Cool Roofs Program as Municipal Policy in ASHRAE Zone 5 Climates

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ABSTRACT

The central purpose of this thesis is to evaluate the effectiveness of the City of Pittsburgh's 2013 Cool Roofs Program, of which the author of this thesis was one of the administrators. The original stated goal of the program according to mission statement and grant agreements was to engage volunteers, reduce greenhouse gas emissions & lessen the heat island effect, and save the City of Pittsburgh operating costs due to a reduced cooling load. The realization of volunteer engagement occurred at the conclusion of the project's implementation, but the other two key metrics for project success required several years of data collection and observation to determine if the project had achieved its stated goals. It has been 3 years since the implementation period of the Cool Roofs Project and the following thesis evaluates whether or not the two remaining goals were achieved and whether this is a viable strategy for other cities in the same climate zone with comparable municipal building assets.

GLOSSARY

CDD: Cooling Degree Day

C^O2: Carbon Dioxide

HDD: Heating Degree Day

kWh: Kilowatts/Hour

MCF: 1,000 Cubic Feet

INTRODUCTION

The focus of this thesis is to evaluate the policy of using Cool Roofs on municipal buildings as primarily a cost-savings measure for municipal governments. Secondary benefits to Cool Roofs can be reducing the urban heat island effect of a given area, reducing net CO^2 and greenhouse gas emissions. The data used in the course of this research will be utility bills from the City of Pittsburgh's Cool Roofs program, which took place in 2013. This thesis will investigate whether or not cities in a comparable climate to the City of Pittsburgh should look to their program as an effective model to repeat.

The main theory behind Cool Roofs is that when a roof material is either made or retrofitted with a high albedo material (highly reflective), it causes the roof and the building envelope to absorb less heat from the sun. This in turn reduces the need for air conditioning to reduce the air temperature inside the building envelope. With a reduced air conditioning load comes a lower electrical demand from the electrical grid and thus While the benefits of Cool Roofs can be seen during "cooling months" or months in a given location that require cooling of the building envelope, there is likewise a "heating penalty". Essentially that Cool Roofs can increase the heating load, CO^2 and other GHG emissions, and the associated municipal operational costs in cold weather, especially in buildings that previously had a black roof which absorbs the heat from the sun into both the roof material (reducing snow accumulation) and the building envelope. The cooler the climate, the greater the heating penalties will likely be and the less the benefits of Cool Roofs will be.

The primary research question driving this thesis is: "Is it sound fiscal and environmental municipal policy for cities in climate zone 5 (Baechler) to enact a Cool Roofs program comparable to the City of Pittsburgh Cool Roofs Program?" Essentially, should cities in climate zone 5 be retrofitting/upgrading/replacing roofs on municipal buildings (if so, what typologies) with highly reflective material in an effort to reduce energy bills, ease strain on HVAC units, lower GHG and CO^2 emissions, in addition to promoting and encouraging the implementation of Cool Roofs for private commercial and residential properties? If so, what particular building typologies should be targeted? For this project, data will be used from the City of Pittsburgh's Cool Roofs program, but the implications for planners will extend to all municipalities that are also located in the ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers) climate zone 5 area.

BACKGROUND

Cool Roofs has been a strategy of reduced operational costs and global warming mitigation of several American municipalities, including New York City, NY and Phoenix, AZ. In 2013, the City of Pittsburgh acquired a Cities of Service Impact Volunteering Fund Grant, financed through the Bloomberg Foundation to implement their own Cool Roofs program, becoming the third city in the United States to do so, and the only city in the zone 5 climate area. The Cool Roofs program in New York City focuses on diverse building owners, private, non-profit, and government partners all over the five boroughs (http://www.nyc.gov/html/coolroofs/html/home/home.shtml).

Unlike the New York City program, the Cool Roofs program in the City of Pittsburgh mainly focused on City-owned buildings, with the exception of a small mini-grant program that netted two participants. At the end of the program, the City of Pittsburgh was able to exceed its project goals and coated over 60,000 square feet of City-owned buildings with highly reflective coating. The project was a collaboration between the Mayor's Office of Service & Civic Engagement, the Mayor's Office of Sustainability and Energy Efficiency, and Department of Public Works. All of the sites selected had roofs where the warranties had expired- they were all 30 years old or more. All of the selected sites had flat roofs comprised of either black asphalt sheeting or EPDM rubber membrane. The coating of the roofs was completed within period from May-October, 2013. The coatings were completed in their entirety with the help of over 200 volunteers from around the Pittsburgh area. The selected sites were varied in their uses for the City of Pittsburgh, from a storage warehouse to a recreation center to the most common building type targeted during the project- firehouses. Typology of building wasn't a main deciding factor when it came to building selection for participation in the program. One of the main challenges for the administrators of the program was satisfying the terms of the grant within the approved schedule as well as complying with the requirements from City Departments such as the Public Works and the City Solicitor. With restrictions such as roof type, roof age, roof warranty status, roof repair status, accessibility and safety concerns for volunteers, and status of ownership, the buildings that were eligible for the program turned out to be limited. In short, every building that could be considered eligible for the Cool Roofs Program was included in the program.

The author of this thesis was one of the main administrators of the program, serving the City of Pittsburgh as a Green Cities Fellow; a fellowship program committed to urban sustainability initiatives that place sustainability Fellows with public, non-profit, and private entities throughout Pittsburgh, PA. The initial budget for the program was $81,000, including $56,000 from the Cities of Service Impact Volunteering Fund Grant. The main goals of the grant makers were two fold- they wanted to execute a program that promoted a more sustainable city and engaged the citizenry in volunteer work. The money had to be exhausted and accounted for by final reporting period for the grant, in this case that was December 2013.

The initial phase of the project was planning. This included site selection for the Cool Roofs, initial volunteer recruitment and scheduling, creation of liability release forms in conjunction with the City Solicitor, establishing a working relationship with the Department of Public Works, materials research, materials bidding, and materials purchasing. The following phase was the implementation, which included site preparation, volunteering scheduling, volunteer management, further materials purchasing, further volunteer recruitment, and the actual painting days. In the final phase of the program, administrators prepared and submitted materials for nomination for the United States Green Building Council's 2013 Malcolm Lewis IMPACT! Award.

It has been 3 years since the implementation of the Cool Roofs program in the City of Pittsburgh. The energy usage and billing data for all of the participating buildings going back to January 2010 is catalogued by a consulting company employed by the City of Pittsburgh (The Eric Ryan Corporation). This catalog of bills and usage records will be the primary source of data for this work.

CONTEXT

Whenever a municipality looks to take on sustainability-focused programs or efforts it can mean a great number of many different things. Goals can vary from water retention/diversion, saving energy, increasing green space, optimizing waste streams, etc.

Just as the goals of a municipal sustainability program can vary widely, the platform on which a program is based can also vary broadly. Sometimes programs are focused on changing the behaviors of the citizenry, some focus on improving the emissions performance of transit systems, and some, like the Cool Roofs Program, focus on the built environment and building assets of a given municipality.

While the Pittsburgh Cool Roofs Program focuses on saving energy on City buildings, it is only one strategy among an array of other potential programs that can focus on advancing sustainability goals for a city. Other strategies could include incorporating green infrastructure where there was previously grey infrastructure in an effort to reduce stress on a combined sewer system or incorporating hybrid vehicles into a city transit fleet in an effort to reduce carbon emissions.

Programs that are comparable to Cool Roofs in that they also aim to reduce energy use coming from municipal buildings could include installing programmable thermostats, updating lighting and lightbulbs, upgrading mechanical systems, etc.

LITERATURE REVIEW

The body of academic literature involving Cool Roofs and Cool Roof policy is relatively limited. Much of the literature is evaluative, mostly with the main goal of proving the effect of Cool Roofs on the cooling load and building envelope of buildings on an annual basis. The vast majority of research involving Cool Roofs has been done at the Lawrence Berkeley National Laboratory in Berkeley, California. Much of the research design has been either large scale simulations using regression models to show the potential effect of widespread Cool Roofs implementation (Levinson et al. 2010) or it has been small-scale experiments carried out in locations such as Nevada, California, and Florida (Akbari 2003, Konopacki et al. 1998). Research has also been conducted internationally, in places such as Canada (Konopacki et al. 2001) and India (Hashem 2011).

The literature by and large supports the use of Cool Roofs as a strategy to reduce energy costs and CO^2 emissions. The main academic researcher in this realm is Hashem Akbari, a researcher that works with the Berkeley National Laboratory and Concordia University in Montreal. His 2003 paper completed with Haider Taha will be the main guiding piece of literature for this thesis. Research within the paper cites earlier studies and sources as well as includes primary research conducted from the Lawrence Berkeley National Laboratory. Beyond providing seminal research, this article also provides several potential templates for analysis methodology, including a predictive multivariate regression to measure the effect of heating and cooling days. This methodology is interesting to note, but ultimately may prove unnecessary for the purposes of this thesis, due to the fact that there exists several years of both before and after implementation energy usage data. Additionally, there is presented a formula for estimating cost effectiveness, based on assumptions regarding average effect of the cool roof on energy usage, effect of lifespan of a given roof, average cost of energy (both heating and cooling) across several years and regions, etc. I can take this methodology and be more targeted due to the exact nature of my data (I know the exact cost of energy at any given time for every targeted building, etc.)

There have been dissenters to the idea of Cool Roofs however, as a 2011 paper from Stanford University asserts that in certain climates, Cool Roofs can actually cause more harm to the environment due to their effect on rainfall absorption and evaporation (Jacobson, et al 2011). The paper asserts that while Cool Roofs might be appropriate for a climate such as Arizona, they will actually have a net negative effect in a place like Florida (even though they will still reduce cooling loads).

These assertions were addressed by Akbari and Levinson (2010) and the debate appears to be ongoing, with various engineers and climate scientists writing more casual, less academic opinions in the years following.

Other concerns with Cool Roofs have to do with building type. High energy, 24/7 buildings may in fact benefit less from Cool Roofs due to their high rate of energy use at all hours of the day (Osmon 2015). This may be a large factor in the selected data for this thesis since most of the targeted sites are high energy use firehouses.

DATA SOURCES/METHODOLOGY

As previously referenced, the data evaluated for the purpose of this thesis are electrical and natural gas usage and price data for all nine buildings that were incorporated into the Pittsburgh Cool Roofs Program. The author of this thesis was provided with the data in spreadsheet form as opposed to copies of the physical bills. The data was presented in billing period formats, with each billing period being roughly a month in length.

The methodology for evaluating the effectiveness of the program was done by normalizing both the electrical usage data and the natural gas usage data to the weather for their respective periods and then calculating the difference between the normalized usage data from three years before the implementation period (2010-2012) and three years after the implementation period (2014-2016).

All buildings that were included in the Cool Roofs program will be observed in the course of this thesis expect for the Parks Department Warehouse located on AVRR, Pittsburgh, PA 15201. Due to the constructed nature of the Parks Department Warehouse on AVRR, the property was excluded from the overall analysis. The property itself is an outlier in terms of size, energy usage, and type of use. It is known that the warehouse is not centrally cooled or heated, only a small office building within the warehouse envelope is climate controlled. Due to the extremely high average electrical usage of the building it can reasonably be concluded that such a small percentage of the energy used for this building is put towards cooling/heating efforts that any change affected by the implementation would be negligible and/or undetectable. This was known to the administrators of the program at the time of the coating, but it was decided to move forward with the painting of the warehouse anyway, both to capture the positive effects on the urban heat island effect in the highly industrial and darkly paved immediate neighborhood and to fulfill the requirements of the grant within the mandatory timeframe.

This methodology was employed due to the asymmetry of the weather conditions from year to year. Some summers are hotter than other summers, some winters are milder than others, from year to year. Simply finding the difference in usage between years without normalizing for the different weather conditions wouldn't yield a fair comparison.

In order to normalize for weather, the amount of Cooling Degree Days (CDD) and Heating Degree Days (HDD) were calculated and summed for each corresponding billing period. For both measurements, a base temperature was selected- in this case that temperature was selected to be 65 degrees Fahrenheit. The base temperature is the assumed controlled internal temperature of the buildings from which to calculate both CDD and HDD.

The reasoning for using CDD and HDD as opposed to simply normalizing the energy usage data to average temperature for a given billing period is the average temperature doesn't account for the fluctuation in temperature that can occur in a given billing period. For example, in a given month the average temperature could be 68 degrees Fahrenheit. That could mean that all of the days in that billing period could have hovered right around 68 degrees, meaning that electricity used for air conditioning purposes would have be minimal. Alternatively, a month with an average temperature of 68 degrees could see a large amount of fluctuation, with several days in the month being in the 70's and 80's and several days in the 50's. In this scenario, much more energy will have been exerted towards both heating and cooling efforts, resulting in unexplained spikes in both natural gas and electrical usage for a period with a seemingly mild temperature.

The calculations for CDD is thus:

*CDD = # of degrees Fahrenheit above the selected base temperature * number of days*

For example, if there were 3 days where the temperature was 82 degrees, 82-65 = 17, 17 * 3 = 51. The CDD for that 3 day period would be 51. HDD are calculated the same way, with the exception of the actual daily temperature being subtracted from the base temperature, as opposed to vice e versa.

For the purposes of this analysis, the total electrical usage (kiloWatt hours or kWh) in that period is divided by the total amount of CDD in the same period in order to find the total normalized usage (kWh/CDD). The same is done for both three-year periods, both before and after Cool

Roofs implementation and then the difference for normalized electrical usage is found. The process is repeated for all buildings included in the program as well as for natural gas usage (One-Thousand Cubic Feet or MCF) and HDD to find any increase in heating load after implementation.

Data for CDD and HDD were acquired from www.degreedays.net, a website catered to energy saving professionals that uses weather data from www.wunderground.com, a commercial weather service that draws its United States weather information from the National Weather Service and is a subsidiary of the The Weather Channel and The Weather Company. The weather station selected for measurement in all analysis was KAGC at the Allegheny County Municipal Airport located in West Mifflin, PA, a municipality adjacent to the City of Pittsburgh to the southeast.

LIMITATIONS

The limitations in the process of conducting this thesis investigation were many and varied. While energy and weather data were readily available to the author, they exist many unaccounted for variables when attempting to quantify the impact(s) of the Cool Roofs program on building performance.

Perhaps the most glaring of these limitations is the lack of reliable detailed information relating to the specifications and operation of each of the participating buildings. One of the main issues with attempting to quantify the effect of the Cool Roofs program on the participating buildings is the lack of information on all of the other variables that affect the energy usage of each building. Even if this information was gathered, quantifying and synthesizing such information would be outside the scope of this thesis and would likely have to be conducted by a team of building performance engineers or similar professionals. The age and type of every cooling system, heating system, light bulb specifications, computer count, kitchen equipment, etc. would have to be accounted for in every building along with an analysis of building airtightness as performed with a blower-door test to understand what percentage of each of the buildings' energy use is put towards the base energy load versus cooling/heating loads. Additionally, information building-user habits over the 6-year analysis period would have to be acquired in order to do a more complete analysis and help isolate the effect of the Cool Roofs. Whether or not each building is equipped with an automatic or manual thermostat as well as other energy consumption habits would have to be observed, recorded, and accounted for in order to execute a more complete analysis.

Related to energy consumption habits is the issue of the assumed base temperature for CDD and HDD. While 65 degrees Fahrenheit is likely a good assumed base temperature for all buildings, there is no replacement for knowing the true base temperature of a given building, broken up into the smallest time frames possible.

Another limitation encountered during the course of analysis was that of usage data only being available on a billing period basis as opposed to a more finite timeframe, such as weekly, daily, or hourly. This created an issue where a more specific correlation between energy usage and CDD/HDD became difficult to achieve. Additionally, since the billing periods did not run from the first of each month to the end of each month and the calculations for CDD/HDD did, therefore there is likely at least some minor misappropriation of kwH/CDD(HDD), especially in the split between January and December (the cutoff months for the observed before/after periods).

Similar to the issue of effectively quantifying building performance is the issue of accurately calculating the environmental impact of the Cool Roofs Program. The fuel source makeup for the electrical supply is unknown for each building and each year, making it impossible to calculate the emission savings from the Program. Additionally, the effect of the retrofitted white roofs on the urban heat island effect is difficult to accurately quantify without having historical surface and air temperatures at a very finite geographical scale.

FINDINGS

The findings of this study using the aforementioned methodology along with the associated limitations should not be interpreted to be a definitive indictment or endorsement of the Pittsburgh Cool Roofs Program. Due to all of the unaccounted for variables in associated with the energy usage, the findings will only help to somewhat explain the impact of the Cool Roofs program in terms of energy usage. Findings related to other purported benefits of Cool Roofs such as the urban heat island effect will also be difficult to quantify due the number of impactful, unmeasured variables that contribute to surface temperature.

The first set of findings (Table 1) is represented in the total difference of kWh/CDD from 2010-2012 and 2014-2016, January through December:

Address	*Type*	*Difference*	
96 Virginia Avenue	Firehouse	7.845024	kWh/CDD
259 McKee Pl	Firehouse	-3.17326	kWh/CDD
321 Merrimac St	Recreation Center	-6.96043	kWh/CDD
916 Steuben St	Firehouse	-1.0825	kWh/CDD
1124 West North Ave	Firehouse	-6.69225	kWh/CDD
2500 Aliquippa St	Firehouse	2.3508	kWh/CDD
2800 Shadeland Ave	Medic Station	-2.37328	kWh/CDD
7024 Lemington Ave	Firehouse	-2.01187	kWh/CDD
TOTAL		**-12.0978**	**kWh/CDD**

Table 1: Year-round difference in kWh/CDD

The sum total of approximately -12 kWh/CDD represents that the buildings that participated in the Cool Roofs Program actually became less energy efficient following the Cool Roofs implementation period. One should hesitant to immediately attribute this causality to Cool Roofs implementation, as that would be counterintuitive and inconsistent with nearly all sustainability and engineering experts. Even those critical of Cool Roofs are often so for other reasons, such as the effect they have on the heating load in colder climates, how the cooler roof temperatures can attract condensation in buildings without proper insulation and without proper vapor barriers, etc. It is much more likely that this difference is explained in either: a real-world effect, such as degrading building envelopes, aging and substandard mechanical equipment, etc., or it is an issue with the assumed base temperature and the calculation of the CDD.

Despite the limitations, a second attempt was made to try and better focus on the energy usage that was devoted to cooling each facility. In this iteration (table 2), only May-September was totaled for each period, the months that tend to have the bulk of the Cooling Degree Days in any given year:

Address	*Type*	*Difference*	
96 Virginia Avenue	Firehouse	5.71525	kWh/CDD
259 McKee Pl	Firehouse	0.932284	kWh/CDD
321 Merrimac St	Recreation Center	-4.88413	kWh/CDD
916 Steuben St	Firehouse	0.675743	kWh/CDD
1124 West North Ave	Firehouse	-1.67177	kWh/CDD
2500 Aliquippa St	Firehouse	3.175574	kWh/CDD
2800 Shadeland Ave	Medic Station	-0.23963	kWh/CDD
7024 Lemington Ave	Firehouse	0.196748	kWh/CDD
TOTAL		**3.900068**	kWh/CDD

Table 2: Summer month difference in kWh/CDD

The sum difference of ~3.9 kWh/CDD indicates that on the whole, participating Cool Roof buildings *have* increased in energy efficiency during the summer months, when one is theoretically most likely to see the benefits of the Cool Roof retrofitting. While the amount of change is more attributable to Cool Roofs in this particular analysis, one cannot make the assumption of Cool Roofs being the sole causal factor. Just as a reduction in energy efficiency can be explained by a degrading building envelope and subpar mechanical systems, improvement in energy efficiency can also be explained by an improvement in the building envelope (pointing brick, new windows, etc.) and by the maintenance, repair, or replacement of mechanical systems.

Another issue with this particular analysis is while the energy efficiency coefficient of each building improved as compared to the year-long analysis, there are still some facilities that saw an overall drop in energy efficiency since the implementation period. The possible reasoning for this returns to the issue of known yet unexplained variables that are causing energy efficiency as whole to be reduced in these facilities; that said, the fact that these negative deficiencies are reduced in the summer-only analysis as compared to the year-long analysis lends further credence that there are gains in the summer months in terms of energy efficiency.

In order to address one of the main critiques of Cool Roofs, one must observe MCF/HDD in addition to kWh/CDD. table 3 shows the difference in MCF/HDD for all months from 2010-2012 and 2014-2016:

Address	*Type*	*Difference*	
96 Virginia Avenue	Firehouse	0.006793	MCF/HDD
259 McKee Pl	Firehouse	0.009979	MCF/HDD
321 Merrimac St	Recreation Center	0.013656	MCF/HDD
916 Steuben St	Firehouse	0.024911	MCF/HDD
1124 West North Ave	Firehouse	0.03138	MCF/HDD

2500 Aliquippa St	Firehouse	0.063388	MCF/HDD
2800 Shadeland Ave	Medic Station	0.007888	MCF/HDD
7024 Lemington Ave	Firehouse	0.045752	MCF/HDD
TOTAL		**0.203747**	MCF/HDD

Table 3: Year-round difference in MCF/HDD

Over the course of 12 months per year, the cumulative difference in MCF/HDD is actually positive, meaning the facilities became more efficient in terms of natural gas use on days that required the use of heating systems. Once again, this conclusion should be considered along with the limitations to the calculation methodology, most specifically the assumed base temperature. One conclusion that could be reached is that while this data does not completely dispel the notion that Cool Roofs adds to the heating load of buildings in the winter, one can confidently reaffirm that it does not *significantly* add to the heating load of a given facility. In order to focus more on the heating loads of the buildings, a comparable analysis is run to the ∆kWh in the summer in the form of ∆MCF only in the months with the majority of HDD (Table 4):

Address	*Type*	*Difference*	
96 Virginia Avenue	Firehouse	-0.03054	MCF/HDD
259 McKee Pl	Firehouse	0.006911	MCF/HDD
321 Merrimac St	Recreation Center	-0.01314	MCF/HDD
916 Steuben St	Firehouse	-0.00184	MCF/HDD
1124 West North Ave	Firehouse	-0.00342	MCF/HDD
2500 Aliquippa St	Firehouse	0.206678	MCF/HDD
2800 Shadeland Ave	Medic Station	-0.0224	MCF/HDD

7024 Lemington Ave	Firehouse	-0.00642	MCF/HDD
TOTAL		**0.135843**	MCF/HDD

Table 4: Difference in winter months for MCF/HDD

Table 4 falls more in line with what would be expected. While the summed difference is still positive, this is mostly due one facility, as all but two facilities show very minor declines in efficiency. Whether or not this is attributable to Cool Roofs is somewhat beside the point- the fact remains that there is no evidence of a *significant* increase in heating loads in the period following Cool Roofs implementation.

CALCULATED SAVINGS

Since the seasonal calculations proved to be a more precise metric when measuring the effect of the Cool Roofs Program, it stands to reason that only the summer periods from both the before and after implementation periods would be the ones used to calculate the total savings seen in usage (kWh), bill amount ($US), and estimated carbon footprint (CO^2).

When one simply looks at and totals the bill amounts from the summers previous to implementation and then subtracts the total bill amount from the post-implementation summers, Table 5 results:

Address	*Type*	*Difference*
96 Virginia Avenue	Firehouse	$3,103.21
259 McKee Pl	Firehouse	$654.63
321 Merrimac St	Recreation Center	-$7.54
916 Steuben St	Firehouse	$1,153.99
1124 West North Ave	Firehouse	$374.28
2500 Aliquippa St	Firehouse	$1,461.17
2800 Shadeland Ave	Medic Station	$58.06
7024 Lemington Ave	Firehouse	$597.69
TOTAL		**$7,395.49**

Table 5: Electricity savings from after the Cool Roofs Program

The 'total' amount indicated in the table is the gross amount. In terms of dollars per summer, the City has saved $2,465.16 per summer in electric bills since Cool Roofs was implemented in 2013. This number belies the true savings however, as each year is not normalized to the average cost of a kWh in each given year and monetary inflation has not been accounted for. When including these factors, the real savings is reflected in Table 6:

Address	*Type*	*Difference*	*Avg Price Before*	*Avg Price After*	*Nominal Total Savings*	*Adjusted to 2010 $*
96 Virginia Avenue	Firehouse	$3,103.21	0.09	0.09	$3,103.21	$3,538.94
259 McKee Pl	Firehouse	$654.63	0.1	0.1	$654.63	$874.73
321 Merrimac St	Recreation Center	-$7.54	0.1	0.1	-$7.54	$582.64
916 Steuben St	Firehouse	$1,153.99	0.09	0.09	$1,153.99	$1,574.75
1124 West North Ave	Firehouse	$374.28	0.1	0.1	$374.28	$796.85
2500 Aliquippa St	Firehouse	$1,461.17	0.1	0.1	$1,461.17	$1,745.81
2800 Shadeland Ave	Medic Station	$58.06	0.1	0.1	$58.06	$216.94
7024 Lemington Ave	Firehouse	$597.69	0.09	0.09	$597.69	$1,055.77
TOTAL		**$7,395.49**			**$7,395.49**	**$10,386.44**

Table 6: 2010 adjusted saving amount

For each site, the average electrical rate was the same for both the before and after period so there was no effect on the savings from the variable electrical rate. When all years involved in the study are adjusted to 2010 dollars using the Consumer Price Index the total savings for the program through 2016 jumped almost $3,000.

Using information from the EPA's 2017 eGRID summary tables (https://www.epa.gov/sites/production/files/2017-02/documents/egrid2014_summarytables_v2.pdf), and estimating the fossil fuel supply for the City, the estimate of total carbon dioxide saved after the implementation of the program is 7.67lbs.

CONCLUSIONS

It is encouraging to see savings, both economic and environmental, 3 years since the completion of the Cool Roofs Program. As previously stated, there are too many 'known unknown' variables to take a more convicted stance on the effects of the program, but the results are nonetheless encouraging.

While economic savings were realized in this case, any City planning to enact a comparable program from their own capital budget or granter looking to fund a comparable program should look at the return-on-investment of Cool Roofs and consider all of the other sustainability measures that could be enacted with the same amount of money, i.e. consider the opportunity cost of doing a Cool Roofs Program. In this case, the total budget for the program was recorded as $81,600.00. With an estimated annual nominal savings rate of $2,465.16, the payback period would be approximately 33 years. Considering each of the roofs retrofitted was already 30 years old, expecting to reach a 'break even' point is wholly unrealistic. The only way for a city to save money using a Cool Roofs Program is to have the costs of the program granted to them.

This begs the question of whether the program can be considered a success through the eyes of the granters, something that always depends on the granters' stated goals and priorities. In the case of the Bloomberg Foundation and the Cities of Service Impact Volunteering Fund, engaging volunteers was one of the main goals of the program. Even if there were other more effective cost-saving sustainability measures, such as installing instant hot water heaters, solar panels, or programmable thermostats, the interest of the granters in this case was to do a project that simultaneously achieved sustainability goals while engaging volunteers.

The City of Pittsburgh can consider the Cool Roofs Program a moderate success as the modest economic and environmental savings observed after the implementation of the program can be considered 100% profit, and the granters achieved both of their stated goals with the project. That said, it should be considered whether or not the program was worthwhile in terms of the administrative effort put towards the program- that is, what is the opportunity cost of committing the necessary attention and assets towards the Cool Roofs Program, where it could have been committed to a program that would show better results than the Cool Roofs Program. When looking at the Cool Roofs Program from that perspective, it is much more difficult to claim the program as an unqualified success.

RECOMMENDATIONS

Many recommendations can be made to cities in similar climates to that of Pittsburgh looking to launch their own Cool Roofs Program, grant makers involved in funding Cool Roofs Programs, and cities such as Pittsburgh that have already completed a Cool Roofs implementation on some of their building stock.

First and foremost, cities should employ the use of a building performance specialist (engineer or otherwise) to review the existing building assets to make sure there are buildings eligible for Cool Roofs retrofitting. At this stage, policymakers should work with a building performance specialist to make sure any other low-cost, high-return solutions have already been explored and enacted to improve building performance, such as programmable thermostats and high-efficiency light bulbs.

Next, a representative from the municipality should do a considerable academic engineering literature review to deem which buildings will benefit the most from a Cool Roofs retrofit. This step should also be completed so that predictive regressions can be completed to calculate what kind of savings can be reasonably expected given building typologies and regional climate conditions.

After a building performance specialist has confirmed that there is sufficient eligible building stock to justify a Cool Roofs program and has completed the necessary predictive analysis, intensive pre-implementation work should begin. The first action item is to establish baseline energy loads as well as baseline cooling loads before the Cool Roofs go into effect. This can be accomplished using Energy Star Portfolio Manager or a similar product used to track and calculate energy usage.

All of the aforementioned steps should not only be completed by any municipality considering a Cool Roofs Program, but these steps should also be required as a mandatory section of a grant requests for any future Cool Roofs Program.

Finally, cities that have already completed a Cool Roofs Program, such as the City of Pittsburgh should make an effort to accurately track the effects of the Cool Roofs implementation, not only in terms of electric and natural gas usage, but also in other theorized effects of Cool Roofs, such as the lifespan of a treated roof and the urban heat island effect. Tracking these different metrics will take considerable resources with most of the direct benefit of doing so will go to the academic and sustainability professional communities, as opposed to the residents of the municipality. For this reason, it is important for municipalities to create collaborative partnerships with academic and non-profit partners to help track the effectiveness of a Cool Roofs program. In order to accomplish this, cities must be willing to share their utility usage and cost information. Beyond establishing formal partnerships with institutions, cities should also consider making their energy usage data publicly available to allow building performance specialists and sustainability experts from the global public to analyze and learn from the available energy usage data.

Cool Roofs should be part of a larger overall sustainability strategy in any given Zone 5 municipality- as the results of the Pittsburgh Cool Roofs Program have shown, the expected effects of a Cool Roofs program are modest at best. Cool Roofs will continue to have a place as part of an overall municipal sustainability strategy but it will not likely be the feature piece of any energy-saving strategy.

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APPENDIX

Program administrators measuring roof dimensions at 1124 North Avenue

Volunteer applies reflective white paint at 259 McKee Pl

Volunteers apply reflective white paint at 7024 Lemington Ave

	Cool Roofs	
Revenue	All Sources	Impact Volunteering Fund
Impact Volunteering Fund Request	$56,000	$56,000
Other grants	$0	$0
Other cash	$25,000	$0
City funds	$0	$0
Event fees	$0	$0

Fees for services	$0	$0
Other funds	$0	$0
Total Cash Revenue	**$81,000**	**$56,000**
Donated Supplies	$600	$0
Donated Services	$0	$0
Total In-kind Revenue	**$600**	**$0**
Total Revenue	**$81,600**	**$56,000**
Expenses		
Staff salary and benefits	$25,000	$0
Position	$0	$0
AmeriCorps matching funds or VISTA cost-shares	$0	$0
Initiative supplies	$53,500	$53,500
Office supplies	$0	$0
Transportation	$0	$0
Equipment	$500	$500
Food/refreshments	$2,000	$2,000
Printing and copying	$0	$0
Telecommunications	$0	$0
Rent and Utilities	$0	$0
Fees	$0	$0
Insurance	$0	$0
Other		
Total cash expenses	**$81,000**	**$56,000**
In-kind		
List item	$600	$0
Total in-kind expenses	**$600**	**$0**
Total expenses	**$81,600**	**$56,000**

Revenue over Expenses	$0	$0

Initial Cool Roofs Budget Request

	Impact Volunteering Fund			**Leverage**		
Expenses	Budget	Actual	Variance	Budget	Actual	Variance
Initiative supplies	$49,900	$14,660.00	$35,240.00			
Equipment	$3,100	$538.64	$2,561.36			
Salary				$25,000	0	$25,000
Food/refreshments	$3,000	0	$3,000			
Total cash expenses	$81,000	$15,198.64	$65,801.36			
In-kind						
Water Access/ Supply	0	0	0	$600	$0	$600
Total in-kind expenses						
Total expenses	$81,000	$15,198.64	$65,801.36	$600	$0	$600

Sealoflex – Primer & Top Coat					
Quantity	Product	Unit	Unit Cost	Total Cost	
114	Sealoflex Reflectowhite	Pail	$90.00	$10,260	
16	Sealoflex EP1 Primer	Pail	$275.00	$4.400.00	
Total Cost: $14,660.00					

Paint Supplies: Westmoreland Supply Company				
Item #	Description	Quantity	Cost	Ext
155	Wooster P3979 4" brush	10	$28.50	$2.85
167	Wooster AR622 Roller Cover	30	$80.70	$2.69
173	Bestt/Liebco Roller Frame	7	$20.93	$2.99
217	Wooster extension pole	7	$97.93	$13.99
220	Wooster Metal Tray	5	$10.45	$2.09
Total Cost: $238.51				

Paint Supplies: Home Depot				
Quantity	Product	Unit	Unit Cost	Total Cost
3	Neverkink Hose		41.97	$125.91
1	Trigger Nozzel		$8.47	$8.47
2	Pushbroom		$28.97	$57.94
1	Contractor Bags		$23.97	$23.97
1	Speedline Pro Wheel		$9.97	$9.97
1	Irwin 2.5 lb Chalk-Blue		$5.97	$5.97
1	Jumbo Debris Dust Pan		$16.99	$16.99
1	Long Tape Measure		$13.99	$13.99
2	Gojo Orange Hand Soap		$7.48	$14.96
2	Rags in a Box 200 –Ct		$10.98	$21.96
Total Cost: $300.13				

Company	Phase 1	Phase 2	Phase 3	Totals
Sealoflex	$14,660.00			$14,660.00

Home Depot	$300.13			$300.13
Westmoreland Paint	$238.51			$238.51
Food	0			0
Totals	$15,198.64			$15,198.64

Phase 1 Budget