

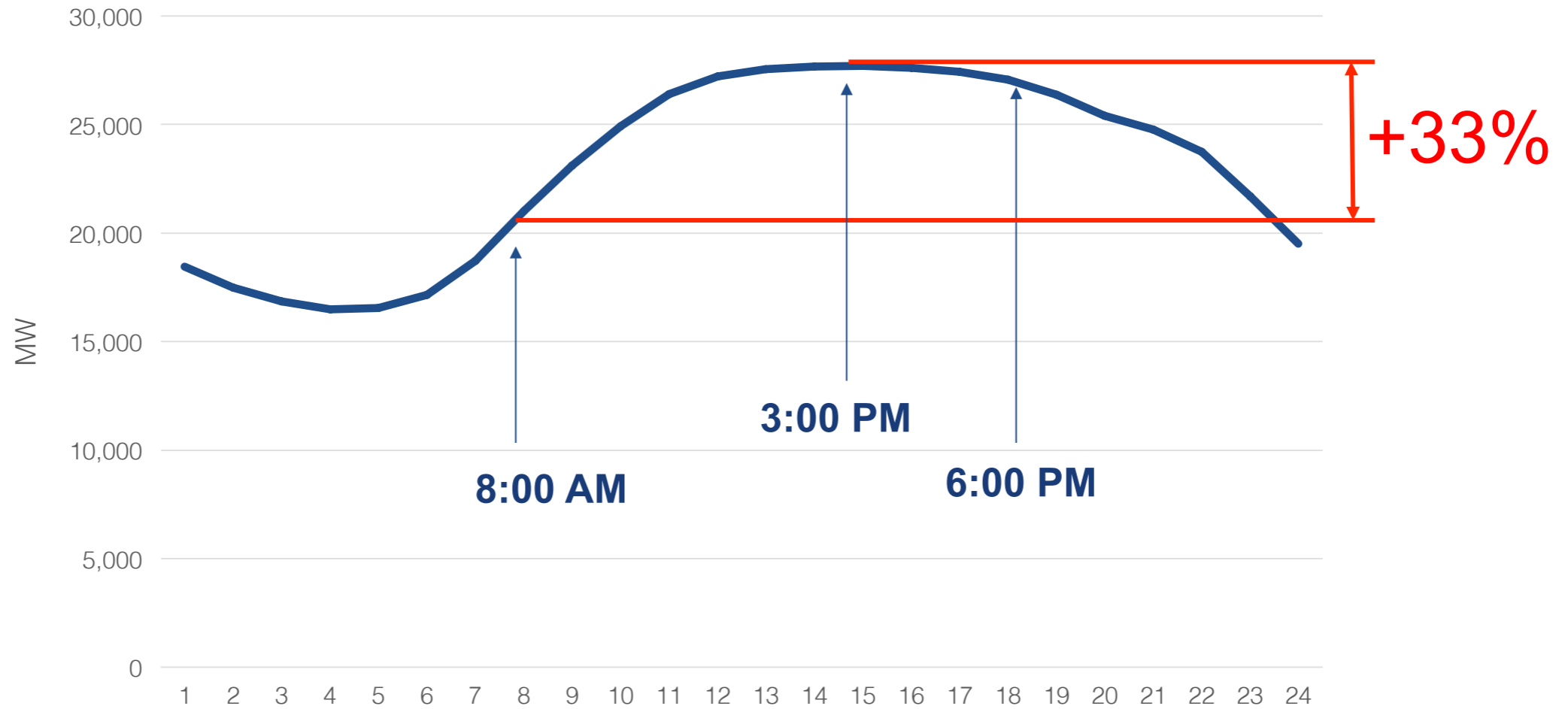
Reducing Peak Energy Demand: The Hidden Benefit of Cool Roofs

*Dr. James L. Hoff, DBA, TEGNOS Research, Inc.,
Keith Gere and Robert Carnick, Duro-Last Inc.*

November 11, 2014



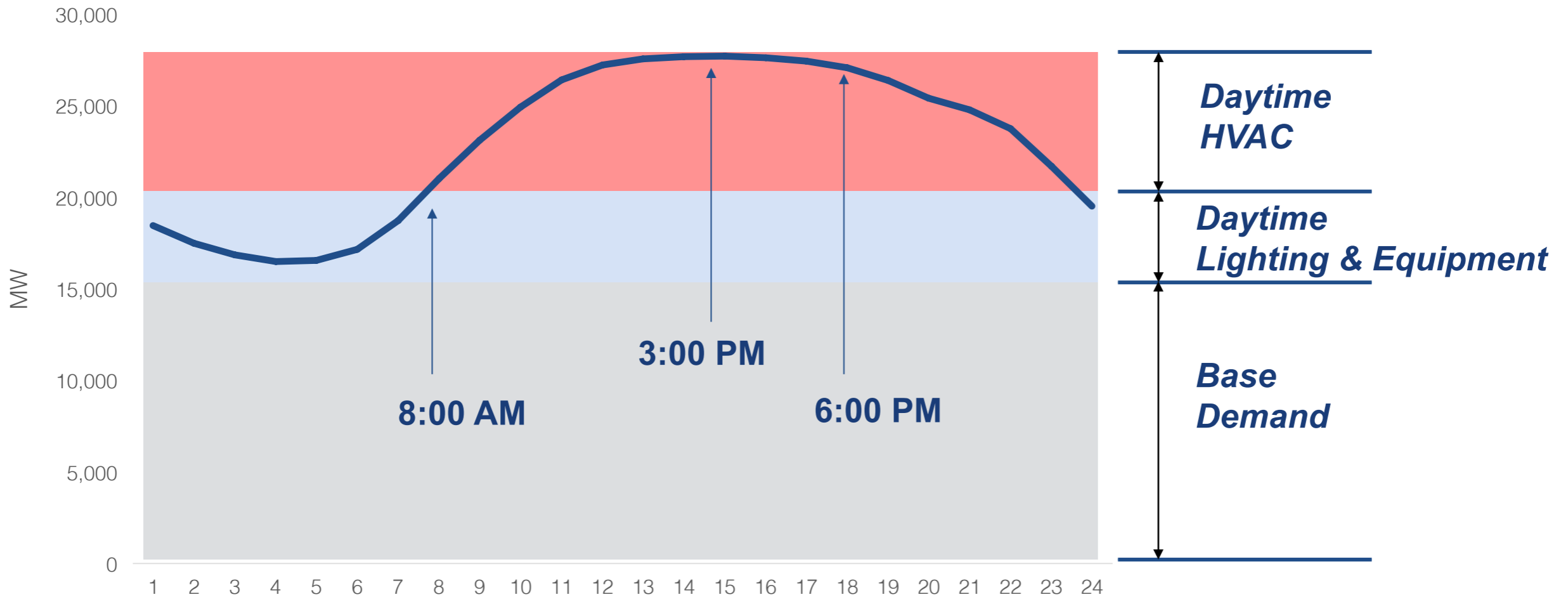
Peak Energy Demand



Hourly Electrical Demand

New England ISO Region, July 22, 2011

Peak Energy Demand



Hourly Electrical Demand
New England ISO Region, July 22, 2011

Peak Energy Demand

- Requires additional power plant capacity
- Reduces overall capacity utilization and return on investment
- Causes imbalances in the power grid
- Increases air pollution at a critical period of the day
- *May result in monthly charges many times higher than base electricity rates*

How Commercial Building Owners Pay for Peak Demand

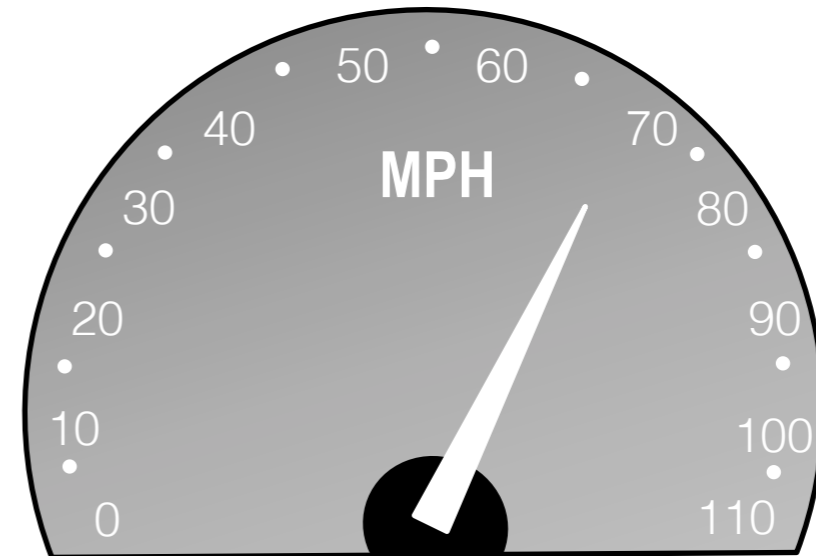
Two Distinct Types of Charges:

1. Base Use: Measured in total kWh used
2. Peak Demand: Measured in highest kW measured during peak periods

Base Use and Peak Demand



*Miles Driven = Base Use
(kWh)*



*Top Speed = Peak Demand
(kW)*

Typical Commercial Electric Bill

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		Days	Meter Reading		Usage	Actual kW
	From	To		Previous	Present		
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 Gasification 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

Typical Commercial Electric Bill

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		Base Use (kWh)		
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	
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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

Base Use Charges

Total Base Use:

\$1854.32

\$0.0330 / kWh

44% of Monthly Bill

Typical Commercial Electric Bill

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

Duke Energy			Peak Demand (kW)
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

Total Peak Demand:

\$2441.94

\$20.10 / kW

56% of Monthly Bill

Peak Demand Charges

Typical Commercial Electric Bill

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

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

Total Base Use: \$0.0330 / kWh
Total Peak Demand: \$20.10 / kW
Total Net Billing: \$0.075 / kWh

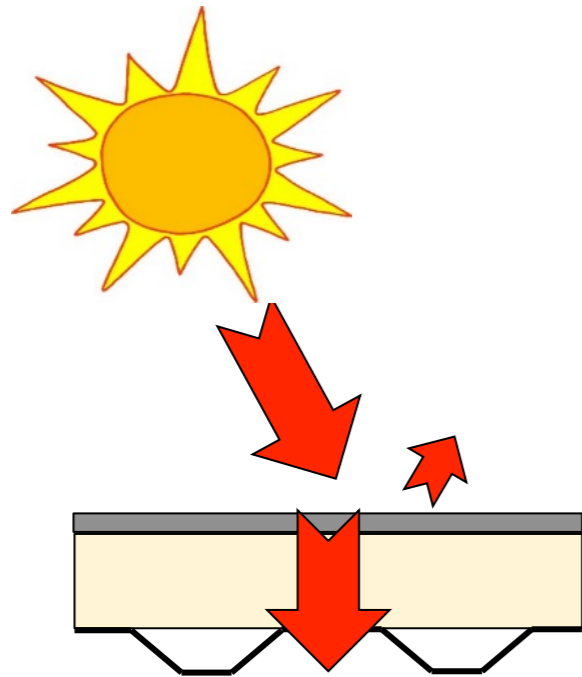
	Base Use (kWh)	Peak Demand (kW)	
Duke Energy Rate HSND – High Load Factor Sec S/v			
Other Charges & Credits		8.12	
Demand Charge			
120.00 kW @	\$ 14.0600000	1,687.20	
Energy Charge			
56,780 kWh @	\$ 0.01683000	955.61	
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120.00 kW @	\$ 2.06452600	250.14	\$ 4,274.38
Total Current Electric Charges			\$ 4,274.38

Source: Duke Energy of Indiana

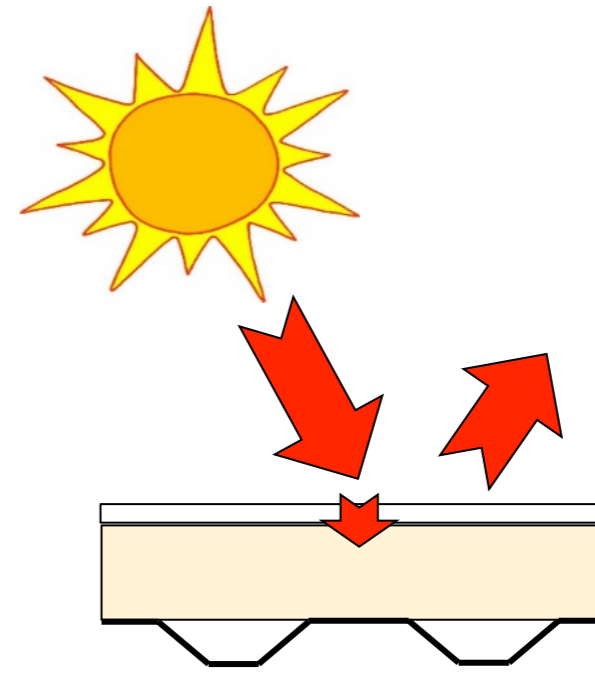
Reducing Peak Energy Demand

- Equipment Improvements
- Lighting Improvements
- Supplemental Daylighting & Solar
- *Reduced Peak Solar Loads*

Cool Reflective Roofing



A Non-Reflective Roof Absorbs the Majority of Solar Heat and Transfers it into the Building



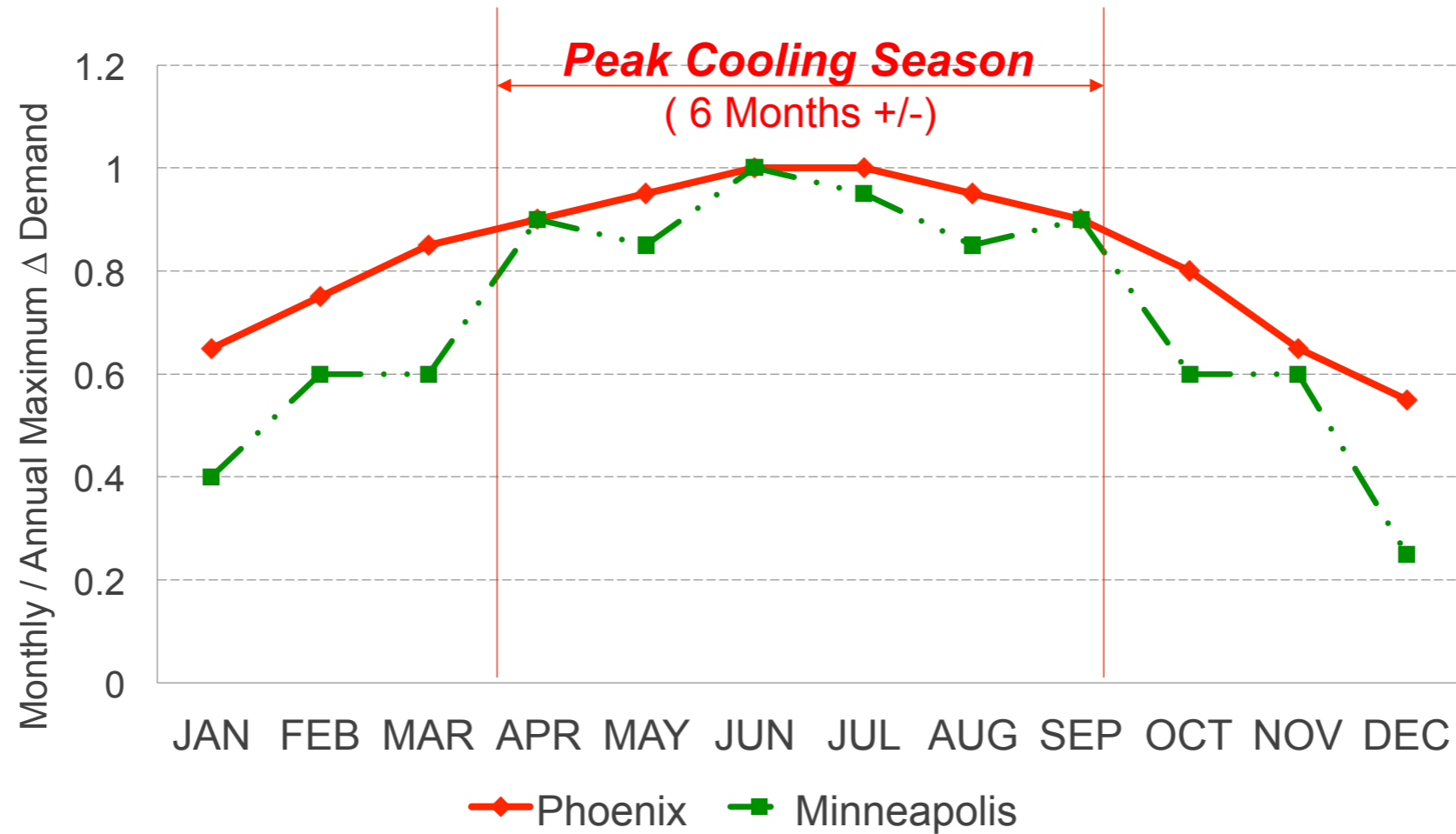
A Cool Reflective Roof Reflects the Majority of Solar Heat and Directs it Away from the Building

Cool Reflective Roof Standards

Reference Standard	Minimum Roof Reflectance	
	Initial	Aged
International Energy Conservation Code (2012)	70%	55%
ASHRAE 90.1 Energy Standard for Buildings (2011)	70%	55%
Energy Star for Roofs (U.S. EPA, 2012)	65%	50%
California Title 24 Energy Standard (2012)	n/a	63%

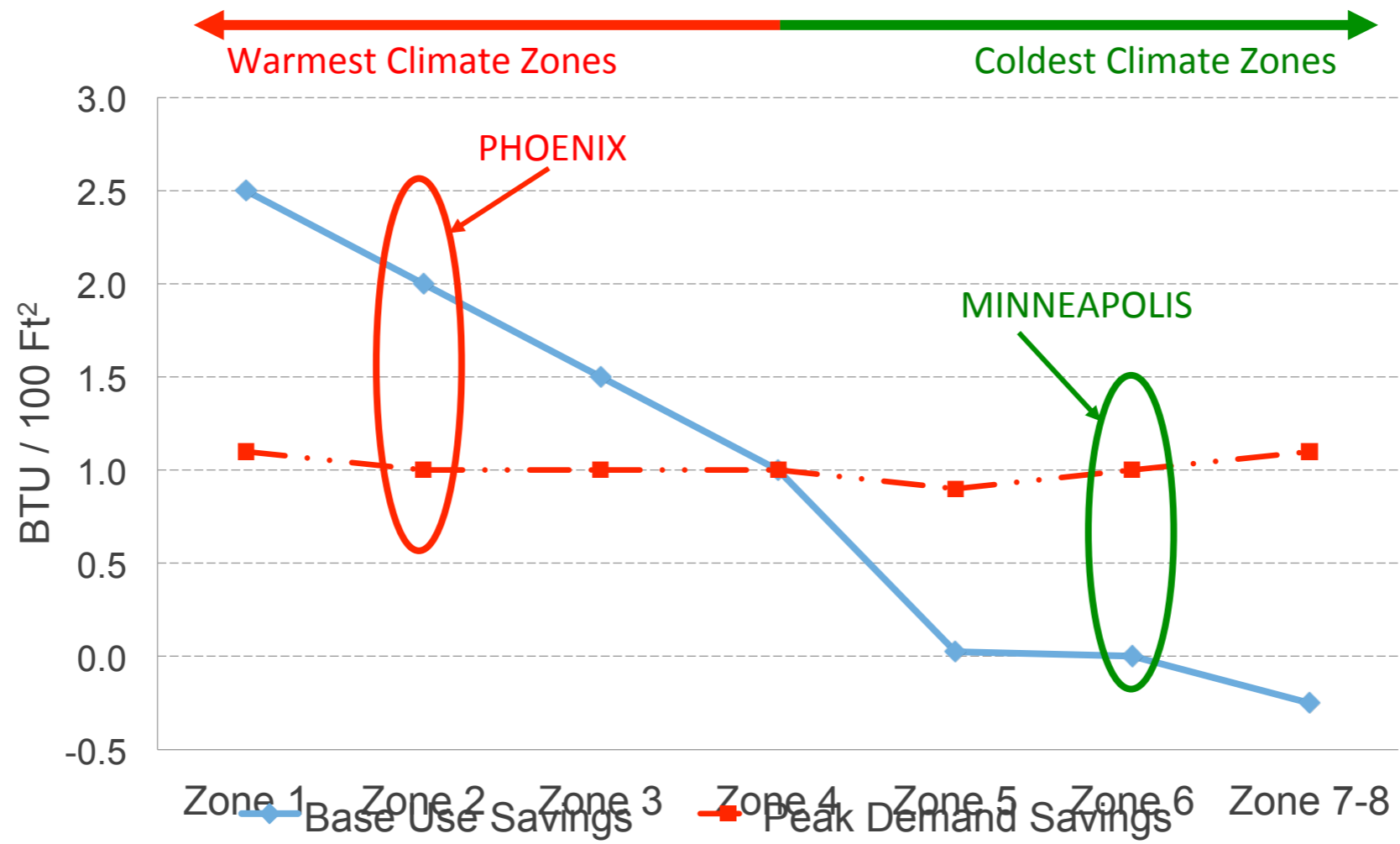
Peak Demand

Not Just a Warm Climate Issue



Roof-Related Air Conditioning Demand:
Ratio of Monthly to Annual Peak

Peak Demand Savings Uniform Through All Climate Zones



Potential Roof-Related Base Use and Peak Demand Savings (by North America Climate Zone)

Source: RoofPoint Energy and Carbon Calculator

Calculating Peak Demand Savings

DOE Cool Roof Peak Calculator

- Developed by Oak Ridge National Laboratories for U.S. Department of Energy
- Based on extensive research and modeling of over 200 locations across North America
- Models the most typical commercial roofing system with above-deck insulation
- Compares a cool roof against a nominal black roof with 5% reflectivity
- *Available online at no charge*

Using the DOE Cool Roof Peak Calculator

DOE Cool Roof Peak Calculator

<http://web.ornl.gov/sci/roofs+walls/facts/CoolCalcPeak.htm>

My State

My 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]

Step 1:

Go to Cool Roof Peak Calculator Web Page

<http://web.ornl.gov/sci/roofs+walls/facts/CoolCalcPeak.htm>

Using the DOE Cool Roof Peak Calculator

DOE Cool Roof Peak Calculator

<http://web.ornl.gov/sci/roofs+walls/facts/CoolCalcPeak.htm>

My State

My 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)

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

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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]

Step 2:

Select city and state
from over 200
locations

Using the DOE Cool Roof Peak Calculator

DOE Cool Roof Peak Calculator

<http://web.ornl.gov/sci/roofs+walls/facts/CoolCalcPeak.htm>

My State	<input type="text" value="Select a State"/>
My City	<input type="text" value="Select a City"/>
My Proposed Roof:	
R-value (HIGH=20; AVG=10; LOW=5) [h·ft ² ·°F/Btu]	<input type="text"/>
Solar reflectance, SR (HIGH=80; AVG=50; LOW=10) [%]	<input type="text"/>
Infrared emittance, IE (HIGH=90; AVG=60; LOW=10) [%]	<input type="text"/>
My Energy Costs and Equipment Efficiencies:	
Summertime cost of electricity (HIGH=0.20; AVG=0.10; LOW=0.05) [\$/KWh]	<input type="text"/>
Air conditioner efficiency (COP) over cooling season (HIGH=2.5; AVG=2.0; LOW=1.5)	<input type="text"/>
Energy source for heating (choose one)	
If electricity, wintertime cost (HIGH=0.20; AVG=0.10; LOW=0.05) [\$/KWh]	<input type="text"/>
If fuel, cost (Natural gas: HIGH=1.00; AVG=0.70; LOW=0.50) [\$/Therm]	<input type="text"/>
(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)	<input type="text"/>
(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]	<input type="text"/>
Months charged for peak demand (Typical = 6) [-]	<input type="text"/>
Total Annual Energy + Demand Savings (relative to a black roof) [\$/ft ² per year]	<input type="text"/>
Cooling energy savings [\$/ft ² per year]	<input type="text"/>
Heating energy savings (heating penalty if negative) [\$/ft ² per year]	<input type="text"/>
Cooling season demand savings [\$/ft ² per year]	<input type="text"/>

Step 3:

Enter proposed roof
R-value

Using the DOE Cool Roof Peak Calculator

DOE Cool Roof Peak Calculator

<http://web.ornl.gov/sci/roofs+walls/facts/CoolCalcPeak.htm>

My State	<input type="text" value="Select a State"/>
My City	<input type="text" value="Select a City"/>
My Proposed Roof:	
R-value (HIGH=20; AVG=10; LOW=5) [h·ft ² ·°F/Btu]	<input type="text"/>
Solar reflectance, SR (HIGH=80; AVG=50; LOW=10) [%]	<input type="text"/>
Infrared emittance, IE (HIGH=90; AVG=60; LOW=10) [%]	<input type="text"/>
My Energy Costs and Equipment Efficiencies:	
Summertime cost of electricity (HIGH=0.20; AVG=0.10; LOW=0.05) [\$/KWh]	<input type="text"/>
Air conditioner efficiency (COP) over cooling season (HIGH=2.5; AVG=2.0; LOW=1.5)	<input type="text"/>
Energy source for heating (choose one)	
If electricity, wintertime cost (HIGH=0.20; AVG=0.10; LOW=0.05) [\$/KWh]	<input type="text"/>
If fuel, cost (Natural gas: HIGH=1.00; AVG=0.70; LOW=0.50) [\$/Therm]	<input type="text"/>
(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)	<input type="text"/>
(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]	<input type="text"/>
Months charged for peak demand (Typical = 6) [-]	<input type="text"/>
Total Annual Energy + Demand Savings (relative to a black roof) [\$/ft ² per year]	<input type="text"/>
Cooling energy savings [\$/ft ² per year]	<input type="text"/>
Heating energy savings (heating penalty if negative) [\$/ft ² per year]	<input type="text"/>
Cooling season demand savings [\$/ft ² per year]	<input type="text"/>

Step 4:

Enter proposed roof solar reflectance (SR) and thermal emittance (TE)

Using the DOE Cool Roof Peak Calculator

DOE Cool Roof Peak Calculator

<http://web.ornl.gov/sci/roofs+walls/facts/CoolCalcPeak.htm>

My State

My 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]

Step 5:

Enter cost of heating and cooling energy and equipment efficiencies

Using the DOE Cool Roof Peak Calculator

DOE Cool Roof Peak Calculator
<http://web.ornl.gov/sci/roofs+walls/facts/CoolCalcPeak.htm>

My State

My 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]

Step 6:
Enter electric demand charge and duration (typically 6 months)

Using the DOE Cool Roof Peak Calculator

DOE Cool Roof Peak Calculator
<http://web.ornl.gov/sci/roofs+walls/facts/CoolCalcPeak.htm>

My State

My 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]

Step 7:

View the savings:

- Total cooling savings
- Heating penalty (if any)
- Cooling season demand savings

Applying the Cool Roof Peak Calculator Model Study

- Composite of model cities in each North American climate zone
- Representative commercial building
 - 20,000 square foot low-rise structure
 - Heated and cooled with typical HVAC equipment (AC C.O.P. = 2.0, Furnace Efficiency = 0.70)
- Two construction conditions / insulation levels
 - “New insulation” meeting 2012 IECC insulation levels
 - “Old insulation” meeting pre-2012 IECC levels
- Cool roof solar reflectance (SR) = 0.60 / thermal emittance (TE) = 0.90
 - Solar reflectance (SR) = 0.60
 - Thermal emittance (TE) = 0.90
 - Compared to black roof with SR=0.05 and TE = 0.90
- Electrical base use and demand charge identical to sample energy bill
 - Base use: \$0.033 / kWh
 - Demand Charge: \$20.10 / kW
 - Plus natural gas for heating at \$0.70 / Therm

Cool Roof Model Study

Climate Zones and Model Cities



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)

Cool Roof Model Study

Climate Zones and R-Values

Climate Zone	Roof R-Value	
	Old Insulation Condition ¹	New Insulation Condition ²
1	10	20
2	15	20
3	15	20
4	15	25
5	15	25
6	15	30
7-8	15	35

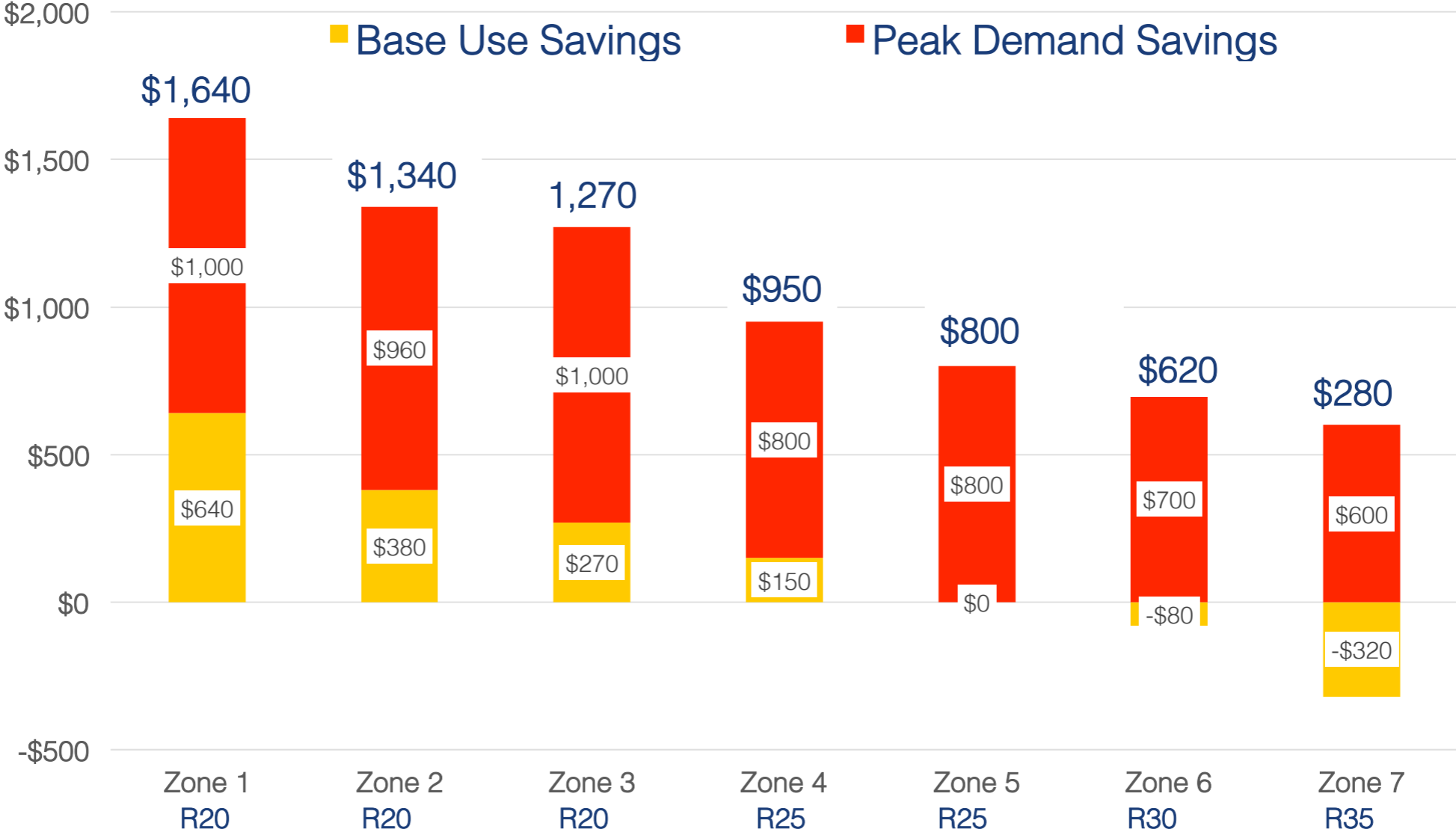
Notes:

1. Per 2006 International Energy Conservation Code

2. Per 2012 International Energy Conservation Code

Cool Roof Model Study

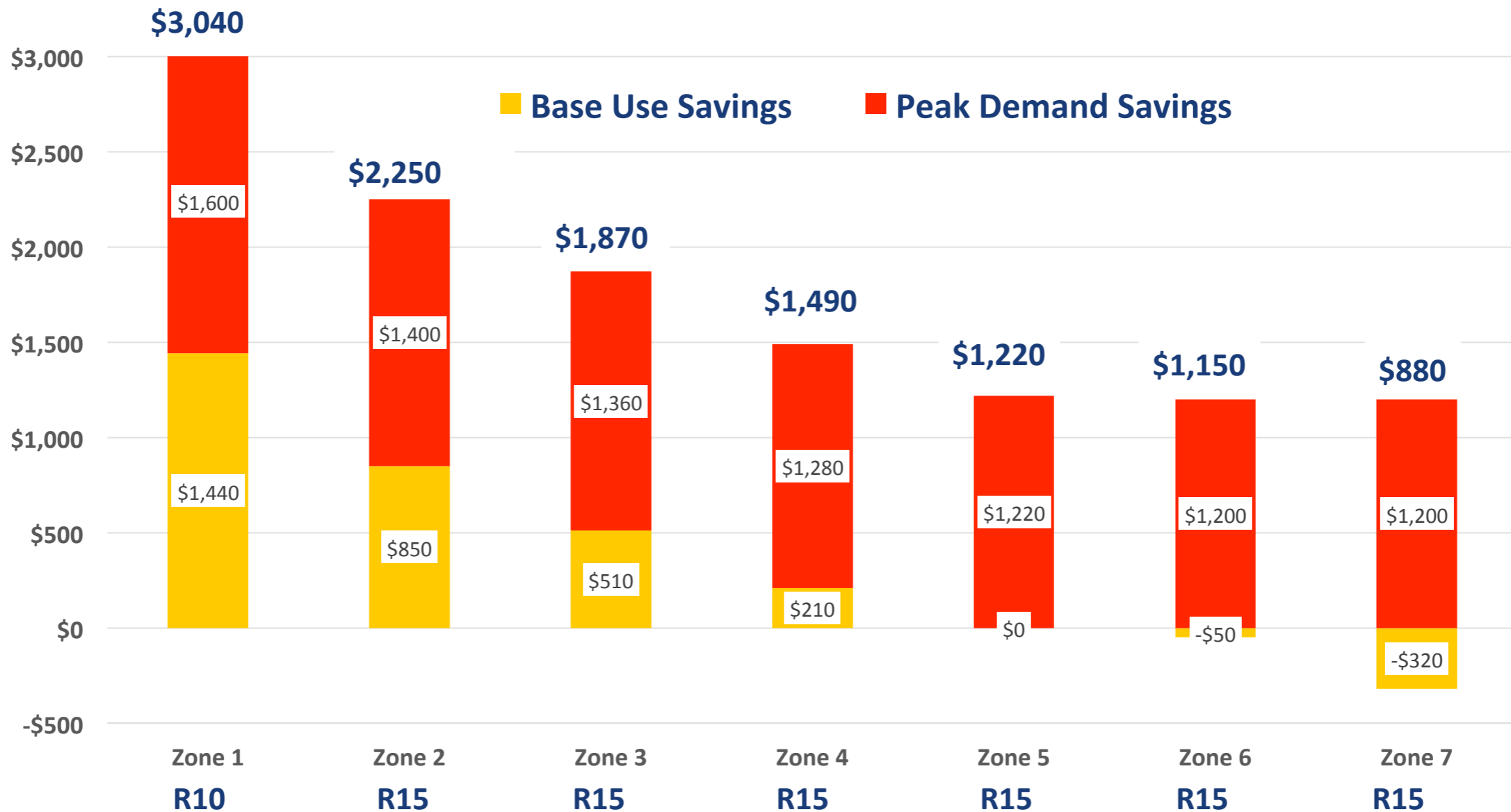
New Insulation Results



Estimated Net Energy Savings: Cool Roof Installed over New Insulation
 (Annual Dollars / 20,000 Square Foot Roof Area)

Cool Roof Model Study

Old Insulation Results



Estimated Net Energy Savings: Cool Roof Installed over Old Insulation
 (Annual Dollars / 20,000 Square Foot Roof Area)

The Bottom Line:

Cool Roofs and Peak Energy Demand

- **Potential savings available in all climates and conditions studied**
 - Zone 1 through Zone 8
 - New roofs or roof recovers
 - All levels of roof insulation
- **Peak demand drives the potential savings**
 - Over 50% in all climate zones
 - Up to 100% in the coolest climate zones

Peak Demand and the Building Design Professional

The Next Steps

- **Get to know your clients' electrical bills**
 - No substitute for actual bills
 - Calculate actual base and peak charges
 - Don't simply divide the total bill by kWh usage
- **Start using the DOE Cool Roof Peak Calculator**
 - Don't rely on tools that only use a single average rate in lieu of base and peak rates
- **Build the results into your roof designs**
 - Base new roof and recover roof designs on total base and peak energy modeling

Reducing Peak Energy Demand: The Hidden Benefit of Cool Roofs

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