MEASURING ENERGY AND ENVIRONMENTAL IMPACTS: A NEW MODELING TOOL FOR ROOFING PROFESSIONALS

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INTRODUCTION

The *RoofPoint Guideline for Environmentally Innovative Roofing Systems* developed by the Center for Environmental Innovation in Roofing (CEIR, 2012) provides a comprehensive, multi-factor approach to evaluate the overall energy contribution of roofing systems. As a foundation for evaluation, RoofPoint identifies different outcomes related to the energy characteristics of roofing systems. These outcomes include:

- **Net Energy Savings**. Roofing systems can reduce building energy costs through a variety of mechanisms, including the use of highly efficient insulating materials, reduction of thermal discontinuities, restriction of air and vapor movement, and the use of climate-appropriate roof surfaces.

- **Peak Energy Demand Reduction**. Roofing systems can reduce the peak energy required by air conditioning through the use of highly reflective roof surfaces or other cool roof strategies.

- **Renewable Energy Production**. Roofing systems can serve as a platform for renewal energy production, using either rooftop photovoltaic or solar thermal arrays. In addition, roof-mounted skylights and other daylighting technologies can offset a portion of the building's lighting requirements.

These energy contributions also influence several important environmental outcomes. In addition to reducing peak energy demand, highly reflective and other cool roof systems can help to mitigate heat-island effects in dense urban areas. And by reducing net building energy requirements, the combined energy reductions and offsets provided by the RoofPoint guideline also reduce emissions of CO^2 and other greenhouse gases associated with fossil-fuel energy production.

In addition to recognizing different energy and environmental outcomes, RoofPoint also identifies a broad array of roof system attributes that influence these outcomes. These attributes form the basis for the six energy credits of the RoofPoint Guideline:

- **Credit E1: High R Roof Systems**. This credit addresses thermal resistance, or R-value of the roofing assembly as a key influencer of building energy efficiency, both in net and peak terms. To effectively address thermal resistance, Credit E1 offers recommended R-value levels by climate zone, based on the prescriptive values identified in ASHRAE 189.1 Standard for the Design of High-Performance Green Buildings (ASHRAE, 2011).

- **Credit E2: Best Thermal Practices.** This credit addresses the challenges of thermal “shorts” or discontinuities within the roofing system that reduce the effectiveness of thermal insulation. To address such discontinuities, Credit E2 identifies a number of strategies, including application of multiple, staggered layers of insulation, the elimination of through-fasteners, and the use of a monolithic insulation application.

- **Credit E3: Roof Surface Thermal Contribution.** This credit identifies a variety of roof surface types that may increase building energy efficiency, especially in regard to net and peak summer cooling loads. These surface types include a broad spectrum of reflective roof surfaces as well as ballasted and vegetative roofs.

- **Credit E4: Roof Air Barrier.** This credit addresses the challenges of free air movement within a roofing system and its effect on thermal efficiency. To address air movement, Credit E4 provides a combination of prescriptive and performance-based recommendations for the effective air seal of the roofing system.

- **Credit E5: Rooftop Energy Systems.** This credit identifies several rooftop energy strategies that may be deployed to provide a renewable energy source for the building. These strategies include rooftop photovoltaic arrays and solar-thermal installations.

- **Credit E6: Roof Daylighting.** This credit identifies roof-mounted skylights and other daylighting technologies available to supplement artificial lighting within the building and offset non-renewable energy sources.

Through this comprehensive approach to key energy and environmental strategies associated with sustainable roof system design, RoofPoint is able to accommodate a wide variety of sustainable roofing solutions frequently overlooked by other sustainable building rating systems.

PROJECT GOALS

Although RoofPoint’s multi-factor approach to energy outcomes and strategies may offer significant value for the roofing designer, research to quantify and validate this approach remains a high priority for the Center. In order to better quantify the value of RoofPoint, this study was commissioned to examine the key factors of the RoofPoint Energy Credit matrix and to integrate these factors into a comprehensive RoofPoint Energy and Carbon Calculator. The primary function of the calculator is to measure the energy and environmental characteristics of roofing systems and compare different roof system solutions in regard to energy and environmental impacts. As an additional feature, the calculator also is intended for general research into roof energy contributions and as a base point for future refinements of the RoofPoint guideline.

METHODOLOGY

Basis of Measurement. In order to facilitate comparison of the various inputs integrated into the RoofPoint Energy and Carbon Calculator, all energy measures are stated in BTUs, either as a direct calculation of energy demand or as a BTU equivalent of energy production. In order to evaluate environmental as well as energy impacts, the final summation of BTU savings identified by the calculator are converted into greenhouse gas equivalents measured in Metric Tons of CO^2.

Modeling Tools. The RoofPoint Energy and Carbon Calculator integrates several established modeling tools to measure the effects of the various RoofPoint energy credits.

- **Net and Peak Energy Demand**. Modeling of roof-related net energy and peak energy demand was accomplished using the DOE Cool Roof Peak Calculator.[1]The data in this publically available on-line calculator is based on a modeling program developed and validated at the Oak Ridge National Laboratory (Wilkes 1989), and consists of hour-by-hour predictions of heat fluxes and temperatures for low-slope roofs in various locations. Net energy demand is assumed to be the summation of all hourly demands during the year, including any heating penalty for cool roofing systems during the winter heating season. The modeling of peak energy demand within the calculator is based on additional modeling conducted by Oak Ridge National Laboratory (Petrie, Wilkes & Dejarlais, 2004), and peak energy demand is assumed to follow from the peak heat flux for any roof. Peak energy demand is calculated as a monthly peak demand charge for energy based on the highest hourly peak in cooling demand during each month. In order to apply a common measure for both net and peak energy, peak energy was determined by multiplying total net energy consumption by the cost ratio of peak demand / net demand to determine the portion of net energy consumption to be allocated to peak energy consumption.

- **Photovoltaic Energy Production**. Modeling of photovoltaic energy production was accomplished using PVWatts Version 1[2]. Developed by the U.S. National Renewable Energy Laboratory (NREL), PVWatts is an online calculation tool used for estimating the average annual energy production of grid-connected PV systems at locations around the world.

- **Other Models**. For measurements of energy demand and production not currently covered by simple on-line tools, a number of unique algorithms were developed to

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[1] Available on-line: http://www.ornl.gov/sci/roofs+walls/facts/CoolCalcPeak.htm

[2] Available on-line: http://rredc.nrel.gov/solar/calculators/PVWATTS/version1/

examine energy effects of several RoofPoint energy credits, including the effects of thermal discontinuities, roof air barriers, rooftop solar-thermal systems and roof daylighting. Additional detail for these algorithms is provided in the Variables and Assumptions portion of this paper.

Variables and Assumptions. The following variables and assumptions were used to develop all calculations in the RoofPoint Energy and Carbon Calculator:

- **Model Cities / Climate Zones**. A model city was selected for the major North American climate zones and sub-zones as identified by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE, 2009). These model cities were used both to calculate net and peak energy efficiency using the DOE Cool Peak Calculator and to calculate rooftop energy production using the NREL PVWatts calculator.

    - Miami, Florida, USA (Climate Zone 1A Moist)
    - Houston, Texas, USA (Climate Zone 2A Moist)
    - Phoenix, Arizona, USA (Climate Zone 2B Dry)
    - Atlanta, Georgia, USA (Climate Zone 3A Moist)
    - Los Angeles, California, USA (Climate Zone 3B Dry)
    - San Francisco, California, USA (Climate Zone 3C Marine)
    - Baltimore, Maryland, USA (Climate Zone 4A Moist)
    - Seattle, Washington, USA (Climate Zone 4C: Marine)
    - Pittsburgh, Pennsylvania, USA (Climate Zone 5A Moist)
    - Reno, Nevada, USA (Climate Zone 5B Dry)
    - Milwaukee, Wisconsin, USA (Climate Zone 6A Moist)
    - Winnipeg, Manitoba, Canada (Climate Zone 7)

- **Roof System R-Values**. A wide range of roof system R-values was selected for “roofs with insulation above deck” as defined by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE, 2009). R-value increments within this range were selected to cover all minimum above-deck prescriptive R-values identified in the 2012 edition of the International Energy Conservation Code (IECC). R-value increments selected include:

    - **R-10**
    - **R-15**
    - **R-20** (2012 IECC requirement for Zones 1 to 3)
    - **R-25** (2012 IECC requirement for Zones 4 and 5)
    - **R-30** (2012 IECC requirement for Zone 6)
    - **R-32**(Note: The 2012 IECC requirement for Zone 7 is R-35, but R-32 is the highest value available in the Cool Roof Peak Calculator.)

- **Roof Surface Type**. Six types of roof surfaces were modeled based on typical aged reflectivity values or an assumed equivalent:

    - **Low Reflective: Aged SR ≥ 0.10**(Typical for an aged dark gray mineral surface or membrane)
    - **Medium Reflective: Aged SR ≥ 0.30**(Typical for an aged mineral surface or light gray membrane)
    - **High Reflective: Aged SR ≥ 0.60** (Typical for an aged Energy Star listed membrane or coating)
    - **Ballasted: Equivalent Aged SR ≥ 0.60** (Assumed to be typical for a ballasted roof with a minimum coverage of 22 lb./ft^2 in Zones 1-4 per California Title 24 or 15 lb./ft^2 in Zones 5-7 per the Chicago Energy Code)
    - **Vegetative: Equivalent Aged SR ≥ 0.60** (Assumed to be typical for an intensive or extensive vegetative roof as defined by RoofPoint credit W1.)
    - **Extra High Reflective: Aged SR ≥ 0.70** (This surface was modeled in order to examine the relative merit of increasing material reflectivity above current typical Energy Star values)

- **Roof Surface Thermal Emissivity**. Roof surface thermal emissivity (TE) was assumed to be 0.90, which is typical for most low-slope roofing systems with insulation above the deck.

- **Heating / Cooling Equipment Efficiencies**. It was assumed that natural-gas fired heating units were used to supply building heat and that an electric air conditioning system was used to supply building cooling. System efficiencies were assumed to be 0.7 for the gas-fired heating units and a COP of 2.0 for the electric air conditioning system.

- **Heating Loads**. Net heating loads are calculated in total annual BTUs using the Cool Roof Peak Calculator for each location and for all variations of R-value and roof surface type modeled.

- **Cooling Loads**. Net cooling loads are calculated in total annual BTUs using the Cool Roof Peak Calculator for each location and for all variations of R-value and roof surface type modeled.

- **Peak Demand Loads.** As part of the development of the Cool Roof Peak Calculator, Petrie, Wilkes and Dejarlais (2004) examined the seasonal variation in cooling demand, and their findings suggest that even though net cooling demand may be significantly higher in warmer, sunnier climates, almost all climates exhibit a seasonal variation in the peaks for this demand. Figure 1 illustrates this common seasonal trend for Phoenix, Arizona (a hot, cooling-oriented climate) and Minneapolis, Minnesota (a cold, heating-oriented climate), modeling a roof with solar reflectivity (SR) of 0.70 and a thermal emissivity (TE) of 0.90.

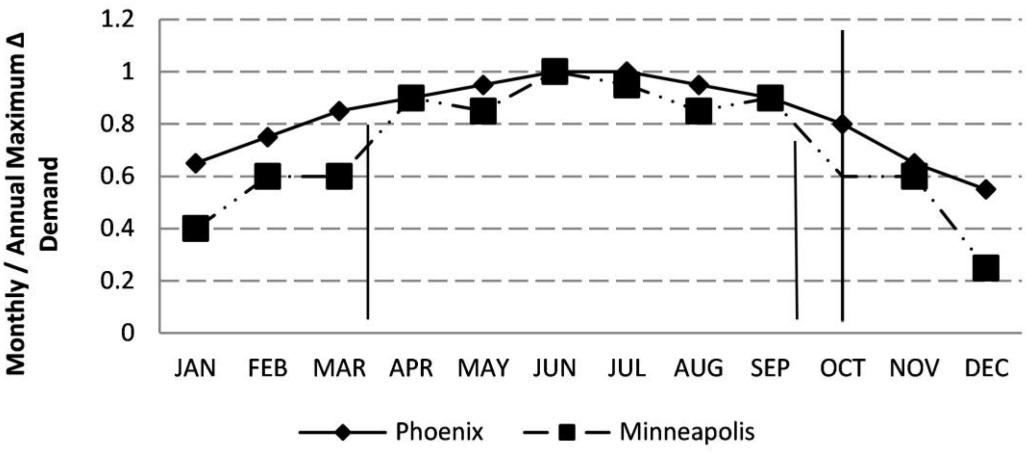

Figure 1: Ratio of Monthly to Annual Peak Cooling Demand
Derived from Petrie, Wilkes and Dejarlais (2004), p. 6

As illustrated in Figure 1, although Phoenix displays a more constant ratio than Minneapolis, the ratio drops off at the beginning and end of the year for both cities, suggesting that a six-month period for peak demand charges may be appropriate for cities located within and between these two extremes.

The presence of a consistent peak cooling season may be critical to understanding the role of demand charges in evaluating peak energy impacts. Although demand charges are not applied uniformly throughout North America, more and more utilities are adopting these charges in order to reduce peaks in electrical demand, which not only strain total electrical capacity but also add significant costs to electricity production and frequently increase atmospheric emissions associated with electricity production.

In recognition of this consistent seasonal variation, the current study assumed that all locations would be subject to peak demand charges. And based on a survey of electric utilities in the Petrie, Wilkes and Dejarlais study, the current study assumed these demand charges to be priced at $10 per monthly peak KW during the six-moth seasonal period as compared to an average annual net cost of $0.10 per KWH. In addition, this study compared peak versus net cooling costs for each location studied, calculating a ratio of total peak demand charges divided by total net cooling costs. In turn, this ratio was used to allocate energy demand for each location between peak and non-peak periods. For the RoofPoint Energy and Carbon Calculator, the ratio of peak to net demand for each location studied is identified in Table 1.

Table 1: Ratio of Peak to Net Energy Demand

Location:	Climate Zone:	Peak Demand / Net Demand:
Miami, FL	1A	0.30
Houston, TX	2A	0.36
Phoenix, AZ	2B	0.28
Atlanta, GA	3A	0.44
Los Angeles, CA	3B	0.64
San Francisco, CA	3C	1.10
Baltimore, MD	4A	0.55
Seattle, WA	4C	1.10
Pittsburgh, PA	5A	0.73
Reno, NV	5B	0.83
Milwaukee, WI	6A	0.92
Winnipeg, MB	7	1.10

As illustrated in Table 1, the ratio of peak to net energy demand tends to be lowest in warm, sunny locations where cooling demand is dispersed throughout the year and highest in cool, cloudy locations where cooling demand is concentrated in a few summer months. It should be noted that this ratio may exceed 1.0 for locations where peak demand during the summer is greater than the sum of net summer cooling demand less net winter cooling losses due to roof surface reflectivity.

It should be noted that the peak energy demand calculated in annual BTUs is not added back to the net energy demand within the calculator. Instead the peak demand energy is used only to evaluate additional CO^2 offsets that may be related to the production of energy during peak periods. Examples of these additional offsets include inefficiencies due to the use of peaking plants and incremental transmission losses during peak periods.

- **Best Thermal Practices**. Past research suggests that thermal loss through mechanical insulation fasteners may be as much as 8% of total calculated R-value (Burch, Shoback & Cavenaugh, 1987) and that the combined thermal loss for insulation fasteners combined with exposed insulation joints may exceed 15%. (Kirby, 2011). In order to account for this thermal loss potential, the RoofPoint Energy and Carbon Calculator applies a specified thermal penalty for the following thermal design options:
    - No thermal breaks: 15% penalty
    - Staggered insulation, mechanically attached: 10% penalty
    - Staggered insulation, loosely laid: 5% penalty
    - Staggered insulation, top layer(s) adhered: 5% penalty
    - Monolithic insulation (e.g. Spray Foam): No penalty

- **Roof Air Barrier**. Research and field observations also suggest that air movement within the roofing system will reduce overall thermal efficiency. In order to account for this thermal loss potential, the RoofPoint Energy and Carbon Calculator applies a specified thermal penalty for the following air barrier conditions:

  - No air barrier installed: 10% penalty
  - Air barrier beneath roof membrane: No penalty
  - Roof membrane serves as air barrier: No penalty

- **Rooftop PV Systems**. Rooftop PV systems are evaluated within the calculator based on the STC rating of the system in kW and the conversion of this rating into total annual estimated power in kWH for each location using the PVWatts on-line calculator for an array installed at the optimal tilt and azimuth factor for the location. Total annual estimated power is also reduced by the recommended DC-to-AC derate factor in PVWatts (0.77). Finally, total annual estimated power is converted from kWh to BTU to allow comparison with other energy inputs.[3]

  The average annual AC energy per kW STC rating for each location derived from PVWatts is shown in Table 2.

Table 2: Annual kW AC / kW STC

Location:	kW AC / kW STC:
Miami, FL	1339
Houston, TX	1220
Phoenix, AZ	1617
Atlanta, GA	1345
Los Angeles, CA	1470
San Francisco, CA	1446
Baltimore, MD	1228
Seattle, WA	970
Pittsburgh, PA	1099
Reno, NV	1534
Milwaukee, WI	1231
Winnipeg, MB	1291

- **Rooftop Solar Thermal Systems**. Rooftop solar thermal systems are evaluated based on the total collector area in square feet and assuming that each square foot of collector area generates 100,000 BTU of usable energy each year for hot water production.

- **Roof Daylighting**. Roof daylighting systems are evaluated based on the average illumination achieved at floor level in foot-candles multiplied by 32 kWh per foot-candle to determine annual equivalent artificial lighting production. In addition, annual kWh is reduced by 25% to compensate for any heat gain or loss associated with the daylighting

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[3] For purposes of this study, it was assumed that each kWH is the equivalent of 3412 BTU

technology. Finally, total annual estimated power is converted from kWh to BTU to allow comparison with other energy inputs.[4]

- **Carbon Offsets**. As stated previously, the final summation of BTU savings identified by the calculator are converted into greenhouse gas equivalents measured in Metric Tons of CO^2. As a basis for this conversion, it is assumed that 1 kilogram (or 0.001 Metric Tons) of CO^2 is emitted into the atmosphere for every 18,000 BTU of annual energy savings. This calculation is based on current U.S. averages for building source energy, including a mix of natural gas for heating and electricity generated by a combination of renewable and non-renewable sources for cooling. This average may vary significantly from location to location across North America, with a lower conversion factor for areas with low heating and cooling demand and/or high levels of renewable energy production.

THE ROOFPOINT ENERGY AND CARBON CALCULATOR

The RoofPoint Energy and Carbon Calculator consists of a series of Excel worksheets that integrate the variables and calculations discussed previously, using one worksheet for each location / climate zone studied. In addition to the variables listed previously, the worksheets feature an input for total roof area in square feet as well the opportunity to conduct a side-by-side comparison between two roof system alternatives.

Input Section. The input section of the calculator features cells for entering the key variables for a “Base Case Roof” and a “RoofPoint Roof.” For non-numerical variables assigned to a specified data set, a pull-down menu is integrated into the cell to ensure the input is within the allowable data set. As an example, the pull-down menu for R-value lists only the specific R-values provided within the calculator design (R-10, R-15, R-20, R-25, R-30 and R-32). For numerical variables, the cell value is limited to any positive whole number. As an example, roof area may be entered in any whole number of square feet.

An example of the input section of the RoofPoint Energy and Carbon Calculator for Miami, Florida is shown in Figure 2. This example compares a 100,000 square foot Base Case featuring a typical older roof in the Miami area (R-10, medium reflective gravel surface, limited thermal breaks, no air barrier) against a RoofPoint roof (R-20, high reflective roof surface, enhanced thermal breaks, roof air barrier). In addition, the RoofPoint roof features several energy production technologies (100 KW solar PV array, 120 square foot solar thermal unit, 10 foot-candle daylighting).

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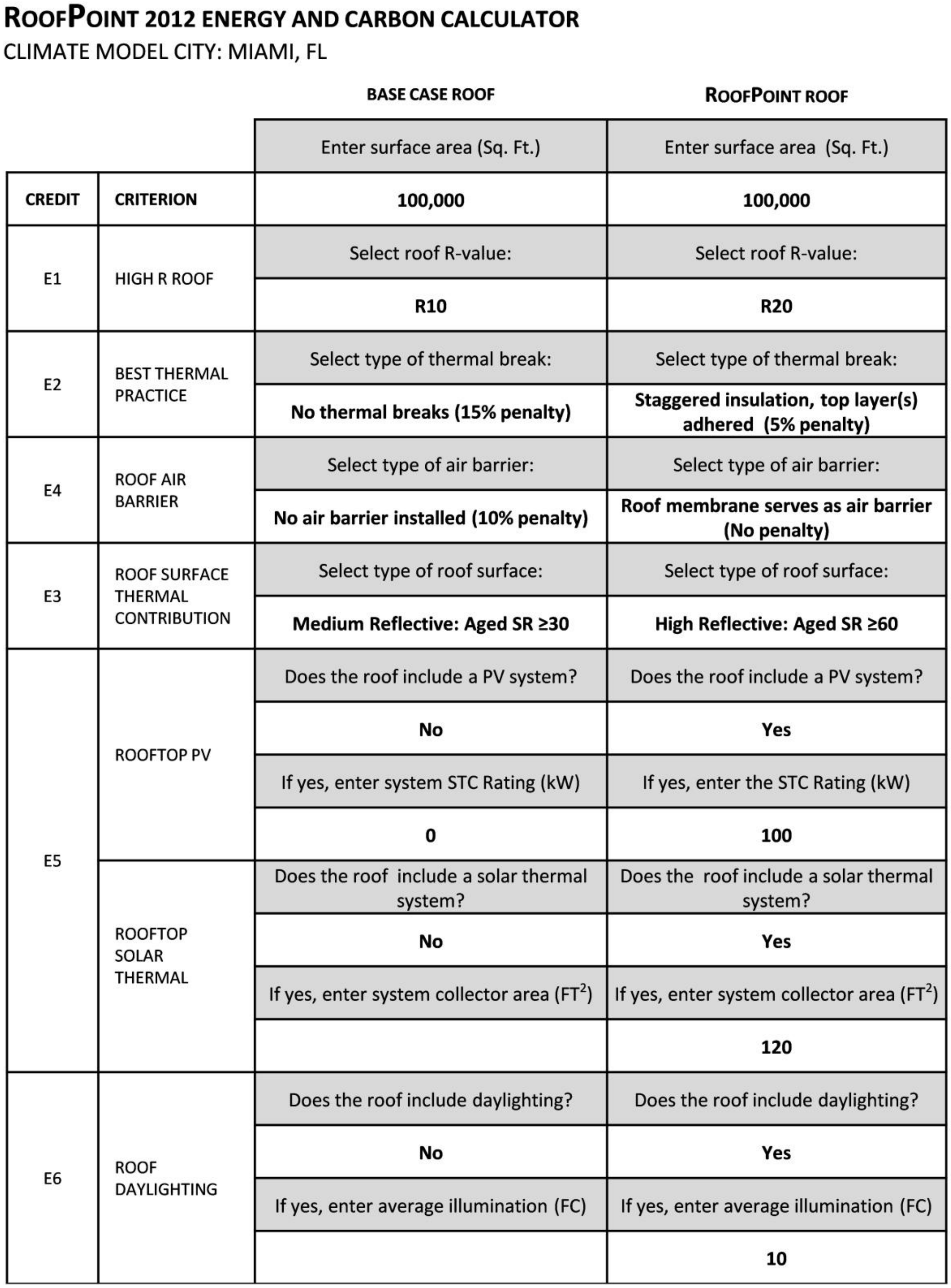
[4] For purposes of this study, it was assumed that each kWH is the equivalent of 3412 BTU



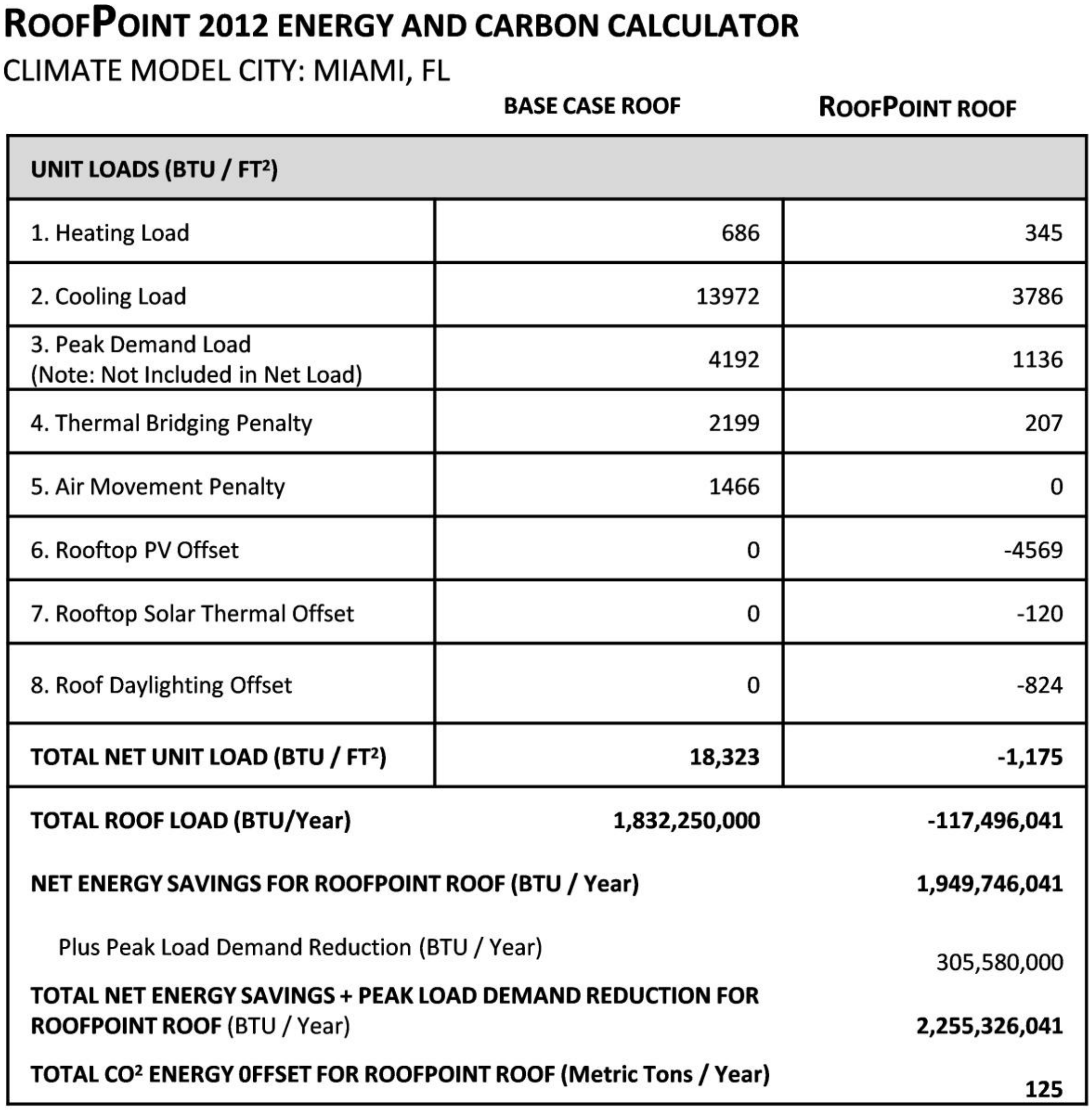
ROOFPOINT 2012 ENERGY AND CARBON CALCULATOR

CLIMATE MODEL CITY: MIAMI, FL

		BASE CASE ROOF	**ROOFPOINT ROOF**
		Enter surface area (Sq. Ft.)	Enter surface area (Sq. Ft.)
CREDIT	**CRITERION**	**100,000**	**100,000**
E1	HIGH R ROOF	Select roof R-value:	Select roof R-value:
		R10	**R20**
E2	BEST THERMAL PRACTICE	Select type of thermal break:	Select type of thermal break:
		No thermal breaks (15% penalty)	**Staggered insulation, top layer(s) adhered (5% penalty)**
E4	ROOF AIR BARRIER	Select type of air barrier:	Select type of air barrier:
		No air barrier installed (10% penalty)	**Roof membrane serves as air barrier (No penalty)**
E3	ROOF SURFACE THERMAL CONTRIBUTION	Select type of roof surface:	Select type of roof surface:
		Medium Reflective: Aged SR ≥30	**High Reflective: Aged SR ≥60**
E5	ROOFTOP PV	Does the roof include a PV system?	Does the roof include a PV system?
		No	**Yes**
		If yes, enter system STC Rating (kW)	If yes, enter the STC Rating (kW)
		0	**100**
	ROOFTOP SOLAR THERMAL	Does the roof include a solar thermal system?	Does the roof include a solar thermal system?
		No	**Yes**
		If yes, enter system collector area (FT^2)	If yes, enter system collector area (FT^2)
			120
E6	ROOF DAYLIGHTING	Does the roof include daylighting?	Does the roof include daylighting?
		No	**Yes**
		If yes, enter average illumination (FC)	If yes, enter average illumination (FC)
			10

Figure 2: RoofPoint Energy and Carbon Calculator Input Section

Output Section. The output section of the calculator provides unit BTU outputs per square foot as well as total BTU outputs for the roof systems being compared. Unit outputs are expressed either as (positive) energy loads on the building or as (negative) energy offsets for roof-related energy production. Total outputs are expressed in BTUs for the roof area entered, and energy savings between the Base Case and the RoofPoint roof are displayed. In addition, an estimate of the equivalent CO^2 offset in Metric Tons is displayed for the calculated energy savings plus an additional equivalent CO^2 savings for peak load demand reduction. An example of the output section of the calculator for the two previously described Miami roofs is shown in Figure 3.



ROOFPOINT 2012 ENERGY AND CARBON CALCULATOR

CLIMATE MODEL CITY: MIAMI, FL

	BASE CASE ROOF	**ROOFPOINT ROOF**
UNIT LOADS (BTU / FT²)		
1. Heating Load	686	345
2. Cooling Load	13972	3786
3. Peak Demand Load (Note: Not Included in Net Load)	4192	1136
4. Thermal Bridging Penalty	2199	207
5. Air Movement Penalty	1466	0
6. Rooftop PV Offset	0	-4569
7. Rooftop Solar Thermal Offset	0	-120
8. Roof Daylighting Offset	0	-824
TOTAL NET UNIT LOAD (BTU / FT²)	**18,323**	**-1,175**
TOTAL ROOF LOAD (BTU/Year)	**1,832,250,000**	**-117,496,041**
NET ENERGY SAVINGS FOR ROOFPOINT ROOF (BTU / Year)		**1,949,746,041**
Plus Peak Load Demand Reduction (BTU / Year)		305,580,000
TOTAL NET ENERGY SAVINGS + PEAK LOAD DEMAND REDUCTION FOR ROOFPOINT ROOF (BTU / Year)		**2,255,326,041**
TOTAL CO² ENERGY 0FFSET FOR ROOFPOINT ROOF (Metric Tons / Year)		**125**

Figure 3: RoofPoint Energy and Carbon Calculator Output Section

DISCUSSION

Preliminary Observations. Because the RoofPoint Energy and Carbon Calculator has not yet been applied extensively in field applications, very few immediate observations may be made. However, several observations both from this study and a previous study that helped establish the basis for the current calculator may help illustrate the potential value of the calculator.

- **Importance of Peak Energy Demand**. Data from a previous study limited only to the roof surface thermal characteristics of RoofPoint (Hoff, 2012) suggests that reducing peak energy demand associated with building cooling loads may be a very important concern in almost all climate zones. As an example, using similar base assumptions as the current RoofPoint calculator a study presented at the 2012 International Roof Coatings Conference (Hoff, 2012) suggested that although the net energy benefit of cool roofs tends to decline from warm, southern climates to cool, northern climates, the peak demand benefit remains relatively constant. The variance in net and peak energy demand is illustrated in Figure 4.

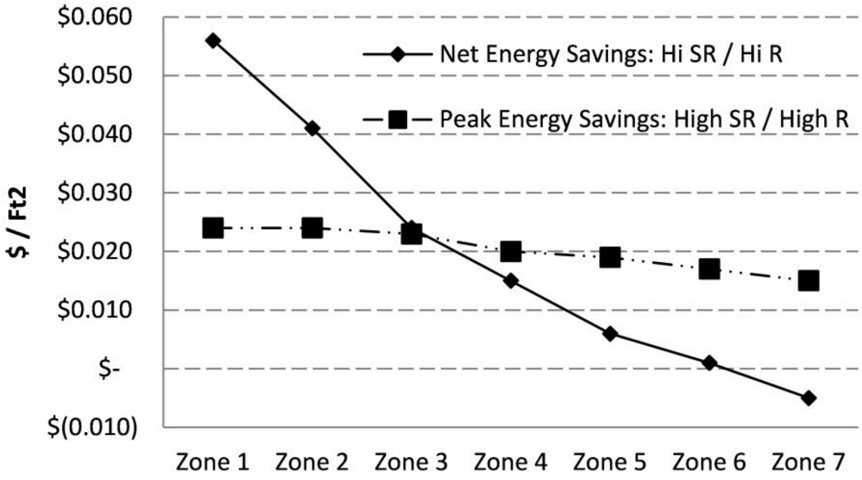


Figure 4: Net Energy versus Peak Energy Savings for a High Reflective / High R Roof As Compared to a Low Reflective Roof with Identical R Value
Source: Hoff (2012)

Although it may seem counter-intuitive that similar peak energy savings may be achieved in cold climates as well as warm climates, Figure 1 presented earlier in this paper may help explain this situation. 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 energy savings in warm climates may be described as a smaller piece of a larger pie, while peak energy savings in cold climates may be described as a larger piece of a smaller pie.

- **Importance of Rooftop Renewable Energy**. As illustrated by the example of the RoofPoint roof design shown in Figures 2 and 3, the potential energy benefits of rooftop energy systems may exceed the benefits of roof energy efficiency by a significant order of magnitude. In the example, the well-insulated RoofPoint roof generates an annual net energy demand of 4,338 BTU per square foot. However, this energy demand is more than offset by small 10 kW PV array, a 120 square foot solar thermal unit and a minimal skylight system delivering 10 foot-candles of illumination. Together these small energy production enhancements provide 5,513 BTU of renewable energy, completely offsetting all roof-related energy demands. If these energy enhancements were upsized to the maximum levels suitable for the 100,000 square foot roof area (perhaps a 1000 kW PV array and 30+ foot-candles of daylighting), the total clean energy contribution would exceed roof-related energy requirements by a factor of 10.

Future Refinements. Several features of the calculator may merit additional refinement in order to increase accuracy and validity of the outputs. Solar thermal calculations currently are based on a national average for solar thermal units in a variety of climates, but the calculator would be much more accurate if a tool similar to PVWatts could be utilized to provide a local solar intensity factor for estimated energy output. In a similar manner, daylighting calculations could be improved significantly through the integration of a more sophisticated daylighting tool that could better quantify the potential heat gain / heat loss offsets associated with different daylighting technologies. Finally, carbon offset calculations could be refined by developing a model that can accommodate regional variations in energy sources, especially in regard to the ratio of renewable to non-renewable source energy.

Beyond specific refinements in current algorithms, the value of the calculator also may be increased through the addition of embodied energy inputs. Although the calculator currently models only operating energy inputs, all building materials and the installation and maintenance of these materials involve embodied energy inputs in addition to operating energy. As methods such as Life Cycle Assessment (LCA) expand in the marketplace and begin to provide accurate embodied energy estimates for common roofing materials, these energy inputs could be added to the calculator.

Beta Testing. The RoofPoint Energy and Carbon Calculator will be released for beta testing beginning in the fall of 2012. Based on testing results, additional refinements may be made to the calculator before the formal presentation of this paper at the 28th RCI International Convention and Trade Show in March, 2013. In addition, it is anticipated that a number of case studies will be conducted to further demonstrate the value of the tool as part of the formal presentation. Finally, an electronic copy of the calculator will be made available to all presentation attendees.

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