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Measuring Energy and Environmental Impacts:

A New Modeling Tool for Roofing Professionals

Dr. Jim Hoff

Center for Environmental Innovation in Roofing

Modeling Tools

Modeling Tools Require Models

Modeling Tool:	*Model:*
DOE Cool Roof Calculator	*ORNL Radiation Control Model*
PV Watts Calculator	*NREL PV Array Simulation Model*
NRCA Energy Wise Calculator	*ASHRAE 90.1*

… and Models Need Modeling Tools

Example: Sustainable Building Models

LEED

Living Building Challenge

Green Globes

How much do they improve the environment?

What do different achievement levels mean?

What savings are achieved?

The Model:

RoofPoint

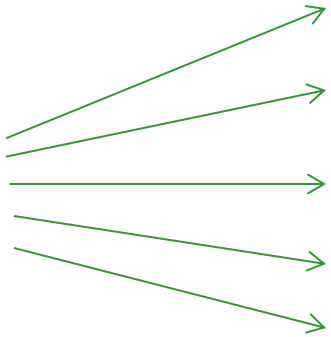
Guideline for Environmentally Innovative Roofing

- Sustainable Guideline and Rating System for Roofing
- Comprehensive Approach to Roofs, Energy, Environment
- Developed by the Center for Environmental Innovation in Roofing
- Vetted in a 2-Step Industry Consensus Process
- Validated in a Successful 2012 Pilot Program
- Simple Web-Based Evaluation System
- Over 200 Roofing Projects Evaluated to Date

Modeling Tools:

The Model:

RoofPoint



Possible Modeling Tools:

Energy Calculator

Carbon Calculator

Water Use Calculator

Solid Waste Calculator

Life Cycle Calculator

The Goal:
Building Credible Modeling Tools for RoofPoint

- Step 1 Determine Outcomes
- Step 2 Identify Strategies
- Step 3 Establish Measures
- Step 4 Identify Variables and Assumptions
- Step 5 Assemble the Model
- Step 6 Test the Model
- Step 7 Look to the Future

Step One: Determine Outcomes

RoofPoint Outcomes
(Intents)

- **ENERGY**
  - Net Energy Consumption
  - Peak Energy Consumption
  - Clean Energy Production
- **LIFE CYCLE**
  - Service Life
  - Resilience
- **ENVIRONMENT**
  - Solid Waste / Recycling
  - Storm Water / Water Use
  - Outdoor Air Quality
  - Global Warming / Heat Islands
- **HEALTH / SAFETY**
  - Accident Prevention
  - Indoor Air Quality

Step Two: Identify Strategies

RoofPoint Energy Strategies
(Credits)

CREDIT	TITLE	OUTCOME / INTENT	STRATEGY
E1	**HIGH R ROOF SYSTEMS**	Reduce Net Energy	Increase Roof R Value
E2	**BEST THERMAL PRACTICES**	Reduce Net Energy	Reduce Thermal Discontinuities
E3	**ROOF SURFACE THERMAL CONTRIBUTION**	Reduce Net / Peak Energy & Heat Island Effects	Install Climate-Appropriate Roof Surface
E4	**ROOF AIR BARRIER**	Reduce Net Energy	Install Air Barrier
E5	**ROOFTOP ENERGY SYSTEMS**	Produce Clean Energy	Install Rooftop Solar
E6	**ROOFTOP DAYLIGHTING**	Produce Clean Energy	Install Roof Daylighting

Step Three: Establish Measures

RoofPoint Energy Measures

CREDIT	TITLE	BASE MEASURE	CONVERTS TO
E1	**HIGH R ROOF SYSTEMS**	R / Ft^2	BTU / Ft^2
E2	**BEST THERMAL PRACTICES**	% Improvement	BTU / Ft^2
E3	**ROOF SURFACE THERMAL CONTRIBUTION**	SRI / Equivalent SRI	BTU / Ft^2
E4	**ROOF AIR BARRIER**	% Improvement	BTU / Ft^2
E5	**ROOFTOP ENERGY SYSTEMS**	W / Ft^2 or BTU / Ft^2	BTU / Ft^2
E6	**ROOFTOP DAYLIGHTING**	Net Lumens / Ft^2	BTU / Ft^2

Step Four: Identify Variables and Assumptions

Model Cities / Climate Zones

CITY	ASHRAE CLIMATE ZONE
MIAMI, FL	1A MOIST
HOUSTON, TX	2A MOIST
PHOENIX, AZ	2B DRY
ATLANTA, GA	3A MOIST
LOS ANGELES, CA	3B DRY
SAN FRANCISCO, CA	3C MARINE
BALTIMORE, MD	4A MOIST
SEATTLE, WA	4C MARINE
PITTSBURGH, PA	5A MOIST
RENO, NV	5B DRY
MILWAUKEE, WI	6A MOIST
WINNIPEG, MB	7

Step Four: Identify Variables and Assumptions

Roof System R-Values

R-VALUE	BASIS
R-10	OLD CODE
R-15	OLD CODE
R-20	2012 IECC ZONE 1-3
R-25	2012 IECC ZONE 4-5
R-30	2012 IECC ZONE 6
R-32	2012 IECC ZONE 7*

* Zone 7 is actually R-35, but R-32 is highest value available in the DOE Cool Roof Calculator

Step Four: Identify Variables and Assumptions

Roof Surface Type

ROOF SURFACE	SOLAR REFLECTIVITY	THERMAL EMMISSIVITY
LOW REFLECTIVE	AGED SR ≥ 0.10	TE = 0.90
MEDIUM REFLECTIVE	AGED SR ≥ 0.30	TE = 0.90
HIGH REFLECTIVE	AGED SR ≥ 0.60	TE = 0.90
BALLASTED[1]	ASSUMED EQUIV. AGED SR ≥ 0.60	TE = 0.90
VEGETATIVE[2]	ASSUMED EQUIV. AGED SR ≥ 0.60	TE = 0.90
EXTRA HIGH REFLECTIVE	AGED SR ≥ 70	TE = 0.90

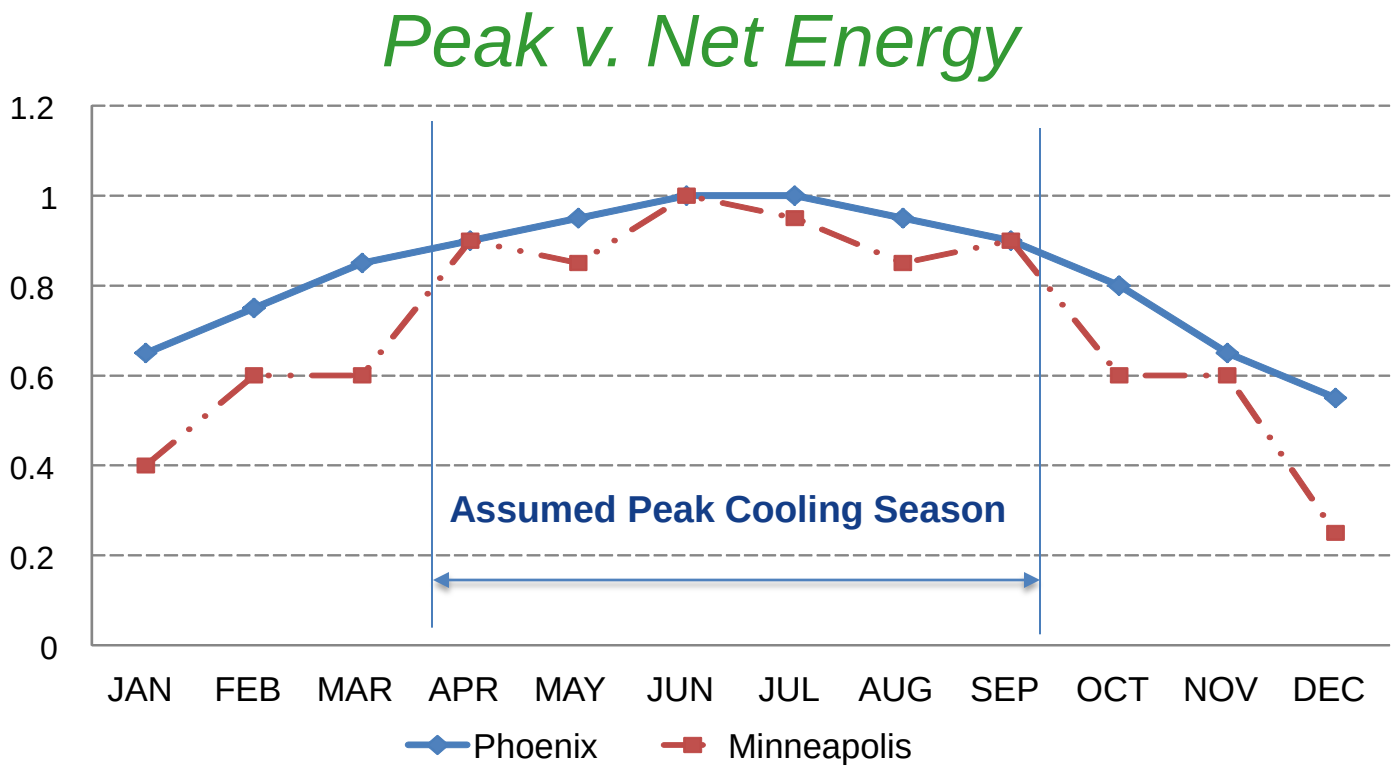
1. Min. 22 lbs. / ft^2 Zones 1-4, Min. 15 lbs . / ft^2 Zones 5-7
2. Intensive or extensive vegetative roof meeting requirements of RoofPoint Credit W1.

Step Four: Identify Variables and Assumptions

Conditioned Space

CONDITION	ENERGY SOURCE	EQUIPMENT PERFORMANCE
HEATING	NATURAL GAS	EFFICIENCY = 0.70
COOLING	ELECTRICITY	COP = 2.0

Step Four: Identify Variables and Assumptions



Ratio of Monthly to Annual Peak Cooling Demand for Phoenix and Minneapolis

Derived from Petrie, Wilkes and Dejarlais (2004)

Step Four: Identify Variables and Assumptions

Peak v. Net Energy

CITY	ASHRAE CLIMATE ZONE	PEAK / NET DEMAND RATIO
MIAMI, FL	1A MOIST	0.30
HOUSTON, TX	2A MOIST	0.36
PHOENIX, AZ	2B DRY	0.28
ATLANTA, GA	3A MOIST	0.44
LOS ANGELES, CA	3B DRY	0.64
SAN FRANCISCO, CA	3C MARINE	1.10
BALTIMORE, MD	4A MOIST	0.55
SEATTLE, WA	4C MARINE	1.10
PITTSBURGH, PA	5A MOIST	0.73
RENO, NV	5B DRY	0.83
MILWAUKEE, WI	6A MOIST	0.92
WINNIPEG, MB	7	1.10

Step Four: Identify Variables and Assumptions

Best Thermal Practice

CONDITION	VALUE
NO THERMAL BREAKS	15% PENALTY
STAGGERED INSULATION, MECH. ATTACHED	10% PENALTY
STAGGERED INSULATION: LOOSELEY LAID	5% PENALTY
STAGGERED INSULATION: TOP LAYER(S) ADHERED	5% PENALTY
MONOLITHIC INSULATION (e.g. SPF)	NO PENALTY

Roof Air Barrier

CONDITION	VALUE
NO AIR BARRIER	10% PENALTY
AIR BARRIER BENEATH ROOF MEMBRANE	NO PENALTY
ROOF MEMBRANE SERVES AS AIR BARRIER	NO PENALTY

Step Four: Identify Variables and Assumptions

Rooftop PV

CITY	Annual kW AC / kW STC[1,2]
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

1. Calculated using NREL PVWatts Version 1
2. Annual kWH converted to BTU (1kW = 3412 BTU)

Step Four: Identify Variables and Assumptions

Rooftop Solar Thermal

- *Rooftop solar thermal assumes annual hot water production of 100,000 BTU per square foot of collector area*

Roof Daylighting

- *Assumed 32 kWh per foot-candle of average daytime illumination*
- *Annual kWH reduced 25% to compensate for any heat gain or loss from skylights*
- *Annual kWH converted to BTU (1kW = 3412 BTU)*

Step Four: Identify Variables and Assumptions

Carbon Offsets

- *Assumes 1 kg (or 0.001 Metric Ton) CO_2 emitted into the atmosphere for every 18,000 BTU of annual energy usage.*
- *Based on current U.S. averages for building source energy, including a mix of natural gas for heating and electricity for cooling generated by a combination of renewable and non-renewable sources.*

Other Notes:

- *US DOE Cool Roof Peak Calculator used to calculate base values for energy use related to roof system R-value and roof surface reflectivity*
- *All resultant values and calculations entered into a series of Excel worksheets, one worksheet for each model city.*
- *Worksheets provide for a comparison calculation of a "Base Case Roof" and a "RoofPoint Roof"*

Step Five: Assemble the Model

INPUTS

	BASE CASE ROOF
ROOF SURFACE AREA	Enter surface area of Base Case Roof (Sq. Ft.)
	100,000
CREDIT E1: HIGH R ROOF	Select R-Value for the Base Case Roof:
Note: See RoofPoint Credit E1 for more information.	**R10**
CREDIT E2: BEST THERMAL PRACTICE	Select type of thermal break for the Base Case Roof:
Note: See RoofPoint Credit E2 for more information.	**No thermal breaks (15% penalty)**
CREDIT E4: ROOF AIR BARRIER	Select type of air barrier for the Base Case Roof:
Note: See RoofPoint Credit E4 for more information.	**No air barrier installed (10% penalty)**
CREDIT E3: ROOF SURFACE THERMAL CONTRIBUTION	Select type of roof surface for the Base Case Roof:
Note: See RoofPoint Credit E3 for more information.	**Medium Reflective: Aged SR ≥30**
CREDIT E5: ROOFTOP PV	Does the Base Case Roof include a PV system?
Note: See RoofPoint Credit E5 for more information.	**No**
	If yes, enter the system STC Rating (kW)
	0
CREDIT E5: ROOFTOP SOLAR THERMAL	Does the Base Case Roof include a solar thermal system?
Note: See RoofPoint Credit E5 for more information.	**No**
	If yes, enter the system total collector area (FT^2)
CREDIT E6: ROOF DAYLIGHTING	Does the Base Case Roof include daylighting?
Note: See RoofPoint Credit E6 for more information.	**No**
	If yes, enter average illumination at floor level (FC)

Step Five: Assemble the Model

INPUTS

	ROOFPOINT ROOF
ROOF SURFACE AREA	Enter surface area of RoofPoint Roof (Sq. Ft.)
	100,000
CREDIT E1: HIGH R ROOF	Select R-Value for the RoofPoint Roof:
Note: See RoofPoint Credit E1 for more information.	**R20**
CREDIT E2: BEST THERMAL PRACTICE	Select type of thermal break for the Base Case Roof:
Note: See RoofPoint Credit E2 for more information.	**Staggered insulation, top layer(s) adhered (5% penalty)**
CREDIT E4: ROOF AIR BARRIER	Select type of air barrier for the RoofPoint Roof:
Note: See RoofPoint Credit E4 for more information.	**Roof membrane serves as air barrier (No penalty)**
CREDIT E3: ROOF SURFACE THERMAL CONTRIBUTION	Select type of roof surface for the RoofPoint Roof:
Note: See RoofPoint Credit E3 for more information.	**High Reflective: Aged SR ≥60**
CREDIT E5: ROOFTOP PV	Does the RoofPoint Roof include a PV system?
Note: See RoofPoint Credit E5 for more information.	**Yes**
	If yes, enter the system STC Rating (kW)
	100
CREDIT E5: ROOFTOP SOLAR THERMAL	Does the RoofPoint Roof include a solar thermal system?
Note: See RoofPoint Credit E5 for more information.	**Yes**
	If yes, enter the system total collector area (FT^2)
	120
CREDIT E6: ROOF DAYLIGHTING	Does the RoofPoint Roof include daylighting?
Note: See RoofPoint Credit E6 for more information.	**Yes**
	If yes, enter average illumination at floor level (FC)
	10

Step Five: Assemble the Model

OUTPUTS

	Base Case Roof	RoofPoint Roof
UNIT LOADS (BTU / FT^2)		
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 / FT^2)	**18,323**	**-1,175**

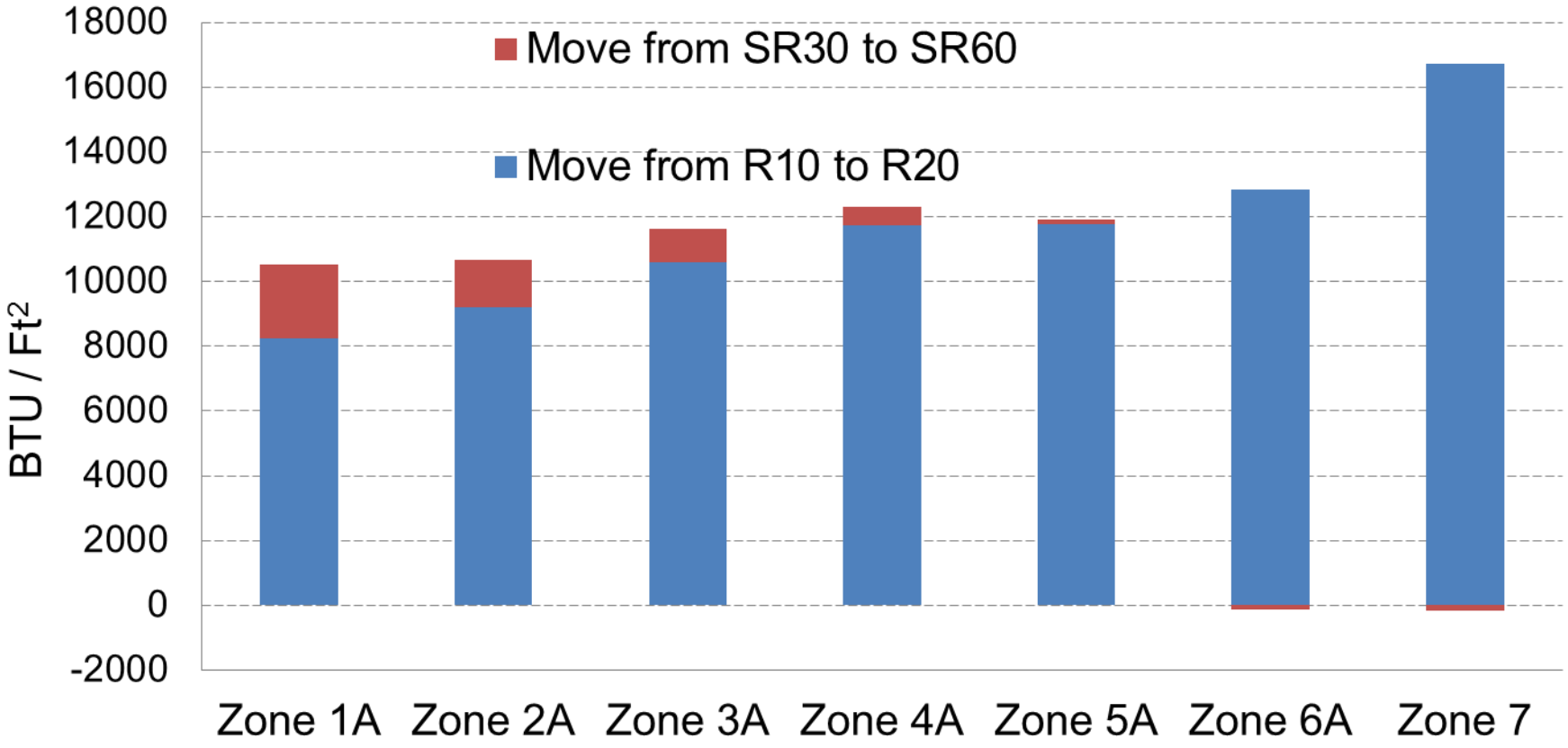
TOTAL ROOF LOAD (BTU/Year)	**1,832,250,000**	**-117,496,041**
NET ENERGY SAVINGS FOR ROOFPOINT ROOF (BTU / Year)		**1,949,746,041**
Plus Peak Load Demand Reduction (BTU / Year)		305,580,000
TOTAL NET ENERGY SAVINGS + PEAK LOAD DEMAND REDUCTION FOR ROOFPOINT ROOF (BTU / Year)		**2,255,326,041**
TOTAL CO^2 ENERGY 0FFSET FOR ROOFPOINT ROOF (Metric Tons / Year)		**125**

Step Six: Test the Model for Value

- Comparative value of key strategies
  - Roof insulation
  - Roof surface
  - Rooftop energy
- Comparative value of key outcomes
  - Net energy savings
  - Peak energy savings

Testing the Model

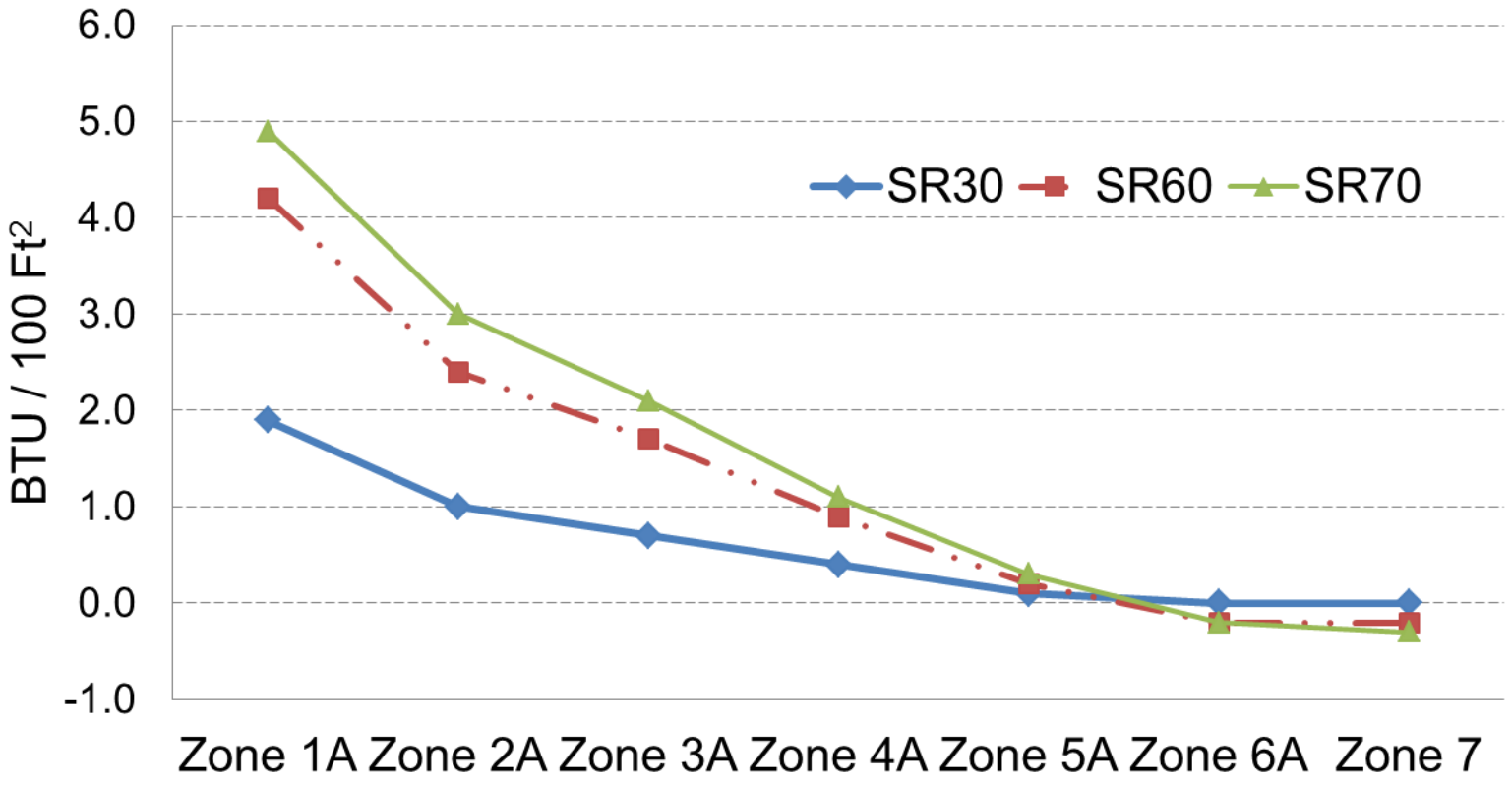
Insulation v. Roof Surface



Relative Contribution of Insulation and Roof Surface

Testing the Model

Roof Surface Reflectivity

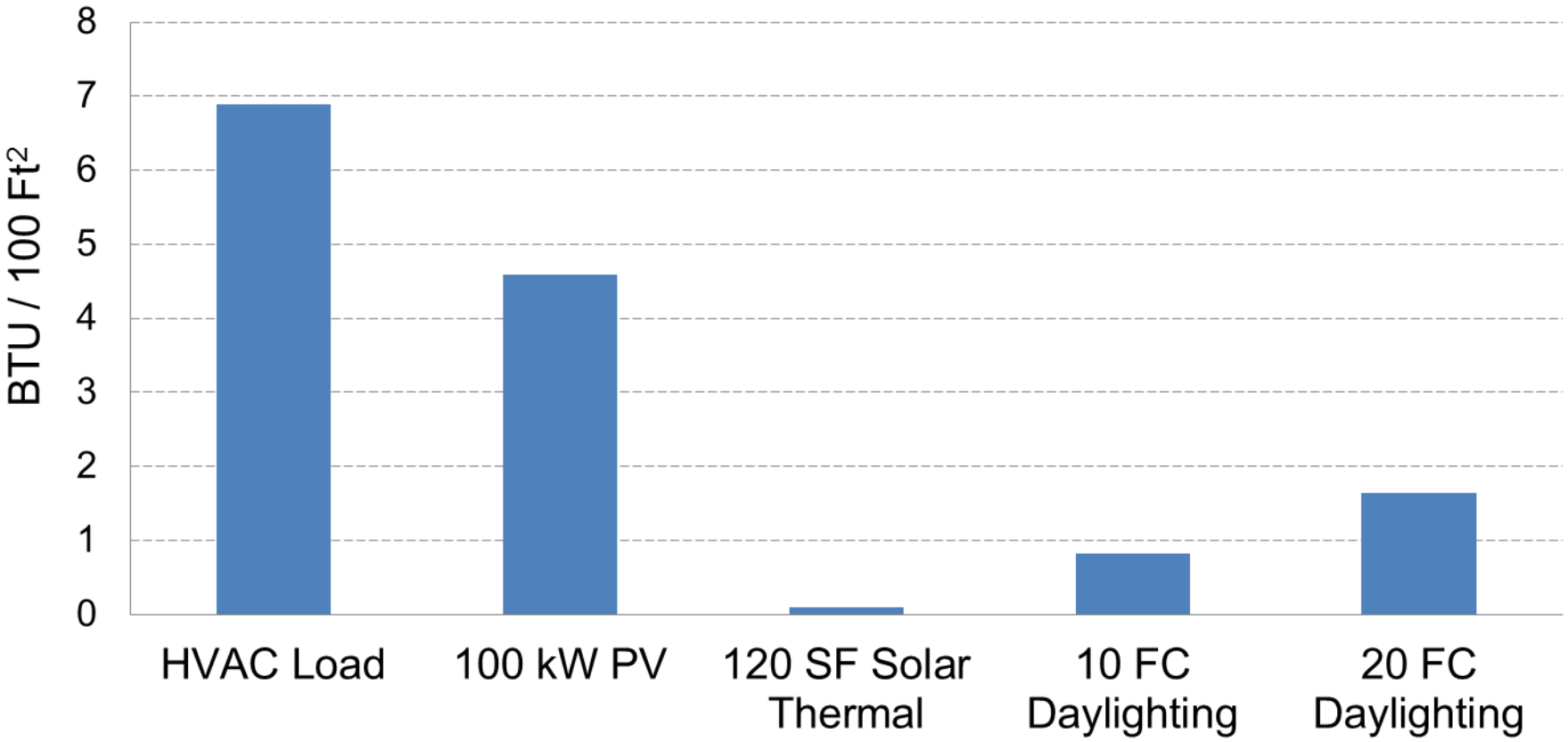


Net BTU for Medium / High / Extra High SR Roof

(Compared to a Black Roof with Identical R Value)

Testing the Model

Rooftop Energy

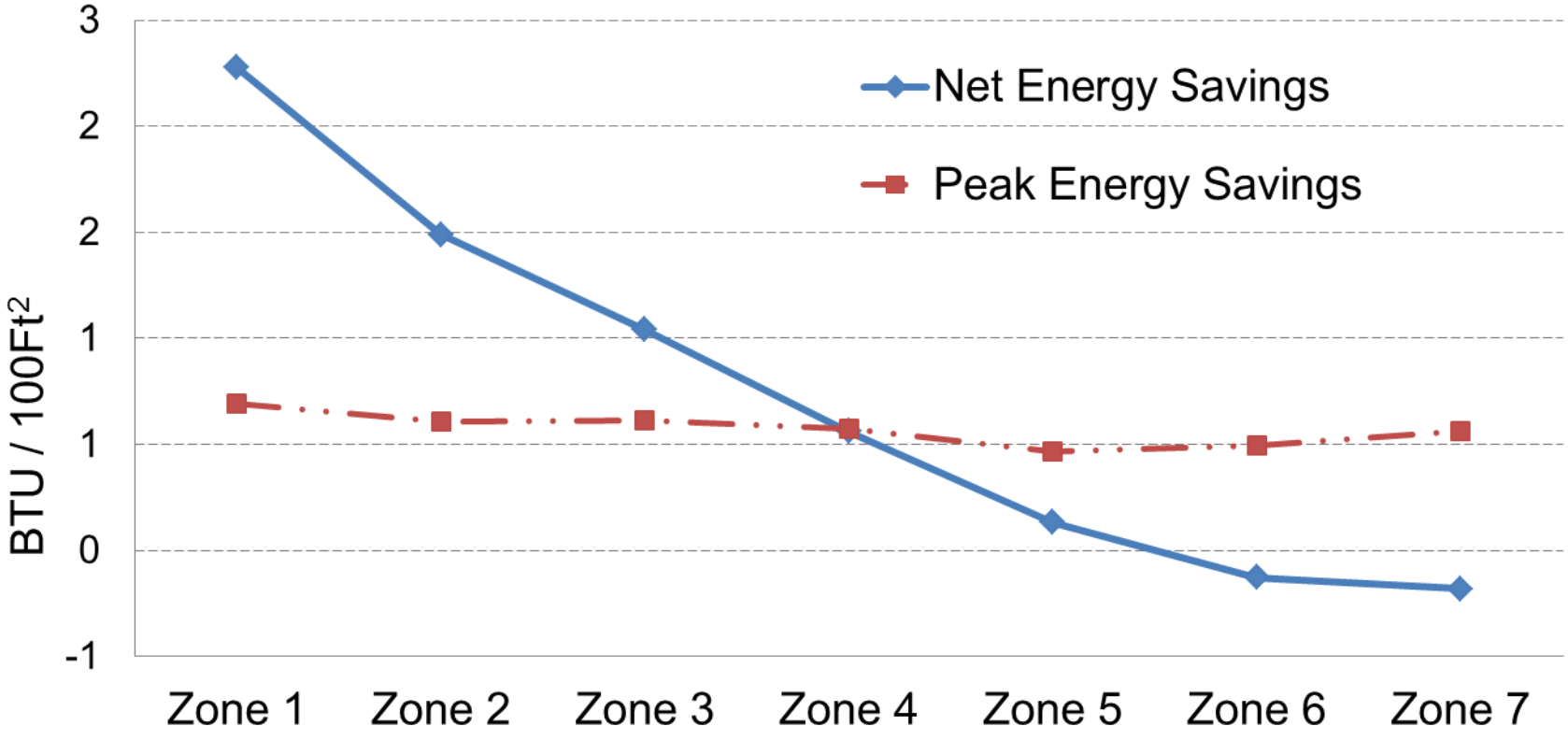


Relative Load / Contribution Per Square

(Zone 3A, R-20, SR60 Roof)

Testing the Model

Peak Energy v. Net Energy



Net Versus Peak Savings for an SR60 /R20 Roof

(Compared to an SR30 Roof with Identical R Value)

Step Seven: Looking to the Future

- Future Refinements
  - Local solar intensity factors for PV
  - Improved daylighting model
  - Improved carbon offset model
  - Addition of embodied energy
  - Conversion into app-type tool
- Field testing
  - You can help!
  - Start by downloading the tool (It's free!)

Go to www.roofingcenter.org and follow the link to the RoofTop Energy and carbon Calculator

QUESTIONS?

THANK YOU!