# Cool Roof Activities in India

Vishal Garg
IIIT Hyderabad
India

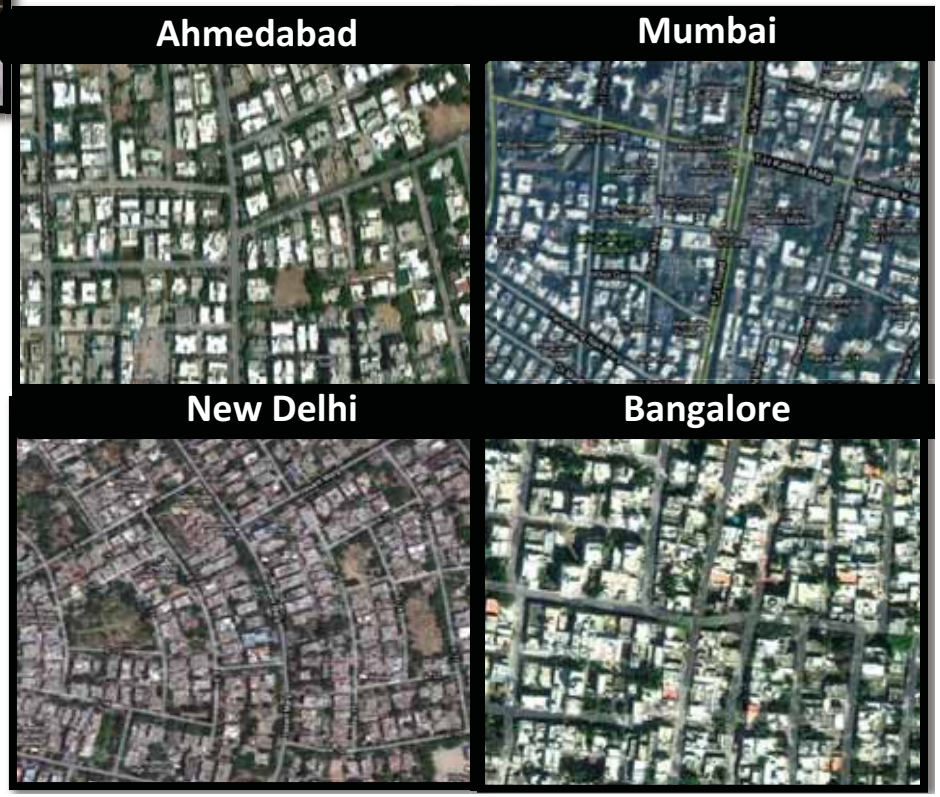
# Contents

- Introduction
- Field Performance Cool Roofs
- Cool Roof Demonstration Project – SLC
- Online Cool Roof Calculator
- Effect of Cool Roof on Requirement of Roof Insulation Thickness in Office Buildings
- Calibrated Simulation
- Projects in pipeline

# Relevance of cool roofs in India

- Use of broken china mosaic and lime wash in traditional Indian roofs

- Traditional Knowledge
- Increasing awareness
- Development of codes and other voluntary programs



# Technology Scope

Cool Roof technology would be effective in almost 90% of the Indian region. It has wide scope of being an effective energy savings solution for both new and retrofit buildings.

# Policy and Code Bodies

- ECBC-2007 - Bureau of Energy Efficiency (BEE)
- LEED India- Indian Green Building Council (IGBC)
- GRIHA - The Energy and Research Institute (TERI/ MNRE)

# Energy Conservation Building Code (ECBC- 2007)

- The Energy Conservation Building Code (ECBC) of 2007 in India makes a mention of cool roof and its testing standard.
- The code states that if a project follows the prescriptive method, then it is necessary to have a cool roof.
- The code allows using high reflectivity in energy simulation when the project takes the whole building performance method.
- The code does not specify the cool roof requirements based on the climatic region, but as a whole specifies the requirements of a cool roof.

# ECBC 2007

- "Roofs with slopes less than 20 degrees shall have an initial solar reflectance of no less than 0.70 and an initial emittance no less than 0.75.
- Solar reflectance shall be determined in accordance with ASTM E903-96 and emittance shall be determined in accordance with ASTM E408-71 (RA 1996)."

# Indian Green Building Council - IGBC

- Use roofing materials with a solar reflectance index (SRI) equal to or greater than the values in the table below for a minimum of 75% of the roof surface. Roofing materials having a lower SRI value than those listed below may be used if the weighted rooftop SRI average meets the following criteria: ***Credit - Heat Island effect: Roof***

$$\frac{\text{Area of Roof Meeting Minimum SRI}}{\text{Total Roof Area}} \times \frac{\text{SRI of Installed Roof}}{\text{Required SRI}} \geq 75\%$$

| Roof Type | Slope | SRI |
|---|---|---|
| Low-sloped roof ≤ | 2:12 (15%) | 78 |
| Steep-sloped roof | > 2:12 (15%) | 29 |

Refers to Cool Roof Rating Council for product information. Default value in IGBC

# GRIHA

- more than 50% of the paved area to have pervious paving/open-grid pavement/ grass paver or
- a minimum 50% of the paved area (including parking) to have shading by vegetated roof/pergola with planters or
- a minimum 50% of the paved area (including parking) to be topped with finish having solar reflectance of 0.5 or higher.

# Testing Standard

| | |
|---|---|
| Standards referred in ECBC | ASTM E903-96, ASTM E408-71 (RA 1996) |
| Standards referred in LEED India | ASTM Standard E1980-01, ASTM E408-71 (1996) e 1, ASTM E903-96, ASTM E1918-97, ASTM C1371-04, ASTM C1549-04 |
| Standards referred by Green Rating for Integrated Habitat Assessment (GRIHA) | The GRIHA rating system takes into account the provisions of the National Building Code 2005; the Energy Conservation Building Code 2007 announced by BEE (Bureau of Energy Efficiency) and other IS codes |

# Infrastructure

- No approved laboratory to test cool roof products
- No rating organization
- Effort ongoing to establish a testing center and a Rating organization for cool roof
- Testing center at International Institute Information Technology at Hyderabad IIIT-H

# Field Performance and Savings Potential of Cool Roofs in India at IIIT Hyderabad

# Field Performance Evaluation of Cool Roofs, an installation in Hyderabad

Acrylic Resin Coating

Glossy Tiles

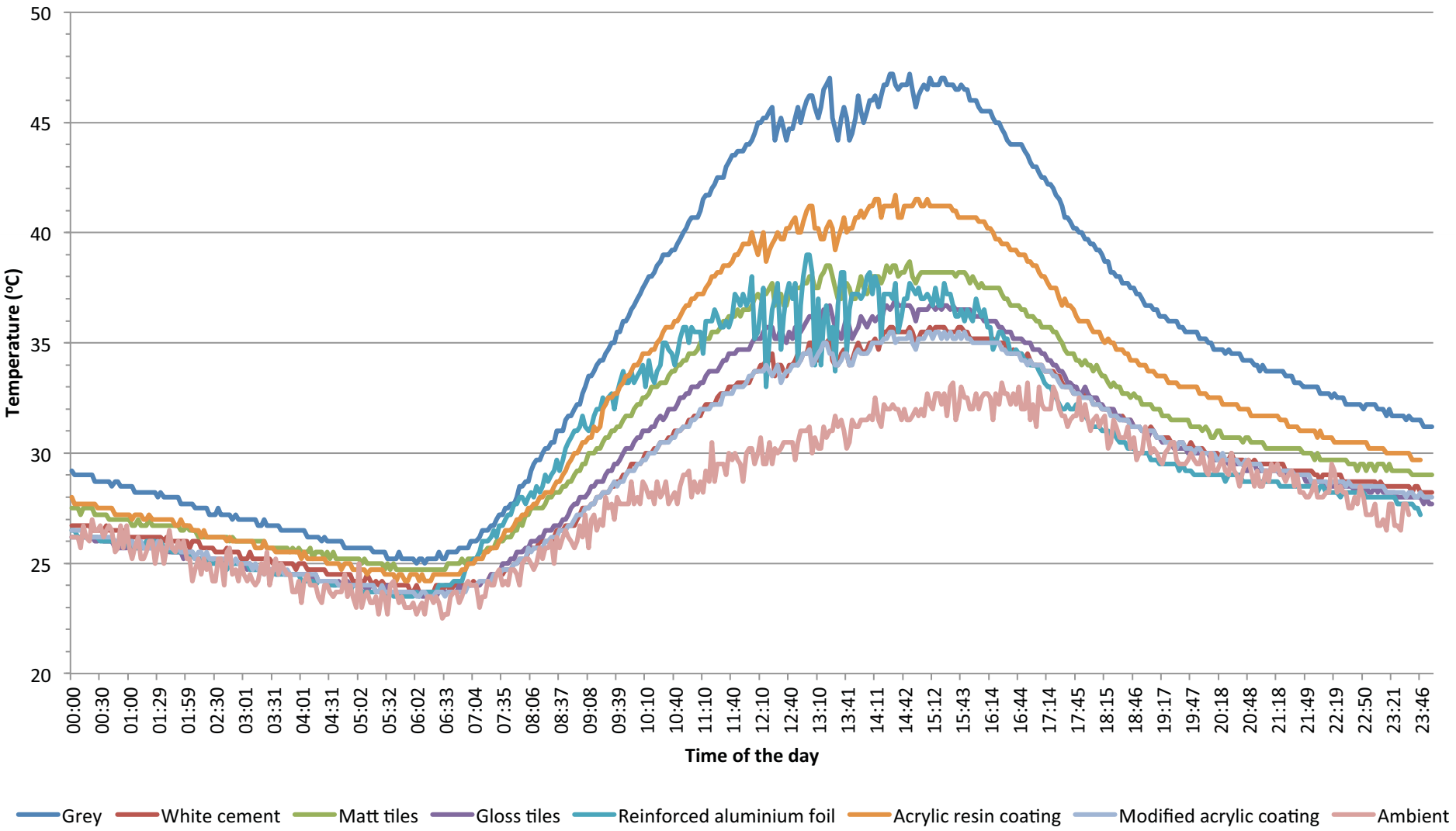
Modified Acrylic Coating

Reinforced Aluminum Coating

Matt Tiles

- Ambient air temperature : 27.93 °C

| Roof type | Average Surface Temperature (°C) in 24 hours |
|---|---|
| Acrylic Resin Coating | 32.18 |
| Modified Acrylic Coating | 29.16 |
| Matt Tiles | 30.93 |
| Glossy Tiles | 29.59 |
| Reinforced Aluminum coating | 30.01 |
| Grey | 34.86 |




- Performance of various cool roof products over a period of 24 hours in month of June in Hyderabad.

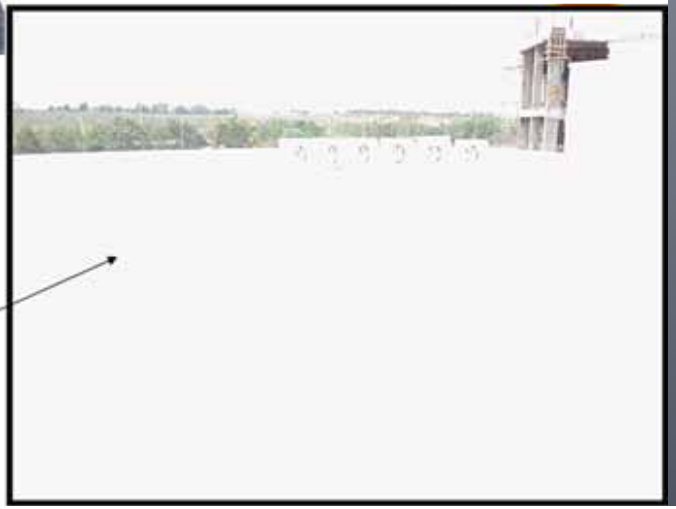
# Cool roof demonstration project – SLC

Applying the hot and cool roof

Existing gray roof

One coat of black roof on East bldg.

Three coats of cool roof on West bldg.



# Introduction

- Sponsor
  - USAID
- Collaborators
  - LBNL
  - SPM Thermoshield (USA and India)
  - Satyam
  - IIIT Hyderabad


- Monitoring the effect of cool roof on cooling energy consumption
- Experiment Site: Satyam Learning Centre, Hyderabad (Composite Climate)

IIIT-HYD

USAID
FROM THE AMERICAN PEOPLE

THERMOSHIELD

BERKELEY LAB

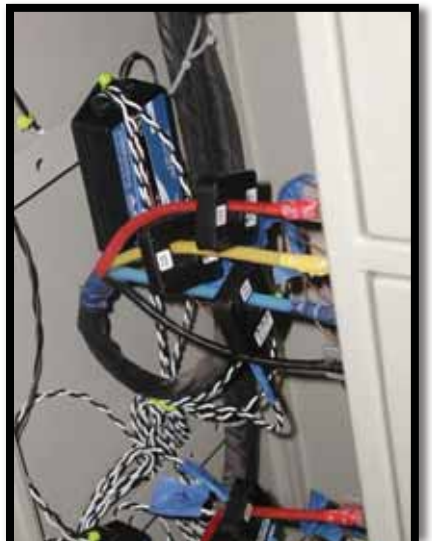
# The Buildings

## Satyam Learning Center (Hyderabad)

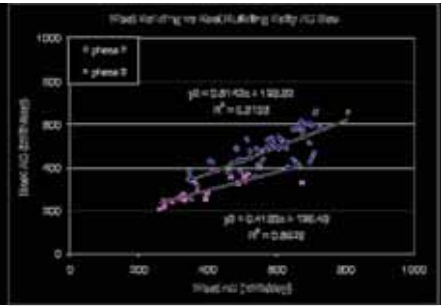
Two almost identical buildings – West Bldg and East Bldg

# About the experiment: Monitoring points


- **Weather:** Wind speed, outdoor temperature and relative humidity, solar flux
- **Energy:** Whole-building electricity use, cooling-electricity use, heat flux through roof
- **Temperature:** Roof surface, roof underside, plenum air, inside air, return air

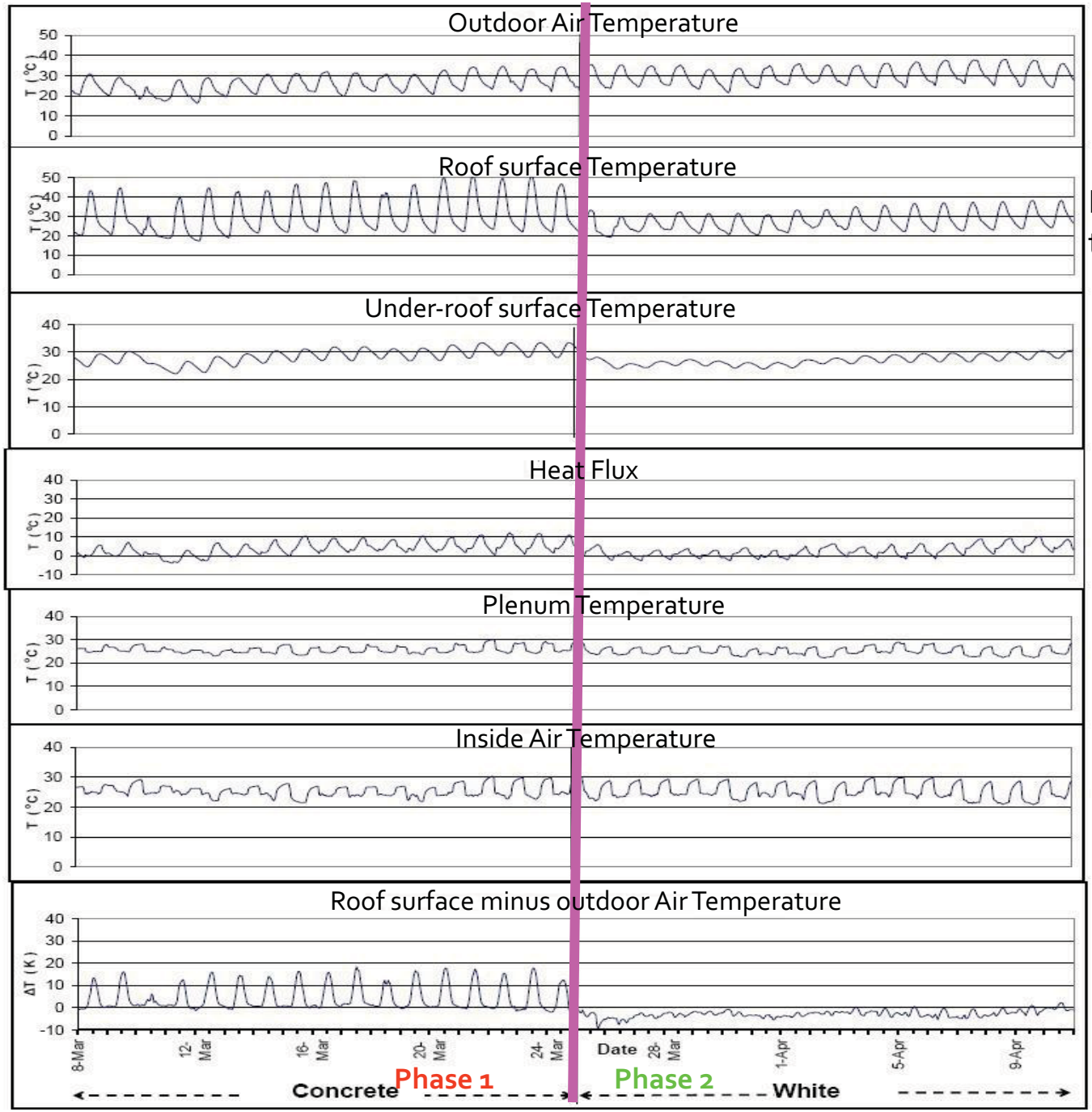


# About the experiment: Monitoring periods



| Period | Dates | West Building Roof | East Building Roof |
|---|---|---|---|
| | 13-15 January 2006 | Monitoring equipment installed | Monitoring equipment installed |
| **Phase I** | 16 January 16 to 22 March, 2006 | Concrete roof | Concrete Roof |
| | 23-26 March 2006 | White coating of roof | Black coating of roof |
| **Phase II** | 27 March to 22 July 2006 | Cool roof | Hot roof |
| | 23 July to 3 August 2006 | | White coating of roof |
| **Phase III** | 4 August to 16 December 2006 | Cool roof | Cool roof |

# Measurements for the Phase 1 & 2 – West bldg




Drop in surface temp by 20 °C

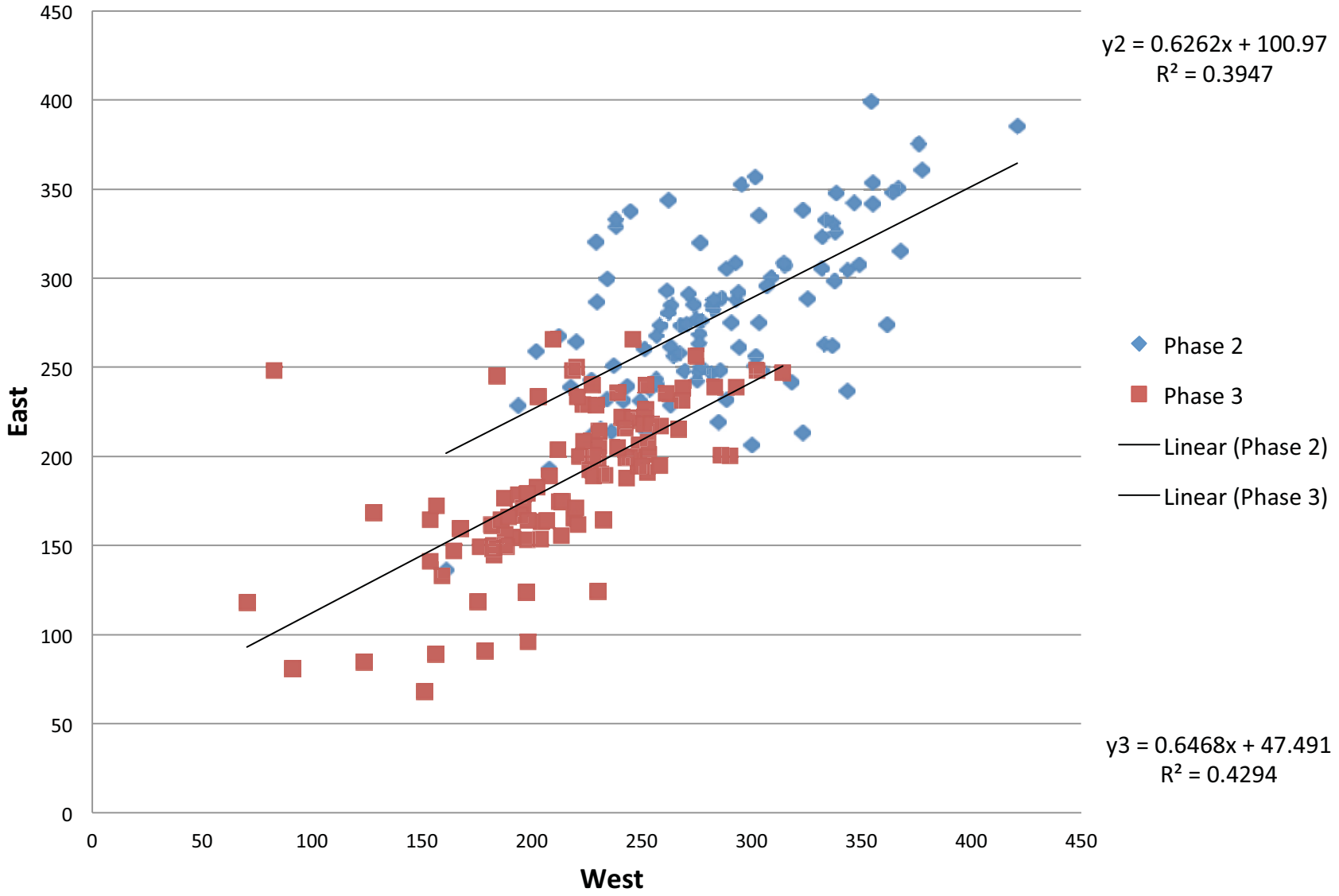
Drop in Underside temp by 10 °C

Drop in H.F by 8 W/m²

Drop in Plenum temp by 4 °C

Roof surface Temp is equal to or < than ambient Temp

# Analysis of data collected onsite



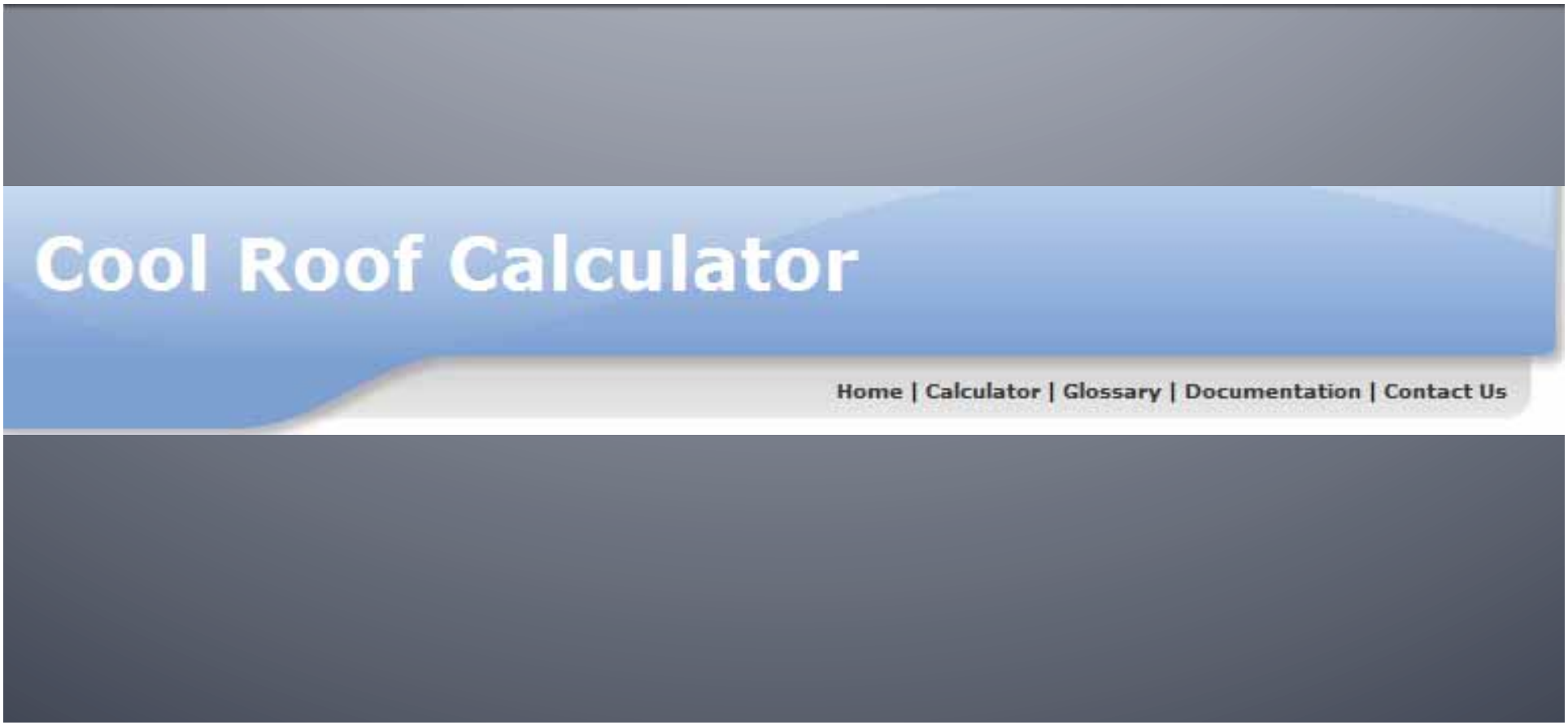

Pre- and post-coating comparison of air-conditioning energy usage for both buildings (two phases) considering 9am-5pm data for 267 days

# Energy Savings

| black to white (0.70-0.10 = 0.60) | | | | |
|---|---|---|---|---|
| | | | | |
| Annual savings kWh/$m^2$ | 20 | 22 | | |
| Percentage Savings | 14% | 26% | | |

| concrete to white (0.70-0.30 = 0.40) | | | | |
|---|---|---|---|---|
| | | | | |
| Annual savings kWh/$m^2$ | 13 | 14 | | |
| Percentage Savings | 10% | 19% | | |

# Development of an Online Cool Roof Calculator



# Introduction

## http://coolroof.cbs.iiit.ac.in

- Existing cool roof calculator
  - DOE Cool Roof Calculator
  - Roof Savings Calculator
- Developed by IIIT Hyderabad
- Funding agency: ClimateWorks Foundation
- Project scope: Development of the tool and hosting
- Compared to other existing tools
  - performs online simulation
  - works on EnergyPlus engine
  - capable of modelling an un-conditioned space
  - generates thermal comfort results
  - does payback analysis
  - works for all major Indian cities

# EnergyPlus Templates

- Five main templates based on the schedule of occupancy
  - Office
  - Institutional
  - Retail
  - Residential (All Day)
  - Residential (Only Night)

Library includes

- 60 weather files
- Roof area ranging between 130 $m^2$ -20,000 $m^2$
- Five common roof types
- 10 different roofing material
- 13 different roof external finish material
- Three types of AC
- Unconditioned building
- WWR, Cost, Internal loads as user inputs

# About the tool – Inputs


- Simple
  - Location
  - Building type
  - Roof Area
  - Roof type
  - Roof external finish
  - HVAC system
  - Electricity rate
- Detailed
  - Location
  - Building type
  - Roof area
  - Roof type
  - Roof external finish
  - HVAC details
  - Internal loads
  - Window area
  - Electricity rate

# Output Table

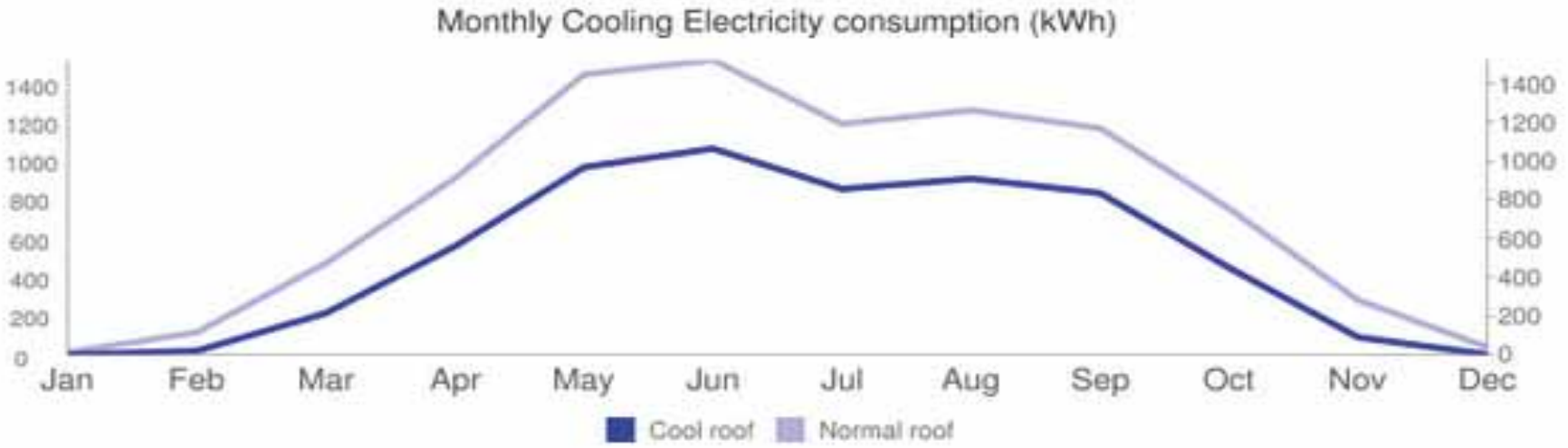
The annual savings achieved due to cool roof specified by you as compared to normal roof, specified by you is **2,703 kWh**, which results in an annual savings of ₹ **16,217**

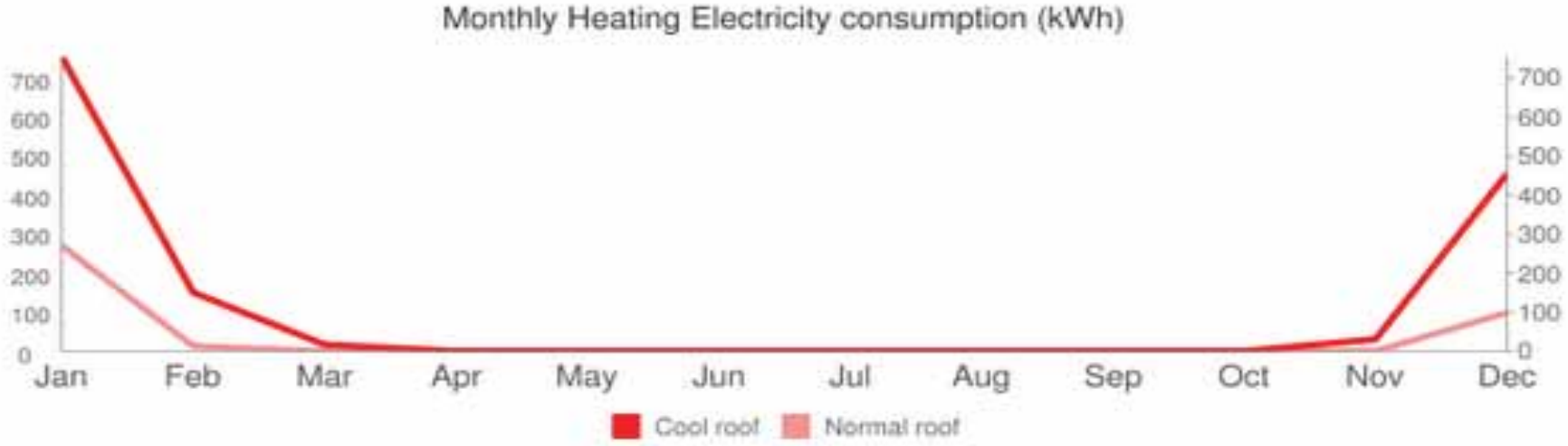
| | Total savings (kWh/year) | Savings per unit area (kWh/$m^2$ per annum) | Saving in cost (INR/year) |
|---|---|---|---|
| Savings in cooling | 3,214.00 | 24.72 | ₹ 19,284.00 |
| Savings in heating | -1,023.78 | -7.88 | ₹ -6,142.68 |
| Overall savings | 2,702.76 | 20.79 | ₹ 16,216.56 |
| Note: Negative value means loss | | | |

- Overall savings in HVAC
- Cooling and heating energy savings
- Savings in cost
- Energy consumption facility wise comparison
- Annual percentage savings

| EndUseCategory | Electricity [kWh] | | % Saving |
|---|---|---|---|
| | Normal roof | Cool roof | |
| Heating | 383.33 | 1407.11 | -267.08 |
| Cooling | 9176.60 | 5962.60 | 35.02 |
| Interior Lighting | 2920.34 | 2920.34 | 0.00 |
| Interior Equipment | 4367.00 | 4367.00 | 0.00 |
| Fans | 1576.82 | 1064.28 | 32.50 |
| Pumps | 0.00 | 0.00 | 0 |
| Heat Rejection | 0.00 | 0.00 | 0 |
| Total | 18424.09 | 15721.33 | 14.67 |

# Output Graphs

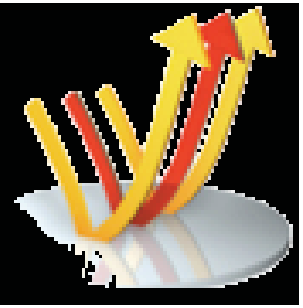


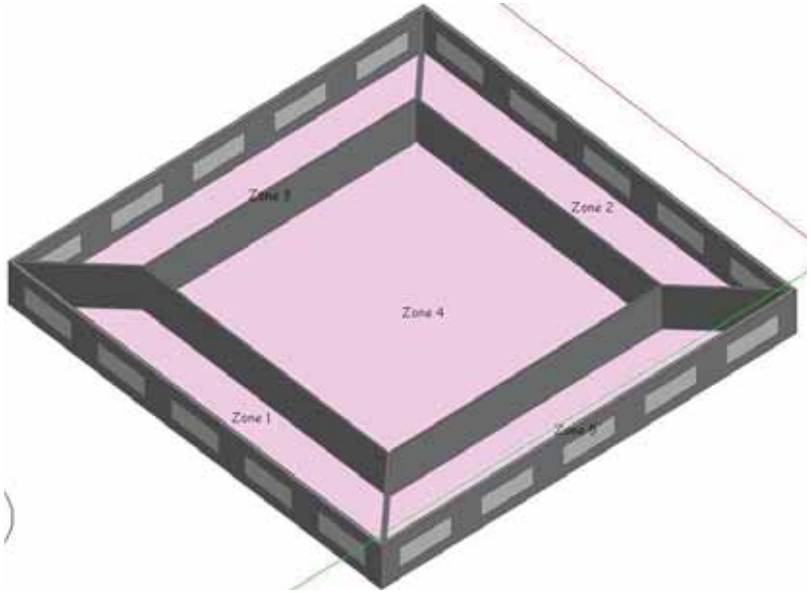

In 10 years, extra cost of material for Cool roof is Rs. 800
and savings in these years is 207.9 kWh/$m^2$ (i.e. Rs. 1247.43)

Simple payback is: 6.41 years

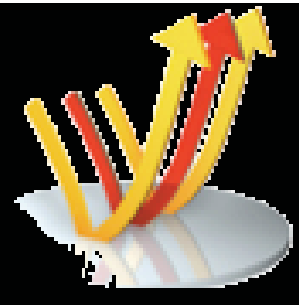
# Savings Potential of Cool Roofs in India : About the model



- 900 $m^2$ conditioned floor area
- A square shaped building
- Single storey
- Perimeter and core zoning
- Office schedules and activities
- Equipment power density:15 W/ $m^2$
- Lighting power density: 10.8 W/ $m^2$
- Occupancy density: 0.11 person/$m^2$
- Window to wall ratio: 30%
- Single Glaze 6mm glass with SHGC of 0.25
- RCC framed structure with brick wall
- Air Cool chiller with COP of 3

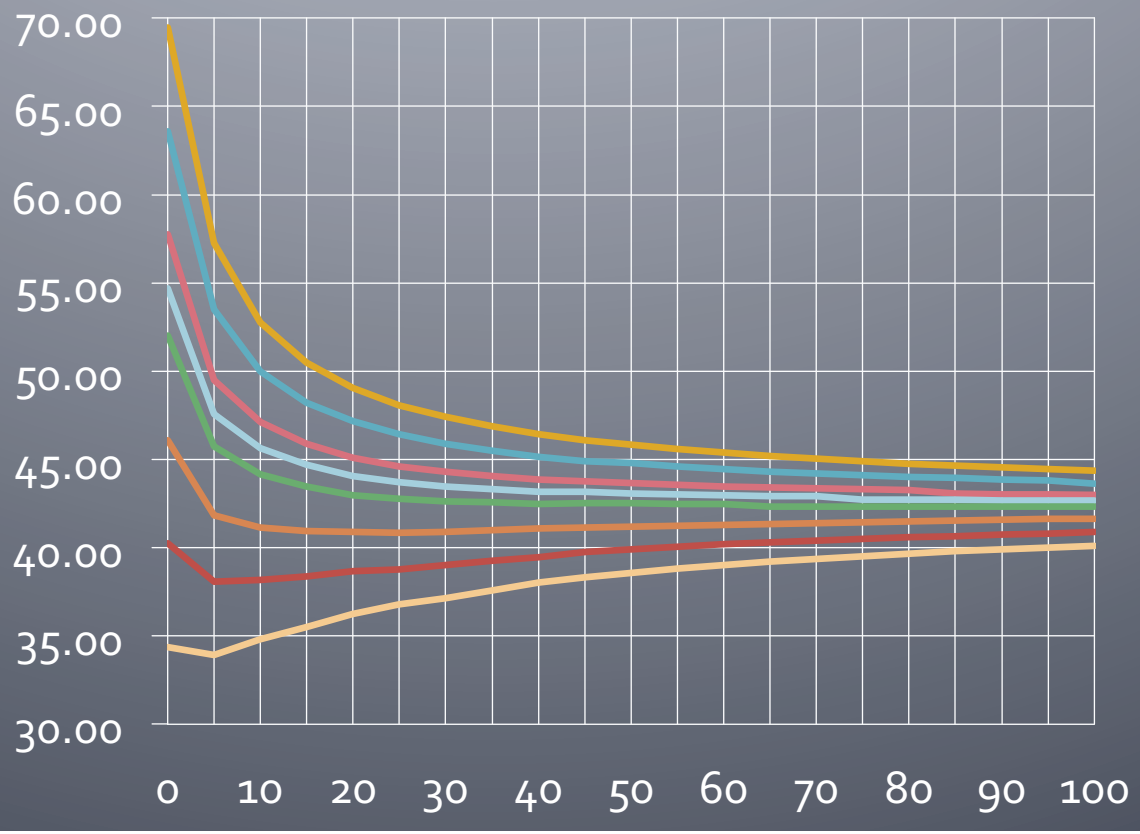


# Savings Potential of Cool Roofs in India



| | Roof without Insulation (kWh/sq m/ annum) | Roof with Insulation (kWh/sq m/ annum) |
|---|---|---|
| Hyderabad | 15.69 | 2.86 |
| New Delhi | 16.28 | 3.01 |
| Mumbai | 16.79 | 3.13 |
| Bengaluru | 16.48 | 3.07 |
| Chennai | 18.48 | 3.32 |

# Effect of Cool Roof on Requirement of Roof Insulation Thickness in Office Buildings in India – A study at IIIT Hyderabad



# Introduction

- Effect of roof insulation on energy consumption
- Effect of roof reflectivity on energy consumption
- The Energy Conservation Building Code of India
- The study targets:
  - Understand the combined effect of roof reflectivity and roof insulation in day time office buildings in India
  - Understanding the ECBC requirements for roof reflectivity and U value ( 2.445 W/ $m^2$ K)
- Simulation variables:
  - SR: 0.2-0.8 at 0.1 step
  - Roof insulation thickness: 0mm-100mm, at a step of 5mm

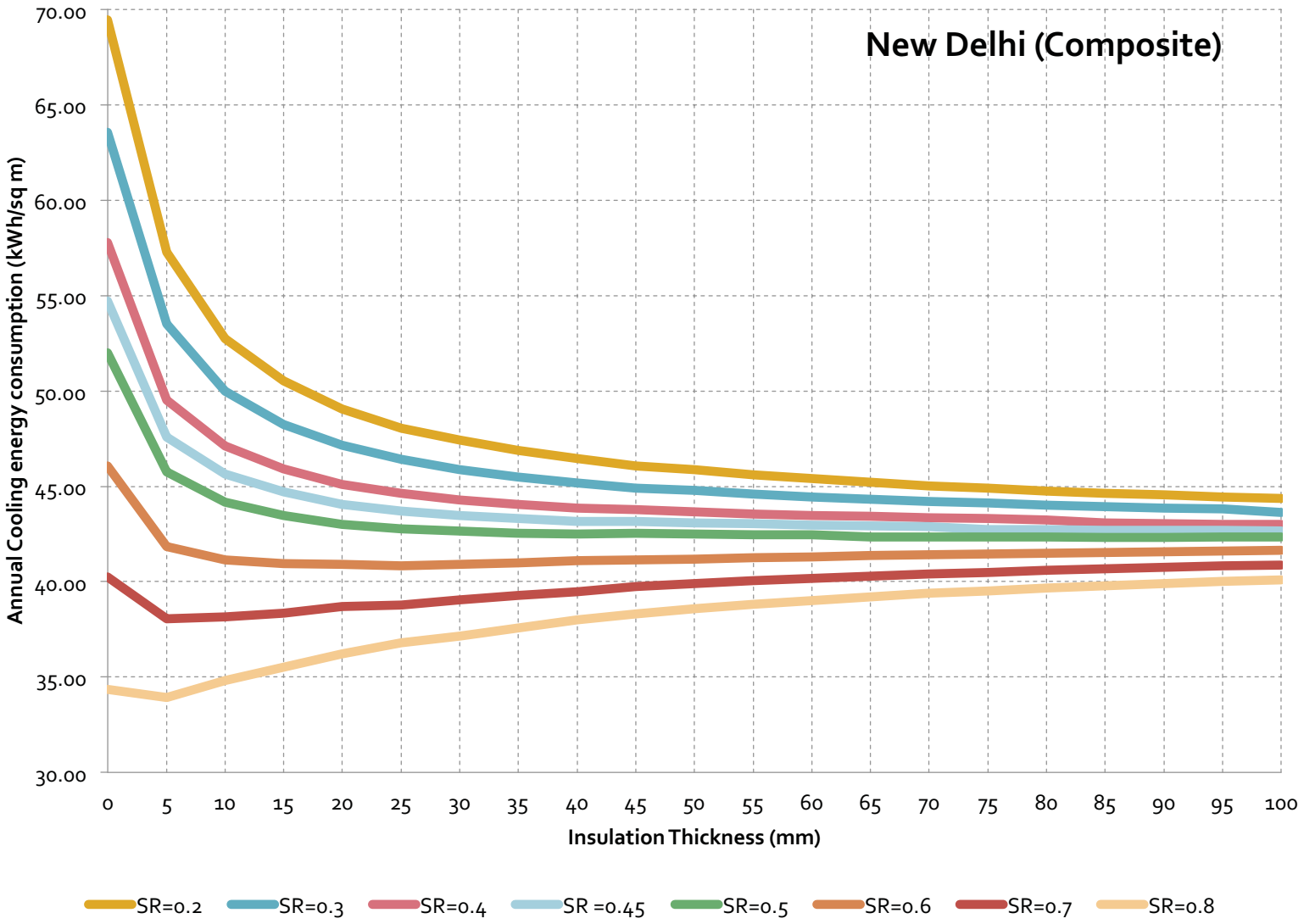
# About the simulation model

| Variable | Units | Input |
|---|---|---|
| Location | - | 5 different climates (as per ECBC climatic zone classification) |
| Geometry | Meters | Square (14.4 x 14.14) |
| Floor area | Square meters | 200 |
| **Activity & Internal Loads** | | |
| Usage | | Office |
| Occupancy schedule | | Day time use building |
| Working days per week | | 5 |
| Occupancy load | $m^2$ /person | 14 |
| Equipment power density | W/ $m^2$ | 16.15 |
| Lighting power density | W/ $m^2$ | 10.8 |
| Infiltration | ACH | Perimeter zones: 0.2<br>Core Zones: 0.1 |

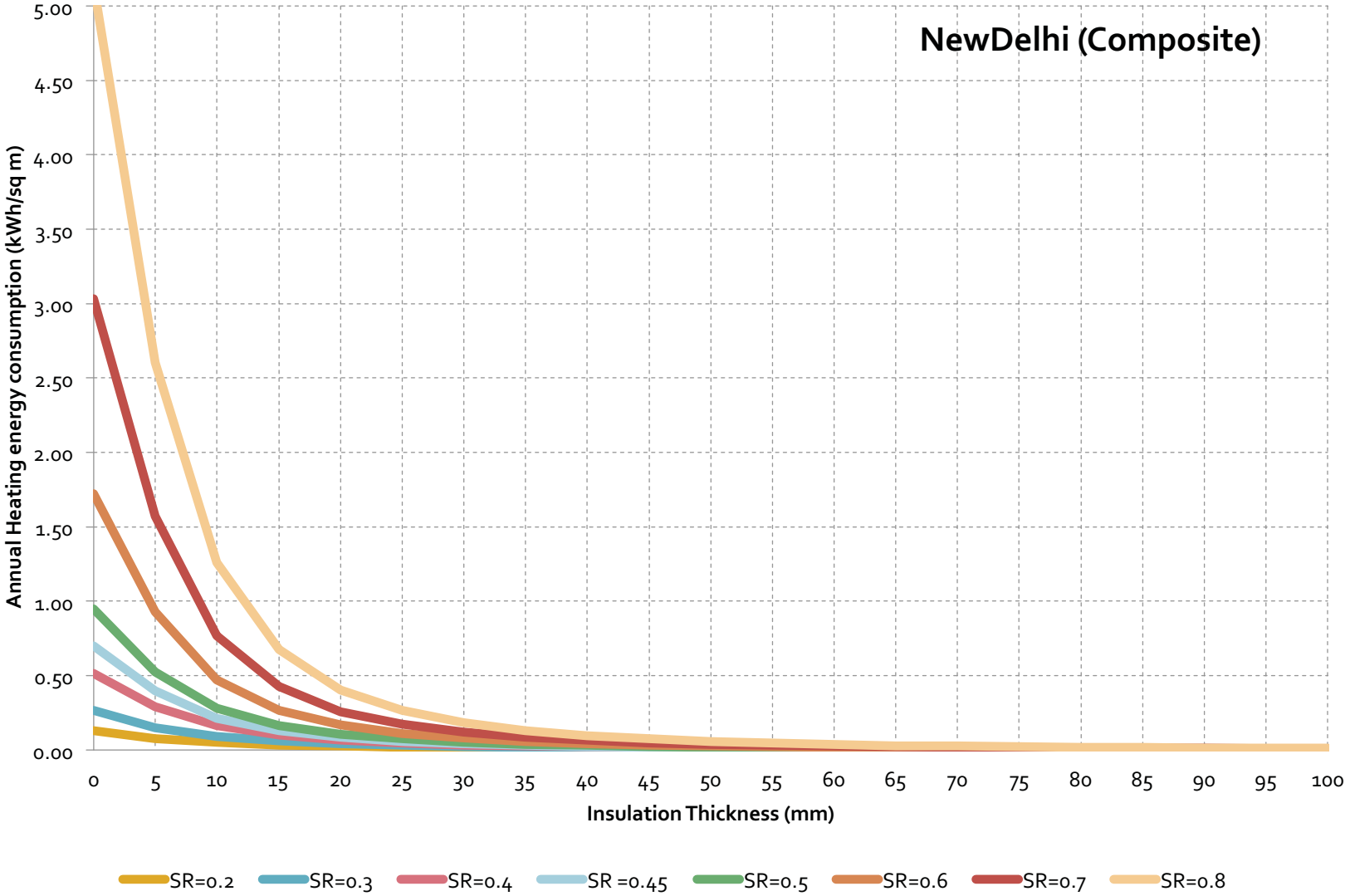
# About the simulation model

| Variable | Units | Input |
|---|---|---|
| **Construction** | | |
| External wall U value | W/ m2K | 0.44 (Mass wall: Insulated brick wall) |
| Roof U value | W/ m2K | Varies with insulation (Mass roof: RCC roof with varying insulation thickness, insulation above deck) |
| **Openings** | | |
| Glazing type | | Single glazing |
| U value of fenestration | W/ m2K | 3.3 |
| SHGC | | 0.25 |
| Light transmission | | 0.2 |
| **HVAC** | | |
| Type | | PTAC (Packaged terminal air conditioner) |
| Heating COP | W/W | 1.0 (Electrical) |
| Cooling COP | W/W | 3.0 |
| Heating temperature setpoint | Deg C | 20 |
| Cooling temperature setpoint | Deg C | 25 |

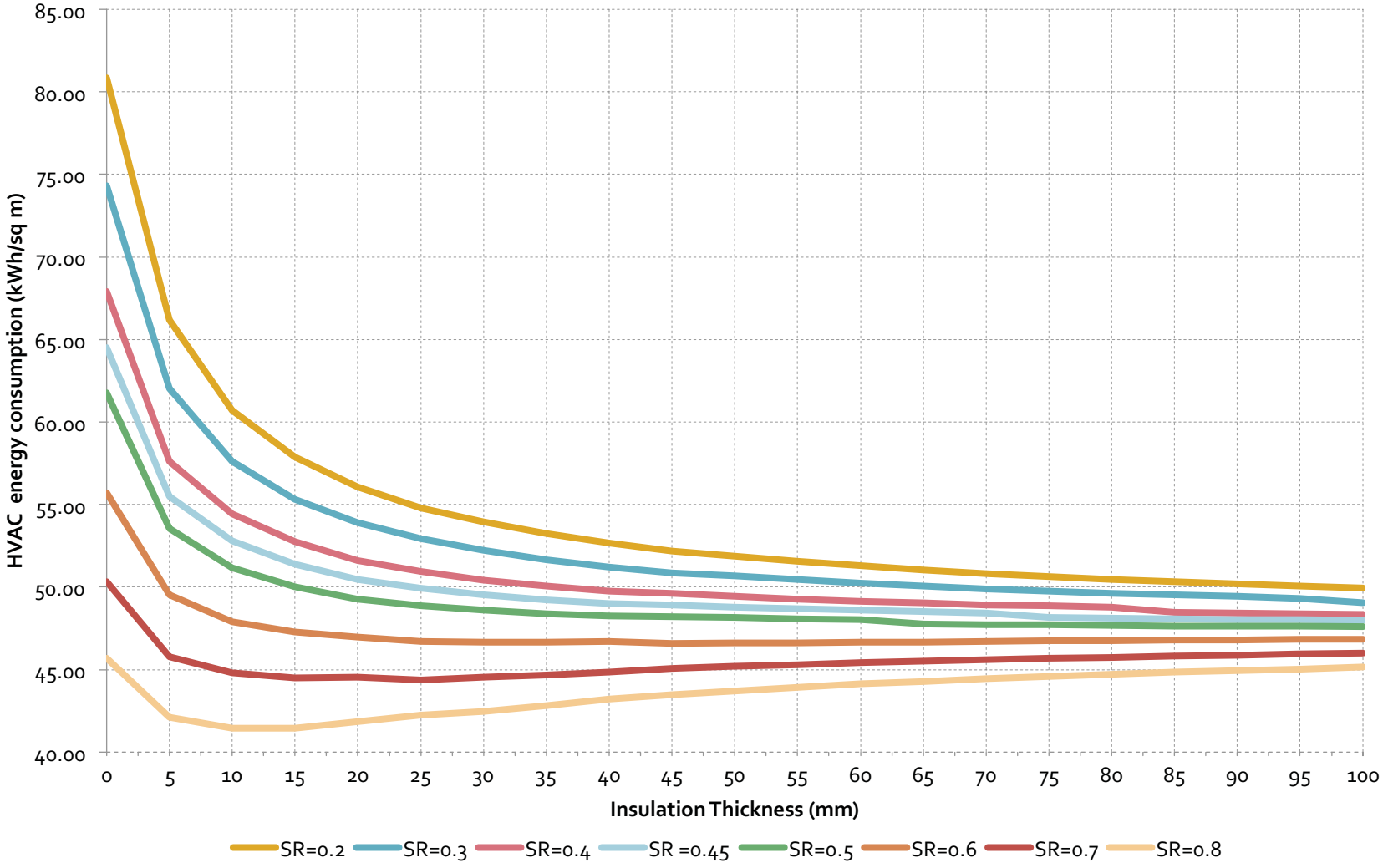
# Results: Cooling Energy Consumption



# Results: Heating Energy Consumption



# Results: Overall HVAC Energy Consumption



# Cost savings per year due to savings in HVAC energy consumption, and a simple payback period, for a roof with SR 0.45

| Insulation Thickness (mm) | Cost of Insulation (INR) | Ahmedabad | | Bangalore | | Mumbai | | NewDelhi | | Shillong | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Savings/ yr (INR) | Payback (years) | Savings/ yr (INR) | Payback (years) | Savings/ yr (INR) | Payback (years) | Savings/ yr (INR) | Payback (years) | Savings/ yr (INR) | Payback (years) |
| 5 | 40 | 57 | 0.70 | 43 | 0.92 | 43 | 0.93 | 54 | 0.74 | 22 | 1.79 |
| 10 | 80 | 75 | 1.07 | 55 | 1.47 | 56 | 1.43 | 70 | 1.14 | 35 | 2.26 |
| 15 | 120 | 85 | 1.42 | 59 | 2.03 | 63 | 1.90 | 79 | 1.52 | 44 | 2.74 |
| 20 | 160 | 92 | 1.74 | 62 | 2.60 | 67 | 2.39 | 84 | 1.90 | 49 | 3.25 |
| **25** | **200** | **96** | **2.08** | **63** | **3.17** | **70** | **2.84** | **88** | **2.28** | **53** | **3.79** |
| **30** | **240** | **100** | **2.41** | **64** | **3.73** | **73** | **3.31** | **90** | **2.67** | **55** | **4.37** |
| 35 | 280 | 101 | 2.76 | 65 | 4.30 | 74 | 3.78 | 92 | 3.05 | 56 | 4.98 |
| **40** | **320** | **104** | **3.07** | **66** | **4.87** | **76** | **4.22** | **93** | **3.44** | **57** | **5.59** |
| 45 | 360 | 106 | 3.40 | 66 | 5.44 | 77 | 4.69 | 94 | 3.85 | 58 | 6.25 |
| **50** | **400** | **107** | **3.73** | **67** | **6.00** | **78** | **5.14** | **94** | **4.24** | **58** | **6.92** |
| 55 | 440 | 109 | 4.05 | 67 | 6.57 | 78 | 5.62 | 95 | 4.63 | 58 | 7.60 |
| 60 | 480 | 108 | 4.45 | 67 | 7.13 | 79 | 6.09 | 96 | 5.02 | 58 | 8.30 |
| 65 | 520 | 109 | 4.78 | 68 | 7.70 | 79 | 6.55 | 96 | 5.41 | 58 | 9.01 |
| 70 | 560 | 110 | 5.11 | 68 | 8.27 | 80 | 7.01 | 96 | 5.80 | 58 | 9.73 |
| **75** | **600** | **110** | **5.44** | **68** | **8.84** | **80** | **7.48** | **98** | **6.11** | **57** | **10.46** |
| 80 | 640 | 112 | 5.74 | 68 | 9.40 | 81 | 7.94 | 98 | 6.50 | 57 | 11.19 |
| 85 | 680 | 112 | 6.07 | 68 | 9.97 | 81 | 8.41 | 99 | 6.89 | 57 | 11.94 |
| 90 | 720 | 113 | 6.40 | 68 | 10.54 | 81 | 8.88 | 99 | 7.28 | 57 | 12.69 |
| 95 | 760 | 113 | 6.73 | 68 | 11.10 | 81 | 9.34 | 99 | 7.67 | 57 | 13.44 |
| 100 | 800 | 113 | 7.05 | 69 | 11.67 | 82 | 9.81 | 99 | 8.06 | 56 | 14.20 |

# Cost savings per year due to savings in HVAC energy consumption, and a simple payback period, for a roof with SR 0.6

| Insulation Thickness (mm) | Cost of Insulation (INR) | Ahmedabad | | Bangalore | | Mumbai | | NewDelhi | | Shillong | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Savings/ yr (INR) | Payback (years) | Savings/ yr (INR) | Payback (years) | Savings/ yr (INR) | Payback (years) | Savings/ yr (INR) | Payback (years) | Savings/ yr (INR) | Payback (years) |
| 5 | 40 | 34 | 1.16 | 23 | 1.77 | 23 | 1.73 | 37 | 1.07 | 29 | 1.38 |
| 10 | 80 | 42 | 1.91 | 24 | 3.40 | 28 | 2.90 | 47 | 1.71 | 46 | 1.74 |
| 15 | 120 | 46 | 2.64 | 23 | 5.32 | 28 | 4.22 | 51 | 2.36 | 57 | 2.10 |
| 20 | 160 | 48 | 3.34 | 21 | 7.56 | 29 | 5.47 | 52 | 3.05 | 64 | 2.51 |
| **25** | **200** | **49** | **4.06** | **20** | **10.05** | **30** | **6.66** | **54** | **3.71** | **68** | **2.94** |
| **30** | **240** | **50** | **4.78** | **19** | **12.81** | **30** | **8.03** | **54** | **4.42** | **71** | **3.39** |
| 35 | 280 | 51 | 5.50 | 18 | 15.72 | 30 | 9.41 | 54 | 5.15 | 73 | 3.86 |
| **40** | **320** | **51** | **6.22** | **17** | **18.82** | **30** | **10.84** | **54** | **5.91** | **74** | **4.35** |
| 45 | 360 | 50 | 7.18 | 16 | 22.08 | 29 | 12.26 | 55 | 6.57 | 74 | 4.85 |
| **50** | **400** | **50** | **7.92** | **16** | **25.47** | **29** | **13.69** | **55** | **7.31** | **74** | **5.38** |
| 55 | 440 | 51 | 8.67 | 15 | 28.97 | 29 | 15.14 | 55 | 8.07 | 74 | 5.91 |
| 60 | 480 | 51 | 9.42 | 15 | 32.61 | 29 | 16.59 | 54 | 8.82 | 74 | 6.46 |
| 65 | 520 | 51 | 10.18 | 14 | 36.34 | 29 | 17.94 | 54 | 9.58 | 74 | 7.02 |
| 70 | 560 | 51 | 10.93 | 14 | 40.23 | 29 | 19.40 | 54 | 10.35 | 74 | 7.59 |
| **75** | **600** | **52** | **11.51** | **14** | **44.12** | **29** | **20.88** | **54** | **11.12** | **74** | **8.16** |
| 80 | 640 | 52 | 12.25 | 13 | 48.13 | 29 | 22.38 | 54 | 11.91 | 73 | 8.74 |
| 85 | 680 | 52 | 13.00 | 13 | 52.17 | 29 | 23.84 | 54 | 12.68 | 73 | 9.33 |
| 90 | 720 | 52 | 13.74 | 13 | 56.29 | 28 | 25.32 | 53 | 13.46 | 73 | 9.91 |
| 95 | 760 | 52 | 14.48 | 13 | 60.59 | 28 | 26.81 | 53 | 14.24 | 72 | 10.50 |
| 100 | 800 | 53 | 15.23 | 12 | 64.92 | 28 | 28.33 | 53 | 15.03 | 72 | 11.10 |

# Conclusion

- Higher is the roof reflectivity lesser is the insulation required
- Because of diminishing returns on incremental insulation, about 25 mm thickness insulation seems to be appropriate in all climatic zones of India except Cold.

# Projects/Activities in Pipeline

- Cool Roof Demonstration in Nainital and Pantnagar
- Design of a Retrofit and Net-Zero homes
- Monitoring effect of cool roof in an apartment building
- Enhancement of Cool Roof Calculator
- Stakeholders conference

# Publications:

- **Quantifying the direct benefits of cool roofs in an urban setting: Reduced cooling energy use and lowered greenhouse gas emissions.** Xu T., Sathaye J. Akbari H., Garg V., Tetali S., *Building and Environment, February 2012, Pages 1-6*
- **Online Energy Savings Calculator for Cool Roof.** Garg V., Tetali S., Chandrasen K., Mathur J. *Clima 2010 - REHVA World Congress, Antalya, Turkey, 2010.*
- **Effect of envelope properties and thermal adaptation on energy consumption and comfort conditions.** Dharka S., Jain V., Garg V., Mathur J., *Accepted for Building Simulation 2011, to be held in Sydney, Nov. 2011*
- **Calibrated simulation for estimating energy savings by the use of cool roof in five Indian climatic zones.** Bhatia A., Mathur J., Garg V. *I.J. Renewable and Sustainable Energy, Vol. 3 No. 2.*
- **Determination of energy saving with cool roof concept using calibrated simulation: Case of a learning centre in composite Indian climate.** Bhatia A., Garg V., Mathur J., Akbari H., *Journal of Solar Energy Society of India, Vol. 20 No. 1-2, pp. 30-42.*

# Thanks

Vishal Garg
vishal@iiit.ac.in

Contributions: Jyotirmay Mathur, Surekha Tetali