Cutting Peak Electrical Demand with Reflective Roof Coatings

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ABSTRACT

This paper, published by the Roof Coatings Manufacturers Association (RCMA), discusses the role and impact of reflective roof coatings in mitigating peak energy demand. Developed in collaboration with Jim Hoff, TEGNOS Research Inc., this paper provides a comparative overview of base use and peak demand of electricity and shares information on how to calculate peak demand savings. The role of cool roofing in promoting energy efficiency is also emphasized, particularly in respect to the unique performance properties of reflective roof coatings. The document can also be viewed as a resource as to the benefits reflective roof coatings provide to buildings, businesses, and the environment at large.

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INTRODUCTION

A sharp peak in electrical demand can be observed in almost every building during the busiest hours of the day. Although a portion of this peak may be attributed to lighting and equipment used in the building, the lions-share of this peak is caused by increased demand for air conditioning in the heat of the afternoon. This peak in demand requires additional power plant capacity, causes imbalances in the power grid, and may result in increased air pollution. But most importantly for the building owner, unnecessary peak demand may result in monthly charges many times higher than base electrical rates. One of the best approaches to shrink peak demand is to reduce the heat load on a building, especially the solar load that drives the need for air conditioning. And few heat reduction strategies can match the energy-savings potential of modern reflective roof coatings.

In an effort to help building owners and designers deal effectively with peak electrical demand charges, this white paper provides a step-by-step review of all aspects of peak demand, including how to identify peak demand charges on a typical commercial electrical bill, how to estimate the potential savings achieved when installing a reflective roof coating, and how to achieve other business and community benefits associated with reducing peak energy demand.

BASE USE VERSUS PEAK DEMAND

The U.S. power grid is effectively subdivided by a number of state and regional typical independent system operators (ISOs) that serve to coordinate, control, and monitor the operation of the electrical power system. Figure 1 illustrates the total hour-by-hour demand for electricity as monitored by one of these ISOs covering the New England states during a typical weekday in July.

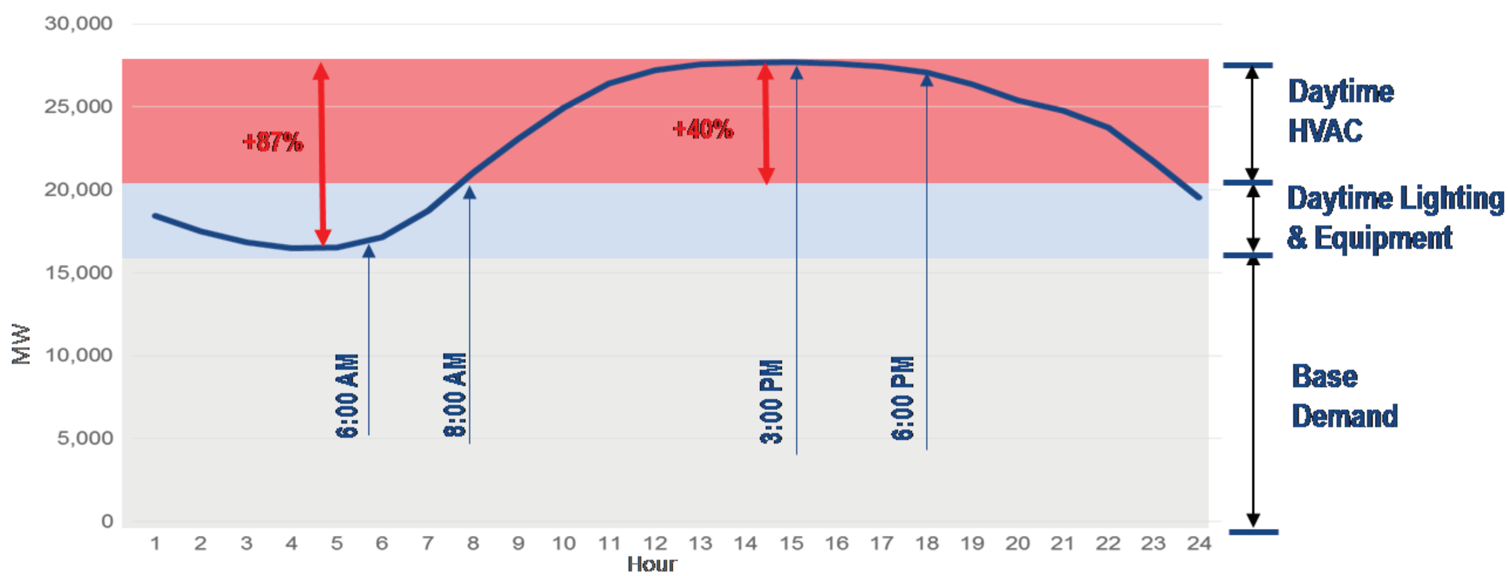


FIGURE 1: HOURLY ELECTRICAL DEMAND (MW) FOR NEW ENGLAND ISO JULY 22, 2011
(Source: USEIA)

As illustrated in Figure 1, electrical demand in New England for this July week day reached a peak of 28,000 MW at approximately 3:00 PM in the afternoon, rising 87% from a low of 15,000 MW at approximately 4:00 AM to 6:00 AM in the morning. Because hourly demand never falls below 15,000 MW for this typical day, it would be reasonable to describe the first 15,000 MW of hourly demand to be **base demand**. The additional demand measured at any hour could then be described as **peak demand**. However, it appears this peak demand may be driven by two distinct factors. Between 6:00 AM and 8:00 AM, hourly demand grows from 15,000 MW to 20,000 MW, an increase of 33%. Because this period is typically associated with normal "start of the working day" activities, it is likely that the additional demand is associated with increased use of lighting and equipment, both in buildings and in residences. However, by 8:00 AM, it would be reasonable to assume that all of the lights and equipment to be used during a normal day have been turned on; and this would imply that any additional increases in electric demand would be associated with an increase in demand for air conditioning. And as shown in Figure 1, the increase in electric demand that can be directly related to air conditioning costs is very significant. Starting at 8:00 AM when all of a building's lighting and equipment are in use, electric demand grows an additional 40% over combined base rate and daytime lighting / equipment demand.

MEASURING BASE USE AND PEAK DEMAND

Billing measures directly related to the unique characteristics of base and peak demand are incorporated in almost every commercial electric bill across the United States. In the case of **base energy use**, the total quantity of electricity supplied for the billing period is used as the billing unit. In the case of **peak energy demand**, the highest amount of power supplied at any one time within the billing period is used as the billing unit. Base energy use is measured in kilowatt-hours (kWh), while peak energy demand is measured in kilowatts (kW). One way to help understand the relationship between base energy use and peak demand measurement is to use the analogy of an odometer and speedometer in a car. As illustrated in Figure 2, the base amount of energy used (kWh) can be compared to miles driven as shown on the odometer, while peak energy demand (Kw) would be similar to the top speed driven, as shown on the speedometer:

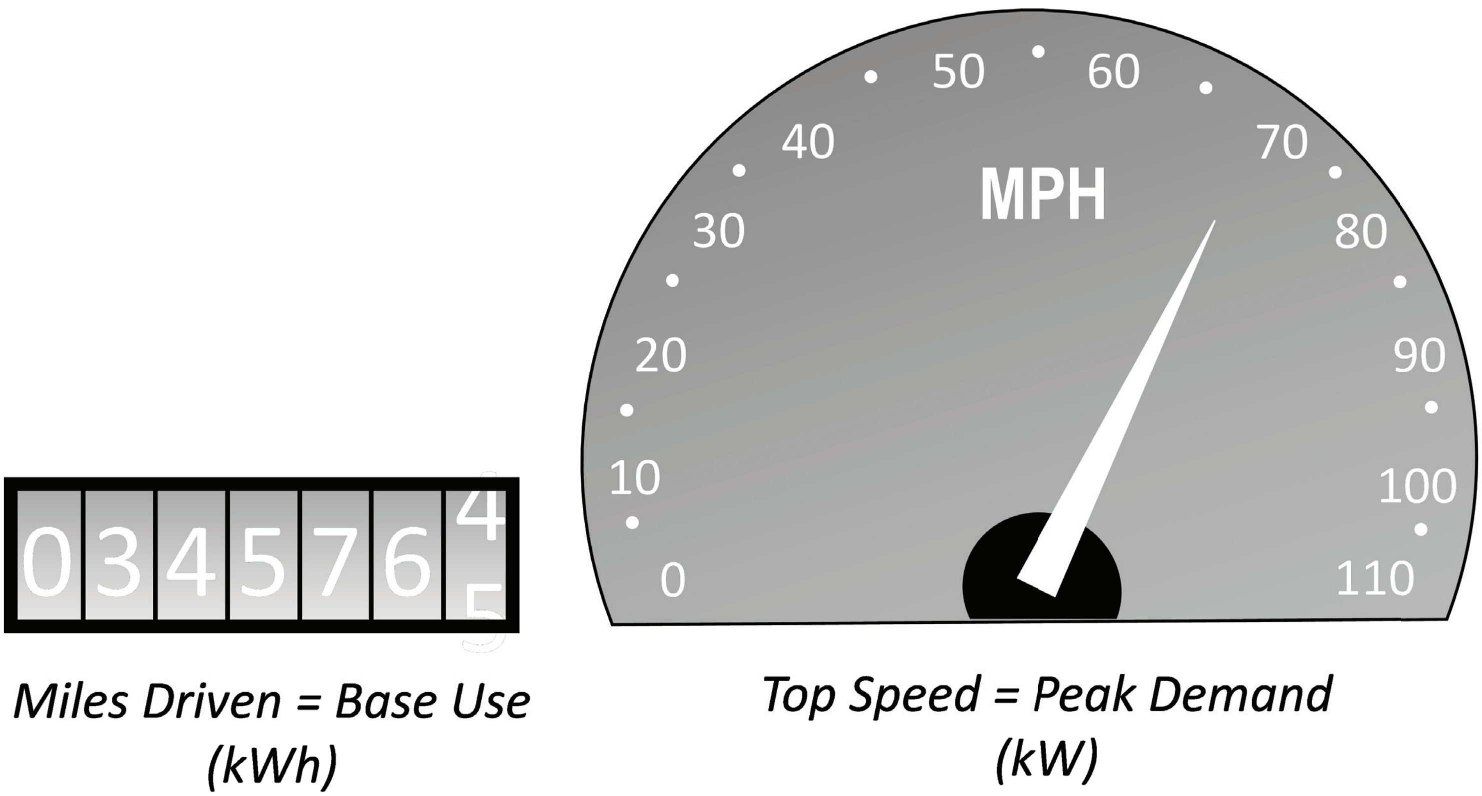
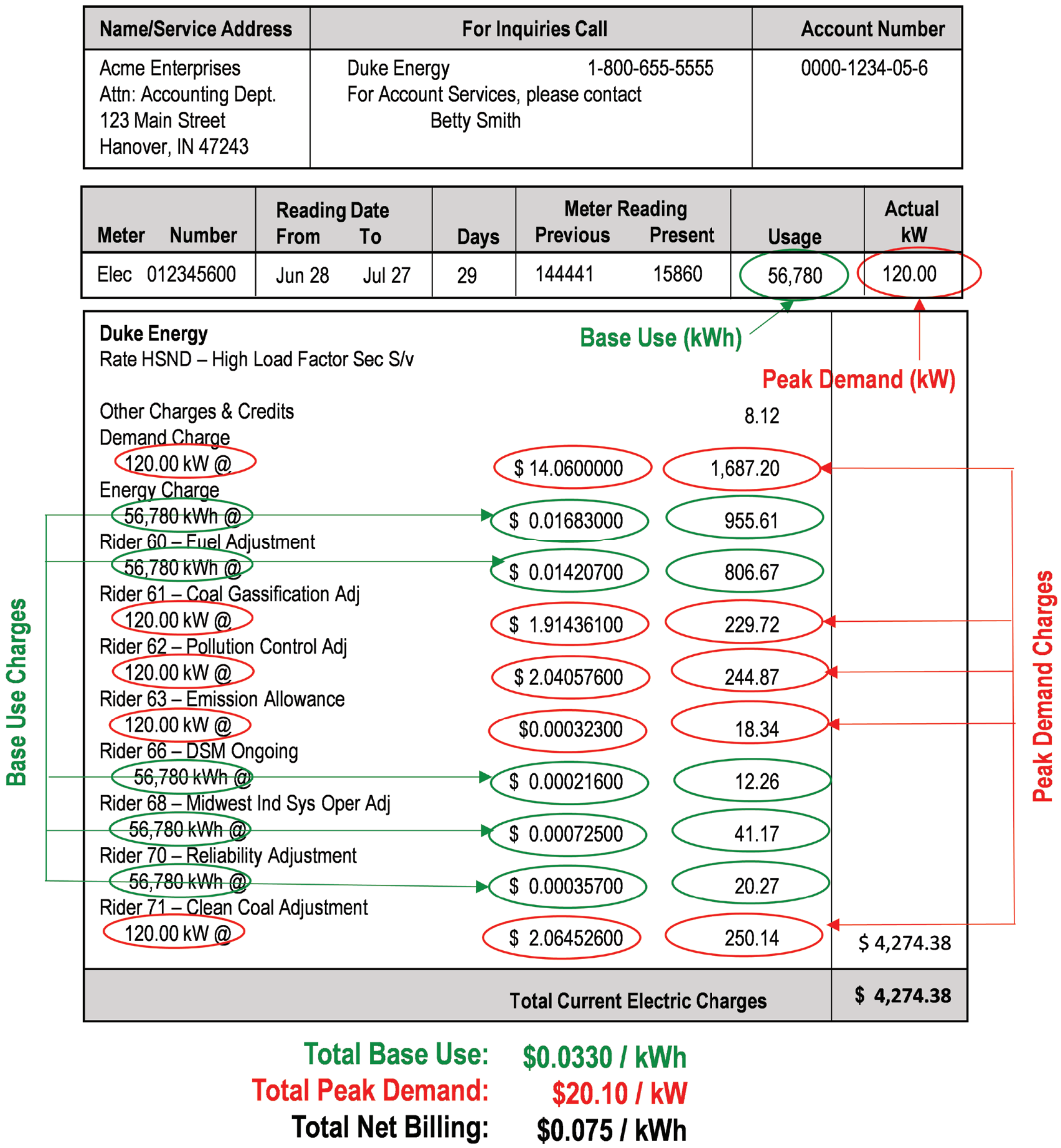


FIGURE 2: BASE USE VERSUS PEAK DEMAND

Like the highest speed achieved during a trip, peak demand seldom occurs for more than a few hours or fractions of hours during each billing period. Typically, peak demand charges are based on the amount of energy consumed in a specified period of time known as a demand interval. Demand intervals are usually 15 or 30 minutes. In a building, the demand charge represents the maximum kilowatt draw from the utility during the billing period. As a result, the electric company will take the demand interval with the highest energy consumption in kilowatt hours (kWh) and divides by the length of the demand interval in hours to calculate customer demand. Mathematically, the hours cancel, leaving kilowatts (kW) as the units of peak demand.

BASE USE VERSUS PEAK DEMAND: LOOKING AT YOUR ELECTRIC BILL

Because electricity is not easily stored, utilities must have adequate capacity to meet customers' maximum requirements, both for the quantity of total level of base energy needed and for the highest level of peak demand required. As a result, commercial and industrial electric rates across the country frequently are designed to cover the cost of providing both base and peak energy. As such, rates are not based on an individual customer's usage levels, but are applied across the board to a class of customers such as manufacturing, light commercial, or commercial. The rate is set in $ per kilowatt hour and is a peak charge. However, identifying these two cost components on the average commercial electrical bill may be a little difficult, especially when most bills are subdivided into a large number of special fees and adjustments. Figure 3 shows a typical commercial electrical bill containing both base use and peak demand charges, as published by an Indiana-based electrical utility[1].



Name/Service Address	For Inquiries Call	Account Number
Acme Enterprises Attn: Accounting Dept. 123 Main Street Hanover, IN 47243	Duke Energy 1-800-655-5555 For Account Services, please contact Betty Smith	0000-1234-05-6

Meter Number	Reading Date From	To	Days	Meter Reading Previous	Present	Usage	Actual kW
Elec 012345600	Jun 28	Jul 27	29	144441	15860	56,780	120.00

Duke Energy
Rate HSND – High Load Factor Sec S/v

Other Charges & Credits		8.12	
Demand Charge 120.00 kW @	$ 14.0600000	1,687.20	
Energy Charge 56,780 kWh @	$ 0.01683000	955.61	
Rider 60 – Fuel Adjustment 56,780 kWh @	$ 0.01420700	806.67	
Rider 61 – Coal Gassification Adj 120.00 kW @	$ 1.91436100	229.72	
Rider 62 – Pollution Control Adj 120.00 kW @	$ 2.04057600	244.87	
Rider 63 – Emission Allowance 120.00 kW @	$0.00032300	18.34	
Rider 66 – DSM Ongoing 56,780 kWh @	$ 0.00021600	12.26	
Rider 68 – Midwest Ind Sys Oper Adj 56,780 kWh @	$ 0.00072500	41.17	
Rider 70 – Reliability Adjustment 56,780 kWh @	$ 0.00035700	20.27	
Rider 71 – Clean Coal Adjustment 120.00 kW @	$ 2.06452600	250.14	$ 4,274.38
Total Current Electric Charges			$ 4,274.38

FIGURE 3: BASE USE AND PEAK DEMAND CHARGES ON A SAMPLE COMMERCIAL ELECTRIC BILL
(Source: Duke Energy[1])

Near the top of the sample bill, monthly base energy use (circled in green) is shown to be 56,780 kWh. In the detail section of the bill, this base energy use is multiplied by a base energy charge as well as additional charges for fuel adjustments, demand side management (DSM) fees, regional system operator adjustments, and reliability adjustments. Altogether, these base energy use-related charges (also circled in green) add up to a total monthly base use charge of $0.033 per kWh.

However, this base fee accounts for less than half of this total monthly electric bill. Also near the top of the bill, peak demand (circled in red) is shown to be 120 kW. In addition to the base use fees discussed previously, the 120 kW of peak demand is multiplied by a basic peak demand charge plus additional demand-related charges for coal gasification adjustments, pollution control adjustments, emission allowances, and clean coal adjustments. Altogether, these peak demand-related charges (also circled in red) add up to a total monthly demand charge of $20.10 / kW.

After calculating base use and peak demand charges, we also may calculate the total electricity rate for this customer. For this bill, the total monthly charge is divided by the 56,780 kilowatt hours used, yielding an effective rate of $0.075 / kWh, or over twice as much as the nominal base usage rate of $0.0330. It should be noted that this total electric usage rate of $0.75 / kWh is actually among the lowest commercial rates available in in the United States. According to the U.S. Energy Information Administration, average electric rates by state for commercial users in 2013 ranged from a low of $0.07 / kWh in Idaho to a high of $0.15 / kWh in New York2.
As illustrated by this sample bill, peak demand charges may account for a significant portion of a business's monthly electrical costs. In this particular example peak demand charges represent $2,430.13 of the total net billing. As a consequence, building owners frequently are interested in learning how these costs may be reduced, especially through the use of energy-efficient building design and operating strategies.

HOW CAN YOU REDUCE BASE AND PEAK ENERGY DEMAND?

As mentioned in the introduction to this white paper, peak energy demand for the majority of buildings occurs in the late afternoon. For commercial facilities operating primarily during normal business hours, a number of factors may help reduce the daily demand peak for electrical power. First, the ubiquitous use of electrical equipment in modern buildings may add to both base and peak demand for electricity. Electrical equipment may include motors associated with manufacturing operations as well as office equipment such as computers, copying machines, etc. Reductions in peak equipment demand may be achieved through the elimination of unnecessary equipment or by using equipment with improved electrical efficiency.

Excessive amounts of indoor lighting also add to base and peak electricity requirements. As a consequence, reducing the amount of lighting used during peak periods can be a useful strategy to reduce peak demand. Reductions in peak demand related to lighting can be achieved by reducing ambient lighting levels and installing task lighting, supplementing electric lighting with daylighting from windows and skylights, and installing more efficient light fixtures using fluorescent or LED technologies.

Although improvements in equipment and lighting may help reduce overall electrical demand, the critical driver of peak demand in almost all commercial buildings is related to the spike in air conditioning loads during the heat of the afternoon. Similar to equipment and lighting loads, peak air conditioning loads may be reduced by improving the efficiency of air conditioning systems or simply by turning up the thermostat. However, peak demand for air conditioning also may be addressed by reducing the impact of climate-related thermal loads on the building. In the case of air conditioning loads generated by high outdoor temperatures, overall air conditioning demand can be reduced by installing additional wall and roof insulation and thermally efficient doors and windows. But a certain amount of the peak in daily air conditioning demand is related to the direct rays of the sun rather than outdoor ambient air temperatures. This means that reducing solar loads by reflecting solar heat away from the building may offer one of the best ways to reduce peak electricity demand in modern buildings.

Fortunately, we have a well-developed and effective technology available today to help reduce solar loads in buildings: the reflective or "cool" roof. As illustrated in Figure 4, cool roofs use a highly reflective surface to direct a significant portion of solar heat of the sun away from the building. Unlike a dark or non-reflective roof surface that absorbs and transfers solar heat into the building, a light-colored, reflective roof surface reflects and drives solar heat away from the building and into the atmosphere.

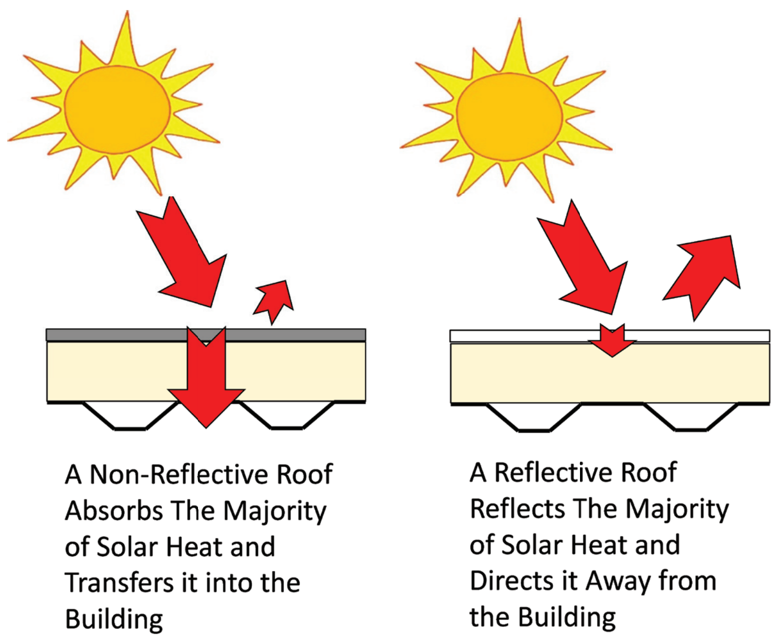


FIGURE 4: REFLECTIVE VERSUS NON-REFLECTIVE ROOF

Reflective roof coatings can be applied to a variety of low slope roofs on multi-family residential, commercial, and industrial buildings. Almost all types of roofs can be coated including metal, spray polyurethane, single-ply, modified bitumen, and built-up roof (BUR) systems. There are two basic types of reflective roof coatings: reflective elastomeric coatings and aluminum coatings. The selection of one of these two types of coatings is typically based on a myriad of project goals including the local microclimate, existing roof conditions, the type and condition of the roof substrate, desired energy savings, building code requirements, budget, and other unique conditions.

For a roofing product to be "cool" by today's standards, the minimum percentage of solar heat reflected away from the building typically falls within a range of 0.50 (50%) to 0.70 (70%), depending on the particular standard being applied and on the aging of the sample tested. Table A provides a brief summary of these new and aged reflectance percentages for four of the most-recognized building codes and standards.

TABLE A: CURRENT COOL ROOF REFLECTANCE STANDARDS[3]

Reference Standard	Minimum Roof Reflectance	
	Initial	Aged
International Energy Conservation Code (2012)	0.70	0.55
ASHRAE 90.1 Energy Standard for Buildings (2011)	0.70	0.55
Energy Star for Roofs (U.S. EPA, 2012)	0.65	0.50
California Title 24 Energy Standard (2012)	n/a	0.63

Because reflective roofing has become a very popular roofing choice, roofing manufacturers typically identify the reflectivity of their products in technical data sheets and brochures. In almost all cases, these measures of roof reflectance are based on standards developed by the U.S. EPA EnergyStar program4 or the ANSI / CRRC-1 cool roof standard developed by the Cool Roof Rating Council5. In addition, both the U.S. EPA and the Cool Roof Rating Council maintain online databases where you can look up the initial and aged reflectivity of many roofing products.

PEAK DEMAND: NOT JUST A WARM CLIMATE PROBLEM

In order to better understand the benefits of reflective roofs in reducing peak energy demand, researchers at Oak Ridge National Laboratories[6] examined the seasonal variation in peak air conditioning demand for a variety of different climates across North America. Their findings suggest that even though base cooling demand may be higher in hot climates as compared to cooler climates, almost all climates exhibit a seasonal variation in the peaks for roof-related air conditioning demand. Figure 5 compares this seasonal trend for a hot, cooling-oriented climate (Phoenix, AZ) and a cold, heating-oriented climate (Minneapolis, MN).

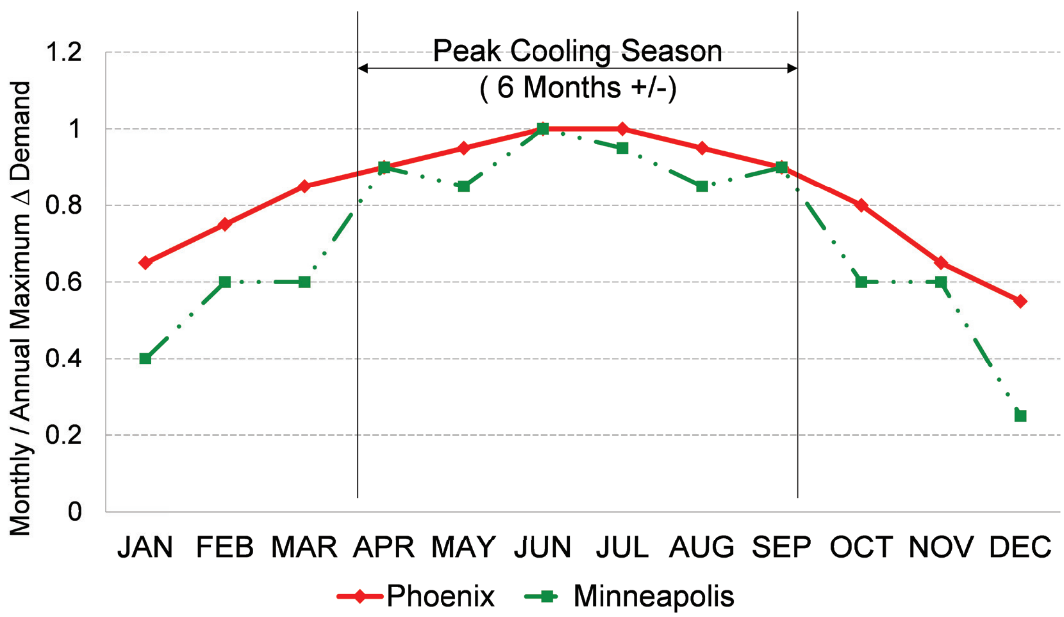


FIGURE 5: RATIO OF MONTHLY TO ANNUAL PEAK IN ROOF-RELATED AIR CONDITIONING DEMAND
(Source: Oak Ridge National Laboratories[6])

Although Phoenix exhibits a higher and more consistent monthly demand for air conditioning as compared to Minneapolis, demand falls off at the beginning and end of the year for both cities, with a substantial portion of peak demand located within a six-month period from April to September. As a result, it may be possible to reduce peak demand in both cities using cool roofing technologies. In fact, a recent study of cool roofs and peak demand costs suggests that the potential for roof-related peak demand savings for hotter cities like Phoenix and colder cities like Minneapolis may be approximately identical[7]. Figure 6 illustrates the comparative base energy and peak demand savings for the seven major climate zones in the United States identified in this study.

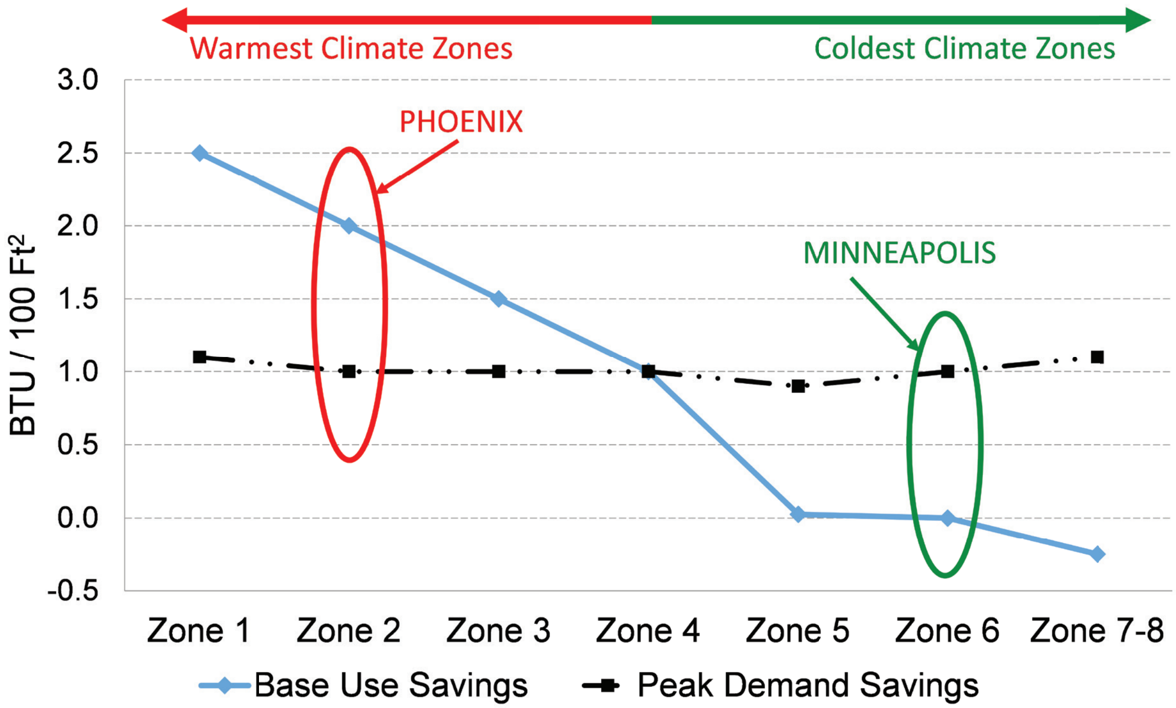


FIGURE 6: ROOF-RELATED BASE USE AND PEAK DEMAND SAVINGS BY NORTH AMERICA CLIMATE ZONE
(Source: RoofPoint Energy and Carbon Calculator[7])

Although the colder climate zone for Minneapolis offers little or no savings potential in terms of base use, the opportunity for peak demand savings is approximately the same as in much hotter climate zones. Although it may seem counter-intuitive that similar peak energy savings may be achieved in cold climates as well as hot climates, Figures 4 and 5 taken together may help explain this apparent paradox. In a hot location such as Phoenix, even though overall cooling loads are very high, the seasonal peak is less pronounced, while the seasonal peak in a cold location such as Minneapolis is much more pronounced even though the overall cooling loads are smaller. In effect, peak demand savings in hot climates may be described as a smaller piece of a larger pie, while peak demand savings in cold climates may be described as a larger piece of a smaller pie.

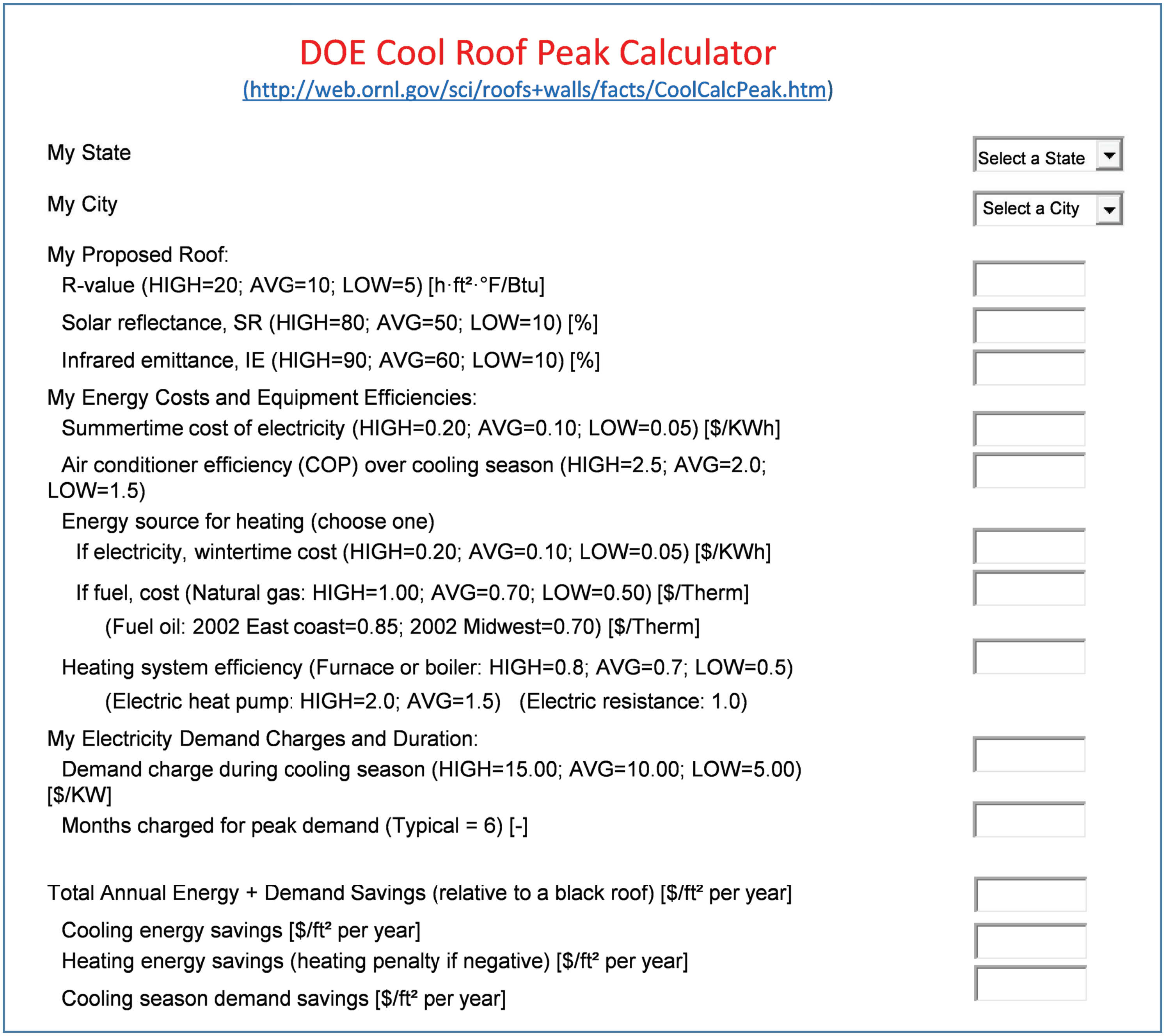
BEYOND THE DOLLARS: OTHER COSTS OF PEAK ENERGY DEMAND

So far we have discussed the immediate economics of peak demand, but there are other costs associated with peak demand that should be discussed as well. Because additional electrical generating capacity is required to meet peak demand levels, it is likely that this will lead to increased atmospheric pollution and environmental impacts due to the need to construct new generating facilities as well as the less-than-efficient operation of existing facilities. Peak energy demand also is strongly associated with the overall heating of large cities and urban areas, commonly referred to as the Urban Heat Island Effect. In turn, increased warming of urban areas may lead to increased production and accumulation of ground-level ozone, which in turn may lead to increased health risks and a growing number of “Ozone Action Days” in cities and towns across North America. Finally, increasing peak electricity demand may increase the potential for “brownouts,” especially during unusually hot weather events.

HOW TO ESTIMATE PEAK DEMAND SAVINGS

The good news for building owners and designers is that the U.S. Department of Energy has developed an online calculator specifically designed to evaluate peak demand and cool roofs: The Cool Roof Peak Calculator[8]. This online calculator, developed by Oak Ridge National Laboratory, provides a fast and easy way to compare the overall energy costs and savings for a wide variety of roof and building conditions. The calculator is easy to access and comes with step-by-step instructions for the user. Because the DOE Cool Roof Peak Calculator includes climate data for over 200 cities across North America, it’s easy to find a model location that can match up with almost any site in the United States or Canada. Unlike some energy calculators that model steep slope residential roofs with attics, the Cool Roof Peak Calculator models the typical low slope commercial roof with insulation placed directly over the deck and under the roofing membrane.

Figure 7 provides and illustration of a partial screen shot of the Cool Roof Peak Calculator from the web site of Oak Ridge National Laboratory.



DOE Cool Roof Peak Calculator

(http://web.ornl.gov/sci/roofs+walls/facts/CoolCalcPeak.htm)

My State — Select a State

My City — Select a City

My Proposed Roof:

R-value (HIGH=20; AVG=10; LOW=5) [h·ft²·°F/Btu]

Solar reflectance, SR (HIGH=80; AVG=50; LOW=10) [%]

Infrared emittance, IE (HIGH=90; AVG=60; LOW=10) [%]

My Energy Costs and Equipment Efficiencies:

Summertime cost of electricity (HIGH=0.20; AVG=0.10; LOW=0.05) [$/KWh]

Air conditioner efficiency (COP) over cooling season (HIGH=2.5; AVG=2.0; LOW=1.5)

Energy source for heating (choose one)

If electricity, wintertime cost (HIGH=0.20; AVG=0.10; LOW=0.05) [$/KWh]

If fuel, cost (Natural gas: HIGH=1.00; AVG=0.70; LOW=0.50) [$/Therm]

(Fuel oil: 2002 East coast=0.85; 2002 Midwest=0.70) [$/Therm]

Heating system efficiency (Furnace or boiler: HIGH=0.8; AVG=0.7; LOW=0.5)

(Electric heat pump: HIGH=2.0; AVG=1.5) (Electric resistance: 1.0)

My Electricity Demand Charges and Duration:

Demand charge during cooling season (HIGH=15.00; AVG=10.00; LOW=5.00) [$/KW]

Months charged for peak demand (Typical = 6) [-]

Total Annual Energy + Demand Savings (relative to a black roof) [$/ft² per year]

Cooling energy savings [$/ft² per year]

Heating energy savings (heating penalty if negative) [$/ft² per year]

Cooling season demand savings [$/ft² per year]

FIGURE 7: THE DOE COOL ROOF PEAK CALCULATOR[8]

Using the DOE Cool Roof Peak Calculator is simple and straightforward, but some specific information is required to operate the calculator effectively. To obtain the maximum benefit from the calculator, the user must identify the following building attributes and conditions:

1. **Location.** The user first must select a U.S. state or Canadian province and then select the closest city from a list provided for each state and province. As an example, the state of Ohio includes data for Akron, Cleveland, Dayton, Mansfield, Toledo, and Youngstown. For all states, an ample number of model cities is provided to allow the user in other cities to make an accurate climate-based comparison.
2. **Proposed Roof R-Value.** If the calculator is being used by a building or roofing professional familiar with past and current energy codes, it is likely that the roof R-value may be estimated based on the age of the roof or building. For the non-professional, the calculator instructions provide suggestions for “high,” “average,” and “low” insulation R-value levels across North America.
3. **Proposed Roof Reflectance.** Roof reflectance is stated as a ratio similar to the values shown in Table A. Roof reflectance for a specific roofing product may be obtained from roofing manufacturer data sheets or from the EPA Energy Star or Cool Roof Rating Council web sites mentioned previously. Once again, the calculator provides suggestions for “high,” “average,” and “low” roof reflectance values. It should be noted that the aged reflectance value should be used in order to accurately estimate the long-term ability of the roof to reflect solar energy.

4. **Proposed Roof Infrared Emittance.** Roof emittance is also stated as a ratio similar to roof reflectance. A full discussion of emittance is beyond the scope of this paper, but essentially it is a measure of the amount of solar energy absorbed into the roof but eventually transmitted back to the atmosphere rather than into the building. Roof emittance for a specific roofing product may be obtained from roofing manufacturer data sheets or from the EPA Energy Star or Cool Roof Rating Council web sites mentioned previously. Once again, the calculator instructions provide suggestions for "high," "average," and "low" roof reflectance values. However, the values shown on the calculator may provide a much wider range than typically found in most low-slope roofing membranes. Typically, the thermal emittance of common single-ply and asphaltic roof coverings runs within a range of 0.75 to 0.90.
5. **Base Energy Costs.** The calculator assumes that the building is being heated in the winter and cooled in the summer, but the user must identify the types of fuel used to heat and cool the building as required. Because the calculator assumes electricity will be used to cool the building, the user must enter the "summertime" cost of electricity in $/kWh, which is identical to the base use rate discussed previously. (Note that the peak demand charge for electricity is entered later in the calculation.) Next, the user must indicate the type of fuel (electricity, natural gas, or fuel oil) used to heat the building as well as the wintertime cost of the fuel. In the case of electricity, the cost is measured in $/kWh and is the same as the base use rate as determined from an electric bill. For natural gas and fuel oil, the cost is measured in therms. Again, the calculator instructions provide a suggested range of typical fuel prices across North America.
6. **Equipment Efficiencies.** After identifying the types of fuel and their corresponding unit costs, the user must enter the efficiency for the air conditioning and heating equipment used in the building. Suggested efficiencies are provided in the calculator instructions.
7. **Electricity Demand Charges and Duration.** Finally, the user must enter the peak demand charge for the building, measured in $/kW. As discussed previously, this demand charge should be determined from a recent electric bill as illustrated in Figure 2. In addition, the user must enter the duration of the peak air conditioning season for the building, which typically is a six month peak cooling season, as illustrated in Figure 5.

Based on the information provided by the user, the Cool Roof Peak Calculator then will provide an estimate of the total roof-related energy and demand savings for the building and roof system selected. In addition, this total cost amount is broken down into three key cost components:

- **Cooling Energy Savings.** This amount includes total air conditioning savings from both base use and peak demand reductions.
- **Heating Energy Savings / Heating Penalty.** This amount includes any changes in overall heating costs due to the cool reflective roof. Essentially, this estimate helps to account for any heating losses incurred in winter when solar radiation that could help heat the building is reflected back into the atmosphere.9
- **Cooling Season Demand Savings.** This is an estimate of the reduction in peak demand charges due to roof reflectivity. The amount shown is included in the cooling energy savings previously identified.

It is important to note that all costs provided by the calculator are stated in dollars per square foot of roof area. As a result, these costs must be multiplied by the total square footage of roof surface area to estimate annual cost savings for the entire building.

It is also important to note that the DOE Cool Roof Peak Calculator is designed to compare the total roof-related net energy costs for a cool roof with a reflectivity as specified by the user to a black roof with a solar reflectance of 0.05 (5%). If the user wishes to compare two cool roofs with different reflective ratings, the user may run separate calculations on each roof and then manually compute the difference in savings between the two roofs.

APPLYING THE COOL ROOF PEAK CALCULATOR

Now that we've reviewed the basic workings of the Cool Roof Peak Calculator, we can examine in greater detail what the calculator may reveal about base use and peak demand savings throughout the United States and Canada. Although it is difficult to accurately estimate exact base use and peak demand without a detailed examination of the construction and cost conditions for a specific building, it may be possible to develop a useful model by applying conservative assumptions suitable to a wide array of locations and buildings across North America. In order to develop an informative portrait of peak demand and cool roofs throughout the U.S. and Canada, this paper provides a climatic analysis for a typical cool roof versus a black roof using the following parameters applied to the Cool Roof Peak Calculator:

- **Climate Zones and Model Cities.** Current energy codes divide the United States and Canada into eight primary climate zones, with Zone 1 the warmest and Zone 8 the coldest. Within each zone, demand for heating and air conditioning tends to fall within a relatively narrow range, allowing for a similar thermal analysis of buildings within the climate zone. A map of the eight climate zones in the United States and Canada is illustrated in Figure 8.

Climate Zone	Model Cities
1	Miami (FL)
2	Houston (TX), Phoenix (AZ)
3	Atlanta (GA), Dallas (TX)
4	St. Louis (MO), Baltimore (MD)
5	Chicago (IL), Pittsburgh (PA)
6	Milwaukee (WI), Minneapolis (MN)
7-8	Duluth (MN)

FIGURE 8: U.S. AND CANADA CLIMATE ZONES[11]

Also included in Figure 8 is a listing of model cities used within the analysis. In the case of the most extreme zones, only one city has been selected since the zones are either small or sparsely populated. In the intermediate climate zones, however, two cities were selected and their climate data averaged to provide a more accurate representation for all cities within the zone.

- **Representative Commercial Building.** Within all climate zones, a representative building was selected. For the purposes of this analysis, the building was assumed to be a low-rise structure of one or two stories with a flat roof area of 20,000 square feet. In addition, it was assumed that the building was cooled with an electric air conditioning system with a Coefficient of Performance (COP) of 2.0 and heated with a natural gas-fired furnace11 with an efficiency rating of 70%.
- **Roof Insulation (R-Value) Level.** Two insulation conditions were selected for the analysis to allow for a comparison of different roofing scenarios. The first condition ("new insulation") assumes that the existing roof is completely removed and replaced with a new roofing system using R-value levels meeting the latest energy code requirements. The second condition ("old insulation") assumes that the existing roof and insulation remains in place and is simply recovered with a new roofing membrane with no additional R-value. The new insulation condition is intended to model the installation of a completely new roof on an existing building or a newly constructed building, while the old insulation condition is intended to model the installation of a roof recovery over an existing roof that remains in place. Because the amount of roof insulation used in buildings varies according to climate zone, lower levels of insulation were assumed for the warmer climates and higher levels were assumed for colder climates. In addition, because code-mandated insulation levels have increased over the past decade, separate insulation levels were applied to the old and new insulation conditions. For the old insulation condition, R-value levels were based on an earlier (2006) version of the International Energy Conservation Code, and for the new insulation condition, R-value levels were based on the most recent (2012) edition of the code. These old and new insulation levels are summarized by Climate Zone in Table B.

Climate Zone	Roof R-Value	
	Old Insulation[1] Condition	New Insulation[2] Condition
1	10	20
2	15	20
3	15	20
4	15	25
5	15	25
6	15	30
7-8	15	35
Notes: 1. Per 2006 International Energy Conservation Code 2. Per 2012 International Energy Conservation Code		

TABLE B. OLD AND NEW R-VALUES BY CLIMATE ZONE

- **Roof Reflectance / Emittance.** The long-term reflectance of most cool roofs tends to fall within a relatively narrow range, specifically from 0.55 to 0.63 for minimum aged reflectance as shown in Table A. Accordingly, the cool roof modeled in the analysis is based on a reflectance of 0.60, which falls approximately mid-range of the aged values in Table A. And because the Cool Roof Peak Calculator automatically compares this cool roof to a black roof with a reflectance of 0.05 and an emittance of 0.90, an emittance value of 0.90 also was selected for the cool roof.
- **Base Use and Peak Demand Charges.** Because the example electric bill from the state of Indiana shown in Figure 2 represents one of the lower rates available in North America, a comparison based on those rates obviously would provide a conservative estimate. As a result, the analysis assumes a base use rate of $0.033 / kWh and a peak demand charge of $20.10 / kW across all eight major climate zones. In addition, the analysis assumes a rate of $0.70 / therm for natural gas, which is very close to the average commercial rate across North America at this time.

Using these assumptions and values, estimated base use and peak demand savings for a typical 20,000 square foot commercial building in all eight climate zones were calculated using the DOE Cool Roof Peak Calculator. For each climate zone, two different roof conditions were examined. The first set of calculations compared a cool roof against a black roof installed over new roof insulation meeting the most recent energy code R-value requirements. The second set of calculations compared the same cool and black roof installed over existing (old) roof insulation meeting an earlier version of the energy code. The comparison of the cool versus black roof over new roof insulation is shown in Figure 9, and the comparison of the cool versus black roof over old insulation is shown in Figure 10. In addition, the range of savings available for both old and new insulation conditions is graphically portrayed on a map of the eight North America climate zones in Figure 11.

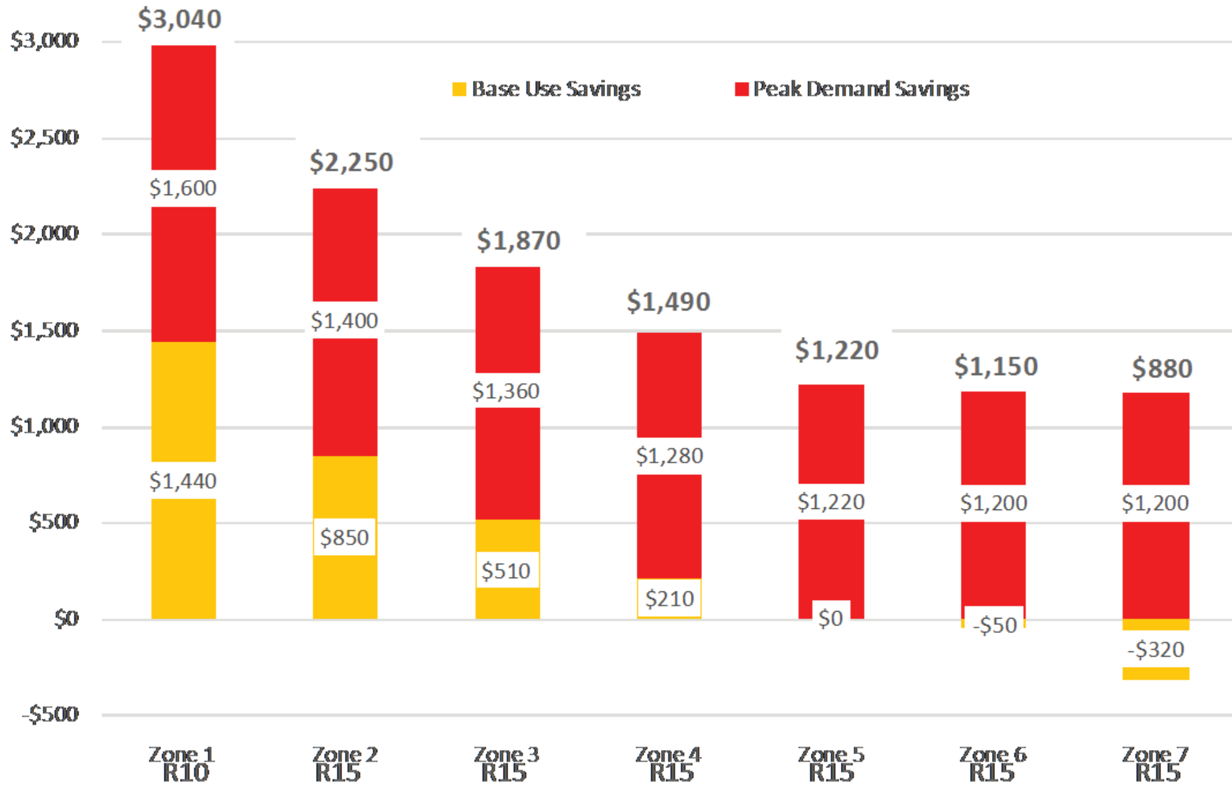


FIGURE 9: ESTIMATED NET ENERGY SAVINGS: REFLECTIVE ROOF INSTALLED OVER EXISTING (OLD) INSULATION*

(Annual Dollars / 20,000 Square Foot Roof Area)

*Old insulation values based on 2006 International Energy Conservation Code (IECC)

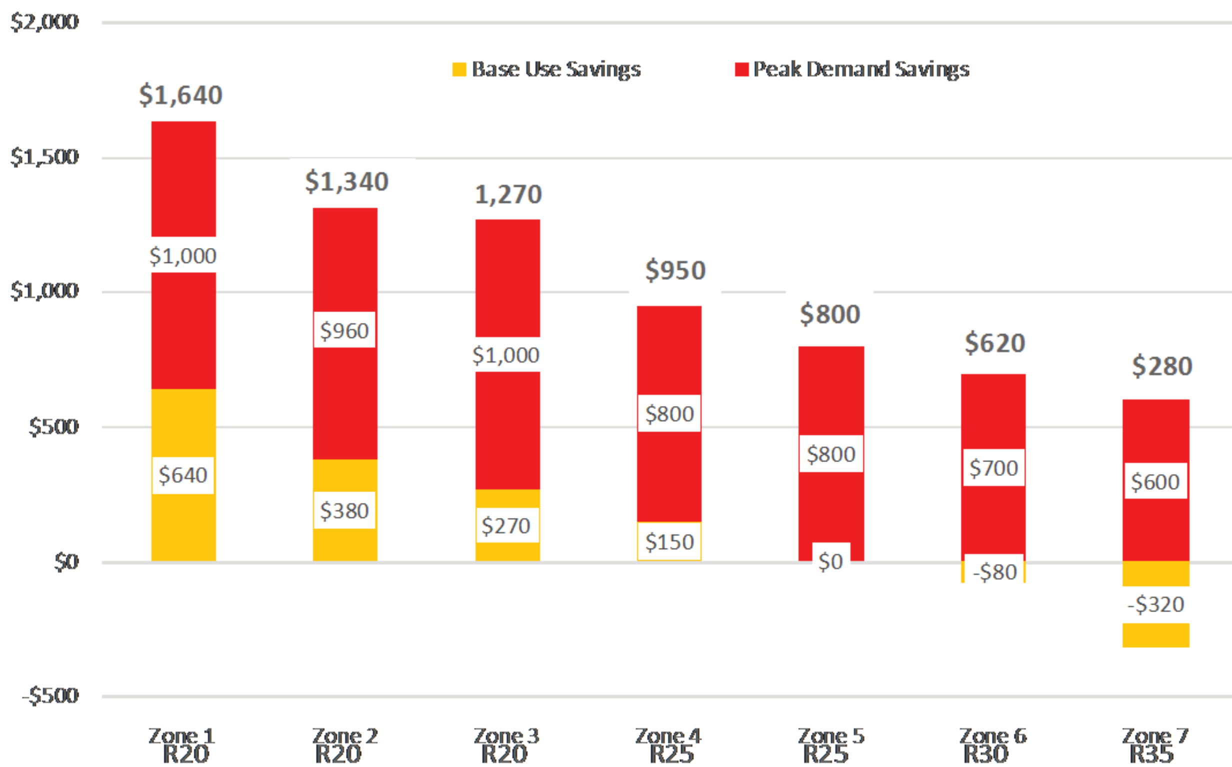


FIGURE 10: ESTIMATED NET ENERGY SAVINGS: REFLECTIVE ROOF INSTALLED OVER NEW INSULATION

(Annual Dollars / 20,000 Square Foot Roof Area)

*New insulation values based on 2012 International Energy Conservation Code (IECC)

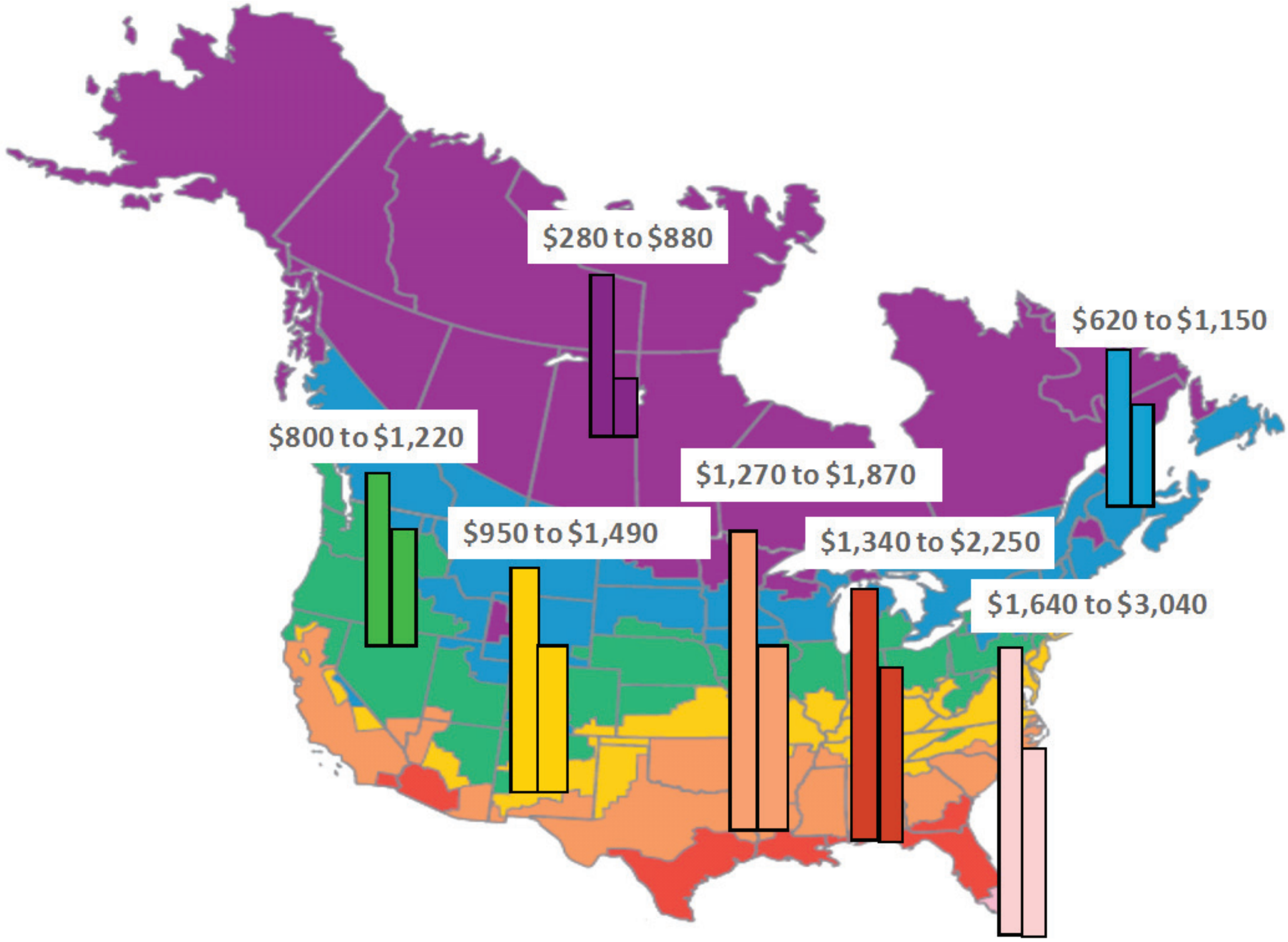


FIGURE 11: ESTIMATED RANGE OF NET ENERGY SAVINGS FOR A REFLECTIVE ROOF BY CLIMATE ZONE
(Annual Dollars / 20,000 Square Foot Roof Area)

THE BOTTOM LINE: REFLECTIVE ROOFS AND PEAK ENERGY DEMAND

Savings in all Climates and Conditions. As illustrated in Figures 8 through 10, the total value of base plus peak energy savings offered by the reflective roof is sizeable, averaging more than $1000 annually in most climate zones for a typical commercial building. In addition, these savings appear to be equally important for buildings with either "old" and "new" levels of insulation. As a consequence, cool roofs may offer a significant opportunity for net energy savings even at the highest levels of roof insulation mandated by the latest building codes. The savings value of cool roofs is further reinforced because modern cool roofing membranes frequently cost no more that darker non-cool roofs. As a result, all of the savings identified in the analysis tend to drop to the bottom line without any additional cost encumbrances.

Reflective Roofs and Insulation Level. Differences in the level of new versus old insulation appear to have a significant effect on the amount of base use savings. In most cases, base use savings using the lower R-value levels of old insulation are reduced by half or more by the addition of the higher R-value levels of new insulation. However, this condition does not appear to hold for peak demand savings. In most cases, the savings available using either old or new insulation levels appears to be significant for all climate zones. As a consequence, it would appear that significant reductions in peak demand cost cannot be achieved simply by increasing insulation levels without also installing a cool roof covering.

Peak Demand Drives the Savings. One of the most striking results from this analysis is that the estimated savings due to peak energy demand reduction provide a substantial majority of the net energy savings throughout all climate zones studied. In fact, peak demand savings account for over 50% of total savings in the warmest climate zones up to 100% in the coldest climate zones. In addition, while base use savings tend to vary widely by climate zone (even falling to negative values in the coldest climates), peak demand savings tend to more significant and consistent throughout all climate zones. As a consequence, the analysis clearly suggests that any estimate of cool roof savings that neglects to include peak demand reduction has little chance of providing an accurate estimate.

NOTES:

1. Derived from "Understanding Your Utility Bill: A Guide for Businesses in Indiana." Duke Energy, Plainfield, Indiana (2013). Available http://www.duke-energy.com/pdfs/understand-bill-guide-in.pdf
2. 2013 Retail Commercial Electrical Rates by State (excluding Alaska and Hawaii) from U.S. Energy Information Administration "Electricity Data Browser." For more information on average electric rates, please visit http://www.eia.gov/electricity/data/browser/
3. Although stated as a percentage in this table, roof reflectivity is typically expressed as a ratio in reference standards. Initial values shown are based on measurements of roofing material as manufactured, while aged values shown are based on measurements after field exposure of test samples.
4. For more information on the Energy Star rated roofing products, please visit: http://www.energystar.gov/productfinder/product/certified-roof-products/
5. For more information on Cool Roof Rating Council rated roofing products, please visit: http://coolroofs.org/products/results
6. Petrie, T. W., Wilkes, K. E., & Desjarlais, A. O. (2004). "Effects of Solar Radiation Control on Electricity Demand Charges – An Addition to the DOE Cool Roof Calculator." Proceedings of the Performance of the Exterior Envelope of Whole Buildings IX International Conference, December 5-10, 2004.
7. Hoff, J. L. (2014). "Introducing the RoofPoint Energy and Carbon Calculator: A New Modeling Tool for Roofing Professionals." Proceedings of the Second International Roof Coatings Conference, Baltimore, MD, July 14-17, 2014.
8. U. S. Department of Energy (DOE) Cool Roof Peak Calculator. Available, http://web.ornl.gov/sci/roofs+walls/facts/CoolCalcPeak.htm
9. It should be noted that the Cool Roof Peak Calculator does not account for the potential for snow cover of the roof in the winter. The presence of accumulated snow on the roof surface may have two effects on overall energy savings. First, snow on either a cool or a dark roof surface will reduce the amount of solar energy absorbed into the building, which may increase heating costs. Conversely, a thick accumulation of snow may provide additional thermal insulation that may reduce heating costs.
10. Climate zones as defined by the International Energy Conservation Code and ASHRAE 90.1. Illustration courtesy of the Center for Environmental Innovation in Roofing and the Polyisocyanurate Insulation Manufacturers Association.
11. Natural gas was selected because it provides over 60% of all commercial building heating demand in the United States, according to the Commercial Building Energy Consumption Survey (CBECS) published by the U.S. Energy Information Administration (http://www.eia.gov/consumption/commercial/)

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Reflective Roof Coatings Institute is RCMA's standing committee focused on advancement of reflective roof coatings through development of research, marketing, technical information, and educational resources