Solar calorimeter at CARBSE, CEPT University

Advancing Building Energy Efficiency Research in India

Part 2 of 2

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Research Snapshot

The Centre for Advanced Research in Building Science and Energy (CARBSE) at CEPT University uses its material testing infrastructure and energy simulation capabilities on various affiliated research projects in India. These projects look at thermal comfort and tubular day-lighting devices and fenestration, develop research for codes and standards that feed into the national building code, and work with various state level governments to implement policies related to the Energy Conservation Building Code (ECBC).

Energy-related Design Assistance Tools

As part of its effort to disseminate its growing database of material and assembly characterization information, CARBSE currently hosts three online tools that it has developed on its website: an Assembly U-Factor Calculator, a Comfort and Weather Analysis tool, and a Multi-City Comfort and Weather Comparison tool.

The Assembly U-Factor Calculator calculates the thermal transmittance (U-Factor) of wall and roof construction for typical construction types practiced in India. The thermal properties of materials used by the tool are specific for each city, and are derived by extensive characterization of generic construction materials available in various parts of India. The tool can be useful for selection of building material, construction, for building energy modeling and analysis as well as for code compliance.

The Comfort and Weather Analysis tool is designed to help the user generate thermal comfort and outdoor weather analysis for Indian cities. The tool efficiently produces comfort charts showing the year-long temperature of a number of Indian cities on the ASHRAE 55 thermal comfort bands, as well as hourly ASHRAE 55 comfort zone distributions throughout a year, with user options to select for twenty-four hour or daytime display.

About the Author

Melissa Smith is an architect and city planner at banduksmithstudio, an architecture, urban design, and research practice. She is a visiting faculty at CEPT University, and consults for the Centre for Advanced Research in Building Science and Energy. She holds an M.Arch. and M.C.P. from the University of California, Berkeley, USA where she was a John K. Branner Fellow. Her work navigates architecture and the city, dealing with issues of material, energy and change in the built environment. At banduksmithstudio, she combines passive cooling and daylight strategies with contemporary expectations to produce energy efficient residential and commercial projects that explore the boundaries of material and craft in the context of contemporary Indian construction.

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Through this, the user can determine the number of operating hours for a project that belong to the comfort zone for a particular month. In this manner, the tool also develops the local weather chart and humidity distribution. The Multi-city Comfort and Weather Comparison tool takes the information generated from the Comfort and Weather Analysis tool, and uses it to compare the conditions in two Indian cities simultaneously.

Developing a Tiered Approach for ECBC Compliance

The Bureau of Energy Efficiency (BEE), India launched the Energy Conservation Building Code (ECBC) in 2007. Through mandatory compliance with ECBC, India can achieve estimated annual energy savings of 1.7 billion kWh. The rate of compliance with the code is predicted to reach 65% by 2017.

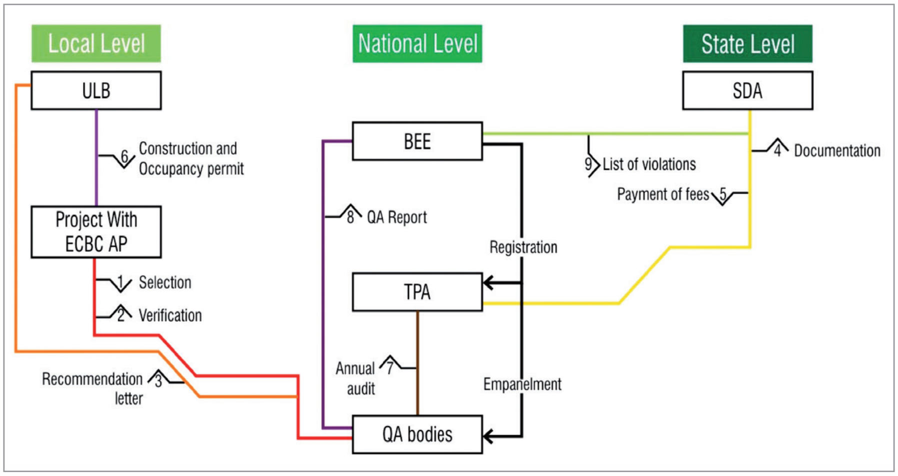

Figure 2: The third party assessment model

The objective of this project was to develop a tiered approach to facilitate compliance with the ECBC. In order to achieve this objective, individual ECBC measures were evaluated for energy savings, incremental cost and ease of enforcement. The findings were peer reviewed and the measures were then bundled into tiers. The lowest tier, Tier 1, includes ECBC measures that are easier for the market to adopt, have a high return on investment and are enforceable through the current building permit process. This will help build capacity over time and allow developers to get experience on the subject matter of building energy efficiency, without reducing stringency of the code. Tiers 2 and 3 can include additional measures that are more difficult to implement or enforce. By keeping Tier 1 easier for market entry, the compliance rates for Tier 1 are projected to increase, resulting in significant energy savings. Please see *Figure 1*.

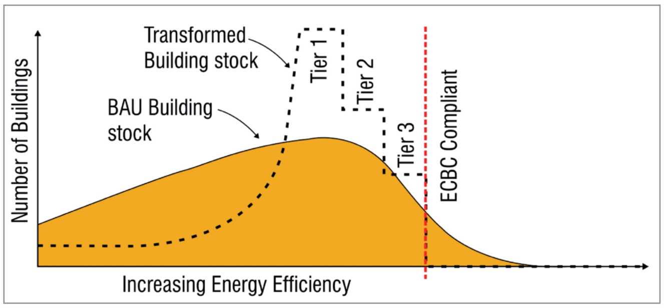

Figure 1: The tiered approach graph

Third Party Assessor Model for ECBC Compliance and Enforcement

Currently, government and public sector agencies do not have the manpower or expertise to enforce ECBC. It is, therefore, crucial to build capacity and create a cadre of professionals outside the public sector.

The objective of this project was to develop a framework for Third Party Assessor (TPA) model that can facilitate ECBC compliance and enforcement. In order to develop this framework, various successful TPA models in India and worldwide were studied. Some of these TPA models were related to building energy codes or rating systems, while others were from the non-building sector, but offered valuable insights towards developing a TPA model for ECBC implementation and enforcement in India. A large stakeholder engagement provided useful feedback for the development of the role of the TPA and organizational framework. Some of the benefits of the TPA model, which is an increasingly popular mode of building code enforcement worldwide, are that it is easily scalable for different growth scenarios, as a market driven model it ensures the availability of TPAs across India, it brings good resolution to challenges related to municipal level regulatory enforcement, and entails a low cost for compliance enforcement.

Adaptive Thermal Comfort

Given India's rapid economic growth and concomitant expansion in its commercial sector, soaring demand for air conditioned commercial buildings can be confidently predicted. This increased demand has been attributed to an increased expectation for stable comfort conditions as the workforce shifts away from industrial production toward a service orientation that is office based. If permitted to grow unchecked, building air conditioning will add immense pressure on electricity infrastructure and exacerbate the already extreme peak-demand problem in the country.

This project is developing an adaptive thermal comfort standard based on rigorous field studies of commercial buildings and their occupants located across the climate zones of India. By climatically adapting indoor design temperatures, the standard will offer India an energy efficient low carbon development pathway for its commercial building sector without compromising overall comfort or productivity.

In addition, the research is developing a contextual design approach to comfort that is cognizant of the greenhouse emissions abatement potential of naturally ventilated and mixed

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mode buildings. This is done through extensively validated and scientifically recognized methodologies for post occupancy evaluation and detailed thermal assessment of buildings and occupants' experience. The study encompasses all five main Indian climatic zones, and thermal comfort surveys will be repeated for seasonally distinct times of year to ensure adequate coverage of a wide range of comfort conditions. The goal is not to compromise on levels of comfort, but rather to demonstrate a much wider-than-usual band of comfort deemed acceptable whenever occupants are permitted to adapt to their indoor environment.

Residential Baseline

India's domestic energy consumption has increased from 80 TWh in 2000 to 186 TWh in 2012. Household electrical demand is expected to rise sharply in the coming decade. This growth of residential floor space, combined with expectations of improved domestic comfort, will require an increase in electricity production leading to a significant escalation in damaging emissions. It is, therefore, vital to develop energy-efficiency strategies specifically focused on the residential sector. This study investigates methods of restraining growth in energy consumption in the Indian residential sector and document energy saving potentials that can be achieved with focused policy and market efforts.

The study conducted a survey of 800 households in four climate zones of India, to map the current penetration rate of domestic equipment and electricity consumption patterns. Key information gathered includes residential unit areas, monthly energy consumption, connected loads and numbers of appliances together with their power ratings and operational patterns. Building energy modeling has also been deployed to quantify comfort benefits and the energy savings potentials of better-performing building envelopes. The trends observed in the survey and the building energy modeling analysis, along with information from past studies, have been used to establish residential electricity consumption projections up to 2050. To further identify savings potentials in the residential sector, four projection scenarios have been developed for India: business-as-usual, moderate, aggressive and very aggressive.

Building Material Characterization and Construction Assembly Database

The project for Building Material Characterization and Construction Assemblies is currently developing an extensive database of the thermo-physical-optical properties of building materials, building components and construction assemblies, using state-of-the-art material testing facilities. This database serves to fill a knowledge gap for professionals working in India, because both the thermo-physical-optical properties of locally available building materials are unknown, and the characterization of newly developed materials has not reached the public domain. To enhance the performance of building materials and construction assemblies, it is essential that this knowledge is created and disseminated.

Calibrated Models for Simulation

The Calibrated Building Energy Simulation Project takes the knowledge developed through material and assembly characterization further by creating and testing two life size 'test beds,' along with a number of real buildings across five climate zones. The idea behind the project is rooted in the inherent discrepancies between virtually simulated models and calculations, and actual measured data. Because building simulations and energy calculations based on detailed modeling form an extremely important tool for design and investigation, they can help to both inform the design as well as analyse the performance of an existing building. These simulation methods also help formulate policy level decisions. While CARBSE works to develop building simulation technologies, it also must address the lack of measured onsite data in the Indian context, with a goal to study differences and parallels between simulated and measured data so that researchers may derive a better understanding of the relationship between them.

Two identical life size test beds are constructed with separate building envelope characteristics. One of these test beds will deploy materials typically found in the Indian construction industry, like brick, whereas the other test bed will use a more sustainable option – for example, the Resource Efficient Brick, which is the subject of the current research project. As the projects move further, this test bed will become a base for experimenting with different materials, building systems and envelope properties. In order to maximize the utility of the test beds, high accuracy sensing and monitoring data loggers are installed. These instruments simultaneously record pertinent data like internal surface temperature, ambient temperature and relative humidity inside both test beds over an intended time period of at least 12 months. The building energy usage is also monitored, along with the weather parameters recorded by an outdoor weather station, which helps researchers analyse and contextualise the data for the internal environment. While the onsite measurements are recorded, virtual simulations in EnergyPlus also generate results for two corresponding building models. The calibrated model for this purpose is

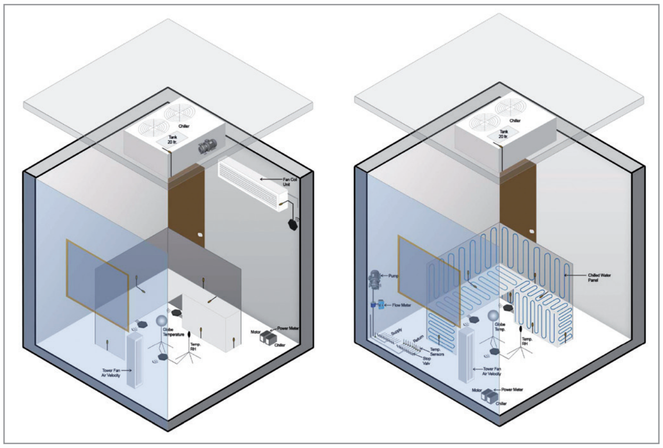

Figure 3: Test beds

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developed based on the guidelines outlined in the ASHRAE International Standards and Guidelines *(ASHRAE Guideline 14-2002, IPMVP-2002)*. The input data in these models is entered to match the construction data of the test beds so that accurate results are ensured.

The results generated may then be compared against the logged data from the two test beds. The differences are studied and analyzed and, where possible, reasons for deviation are evaluated. This comparison and research can inform building simulators and help increase the accuracy of results from calibrated models. This research can then be further developed by calibrating a varied range of building envelopes, and analyzing them to create a critical database relevant to the Indian context. CARBSE has already begun this process by carrying out similar work in five buildings across India.

Net Zero Energy Building: The Living Laboratory

CARBSE's many varied endeavors all come together in its latest project, the Living Laboratory, a Net Zero Energy Building. Everything the Centre preaches will be practiced here – a mess to test what they say. A Net Zero Energy Building (NZEB) is defined as a highly energy efficient building, which on annual basis produces as much energy at site using renewable energy sources as it consumes. The under construction NZEB at CEPT University campus in Ahmedabad, Gujarat, will be the new home for CARBSE. It will house state-of-the-art laboratory facilities for building materials characterization, thermal comfort studies, day-lighting and energy measurement studies.

Along with dedicated testing facilities, the building itself will be used to evaluate the performance of various materials, construction technologies and systems. This will provide a unique opportunity for industries to participate in experimental research with the objective of generating new knowledge and product validation, along with an engagement in policy and regulation driven research projects.

Throughout design and construction, the goal has been to use an integrated design process that demonstrates the symbiotic relationship between architecture and services. In this intensely focused collaborative effort, one of the most unique aspects is that CARBSE is working as designer, building operator and monitor, which gives the Centre an ideal situation in which it may control the research it wishes to conduct, while also testing the technologies it has worked to develop and support at the scale of an actual building. Furthermore, occupying the building will give researchers themselves insight into the relationship between designed intentions and practical application and use.

The building envelope minimizes glare and heat gain by orienting openings away from East and West, focusing fenestration on a North-South axis. It uses materials – bricks, insulation and a cool roof – to reduce heat gain. The building floor plate is thin to allow cross ventilation and optimal daylight, with well-shaded operable windows to aid in natural ventilation. The project has been monitored continuously during construction

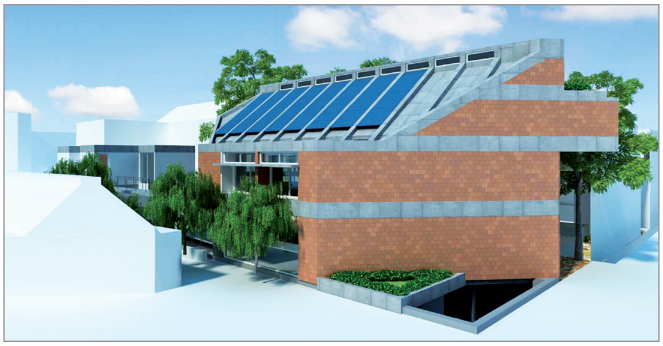

Figure 4: The Net Zero Energy building

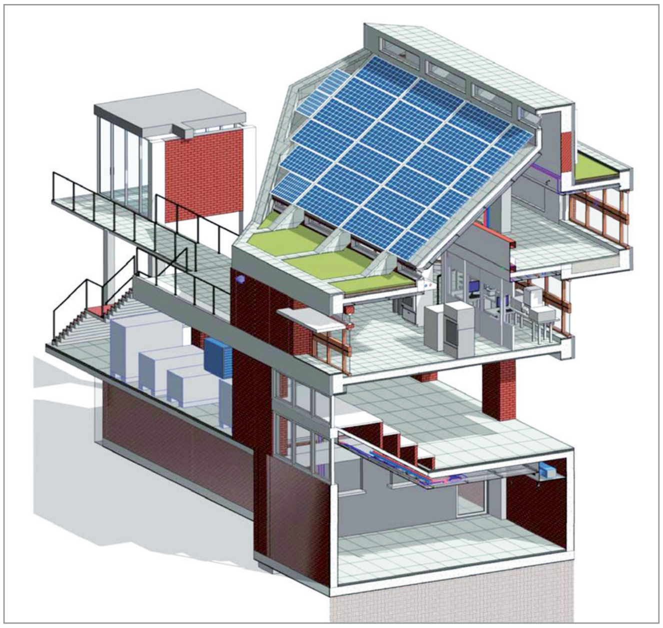

Figure 5: NZEB building information modeling

and will continue to be monitored after occupation. In its attempt to combine state-of-the-art technology with passive technologies rooted in the tradition of the area, architect BV Doshi sees this architecture sitting at the edge of new trends of thought, suitable not only to India but also to the future, in and outside the country. The building builds on past knowledge but looks toward the future.

To achieve its goal in operation, the building design contains sophisticated and flexible control systems that can support continuous research experiments on building monitoring and performance optimization. The control system in the building is designed to serve as a single platform for monitoring and controls in the building, to provide test beds for development of new technologies and control algorithms, and to integrate with test chambers for effective operations and controls. This control system is mainly divided in four components: monitoring, integration, controls, and display.

The monitoring component incorporates high accuracy research grade sensors to continuously monitor building performance and occupant comfort. The air conditioning and envelope monitoring

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system contains built-in controllers with networking capabilities and will be integrated with the building control system. Envelope, energy, and environment systems have been specified with built-in controllers for integration with the building control system. Key energy and operational parameters (such as building information, current operation, historical energy consumption, and current energy consumption) would be continuously displayed on a display screen located on the ground floor.

The hybrid ventilation and cooling system combines natural ventilation with radiant cooling to maximize the use of fresh air for passive cooling, and still offsets peak temperature discomfort. In natural ventilation mode, the active air conditioning system will be turned off and chimney window will be opened to allow natural draft through the building. In mechanical system mode, the building will run a primary (active radiant system with direct outdoor air units) and secondary cooling system (VRV/digital scroll) to maintain space comfort. In lighting, with a goal of just three to four watts per square meter, minimal artificial lighting is used, and what is required is designed with reduced lighting power density.

The Living Laboratory will house CARBSE's test chambers: the thermal comfort chamber, guarded hot box and mirror box – artificial sky. Their control platforms will be integrated with the building level platform. These chambers will be available both for scholarly research and for industry testing.

Affiliation and Recognition

CARBSE has received recognition across India and internationally, and is affiliated with government partners, industrial organizations and industry partners. It has been awarded a status of a 'Regional Energy Efficiency Centre on building energy efficiency' by USAID ECOIII program and 'Centre of Excellence' by Ministry of New and Renewable Energy, Government of India. CARBSE is leading research under the prestigious US India Joint Centre Building Energy Research and Development (CBERD). CARBSE works very closely with SSEF – CWF. In addition, it has successfully secured a Global Innovation Grant for a joint research project between Loughborough University (UK), University of California at Berkeley (USA) and CEPT University, Ahmedabad.

CARBSE is funded and recognized by the Ministry of New and Renewable Energy (MNRE), Department of Science and Technology, Government of India, GEDA and United States Agency for International Development (USAID). Its lab facility is recognized by the Bureau of Energy Efficiency (BEE) and National Accreditation Board for Testing and Calibration Laboratories (NABL). It is also part of an inter-laboratory round robin maintained by Lawrence Berkeley National Laboratory, US. CARBSE received a seed grant from the National Fenestration Rating Council (NFRC) at conception stage.

The Centre works with various organizations such as US DoE through its national laboratories, LBNL and ORNL. It is involved in the activities of SDC, GSI IIF, IGBC, ISHRAE and ASHRAE WIC. Its industry partners include SINTEX, OC, SGL Carbon ASAHI, and SUVEG Electronics.