RCI Foundation
<u>Cool Roofing …Cutting Through the Glare</u>
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"Cool Roof Coatings to Reduce Energy Demand and Temperature in an Urban Environment"

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Abstract

The Energy Coordinating Agency is a Philadelphia based private non-profit corporation dedicated to ensuring that low and moderate income people have access to safe, affordable and reliable sources of energy and water. ECA works to develop a sustainable energy future for the region through energy conservation and renewable energy. ECA coordinates and provides energy conservation services to thousands of households in the Philadelphia area every year.

In 2000 ECA began a pilot program to investigate the potential for "cool roof coatings" as a means of reducing cooling energy costs and providing passive cooling to row homes. Results of energy monitoring as well as roof and interior temperatures proved that this technology was viable and could be part of a more comprehensive program to reduce overall energy costs to residents.

The success of the early experiments was followed up with a more comprehensive program called "Cool Block" where an entire city block of row homes was coated. Monitoring in this study included actual outside temperatures in the alley which ran the length of the block Peak temperatures were compared to a control block with black uncoated roofs and found to be lower as a result of the reflective coating. Thus the reflective coating actually had an impact on lowering the "urban heat island" temperature.

Actual case histories and performance data will be detailed, including an update on this program and efforts to replicate the program in other urban areas.

Background

The Energy Coordinating Agency is a Philadelphia based private non-profit corporation dedicated to ensuring that low and moderate income people have access to safe, affordable and reliable sources of energy and water. In the mid 1990's, ECA began exploring ways to assist their clients in dealing with issues relating to summertime cooling. While some homeowners had air conditioners, the cost of electricity relative to their income sometimes prevented them from operating them. In addition, extreme summertime heat events in Chicago and other major urban areas caused ECA to consider alternative methods to assist their clients. These "killer heat waves" achieved dubious notoriety when in 1995, 435 people died in Chicago due to heat related illnesses. In Philadelphia, these heat waves were directly responsible for 118 deaths in 1993, 61 deaths in 1995 and 67 in 1999. The most vulnerable are comprised mainly of low income seniors who have a higher risk of heat related health problems due to poor general health status, social isolation, physical limitations, and safety concerns that detract from their ability to manage high temperatures.

Early Experiments:

Research published by Rohm and Haas, National Coatings Corporation and Oak Ridge and Lawrence Berkeley National Laboratories $_{1\text{-}18}$ showed that some cooling and reduction in air conditioning load and electricity required to condition buildings could be realized by coating low slope roofs white to reflect the infra red portion of solar radiation. The studies also showed energy and life cycle benefits for reflective roof coatings. Almost all of ECA's clients live in densely populated urban two story row homes, with low slope asphalt built up or modified bitumen roofs.

"Cool Homes" Program

ECA began a pilot program coating several homes in Philadelphia. Each home was equipped with recoding thermometers placed strategically in the structure. A set of uncoated "control" homes were also monitored to determine the effect of the reflective coating. Electricity demand was also monitored. However, it would be preferred to reduce the temperatures in these homes without or minimum mechanical/electrical cooling. The homes had blown-in insulation in the cavity spaces under the roof deck and above the 2nd floor ceilings. The R values ranged from 8-12. The reflective roof coating used in the project had solar reflectance of 0.83 and thermal emittance of 0.89.

The Cool Home pilot collected temperature and humidity with data loggers at 35 houses. Six of these houses were logged in the summer 2001 and treated before the summer of 2002. Six more houses were designated for the comparison group and did not receive coating during the summer, leaving 23 houses with potential for short-term pre/post analysis. Three of these houses did not have any data from the second floor bedroom wall and one of the remaining houses did not receive any major coatings during the summer, leaving 19 houses for the pre/post analysis. All but two of these 19 houses have air conditioners.

Temperature Time Series Profiles

There were few days with similar outdoor temperatures between the pre and post coating periods, but July 2nd and July 16th were fairly similar with peak temperatures in the mid-90s and clear skies. Both also had similarly warm days preceding them (reducing the potential impact of thermal mass effects).

The figure below (Figure 1) shows the temperature data for four houses where the data for each of these two days is overlapped. The dashed lines show the July 2nd data (representing the "pre-coating" condition) and the solid lines show the July 16th data (post coating). The bold lines show the 2nd floor bedroom indoor air temperatures while the lighter lines show the outdoor temperatures.

(**Note: In all cases "indoor air temperatures" refers to the temperature measured at chest height.**) "T in Pre" is interior (chest height) temperature prior to coating, "T in Post" is interior (chest height) temperature after coating, "T out Pre" is exterior temperature prior to coating, and "T out Post" is exterior temperature after coating.

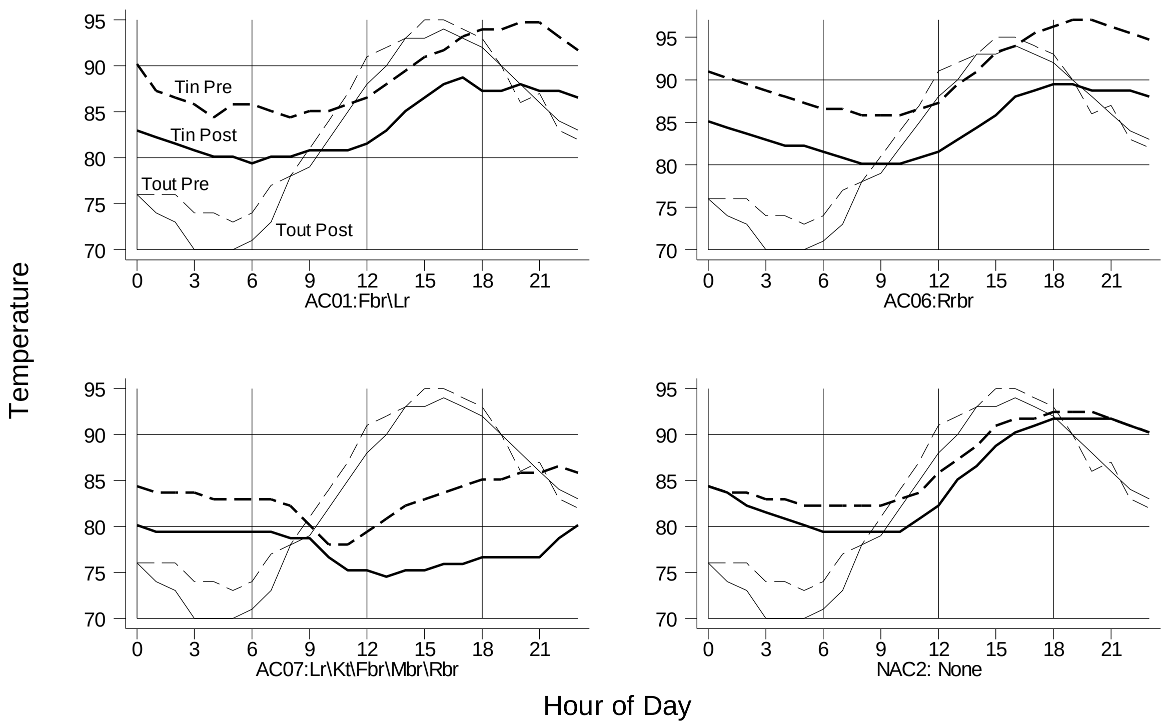


Figure 1. Matched day overlapped comparison of temperatures for four houses

Site NAC2 had no coatings between the two days and the temperature profiles of both days look similar with nearly identical peaks, although the pre-coating day is a little warmer. Sites AC01 and AC06 show noticeably larger differences in 2nd floor temperatures between the two days, indicating the impact of coating. The difference between the days is clear throughout the 24 hour cycle. Site AC07 shows obvious air conditioning but also cooler indoor temperatures after coating. It is not clear how much of this change may be due to the coatings or different air conditioning settings.

The similarity of sites AC06 and AC08 and the fact that AC06 was treated on July 10th while AC08 was treated July 16th allows for another graphical assessment of the coating impacts. The figure below shows the second floor temperatures for both of these sites along with the outdoor temperatures (dotted line) from late June through July 19th. Site AC08 is the bolder line.

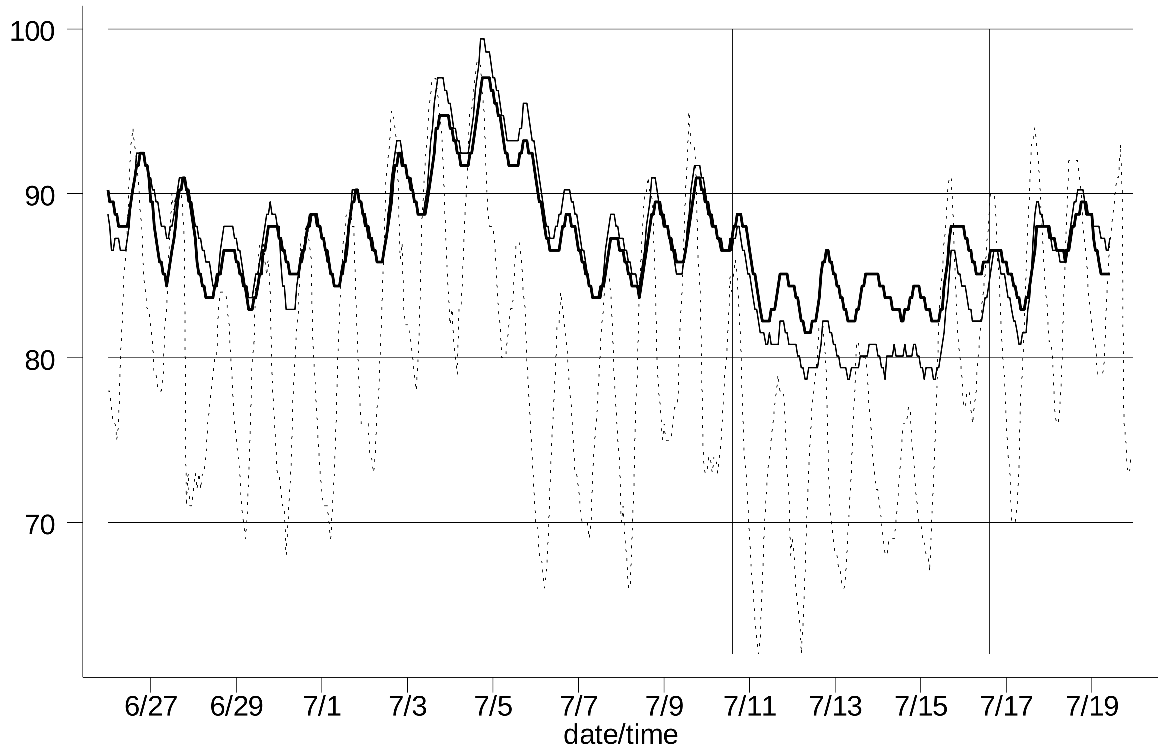


Figure 2. 2nd Floor Temperatures of houses AC06 and AC08 with 1 week gap between coating application to house AC06 and AC08.

Figure 2 above shows that AC06 was a little hotter than AC08 until coating (first vertical line), then was much cooler until AC08 was treated (second vertical line). Once they were both treated the original pattern re-emerged (although both are cooler than before). This figure shows a clear impact from the reflective roof coating. Although the outdoor temperatures were cooler during the week of interest, potentially skewing results, the similarity in temperature patterns before and after both were treated provides convincing evidence of a noticeable coating impact.

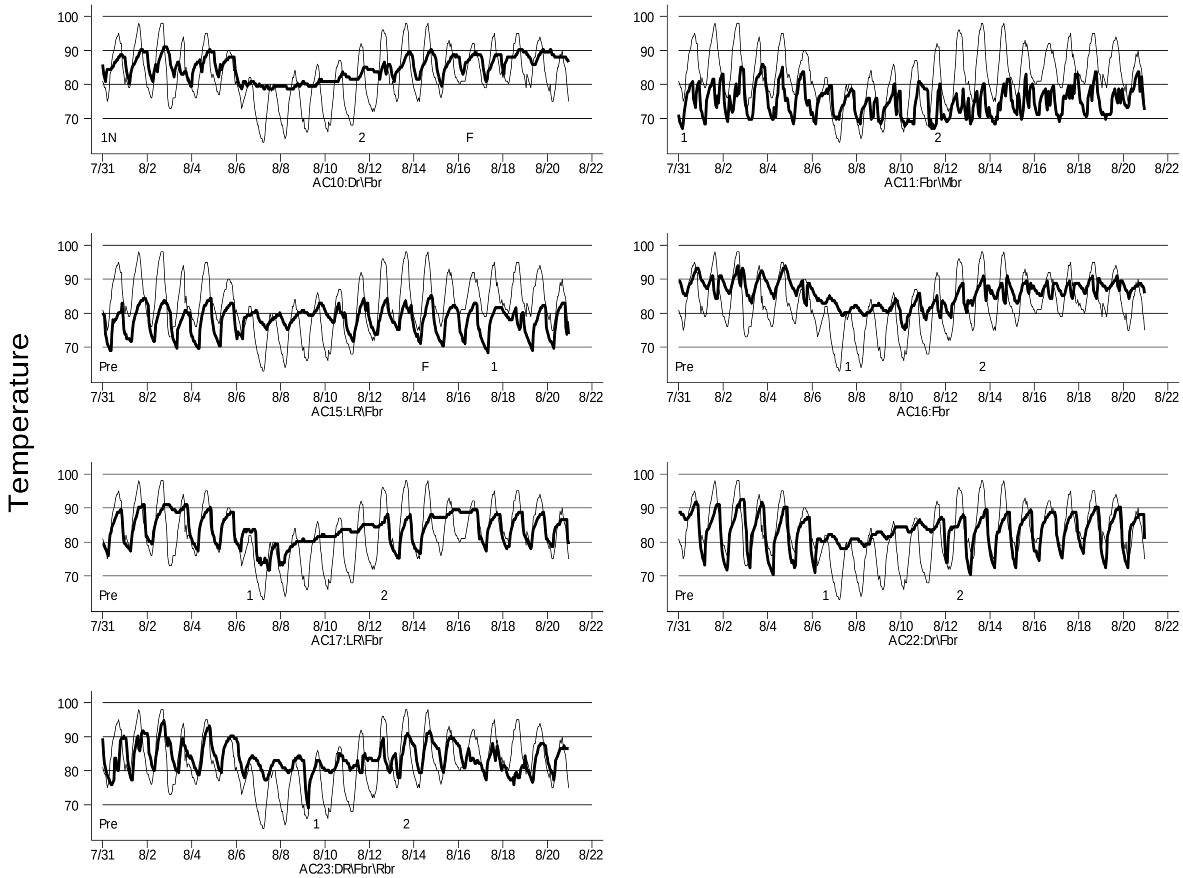


Figure 3. 2nd Floor Temperature Profiles for houses with front bedroom air conditioners and with August data

Error! Reference source not found. includes three sites from the earlier analysis (AC10, AC11, and AC15) with data consistent from July. The other four houses all show more moderate A/C usage as temperatures peak at about 90^o F for all of them. These four houses all appear to exhibit some impacts from coating as peak temperatures decline from the early August heat wave to the mid-August heat wave. While the reflective roof coating provided some cooling, there is still the heat transfer from the walls and windows in these house.

Daily Temperature Summaries

The time series plots of temperatures provide a solid overview of temperature patterns at each site and indicate potential air conditioning usage patterns as well as point toward potential coating impacts. However, these plots do not allow for easy comparison of changes in temperature profiles due to coating. This is obviously because each day's exterior air temperature will vary. A further complicating factor is that each house studied differs slightly in solar orientation, vertical wall exposure, and window configuration. One alternative approach involves summarizing each day's temperature profile and plotting indoor and outdoor conditions against each other.

Error! Reference source not found. and **Error! Reference source not found.** show the maximum daily indoor (2^{nd} floor bedroom) temperature plotted against the maximum daily outdoor temperature with a line drawn to show equal temperatures. The graphs include all days hotter than 85 F. Circles (**o**) are used for days before coating and plus signs (**+**) for days after coating.

Error! Reference source not found. shows all houses with no air conditioning reported in the front bedroom. The maximum indoor and outdoor temperature track fairly closely for most houses. Site AC12 has noticeably cooler indoor temperatures, consistent with the earlier analysis that suggested there may be some air conditioning there. The figure also shows that temperatures generally declined after coating – the plus signs are generally below the circles for most houses at most temperatures. This is the most noteworthy conclusion of the data shown below.

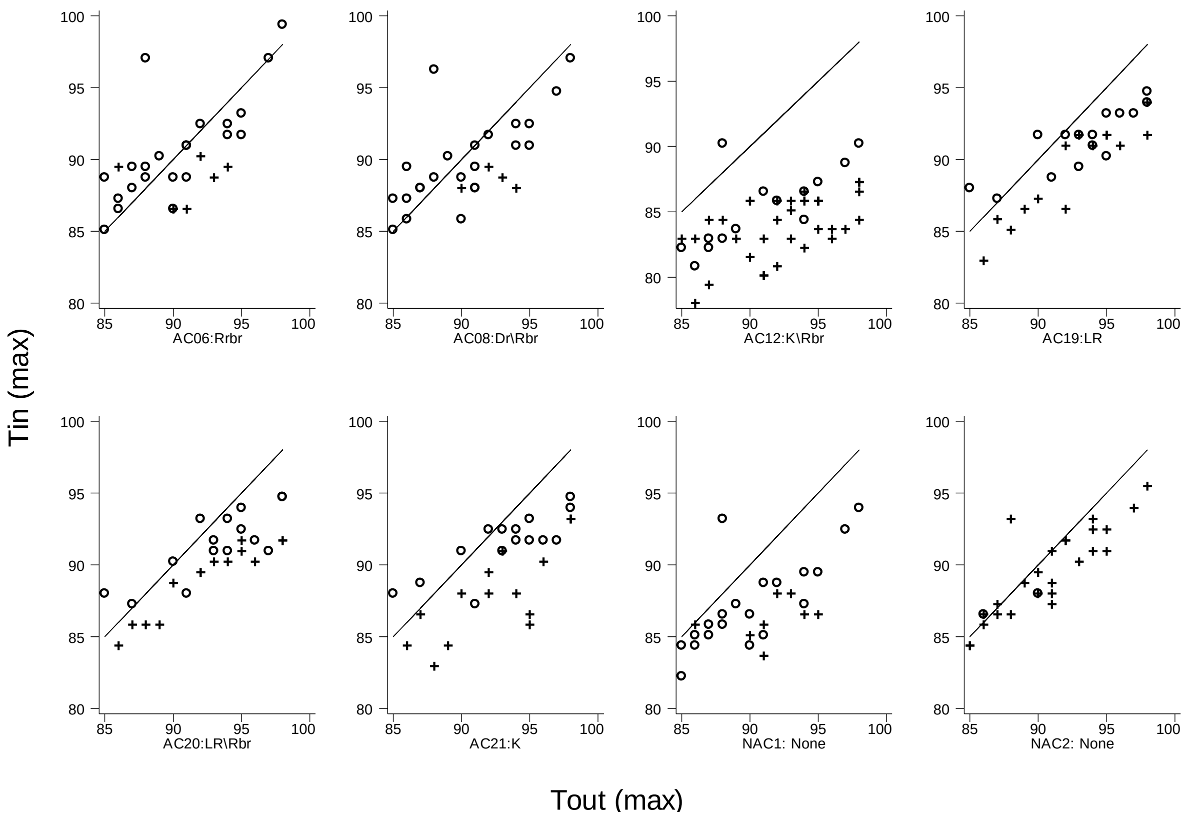


Figure 4. Maximum daily indoor and outdoor temperatures: houses without air conditioning in bedroom. Circles indicate pre-coating days, plus signs are post coatings days.

Error! Reference source not found. shows the results for sites with air conditioning in the front bedroom. Most of these houses already had considerably lower indoor temperatures due to air conditioning prior to coating. Sites AC4, AC7, AC11, and AC15 again have the most obvious cooling, as the indoor temperatures are relatively constant. Several of the other sites resemble the houses without cooling. AC16, AC22 and AC23 all show the heat reducing impacts from coatings.

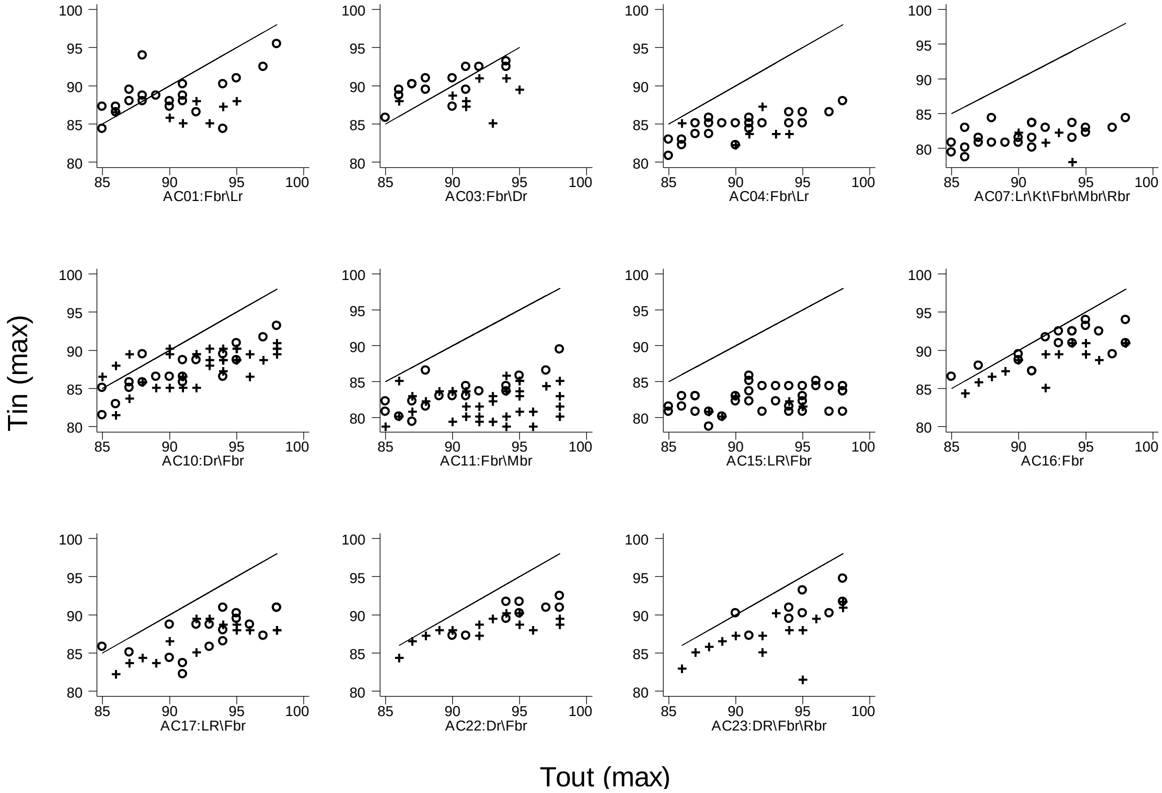


Figure 5. Maximum daily indoor and outdoor temperatures: houses with air conditioning in bedroom

Ceiling Temperatures

Error! Reference source not found. and **Error! Reference source not found.** show the same relationships between daily maximum temperatures except the indoor temperature is for the 2nd floor bedroom ceiling. As expected, the impact of coatings is more pronounced on these graphs since the coatings directly affect heat gain through the ceiling and therefore only indirectly affect air temperatures. By focusing on the ceiling temperatures, the impact on air conditioned houses appears almost as clearly as among houses without bedroom air conditioning. This finding is significant in that it implies that the impact of coatings may appear as indoor temperature reductions in houses without air conditioning in the bedrooms, but could appear as either temperature reductions or cooling load reductions in the air conditioned houses.

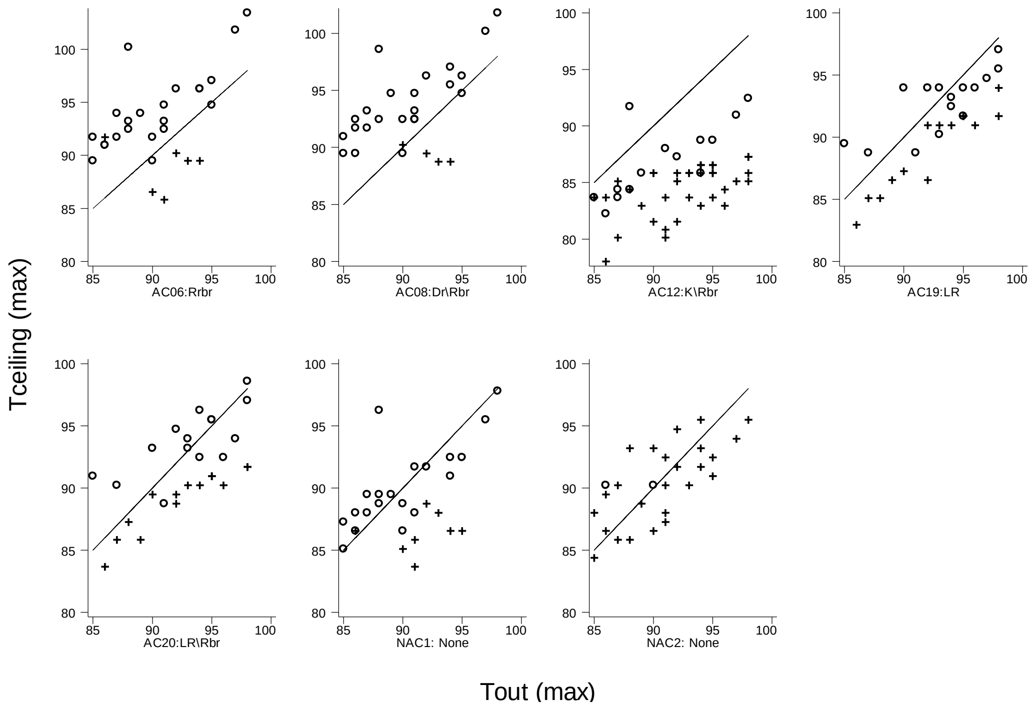


Figure 6. Maximum Daily Ceiling and Outdoor Temperatures: houses without air conditioning in bedroom.

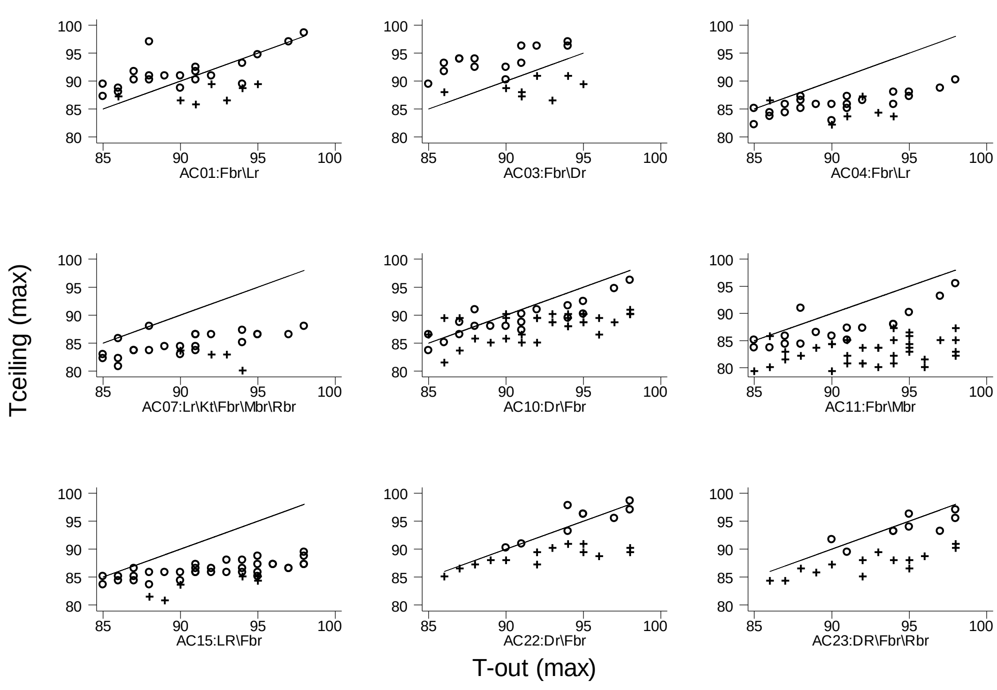


Figure 7. Maximum Daily Ceiling and Outdoor Temperatures: houses with air conditioning in bedroom

Another approach for assessing coating impact is to compare the ceiling and air temperatures in the 2nd floor bedrooms. The heat transfer from the roof to the house should be directly proportional to the difference in these temperatures – the area between the two curves provides an estimate of the overall heat transfer. If the coatings are fully effective at reducing heat gain from the roof, then the difference between the ceiling and air temperatures should drop dramatically from the use of coatings. **Error! Reference source not found.** shows the daily maximum ceiling and air temperatures for the houses with July data and **Error! Reference source not found.** shows the August houses. The location of the number "1" is when the coating was applied.

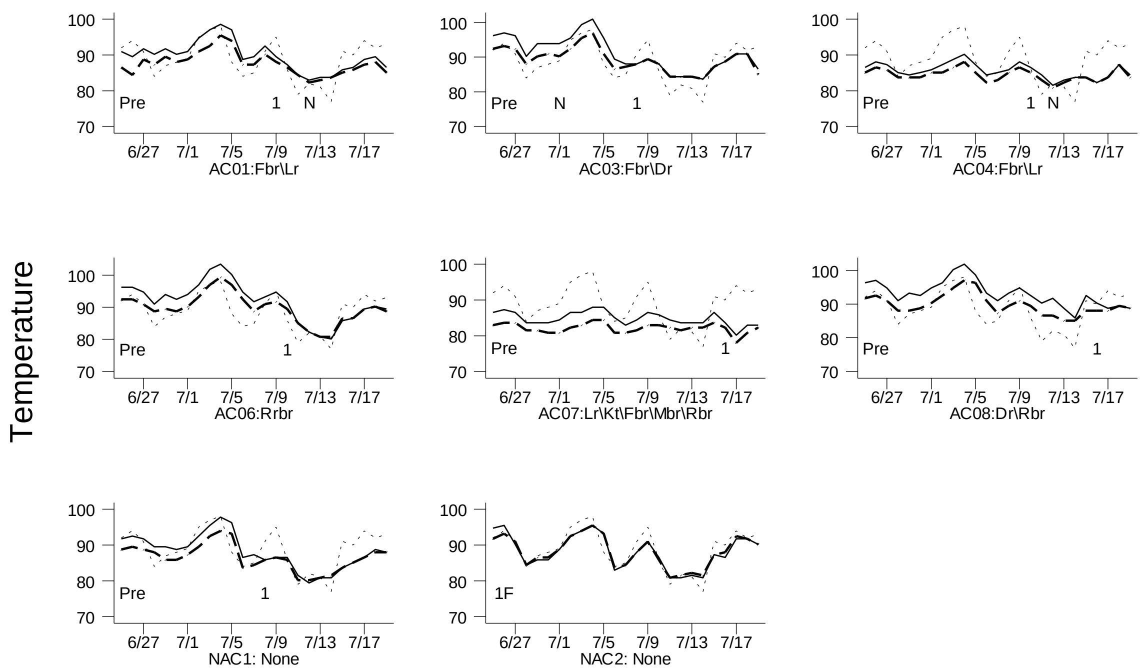


Figure 8. Maximum Daily Ceiling and air (dashed line) temperatures -- July houses (outside maximum temperatures shown as dotted line)

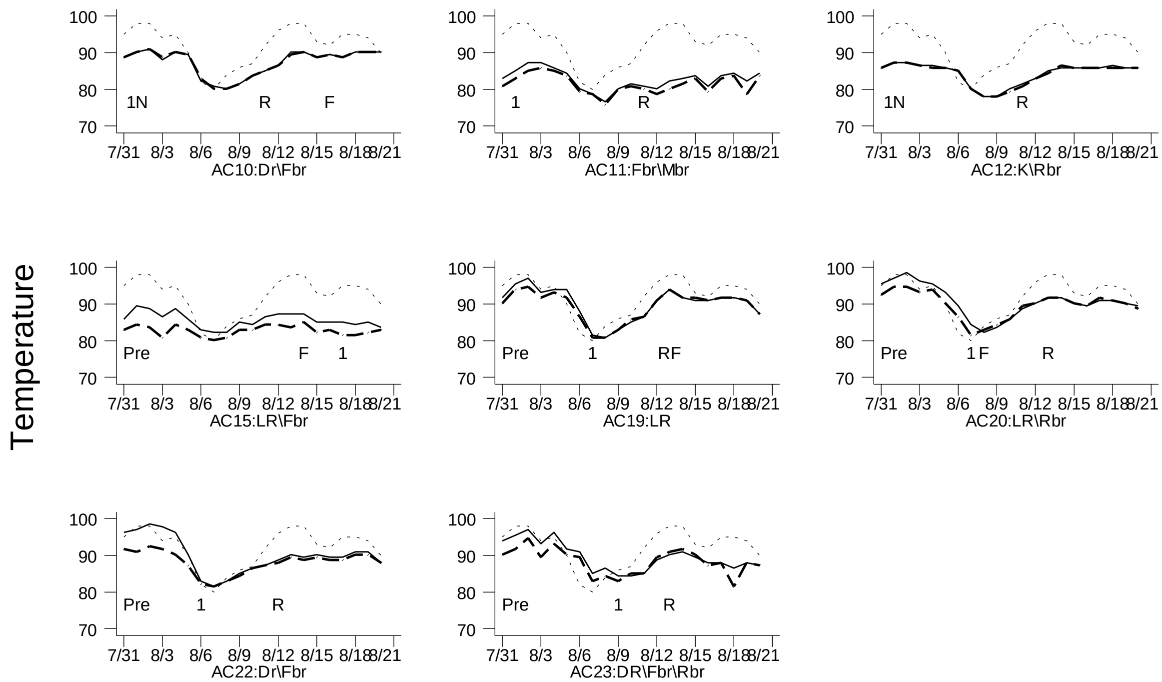


Figure 9. Maximum Daily Ceiling and air (dashed line) temperatures -- August houses (outside maximum temperatures shown as dotted line)

Notes on the graphs referring to "Pre" refer to prior to coating. "R" refers to after roof coating.

In most houses, the difference between the ceiling and air temperatures narrows or is even eliminated after coating (e.g., AC03, AC06, AC20, AC22, AC23). Houses which had already been coated by the start of the data mostly showed ceiling and air temperatures that were indistinguishable (NAC2, AC10, AC12). This comparison clearly shows coating impacts even on air conditioned houses. Of course, houses with heavy air conditioning usage (AC07, AC11, AC15) will still have a temperature difference between the ceiling and air due to normal conduction.

An alternative approach to this analysis is to plot the difference between the ceiling and air temperature in the 2nd floor bedroom over time. **Error! Reference source not found.** shows this for site AC06 with a vertical line showing when the roof was coated.

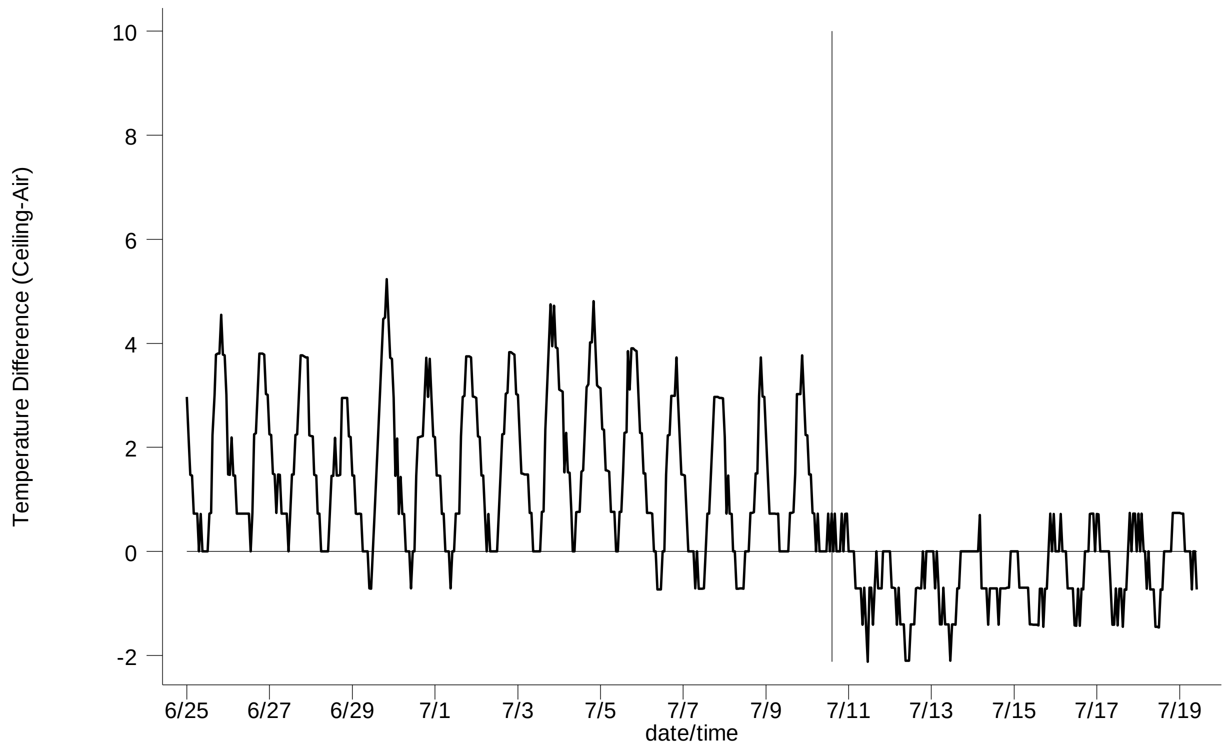


Figure 10. Temperature Difference between Ceiling and Air: site AC06

The figure shows a clear and immediate impact from the roof coating, confirming the prior conclusions that heat gain through the roof was essentially eliminated by the coatings.

First Floor Temperatures

We also examined the impact of Cool Home coatings on first floor temperatures. Most houses had air conditioners on the first floor which can obviously obscure any potential impacts. One house – site NAC1 -- had no air conditioning on either floor and also had data from before and after the roof coating. Figure 1 shows the temperature profile for NAC1.

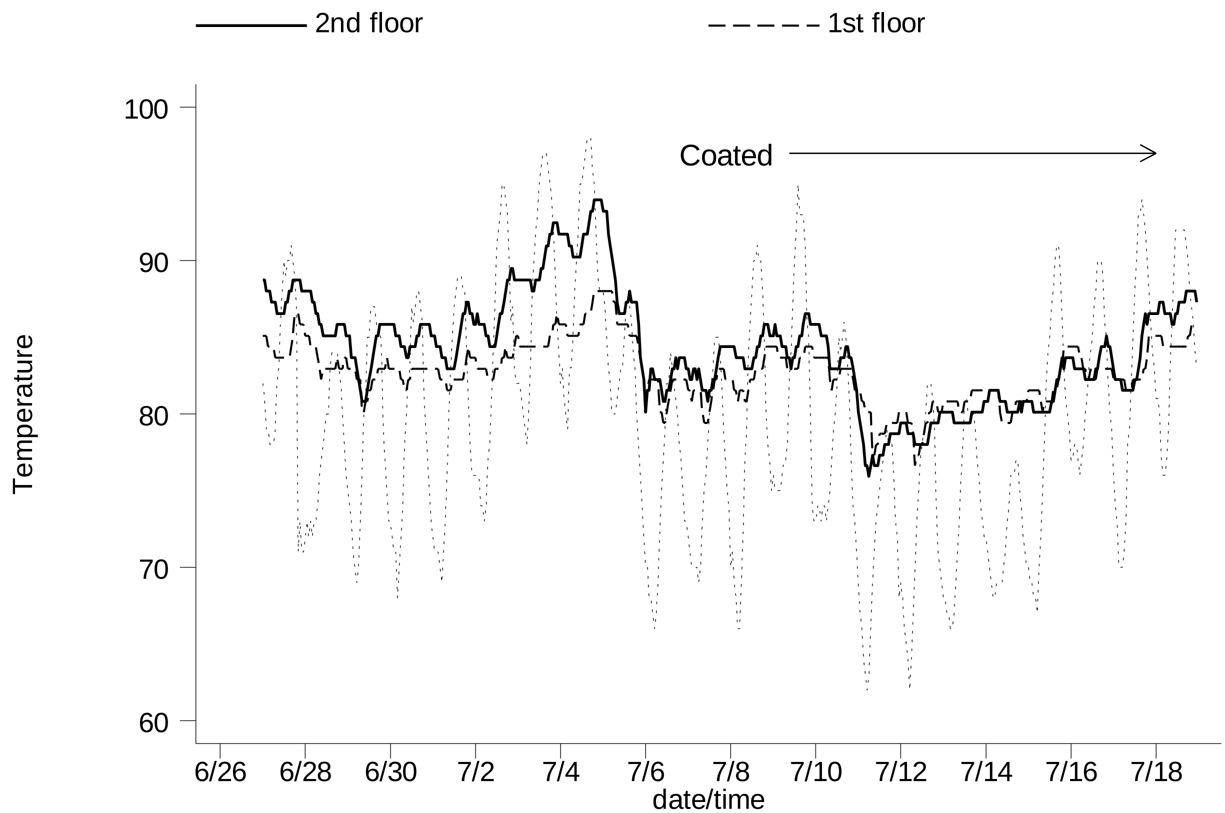


Figure 11. 1st and 2nd floor temperatures for site NAC1 (no air conditioning).

The figure shows that the second floor was much hotter than the first floor during hot days before the coating (July 8th) and then the two floors were quite similar after the roof coating. This finding is consistent with a substantial reduction in 2nd floor specific heat gain. When 1st floor temperature data were similar to what was presented in Table 1, we found no significant change in maximum temperatures. On average, the first floor was a half degree warmer after coating. The data for site NAC1 shows a one degree increase. The reason the first floor now appears cooler than the 2nd floor is the largest source of solar heart gain is no longer the roof, but the walls and windows.

Statistical Assessment of Coating Impacts

Although the graphs of the preceding section indicate that the coatings are affecting the indoor temperatures, they are a qualitative rather than quantitative assessment of coating impacts. Statistical analysis of the temperature data for different coating periods within and between sites is needed to provide a quantitative assessment of coating impacts.

Examination of the preceding maximum temperature graphs led to the first approach used to statistically summarize the coating impacts. The approach involved calculating the daily minimum, maximum, and average for each temperature at each site and for the corresponding outdoor temperature. Each day's indoor air and ceiling temperatures were subtracted from the corresponding outdoor temperature summary to measure how much cooler the indoors was compared to the outdoors. Next, all days with outdoor maximum temperatures cooler than 90 degrees, or with the prior day cooler than 90 degrees, were removed to focus the analysis on hot days and exclude the initial day of each heat wave. The temperature difference summaries (indoor/outdoor difference in minimum, maximum, and average temperatures) for the remaining hot days were then averaged for each site and each coating status. The net impact of the coatings for each site was then calculated as the change in the in/out temperature difference between the pre-coating period and the final post-coating period. Table 1 shows the results of this analysis.

Table 1. Change in Indoor/Outdoor Temperature Differences after Coating

			Change in Tin-Tout between pre and post (positive = cooler)					
			Maximum Temperature		Average Temperature		Minimum Temperature	
A/C in bedroom	Job	Exposure: shade	Ceiling	Air	Ceiling	Air	Ceiling	Air
no A/C	AC06	W:total	6.3	2.7	4.2	2.3	2.6	1.7
no A/C	AC08	W:total	6.4	2.6	3.5	1.6	0.3	0
no A/C	AC12	S:total	3.8	2.3	2	1.1	2.5	2.1
no A/C	AC19	N:some	2.7	1	2.4	1.3	4.1	2.7
no A/C	AC20	S:no	4.2	1.8	2.6	1.1	2.2	1.3
no A/C	AC21	N:total		2.9		1.5		0.5
no A/C	NAC1	N:no	4.9	2	2.4	0.7	1.7	0.6
A/C	AC01	S:no	3.3	1	2.4	0.4	2.1	1.3
A/C	AC03	E:some	7.2	4.3	4.5	3.1	0.6	-1
A/C	AC10	N:some	3	1	0.7	-0.4	0	-0.7
A/C	AC16	E:no		2		1.5		1.7
A/C	AC17	W:total		0.7		-1		-1.2
A/C	AC22	W:some	5.3	1	2.9	0.4	3.1	1.8
A/C	AC04	S:total	1.6	0.1	1.7	1.1	2	1.3
A/C	AC07	E:total	3.7	2	2.3	1.4	-0.3	-1
A/C	AC11	E:no	6.6	3.6	5.7	4.3	5.1	2.8
A/C	AC15	S:total	0.5	-1.1	1.4	0.6	3.1	3.8
A/C	AC23	S:no	5.1	2.5	3	0.6	1.8	-0.1
Average Impacts:								
Houses without A/C in bedroom			4.7	2.2	2.9	1.4	2.2	1.3
Houses with A/C in bedroom			4.0	1.6	2.7	1.1	1.9	0.8
Overall			4.3	1.8	2.8	1.2	2.1	1.0

The table shows that, in 2nd floor bedrooms, the daily maximum ceiling temperature dropped by an average of 4.3 degrees due to program coatings and the maximum air (i.e. wall) temperature dropped by an average of 1.8 F after coating. The impact were somewhat larger in houses without bedroom air conditioners – ceilings became about 4.7 F cooler and the bedroom air temperature dropped by about 2.2 F compared to outside. The impacts on air temperatures were only about half as large as the impact on ceiling temperatures. The impacts of the coatings on average and minimum temperatures were positive but smaller than the impact on maximum temperatures. Minimum temperatures declined by about half as much as maximum temperatures did.

When the analysis were re-run restricted to only the hottest days (tout max>=95 F), the impacts were slightly larger but the sample size smaller.

A similar examination of the difference between the ceiling and room air temperatures found that the average temperature difference declined from 2.4 to 1.0 F after coating.

If one eliminates three houses with heavy air conditioning usage, the decline was about 80% (from 2.0 F to 0.4 F), implying an 80% reduction in heat gain through the ceiling. A simple heat transfer calculation indicates that this change in temperature should reduce daily cooling loads by about 30,000 Btus during hot weather, or the equivalent of nearly 4 hours continuous runtime for a typical 8000 Btu/hr window air conditioner.

Regression analysis is another approach to statistically estimate the impact of program coatings on maximum indoor air and ceiling temperatures. The advantage of regression over the previous method of averages is that it can account for the relationship between outdoor temperatures and indoor/outdoor temperature differences as well as incorporate information on the prior day's maximum temperature. This approach should provide more reliable estimates in cases where these factors may differ between the pre and post periods. Table 2 shows the results from the regression analysis.

Table 2. Regression Estimates of Impacts on Maximum Temperatures *(italics denote numbers with large uncertainty)*

A/C in bedroom	Job	Exposure	Ceiling	Air
no A/C	AC06	W:total	7.3	3.6
no A/C	AC08	W:total	7.2	3.5
no A/C	AC12	S:total	4.8	3.1
no A/C	AC19	N:some	2.2	0.7
no A/C	AC20	S:no	4.5	2.0
no A/C	AC21	N:total		2.7
no A/C	NAC1	N:no		1.8
A/C	AC01	S:no	4.4	2.4
A/C	AC03	E:some	5.6	1.8
A/C	AC10	N:some	*3.3*	*1.3*
A/C	AC16	E:no		*2.3*
A/C	AC17	W:total		*0.5*
A/C	AC22	W:some	6.4	1.8
A/C	AC04	S:total	2.3	*1.0*
A/C	AC07	E:total	*3.9*	*2.2*
A/C	AC11	E:no	*6.5*	3.4
A/C	AC15	S:total	*1.5*	0.3
A/C	AC23	S:no	5.4	*2.5*
Average Impacts:				
Houses without A/C in bedroom			5.2	2.5
Houses with A/C in bedroom			4.4	1.8
Overall			4.7	2.1

The overall results are quite similar to the prior table – average impacts of 4.7 F on ceiling maximum temperatures and 2.1 F on air maximum temperatures (vs. 4.3 and 1.8). The similar findings tend to reinforce both results.

A third approach for estimating the program impacts involved using a single pooled regression model that includes the same factors as the site-specific model but also incorporates inter-site differences (e.g., exposure, shading, the presence of air conditioning, etc.). Several approaches were explored for building such a model. Impact estimates were quite consistent across a variety of model approaches – the impact estimates were about 2.3^{o} F for maximum air temperatures in houses without A/C in the bedroom, 1.9 F for those with A/C, and 4.4 F impacts on ceiling temperatures for both houses with or without bedroom air conditioners. These findings are consistent with the prior two analyses.

Further studies were conducted where some houses were also insulated in the plenum space between the roof deck and second floor ceiling.

Temperature profiles during heat waves before and after coatings are shown below in Figure 12. Black line is bedroom temperature, thick gray line is ceiling temperature and thin lighter gray line is outside temperature. Ceiling and room temperature peaks decline relative to outdoor temperature. Difference between ceiling and room temperatures drops dramatically, indicating reduction in heat transfer from attic to bedroom. Some room air conditioning obscures some of the relationships.

Figure 12 Temperature profiles before and after coating

The same data are presented in Figure 13, but the graph shows the difference between the ceiling and bedroom temperatures. The amount of dark gray shaded area on each plot is approximately proportional to the amount of heat gain from the attic into the bedroom. The difference between the pre and post coating periods is dramatic. The program coatings have nearly eliminated heat gain from the attic.

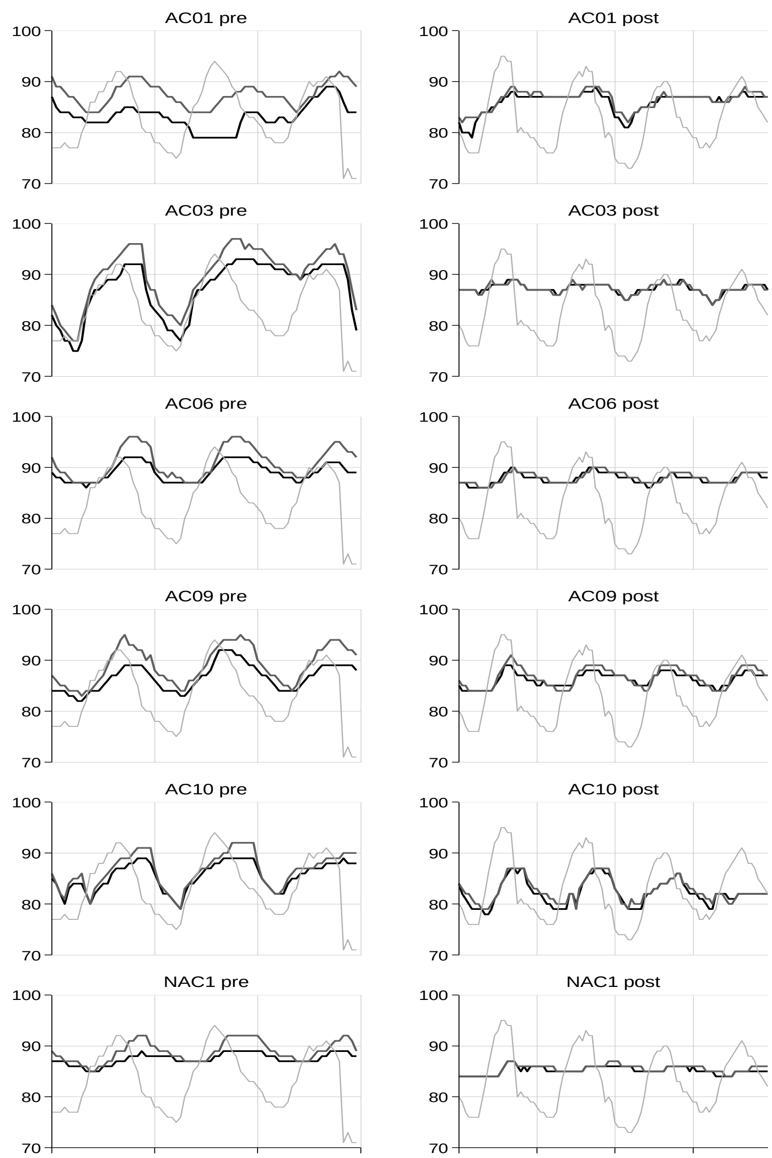
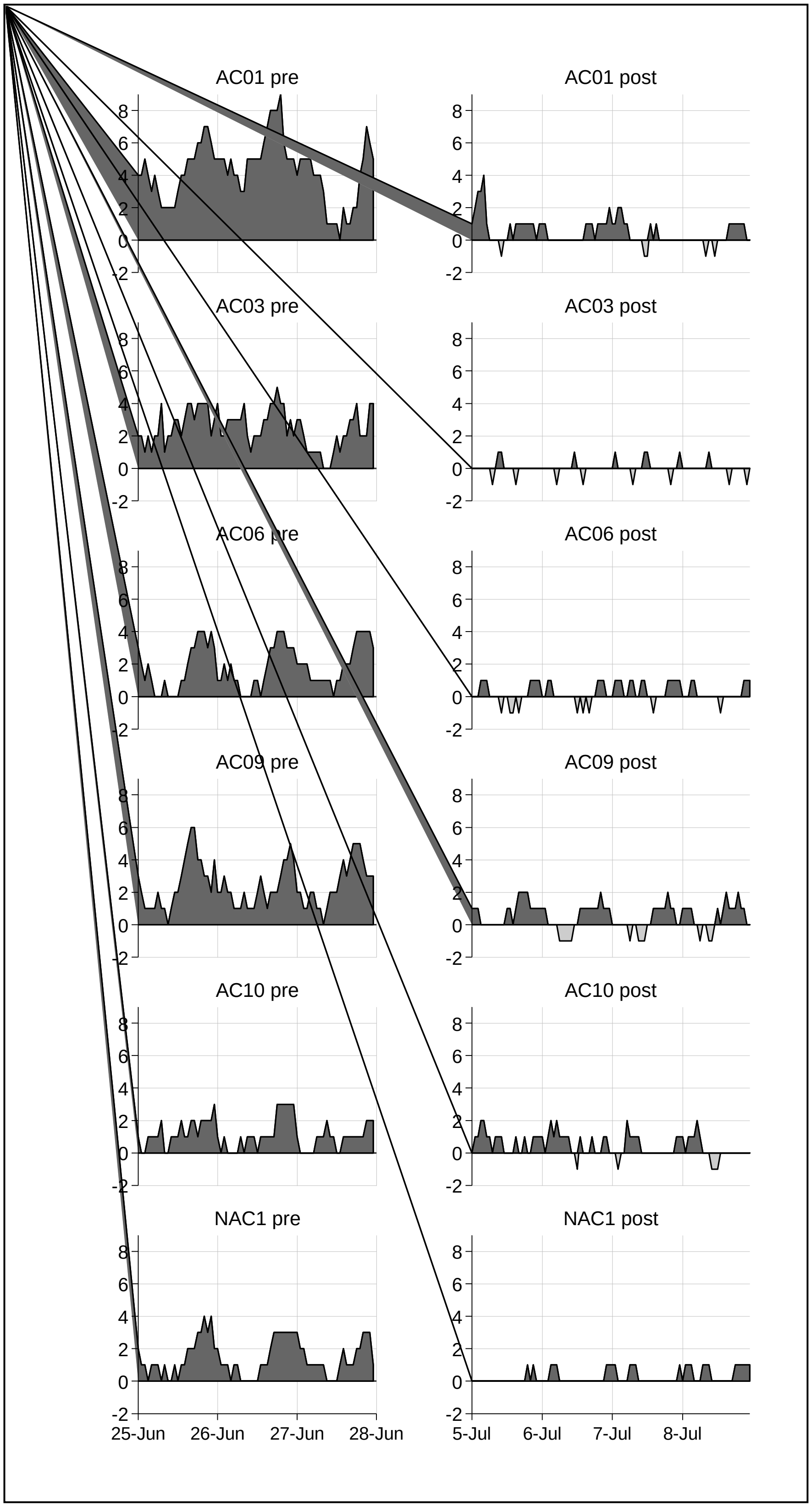


Figure 13. Temperature Differentials between ceiling and bedroom



Results for hot days (defined as maximum daily temperature >=90°F and prior day's maximum temperature >=87°F) for homes without bedroom air conditioners:

Table 4. Statistical analysis results – temperature impacts from program treatments:

	Temperature Reduction °F		
	Daily Max	Daily Average	Daily Min
Ceiling – Overall	4.8	3.5	1.8
-Coating & Insulation Effect	4.7	2.9	0.6
-Fan Effect	0.0	.6	1.2
Bedroom - Overall	2.5	2.6	2.1
-Coating & Insulation Effect	2.4	1.6	0.1
-Fan Effect	0.1	1.0	2.0

Ceiling temperatures maximums dropped from being about equal to outside temperature maximums to being nearly 5°F cooler than outdoor temperature maximums. On a 95°F day, the surface temperature drop from about 95°F to about 90°F represents a dramatic reduction in heat gain to the room as well as a dramatic improvement in mean radiant temperature conditions for comfort. The reduced ceiling temperature lead to a reduction in room air temperature about half as large. The combined changes in air and radiant temperatures can be expected to more than double an occupant's ability to cool off by losing heat to their surroundings. Window mounted exhaust fans were installed to pull cooler air form outside into the 2nd floors. The fans ere only used when the outside temperature was lower than the interior temperature. Fans had a substantial effect on minimum temperatures – reducing night time minimum room temperatures by an average of 2°F. These minimum temperatures can also be an important factor for occupant health.

Gas Usage Analysis

We were able to collect monthly gas usage data from PGW records for 66 participants. We analyzed the data in several ways to estimate what, if any, impact the white roof coating may have had on the insulation savings or household energy usage. We used a pooled time series cross-sectional regression approach to model the impacts of the multiple program interventions. This analysis found that the insulation saved approximately 100-120 therms of gas per year on average and that white roof coating had no statistically discernible effect on these savings. The "best" estimate of the roof coating effect was a 13 therm/yr increase in gas usage, but this value had an uncertainty of +-250%. These results are consistent with expectations since the heat loss through an insulated attic should be quite small and therefore changes in the temperature of the roof should have little if any effect on overall heating usage.

Cooling Load Modeling

We performed building simulation modeling of the expected impacts of the roof coating and insulation coatings using a proprietary model that incorporated solar gain, attic ventilation, house/attic air exchange, and conduction between the attic and the outside and between the attic and the house. This modeling estimated that typical summer day attic temperatures should drop from

106°F to 89°F if a black roof is coated white. The model indicated that overall building cooling loads (if the building were fully air conditioned) should drop by 22% from the coating alone (from 14.9 MMBtu/yr to 11.7 MMBtu/yr), yielding 472 kWh/yr savings. The addition of roof insulation should reduce loads to 11.1 MMBtu/yr, a very slight improvement. If insulation were added first, the incremental load reductions would be reversed. Essentially, either roof insulation or white roof coating will almost entirely eliminate heat gain through the attic while both combined provides only a slight added cooling benefit. The advantages of the white roof coating include immediate roof integrity improvements as well as a cooler roof surface which should provide a longer lasting roof. The white roof coating also keeps the attic space much cooler, which will provide performance benefits if the insulation quality is imperfect. The primary advantage for roof insulation is that it provides substantial winter heating savings. Roof coating alone without insulation may increase winter heating loads as it reduces the benefits of roof solar gain. Measure longevity has no clear "winner" since the white roof coating may get dirty over time but the insulation performance could be severely compromised if the roof leaks. The combined coating approach provides both the winter and summer performance benefits while protecting the insulation from potential problems due to roof leaks.

"Cool Block" Program

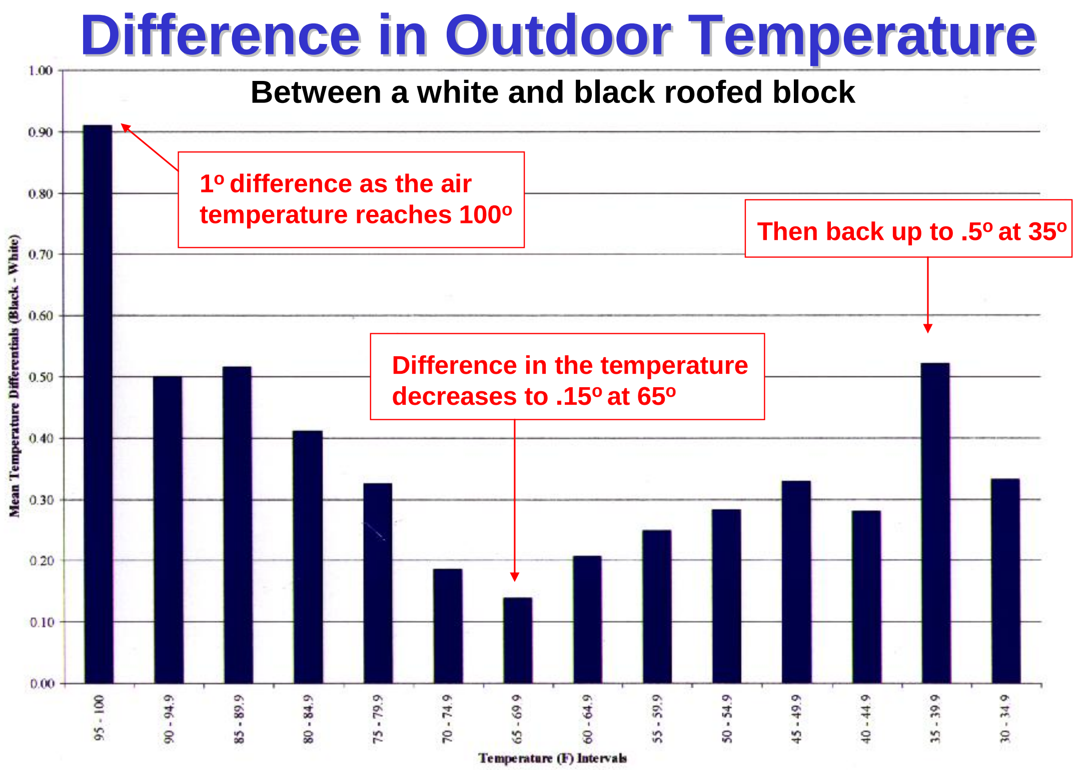
Introduction:

Based on the encouraging results of the preliminary experiments where only individual houses e in a block was coated, it was theorized that coating an entire block could reduce the cooling load on all the houses. Since these homes shared common walls, the heat load reduction in one house could positively affect the heat load in the adjoining homes. Moreover, if the entire block was coated, it was theorized that this could create an urban "thermal oasis" which would have lower ambient air temperatures compared to a block with conventional black roofs. If so, this could provide direction for solving or at least mitigating the "urban heat island effect" where urban areas retain significant heat during summer night time.

Experimentation and Results:

Temperature recording data loggers were placed strategically in the 6200 block of Catherine Street. This is a densely populated section of southwest Philadelphia. This was the "cool block" where all the homes were coated with a white elastomeric acrylic coating. A "control" block, 6200 Webster Street, was identified as having nearly identical radiative properties. Both blocks had virtually no tree cover and were bounded by asphalt covered street paving. Thus the only difference was the reflective coating on 6200 Catherine. Figure 14 below shows the impact of the white roof coating on ambient air temperature. The data was collected over a one year period and is organized as mean temperature difference between the white "cool block" and the black "control block". The X axis is air temperature intervals in 5 degree increments. It is noteworthy that when the air temperature is between 95 and 100^o there is an almost 1 degree difference in ambient air temperature. This difference in air temperatures varies depending on the ambient air temperature. The exact reason for the variability is not fully understood, but is probably related to a number of confounding factors such as wind speed, rainfall, rain and dew evaporation, cloud cover, snow, and fog. The summary effects of these coatings have been to create an urban "cool oasis" in the midst of the heat island. This work will be followed closely to get additional data inputs to further refine the model.

Figure 14



Conclusions:

These results are encouraging as having demonstrated the ability of cool roof coatings as a method for reducing, not only interior air temperatures and air conditioning costs, but also in mitigating the urban heat island effect. Key conclusions are that reflective roof coatings can reduce roof and ceiling temperatures. The roof is no longer the single largest contributor to the heat gain, but has been supplanted by the walls and windows as leading source for heating. The need for large numbers of data inputs is necessary to identify trends in actual occupant inhabited buildings to eliminate or account for other residential lifestyle factors that may mask or confound some data.

This research has demonstrated the value of energy savings, with resulting reduction in smog and pollution, reducing the urban heat island effect, improving social conditions in densely populated urban areas and improving health and living conditions for at-risk vulnerable urban residents.

Next Steps:

Now that estimated temperature impacts of the coatings has been defined, further evaluations should examine how these temperature changes affect occupant health and safety as well as cooling loads (in houses with air conditioners). The former task can be assessed using existing models of heat stress and examining how these temperature changes should affect the ability of a person to lose heat to their surroundings. The latter task can be estimated using engineering models of heat transfer from the ceiling to the air and, to the extent that sufficient data are available, by analysis.

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Appendix

Photos below document the roof coating and data capture process

Application of Elastomeric Acrylic Roof Coatings to Residential Roofs

Comparison of Coated and Uncoated Roofs

Overview of Several Residential Roofs

Installing Data Loggers for "Cool Block" Comparison

Data Logger Located at a Residence

“Cool Block” 6200 Catherine Street