Project Summary

**Timeline:**

- **Start date:** October 2012
- **Planned end date:** September 2017

**Key Milestones:**

- Initiation of cool roof test apparatus experiments in 4 climates with the first set of materials – September 2015
- IBPSA BS2015 paper on Laser Cut Panels – September 2015
- ORNL-CEPT inter laboratory PCM test comparisons – June 2016

**Budget:**

**Total Project $ to Date:**
- DOE: $480k
- Cost Share: NA

**Total Project $:**
- DOE: $675K
- Cost Share: NA

**Key Partners:**

<table>
<thead>
<tr>
<th>Partner Name</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>International Institute of Information Technology, Hyderabad</td>
<td></td>
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<tr>
<td>Centre for Environmental Planning and Technology University (CEPT), Ahmedabad</td>
<td></td>
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<tr>
<td>Saint-Gobain Research India</td>
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<tr>
<td>Saint-Gobain/CertainTeed (USA)</td>
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<tr>
<td>Pluss Polymers</td>
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**Project Outcome:**

Enable rapid solar shading evaluation for fins, overhangs and awnings for designers. Evaluate the use of phase-change materials in mixed-mode buildings. Create infrastructure for cool-roofs and phase change materials in India that allows US manufacturers to sell their products in India.
Project Scope: Envelopes

- Heat transfer through the building envelope
  - Walls – phase change materials (PCM)
  - Roofs – cool roof materials
  - Windows – light redirection and solar reduction
  - Foundation – not addressed in this project
Project Team

- **US**
  - Lawrence Berkeley National Laboratory
    - Ronnen Levinson, Charlie Curcija, Robin Mitchell, Christian Kohler
  - Oak Ridge National Laboratory
    - Andre Desjarlais, Kaushik Biswas
  - DOE
    - Karma Sawyer, Chioke Harris, Brent Nelson
- **India**
  - CEPT Ahmedabad
    - Rajan Rawal, Yash Shukla, Agam Shah
  - IIIT-H Hyderabad
    - Vishal Garg, Hema Rallapalli, Sraavani G
  - Saint Gobain Research India
    - Rathish
Purpose and Objectives

Problem Statement:
• Mixed mode or unconditioned buildings are often not comfortable. Potential for phase change materials.
• Lack of cool roof standards and infrastructure in India.
• Evaluating the effect of non co-planar shading solutions (overhangs, awnings, fins) for windows is difficult.

Target Market and Audience: Code officials, architects, developers, and building owners that influence commercial and government building product selection in India. 2030 technical potential savings in India are 2.2 TWh/y site energy, 2.6 Mt/y CO$_2$ for cool roofs alone. US Manufacturers of cool roof and phase change materials and window shading.

Impact of Project: Create Indian cool roof and phase change walls infrastructure based on field experiments, simulation and rating assistance. Facilitate proper selection of solar shading solutions for windows and increase daylight use in Indian buildings. Support to DOE’s attachment ratings effort in the US. Allow US manufacturers to seamlessly sell their US rated products in India.
Approach: **Cool roofs**: Assess energy savings in Indian climates via simulation (Indian cool roof calculator), real-building experiment and test chamber in 4 climates. Natural exposure trials in 4 climates in India. **PCM**: Develop measurement infrastructure in India, perform field experiment. **Windows**: Assist with construction of measurement devices, collaborate on shading algorithm development.

**Key Issues**: Natural exposure trials takes 3 years, so completion of natural exposure and adaption of lab aging practice may follow end of CBERD.

**Distinctive Characteristics**: Field tests and software code development in India are much cheaper than in the US, leveraging Indian investment for US market benefits. Identical cool roof test chambers in four Indian climates permit controlled measurement of energy savings.
Efficiency in the Indian context

- With strong economic growth, urbanization and increased standard of living the per-capita energy consumption will grow rapidly
- Amory Lovins: Efficiency is the attitude: 'Do the same or more with less.'
Indian climates

![Cooling Degree Days]

- Ahmedabad: 6,000
- Chennai: 4,500
- Phoenix: 4,000
- New York: 1,000

Significant cooling load issues
Experiment sites

Cool-roof test chamber sites

Natural exposure sites (planned)
Cool roof test chambers in Bangalore showed 15% AC energy savings in July 2015

gray roof (albedo 0.30)  white roof (albedo 0.58)
Indian cool roof calculator can estimate energy savings in conditioned space or comfort improvement in unconditioned space

**Simple input**

**Output**
Progress and Accomplishments

Accomplishments: Built and calibrated **cool roof test chambers** at four sites; cool roof experiments underway for past 4 – 8 months. Indian cool roof energy savings / indoor comfort calculator online at [http://coolroof.cbs.iiit.ac.in/calculator_detailed.php](http://coolroof.cbs.iiit.ac.in/calculator_detailed.php).

Market Impact: (too early for market impact)

Lessons Learned: Logistics of real-building cool roof experiments proved especially challenging in India, so we built controllable test chambers to simulate core of office buildings.

Natural exposure testing
Phase Change Accomplishments

- Facilities now in place in India to monitor PCM performance. Comparison of results with US is ongoing.
- Field experiment is in progress

Measurement of performance of ceiling tiles made of new phase change materials in test bed, in naturally ventilated and forced ventilation modes.

Laboratory measurement of phase change materials.
Accomplishment: SHGC for non co-planar shading

- Calculate the SHGC of a window with and without a shade.
- Allow comparison of solar control low-e coatings and architectural features like fins, overhangs and awnings.
- Parametric calculations for >15 shading types, 4 orientations, 4 cities and 3 glazing types
- Based on EnergyPlus and Berkeley Lab WINDOW
- Will be incorporated into COMFEN
Accomplishments: Windows and Daylighting

• COMFEN India release:
  – Early design simulation tool developed by LBNL with DOE funding, adopted to Indian building types, schedules and HVAC systems by Indian team.
  – Allows wider proliferation of DOE supported software tools, and potential future software code contributions.
  – https://windows.lbl.gov/projects/CBERD/

• Regional Data Aggregator Framework released. This effort de-centralizes the collection, review and maintenance of glazing spectral data. Previously DOE funded at LBNL. The plan is that each region processes its own spectral data, and submits it to one international harmonized glazing database.

• Design assistance for a outdoor goniophotometer to properly characterize the solar and optical properties of Tubular Daylighting Devices.
Project Integration and Collaboration

**Project Integration:** Monthly conference calls between US and Indian teams

**Partners, Subcontractors, and Collaborators:** ORNL, IIIT-H, CEPT, SGRI, CertainTeed, Pluss Polymers.

**Communications:**
Papers presented at Urban Heat Island Countermeasures conference in Venice (Oct 2014) and Singapore (May 2016), and at ACEEE Summer Study (Aug 2016).
Next Steps and Future Plans:

• Develop lab aging practice for cool roofs in an Indian climate.
• Create web based calculator based on non co-planar shading algorithms
• Update cost data in COMFEN India
• Analyze results from phase change material field trial
REFERENCE SLIDES
Project Budget

**Project Budget**: $135K per year for FY13-17

**Variances**: NA

**Cost to Date**: Total funding received to date $480K, total cost to date $390K

**Additional Funding**: NA

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### Budget History

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<td><strong>DOE</strong></td>
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<td><strong>Cost-share</strong></td>
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* Total expected funding
# Project Plan and Schedule

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<thead>
<tr>
<th>Task 5: Building Envelopes</th>
<th>FY2013</th>
<th>FY2014</th>
<th>FY2015</th>
<th>FY2016</th>
<th>FY2017</th>
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<tr>
<td>5.1 - Advanced Building Materials</td>
<td>Q1 (Oct-Dec)</td>
<td>Q2 (Jan-Mar)</td>
<td>Q3 (Apr-Jun)</td>
<td>Q4 (Jul-Sep)</td>
<td>Q1 (Oct-Dec)</td>
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<tr>
<td>5.2 - Cool Roofs</td>
<td>Q2 (Jan-Mar)</td>
<td>Q3 (Apr-Jun)</td>
<td>Q4 (Jul-Sep)</td>
<td>Q1 (Oct-Dec)</td>
<td>Q2 (Jan-Mar)</td>
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<tr>
<td>5.3 - Windows and Daylighting</td>
<td>Q3 (Apr-Jun)</td>
<td>Q4 (Jul-Sep)</td>
<td>Q1 (Oct-Dec)</td>
<td>Q2 (Jan-Mar)</td>
<td>Q3 (Apr-Jun)</td>
</tr>
</tbody>
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**FY2016 Q1 Milestone:**
- 5.1 - Construction of Universal Goniometer – Part 1 (CEPT)
- 5.2 - Installation of products for weathering and aging experiment (IIT-H, CEPT)
- 5.2 - Energy simulation study for assessing the effect of cool roofs on energy use and thermal comfort (IIT-H)

**FY2016 Q2 Milestone:**
- 5.1 - Regional Data Aggregator - Phase 1
- 5.3 - Construction of Universal Goniometer – Part 2 (CEPT)

**FY2016 Q3 Milestone:**
- 5.1 - Regional Data Aggregator - Phase 2
- 5.2 - Reporting the results of field experiments
  - In real buildings (IIT-H)
  - In controlled experiment with first set of materials (SGRI)

**FY2016 Q4 Milestone:**
- 5.1 - Field tests for PCMs in one climate zone.
- 5.3 - ORNL-CEPT inter laboratory PCM test comparisons

**FY2017 Q1 Milestone:**
- 5.2 - Initiation of experiments with the second set of materials for the cool roof test apparatus

**FY2017 Q2 Milestone:**
- 5.2 - Analysis of preliminary data from the weathering and aging studies (IIT-H, CEPT)

**FY2017 Q3 Milestone:**
- 5.2 - Analysis of preliminary data from the weathering and aging studies (IIT-H, CEPT)
- 5.3 - Testing of daylight devices such as TDD, LCP for development of test protocol – Part 1