Energy and Buildings 114 (2016) 136–142

Contents lists available at ScienceDirect

Energy and Buildings

journal homepage: www.elsevier.com/locate/enbuild

Development for cool roof calculator for India

Vishal Garg, Shikher Somal, Rathish Arumugam, Aviruch Bhatia*

International Institute of Information Technology, Hyderabad, India

ARTICLE INFO

Article history:
Received 27 March 2015
Received in revised form 2 June 2015
Accepted 5 June 2015
Available online 9 June 2015

Keywords:
Cool roof
Energy savings
Internal rate of return

ABSTRACT

In tropical countries such as India, increasing the roof albedo helps to reduce the heat ingress through the roof. This further reduces air-conditioning energy consumption in conditioned buildings and increases comfort in unconditioned buildings. In order to help users determine the benefits of high albedo roofs under varying conditions, a simple calculator has been developed. Parameters such as location, building type, roof area, and surface properties of the roof are taken as inputs. Annual EnergyPlus simulations are performed for the given parameters and the results are displayed in both graphical and tabular formats. It also calculates the simple payback by comparing a given base case roof albedo with the proposed roof albedo. The calculator can perform comfort simulations for unconditioned buildings and simulates measures including a radiant barrier system and under deck roof insulation. The calculator also runs a parametric simulation between insulation thickness and roof albedo to find an optimum roof insulation thickness based on incremental internal rate of return. This paper presents the features of the cool roof calculator and the type of analysis that can be performed using the cached results.

1. Introduction

A roof that reflects and emits the solar radiation back to the sky rather than transferring it into the building is termed a cool roof [1]. Cool roofs help reduce air-conditioning energy consumption in a conditioned building and improve thermal comfort in an unconditioned building in hot climates. The energy savings achieved in a building from cool roofs is dependent on various parameters such as the location, orientation of the building, local shading by trees or other buildings, construction type, insulation type, plenum ventilation, equipment load, occupancy and operational schedules [2]. There have been several studies [3–5] to demonstrate the benefits of cool roofs. Most of them have been experimental studies.

Considering the advantage and flexibility in evaluating the effect of cool roof through simulations and models, research exists in the development of various simulation models and tools calculating the effect of cool roof.

There exists two internet based calculators for understanding the benefits of cool roofs: DOE's cool roof calculator [6], the closely-related DOE Steep Slope Calculator [7], and the roof savings calculator (http://rsc.ornl.gov/). All tools are developed for the United States (US) and either use DOE 2.1 platform for simulations or lookup tables based on data from experimental facilities in the US.

DOE cool roof calculator calculates the annual energy savings in cooling and heating for a given roof solar reflectivity (SR) in comparison with a black roof. The tool also calculates the necessary roof insulation *R*-value to achieve the same savings as achieved by the given solar reflectivity. This tool supports 243 different locations, with 235 of them belonging to the US, Pacific territories and Puerto Rico, and the remaining 8 to Canada. The inputs that need to be provided by the user in this calculator are *R*-value, solar reflectivity, infrared emissivity (IE), electricity costs, and HVAC equipment efficiency. The output includes cooling and heating energy savings. This calculator also estimates the energy and peak demand savings for a given solar reflectivity in comparison with a black roof. The input fields are the same. However, the output includes the heat load reduction values during the cooling season. The DOE steep slope calculator performs similar functionality for residential roofs with non black surfaces and for steep roofs.

Roof savings calculator (RSC) developed by Oak ridge National Laboratory (ORNL) and Lawrence Berkeley National Laboratory (LBNL), has been recently updated, and is now running in its beta release. The tool has two building categories, residential and commercial, and two modes, simple and advanced. The calculator performs whole building energy simulations using the DOE 2.1E engine for fast energy simulation and integrates AtticSim for advanced modeling of modern attic and cool roofing technologies. The calculator runs an hourly simulation for the provided building

* Corresponding author. Tel.: +91 9160000798.
E-mail addresses: vishal@iiit.ac.in (V. Garg), shikher111@gmail.com (S. Somal), rathish.iiit@gmail.com (R. Arumugam), aviruch@hotmail.com (A. Bhatia).

http://dx.doi.org/10.1016/j.enbuild.2015.06.022
0378-7788/

properties such as conditioned floor area, number of floors, window details, HVAC details, and the existing and proposed roof details for the selected location. The annual energy savings reported are based upon heating and cooling loads and thus this calculator is only relevant to buildings with a heating and/or cooling unit. New et al. [7] have discussed interface and UI of the calculator. Jones et al. [8] built a visual analytics tool to assist in the exploration and identification of features in the data for roof savings calculator simulation ensembles.

For simulating the benefits of cool roofs in Indian climates a tool has been developed by Garg et al. [9] that uses EnergyPlus [10] to perform online simulations. Compared to other tools, the cool roof calculator provides more input details about the building and also more detailed set of results including comfort. Another advantage of the cool roof calculator over the other tools is that it has the capability of simulating an unconditioned building for which the comfort achieved through the use of cool roof will be reported. Therefore, some of the major differences of the cool roof calculator compared to other calculators are the features listed below:

- Performs online simulation
- Works on EnergyPlus simulation engine
- Capable of modeling an unconditioned space
- Generates thermal comfort results
- Creates payback analysis
- Caching of results
- Works for all major Indian cities

2. Description of models

There are four kinds of building types considered in the calculator – Office, Educational Institute, Retail, and Residential. All these models are square in shape with flat roof. There are five zones in each model – one core and four perimeter. Plan of the model is shown in Fig. 1. The base model is generated from EnergyPlus example file generator [11] based ASHRAE 90.1-2007 specifications. The envelope details, lighting power density, equipment power density, and occupancy density of the models used in the tool are summarized in Table 1. The base model was modified as per user inputs at run time and commonly used schedule in such buildings in India. Schedule profile used in the models is shown in Figs. 2–6.

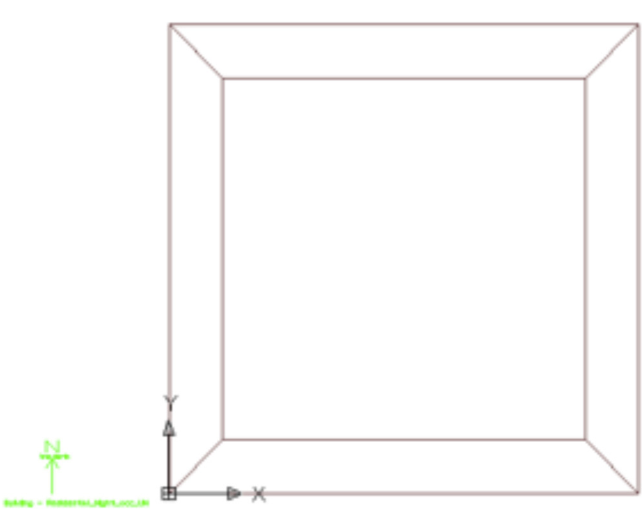

Fig. 1. Top view of the model.

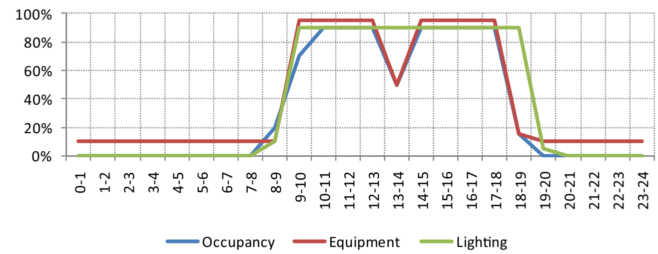

Fig. 2. Uses pattern for office model.

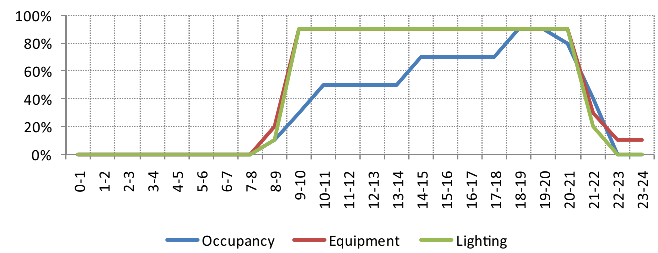

Fig. 3. Uses pattern for retail model.

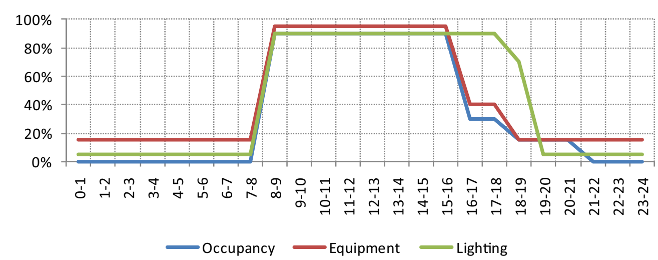

Fig. 4. Uses pattern for educational institute model.

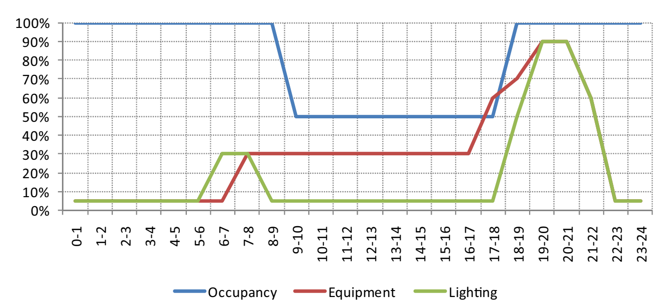

Fig. 5. Uses pattern for residential model (24 h).

3. User interface and backend

The tool is hosted using an Apache/2.2.16 (UNIX) [12]. Web pages are developed in PHP [13] and use other common web

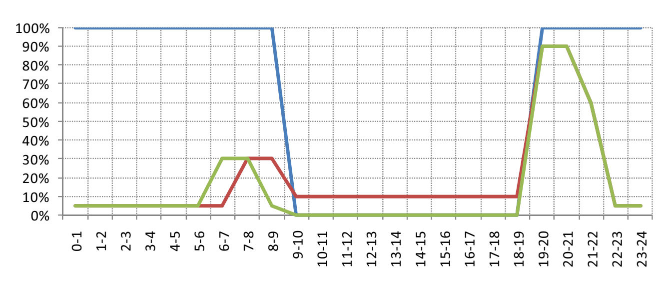

Fig. 6. Uses pattern for residential model (night time operation).