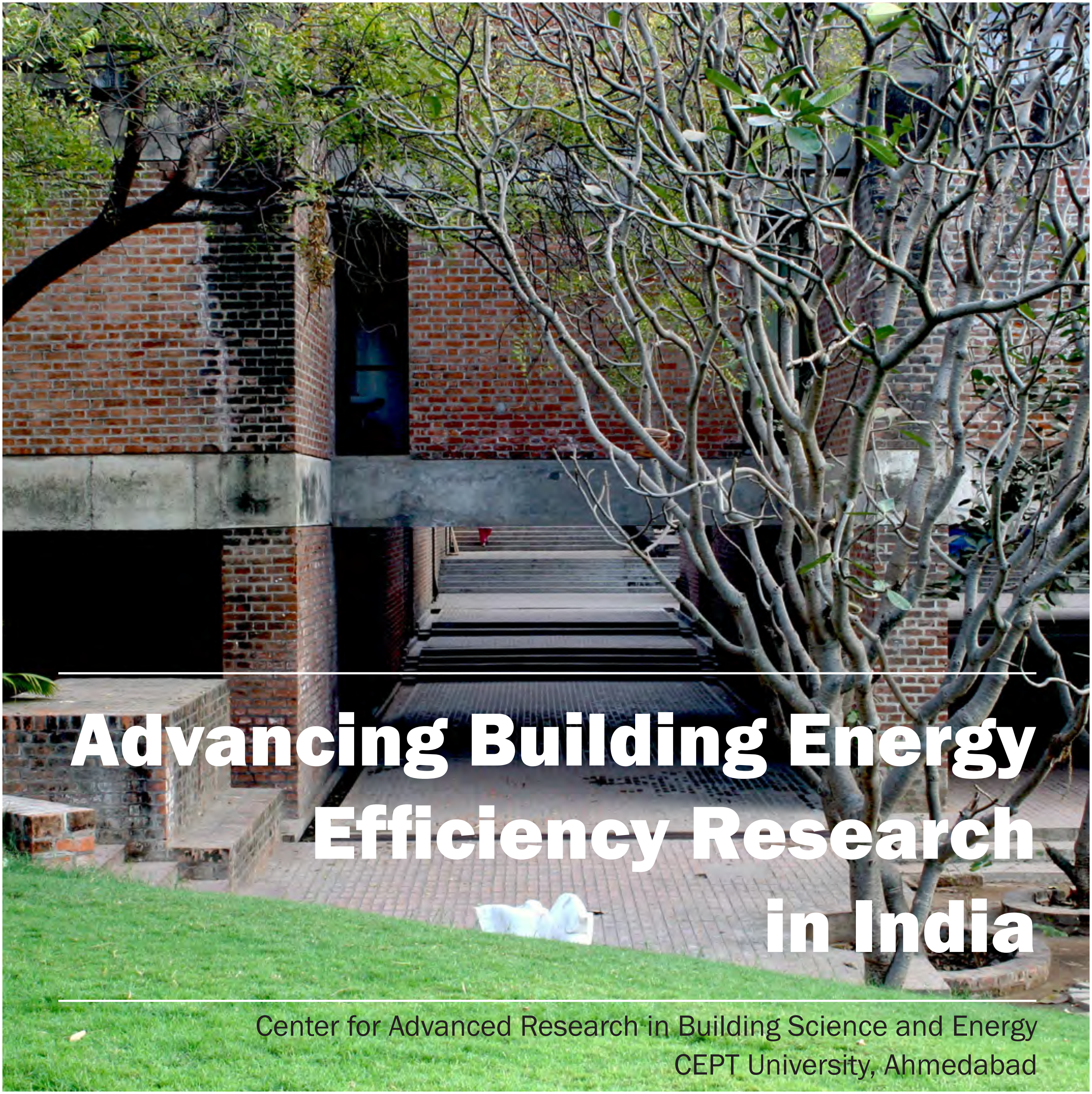


Advancing Building Energy Efficiency Research in India

Center for Advanced Research in Building Science and Energy
CEPT University, Ahmedabad

Introduction

Today, one of the most pressing issues for the building industry is the concern for energy consumption. The building construction sector contributes significant amounts of energy use to the global total, and therefore any realistic attempt to address growing energy use must include measures to make building construction and operation more efficient.

Currently, commercial and residential sectors account for about one third of the electricity used in India. In the next twenty years, these sectors will add twice and thrice the amount of new floor space, respectively, of what currently exists. In addition, residents of India will be continuously increasingly their daily use of energy intensive devices, which will further add to the energy intensity and lead to an increase in the amount of energy used in this country. The government of India is working to fight climate change, and in this effort has launched a national energy conservation building code, which requires new commercial buildings to meet minimum energy performance criteria. However, considering the large existing building stock, which is already contributing to substantial energy use, and the relatively long lifespan of buildings, it is imperative that measures to increase energy efficiency go beyond incremental increases focused only on the future building stock.

Finally, with growing expectations for thermal comfort, India is currently witnessing a rise in the use of artificial air conditioning, which requires sealed buildings. This requires attention to health and productivity, since the current standard of construction does not adequately address ventilation, except through manually operated openings.

Research, Education And Industry Collaboration: In Context

In the context of pressing energy concerns for the future, a relatively ignorant building industry already using a significant amount of India's overall energy, and increased user expectations for thermal comfort and energy use, any effort in understanding energy efficiency in India must use a multi-pronged approach. In the building industry, there is a gap in the knowledge of building material and building performance in India, both at the academic and the professional level. While there is ample knowledge available outside India, very little is applicable in India, both because its climate and latitude differ from the locations in which materials are typically characterized, and its building stock is made from a very different process of construction than what has been documented. India not only needs data on how materials available here perform in this climate, but it also needs tools appropriate to the method of construction that exists here.

The Center for Advanced Research in Building Science and Energy (CARBSE) at CEPT University, Ahmedabad has uniquely positioned itself in the Indian context to work as a node among the networks that comprise the building profession. Its objective is to generate knowledge contextual to India, which entails research on the demand side of buildings and cities, building physics, modeling, and lab and onsite testing, combining scientific rigour with traditional wisdom, to aid in the creation of physical environments.

CARBSE carries out in-depth research in the fields of energy efficient buildings and city design and operation, energy efficient building construction processes, environment friendly construction materials and resource audit & management. This research is supported by extensive work to create an infrastructural facility that characterizes thermo-physical-optical properties of building materials, their assemblies and building components, uses a full scale test bed for comparative simulation and on site measurements in whole building envelope performance, and tests HVAC and lighting systems for post-occupancy evaluation. Along with this targeted approach laboratory, the Centre does research in building technologies and

building energy simulations, both digitally and physically, and uses its research to inform policy at the state and national level in India. These aims, combined with efforts in capacity building and outreach, all come together in the Centre's ongoing project for The Living Laboratory, a Net-Zero Energy Building that will house its state-of-the-art testing facilities, working as a platform for building and building component performance evaluation, and knowledge dissemination. It is envisaged that this demonstration building will act as living laboratory for research and development in the areas of building energy efficiency, thermal comfort modeling, daylighting and low energy cooling technologies. The research facilities here can serve more than just Indian interests. With the most advanced facilities east of Turkey and south of China, CARBSE aims to be a resource for energy efficiency throughout Asia.

CARBSE also participates in the creative educational environment at CEPT University. The Centre works as an interdisciplinary hub, drawing on the expertise of academicians from multiple faculties, and providing a platform for students and scholars from diverse majors. Aligned with its research is CARBSE's effort to build capacity through outreach, both within and outside the university. The research conducted at the facility feeds into both undergraduate and graduate courses. Beyond just student and academic interaction, CARBSE has the goal of making its work accessible to architects, engineers and other professionals, and using its location within the university as a means to share knowledge from practice and research, so that academicians and professionals both may benefit. CARBSE provides a platform for visiting scholars, trains professionals, conducts webinars, and works to disseminate findings from its research via website, journals and magazines available to Indian professionals.

CARBSE collaborates extensively with industries through professional training programs, material database development and commercial product testing services for insulation and fenestration products. The establishment of its capabilities has helped CARBSE to provide support for uniform implementation of the energy code in the building sector in India developed by the Bureau of Energy Efficiency (BEE). In all pursuits, the Centre follows international best practices.

Building And Material Charactrization Facilities

Thermal Characterization

- Thermal Conductivity to derive R-Value and U-Value
- Thermal Diffusivity and Specific Heat
- Air Leakage of fenestration products
- Hygrothermal Characterization
- Post-Occupancy Evaluation for a building's indoor environment and energy performance
- U-Factor and Solar Heat Gain Coefficients of fenestration and wall assembly products

Optical / Visual Characterization

- Transmittance, Absorptance, Emittance and Reflectance of glazing materials
- Reflectance of thermal mirrors (Non planar Surfaces)
- Daylight performance of building in various sky conditions
- Sun Shadow Analysis

The infrastructure capabilities to produce these results are outlined individually by equipment type.

Solar Calorimeter

The solar calorimeter measures the solar gain through fenestration products. This is the fundamental test by which the solar gains through the window assembly of any such components can be measured. It can also be used for the measurement of the solar efficiency of photo voltaic cells used in Solar PV panels. The solar calorimeter is an insulated enclosure designed to permit the continuous introduction and extraction of a measured flow of fluid mass and equipped with an empty aperture into which a fenestration system is inserted for characterization. The main components of this equipment include room side metering chamber, guard chamber, surround panel for installing test specimen, calibration panel, heliostat and enclosure.

Spectro-photometer and Fourier Transform Infrared Spectrometer (FTIR)

Solar spectral reflectance is measured using a spectro-photometer equipped with a 150mm integrating sphere. This is a photometer (a device measuring light intensity) that

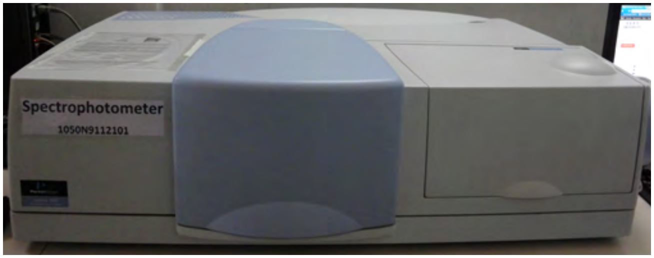
measures intensity as a function of colour (wavelength) of light. It provides the facility for characterization of optical properties of glazing materials, and systems of relevant to energy transfer in flat specular glazing materials. The glazing may be monolithic, coated, with applied film, or laminated. The solar absorptance, reflectance and transmittance of a material are determined using both the spectrophotometer and integrating spheres. For glazing materials, optical properties are measure for UV/Vis/NIR spectral range, and solar reflectance for opaque building materials is measured for the SRI calculation. Reflectance and transmittance at various angles of incidence can also be measured with the Angular Tubes Spectrometer Accessory, which is useful for flexible and thin materials, like shade fabrics.

The emissivity of glazing and cool roof material is measured in Infra Red (IR) range (Approx. 1300 nm – 44000 nm) by a Fourier Transform Infra Red Spectrometer (FTIR), which collects spectra based on measurements of the coherence of a radiative source, using time domain or space domain measurements of the electromagnetic radiation, or another type of radiation. It can be applied to a variety of types of spectroscopy. It is able to compare the ability of a surface to emit radiant energy with that of a black body at the same temperature and of the same area. This equipment is useful for calculating the solar reflectance index (SRI) of cool roofs and cool roof products.

One of the research projects to be carried out through the use of the FTIR is the study of accelerated and natural aging of roofing materials. For accelerated aging, reflectance and emittance is characterized before and after soiling agents are applied to the surface. For the study of natural aging, materials are left exposed for a period of approximately five years, and characterized for reflectance and emittance every three months.

Heat Flow Meter

At CARBSE, thermal conductivity characterization is done with two methods: steady state and transient measurement. Using the heat flow meter, which measures thermal conductivity of insulating materials, it also intended to measure enthalpy, as well as the active range for phase change materials. The thermal conductivity of a specimen is determined by measuring the heat flux,



specimen thickness, and temperature difference across the specimen. Materials tested range from polyurethane foam, insulating industrial material, EPS, XPS, Glasswool and Rockwool. Specimens sized 600mm x 600 mm and of thicknesses up to 200 mm are characterized for the thermal conductivity range from 0.01 to W/m.K to 0.2 W/m.K.

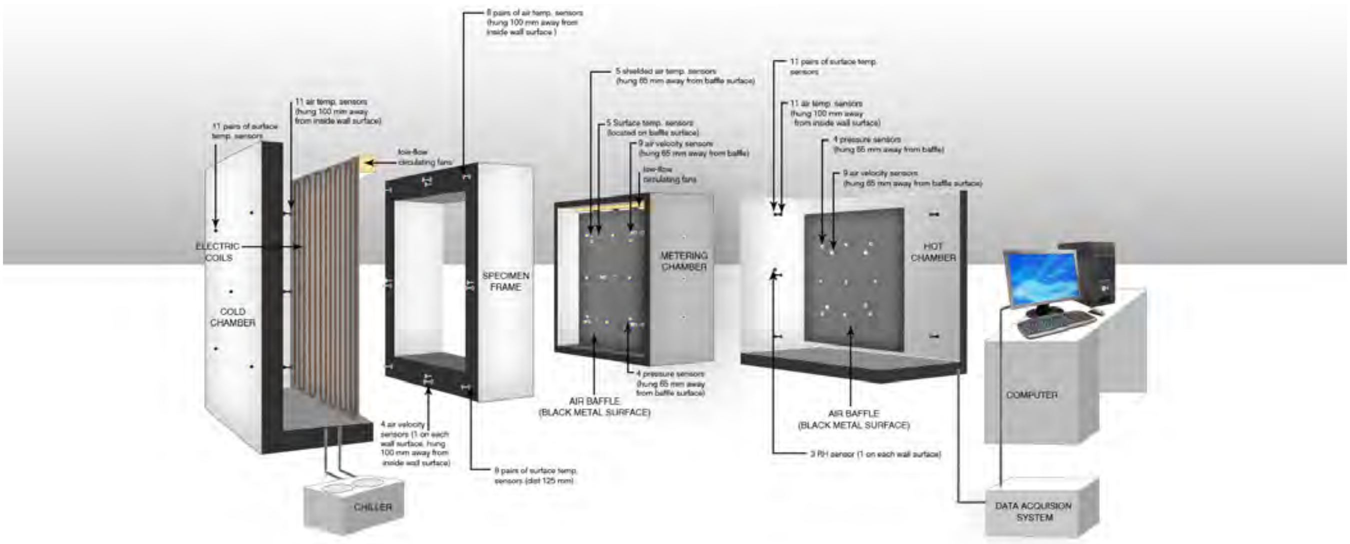
Coupled with another instrument, the heat flow meter can work as per transient method. It can characterize thermal conductivity thermal diffusivity and specific heat capacity for material in solid, liquid, powder and pest forms. It measures temperatures ranging from a cryogenic 10 K to almost 1000 K.

Guarded Hot Box

A Guarded Hot Box is used to test the thermal performance of non-homogenous specimens, such as complex wall assemblies, cavity walls, ventilated shaded wall assembly or walls with phase change materials. It determines the amount of heat transfer through a given material or assembly of various materials. This is done by controlling the temperature on both sides of the material and minimizing the extraneous heat transfers other than those through the given material, which can be used to determine the thermal transmittance of a homogenous as well as non-homogenous specimen, and can test a specimen with a maximum thickness of 350mm. The metering chamber is cooled using chiller and the guard chamber is maintained at same temperature using an HVAC system. The climatic chamber is maintained at higher temperature using electric coils. Surface, water and air temperature sensors for temperature control along with humidity (RH), pressure, and air velocity sensors are placed at equal distances.

Hygrothermal Characterization Facilities

CARBSE employs hygrothermal test facilities, which employ three types of test for material characterization. The first determines the sorption isotherm, the second derives water vapor transmission, and the third quantifies water uplift characteristics due to capillary action. The material properties derived from these tests help in calculating the water content of building materials subjected to various temperatures, pressure and RH conditions. Such characterization aids the understanding of moisture



migration occurring in opaque building assemblies, which impacts structural stability, indoor air quality and energy demand for the maintenance of desired indoor conditions.

Air Leakage Chamber

The Air Leakage Chamber is used to determine the air-leakage rates of windows, doors and curtain walls. It is modified for the requirements of each type of assembly tested, and helps evaluate the relative performance of various fenestration products. Air leakage characterization helps improve performance of air conditioned, mixed mode and naturally ventilated buildings.

Energy and Indoor Environment Audit Systems

CARBSE also has a range of energy and indoor environment audit systems, which are used in monitoring the performance of existing buildings. Each tool measures aspects of temperature and humidity, air velocity, and light, and some measure multiple criteria. Its micro weather station, with a four-sensor data logger, uses a network of smart sensors to take measurements, which helps in multi-channel monitoring of microclimates. The micro sensors measure temperature, RH, rain, wind speed and direction, soil moisture, solar radiation and photosynthetic active radiation, Resistance Temperature Detector Sensors (RTDs) measure surface temperature, and can be used to study the thermal performance of materials, and thermal lag of a building. An infrared (IR) thermometer, for non-contact temperature measurement, determines an object's surface temperature by measuring the amount of infrared energy radiated by the object's surface. The universal light meter is used for conducting post-occupancy evaluation studies, daylight penetration studies and need for electric light and related energy usage in conditioned environments.

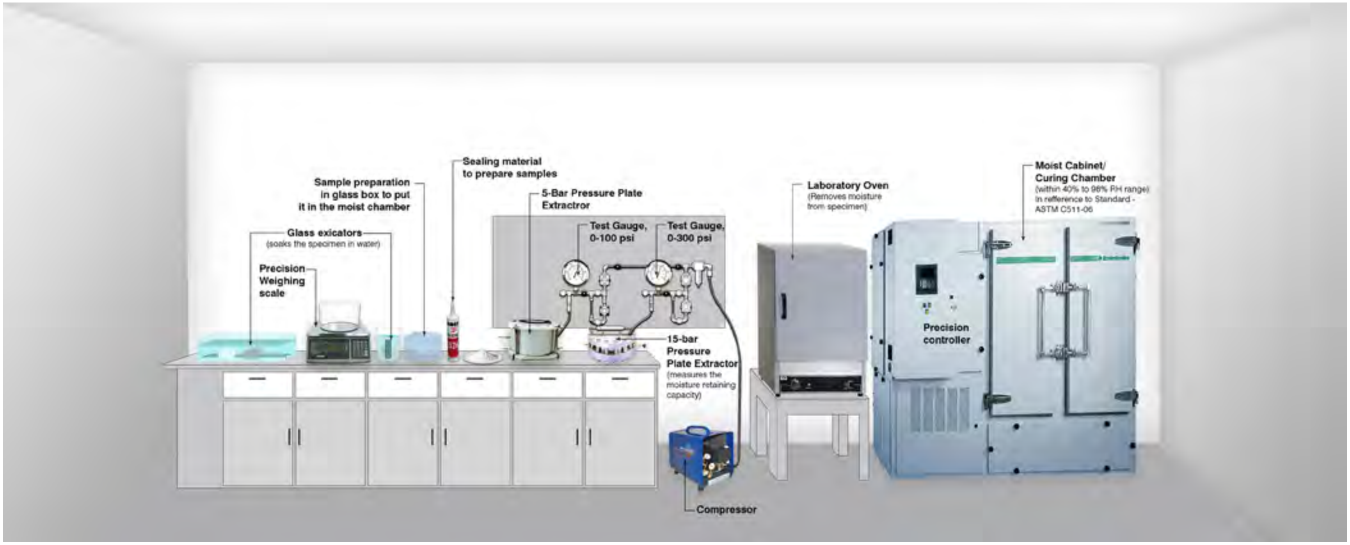
Indoor air quality meters are capable of logging as well as taking instantaneous measurements for environmental parameters. These are useful for conducting Post Occupancy Evaluation studies as well as in determining user perceived thermal comfort standards. The Air Velocity Meter gives an accurate air velocity measurement, by simultaneously measuring temperature and velocity. It calculates volumetric flow and actual velocity, and is also capable of measuring relative humidity and CO or CO_2. Stand-alone data loggers monitor temperature, humidity, and luminance both inside and outside buildings, over long periods of time, at regularly defined intervals. CO/ CO_2 can also be measured with an additional probe. The Heat Stress Wet Bulb Globe Temperature (WBGT) meter measures and displays heat stress index, which describes how hot it feels when humidity is combined with temperature, air movement, and direct or radiant sunlight.

Post-occupancy evaluation and building performance monitoring hold important roles in understanding the existing condition of the building stock, identifying areas for improvement, and addressing issues that can be retrofitting to improve energy efficiency. But along with these goals, data acquired stands to hold great value in improving the design process for future buildings, where larger gains in efficiency can be implemented, because of more informed design decisions, and the possibility for more gradual or radical change. For that reason, CARBSE works to put its data to use in developing simulation tools, both digital and physical, that test various building technologies, and advance their potential as systems within both existing and new construction projects. The development of online tools, sky simulators and thermal comfort chambers, which will be made available to practitioners, and can give designers valuable information to feed into their design processes.

Daylight Studies using Mirror box, Single Patch Sky Simulator

Daylight, when used correctly, can work to improve energy efficiency in buildings through the controlled admission of natural light, both direct and diffused, into a building. This can reduce electric lighting and save as much as one third of total building energy costs. Daylighting cannot be accomplished simply by allowing sunlight to enter the building. The introduction of daylight into the interior space must be optimized according to the program of the space, and must also respond to the dynamic patterns of outdoor illumination. But in doing so, designers using daylight have the opportunity to create a visually stimulating and productive environment for building occupants, that transforms throughout the course of the day. Toward this end, CARBSE is developing a mirror box and a single patch sky simulator, which can produce artificial sky conditions.

The CARBSE mirror box will used to simulate overcast sky conditions for building models, which helps architects and engineers to understand daylighting inside a building and take necessary steps to increase building performance and reduce energy consumption for artificial lighting. The mirror box consists of an extremely bright homogenously lit ceiling and mirrored walls. The light source is a milky white diffusing acrylic sheet illuminated from behind with over 6,000 LEDs. The mirrors, arranged vertically all around the

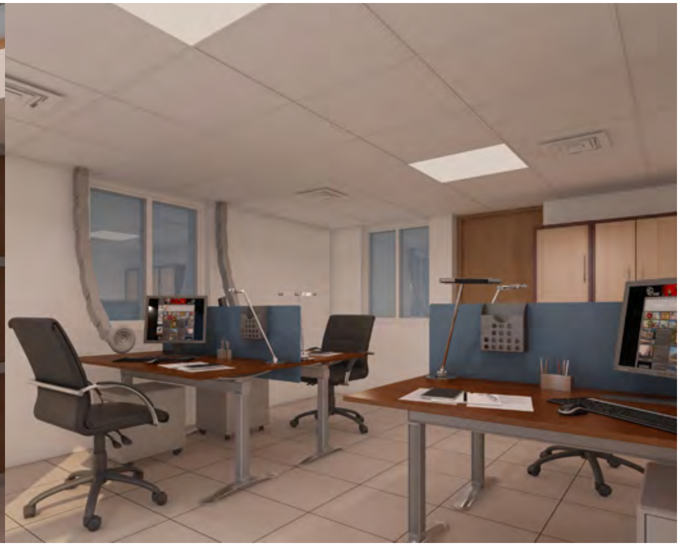


periphery of the box, produce an image of the lit ceiling by reflection and inter-reflection to infinity, which accurately simulates a perfectly distributed overcast sky. The mirror box generates light levels between 12,000 to 15,000 lux on work plane placed in the center of the box, at the bottom edge of the mirrors, which replicates the situation of a perfectly flat and clear horizon. A building model to be analyzed for daylighting is placed inside the mirror box and illuminance levels are measured using a lux meter.

CARBSE's Single Patch Sky Simulator complements the mirror box. The system consists of a turntable, mirror and Fresnel lamp. By emulating one sky patch out of the total 145 virtual divisions with equal area of the sky dome, as per Tregenza's model, a building model placed on the turntable can be rotated so that the lamp is directed from each of the sky dome's 145 divisions, and illuminance levels can taken. These measurements are then aggregated so that they accurately reflect the daylight performance of the space under the whole sky dome. The advantage of this is that because the measurements are taken according to 145 patches, once measured physically only once, the effective sky can be altered to simulate any sky condition simply by adjusting the weightage of individual patches, and calculating the effect on the building's illuminance levels.

Thermal Comfort Chamber

The Thermal Comfort Chamber (TCC) is a chamber sized 6m x 5m x 3m, which can precisely simulate a wide range of indoor environmental conditions with temperatures ranging from 15°C to 40°C and relative humidity from 16% to 95%, along with changing air distribution patterns and speed. This particular capability is useful for Indian studies because it allows researchers to measure the impact of air velocity, a necessary criteria in a context dependent on the use of fans for cooling. These conditions are maintained and monitored by sophisticated air conditioning systems and control devices. The purpose of the TCC is to conduct experiments to evaluate the impact of various indoor environmental conditions on occupant comfort, productivity, and wellbeing. People participating in the research would sit on four workstations in the TCC and experience thermal conditions set by the research team.



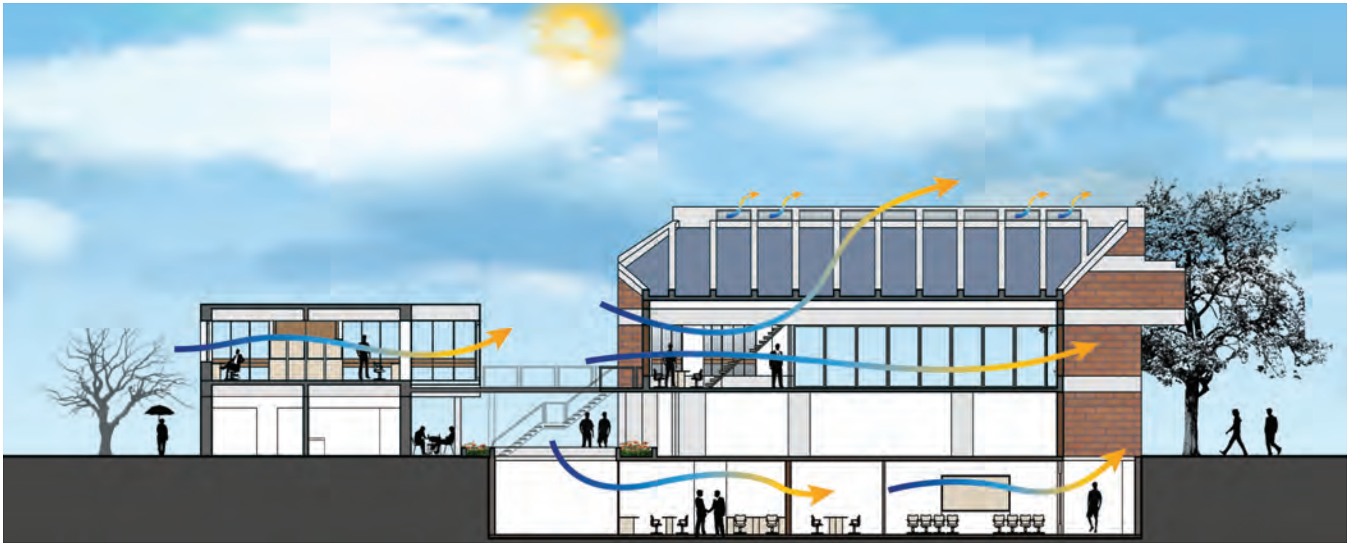
CARBSE uses its material testing infrastructure and energy simulation capabilities on various affiliated research projects in India. These projects look a thermal comfort, tubular day lighting devices and fenestration, develop research for codes and standards that feed into the national building code,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

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 yearlong 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. 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. These tools take the information generated from the Comfort and Weather Analysis tool, and use it to compare the conditions in two Indian cities simultaneously.



Developing a Tiered Approach for ECBC Compliance

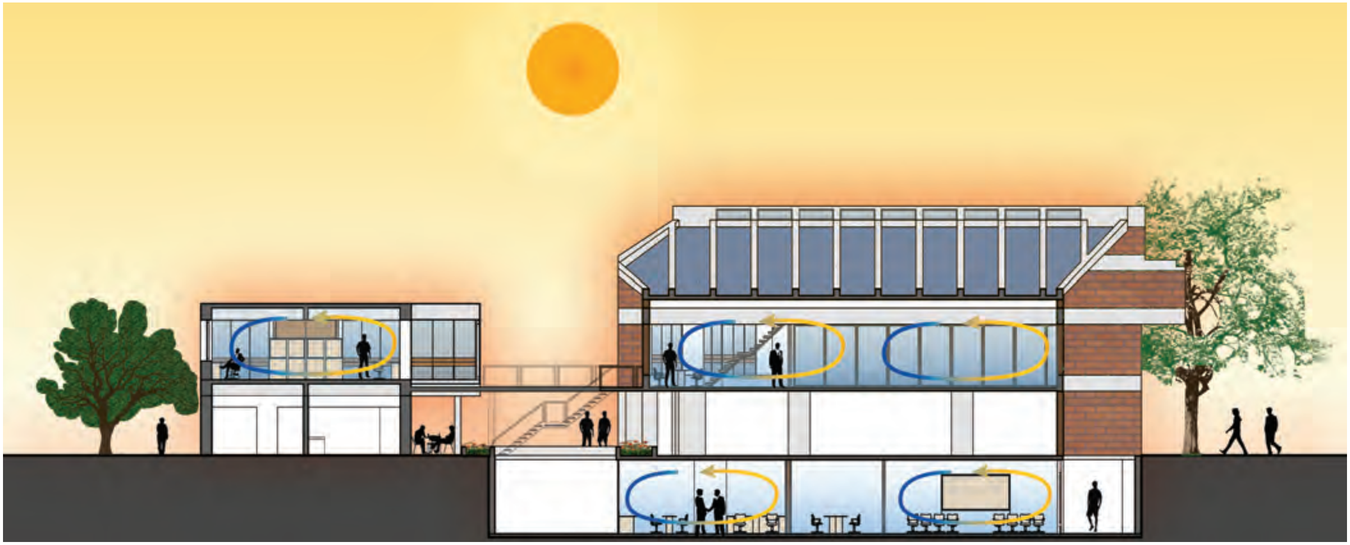
The Bureau of Energy Efficiency (BEE), India, launched the Energy Conservation Building Code (ECBC) in 2007. Through mandatory compliance with the ECBC, India can achieve estimated annual energy savings of 1.7 billion kWh. The rate of compliance with the code is predicted to reach 65% by 2017.

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.

The 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 ratings 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 TPA's role and organizational framework. Some of the benefits of the TPA model, which is an increasingly popular mode of building code



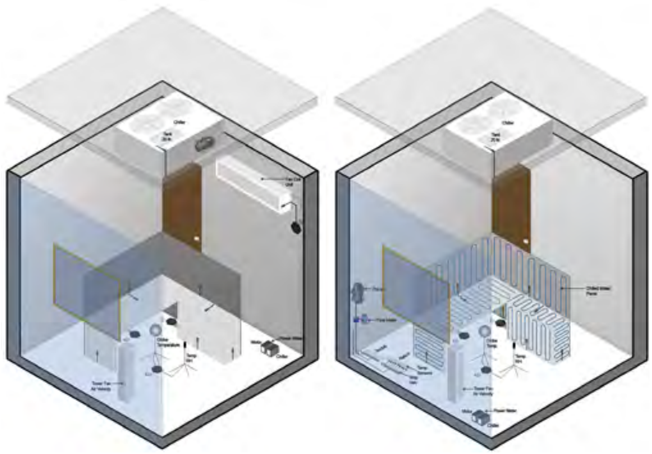
enforcement worldwide, are that it is easily scalable for different growth scenarios, as a market driven model it ensures the availability of TPAs across India, it brings good resolution to challenges related to municipal level regulatory enforcement, and a entails a low cost for compliance enforcement.

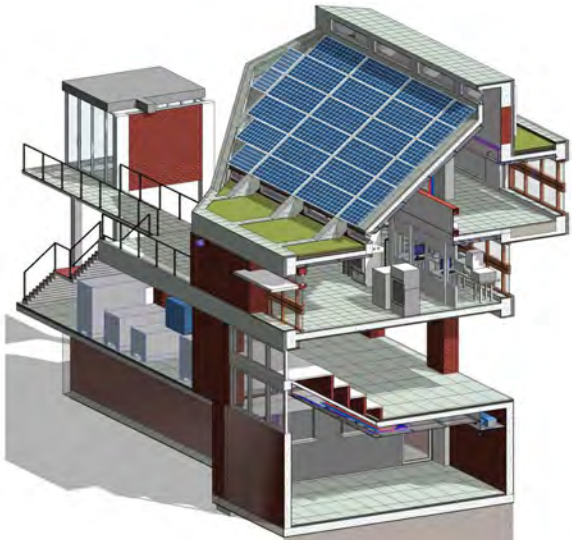
Adaptive Thermal Comfort

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 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.





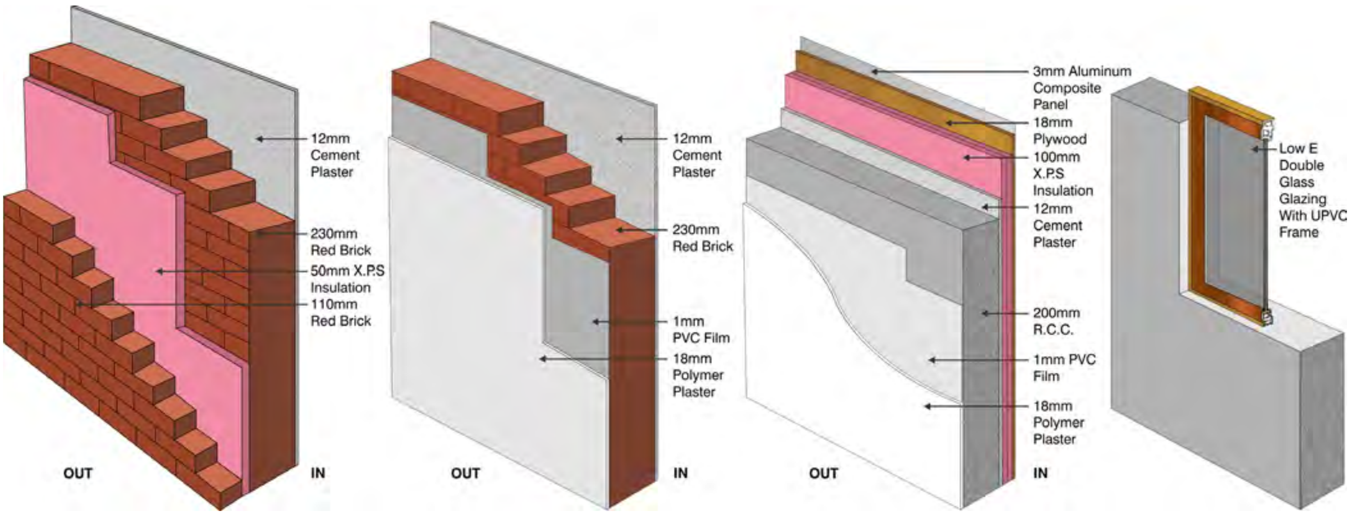
Residential Baseline

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 projects 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

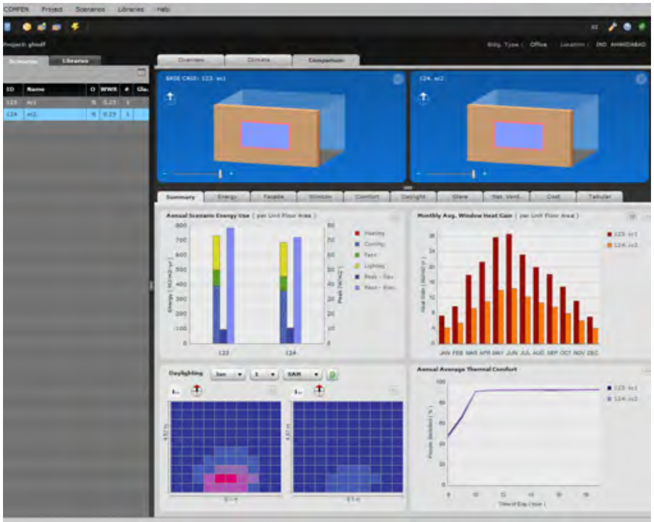
The project for Building Material Characterization and Construction Assemblies is currently developing an extensive database of the thermo-physical-optical properties of building materials, building components and construction assemblies, using state-of-the-art material testing facilities. This database serves to fill a gap in knowledge 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 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 on-site 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 moves 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 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 the 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.

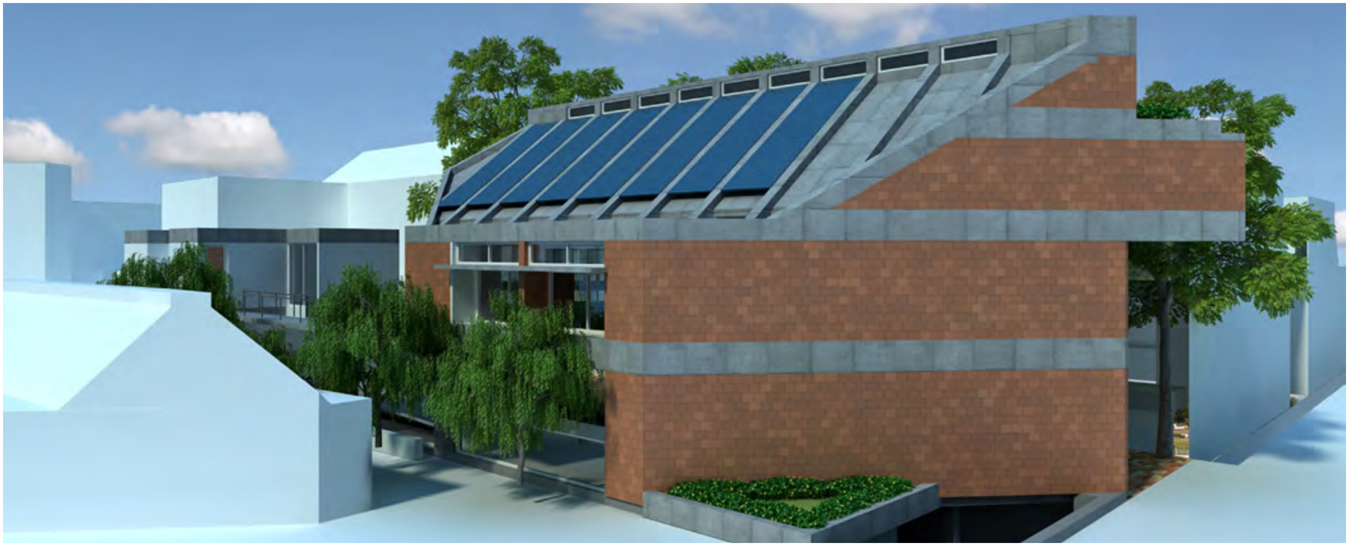
Net Zero Energy Building : The Living Laboratory

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 consumes as much energy as it produces energy at site using renewable energy sources. The under construction NZEB at CEPT University campus in Ahmedabad, Gujarat, will be the new home for CARBSE. It will house state-of-art laboratory facilities for building materials characterization, thermal comfort studies, daylighting 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, 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

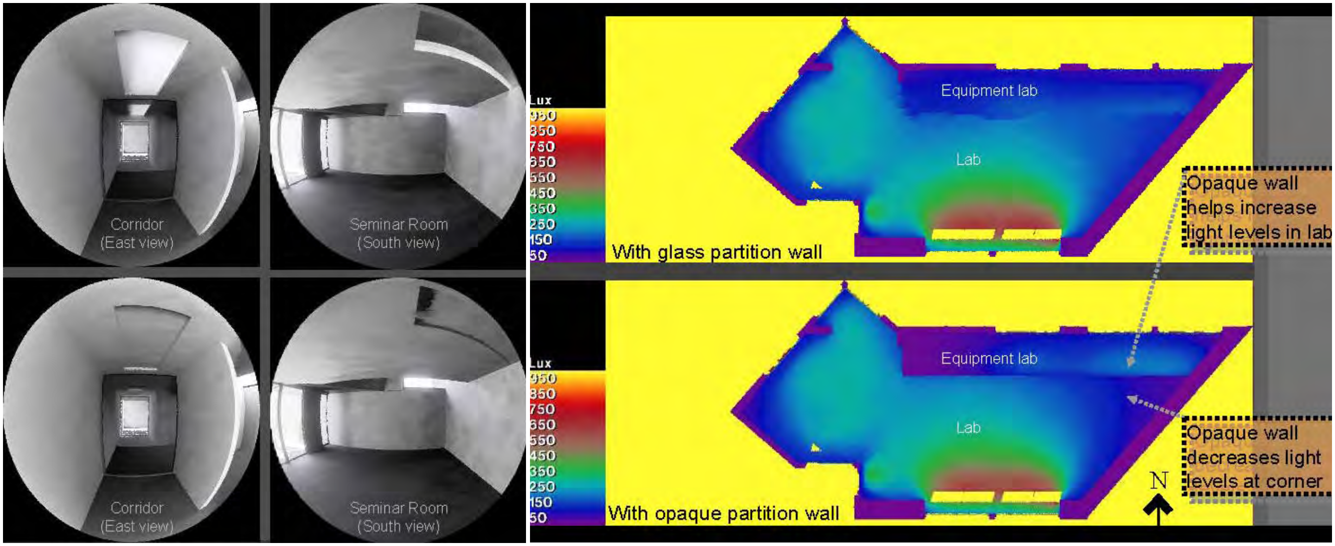


aid in natural ventilation. The project has been monitored continuously during construction and will continue to be monitored after occupation. In its attempt to combine state-of-the-art technology with passive technologies rooted in the tradition of the area, architect BV Doshi sees this architecture 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 bed 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.

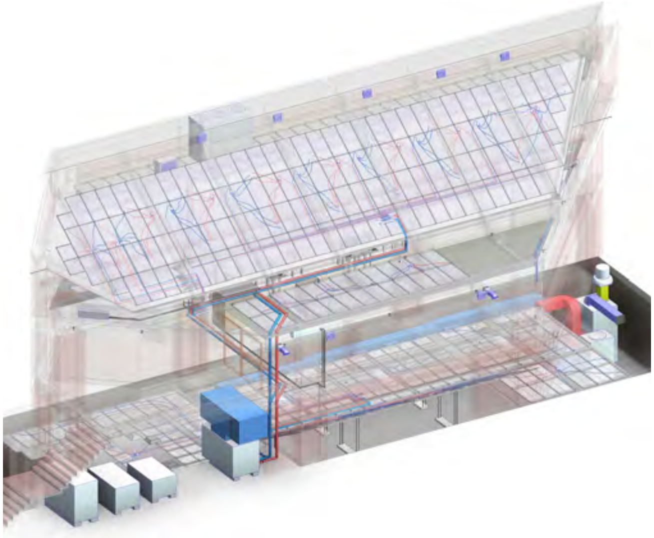
The monitoring component incorporates high accuracy research grade sensors to continuously monitor building performance and occupant comfort. The air conditioning and envelope monitoring system contains built-in controllers with networking capabilities and will be integrated with the building control 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 the 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 and industry organizations. It has been awarded a status of a "Centre of Excellence" by Ministry of New and Renewable Energy, Government of India under five year research grant, "Energy Efficiency Centre for Buildings" by USAID ECOIII program. It is authorized training center for Energy Codes recognized by Bureau of Energy Efficiency, Govt of India. CARBSE is leading research under the prestigious US India Joint Centre Building Energy Research and Development (CBERD). Gujarat Energy Development Agency, Government of Gujarat is supporting Near Net Zero Energy Building – A living laboratory for CARBSE at CEPT University. CARBSE works very closely Shakti Sustainable Energy Foundation, Climate Works Foundation and Global Buildings Performance Network. 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 received a seed grant from the National Fenestration Rating Council (NFRC) USA at its conception stage.

CARBSE laboratory facility is recognized by the 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.

The Center works with various organizations such as US Dept. of Energy through its national laboratories, Lawrence Berkeley National Laboratory, and Oak Ridge National Laboratory. It is involved in activities of Swiss Development Corporation in India, Glazing Society of India. India Insulation Forum, India Green Building Council, Indian Society of Heating Refrigerating Air Conditioning Engineers and American Society of Heating Refrigerating Air Conditioning Engineers. Its industry partners include Bayer Material Science, SINTEX Industries, Ownes Corning, SGL Carbon, Uponor, ASAHI Glass India, Saint-Gobain Glass India, Pidilite Industries and SUVEG Electronics.

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