The Twelve Percent Effect

Improvements in evidence-based design towards net-zero building performance

Sreejith Jayaram[1], Suyashi Srivastava[2], Amanda Thounaojam[1], Janani Venkatesh[1], Gaurav Vakil[2], Yashima Jain[1]
[1]Indian Institute for Human Settlements, Bengaluru, India
[2]Alliance for an Energy Efficient Economy, New Delhi, India

Abstract

The building sector in India contributes to about one-fifth of the country's total CO2 emissions. At COP26, India has committed to achieving net-zero by 2070 (RMI India, 2021). Net-Zero Energy Buildings (NZEBs) can accelerate the pace at which India can achieve its net-zero goals. Since, approximately 70% of India's buildings for 2040 are yet to be built, these can be designed, built and operated as NZEBs. There is significant scarcity of workforce and lack of training in college curricula about NZEBs. Solar Decathlon India (SDI) competition addresses this by enabling student teams to learn and design real NZEBs. The participating teams were provided learning resources and Building Performance Simulation (BPS) tools. This paper reports on an analysis of the final submissions over two years to evaluate their ability produce evidence-based designs for their projects. A similar analysis after the first year's submissions revealed areas of weakness in the students' ability to provide evidence-based designs, and additional resources and training were provided to teams and faculty in the second year to improve BPS skills. We observed that 12% more teams who provided evidence for their designs in the second year. Evidence for daylighting strategies saw the largest increase of 37%, and natural ventilation strategies were next at 18% increase. This research identified areas where students were able to provide BPS based evidence and the interventions improved their ability to do that.

Key Innovations

Based on the results of an analysis on student work done at the end of year 1 of SDI, the organisers introduced interventions to strengthen the ability of students and faculty to learn more about NZEBs and BPS.

- A Faculty Development Programme (FDP) was organised for faculty mentors of the participating teams.
- All team members and faculty were offered a one-year licence of the DesignBuilder™ Engineering Plus software to learn BPS and test their designs.
- Online simulation training workshops were conducted by a simulation expert from DesignBuilder™ on topics such as climate analysis, envelope and shading, passive design and natural ventilation, HVAC load calculation, Unitary and centralised HVAC systems, and solar PV systems.

Research Implications

This paper analyses how collegiate students are able to respond to competition requirements and provide BPS results as evidence for their design decisions. It shows a 12% increase between year 1 and year 2. This is possibly due to the interventions introduced in year 2. With the huge capacity gap in the building industry to provide high performance and net-zero buildings, the ability of these students to evaluate the impact of their design decisions is a critical improvement for India's future professionals. This approach shows how curriculum can be improved in building sector related college coursework to address the country's Panchamrit goals of net-zero by 2070.

Introduction

The Intergovernmental Panel on Climate Change (IPCC) report, followed by the Glasgow COP26 summit, are unequivocal that climate change is a reality and that it is anthropogenic (IPCC, 2021). In India, summer temperatures are crossing 45°C, and rains have wreaked havoc across coastal regions (Mahapatra, 2018). India is a rapidly urbanising economy with increasing per-capita emissions across sectors. The building sector alone contributes 33% to carbon emissions (RMI India, 2021). At COP26, India committed to achieving net-zero by 2070, and this offers the building sector an opportunity to future-proof our infrastructure in the decades to follow. Net-Zero Energy Buildings (NZEBs) can help reduce energy demand in buildings as they are energy efficient and give back clean electricity to the grid. In the process of designing NZEBs, BPS on energy, comfort and lighting play a vital role in the design decisions. It provides feedback on how the building is likely to perform even before it is built. Globally, BPS education is a niche domain and is accessed only by post-graduate candidates in courses related to buildings and energy efficiency.

In India, there is a lack in capacity to design and build NZEBs at the scale needed. Furthermore, there is a capacity gap among building professionals in designing and implementing NZEBs. Over 500,000 students in India graduate annually out of courses related to the built environment, but a meagre 50 are formally trained to deliver NZEBs (Bhadra et al., 2021). A review of the current education system related to building professions showed that students are not given the training and resources necessary to address climate change in their careers (Manu et al., 2017). Particularly, the current educational curriculum does not offer any formal training on Building Performance Simulations (BPS) to undergraduate students (Mathur, J. 2022). Solar Decathlon India (SDI) attempts to address this gap and provides students with learning resources and tools to train these professionals in this area. It is an annual 9-month challenge for students to learn and design net-zero energy and water, climate resilient buildings by partnering with real estate developers and working on real building projects. Modelled on the US Solar Decathlon, SDI intends to create a net-zero design capable workforce for India.

In SDI, any undergraduate and post-graduate student from Indian institutions may participate and learn building science, net-zero design techniques and building energy simulations. Over the two years of the challenge, a total of 2212 students participated and collaborated with 109 real estate developers, 70 industry experts, and 195 faculty mentors.

In year 1, SDI provided the teams with a variety of resources, like online Self-Learning Modules (SLMs), tools for cost-benefit analysis and water calculation, and technical webinars delivered by industry experts to build their capacity to compete in the Design Challenge. Licenses to BPS software (DesignBuilder™), and online simulation training sessions were provided to a maximum of 3 members in each team. The teams were also given access to a group of industry expert mentors, called the Technical Resource Group (TRG), who are also past participants of Solar Decathlons around the world.

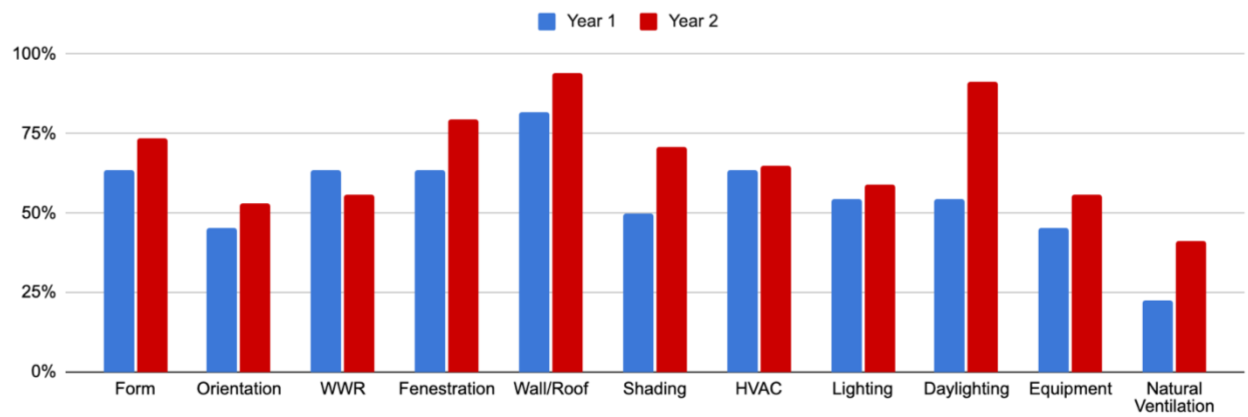
The teams demonstrated their integrated building designs and reported on ten contest areas of the decathlon namely, Energy Performance, Water Performance, Resilience, Environmental Quality and Comfort, Affordability, Architectural Design, Engineering Design and Operations, Scalability and Market Potential, Innovation and Presentation. SDI also provided a Competition Guide (Solar Decathlon India, 2018) that was intended to guide teams on how to report on the ten contests and the technical information that they should provide in their reports. Beyond the reviews of the jury members, the organisers conducted a review of the submissions to evaluate the finalists for providing evidence of their design decisions for the Energy Performance contest (Jayaram et al., 2022). The findings of this analysis and feedback from the participants were the basis for additional interventions in year 2: More access to simulations tools in form of DB licenses to every single participant and faculty mentor, and training in the form online simulation webinars that showed how to build building performance models and how to use the simulation results to drive design decisions.

This paper assesses the ability of the finalist teams of year 2 to provide evidence, and the effectiveness of the interventions. The findings of the research can help improve the building sector related curriculum towards integrated BPS and creating a pathway for a supply of Net-Zero capable workforce in India.

Method

The research was conducted by analysing the final submissions of 56 teams across both year 1 and year 2. The report submissions contained detailed design documentation. The data in the study is limited to the information provided in the reports. No additional investigation in the form of interviews or surveys were undertaken, and the analysis is purely based on the design documents, the ECMs described by the students, and the evidence provided by them. The authors were coordinators for the jurying process of the reports and were familiar with the overall process of the competition. They had access to the submissions as well as insights into the discussions of the jury.

The authors observed and analysed the ECMs that the student teams had proposed in their designs. First, the authors listed the ECMs that a team proposed and investigated whether they claimed to integrate it into their design. A score of 1 point was given to a team that claimed to integrate an ECM into their project and 0 to those that did not. Next, the reports were investigated for whether the teams provided evidence for the ECMs that they claimed to integrate into their projects. A score of 1 point was given to a team that provided evidence and 0 to those that did not.



Results

In total, 86% of the teams described ECMs in their reports. These fell in the following categories: Form, Orientation, Window to Wall Ratio (WWR), Fenestration type, Wall/Roof insulation, Shading, HVAC type, Lighting, Daylighting, Equipment, and Natural Ventilation. For these ECMs, a range of 80-98% teams had integrated them into their designs, while 34-89% of the teams provided evidence to support their design decisions.

Further, the results of both years were compared. In the comparison, it was observed that in year 2, overall, 12% more teams provided BPS evidence for their designs in their reports.

In year 2, 37% more teams provided BPS based evidence in daylighting strategies.

Similarly, there were 12-21% more teams who provided BPS evidence for strategies related to building envelope which includes wall and roof assembly optimisation and shading optimisation.

In year 2, there were 10% more team who presented BPS evidence for passive design strategies such as form optimisation and orientation of their building design.

However in year 2, 8% less teams provided BPS evidence for Window to Wall Ratio (WWR) optimisation of the building envelope.

The percentage of teams providing evidence HVAC strategies were roughly similar in year 1 and year 2.

Natural ventilation strategies, which had the least number of teams providing BPS evidence in year 1 saw 18% more teams providing BPS evidence year 2.

Discussion

In India, the All India Council for Technical Education (AICTE), and the Council of Architecture (COA) which are national statutory bodies responsible for development of the technical educational curriculum for engineering and architecture offer courses on concepts of climate, concepts of thermal comfort, and concepts of passive design as part of the curriculum for the architecture coursework (All India Council For Technical Education (AICTE), 2018);(All India Council For Technical Education (AICTE), 2019); (Council of Architecture, 2020) . The courses offered are not comprehensive and are not mandatory. For engineering, courses on energy efficiency in electrical systems are offered. However, specific coursework related to BPS to evaluate buildings in the design stage for energy, thermal comfort, daylighting, artificial lighting are not included.

The findings from this analysis show that daylighting strategies had been addressed in both years by more than 50% of teams even when it was not a requirement of the contest. They provided evidence for daylighting and demonstrated their capabilities through simulation results. For strategies related to load reduction by optimising building envelope, year 2 saw a 16% increase in teams providing evidence based designs. This may have been due to the inclusion of the year 2 interventions introduced by the organisers in year 2.

Even though simulation training on HVAC load calculations and system design were offered by SDI, engineering systems related strategies did not see a significant increase in the percentage of teams attempting to provide simulation results as evidence. HVAC and other engineering related simulations may have been difficult for students to comprehend or the faculty mentors of the teams may have lacked expertise in this area. Further study is required to understand the challenges faced by students for HVAC related simulations, and it seems this is an area for improvement.

Percentage of teams providing evidence for natural ventilation strategies had almost doubled from year 1. The teams had presented Computational Fluid Dynamics (CFD) analysis results in their reports. CFD analysis require higher level of technical skill and knowledge to perform the simulations. Students may have used various open source CFD software available for free.

Across both years, for passive strategies such as building form and orientation, evidence was provided by 53-74% of teams.

Considering that all teams are multi-disciplinary and have students from architecture and other building related coursework backgrounds, it was interesting to note that 100% of teams did not attempt any of the strategies.

In order to build capacity among student groups, it is important to note that faculty mentors of students also need to be upskilled. In year 2, the Faculty Development Programme (FDP) was conducted where experts pointed out gaps in the current curricula and drew attention towards specific skills and perspectives that the students need to develop. However, the FDP did not upskill the faculty on BPS. In the FDP, a framework was provided so that faculty could guide students towards developing more holistic innovations for their designs.

During the FDP, the faculty gave critical feedback to the organisers by mentioning that inclusion of technical subjects related to NZEBs and simulation education should be included as part of the educational curriculum (Solar Decathlon India, 2021). Since SDI offers resources to learn these subject areas, a few of the participating institutions have included the SDI into their existing curriculum. The faculty also gave feedback that the curriculum inclusion will help students to upskill themselves in BPS tools without any additional coursework taken up by the students.

Conclusion

This paper documents the improvement in evidence-based design related to the Energy Performance contest in the 2 years of Solar Decathlon India (SDI). The analysis results show that 34-89% of teams provided PBS evidence of their proposed energy efficiency strategies. In year 2, 12% more teams provided BPS simulation based evidence, compared with that year 1. Other than window to wall ratio strategies all other strategies saw an increase in the demonstration of BPS evidence. Among these, daylighting showed the most increase, and HVAC the least. Notably, natural ventilation through CFD simulations, a difficult task, showed a marked increase.

Between year 1 and year 2 the organisers of SDI introduced a few interventions and it is possible, although there is no conclusive evidence, that the increase was a result of those.

SDI's competitive environment provides an exciting learning environment for the students, and the learning resources provided to students and faculty gives them support them in integrating BPS to test their design ideas towards net-zero performance. Even though SDI is a successful program bringing in over a thousand students each year, it is only a beachhead strategy to influence the education curricula related to buildings all over India. The lessons learned through SDI need to be applied more widely. The CoA and AICTE will need to formalise BPS in education and provide BPS training as a mandate for buildings related coursework. This is crucial for India to achieve its net-zero goals.

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