DOE's Roof Savings Calculator (RSC)

http://rsc.ornl.gov
(www.roofcalc.com)

in collaboration with EPA, ORNL, LBNL, WBT, CEC

Joshua New, Ph.D.

Building Technologies Research & Integration Center (BTRIC)

Whole Building and Community Integration Group

for:
MCA Roofing Council
Clearwater Beach, FL
January 27, 2014

Presentation summary

- Context – US Energy and ORNL BTRIC
- Building Physics
- Roof Savings Calculator
- Empirical Validation of AtticSim
- Ongoing Validation
- Preliminary Cool Roofing Economics
- Previous Related Projects
- Recent Support Software Upgrades

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Buildings use a lot of energy

Update: **41%** of all **energy** and **72%** of all **electricity** used in the US; over **$220 billion** in **annual energy costs**

Source: US Department of Energy

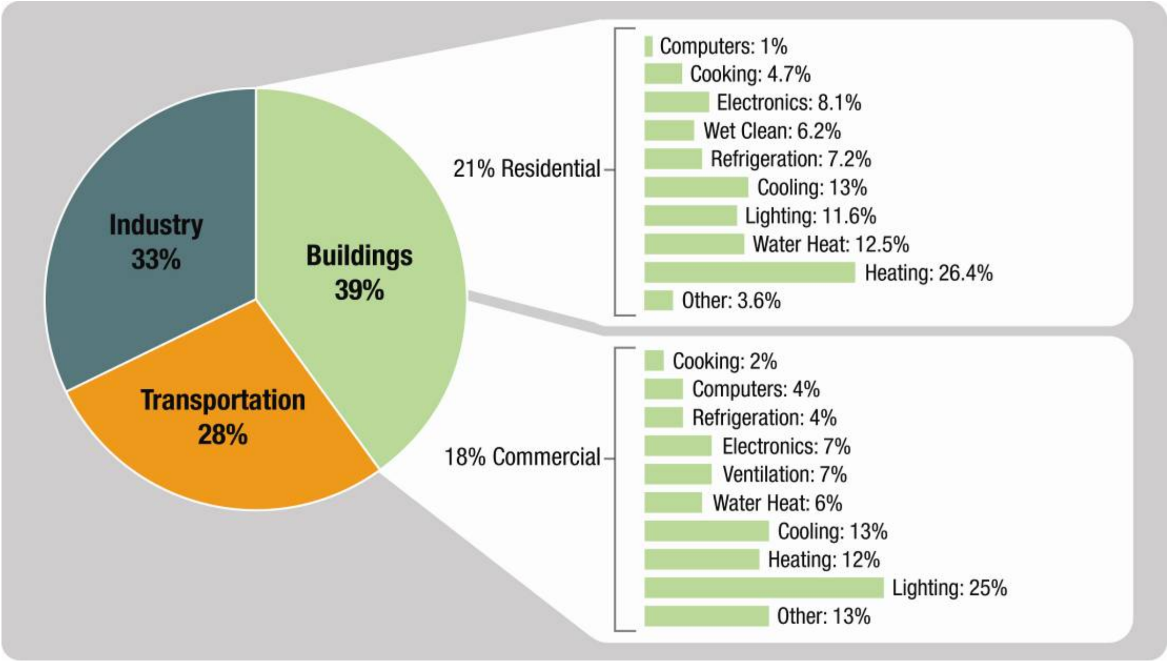
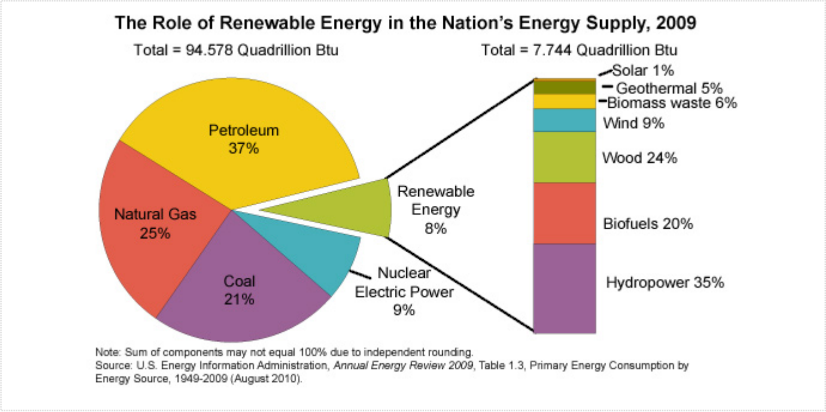


Figure 1. U.S. Primary energy consumption, 2006

Source: Building Energy Data Book, U.S. DOE, Prepared by D&R International, Ltd., September 2008.



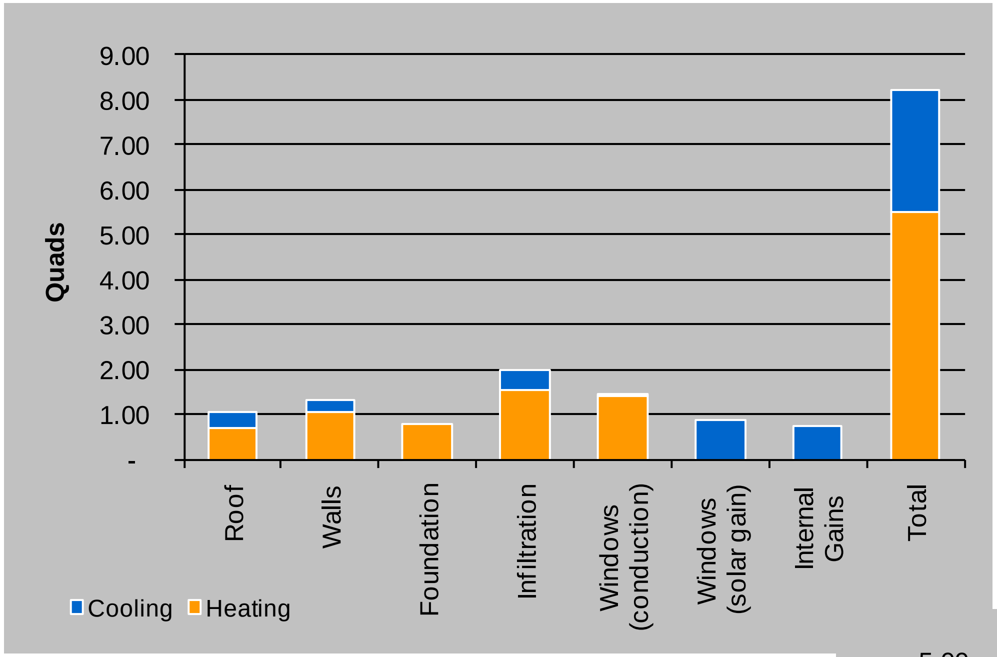
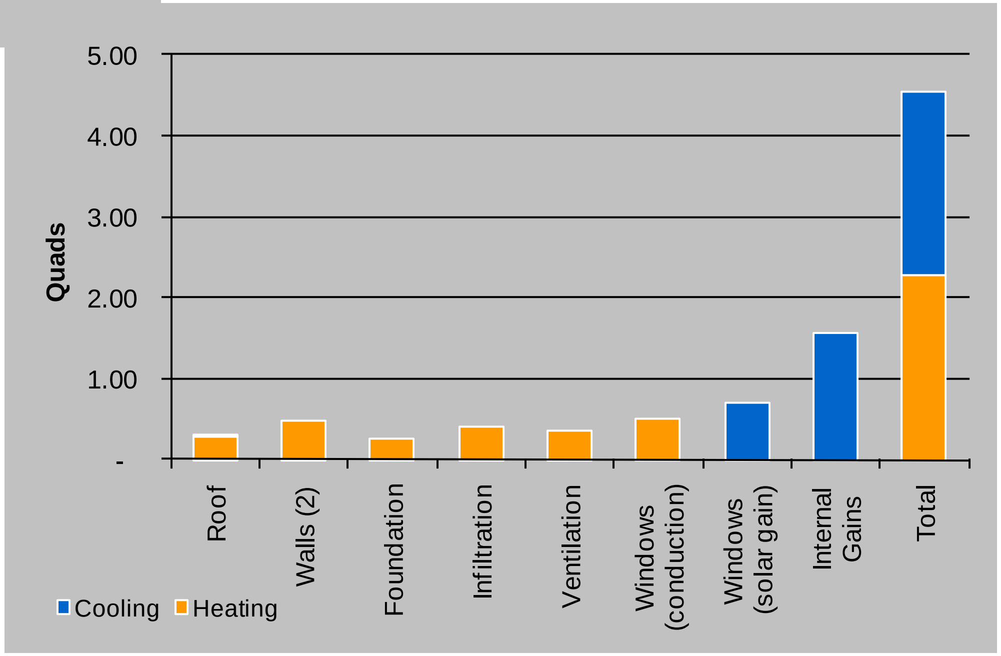


Figure 2. Residential energy loads attributed to envelope and windows

Source: Building Energy Data Book, U.S. DOE, Prepared by D&R International, Ltd., September 2008.

Figure 3. Commercial energy loads attributed to envelope and windows

Source: Building Energy Data Book, U.S. DOE, Prepared by D&R International, Ltd., September 2008.



Science to transform today's buildings into smart, responsive, and efficient structures

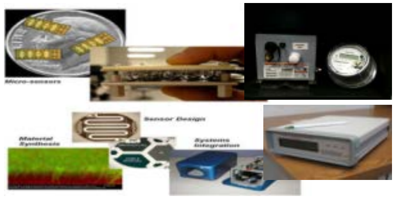
Experimental S&T Capabilities

Building Science

Materials Science

Neutron Science

Sensors, Controls, Grid



Data/Knowledge

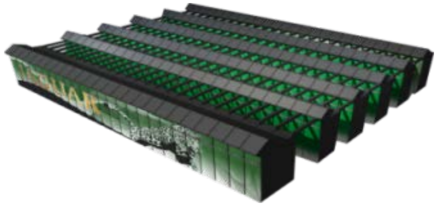
Data/Knowledge

Data/Knowledge

Data/Knowledge

Modeling and Visualization R&D

Automated Model Calibration & GIS



Computational Science

Applied R&D

Industry CRADAs

Web-Based Tools

Innovative Products

Better Buildings via Novel Tools and Technologies

Next Generation Commercial Buildings

Next Generation Residential Buildings

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Facing our energy challenges

“We're using 19th and 20th century technologies to battle 21st century problems like climate change and energy security.”

Remarks of President Barack Obama,
Signing of the American Recovery and Reinvestment Act, February 17, 2009

“Make it white,”
Former Secretary Steven Chu,
Daily Show, July 21, 2009

Cool roof context

Goal to address climate change,
manage Earth's heat budget
(amount of Earth's heat from the sun minus amount reflected into space)

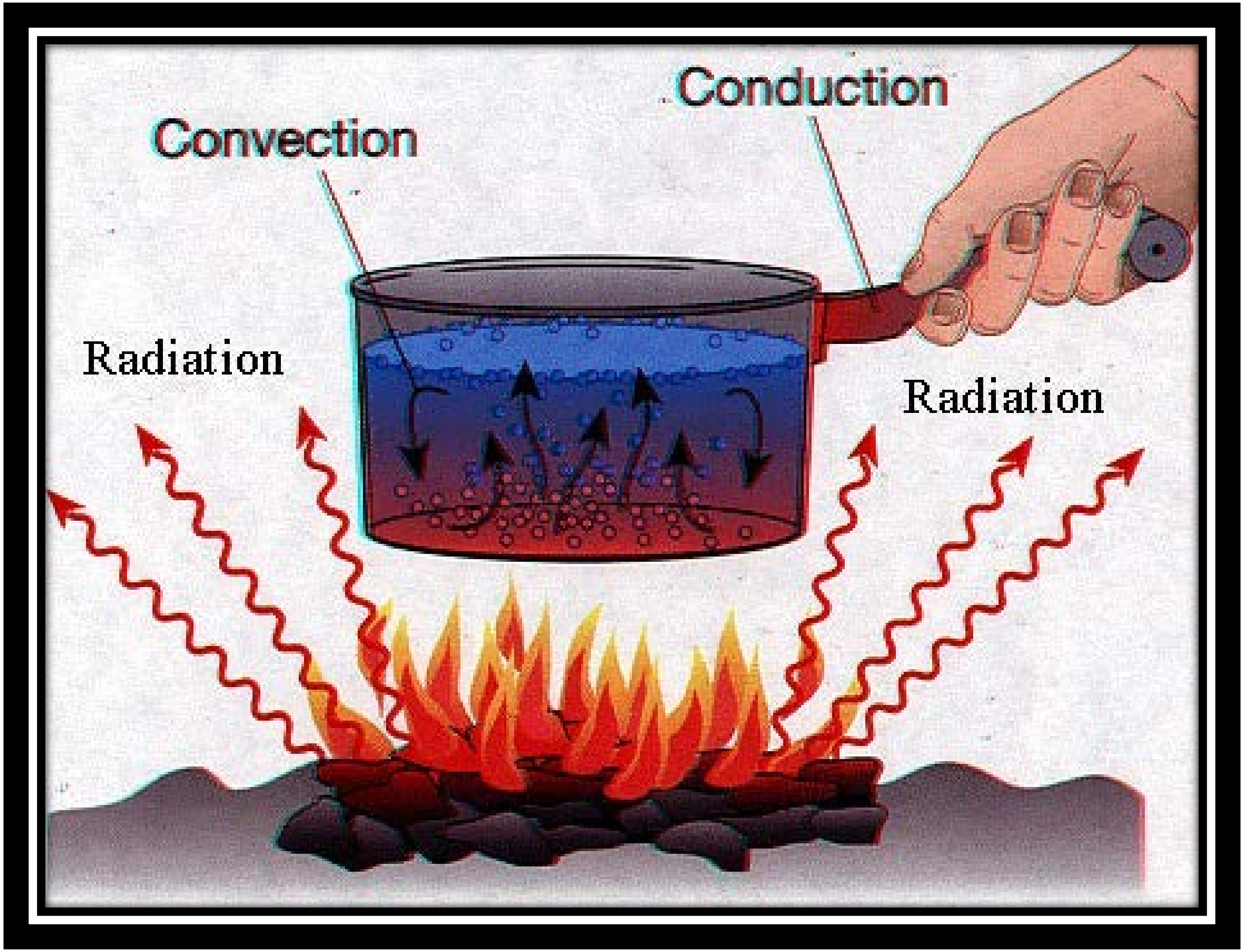
2 pillars of geo-engineering:

- Albedo engineering for solar radiation management – increasing Earth's reflectance
Examples: cloud whitening, stratoshield/stratospheric doping (SO_2, Pinatubo option), reflective aerosols in jet fuel

- Greenhouse gas remediation – primarily carbon sequestration (capture and storage)
Examples: iron fertilization, artificial trees, biochar charcoal, ocean dissolution

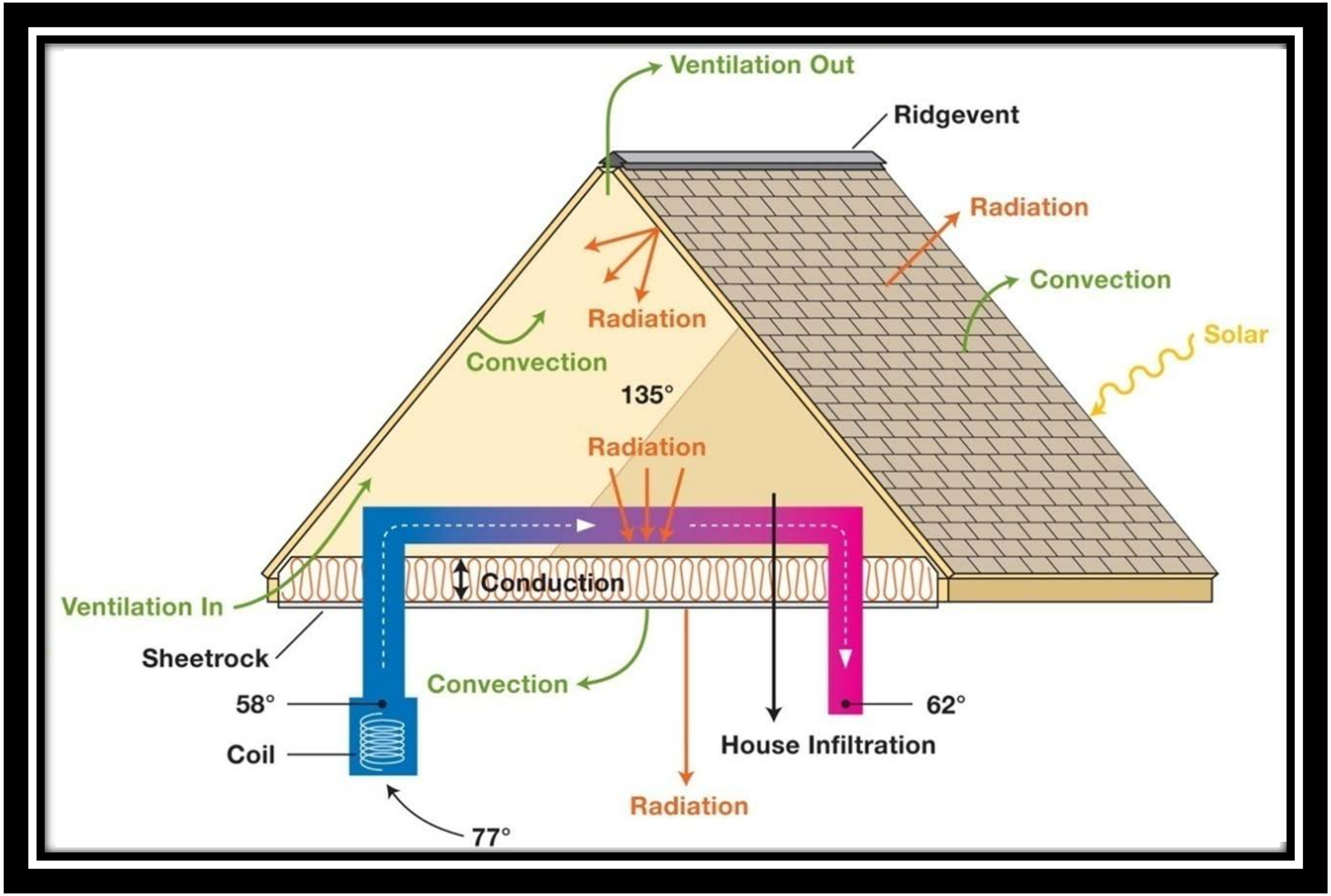
Terms

- Thermodynamics



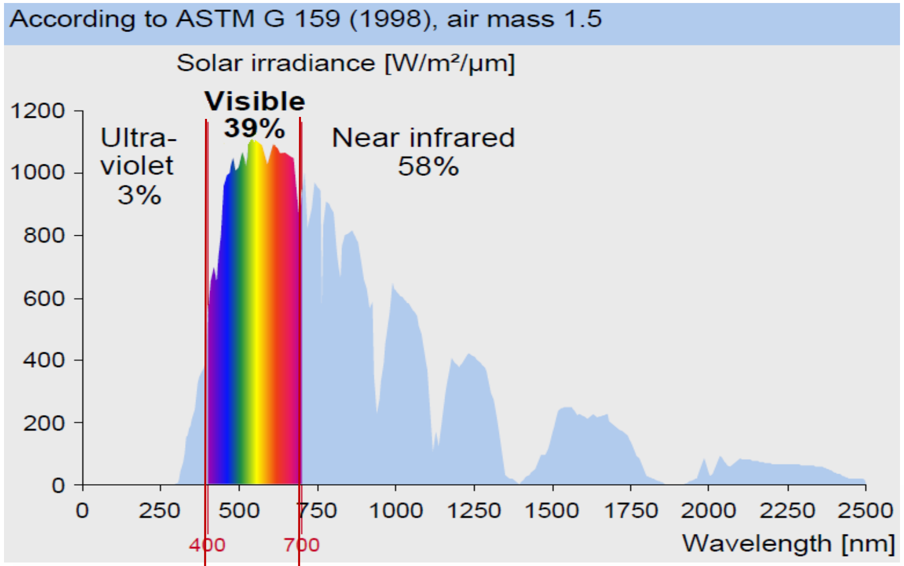
Terms

- Overview of attic physics

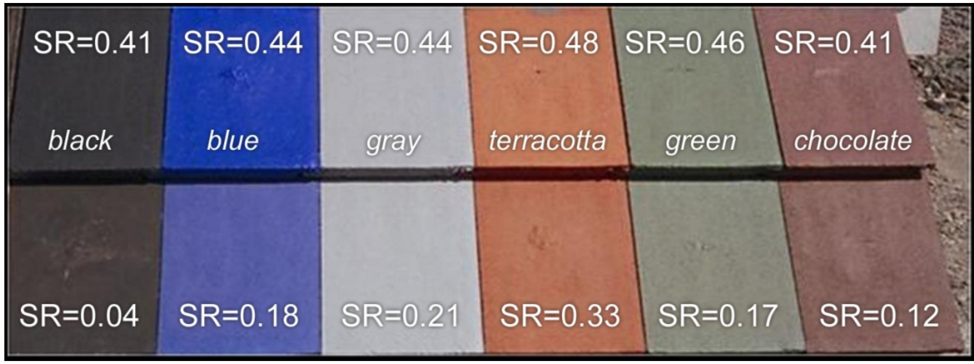


Camouflage invisible to night vision

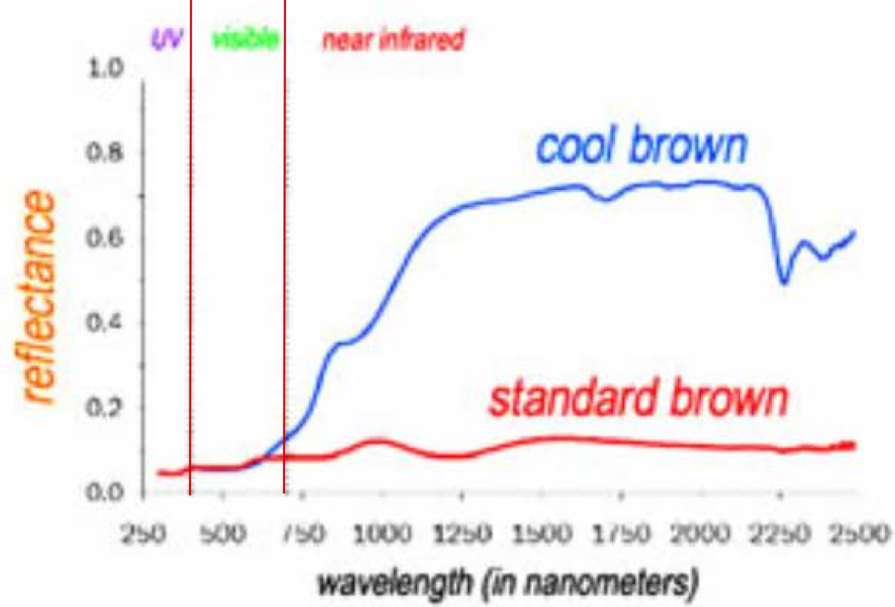
Terms



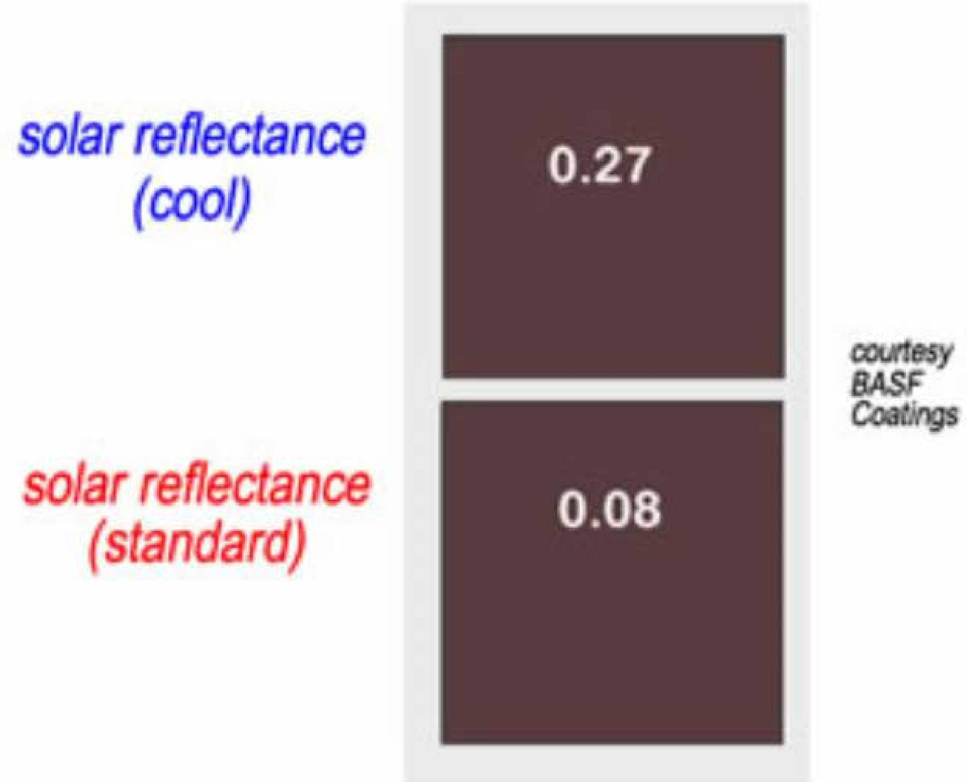
According to ASTM G 159 (1998), air mass 1.5
Solar irradiance [W/m²/µm]
Ultra-violet 3%
Visible 39%
Near infrared 58%
1200
1000
800
600
400
200
0
0
250
500
750
1000
1250
1500
1750
2000
2250
2500
400
700
Wavelength [nm]



SR=0.41
SR=0.44
SR=0.44
SR=0.48
SR=0.46
SR=0.41
black
blue
gray
terracotta
green
chocolate
SR=0.04
SR=0.18
SR=0.21
SR=0.33
SR=0.17
SR=0.12



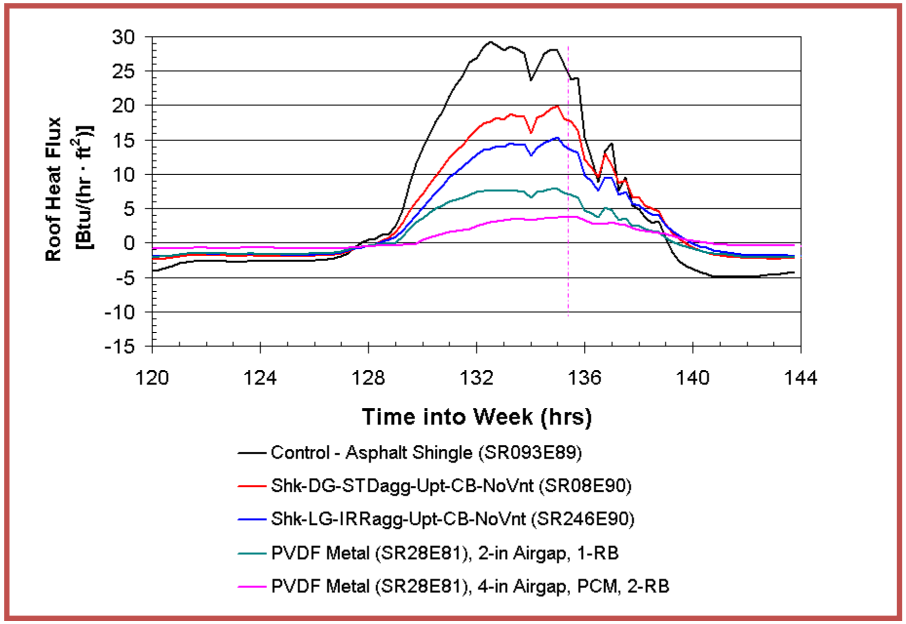
UV
visible
near infrared
reflectance
1.0
0.8
0.6
0.4
0.2
0.0
cool brown
standard brown
250
500
750
1000
1250
1500
1750
2000
2250
2500
wavelength (in nanometers)



solar reflectance (cool)
0.27
solar reflectance (standard)
0.08
courtesy BASF Coatings

Multifunctional steep slope roofing system research success

- Multifunctional roof reduces peak energy demand by 90% (PCM, ASV, RB)



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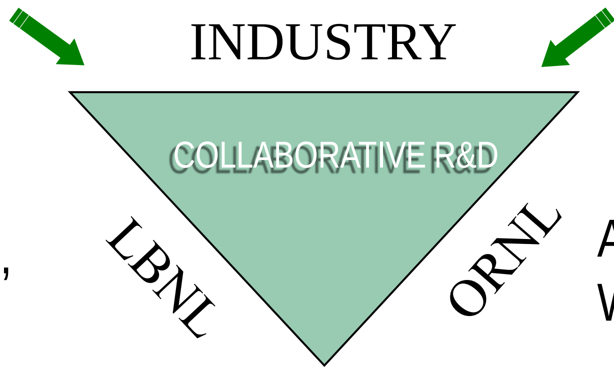
COMPUTER TOOL FOR SIMULATING COOL ROOFS

Roof Savings Calculator (RSC)

Chris Scruton
CEC

INDUSTRY

Marc LaFrance
DOE BT



R. Levinson,
H. Gilbert,
H. Akbari

A. Desjarlais,
W. Miller,
J. New

WBT
Joe Huang,
Ender Erdem

Roof Savings Calculator

- **Replaces:**
  - EPA Roof Comparison Calc
  - DOE Cool Roof Calculator
- **Minimal questions (<20)**
  - Only location is required
  - Building America defaults
  - Help links for unknown information

Calculator Input Comparison Chart

	RSC[1]	PAC Slides[2]	PAC QRpt[3]	EPA[4]	DOE[5]
Building Type	✓	✓	✓	✓	
Location	✓	✓		✓	✓
Days of Operation per week		✓	✓	✓	
Building stock	✓	✓		✓	
Cooling system efficiency (SEER)	✓	✓	✓	✓	✓
Type of heating	✓	✓	✓	✓	✓
Heating system efficiency	✓	✓	✓	✓	✓
Duct location	✓	✓	✓		
Level of roof/ceiling insulation	✓	✓	✓	✓	✓
Above-sheathing ventilation	✓	✓			
Radiant barrier	✓	✓			
Roof thermal mass	✓	✓			
Roof solar reflectance	✓	✓	✓	✓	✓
Roof solar reflectance (black compare)	✓		✓	✓	
Roof thermal emittance	✓	✓	✓		✓
Roof thermal emittance (black compare)	✓		✓		
Internal load		✓			
Conditioned space under roof		✓			
Gas and electricity costs	✓	✓	✓	✓	✓
Inclination / Roof Area	✓			✓	
HVAC Schedule			✓		
Conditioned space (ft^2)	✓			✓	
Number of floors	✓				
Window-to-wall ratio	✓				

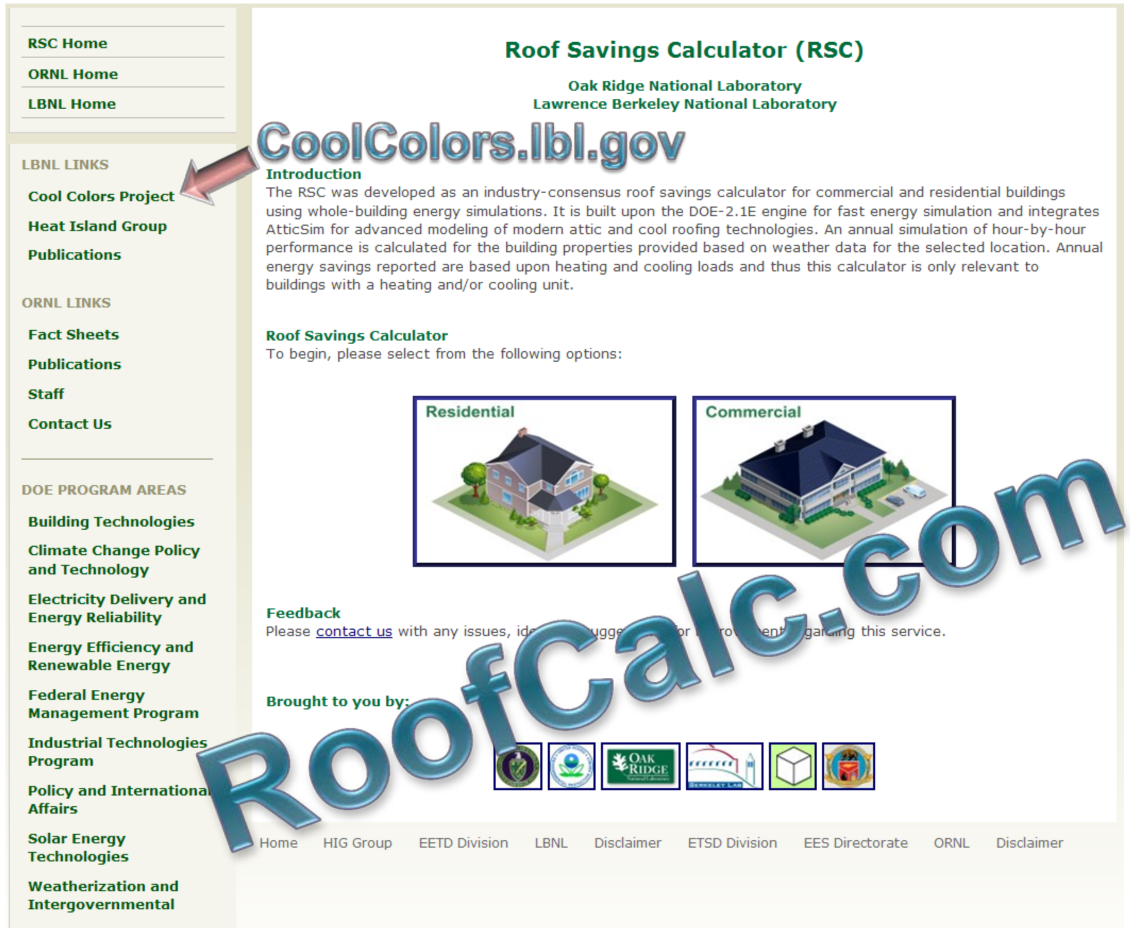
[1] Current version of the "Roof Savings Calculator" (RSC) as of 1/11/10
[2] Based on March 6, 2008 Project Advisory Committee Meeting (PAC_Inputs.ppt).
[3] Based on January 21, 2009 Project Advisory Committee Quarterly Report (Qrpt-08Q4.pdf).
[4] Based on http://www.roofcalc.com/RoofCalcBuildingInput.aspx
[5] Based on http://www.ornl.gov/sci/roofs+walls/facts/CoolCalcEnergy.htm

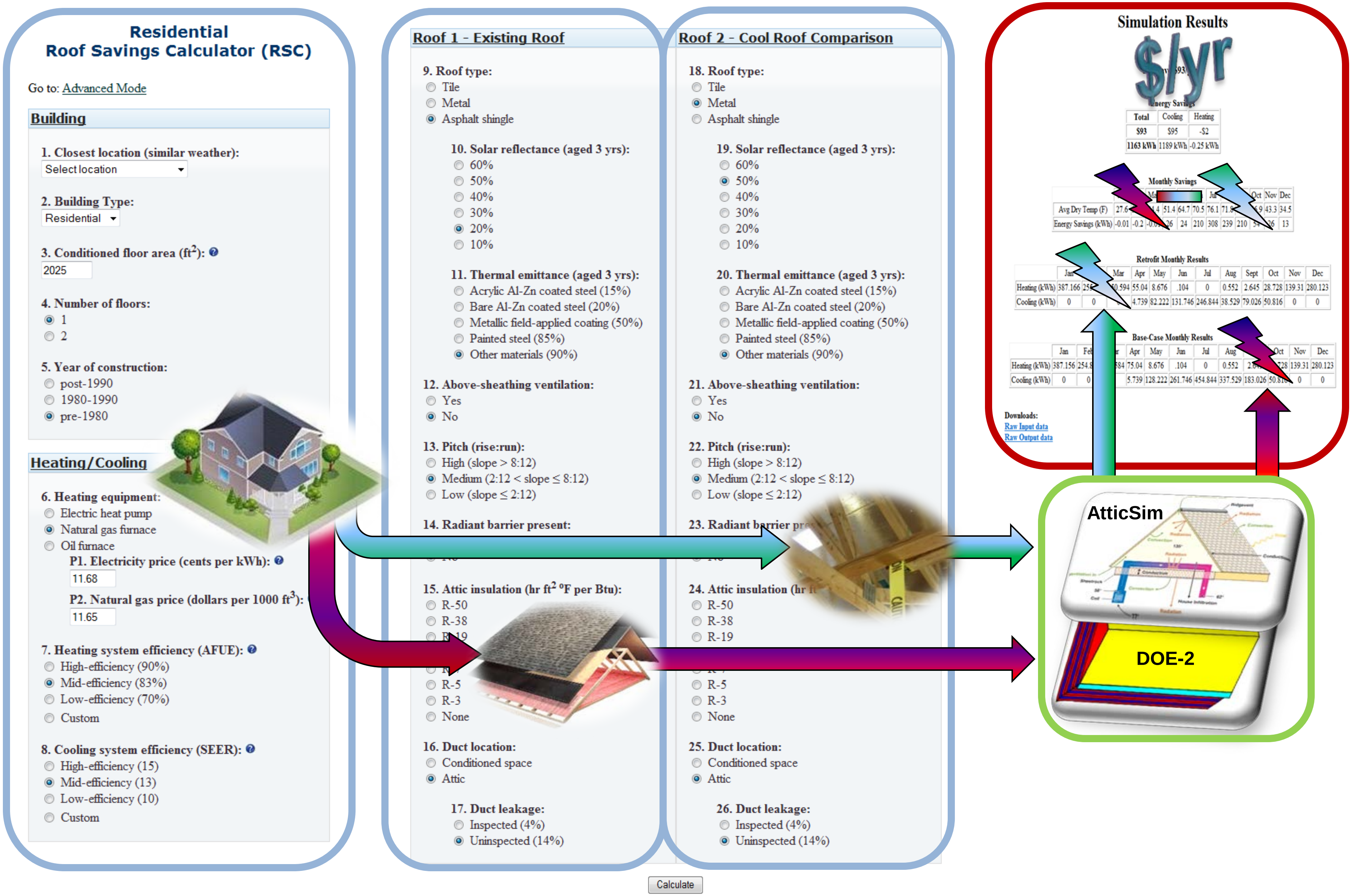
Roof Savings Calculator

DOE-2.1E+AtticSim

- Building Details
- HVAC efficiency and utility prices
- Roof and Attic Information
  (base vs. comp)

- Reports energy and cost savings

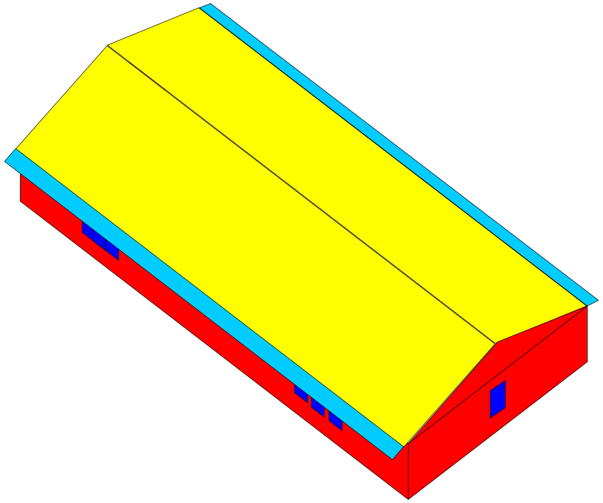




Residential
Roof Savings Calculator (RSC)
Go to: Advanced Mode
Building
1. Closest location (similar weather):
Select location
2. Building Type:
Residential
3. Conditioned floor area (ft²):
2025
4. Number of floors:
1
2
5. Year of construction:
post-1990
1980-1990
pre-1980
Heating/Cooling
6. Heating equipment:
Electric heat pump
Natural gas furnace
Oil furnace
P1. Electricity price (cents per kWh):
11.68
P2. Natural gas price (dollars per 1000 ft³):
11.65
7. Heating system efficiency (AFUE):
High-efficiency (90%)
Mid-efficiency (83%)
Low-efficiency (70%)
Custom
8. Cooling system efficiency (SEER):
High-efficiency (15)
Mid-efficiency (13)
Low-efficiency (10)
Custom
Roof 1 - Existing Roof
9. Roof type:
Tile
Metal
Asphalt shingle
10. Solar reflectance (aged 3 yrs):
60%
50%
40%
30%
20%
10%
11. Thermal emittance (aged 3 yrs):
Acrylic Al-Zn coated steel (15%)
Bare Al-Zn coated steel (20%)
Metallic field-applied coating (50%)
Painted steel (85%)
Other materials (90%)
12. Above-sheathing ventilation:
Yes
No
13. Pitch (rise:run):
High (slope > 8:12)
Medium (2:12 < slope ≤ 8:12)
Low (slope ≤ 2:12)
14. Radiant barrier present:
15. Attic insulation (hr ft² °F per Btu):
R-50
R-38
R-5
R-3
None
16. Duct location:
Conditioned space
Attic
17. Duct leakage:
Inspected (4%)
Uninspected (14%)
Roof 2 - Cool Roof Comparison
18. Roof type:
Tile
Metal
Asphalt shingle
19. Solar reflectance (aged 3 yrs):
60%
50%
40%
30%
20%
10%
20. Thermal emittance (aged 3 yrs):
Acrylic Al-Zn coated steel (15%)
Bare Al-Zn coated steel (20%)
Metallic field-applied coating (50%)
Painted steel (85%)
Other materials (90%)
21. Above-sheathing ventilation:
Yes
No
22. Pitch (rise:run):
High (slope > 8:12)
Medium (2:12 < slope ≤ 8:12)
Low (slope ≤ 2:12)
23. Radiant barrier
24. Attic insulation
R-50
R-38
R-19
R-5
R-3
None
25. Duct location:
Conditioned space
Attic
26. Duct leakage:
Inspected (4%)
Uninspected (14%)
Calculate
Simulation Results
$/yr
Total Cooling Heating
$93 $95 -$2
1163 kWh 1189 kWh -0.25 kWh
Monthly Savings
Retrofit Monthly Results
Base-Case Monthly Results
Downloads:
Raw Input data
Raw Output data
AtticSim
DOE-2

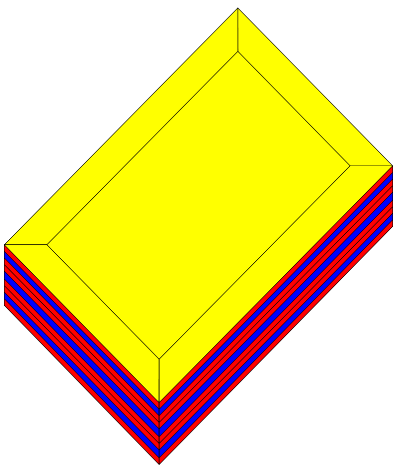
Residential buildings

Residential

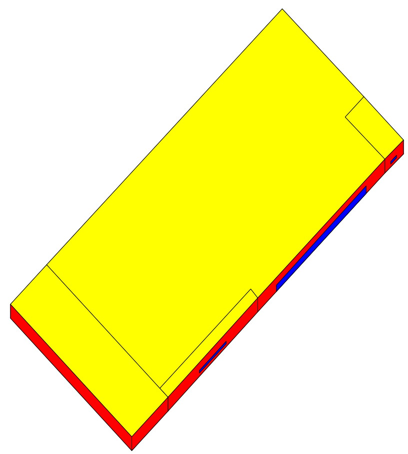


Commercial building types

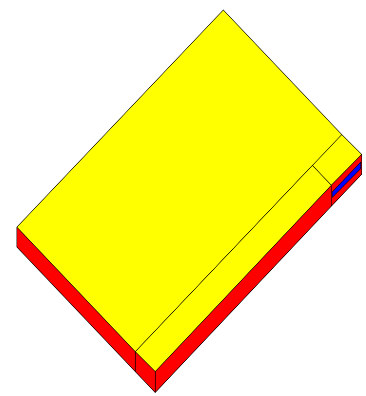
Office



“Big Box” Retail



Warehouse



Torcellini et al. 2008, “DOE Commercial Building Benchmark Models”, NREL/CP-550-43291, National Renewable Energy Laboratory, Golden CO.

Roof Savings Calculator

www.roofcalc.com

Residential Roof Savings Calc (RSC)

Go to: Simple Mode

Building

1. Closest location (similar w
Select location

2. Building Type:
Residential

3. Conditioned floor area (ft^2
2025

4. Number of floors:
1

A1. Window-to-wall ratio:
0.145

5. Year of construction:
- ○ post-1990
- ○ 1980-1990
- ⦿ pre-1980

Commercial Roof Savings Calculator (RSC)

Go to: Simple Mode

Building

1. Closest location (similar weather):
Select location

2. Building Type:
Office

3. Conditioned floor area (ft^2):
10000

4. Number of floors:
1

A1. Window-to-wall ratio:
0.40

5. Year of construction:
- ○ post-1990
- ○ 1980-1990
- ⦿ pre-1980

Heating/Cooling

6. Heating equipment:
- ○ Electric heat pump
- ⦿ Natural gas furnace

P1. Electricity price (cents per kWh):
11.68

P2. Natural gas price (dollars per 1000 ft^3):
11.65

7. Heating system efficiency (AFUE):
- ○ High-efficiency (90%)
- ⦿ Mid-efficiency (83%)
- ○ Low-efficiency (70%)
- ○ None
- ○ Custom

8. Cooling system efficiency (SEER):
- ○ High-efficiency (15)
- ⦿ Mid-efficiency (13)
- ○ Low-efficiency (10)
- ○ None
- ○ Custom

Roof Savings Calculator

www.roofcalc.com

9. Roof type:
- ○ Tile
- ○ Metal
- ◉ Asphalt sh

Residential Roof Types

Roofs can be created with many material types involving different durability and thermal properties. This calculator supports the most common residential roof types for the US:

Asphalt Shingles

Metal Roof

Tile Roof

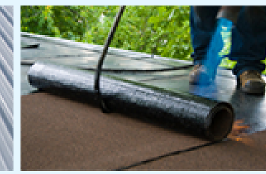
Commercial Roof Types

Roofs can be created with many material types which have varying durability and thermal properties. This calculator supports the most common commercial roof types for the US building stock including:

Built-Up

Metal

Modified Bitumen



Concrete Pavers

Single-Ply Membranes

9. Roof type:
- ○ Single-ply membranes
- ○ Concrete pavers
- ○ Modified bitumen
- ○ Metal
- ◉ Built up

Roof Savings Calculator

www.roofcalc.com

10. Solar reflectance (aged 3 yrs):

- ○ 60%
- ○ 50%
- ○ 40%
- ○ 30%
- ◉ 20%
- ○ 10%
- ○ Custom

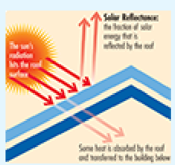
Solar Reflectance

Increased reflectance saves energy by reflecting incoming solar radiation back towards space. Maximum reflectivity is achieved with white roof products. But don't let looks fool you; there are also "cool color" roof products which look dark in the visible spectrum but still reflect most of the heat, giving homeowners the more traditional roof color options as well as the potential energy savings. This calculator models customizable aged reflectance of the outermost roofing product.

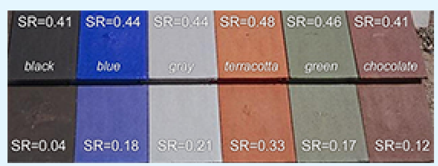
Aged (3-year) reflectance is recommended, as studies show most products stabilize their reflectivity within 3 years and are more indicative of lifetime performance. Aged (or weathered) reflectance values can be found on some product labels and the Cool Roof Rating Council (CRRC) lists aged reflectance values for many products. The aged reflectance can be estimated from the initial solar reflectance, based on the California Energy Commission's Worksheet, using the following equation:

$SR_{3yrs}=0.2+0.7(SR_i-0.2)$

Reflectance



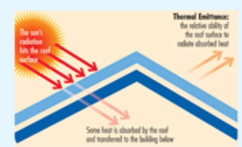
Cool Color Products



Thermal Emittance

Roof products with a low thermal emittance save energy by radiating the absorbed heat toward space. Approximately 90% of materials have an emittance of 90%; low-emittance surfaces such as aluminum foil or a car's sun shade, can have emittances of 5% and emit heat from the reflective side. Solar reflectance and emittance are the two radiative properties used to measure the "coolness" of a roof. This calculator models customizable emittance of the outermost roofing product.

Many organizations, such as the United States Green Building Council (USGBC) and its Leadership in Energy and Environmental Design (LEED) rating system, utilize a combined metric known as the Solar Reflectance Index (SRI).



More info:
LBNL SRI Excel
ORNL SRI Calculator

11. Thermal emittance (aged 3 yrs):

- ○ Acrylic Al-Zn coated steel (15%)
- ○ Bare Al-Zn coated steel (20%)
- ○ Metallic field-applied coating (50%)
- ○ Painted steel (85%)
- ◉ Other materials (90%)
- ○ Custom

Roof Savings Calculator

www.roofcalc.com

12. Above-sheathing ventilation:

- ○ Yes
- ◉ No

Above-Sheathing Ventilation

Above-sheathing ventilation (ASV), also known as "roof on a roof", provides an air gap with thermally induced air flow patterns which has been shown to reduce heat flow penetrating the attic by at least 30% compared to a direct-to-deck nailed roof. This calculator models ASV using a 4" air gap.

Roof Pitch

The pitch of a roof, also known as angle or inclination, determines how much solar radiation impinges on a building throughout the day. The typical unitless metric is rise-in-run. This calculator supports pitches of 2:12, 4:12, and 8:12 (17, 32, and 59 angular degrees, respectively) for residential buildings; all commercial buildings are modeled as flat roofs with 0.25:12 for rainfall runoff.

13. Pitch (rise:run):

- ○ High (slope ≥ 8:12)
- ◉ Medium (2:12 < slope < 8:12)
- ○ Low (slope ≤ 2:12)

Roof Savings Calculator

www.roofcalc.com

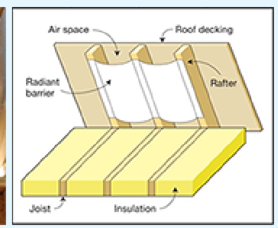
14. Radiant barrier present:

- ○ Yes
- ◉ No

Radiant Barrier

Radiant barriers (RB) save energy by reducing the heat radiated into the attic as the roof heats up during the day. RBs consist of a thin layer of highly reflective material, usually aluminum, and must have an emittance less than 0.1 as measured by ASTM C1371. This calculator models a RB in its most effective location, attached to the underside of the rafters with the reflective side facing the attic floor.

More info: RB Calculator RB Fact Sheet



Attic Insulation

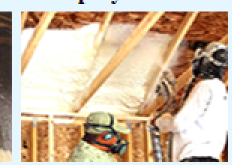
Attic insulation protects your home against unwanted heat gain/loss. It is measured by R-value which depends on the material, its thickness, and density with multiple layers added together. Insulation is often one of the most economical ways to make your home more energy efficient. The most common types of insulation are fiberglass batts (usu. pink), cellulose insulation, and spray foam insulation. This calculator supports a custom R-value of attic insulation.

More info: Insulation Calculator Insulation Fact Sheet

Fiberglass Batt

Blown-in, Loose-Fill

Spray Foam



15. Attic insulation (hr ft^2 °F per Btu):

- ○ R-50
- ○ R-38
- ○ R-19
- ◉ R-11
- ○ R-7
- ○ R-5
- ○ R-3
- ○ None
- ○ Custom

Roof Savings Calculator

www.roofcalc.com

Duct Location

Heating, Ventilation, and Air Conditioning (HVAC) ducts are typically located in non-conditioned spaces, such as the attic, because it is easier and cheaper given the way US buildings are constructed; this is the worst location from an energy perspective. Locating ducts inside a conditioned space, such as between floors or in a conditioned basement, removes the losses from leaky ducts as well as exposure to adverse environmental conditions and can decrease your utility bills significantly. This calculator supports ducts located in a conditioned space or in the attic; simulations in conditioned spaces will run faster as the computationally intensive duct loss model is not invoked.

Ducts in the Attic

Ducts in a Conditioned Space

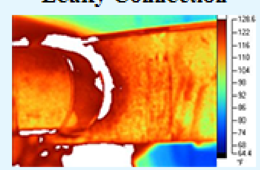
16. Duct location:

- ○ Conditioned space
- ◉ Attic

Duct Leakage

Leaky ducts in unconditioned spaces are effectively costing you money to condition the planet, not your house. Commercial buildings have typical leakage rate of 10-20%; likewise, residential buildings typically have duct leakage rates near 14%. The CEC's Title 24 target leakage rate for inspected ducts is 4% and requires no greater than 6%. This calculator supports duct leakage rates of 4% and 14%.

Leaky Connection



Damaged Duct

Sealed Ducts

17. Duct leakage:

- ○ Inspected (4%)
- ◉ Uninspected (14%)

Roof Savings Calculator

www.roofcalc.com

Simulation Results

You save $117/year!

Energy Savings

Total	Cooling	Heating
$117	$96	$21
	933 kWh	0 kWh 3 MBtus

Monthly Savings

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	**Total**
Cooling Savings (kWh)	-4.9	-19.1	-2.6	48.1	123.4	208.6	210.4	181.9	143.7	51.3	-5.1	-2.9	**932.7**
Heating Savings (kWh)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
Heating Savings (MBtus)	1.9	0.4	-0.4	-0.3	-0.0	0.0	0.0	-0.0	-0.0	-0.4	0.1	1.3	**2.5**

White-Roof Utility Usage

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	**Total**
Cooling (kWh)	25.4	140.5	597.5	1978.1	3969.2	6145.9	7027.0	6442.0	4476.9	1785.4	595.9	4.7	**33188.5**
Heating (kWh)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
Heating (MBtus)	62.4	27.1	13.9	2.9	0.7	0.6	0.6	0.6	0.6	2.7	15.6	38.3	**166.1**

Base-Case Utility Usage

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	**Total**
Cooling (kWh)	20.5	121.4	594.9	2026.2	4092.6	6354.5	7237.4	6623.9	4620.6	1836.7	590.8	1.8	**34121.2**
Heating (kWh)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
Heating (MBtus)	64.3	27.6	13.5	2.7	0.7	0.6	0.6	0.6	0.6	2.3	15.6	39.6	**168.7**

Roof Savings Calculator

www.roofcalc.com

```
 ****    ***   *****          ***      *    *****
 *   *  *   *  *             *   *    **    *
 *   *  *   *  *****  ***      *       *    *****
 *   *  *   *  *              **       *    *
 ****    ***   *****         ***** *  ***   *****
```

B U I L D I N G   E N E R G Y   A N A L Y S I S   P R O G R A M

DEVELOPED BY

LAWRENCE BERKELEY LABORATORY/UNIVERSITY OF CALIFORNIA,
WITH THE ASSISTANCE OF HIRSCH & ASSOCIATES, CAMARILLO, CA

WITH MAJOR SUPPORT FROM

UNITED STATES DEPARTMENT OF ENERGY
ASSISTANT SECRETARY FOR ENERGY EFFICIENCY AND RENEWABLE ENERGY
OFFICE OF BUILDING TECHNOLOGIES
BUILDING SYSTEMS AND MATERIALS DIVISION

AND ADDITIONAL SUPPORT FROM

SOUTHERN CALIFORNIA EDISON CO., PACIFIC GAS AND ELECTRIC CO.,
GAS RESEARCH INSTITUTE, ELECTRIC POWER RESEARCH INSTITUTE

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*                                                                          *
*                                                                          *
****************************************************************************
```

Downloads:

[Base-Case Building Input]
[White-Roof Building Input]
[Base-Case All Output]
[White-Roof All Output]

```
##set1 Location     CO_Boulder
##set1 bldg_type_name    residential
##set1 Bldg_Len     45
##set1 Bldg_Wid     45
##set1 Flr_Area     2025
##set1 floors       1
##set1 WWR  0.145
##set1 Vintage      Exist
##set1 HVAC_Type    FurnAC
##set1 p_electric 11.68
##set1 p_gas        11.65
##set1 Furn_AFUE    90
##set1 HP_HSPF      7
##set1 AC_SEER      0
##set1 Roof_Type_res     Asphalt
##set1 Roof_Type_com     bur
##set1 Roof_Refl    20
##set1 Roof_Emit    90
##set1 Attic_Vent no
##set1 Roof_Pitch 4-12
##set1 Radiant_Barrier   Yes
##set1 Ceil_R       11
##set1 Duct_Loc     Attic
##set1 Duct_Leak    Uninsp
```

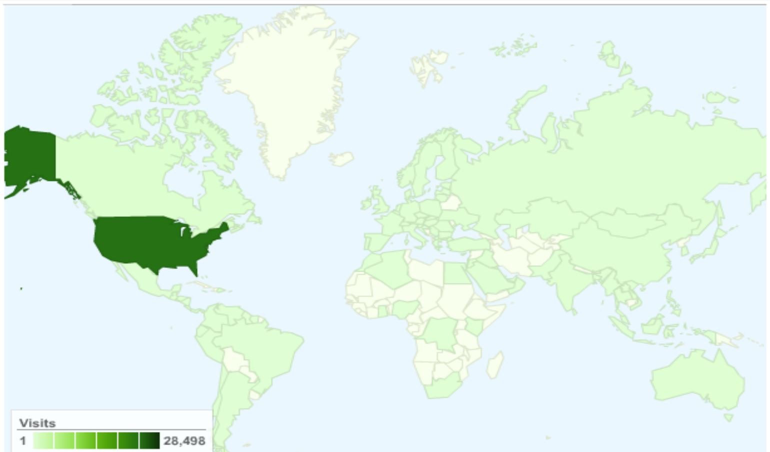
RoofCalc.com Impact

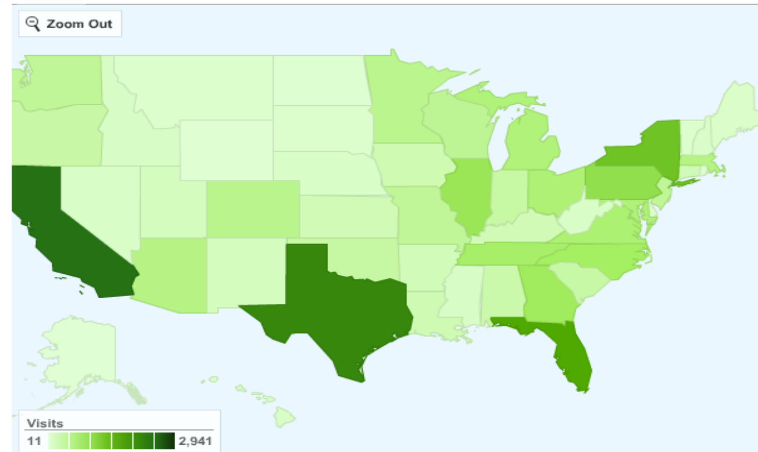
Dashboard

Apr 20, 2010 - Feb 28, 2011

24,100 web simulations, 156 users/feedback, 3+ million runs

Average: ~80 visitors/day





30,752 visits came from 112 countries/territories

Detail Level: City | Country/Territory | Sub Continent Region | Continent Dimension: None

Site Usage | Goal Set 1 Views:

Visits	Pages/Visit	Avg. Time on Site	% New Visits	Bounce Rate
30,752 % of Site Total: 100.00%	1.42 Site Avg: 1.42 (0.00%)	00:01:25 Site Avg: 00:01:25 (0.00%)	88.26% Site Avg: 88.23% (0.04%)	70.34% Site Avg: 70.34% (0.00%)

	Detail Level: Country/Territory	Visits	Pages/Visit	Avg. Time on Site	% New Visits	Bounce Rate
1.	United States	28,498	1.42	00:01:25	88.35%	70.34%
2.	Canada	483	1.36	00:01:05	91.30%	73.08%
3.	India	156	1.42	00:01:08	80.77%	73.72%
4.	Australia	129	1.66	00:01:42	82.17%	66.67%
5.	United Kingdom	94	1.39	00:01:13	94.68%	65.96%
6.	South Korea	79	1.52	00:01:07	70.89%	68.35%
7.	Italy	66	1.61	00:01:33	89.39%	63.64%

This country/territory sent 28,498 visits via 52 regions

Detail Level: City | Region Dimension: None

Site Usage | Goal Set 1 Views:

Visits	Pages/Visit	Avg. Time on Site	% New Visits	Bounce Rate
28,498 % of Site Total: 92.67%	1.42 Site Avg: 1.42 (-0.09%)	00:01:25 Site Avg: 00:01:25 (0.96%)	88.35% Site Avg: 88.23% (0.14%)	70.34% Site Avg: 70.34% (-0.00%)

	Detail Level: Region	Visits	Pages/Visit	Avg. Time on Site	% New Visits	Bounce Rate
1.	California	2,941	1.37	00:01:21	82.66%	73.95%
2.	Texas	2,558	1.43	00:01:26	90.30%	68.22%
3.	Florida	1,965	1.47	00:01:43	89.52%	68.09%
4.	New York	1,608	1.35	00:01:09	91.42%	73.45%
5.	Pennsylvania	1,206	1.39	00:01:20	91.04%	71.72%
6.	Illinois	1,114	1.36	00:01:12	89.41%	73.79%
7.	Georgia	1,032	1.40	00:01:18	90.50%	69.09%

Presentation summary

- Context – US Energy and ORNL BTRIC
- Building Physics
- Roof Savings Calculator
- Empirical Validation of AtticSim
- Ongoing Validation
- Preliminary Cool Roofing Economics
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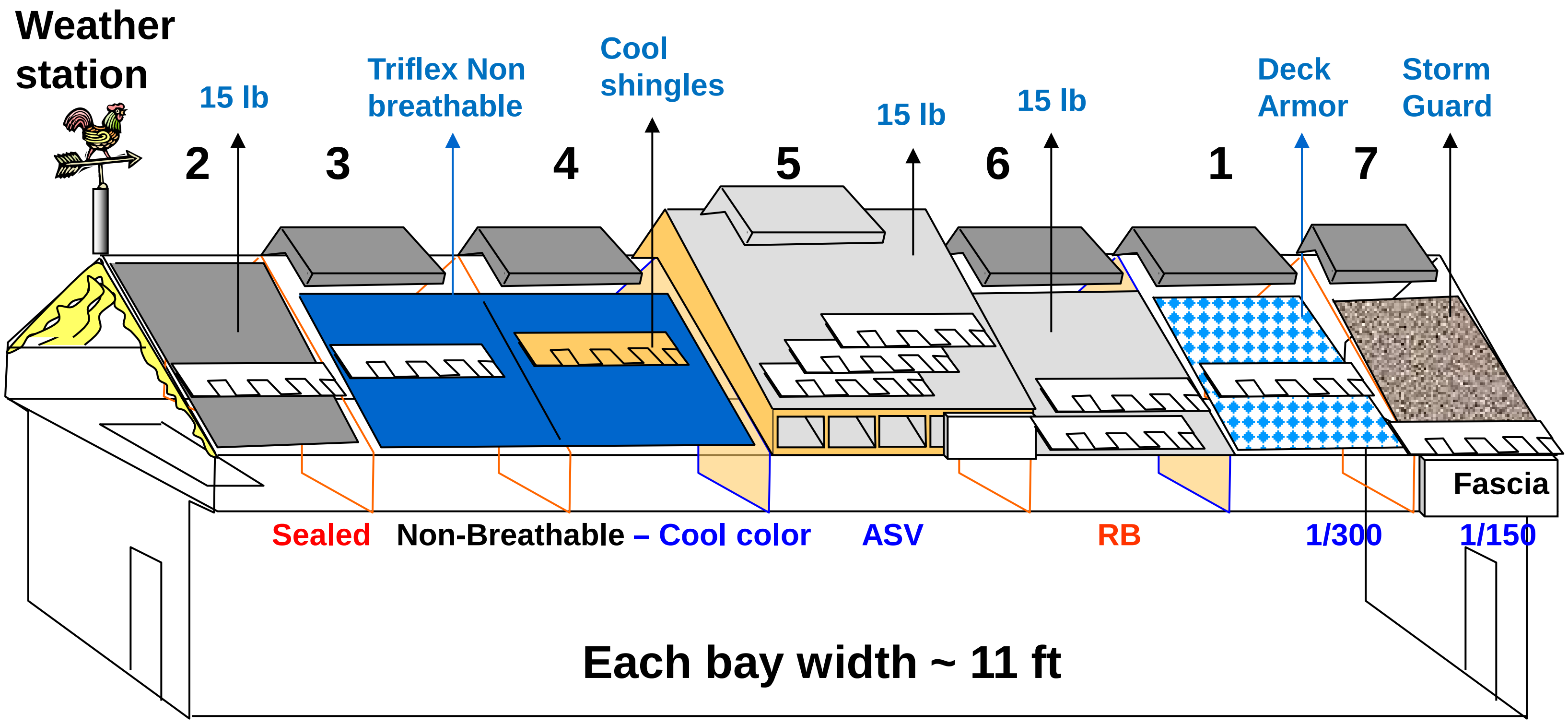
Attic Systems – Charleston SC NET Facility



AtticSim *(Attic Simulation)* Model

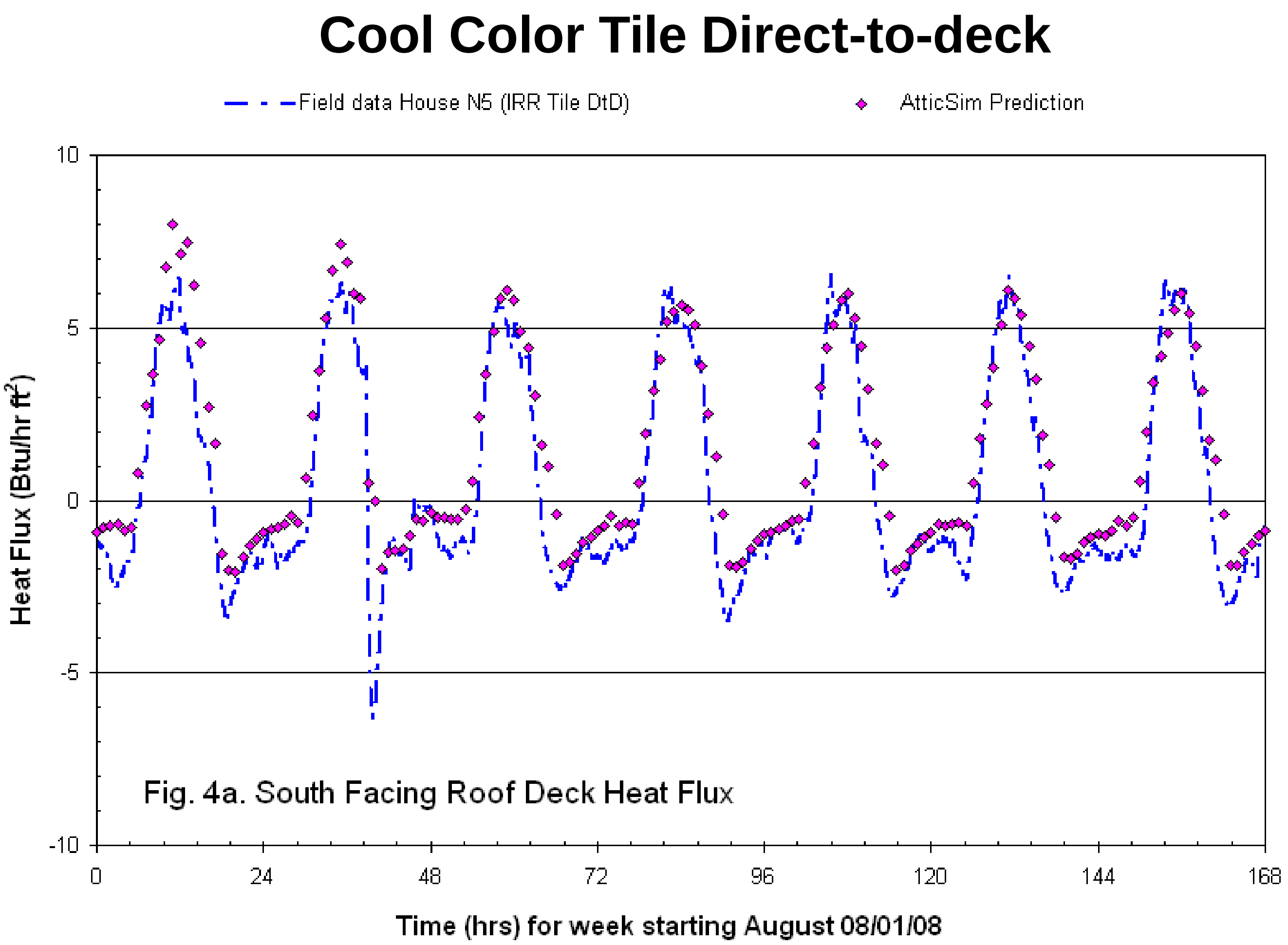
ASTM C 1340 Standard For Estimating Heat Gain or Loss Through Ceilings Under Attics

Roof & Attic Energy Balance

Petrie, T. W., K. E. Wilkes. (1998). “Effect of Radiant Barriers and Attic Ventilation on Residential Attics and Attic Duct Systems: New Tools for Measuring and Modeling,” *ASHRAE Trans*., vol. 104, 1175-1192.

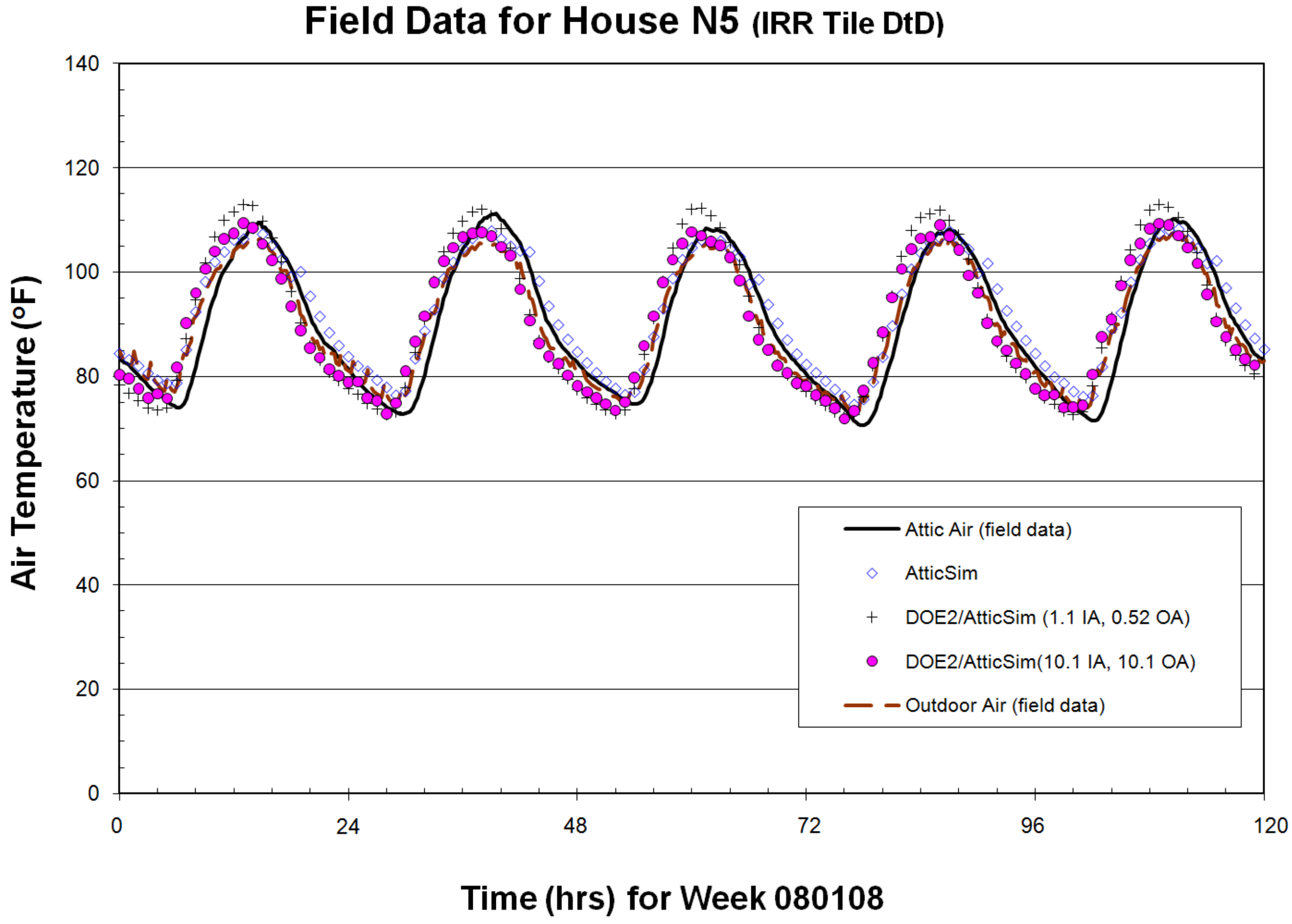
Miller et al. (2007), “Natural Convection Heat Transfer in Roofs with Above-Sheathing Ventilation.” in Thermal Performance of the Exterior Envelopes of Buildings, X, proceedings of ASHRAE THERM X, Clearwater, FL., Dec. 2007.

AtticSim Benchmark of Ft Irwin House (South-facing Roof Deck)



Miller, W. 2010. Field experiments to evaluate cool-colored roofing. Task 2.5.7 CEC milestone report.

AtticSim and DOE-2.1E/AtticSim Benchmark of Ft Irwin House "Attic Air Temperature"



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Presentation summary

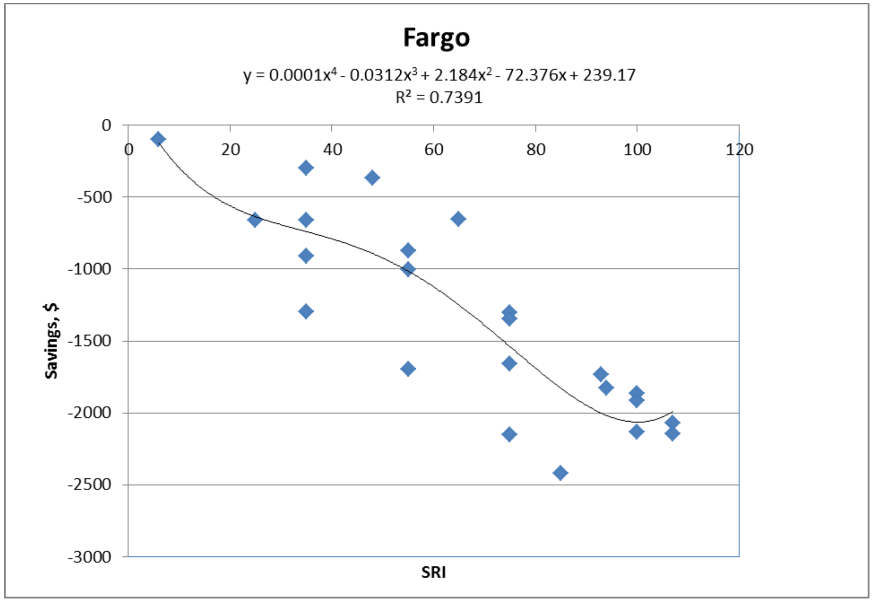
- Context – US Energy and ORNL BTRIC
- Physical Properties
- Roof Savings Calculator
- Software Design
- Ongoing Projects

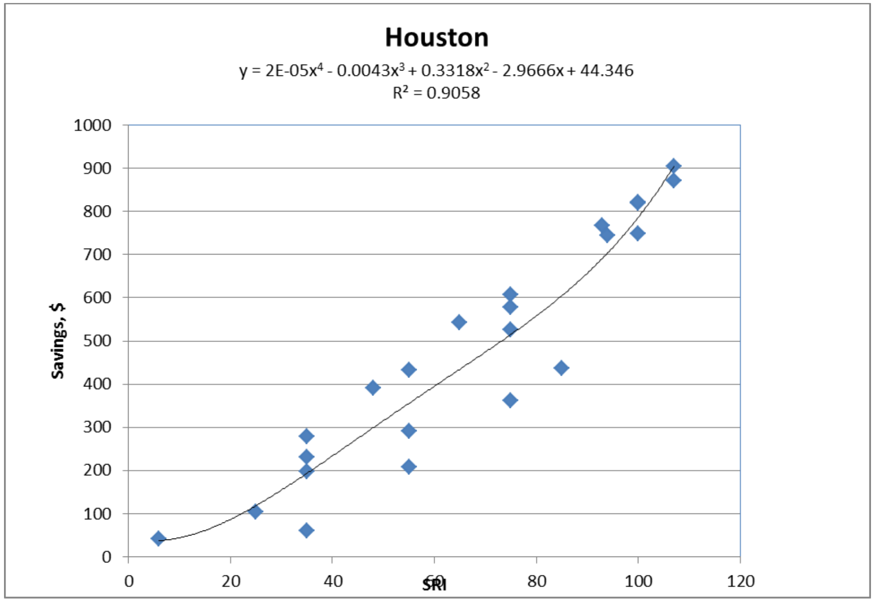
Current Results

Description	Reflectance	Emissivity	SRI	Atlanta	Austin	Baltimore	Chicago	Fairbanks	Fargo	Houston	Kansas City	Los Angeles	Miami	Minneapolis	New York	Phoenix	San Francisco
BUR No Coating	10	90	6	-54	0	-66	-36	-125	-99	42	-47	98	75	-53	-89	39	-68
Mineral Mod Bit	25	88	25	-422	-39	-507	-325	-941	-659	103	-368	383	276	-419	-669	70	-420
Single Ply	32	90	35	-384	71	-437	-253	-901	-660	230	-320	614	441	-382	-582	154	-494
Mineral Mod Bit	33	92	35	-574	3	-655	-407	-1302	-908	197	-477	648	463	-560	-871	118	-659
Metal	35	82	35	-883	-191	-1000	-742	-2213	-1296	60	-698	293	212	-863	-1558	74	-322
Aluminum Coating over BUR	43	58	35	-9	189	-64	-46	-237	-298	279	-45	585	372	-93	-189	294	-58
Mineral Mod Bit	45	79	55	-564	84	-657	-408	-1385	-1003	291	-475	872	594	-582	-907	216	-693
Coating over BUR	49	83	55	-413	231	-461	-250	-1154	-872	433	-345	1075	742	-441	-680	348	-640
Metal	49	83	55	-1191	-126	-1231	-837	-2855	-1697	208	-857	771	576	-1102	-1891	138	-957
Aluminum Coating over BUR	55	45	48	39	174	-35	-29	-276	-367	390	-21	825	502	-90	-202	419	-51
Mineral Mod Bit	63	88	75	-909	203	-996	-571	-2372	-1661	525	-726	1473	1105	-933	-1380	300	-1419
Coating over BUR	63	86	75	-606	334	-664	-347	-1787	-1305	607	-501	1512	1102	-659	-980	452	-1104
Metal	63	84	75	-1487	-31	-1465	-919	-3600	-2151	361	-1028	1295	986	-1356	-2198	171	-1704
Single Ply	64	80	75	-637	304	-712	-386	-1850	-1345	578	-528	1480	1067	-694	-1031	408	-1105
Aluminum Coating over BUR	65	45	65	-80	272	-160	-88	-696	-655	542	-123	1230	758	-227	-399	558	-301
Metal (White)	70	85	85	-1622	14	-1592	-967	-4005	-2422	436	-1133	1522	1211	-1502	-2353	166	-2131
Coating over BUR (White)	75	90	93	-770	417	-875	-443	-2391	-1732	767	-664	1822	1460	-900	-1261	526	-1642
Single Ply (White)	76	87	94	-840	384	-962	-502	-2547	-1829	745	-722	1808	1460	-974	-1358	471	-1720
Coating over BUR (White)	79	90	100	-812	450	-928	-471	-2571	-1862	820	-710	1906	1576	-974	-1336	553	-1825
Mineral Mod Bit (White)	81	80	100	-1025	355	-1161	-642	-3006	-2131	748	-867	1876	1556	-1175	-1634	444	-2057
Single Ply (White)	82	79	100	-819	455	-949	-494	-2643	-1912	822	-722	1934	1578	-1002	-1373	554	-1847
Coating over BUR (White)	85	90	107	-873	499	-1008	-524	-2845	-2073	905	-782	2003	1761	-1097	-1454	592	-2123
Single Ply (White)	85	87	107	-936	459	-1083	-577	-2969	-2143	871	-830	1974	1736	-1156	-1536	531	-2167

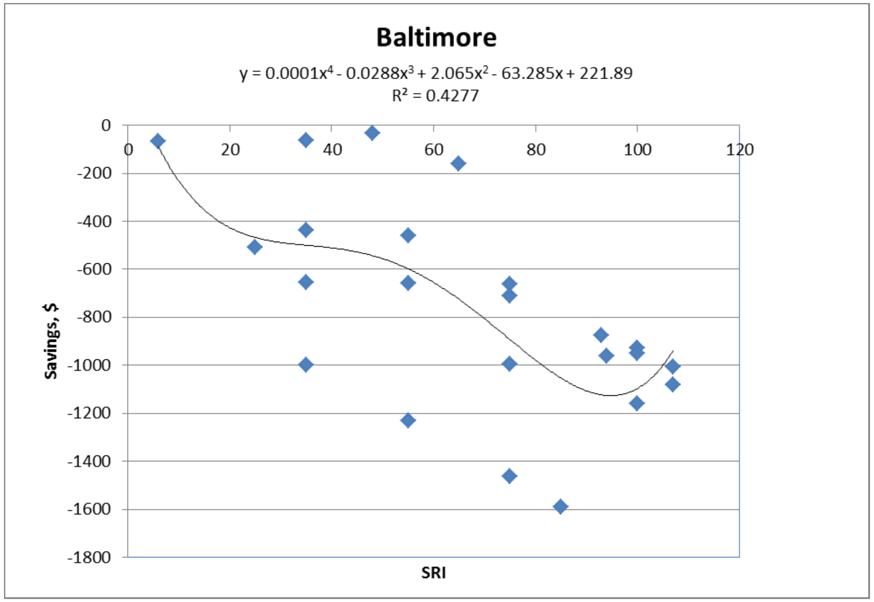
RCMA
ROOF COATINGS
MANUFACTURERS ASSOCIATION

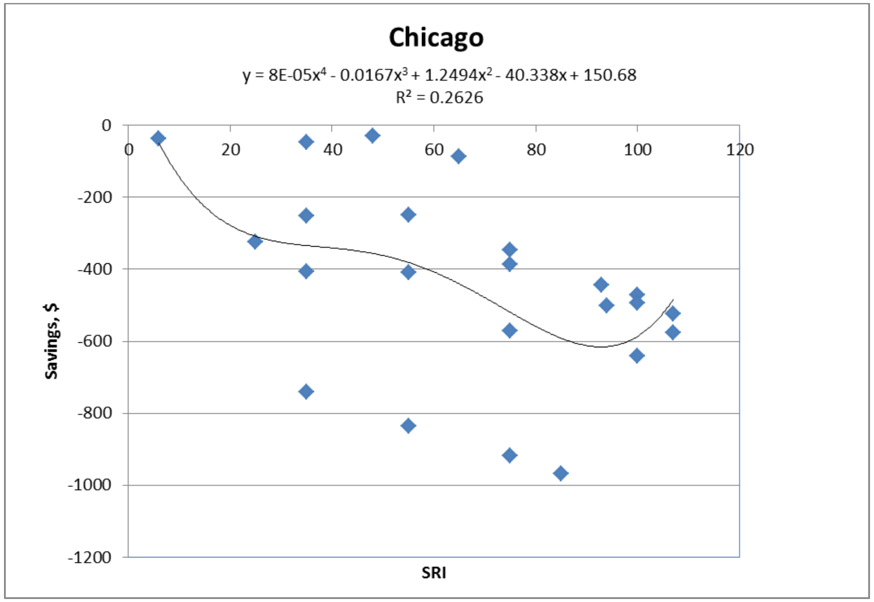
Expected Results



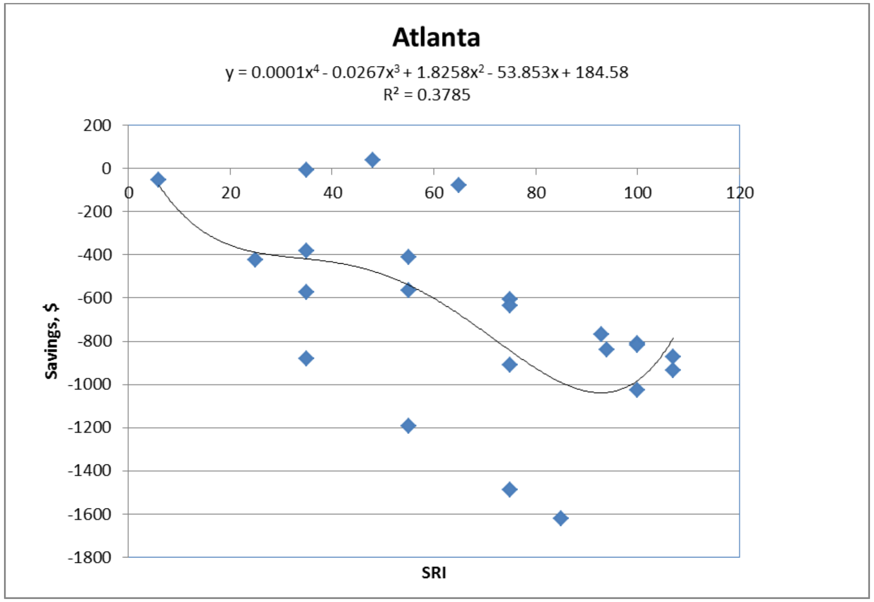


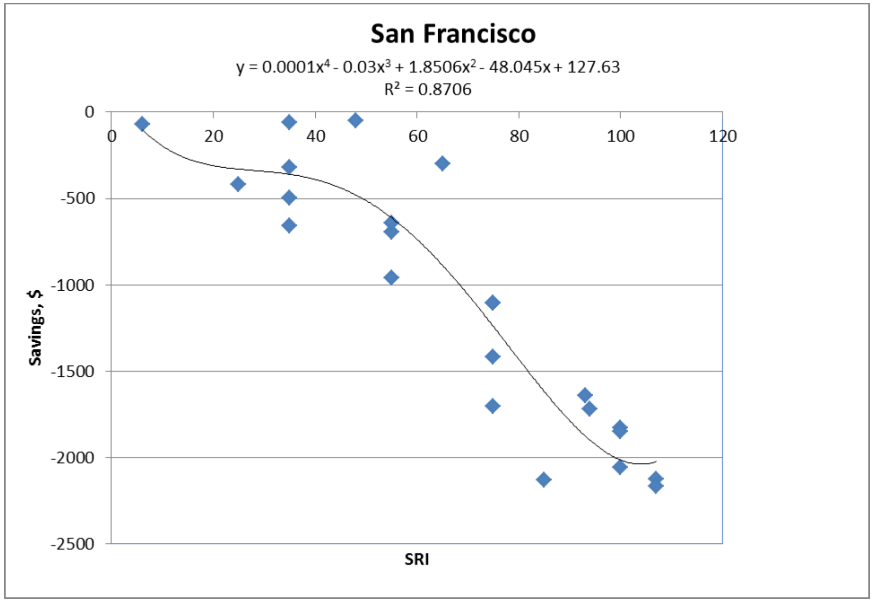
Unusual Results



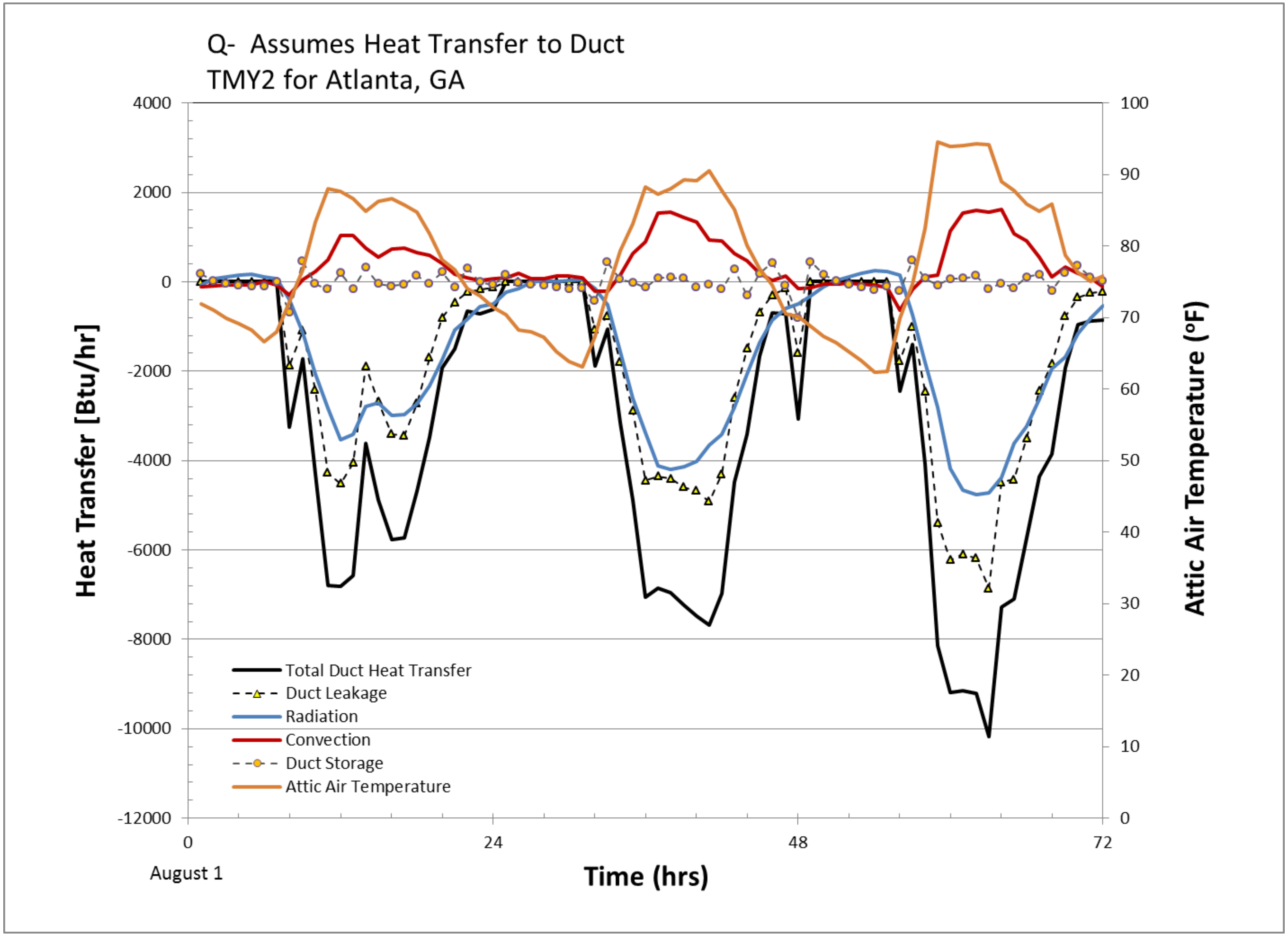


Surprising Results

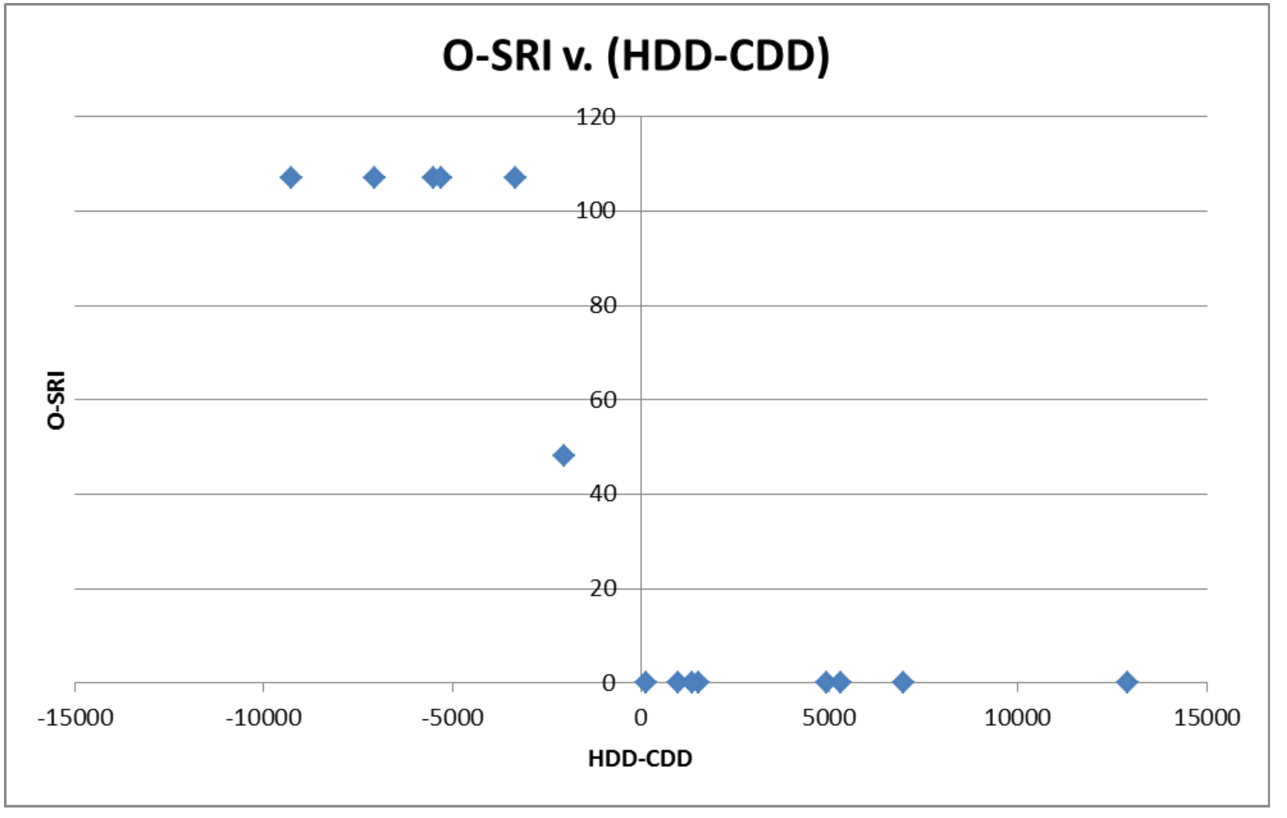




Summer Operation of HVAC Duct in ASHRAE Climate Zone 3



Summary


O-SRI v. (HDD-CDD)
120
100
80
60
40
20
0
O-SRI
-15000
-10000
-5000
0
5000
10000
15000
HDD-CDD

Optimal Roofing Systems

Location	Observed Optimized Condintion	Trend Desired SRI	Maximum Observed Savings, $	Best Observed System	Related SRI
Atlanta	Maximized	107	1080	Aluminum Coating over BUR	65
Austin	Maximized	107	2680	Coating over BUR (White)	107
Baltimore	Maximized	107	1000	Single Ply White/Coating over BUR (White)	103.5
Chicago	Modal	64.95	360	Aluminum Coating over BUR	48
Fairbanks	Modal	42.68	680	Aluminum Coating over BUR	48
Fargo	Modal	40.58	160	Aluminum Coating over BUR	48
Houston	Maximized	107	1840	Coating over BUR (White)	107
Kansas City	Maximized	107	800	Coating over BUR (White)	107
Los Angeles	Maximized	107	440	Aluminum Coating over BUR	65
Miami	Maximized	107	4440	Coating over BUR (White)	107
Minneapolis	Modal	47.05	360	Aluminum Coating over BUR	48
New York	Maximized	107	560	Aluminum Coating over BUR	65
Phoenix	Maximized	107	3000	Coating over BUR (White)	107
San Francisco	Modal	39.31	200	Aluminum Coating over BUR	48

Presentation summary

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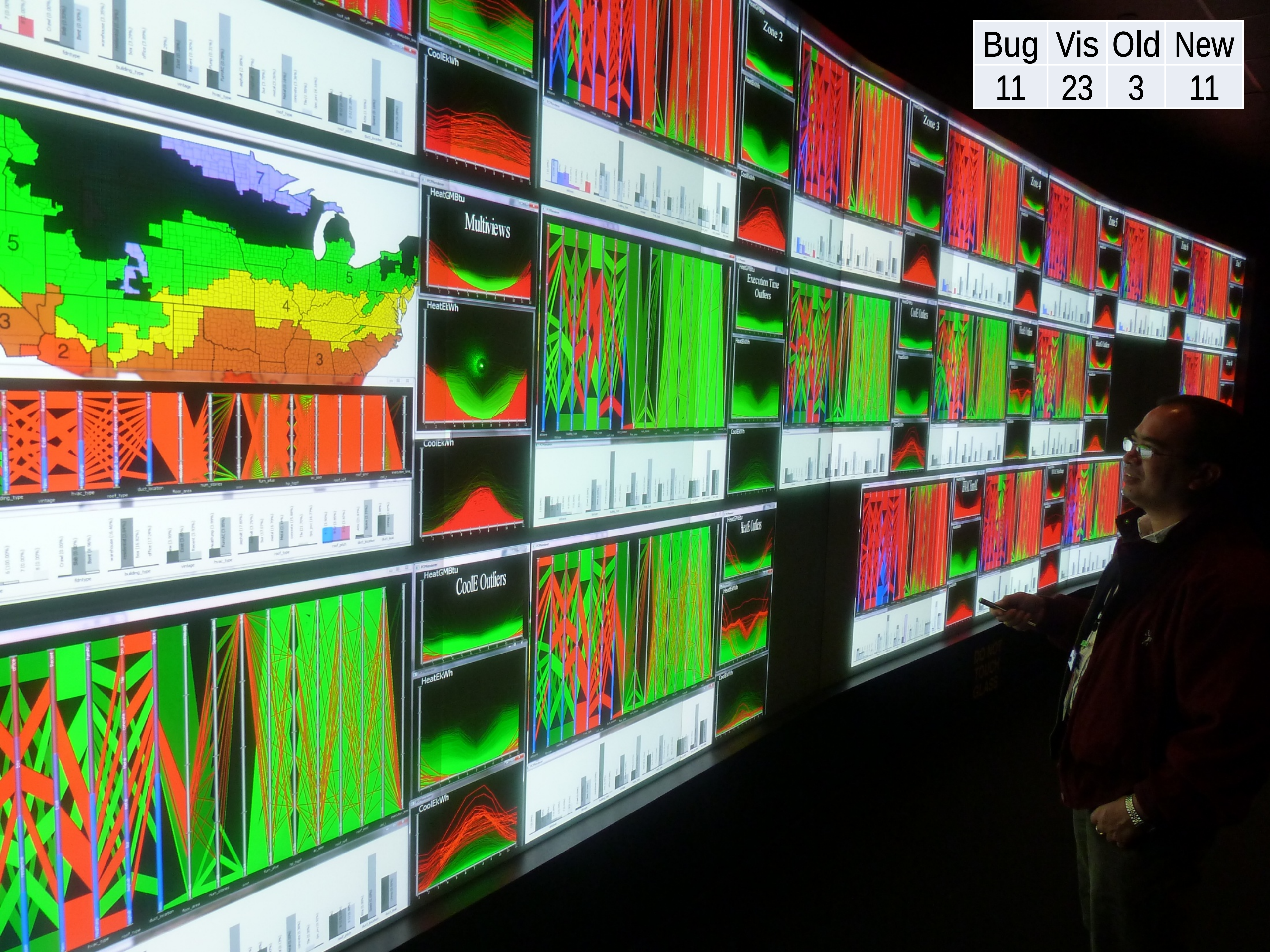
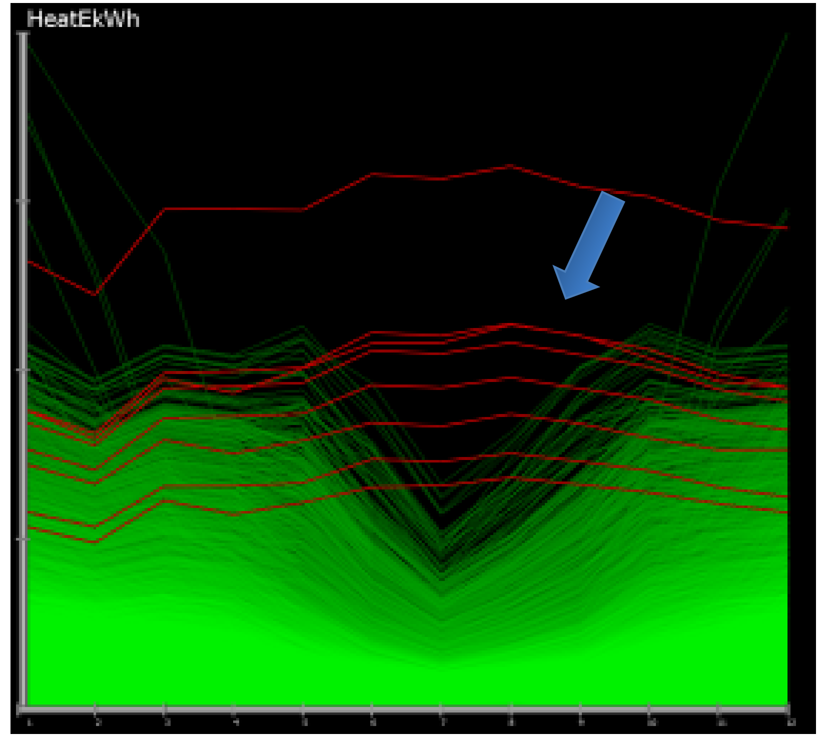
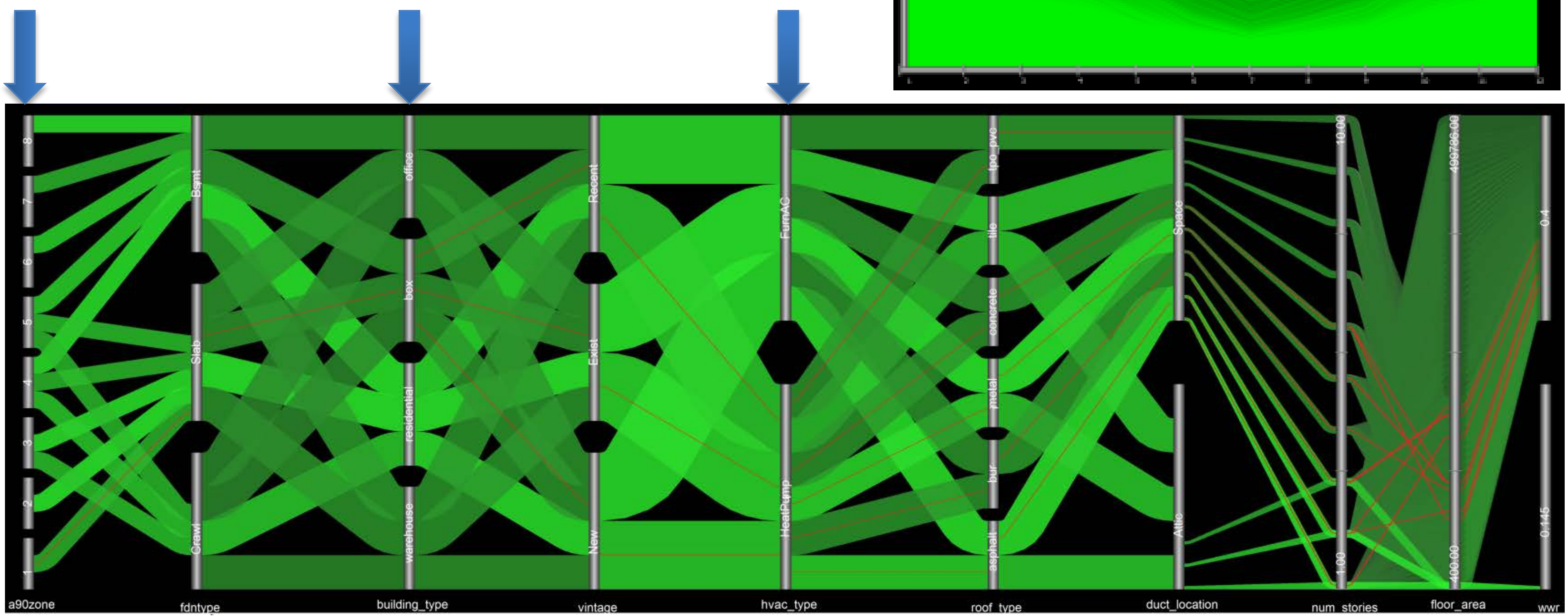
Bug	Vis	Old	New
11	23	3	11



Outliers (Heating)

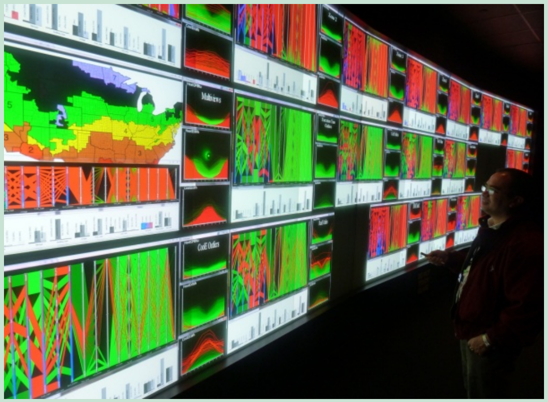


- Selection of heating outliers
- Find all are from Miami, have box building type, and heat pump



HPC used to verify building simulation engine of tool enabling industry promotion of energy efficiency

DOE: Office of Science | CEC & DOE EERE: BTO | Industry & Building Owners

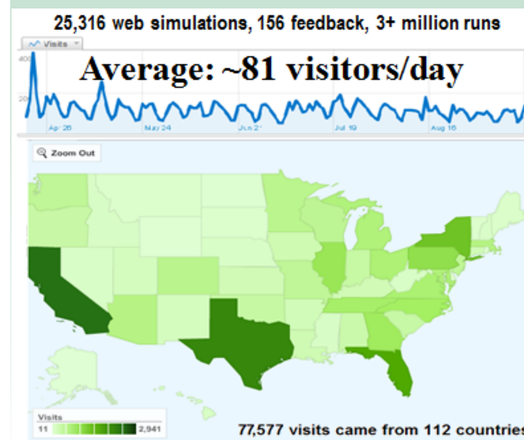


Engine (AtticSim/DOE-2) debugged using HPC Science assets enabling visual analytics on $3x(10)^6$ simulations

Roof Savings Calculator (RSC) web site/service developed and validated [estimates energy cost savings of improvements to flat or sloped roofs for any existing condition or climate]

Industry partners install 2000+ roofs/mo, is integrating RSC into their proposal generating system (others expected to follow)

Potential cumulative savings 117.2 Gwh/yr ($1.6 billion/yr)



Leveraging HPC resources to facilitate deployment of building energy efficiency technologies

RCMA ROOF COATINGS MANUFACTURERS ASSOCIATION

Presentation summary

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Current RSC Site

http://www.roofcalc.com

Parameter Entry

Building

1. Closest location (similar weather):
Select location

2. Building Type:
Office

3. Conditioned floor area (ft^2):
10000

4. Number of floors:
1

5. Year of construction:
- ○ post-1990
- ○ 1980-1990
- ◉ pre-1980

Heating/Cooling

6. Heating equipment:
- ○ Electric heat pump
- ◉ Natural gas furnace

P1. Electricity price (cents per kWh):
10.31

P2. Natural gas price (dollars per 1000 ft^3):
8.59

7. Heating system efficiency (AFUE):
- ○ High-efficiency (90%)
- ◉ Mid-efficiency (83%)
- ○ Low-efficiency (70%)
- ○ None
- ○ Custom

8. Cooling system efficiency (SEER):
- ○ High-efficiency (15)
- ◉ Mid-efficiency (13)
- ○ Low-efficiency (10)
- ○ None

Result Output

Simulation Results

You save $-332/year!

Energy Savings

Total	Cooling	Heating
$-332	$208	$-540
	2017 kWh	0 kWh -65 MBtus

Monthly Savings

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
Cooling Savings (kWh)	0.0	0.0	14.8	73.1	365.6	507.1	391.0	414.0	245.7	5.6	0.0	0.0	**2016.9**
Heating Savings (kWh)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
Heating Savings (MBtus)	-2.6	-4.0	-8.7	-10.3	-9.7	-5.1	-4.5	-3.7	-4.9	-5.7	-3.4	-2.1	**-64.5**

White-Roof Utility Usage

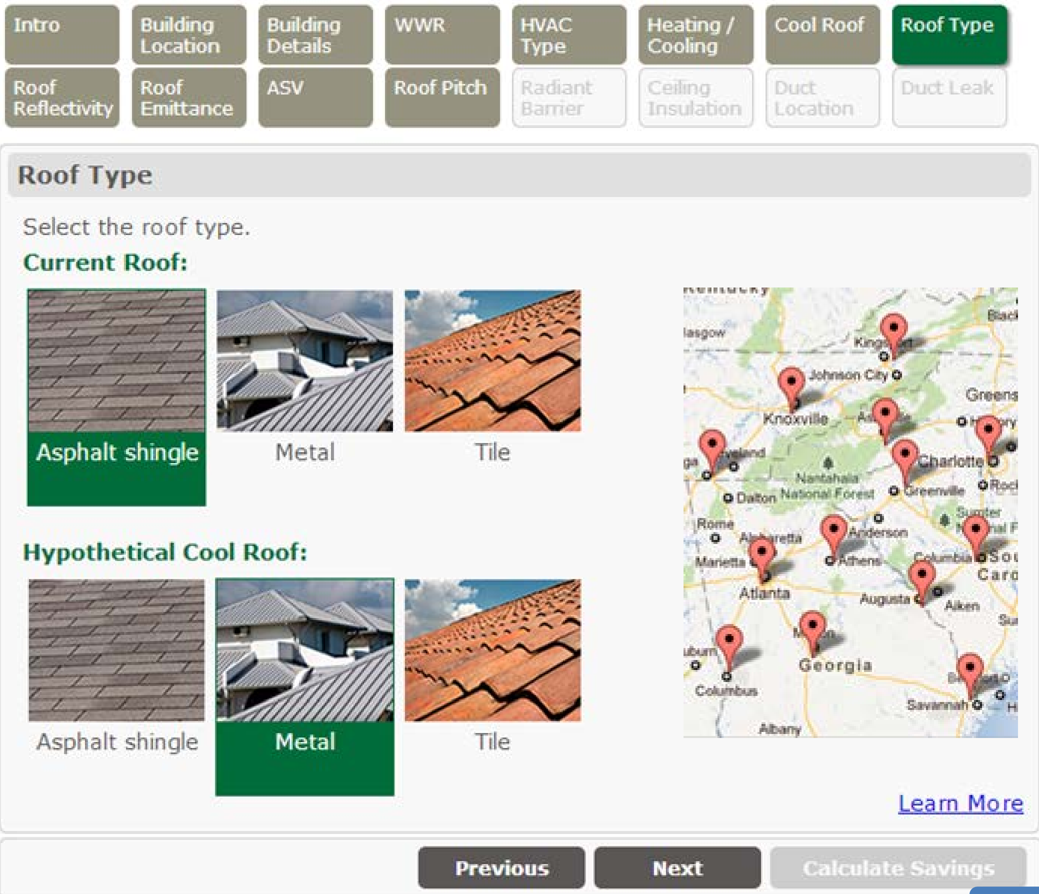
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
Cooling (kWh)	0.0	0.0	2.4	4.7	391.8	487.5	626.2	873.1	213.5	0.0	0.0	0.0	**2599.2**
Heating (kWh)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
Heating (MBtus)	121.8	99.4	88.1	70.1	40.0	16.4	11.1	11.6	29.2	71.2	97.9	111.3	**768.1**

Base-Case Utility Usage

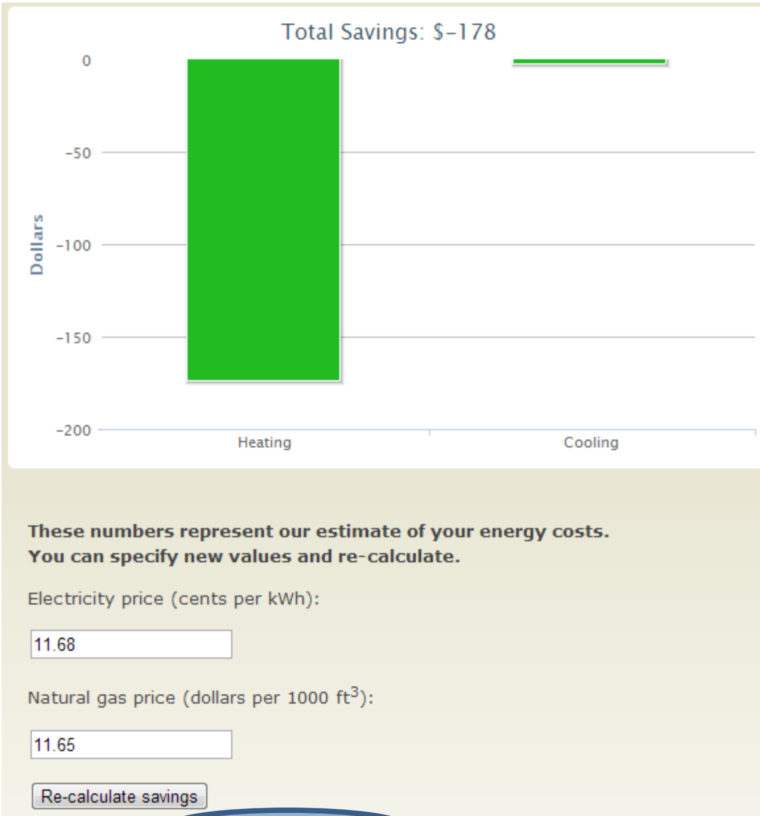
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
Cooling (kWh)	0.0	0.0	17.2	77.8	757.4	994.6	1017.2	1287.1	459.2	5.6	0.0	0.0	**4616.1**
Heating (kWh)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
Heating (MBtus)	119.3	95.3	79.4	59.8	30.3	11.3	6.6	8.0	24.3	65.5	94.5	109.2	**703.6**

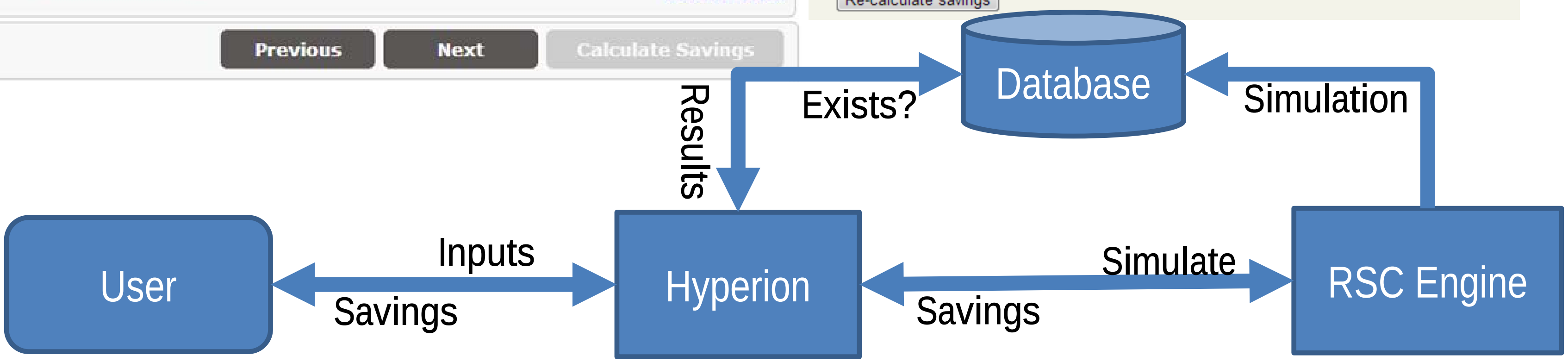
Enhanced RSC Site

Input Parameter GUI



Result Output





RSC Web Service

- SoapResults = simulate(SoapModel)
  - Accepts a model and returns the RSC results
- ZipString = test(SoapModel)
  - Forces the model to be evaluated by the engine (rather than checking the database) and returns a zip (as a base64-encoded string) of the DOE2/AtticSim output files
- ScenarioID = upload(SoapModel, SoapResults)
  - Uploads the model and results to the database, bypassing the engine
- (SoapModel, SoapResults) = download(ScenarioID, VersionNumber)
  - Downloads a model/result pair for the scenario ID and version number

RSC Service Example (Python)

```
client = suds.client.Client('URL/TO/WEB/SERVICE/rsc.wsdl')
print(client)

sm = client.factory.create('schema:soapmodel')
load_soap_model_from_xml('../examplemodel.xml', sm)
sr = client.service.simulate(sm)
print(sr)

sm = client.factory.create('schema:soapmodel')
load_soap_model_from_xml('../examplemodel.xml', sm)
print(sm)
contents = client.service.test(sm)
with open('pytest.zip', 'wb') as outfile:
    outfile.write(base64.b64decode(contents))

sm = client.factory.create('schema:soapmodel')
load_soap_model_from_xml('../examplemodel.xml', sm)
sr = client.factory.create('schema:soapresults')
load_soap_results_from_xml('../exampleresults.xml', sr)
sid = client.service.upload(sm, sr)
print(sid)

modres = client.service.download(83356208, '0.9')
print(modres['soapmodel'])
print(modres['soapresults'])
```

RSC Web Service XML

Soap Model

- buildingLocation
- buildingType
- buildingArea
- buildingFloors
- buildingWwr
- buildingVintage
- heatingType
- heatingEfficiency
- coolingEfficiency
- atticVent
- atticInsulation
- atticRadiantBarrier
- ductLocation
- ductInspection
- roofType
- roofReflectance
- roofEmittance
- roofPitch

Soap Result

- source
- executionTime
- scenarioId
- versionNumber

- heatingGas01
- heatingGas02…
- heatingGas12

- heatingElectricity01
- heatingElectricity02…
- heatingElectricity12

- coolingElectricity01
- coolingElectricity02…
- coolingElectricity12

- fanElectricity01
- fanElectricity02…
- fanElectricity12

Testing RSC

Test Script

```
def calculate_error(self, scenario_id, version):
    download = self.client.service.download(scenario_id, version)
    old_results = self._convert_to_dict(download['soapresults'])
    new_results = self._run_engine(download['soapmodel'])
    error = self._calc_result_error(old_results, new_results)
    if error > 0.0001:
        raise AssertionError('Error is {} > 0.0001'.format(error))
```

Test File

```
***Settings***
Library rsctests.RSCTestLibrary

***Test Cases***
www.roofcalc.com 1     Calculate Error        83342208       0.9
www.roofcalc.com 2     Calculate Error        83336950       0.9
www.roofcalc.com 3     Calculate Error        83325075       0.9
```

Testing RSC – Python Robot Framework

Roofcalc Tests Test Report

Generated
20130725 14:20:19 GMT -05:00
33 seconds ago

Summary Information

Status:	1 critical test failed
Start Time:	20130725 14:19:52.537
End Time:	20130725 14:20:19.059
Elapsed Time:	00:00:26.522
Log File:	log.html

Test Statistics

Total Statistics	Total	Pass	Fail	Elapsed	Pass / Fail
Critical Tests	3	2	1	00:00:26	
All Tests	3	2	1	00:00:26	

Statistics by Tag	Total	Pass	Fail	Elapsed	Pass / Fail
No Tags					

St

Roofcalc Tests

Test Details

Totals | Tags | Su

Type:

Test Details

LOG

Totals | Tags | Suites

Name:	Roofcalc Tests
Status:	3 critical test, 2 passed, 1 failed 3 test total, 2 passed, 1 failed
Start / End Time:	20130725 14:19:52.537 / 20130725 14:20:19.059
Elapsed Time:	00:00:26.522
Log File:	log.html#s1

Name	Documentation	Tags	Crit.	Status	Message	Elapsed	Start / End
Roofcalc Tests . www.roofcalc.com 1			yes	PASS		00:00:20.589	20130725 14:19:52.886 20130725 14:20:13.475
Roofcalc Tests . www.roofcalc.com 2			yes	FAIL	Error is 31.2461959519 > 0.0001	00:00:01.228	20130725 14:20:13.476 20130725 14:20:14.704
Roofcalc Tests . www.roofcalc.com 3			yes	PASS		00:00:04.354	20130725 14:20:14.704 20130725 14:20:19.058

Discussion