NRDC CASE STUDY

Building Smart from the Start: Spotlight on Energy-Saving Commercial Office Building in Noida, India

The lightwell on the Legacy Spectral Building lets in natural daylight to reduce electricity use.

Photo Credit: Anjali Jaiswal

"If we can change the way you think about building, maybe what you build will change the world."

– Dr. Prem C. Jain, Founder, Legacy Spectral Services

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Prepared by: Natural Resources Defense Council and Administrative Staff College of India

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As India experiences rapid urbanization and energy demand soars, constructing energy-smart buildings in the country's expanding cities is more important than ever. India's energy demand could more than double by 2027 from 2012 levels, according to the Planning Commission.[1] Unreliable transmission, escalating electricity rates, frequent blackouts and highly polluting sources of electricity compound the energy problem and hurt businesses' bottom line. To handle this projected growth sustainably, energy efficiency offers a huge opportunity to cut costs, save energy and build clean energy resources. By building smart from the start, business owners can reap energy and cost savings that also increase worker satisfaction and productivity as well as boost property values.

This case study highlights the former Spectral Services headquarters (now AECOM Building Engineering Group), an everyday office building in Noida that makes an extraordinary business case for energy efficiency—reaping energy savings for the life of the building through measures that paid for themselves within the first four years. The Legacy-Spectral building, constructed in 2007, shows that greener, energy-saving buildings are practical and profitable in India's rapidly transforming building market and provides replicable practices to lock in cost and energy savings.

BUILDING BASICS
Location: Noida, Uttar Pradesh
Climate Zone: Composite
Temperature Range: 7°C – 43°C (45°F – 110°F)
Building Gross Area: 1,500 m^2 (16,000 ft^2)
Occupancy: 150-200 persons
Number of Floors: 5
Building Use: Office Space
Building Occupant: AECOM (formerly Spectral Services)
Financing: Self-financed by Spectral Services (no debt financing)
Project Team: Architect: ABRD Architects; Commissioning Agent: Godrej & Boyce; Spectral Services
Utility Company: Paschimanchal Vidyut Vitran Nigam Limited

LEGACY SPECTRAL COMMERCIAL OFFICE BUILDING

The Legacy Spectral building is a five-story office building built in 2007 that originally housed the Spectral Services headquarters before the company was acquired by AECOM. Spectral Services focused on energy efficiency from the start of its building design—with energy efficiency at its core. The building is certified as Leadership in Energy and Environmental Design (LEED) Platinum.

The high performance efficiency measures include an energy management system, energy-saving lighting, natural lighting and a high-efficiency heating, ventilation and air-conditioning (HVAC) system. The company invested an additional upfront cost Rs. 36.3 lakh ($88,000 as per 2007 exchange rates) or 8% more than the construction cost of a conventional building of its size, to pay for these energy efficiency measures. These efficiency investments had a actual payback period of 3.3 years and continue to save the company a minimum of Rs. 10.71 lakh ($17,860 as per current exchange rates) in annual energy bills since the first year of operation.

DESIGNING SMART: BUILDING SIMULATIONS THAT SELECT ENERGY SAVING FEATURES

Starting with the design, the Spectral team used energy simulations to determine which energy conservation measures would be the most cost-effective. The energy simulation runs models of a building's energy use based on the building design, including the HVAC system, insulation, electricity load and windows. The energy use and the cost of different design features determine the cost-effectiveness of identifying and implementing the energy conservation measures – the actual measure that should be included in the building. Daylighting simulation, or the amount of natural light for the building, was also performed at the building design stage. The analysis simulates daylight that enters the building and is used to design placement of windows and type of glass to optimize the amount of natural light entering the space. The Spectral team designed the placement of windows based on the daylighting analysis using Desktop Radiance software and installed daylighting controls to turn off electrical lights when the sun provided enough illumination.[2]

ENERGY SAVING MEASURES AND MATERIALS

Based on the simulation, the building team implemented efficiency measures in almost all areas of the building, including efficient windows, building envelope, air conditioning, air distribution, electrical distribution system, lighting and daylighting. The majority of energy efficient products were readily available throughout India.

The main characteristics of the **efficient windows** are:

- *Lightwell* in the center of the building and placement windows to maximize the potential for daylighting and views. Since the window wall ratio was designed for 22.5 percent, nearly 75 percent of the office space is lit by natural light and allows for the lights to be turned off, saving energy during much of the day. Natural light and views have been shown to increase worker productivity and longevity too.[3]
- *Optimized daylighting* in the basement through atriums and ground reflection, which reduces the lighting energy use in the basement (see Figure 1).
- *Recessing windows* to reduce heat from direct sunlight through the windows and to block solar radiation, installing "fins" on the west façade blocks and adding an exterior shading system to keep heat from entering the building.
- *Efficient window glass* to optimize daylight and cooling has a solar heat gain coefficient of 0.33 and visual light transmittance of 0.48, allowing less heat but more light to come into the building.

The main characteristics of the **building envelope** are:

- *Efficient walls* allow 75 percent less heat to transfer into the building than a conventional building. The wall consisted of 20 mm of stone cladding, a 225 mm thick autoclaved aerated concrete (AAC) block, 25 mm of nitrile rubber, and 12 mm gypsum board.

FIGURE 1: ENERGY EFFICIENT LIGHTING: MODELED DAYLIGHTING STRATEGY OF BASEMENT AND LEGACY SPECTRAL BUILDING'S RECESSED WINDOWS

- *White roof* that allows 40 percent less heat into the building than a conventional building. The roof was made from a 100 mm roller-compacted concrete (RCC) slab, 75 mm thick pieces of extruded polystyrene insulation, and high albedo paint with a reflectivity better than 0.45.

The main characteristics of the **air conditioning system** are:

- *Efficient 72-ton screw chiller* with a coefficient of performance (COP) of 4.48 that continuously compresses the refrigerant that cools water for the air conditioning system.
- *Cooling towers* with a variable frequency drive on the roof which help to improve indoor air quality.

The main characteristics of the **air distribution system** are:

- *Air handling unit* (AHU) for each floor with a variable frequency drive to reduce the energy used under reduced load, equipped with a humidification/ dehumidification package for occupant comfort.
- *Variable air volume* (VAV) boxes that adjust to reduce cooling load variations and hence use less energy at lower loads.
- *High efficiency motors and fans* to distribute air and air-side economizers.
- *Ventilation system* that uses 30 percent more fresh air than American Society of Heating and Refrigeration Engineers (ASHRAE) Standard 62.1-2004. The exhaust and fresh air intake are separated by a minimum of 25 feet.
- *Two stage Minimum Efficiency Reporting Value -13 (MERV-13) filters* to remove air contaminants before entering occupied areas and carbon dioxide sensors to signal the distribution system to add more fresh air when rooms are highly occupied.

The main characteristics of the **electrical distribution system** are:

- *Maximum efficiency and minimum power losses* in the electrical distribution system by stabilizing voltage, requiring 110 kW peak power, maintaining a power factor of 0.98 and above.

The main characteristics of the **electrical lighting** are:

- *High efficiency T5 lighting* with dimmable ballasts. The internal lighting power density is 0.63 W/ft2, which is 37 percent lower than the IESNA standard.
- *Daylighting controls* to maintain a constant illumination level by including a dimming function that allows the lights to be turned down when natural light enters the space.
- *Occupancy sensors* in areas that are not consistently used.

EXCEEDING PREDICTIONS: REAL ENERGY AND COST SAVINGS FROM ENERGY EFFICIENCY MEASURES

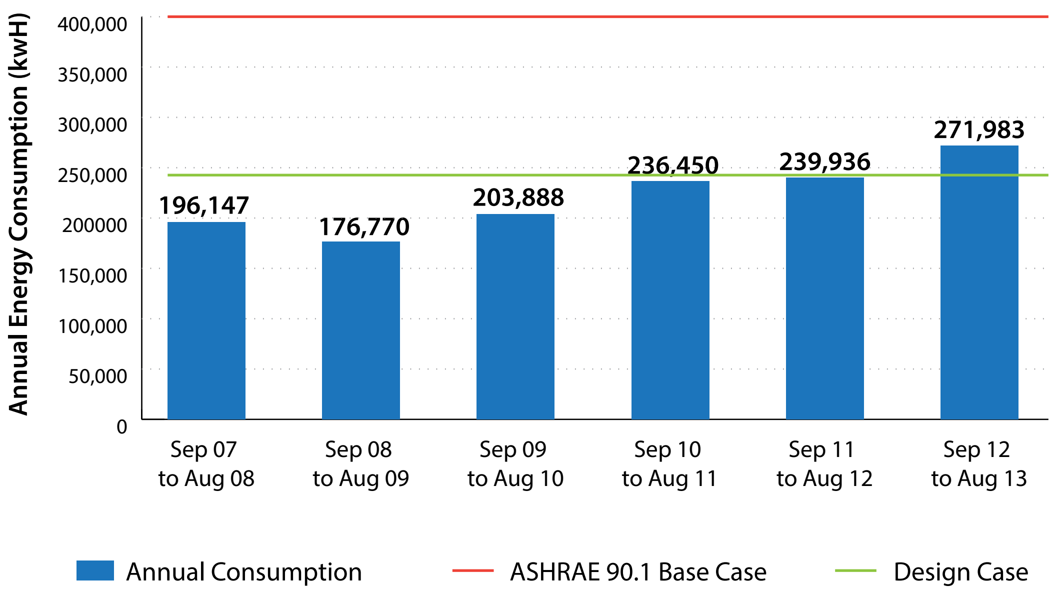
The additional costs of the energy efficiency investments were Rs. 36.3 lakh ($88,000 as per 2007 exchange rates) or 8% more than the construction cost of a conventional building, according to Spectral. Estimates during the construction of the building predicted that the design case would consume 38.6% less energy than the base case. Actual building operations post-construction show that in the first year, the building actually used 50.2% less energy than the base case.

Over the years, the real energy consumption of the building increased, and was highest in the twelve months from September 2012 to August 2013. Despite the increased load, the building consumed 31% less than the ASHRAE 90.1-2004 base case in that same twelve month time period. Further, Legacy Spectral building utility records show that average electricity tariffs rose at an annual rate of 9.41% per year between September 2007 and August 2013. The energy cost savings were even greater in subsequent years as electricity prices increased, making a strong case for energy efficiency.

The actual payback period achieved for the Legacy Spectral building, examined through utility bills from 2007-08 to 2012-13 was 3.3 years. The modeled payback period showed 3.1 years with an increasing tariff and 3.4 years with a fixed tariff. The actual payback period as compared to the modeled payback period are very close, demonstrating the real world accuracy and predictability of modeling results. For more information about how the payback period was modeled and measured, please see energy saving scenarios.

It took less than three and a half years for Spectral Services energy efficient construction to pay for itself.

FIGURE 2: ANNUAL ENERGY CONSUMPTION AT LEGACY SPECTRAL BUILDING, SEP '07 TO AUG '13



Close-up of the white rooftop materials used to naturally keep the Legacy Spectral building cooler by reflecting light and heat.

Photo Credit: Anjali Jaiswal

PROJECT TEAM & ROLES

The Legacy Spectral building example shows that to maximize energy savings, a cohesive design and construction team dedicated to energy efficiency must work together from the start of the project through building operation. Spectral hired a team of consultants along with its own employees to work together to meet Spectral's aspirations for minimal energy use.

The project team consisted of:

- Architect: *ABRD Architects*
  Spatial design of a building itself has a large impact on energy use. The architect brought together designs from all parts of the building to control the energy efficiency and maximize energy savings.
- Energy Consultant: *Environmental Design Solutions*
  Having an expert on the design team whose goal is to save energy ensures energy efficiency is incorporated wherever effective. Energy consultants help identify energy savings through energy simulation, daylighting design and material selection.
- LEED Facilitation: *CII - Sohrabji Godrej Green Business Centre*
  If LEED certification is desired, design considerations must be incorporated from the inception of the building to ensure the design will be LEED certified.
- Mechanical Electrical & Plumbing (MEP) Consultants: *Spectral Services Consultants*
  The mechanical, electrical and plumbing systems control a majority of a buildings energy use. Hiring a MEP consultant with a commitment to energy efficiency greatly enhanced the efficiency of the building.
- Construction Manager: *Consortium Consultancy*
  Hiring a construction manager committed to constructing the building as designed maximized savings and keeping the construction manager informed on energy efficiency decisions ensured the efficiency measures were properly constructed.
- Civil and Electrical Contractor: *Ahluwalia Contracts*
  The electrical contractor influenced the electrical system performance and how much power is lost as it enters the building to reduce overall energy losses.
- Commissioning Agent: *Godrej and Boyce*
  The commissioning agent ensured the building performed as designed to meet its full energy efficiency potential.
- Building Management System Contractor: *iMetrex Technologies*
  The building could be designed for energy efficiency, but energy savings will not be recognized if it is not operated efficiently. Including building management systems on the initial design team helped highlight opportunities to facilitate efficient building operation, a critical component to reap energy savings in actual performance.

The Legacy Spectral building shows that newly constructed buildings in India can measurably save energy and costs. Not only are these efficiency investments paid back quickly, but they continue to save money and energy for the lifetime of the building. The energy conservation measures also improve equipment reliability, increase the quality and property value of the building, enhance occupant comfort and amplify a company's environmental commitment. This model is replicable and offers strong motivations for other Indian building owners to build efficiently from the start and lock in cost and energy savings.

ENERGY SAVING SCENARIOS

CALCULATING THE ENERGY CONSUMPTION

Prior to construction, it was predicted that the energy efficient features used in the Legacy Spectral building would save the company 38.6% in annual energy and costs as compared to the base case design using the ASHRAE standard 90.1-2004.[4] In other words, the Legacy Spectral building was predicted to save 152,110 kWh of energy use—a saving of Rs. 6.53 lakh ($10,875 at current exchange rates) on energy bills in the first year of operation at the then-prevalent tariff rate of Rs. 4.29 ($0.07) per unit. Actual building performance data showed that once constructed, the Legacy Spectral building exceeded predictions, and energy use for the first year of operation was 196,147 kWh, resulting in savings of Rs. 8.50 lakh ($14,160 as per current exchange rates) or 50.2% on energy bills over the ASHRAE 90.1-2004 base case building.

As a baseline comparison, the energy consumption of a conventional building was assumed to be an average of 300 kWh/m2/year.[5] By comparison, a building compliant with the ASHRAE Base Case 90.1-2004 would consume 269.1 kWh/m2/year (25 kWh/ft2/year). For calculation of savings over time, the cost of a kWh unit of electricity was obtained from tariffs recorded in the monthly electricity bills. The electricity bills provided different tariffs for three different time slots during a 24-hour period. The tariff used for this analysis was for the time from 6 am to 5 pm during which the biggest share of energy is consumed.[6]

As shown in Figure 2, the building's annual energy consumption generally increased from one year to the next. This increase can be attributed mainly to two factors that caused the building operation to deviate from original design. First, the occupancy level of the building nearly doubled over the period from 2007 to 2013, causing an increase in consumption and associated plug loads. The second has been the installation of a new data center in the year 2010.

CALCULATING THE PAYBACK PERIOD

To calculate the payback period achieved for the Legacy Spectral building, we evaluated four different scenarios to help capture the impact of two key variables on payback period calculations. The first variable is impact resulting from variation in the energy consumption of the building. The second variable is the impact of escalation in tariffs. To summarize, the four scenarios can be described as follows:

1. Fixed consumption, fixed tariff
2. Fixed consumption, escalating tariff
3. Actual consumption, fixed tariff
4. Actual consumption, actual tariff

The actual payback period achieved for the Legacy Spectral building, examined through utility bills from 2007-08 to 2012-13 is 3.3 years (Scenario 4). The modeled payback period showed 3.1 years (Scenario 2) with an increasing tariff and 3.4 years with a fixed tariff (Scenario 1). The actual payback period as compared to the modeled payback period are very close, demonstrating the real world accuracy and predictability of the modeling results.

SCENARIOS 1 AND 2: SIMULATED MODELED SAVINGS

In Scenario 1, the annual energy consumption is assumed to remain constant over the years assumed to remain at 2007 levels. This scenario simulates a simple payback calculation at the time of construction. The purpose of keeping the energy usage constant is to eliminate the effect from increases/decreases in usage primarily due to weather and occupancy from year to year so as to obtain a conservative estimate. The annual energy savings were calculated as 249,785 kWh. The payback period under Scenario 1, fixed tariff was calculated as 3.4 years. When the effect of annual increase in energy tariffs is taken into account, the payback from energy efficiency becomes significantly more attractive. Under Scenario 2, the simulated payback with an annually increasing tariff is 3.1 years.

FIGURE 3. SCENARIOS 1 & 2: ENERGY COST SAVINGS REALIZED BY SPECTRAL UNDER THE FIXED AND VARYING TARIFF CASES OVER TIME WHEN ENERGY CONSUMPTION IS ASSUMED TO REMAIN CONSTANT AT 2007 LEVELS OVER THE YEARS.

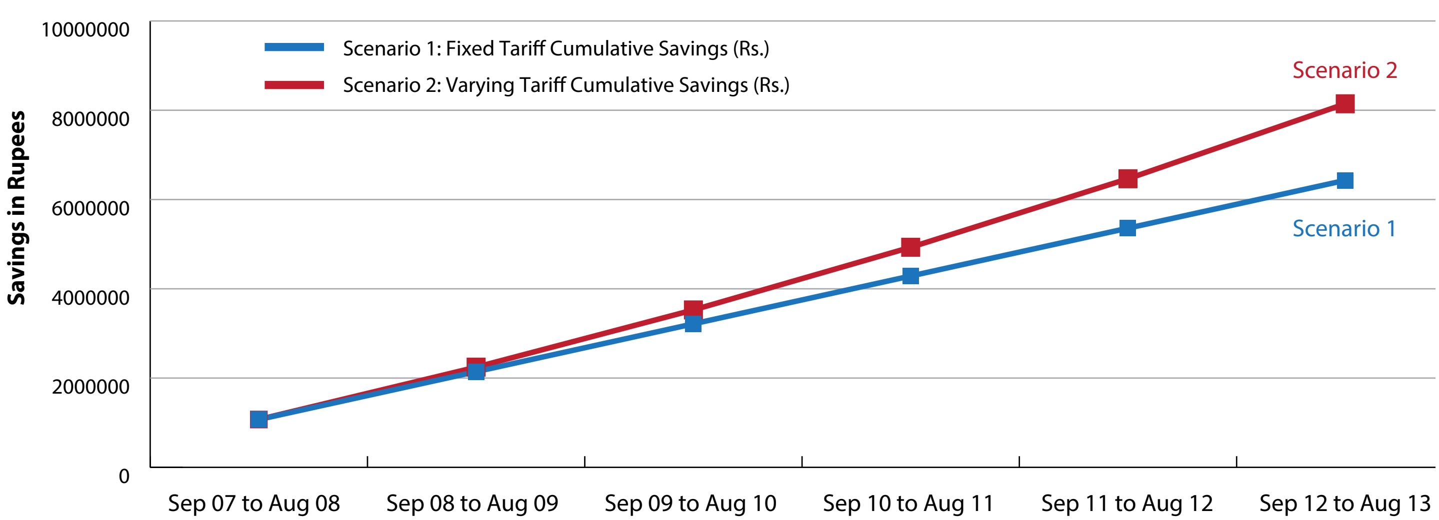
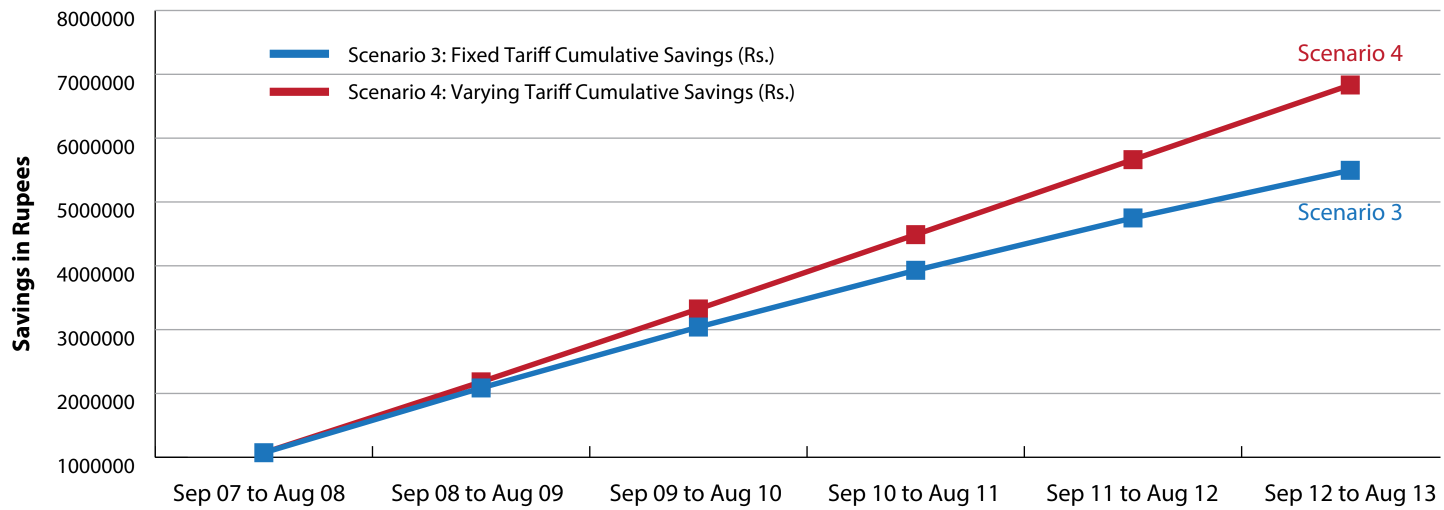


FIGURE 4. SCENARIOS 3 & 4: ENERGY COST SAVINGS REALIZED BY SPECTRAL OVER TIME UNDER FIXED AND VARYING TARIFFS ACCOUNTING FOR ESCALATING ENERGY USAGE BY SPECTRAL OVER THE YEARS



SCENARIOS 3 AND 4: ACTUAL SAVINGS

In scenario 3, the annual energy consumption of a conventional building is assumed to remain constant over the years, but actual energy consumption data is aggregated from monthly utility bills. The bill data shows an increase in Spectral's energy consumption over the years, as is also shown in Figure 2. Annual energy savings were calculated between 173,949 - 249,785 kWh. The payback period under fixed tariff (Scenario 3) was calculated as 3.7 years and under increasing tariff as 3.3 years (Scenario 4). To develop Scenarios 3 and 4, monthly energy consumption data from September 2007 to August 2013 was obtained from the buildings' monthly electricity bills and the building management system data.

ROBUSTNESS OF ANALYSIS OF THE FOUR SCENARIOS

The analysis of payback period was completed using energy billed data and BMS data from 2007 to 2013. In Scenario 1, having used data from Sep 2007 – Aug 2008 as constant across the years to establish a conservative estimate of payback period, it was required to confirm that the weather within that year was not particularly extreme possibly leading to an overestimation of the payback period. To confirm this was not the case, heating degree-days and cooling degree-days for each month between Sep 2007 – Aug 2008 were plotted and compared across the years. From this analysis, it was found that the Sept 2007- Aug 2008 was relatively mild leading to a conservative estimate in the payback period. Occupancy was another variable in the design that was controlled for in the case of Scenarios 1 and 2, by keeping the energy data constant across the years. As could be expected, occupancy and additional load within the Legacy Spectral building would increase over the years but since data regarding this increase in occupancy and additional loads were not available, keeping the actual consumption constant across the years is considered a conservative estimate of the savings.

Additionally, the analysis conducted did not include assessment of the costs that have been saved by Spectral due to decrease in consumption of diesel fuel and capital cost of the diesel generator (DG) during blackouts. Compared to a conventional building a reduced overall energy usage within the Legacy Spectral building would be expected to improve the payback period through a lower capital cost in a lower rated diesel generator set. Spectral has currently installed 100% DG backup through two 150 KVA diesel generators. The rating and capital cost required by a diesel generator for a conventional building could be expected to be higher therefore resulting in more savings for Spectral when compared to the conventional building.

Our analysis showed that under various scenarios, Spectral recovered their investments on energy efficiency in four years or less. The payback periods are shorter when energy consumption and tariffs are increasing over the years, which is closer to the real life scenario in this case. Spectral performed better than predictions, as the annual energy savings were between 39-56% when compared to a conventional building and between 31-50% when compared to a base case building.

NRDC AND ASCI'S BUILDING ENERGY-EFFICIENCY WORK

NRDC and ASCI are working to accelerate efficient building construction in India by engaging business and government leaders to unleash widespread implementation of energy-saving measures. We are engaging with real estate developers on a series of case studies that demonstrate the business case for energy efficiency.

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Researchers and authors: The Natural Resources Defense Council (NRDC) and Administrative Staff College of India (ASCI).

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AECOM

CREDAI

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Endnotes

1 Government of India, Planning Commission, (2013) "12th Five Year Plan" http://planningcommission.gov.in/plans/planrel/12thplan/welcome.html; See also, Government of India, Planning Commission, "India Energy Security Scenarios, 2047" (2014), http://indiaenergy.gov.in/ (accessed March 12, 2014)..

2 The Desktop Radiance software is developed by the Building Technologies Department of the Environmental Energy Technologies Division at the Berkeley Lab, with support from Pacific Gas & Electric Company (PG&E) through the California Institute for Energy Efficiency (CIEE), as part of PG&E's Daylighting Initiative for Market Transformation. The links to the AutoCAD Release 14 software are developed by MarinSoft. http://radsite.lbl.gov/deskrad/

3 Edwards, L. et al, NRL, "A Literature Review of the Effects of Natural Light on Building Occupants" (2002) http://www.nrel.gov/docs/fy02osti/30769.pdf.

4 The design case in Figure 2 shows a predicted 242,086 kWh of energy use as compared to the base case of 394,196 kWh of energy.

5 UNDP India Global Environment Facility Project Document – Energy Efficiency Improvements in Commercial Buildings. April 2011, http://www.undp.org/content/dam/india/docs/energy_efficiency_improvements_in_commercial_buildings_project_document.pdf (accessed Oct 1, 2013).

6 Monthly data from 2007 to 2013 indicated similar annual trends within each year with highs and lows during the same periods due to seasonal variation.