# Cool Roofs in California

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## ABSTRACT

A cool roof refers to a rooftop that has been designed to be passively cooled. Cool roofs as an alternative to the conventional rooftop not only keep a roof and its indoor environment at lower temperatures, but also can save money and energy, improve air quality, and mitigate the urban heat island effect. Requiring less initial cost investments and lower maintenance than other "green" roofing options, cool roofs are increasingly becoming more feasible and being integrated into policy (eg. Title 24, CalGreen, etc.). A number of California utility companies have been providing rebates for customers with cool roof installations. This project located records of cool roof installations from Sacramento Municipal Utility District (SMUD) and aggregated them in Microsoft Access Database. The goal is to be able to centralize and organize this data that had been locked up with SMUD. In addition, policy and codes were analyzed to further assess the progress and future of cool roofs. This project will aid California Air Resources Board (CARB) and other stakeholders in assessing the success of cool roof rebate programs and help to determine future funding, research and investments in the technology.

## KEYWORDS

albedo, reflectivity, heat island effect, climate action, Sacramento Municipal Utility District (SMUD)

## INTRODUCTION

The International Panel on Climate Change (IPCC) estimates a 0.3°-6.4° C rise in global average temperatures by the end of the 21$^{st}$ century. They speculate that this is an average and may be higher in certain regions and lower in others. A contributing factor to climates in cities is the landscape of a city where a phenomenon called the urban heat island effect is caused by a lack of vegetation, impervious surfaces, limited wind circulation, and the heat capacity of materials in an urban built environment (Stone 2007). This effect can make cities regional hotspots that capture and hold onto more heat than surrounding rural areas. This coupled with climate change, may lead to the more extreme conditions in the urban environment rather than in other more rural locations that the IPCC's projected global average predicts.

Urbanization alters the Earth's natural surface cover that impairs earth's ability to naturally cool itself. The urban heat island effect has come to be a phenomenon that is a defining characteristic of major urban areas (Oke 2003). The urban heat island effect refers to the higher temperatures in major urban areas compared to surrounding rural areas because of greater areas of the concrete surfaces, steel and metal structures that have thermal properties that heat the space, limited vegetation that reduces evapotranspiration, the process by which plants cool themselves through water loss, that would normally cool the space, and obstacles for naturally cooling wind flow. According to the Environmental Protection Agency, a city with 1 million residents or more can be 1.8°F – 5.4°F higher during the day than that of surrounding areas, and can be up to 22°F higher at night. These temperature differences are not mitigated by the characteristics of the steel and concrete in a built environment. Different cool or pervious pavements, increased vegetation, and rooftops are among the tools that cities can use to mitigate the urban heat island effect.

Urban rooftops constitute 20 – 25% of urban surfaces (Akbari 2003). Currently, rooftops reflect about 10-20% of sunlight they receive (Akbari et al. 2009). With most of the energy that hits the rooftops being absorbed into the building, the built environment of a city has great potential for storing heat and energy, which only exacerbates the overall urban heat island effect citywide. Many studies have shown buildings' energy savings of 20% or more if the roof reflectivity were to be about 60% rather than 10 - 20% (Akbari et al. 2009). Increasing the albedo of rooftops can reduce the summertime urban temperature (Taha et al. 1997).

A cool roof refers to a surface that is minimally heated by and highly reflective of the sun. The ideal cool roof is highly reflective of sunlight, reducing solar heating, and thermally emittive of infrared radiation, increasing radiative cooling (Berdahl 1997). This can be a white roof top, but is not always, or a roofing product that is cooler than a comparable standard product. For a building owner, the energy benefit of a cool roof will usually be a secondary concern. With some sloped residential roofs, white is often not the optimal color for aesthetic considerations (Levinson 2006). Despite aesthetic concerns on behalf of the consumers, there are many direct and indirect benefits that cool roofs can provide thermally. Cool roofs are rooftops that are designed with two radiative properties in mind: reflectance and emittance, both of which are measured on a scale of 0 to 1 – the lower, the better. Reflectance gives a measure of how much light energy gets reflected from the roof, and emittance gives a measure of how much thermal energy is radiated from the roof. Cool roofs can be a tool for urban heat island mitigation because of these properties.

The overall impact of cool roofs on California statewide has not been adequately assessed, and most studies are regional, building, or test plot specific. Archives of data are limited to a certain district and. For example, data for Sacramento states that 20% of the city's surface area is dark roofing. In the same study, this figure corresponds to the potential to increase the city of Sacramento's albedo by 18% (Bretz et al. 1997). Because of the relative age of the field of cool roofs as a tool for building energy efficiency, no study has attempted to assess the impacts of cool roofs on a large scale.

Cool roof benefits range from quantifiable factors that are economic to those regarding quality of life that are more intrinsic. Direct benefits refer to the energy savings of an individual building as a result of an increased exterior albedo that reduces heat transfer through the building envelope and lowers cooling demand. This same effect also improves the comfort of the indoor environment for the occupants of the building, especially if the building does not have an air conditioning system. Regional studies in Florida and California have shown savings of 10 – 70% (Akbari et al. 1993). Cool roofs have a longer life-span than a standard roof because cool roof tiles do not undergo the same degree of contraction and expansion from heat as standard roof tiles do (Levinson 2009). Indirect benefits occur as the collective reduction in energy absorption lowers the ambient air temperature of a whole city. There is also evidence that higher urban air temperatures can alter urban air chemistry in a way that increases smog formation (Taha 1997).

At the forefront of technology, research, and legislation, California has been leading the nation in climate action. As part of California's Global Warming Solutions Act of 2006, the California Energy Code- Title 24, outlines rules and regulations on building codes in the state of California. Updates in 2007 responded to the California energy crises in promoting and implementing cost-effective building energy efficiency in both residential and commercial sectors (California Energy Commission). Another goal of the 2007 revisions was to create appropriate market incentive programs for specific technologies. As part of the 2007 revisions, cool roofs became a requirement on new construction for commercial buildings (Title 24). Many energy utility companies including Pacific Gas and Electric (PG&E) and SMUD provide rebates funded by the state of California for customers that retrofit for a cool roof.

In this study, I compiled data, including building manager information, building characteristics, roof characteristics, etc., and location of all the cool roofs that exist in California in both the commercial and residential sectors. I created a single source of aggregated information on all the progress that cool roofs have made in the SMUD. Using this database, I assessed the energy savings these cool roofs had provided. This data helped to assess performance of cool roofs and provided points of interest for further investigation. Where past studies have been regionally and conditionally limited, I will create a source that will generate a better idea of how effective cool roofs are when implemented.

I hypothesize that extreme savings or increases may be a result of synergistic interactions from retrofitted features in other components of the building contributing to even more savings than just a retrofitted cool roof may provide. For example, improved insulation or more efficient air conditioning systems are other possible features that may enhance the effects of a cool roof. Other factors like education for the building occupants on reducing energy consumption may contribute as well. Vice versa, if none of these measures are taken, there may be little to no energy savings, or even an increase. If these features were due for repair or replacement was neglected, energy consumption could possibly increase.

## METHODS

I identified the utility companies that are currently providing or have ever provided cool roofs rebates. I worked in close collaboration with SMUD. I looked at their records of cool roof installations and rebates. I gained access to these records from one of their constituents.

**Table 1.**

| | |
|---|---|
| Burbank Water and Power | Sacramento Municipal Utility District (SMUD) |
| Los Angeles Department of Water and Power | San Diego Gas and Electric |
| Pacific Gas and Electric (PG&E) | Silicon Valley Power |
| Roseville Electric | Southern California Edison |

**California utility companies that have offered cool roof rebates.**

Once I had the data records, I was able to compile a Microsoft Access Database with this information. I selected what pieces of information were relevant to the database (Table 2). I organized and summarized the data from SMUD. I ran different reports, forms, queries, and summaries within the database software to find certain statistics about the data set, or to point out certain trends.

I wanted to find out how the cool roofs were performing. I looked for energy billing data in sum and average for the 12 months pre-installation and the 12 months post-installation. I also gathered reflectivity values in average and range for the cool roofs. Lastly, I determined the district the cool roofs covered with zip codes.

**Table 2.**

| | |
|---|---|
| ID | roofing product model # |
| energy company | roofing product type |
| energy company ID number | solar reflectance of roofing material |
| name of building owner/manager | qualified retrofitted roof area (square feet) |
| building owner/manager contact address | date of installation |
| building owner/manager phone number | Roof type |
| building owner/manager email | building type |
| address of retrofitted building | building floors |
| city of retrofitted building | type of A/C |
| zip of retrofitted building | utility bill/ energy use post-retrofit |
| roof contractor name | utility bill /energy pre-retrofit |
| roof contractor address | cost of qualified roof retrofit ($) |
| roof contractor phone number | qualified roof rebate total ($) |
| roof contractor email | climate zone |
| roofing product manufacturer name | customer feedback |
| roofing product name | |

**Data fields of interest.**

This study is meant to be qualitative due to the limitations in data acquisition. Records from different utilities come in varying formats, and some pieces of information were missing. The lack of uniformity across billing periods adds another element of complication if quantitative measures were to be pursued. It is the first study to be conducted between an outside constituent and a utility company. This database and summary points was passed onto the Heat Island Group for continual data acquisition and analysis. Its intent is to pull together data from utility companies into a central location for future analysis and investment assessment by California Air Resources Board, California Energy Commission, Lawrence Berkeley National Labs, and other stakeholders.

## RESULTS

With the data collected for the records of both residential and commercial sector cool roofs from the SMUD, the total of cool roofs installed is 570, with 207 being residential and 363 commercial. Added together, this number accounts for 9,5 million square feet of cool rooftop surface area.

The land area of the City of Sacramento is 97.2 square miles, being an equivalent of 2,709,780,480 square feet. In assuming that 25% of this land area is urban rooftop (Akbari, 2003), the amount of rooftop is 677,445,210 square feet. The percentage of cool rooftop surface area in comparison to conventional rooftop surface area is approximately 1.4%.

**Table 3.**

| | **Invalid** | **No change** | **Increased** | **Decreased** |
|---|---|---|---|---|
| **Count** | 112 | 92 | 141 | 147 |
| **Percent** | 22.8 | 18.7 | 28.7 | 29.9 |

**Summary of energy usage statistics.**

There were 492 entries of energy billing data. Invalid entries accounted for 112, meaning there were billing periods that were left blank, or there were incomplete periods for either or both of the 12 month periods before and after the installation date. Units that exhibited no significant change were 92. The criteria used to determine this factor was an increase or decrease in kilowatt-hours used of less than 500. Units with an increase in energy usage were 141 with an increase in kilowatt-hours used of 500 or more. Units with a decrease in energy usage were 147, which used 500 kilowatt-hours or less.

**Table 4.**

| | Range | Average |
|---|---|---|
| **Commercial** | 0.29-0.91 | 0.82 |
| **Residential** | 0.37-0.92 | 0.74 |
| **Total** | 0.29-0.92 | 0.79 |

**Measures of reflectivity.**

Reflectivity for commercial rooftops ranged from 0.29 to 0.91. Reflectivity for residential rooftops ranged from 0.37 to 0.92. Total range and average was 0.29-0.92 and 0.79, respectively.

## DISCUSSION

Cool roofs are a technology that has progressed to the point where they are indistinguishable from a regular rooftop. Not only do they have the capability to save money, but also, energy and overall heat island mitigation in a community – improving air quality and quality of living. With consumer barriers removed such as aesthetics and monetary incentive from a regulatory level, cool roofs have the potential to make great changes in the landscape of urban topography.

Comparing the figures obtained through SMUD data, cool roof implementation shows no significant difference in energy savings. Though these numbers are contrary to many Heat Island Group findings (Akbari and Levinson), it is important to note that laboratory findings do not always parallel field observations. However, utility data is still important to obtain and analyze so that cool roofs in practice can be better understood and utilized by the customer to gain their full benefits.

A significant amount of data was rendered invalid – just about half. The inconsistencies of the form of data in this study should not be completely disregarded. These remain records of cool roofs installed and do not exhibit rigid regulation with experimentation. The age of these cool roofs have not been taken into account and thus may not reflect the true amount of energy saved as an aged roof might. This study serves as a rough estimate for the potential of cool roofs in practice, but does not strive to be the most rigid quantitatively.

The small area of cool roofs thus far and high reflectivity of cool roofs installed currently in place show an amazing potential for a cooler urban climate. Cool roofs, though they have been receiving increasing attention, have barely breached the market. If the SMUD trend shows up in other sectors, it can be reasonably apparent that cool roofs have yet to penetrate the field. With a large area yet to cover and, on average, higher reflectivity rather than minimums reflectivity, cool roofs can do great things for a city. From the perspectives of building professionals, homeowners/building managers, and city representatives - cool roofs to date have been limited in information distribution and also research parameters (Heat Island Group – Cool Communities).

Studies in the past conducted through the Heat Island Group have been limited to test plots, ie. Los Angeles, Sacramento, and not actual rooftops. Numbers and figures have typically been extrapolated to other regions from these studies (Rosenfeld 1998). Information has been gathered at a level where a cool roof is not really in practice. With this record of actual field cool roofs, the quest for such data may one day become easier. In directing policy negotiations, this record will serve as an indicator of progress and also what provisions need to be set.

While savings can be realized in the summer, losses may be experienced during colder months due to increased heating energy requirements. However, in climates where demand for cooling loads dominates for most of the year, these seasonal factors may be negligible (Taha 1988) and in most cases - winter increases are often much smaller than summer savings (Levinson 2009). Other reasons for discrepancies in energy use may be contributed from a feedback in which the consumer may perceive that a higher efficiency product means using more energy may be inconsequential. How a building functions is a result of many factors – insulation, heating, ventilation, air conditioning systems, windows, etc. There may be a number of other features in the home that could have affected the implementation of a cool roof.

Future points of interest will be to investigate further into these causes of discrepancies in energy use. Case studies or interviews with homeowners and roofing contractors would be a useful tool in investigating the effects of cool roofs in the field. The database created in this study will serve as a tool on which sets of data from other utility companies can be added. Most interesting will be to track the progress of cool roofs as Cal Green comes into affect.

Sacramento, among 31 cities in California and another 5 in the process of drafting, to hold a Climate Action Plan does not explicitly list cool roofs as a technology - though there are cities that specifically endorse cool roofs (Berkeley, Emeryville, Los Angeles). Cool roofs are increasingly becoming an option through which climate action goals can be achieved locally and regionally.

Cool roofs continue to make headway in fields of contracting, codes, and policy. California has recently passed Cal Green, a mandatory building program of green building policies that will supersede LEED in California (Cal Green). This policy is groundbreaking in many ways, making California the first state to make green building the norm. Cal Green is an initiative that explicitly lists cool roofs as a mandatory installation for a certain level of certification.

Provisions like Cal Green and other Climate Action Plans can make the bold statement of enforcement and performance measurements that would work to contribute toward climate action goals. Cool roofs bear much potential for social, monetary, and energy savings. The proliferation of cool roofs has barely reached its climax as numbers from this study have indicated. The centralization of these records will hopefully enable education and communication about this technology amongst homeowners/building managers, contractors, and city representatives. Cool roofs are a technology that has untapped potential in proliferation of information. This project serves as a step toward a more conscious and sustainable society in its built environment. The connections between science, policy, and citizens are crucial to the development and implementation of any technology.

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