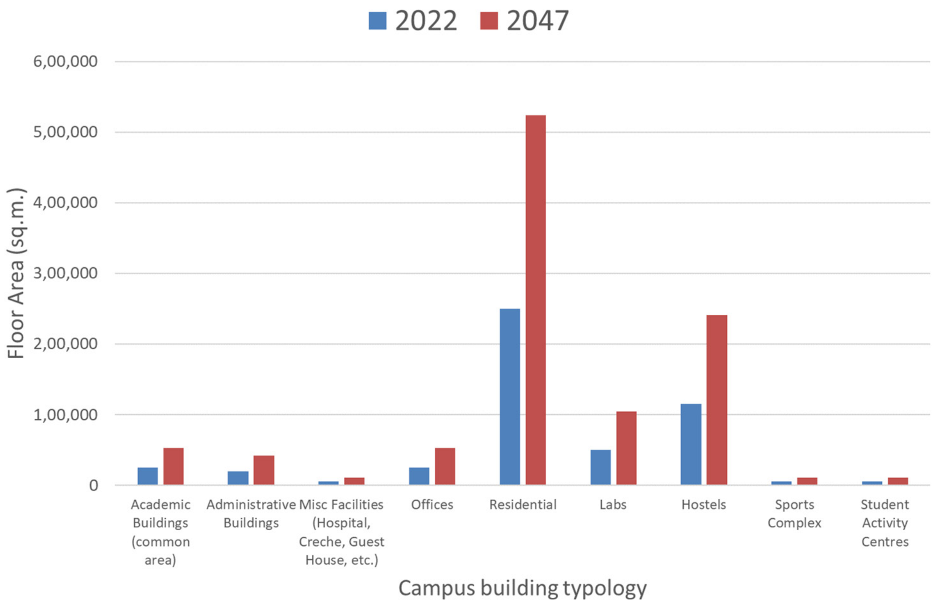

Figure 7. Floor area increase for the campus buildings from 2022 to 2047.

Table 4. EPI (kWh/m^2-year) for different buildings on the campus.

Building Typology	EPI (kWh/sq.m.-year)
Academic Buildings (common area)	40
Administrative Buildings	175
Misc Facilities (Hospital, Creche, Guest House, etc.)	100
Faculty Offices	200
Residences	140
Labs	200
Hostels	35
Sports Complex	100
Student Activity Centers	100

For discussion, we look into the future, develop plausible scenarios that are likely to unfold, and use them as the basis of analysis. The scenario analysis combining strategic foresight is an accepted approach to allow informed decisions on pathways to guide policy making. In this study, we consider three plausible future scenarios, as described in Figure 8, that are likely to affect the net-zero ambition of the future. All our scenarios are projected for 2047, aligning with the Nation's Atmanirbhar Bharat mission (translated to "Self-reliant India") in 100 years of independence. Figure 8 describes the use of "High", "Medium", and "Low" as qualitative indicators of change in energy use in the next 25 years based on the following assumptions.

- Scenario "BAU": The Campus will expand its infrastructural capacity to accommodate more students on-campus, hire a nominal number of faculty/staff to meet the needs, build more energy-consuming labs, and procure and add more appliances for business continuity and productivity;
- Scenario "Top-Down": The Campus will expand its infrastructural capacity to accommodate more students on-campus, hire more faculty to meet the needs, build more energy-consuming labs, and procure and add more appliances for business continuity and productivity—all the above would be performed to meet regulations set by the governing council for education such as accreditation bodies to transition to net zero;
- Scenario "Bottom-Up": The campus will expand its infrastructural capacity to accommodate more students on-campus, hire more faculty to meet the needs strategically (e.g., computer science faculty with experience in climate change, behavioral change, and sustainability), build energy-aware learning environments, and procure appliances with a long-term energy footprint in-mind—all the above would be performed not to meet the regulations but through behavioral interventions for the campus community consisting of the faculty, staff and students, and greater awareness for the administration to reduce energy consumption, strategic industry partnerships to learn the best practices and focus on long-term stewardship.

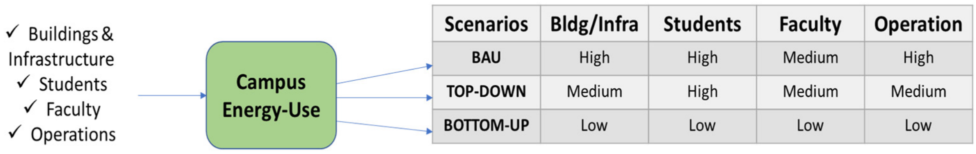

Figure 8. Factors influencing the plausible future net-zero transition scenarios.

Table 5 allows transcribing the qualitative indicators described in Figure 8 into meaningful values for carrying out a quantitative analysis of plausible futuristic scenarios. The values for the energy use factor for the administration, students, faculty, and the hours of operation correspond to the scenarios in Figure 8 where the energy use would be "High", "Medium", or "Low". For example, for the BAU scenario for 2047, the energy use for the buildings managed by campus administration and students would remain "High", and for the faculty-managed spaces, it would remain "Medium". The "operations" factor here considers whether the classes are held online or in hybrid mode, whether any bachelor's degree courses or continuing education courses have been offered fully in online mode, or has the nature of learning changed to having some of the classes as field trips that consume much less energy. In the BAU case, the operations factor would mean the use of campus facilities conventionally managed by the administration, with a factor value of "High". In the "Top-Down" scenario, the administration would follow the regulations so they may have the sense to reduce energy consumption, but the faculty and the students may not be motivated to move towards net-zero goals. Likewise, for the "Bottom-Up" scenario, the proposed interventions would work, and the energy use would come down for all the stakeholders on the campus, so a "Low" value has been assigned for the energy use factor for all the cases. We can assume the behavioral interventions proposed as a part of the UNGLEE model to work effectively to lead to "Low" energy use. For instance, the faculty, staff, and students may have greater climate change awareness, or they may become inspired by communities leading a low-carbon lifestyle, or they may have had greater nature experiences for them to minimize their energy consumption. The energy use for all three future scenarios can be computed using the following set of Equations: (1) and (2):

$$\text{Electricity consumption (kWh/year)} = \text{Floor area (in sq.m.)} \times \text{EPI (kWh/sq.m.-year)} \quad (1)$$

$$\text{Electricity consumption (kWh/year) for a scenario for 2047} = \text{Summation of (Floor area (in sq.m.)} \times \text{EPI (kWh/sq.m.-year)} \times \text{Energy Use Factorx Operations Factor) for each of the stakeholders of administration, students, faculty and academic staff.} \quad (2)$$

These two equations would help find the electricity consumption for all three scenarios in 2047 and compare it with 2022.

Table 5. Estimation of the factors influencing the plausible future net-zero transition scenarios.

Influencing Factors	High	Medium	Low
Energy Use Factor for Administration	1	0.7	0.4
Energy Use Factor for Students	1	0.8	0.2
Energy Use Factor for Faculty and Academic Staff	1	0.6	0.3
Hours of Operation	1	0.8	0.6

The energy demand for the "Bottom-Up" scenario goes below 20 GWh/year, which is already being provided by renewable energy sources, as per Figure 9. Our analysis of Figure 9 shows that electricity consumption would double in the "BAU" scenario, would be about 1.5 times in the "Top-Down" scenario, and has the potential to reduce to more than half in the "Bottom-Up" scenario. So, the Shunya campus can become net zero through this pathway. Similarly, the scenarios could be more detailed and have more predictive value if we follow the UNGLEE model. We should have access to data through digitization, which are used to make informed decisions about the interventions to decarbonize the campuses. We could also prioritize our efforts where we would be able to reduce energy consumption with less effort. For instance, the residences constitute about 60% of the total energy consumption, so the efforts focused on the faculty and academic staff living in these residential buildings would lead to greater benefits, as per Figure 10.

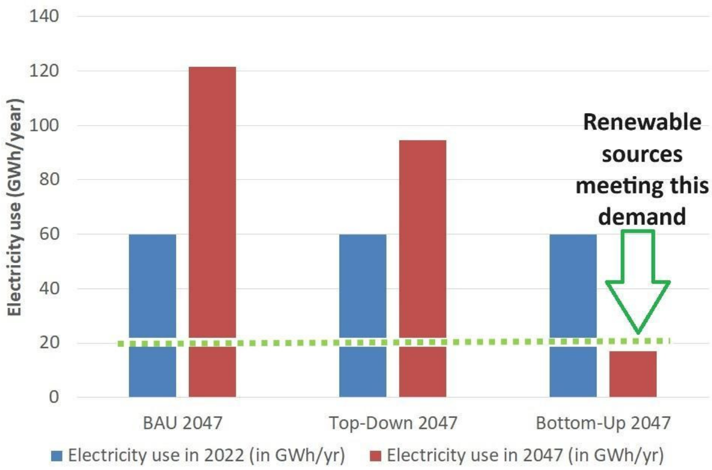

Figure 9. Comparison of electricity use (GWh/yr) for the three scenarios between 2022 and 2047.

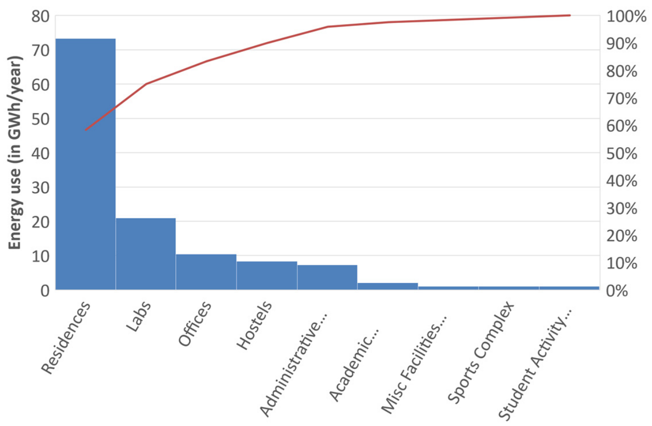

Figure 10. Energy use (in GWh/yr) in 2047 for the "BAU" scenario.

4. Discussion

The physical characteristics of the building, as well as the needs and behavioral patterns of the occupants, influence the energy used in a dwelling. Understanding the occupants' interaction with buildings, household energy behavior, and adopting energy-efficient practices is the key to establishing a better evidence base to inform societal actions, predict energy usage precisely, and determine the building needs and designs for healthy living. Childhood and early adulthood exposure to the types of homes and dwellings has an impact on later energy consumption behaviors [17]. Social practice theories explain how ordinary behaviors become globalized through migration, spreading from one location to another and supplanting local, often more sustainable, practices. Migrants "carry" habits that can "travel" across cultures, generations, time, and living conditions [53].

Among the novel techniques used for climate education, a recent study introduced "Walking with Energy", a new technique to actively engage and (re)connect citizens with where their energy is coming from [54]. The authors experimented with the application of this method in the European region (UK and Sweden). The study considers viewing and talking about heating provision, while in the energy landscape, it can encourage participants to reflect upon their local, mundane energy experiences and foster a greater sense of energy citizenship and greater motivation to engage in debates around heating transition. However, we argue that while the reflexive approach might prove to be a strong force to propel energy transition in developed nations, it may perhaps not be equally effective in developing economies where personal motives are far more superior to global/collective interest. Thus, our proposed UNGLEE model is unique in the sense that it blends multiple techniques from computational social sciences, including gaming (e.g., reward-based league competition), from law and public policy, such as passing an energy bill in the university (equivalent to passing an act in the parliament), and enabling data-driven responsible urban governance (e.g., forging trust through transparency in energy use/audit and the budgeting of upgrades/retrofits in energy-intensive equipment in facilities). For example, introducing guided walks in the foundational educational courses that sensitize students to systems thinking by "observing systems in the wild" around them in the campus ecosystem develop a sense of sustainable thinking by educating them about sustainable development goals while learning to think computationally and implement them via computer programs. In spirit, the proposed model embraces all three principles outlined in the SDSN handbook on the unique position university and college campuses have in the race to net zero in terms of amplifying change, deeply engaging with the student body, and fostering the culture of innovation, leading to new knowledge through student-led research [21]. SDSN is a global initiative of the UN. It aims to mobilize its members and leverage their collective strength to SDGs through education, awareness, engagement, and developing solutions. There are currently about 73 active SDSN nodal agencies in South Asia, of which about 27 are from Indian academia, which involve youth through experiential education to contribute positively to sustainable development.

In the past decade, between 2008 and 2020, the Infosys Corporation has moved away from a rule of thumb to a data-driven approach to tracking energy use across campuses and at multiple levels [55]. While increasing the workforce by 166%, their integrated design approach has enabled a limit in electricity consumption by 20%, saving 2.63 billion kWh of electricity across 28.9 million sq. ft. office areas spread across the nation. Digitalization has served as the foundation for Infosys' data-driven energy-efficiency initiative. Installing equipment-level metering for granular energy-usage data, integrating more than 19,500 sensors, 10,000 energy meters, 1650 flow meters, and advancing the building management system (BMS) across their Indian office buildings deployed across 30 million sq. ft. office area, etc., are some examples of how digital solutions improve energy efficiency by providing 24 × 7 real-time monitoring ability and AI-driven facilities management across Infosys campuses. Setting up a Sustainability Policy, followed by building a Green Initiatives team, patent-winning technological solutions for efficient cooling systems, stewardship by pledging for carbon neutrality at the UN, and winning climate-neutral awards at COP25 are examples of good and proactive governance. Combined digitalization and governance have enabled Infosys to not only baseline its decarbonization story but also benchmark against other best-in-class global corporations. Their leadership model serves as a template for low-carbon and digital transformation for many large institutions for prioritizing and planning energy-efficiency interventions. All these studies highlight the significance and need for experiential educational tools and programs within the hard-to-abate AEC sector.

With the democratization of digital data, interventions can be considered for decarbonization. One of the novel methods we have proposed in this study is to learn from groups or communities who may be leading a low-carbon lifestyle due to the nature of their work or cultural or economic reasons. One such example is the group of Jain monks and nuns from India leading a life without the use of any electricity after attaining monkhood [56]. Having the students spend time with them could inspire them to reduce consumption-based lifestyles. The monks are shining examples of leading a life in sync with nature, where the world suffers from climate change due to excessive energy use. Their lifestyle could be studied in terms of different aspects of their life. From the interviews with some of them in May 2023, they manage heating and cooling due to their psychological thermal adaptation of maintaining equanimity even if their body feels thermal discomfort physiologically. Likewise, they travel barefoot, thereby reducing material and transport-related emissions. They carry their belongings when they travel barefoot. This means that they have minimal material belongings with them. With our current urban ways of living, we may not be able to follow their ways of life fully, but it helps us to introspect our lifestyles to find ways to reduce consumption. After spending time with these monks and nuns, some students felt inspired to reduce their cooling needs. During a heat wave in May 2023 in Delhi, it did not feel uncomfortable to sit beside these monks and nuns for more than 5–6 h with indoor air temperatures between 35 °C and 40 °C. The students could not believe that they were fine sitting with them with the indoor air temperature being so high. During the same time, for a thermal comfort point-in-time survey, 18 out of 20 (90%) of them found the thermal conditions to be acceptable, while the UTCI thermal comfort index [57] varied between 35 °C and 40 °C relating to conditions of strong to very strong heat stress [58]. The advice from these monks and nuns for others to lead a low-carbon lifestyle is to reduce their needs a little bit at a time. For instance, if someone is used to living with air conditioning all the time, then they could avoid using it for 2–3 h a day, thereby increasing the number of hours with time.

The soldiers serving the borders at high altitudes in India, slum dwellers, or laborers living in hotter climates in India with minimal access to active thermal comfort, religious or tribal communities, and their low-carbon lifestyles should also be studied. Many villages in India did not have electricity since India's independence, but people still lived comfortably without it. We must reflect on the aspects of our lifestyles and adapt our energy usage behaviors to reduce our energy footprint. During COP26, India's Prime Minister suggested the concept of LIFE (http://missionlife-moefcc.nic.in/, accessed on 23 August 2023)—"Lifestyle for Environment" as a mass movement to lead a life in sync with nature. India is the first country to include LIFE in its Nationally Determined Contributions to combat climate change. Chetan Singh Solanki, an awardee of the Avoid-Minimize-Generate award and a faculty at IIT Bombay, has recently suggested that human beings should avoid one-third of their energy consumption by changing their lifestyles [59]. In an interaction with school students, he asked them if their families could avoid ironing clothes to reduce their carbon footprint. IPCC states that lifestyle changes must stay within the 2-degree climate change limit agreed in the Paris Agreement [60]. Austria, Portugal, the Netherlands, and Slovakia suggest lifestyle changes in their NDCs, such as low-carbon diets, reduced material consumption, reduced energy consumption, etc. Altering energy behavior through several energy-conservation strategies, including print media, interactive face-to-face discussions, and eco-feedback, was effective in promoting energy conservation even among low-income households in developing economies such as South Africa [61]. Similar experiments in developed economies were also carried out, and results from such programs exemplify the important roleplay of community-initiated bottom-up initiatives in promoting sustainable consumption with financial support from the local (district) government [62].

Hiking and camping are also becoming popular with tourists instead of high-energy-consuming entertainment projects. Tourists may also choose to eat locally produced food, stay at low-carbon accommodations, and use products with green packaging [63]. To simulate a low-carbon lifestyle in a fun way, the students can be taken for multi-day camping and trekking experiences with nature. There are many multi-day treks in the Himalayas lasting for four days, with an average of 7 km of hiking per day involving sleeping in tents, carrying one's own backpack, and living without energy and possibly no internet connectivity. The backpackers learn to manage with fewer belongings as the more they carry, the heavier their backpack becomes. Moreover, they must stay for the night in a basic tent with the temperatures on the colder side. Despite these hurdles, there is quite an incentive to spend time in the beautiful Himalayan landscapes. The backpackers also realize that the littered plastic in the Himalayas does not belong there, and it stays etched in their minds even when they return from the trekking trip. It goes without saying that the trek also improves their fitness. This activity is suggested for the students to help them live a low-carbon lifestyle while having fun. The students can be made aware to continue with this lifestyle when they return to their universities and how it can benefit the planet. Another activity to help students improve their fitness and become incentivized to use low-energy mobility options is to make them use fitness apps for cycling, jogging, and walking. These apps are like social media for fitness, and, with friends posting their activities on these apps, this can gamify the experience. It also helps the students to stay connected, no matter which part of the world they are in. Climate education in universities can also be promoted by offering courses in sustainable habitats. The students can be taught to build low-cost data loggers for environmental monitoring. They can utilize them to conduct experiments to understand air quality, thermal comfort, energy metering, etc., and the impact of interventions to improve their surrounding environments. The immersive experiences of low-carbon lifestyles can also be a part of such courses. Global relevance wise, in New Zealand, despite having a strong zero-carbon goal, the construction industry that contributes towards one-fifth of the carbon emissions is not equipped with sufficient skills, knowledge, processes, and procedures to deliver the zero-carbon goals. As a result, it was determined that the education of the next generation of construction professionals will enable the acceleration of the transformation of industry practices to zero carbon.

Jain [64] suggests that bottom-up approaches can work better than top-down. Indraganti [41] suggests that behavioral interventions can help with energy efficiency. These models do not involve higher economic costs or administrative hurdles at the outset. Social acceptance can be taken care of through behavioral design methods of figuring out ways to minimize the task complexity to implement target behaviors. The "Bottom-Up" models make every citizen responsible for helping with climate change. The climate crisis is unprecedented, so we also need to try all possible methods. Having said that, the behavioral interventions need to be tested with a higher sample size to prove their efficacy. The scenario analysis should also be detailed with sensitivity analysis to ensure that campuses are still on track toward net zero with the uncertainties involved.

5. Conclusions and Future Work

Environmental education plays a crucial role in nurturing the environmental consciousness of college students. Higher education institutions bear the responsibility of instilling environmental ethics and building a reservoir of environmental knowledge among students for their future professional endeavors. A comprehensive and transformative shift within higher education institutions is essential to promote sustainability. For significant economic and environmental advantages, it is important to implement a wide range of strategies. Several global studies have shown that implementing combined interventions for behavior change can result in more substantial outcomes than employing single interventions alone. The findings from this study conclude that a new league-based governance model (UNGLEE) built on the foundations of 3Ds (digitization, democratization, and decarbonization) and the principle of decentralized participatory governance (energy citizenship) can reduce more than half of the energy consumption demand expected by 2047 from campus-like communities across India. This proposed model is tailored to the Indian context, encompassing innovative indigenous (socio-cultural and behavioral) interventions and their seamless integration with other global approaches. In this study, we conducted a scenario analysis to assess the feasibility of such blended interventions to achieve net-zero energy goals, particularly within Indian campus-like communities. These contributions not only enhance the existing body of knowledge of relevance to sustainable, just, and inclusive net-zero transition but also provide a practical framework for implementation in India. While related work provides hints on how net-zero energy buildings and communities in India are garnering attention, our future work shall focus on building the low-carbon transition momentum through education, outreach, and engagement. We hope to scale up the implementation of such models across campus-like communities in India, possibly through the Collective Voices for Buildings in India (www.cvbi.in, accessed on 23 August 2023), allowing us to test and validate our findings against empirical evidence. Likewise, we encourage researchers and practitioners in other parts of the world to also explore indigenous knowledge about sustainable living (e.g., the Māori culture in New Zealand, the Amish communities in the USA, and the usage of wind catchers or Badgirs in Iran) and think of ways to make it relevant for novel ways of imparting climate education in their socio-cultural context.

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