



U.S. Department of Energy
**Energy Efficiency
and Renewable Energy**
Bringing you a prosperous future where energy
is clean, abundant, reliable, and affordable
Building Technologies Program



Building
AMERICA 
U.S. Department of Energy
Research Leading to Zero Energy Homes

BEopt – Building Design on the Path to Zero Energy

Sarasota County

Renewable Energy Community Workshop

September 11, 2008

Tim Merrigan

(w/ credits to Craig Christensen and Scott Horowitz)

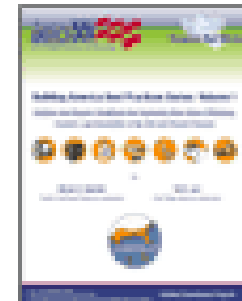
National Renewable Energy Laboratory



Building America Approach

Building America Teams -- Leading experts in building science and systems engineering offer home builders cost-shared technical support

- Whole house energy design assistance by climate
- Energy modeling
- Performance specification writing
- Training, workshops and monitoring
- Prototype homes and communities



- Building America's Best Practices series on web
[Building Technologies Program: Building America](#)

Building America Teams

- Building Industry Research Alliance (BIRA)
- Building Science Corporation (BSC)
- Consortium for Advanced Residential Buildings (CARB)
 - Davis Energy Group (DEG)
- Industrialized Housing Partnership (IHP)
- Integrated Building and Construction Solutions (IBACOS)
- NAHB Research Center





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Home Builders

LENNAR



STANDARD PACIFIC HOMES
Making You Right At Home®



HUGH FUTRELL CORPORATION

HOMES by TOWNE
ZILBER BUILT SINCE 1949

Pardee Homes
THE WAY YOU WANT TO LIVE

Tim Lewis
COMMUNITIES
Bringing five-star quality home

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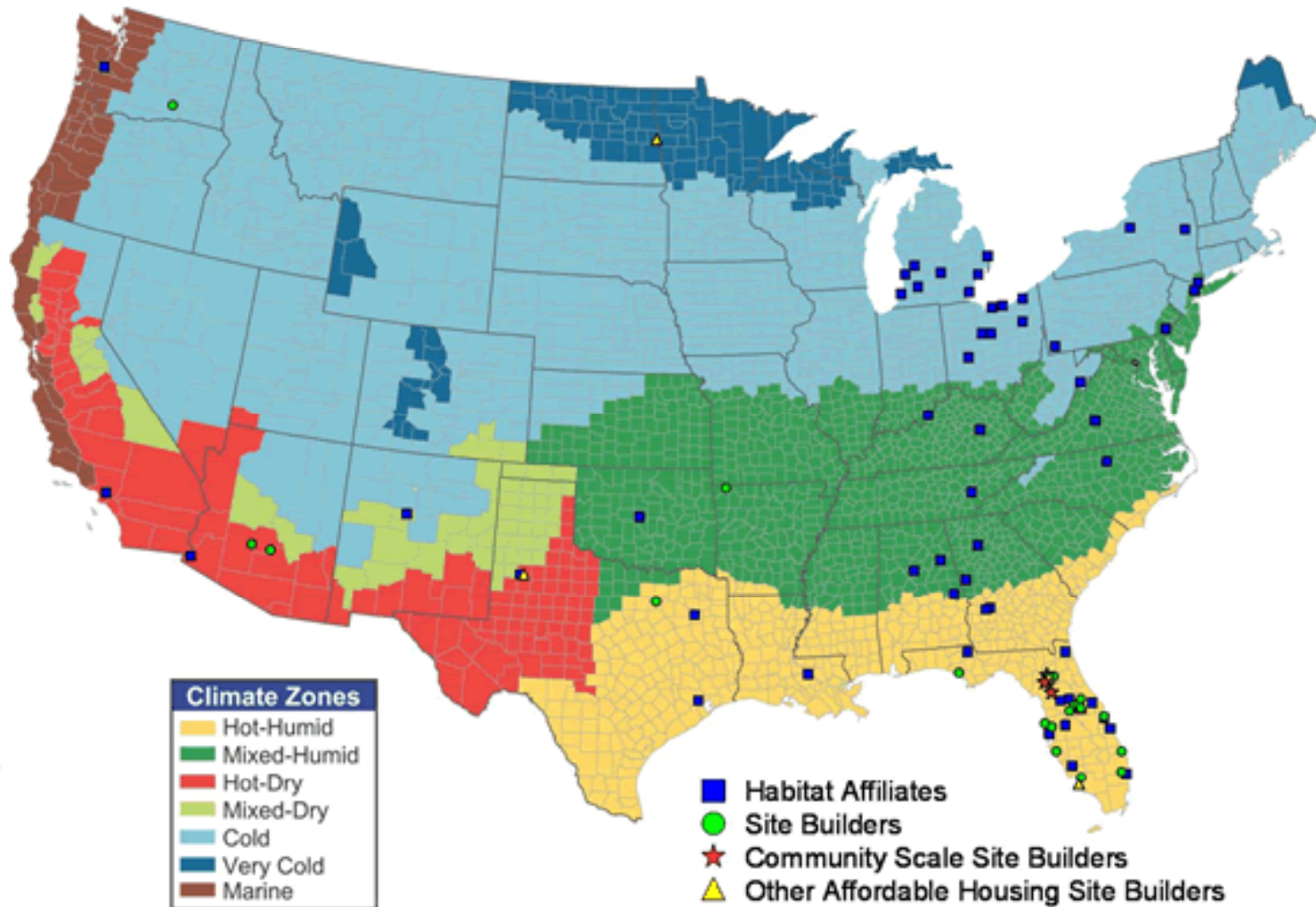


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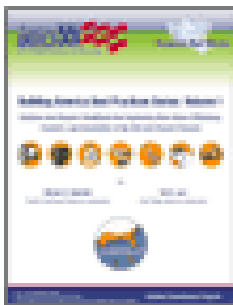
US Climate Zones



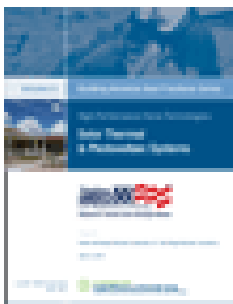


Building America Best Practices

- Building America's Best Practices series on web
[Building Technologies Program: Building America](#)



Volume 1: Hot-Humid Climate
Best Practices Guide



Volume 6: High-Performance
Home Technologies: Solar
Thermal & Photovoltaic Systems

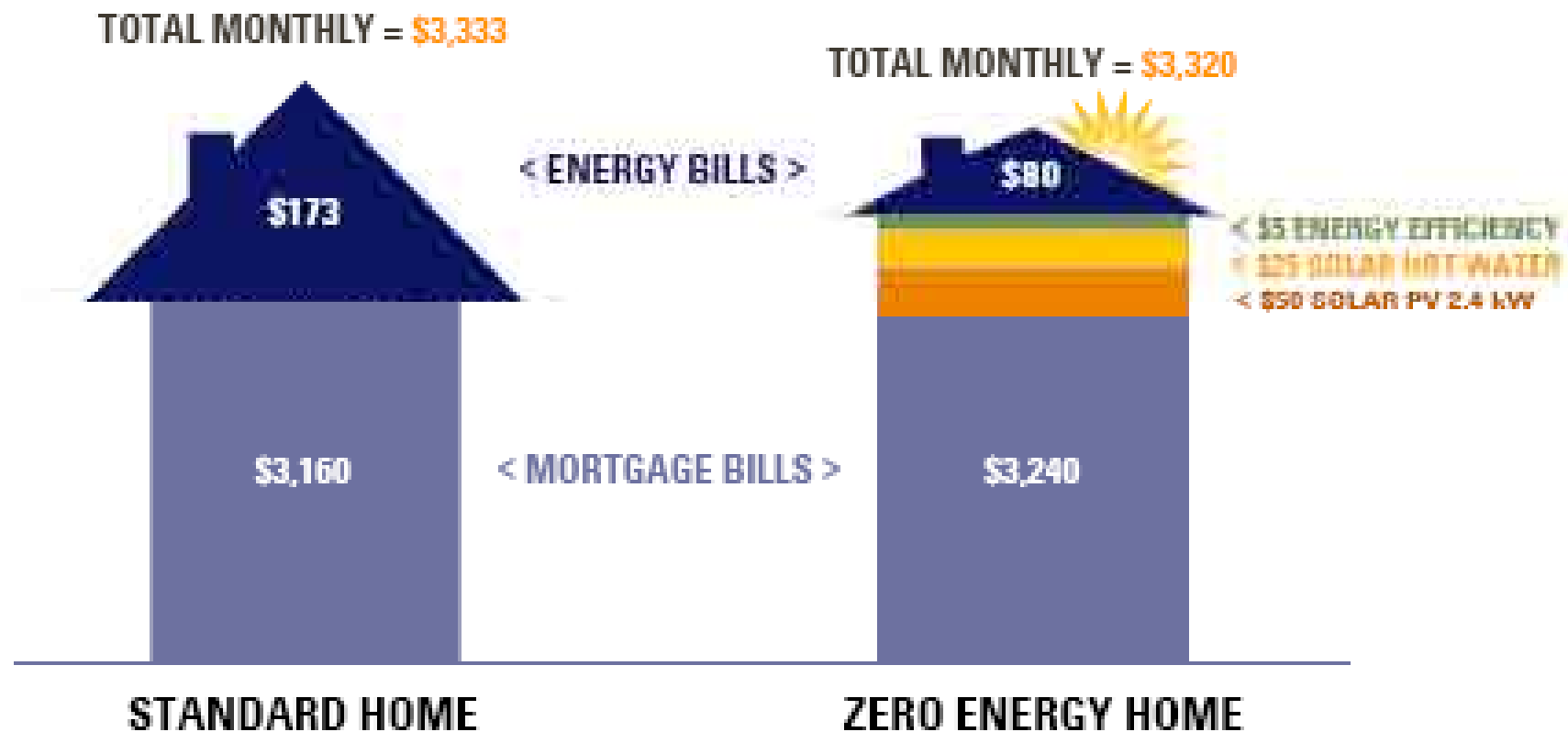


Building America: Research Leading To Zero Energy Homes (ZEH)

- ZEH--Homes that are highly energy efficient and produce all their own energy—annually
- Today's marketable ZEH—cuts energy use 40-60% including energy efficiency & renewable energy
- Tomorrow's ZEH—Energy savings of 60-70% *plus 30-40%* on-site renewable energy



Homeowner Monthly Costs





U.S. Department of Energy
Energy Efficiency and Renewable Energy

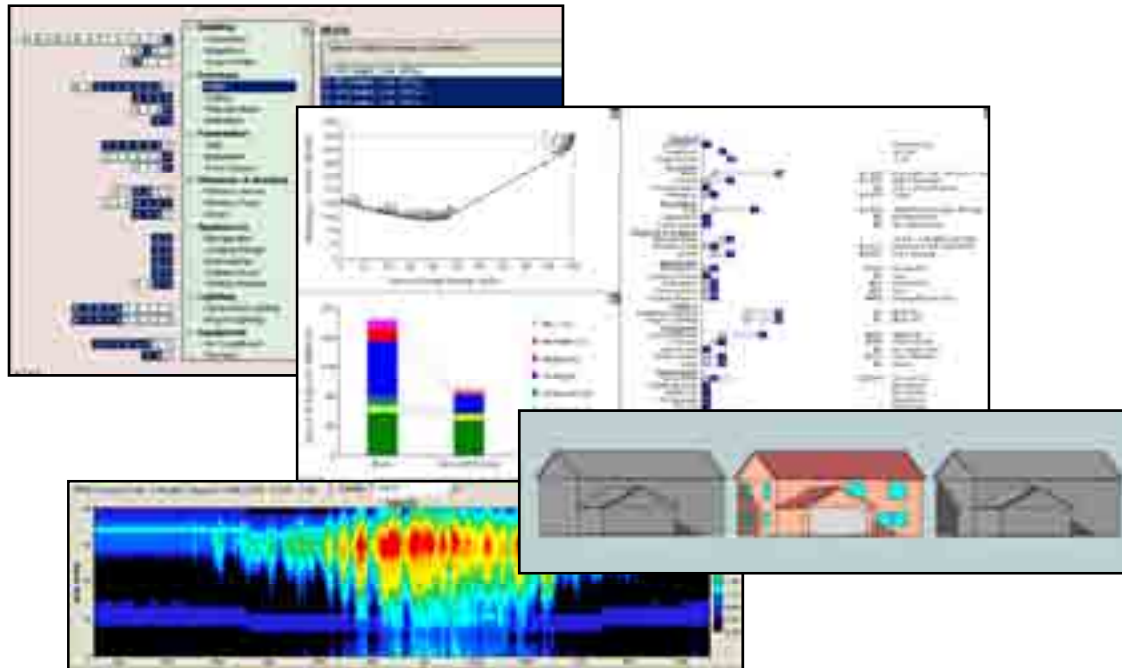
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U.S. Department of Energy
Research Leading to 21st Century Energy

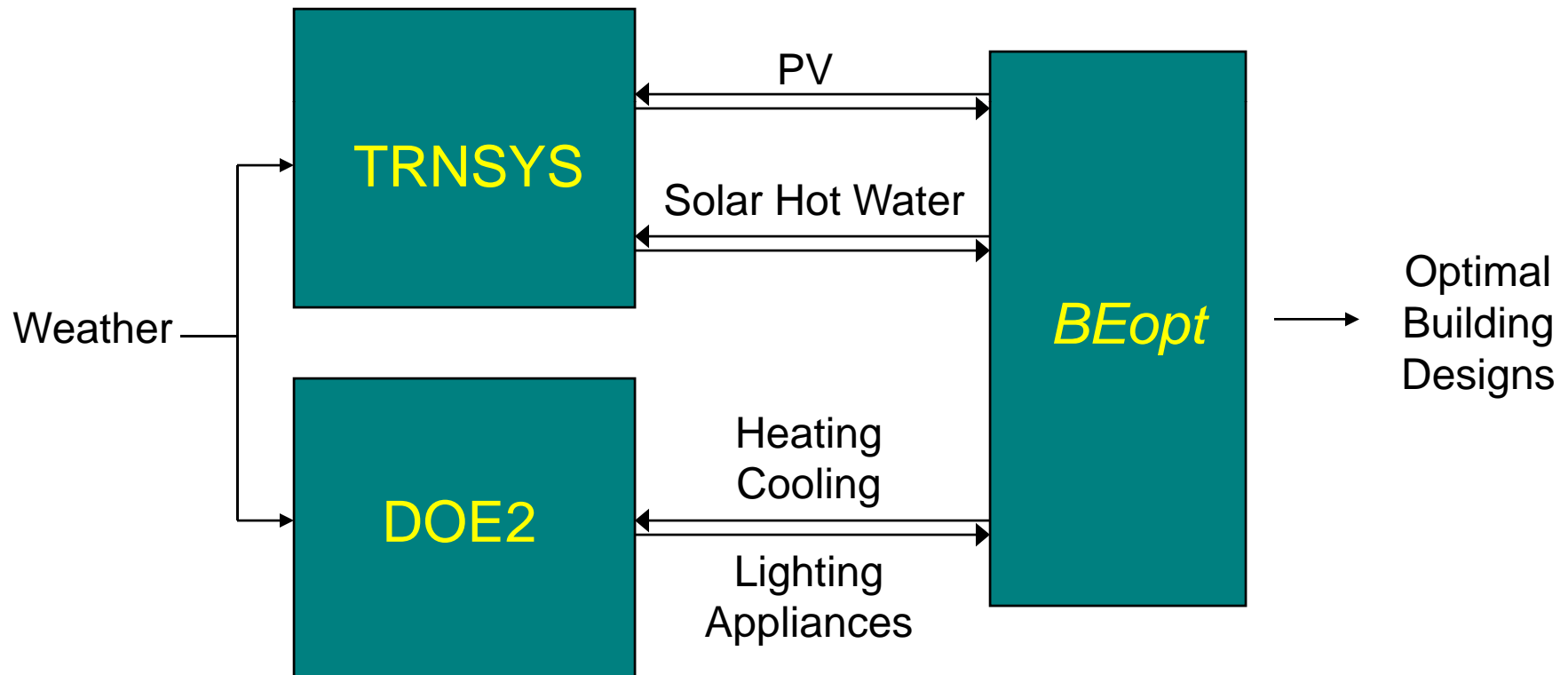
BEopt *Building Energy Optimization with Hour-by-Hour Simulations*

Craig Christensen, Scott Horowitz
Center for Buildings and Thermal Systems, NREL





BEopt Optimization Software





Current *BEopt* Capabilities:

- Runs hour-by-hour detailed simulations.
- Accurately accounts for interactions across categories (e.g., glass type and HVAC)
- Evaluates realistic (discrete) options for building efficiency and solar water heating.
- Finds optimal (efficiency, SWH, PV) designs for entire range of energy savings from base case to zero net energy home.
- Identifies near-optimal alternative designs.
- Automatically implements the Building America Benchmark.

BEopt input

1) Building Inputs

| | | |
|---|--|---|
| <p>Location</p> <p>EPW Location: USA_CO_Boulder_TMY2.epw</p> | <p>Garage</p> <p><input type="radio"/> None <input type="radio"/> One Car <input checked="" type="radio"/> Two Car</p> <p>Position: Left Protrusion: 100 %</p> | <p>Roof</p> <p><input checked="" type="radio"/> Gable <input type="radio"/> Hip <input type="radio"/> Flat</p> <p>Pitch: 6:12</p> |
| <p>Building Geometry</p> <p>Finished Floor Area (Above Grade): 2500 ft² # Floors (Above Grade): 2 Number of Bedrooms: 3 Number of Bathrooms: 2 Wall Height: 8 ft</p> | <p>PV</p> <p>PV Module: Generic - c-Si Installed Cost: 7.50 \$/W DC Derate Factor: 15.0 %</p> | |

Previous runtime: 1m (6 simulations)

BEopt input

2) Economics Inputs

Electricity Rate

User Specified Marginal \$/kWh
 State Average Fixed \$/month
 National Average Average 0.0892 \$/kWh

Mortgage

Mortgage Period years
 Mortgage Interest Rate (Nominal) %
 Marginal Income Tax Rate %

Net-Metered Excess Electricity Sellback Rate

Retail Electricity Cost \$/kWh
 User Specified

Miscellaneous

Project Analysis Period years
 Inflation Rate %
 Discount Rate (Nominal) %
 Elec. Source/Site Ratio
 Gas Source/Site Ratio
 Efficiency Cost Multiplier

Natural Gas Rate

User Specified Marginal \$/therm
 State Average Fixed \$/month
 National Average Average 0.9126 \$/therm

BEopt input

[] 1 - Base [] 2 - Walls [] 3 - Window Type [] 4 - Lighting [] 5 - Furnace [] 6 - Water Heater

3) Option Inputs

- [-] **Building**
 - Orientation
 - Neighbors
 - Aspect Ratio
 - Misc Electric Loads [1 2 3]
 - Heating Set Point [1 2 3]
 - Cooling Set Point [1 2 3]
- [-] **Envelope**
 - Walls [1 2 3 4 5 6 7 8 9 10 11 12 13 14]
 - Ceiling [1 2 3 4]
 - Thermal Mass [1 2 3 4]
 - Infiltration [1 2 3 4]
- [-] **Foundation**
 - Slab [1 2 3 4 5 6 7]
 - Basement [1 2 3 4 5 6 7]
 - Crawl Space [1 2 3 4 5]
- [-] **Windows & Shading**
 - Window Areas [1 2 3 4 5 6]
 - Window Type [1 2 3 4 5 6 7 8 9 10 11]
 - Eaves [1 2 3 4]
- [-] **Appliances**
 - Refrigerator [1 2]
 - Cooking Range [1 2]
 - Dishwasher [1 2]
 - Clothes Dryer [1 2]
 - Clothes Washer [1 2 3 4]
- [-] **Lighting**
 - Hardwired Lighting [1 2 3 4 5 6 7 8 9 10]
 - Plug-in Lighting [1 2 3 4 5 6 7 8 9 10]
- [-] **Equipment**
 - Electric Conditions [1 2 3 4 5 6 7 8]

| Walls options | R Assembly (hr-sqft-F/Btu) | Framing Factor | Lifetime (years) |
|---|----------------------------|----------------|------------------|
| 1) R11 batts, 2x4, 16"oc | 8.2 | 25% | 30 |
| 2) R13 batts, 2x4, 16"oc | 9.1 | 25% | 30 |
| 3) R15 batts, 2x4, 16"oc | 9.8 | 25% | 30 |
| 4) R19 batts, 2x6, 24"oc | 14.4 | 20% | 30 |
| 5) R21 batts, 2x6, 24"oc | 15.3 | 20% | 30 |
| 6) R11 batts, 2x4, 16"oc + 1" foam | 15.9 | 25% | 30 |
| 7) R13 batts, 2x4, 16"oc + 1" foam | 17.0 | 25% | 30 |
| 8) R19 batts, 2x6, 24"oc + 1" foam | 22.4 | 20% | 30 |
| 9) R21 batts, 2x6, 24"oc + 1" foam | 23.5 | 20% | 30 |
| 10) R19 batts, 2x6, 24"oc + 2" foam | 29.9 | 20% | 30 |
| 11) Double Stud, R33 2x4 24 o.c., 12 inch total | 27.2 | 14% | 30 |
| 12) Double Stud, R39 2x4 24 o.c., 12 inch total | 30.6 | 14% | 30 |
| 13) Double Stud, R45 2x4 24 o.c., 12 inch total | 33.6 | 14% | 30 |
| 14) Double Stud, R51 2x4 24 o.c., 14 inch total | 38.7 | 14% | 30 |

R-values are air-to-air and include the effect of the framing factor.

The matrix provides a snapshot of selected options across all categories. Note that it is also active.

Previous runtime: 1m (6 simulations)

BEopt input

File Screen Case Run Tools Help

Input: Output: Run: Tools

Analysis: [D] Design Ref Bldg: 1 - Base Costs: Default

what-ifs envelope, equipment designs 1-category sensitivity 2-category sensitivity Combined Graphs

1 - Base 2 - Walls 3 - Window Type 4 - Lighting 5 - Furnace 6 - Water Heater

- Building
 - Orientation: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
 - Neighbors: 1 2 3 4
 - Aspect Ratio: 1 2 3 4 5
 - Misc Electric Loads: 1 2 3
 - Heating Set Point: 1 2 3
 - Cooling Set Point: 1 2 3
- Envelope
 - Walls: 1 2 3 4 5 6 7 8 9 10 11 12 13 14
 - Ceiling: 1 2 3 4
 - Thermal Mass: 2 3 4
 - Infiltration: 1 2 3 4
- Foundation
 - Slab: 1 2
 - Basement: 1 2
 - Crawl Space: 1 2 3 4 5
- Windows & Shading
 - Window Areas: 1 2 3 4 5 6
 - Window Type: 1 2 3 4 5 6 7 8 9 10 11
 - Eaves: 1 2 3 4
- Appliances
 - Refrigerator: 1 2
 - Cooking Range: 1 2
 - Dishwasher: 1 2
 - Clothes Dryer: 1 2
 - Clothes Washer: 1 2 3 4
- Lighting
 - Hardwired Lighting: 1 2 3 4 5 6 7 8 9 10
 - Plug-in Lighting: 1 2 3 4 5 6 7 8 9 10
- Equipment
 - Air Conditioning: 1 2 3 4 5 6 7 8 9 10

Category

| Walls options | R Assembly (hr-sqft-F/Btu) | Framing Factor | Lifetime (years) |
|---|----------------------------|----------------|------------------|
| 1) R11 batts, 2x4, 16"oc | 8.2 | 25% | 30 |
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| 14) Double Stud, R51 2x4 24 o.c., 14 inch total | 38.7 | 14% | 30 |

Options

R-values are air-to-air and include the effect of the framing factor.

The matrix provides a snapshot of selected options across all categories. Note that it is also active.

Previous runtime: 1m (6 simulations)

BEopt input

Analysis Modes:
 (D) Design
 (P) Parametric
 (O) Optimization

- [-] Building
 - [-] Orientation
 - [-] Neighbors
 - [-] Aspect Ratio
 - [-] Misc Electric Loads
 - [-] Heating Set Point
 - [-] Cooling Set Point
- [-] Envelope
 - [-] Walls
 - [-] Ceiling
 - [-] Thermal Mass
 - [-] Infiltration
- [-] Foundation
 - [-] Slab: 1 2 3 4 5 6 7
 - [-] Basement: 1 2 3 4 5 6 7
 - [-] Crawl Space: 1 2 3 4 5
- [-] Windows & Shading
 - [-] Window Areas: 1 2 3 4 5 6
 - [-] Window Type: 1 2 3 4 5 6 7 8 9 10 11
 - [-] Eaves: 1 2 3 4
- [-] Appliances
 - [-] Refrigerator: 1 2
 - [-] Cooking Range: 1 2
 - [-] Dishwasher: 1 2
 - [-] Clothes Dryer: 1 2
 - [-] Clothes Washer: 1 2 3 4
- [-] Lighting
 - [-] Hardwired Lighting: 1 2 3 4 5 6 7 8 9 10
 - [-] Plug-in Lighting: 1 2 3 4 5 6 7 8 9 10
- [-] Equipment
 - [-] Air Conditioner: 1 2 3 4 5 6 7 8

| Orientation options | Azimuth (degrees) | Lifetime (years) |
|---------------------|-------------------|------------------|
| North-facing | 180.0 | - |
| Northwest-facing | 90.0 | - |
| West-facing | 0.0 | - |
| Southwest-facing | 270.0 | - |
| South-facing | 315.0 | - |
| Southeast | 45.0 | - |
| West-southwest | 225.0 | - |
| West-northwest | 135.0 | - |
| North-northwest | 337.5 | - |
| North-northeast | 292.5 | - |
| Northwest | 247.5 | - |
| North | 202.5 | - |
| Northwest | 157.5 | - |
| 13) NNW | 112.5 | - |
| 14) WNW | 67.5 | - |
| 15) WSW | 22.5 | - |
| 16) SSW | | |

Direction the front of the house (with garage) faces.

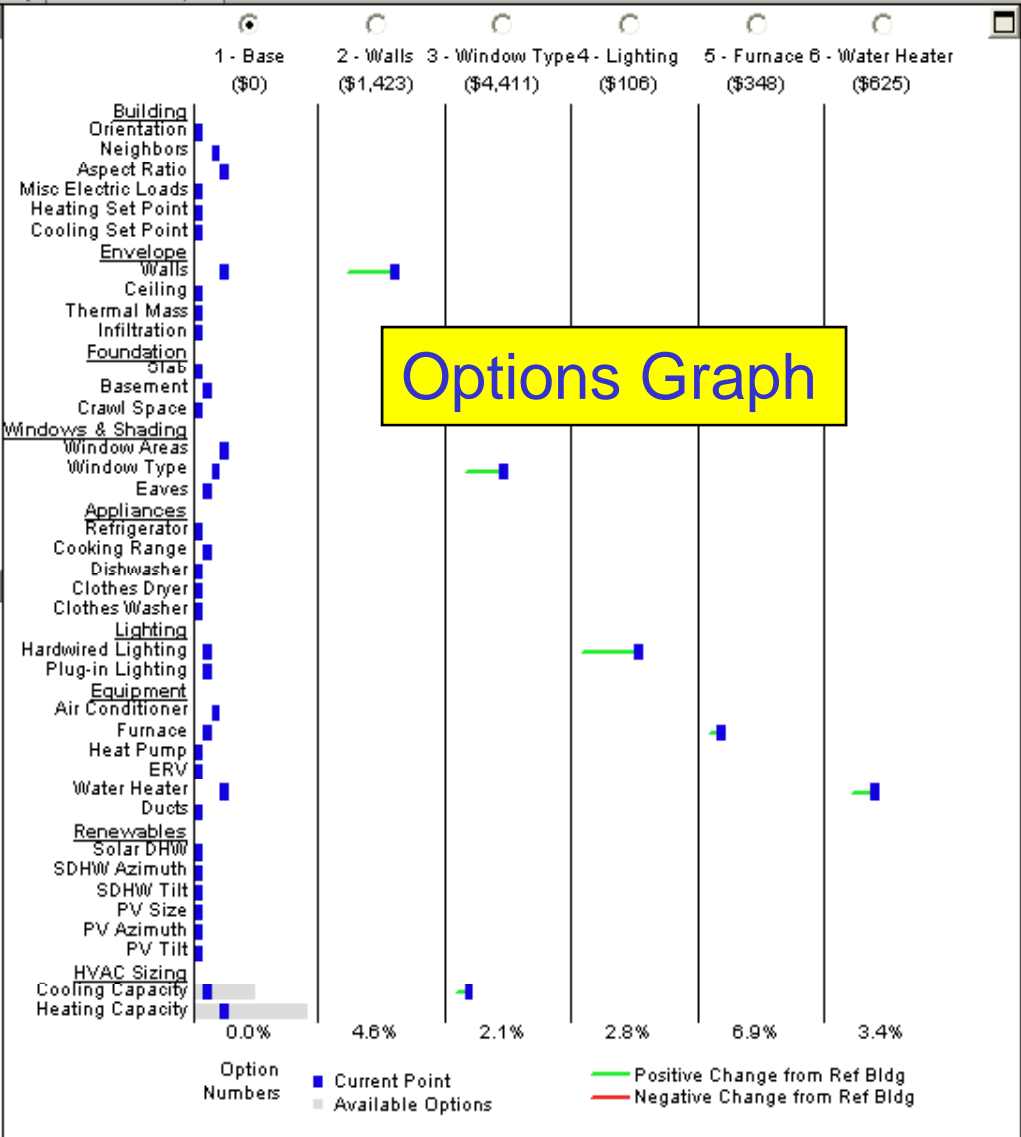
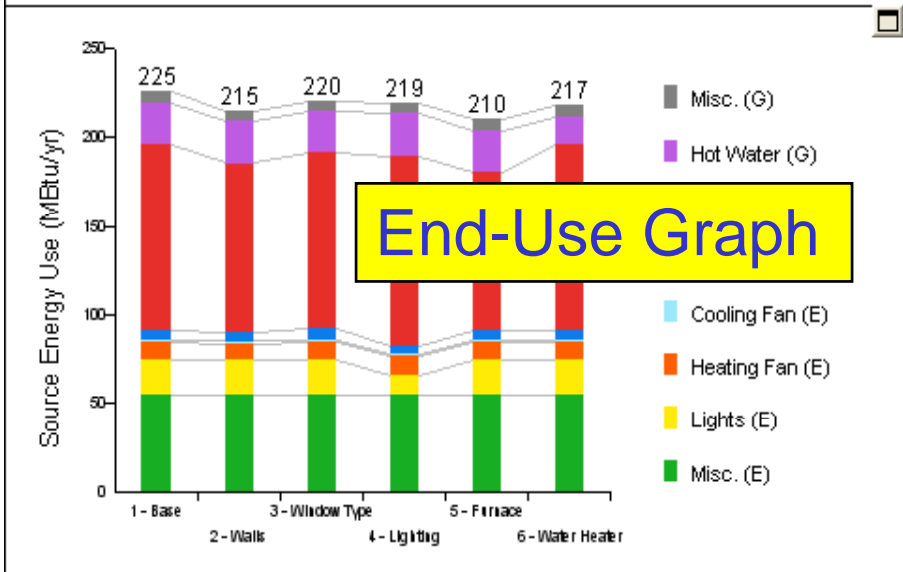
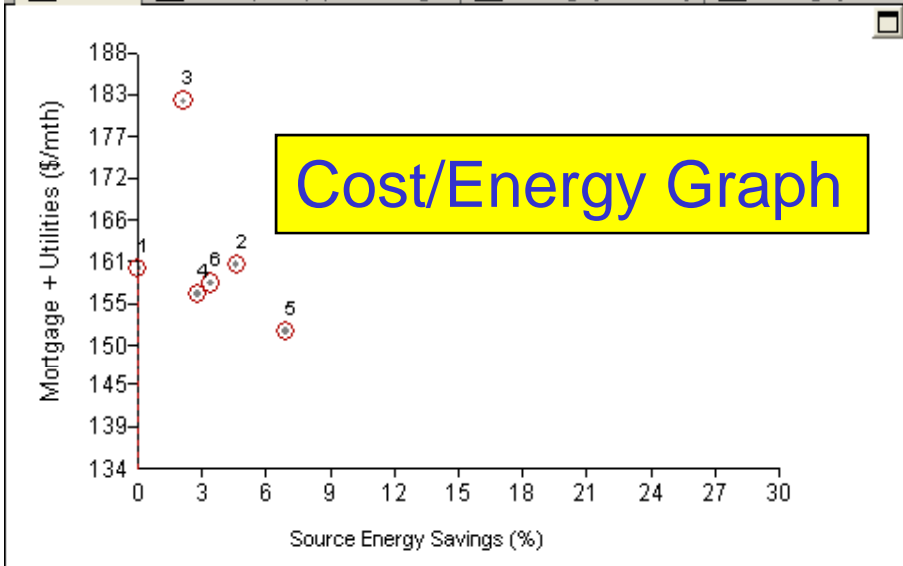
BEopt output

File Screen Case Run Tools Help

Input: Output Run Tools

Graph: Rel Bldg: 1 - Base

what-ifs envelope, equipment designs 1-category sensitivity 2-category sensitivity Combined Graphs



Right-click for graph options.

Previous runtime: 1m (6 simulations)



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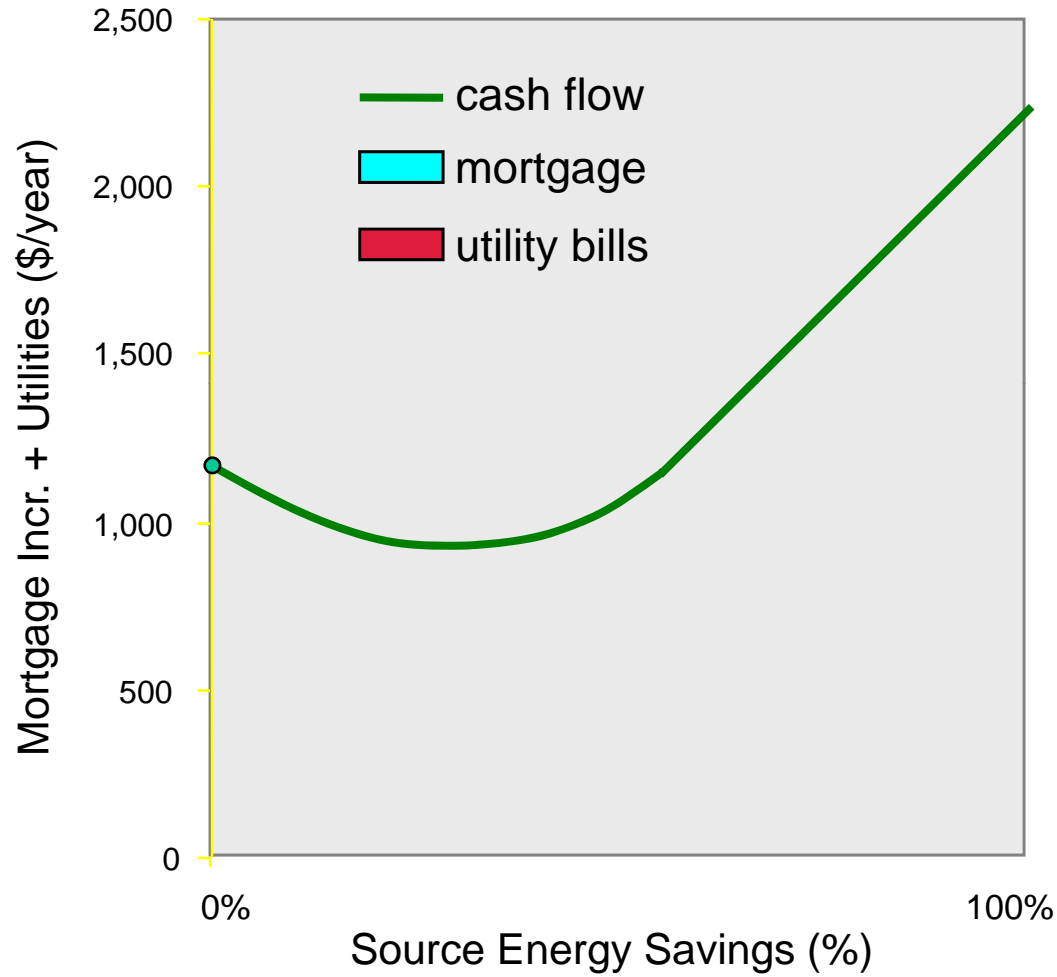
The Path to Zero Net Energy

Finding minimum cashflow
designs at various energy-savings
levels



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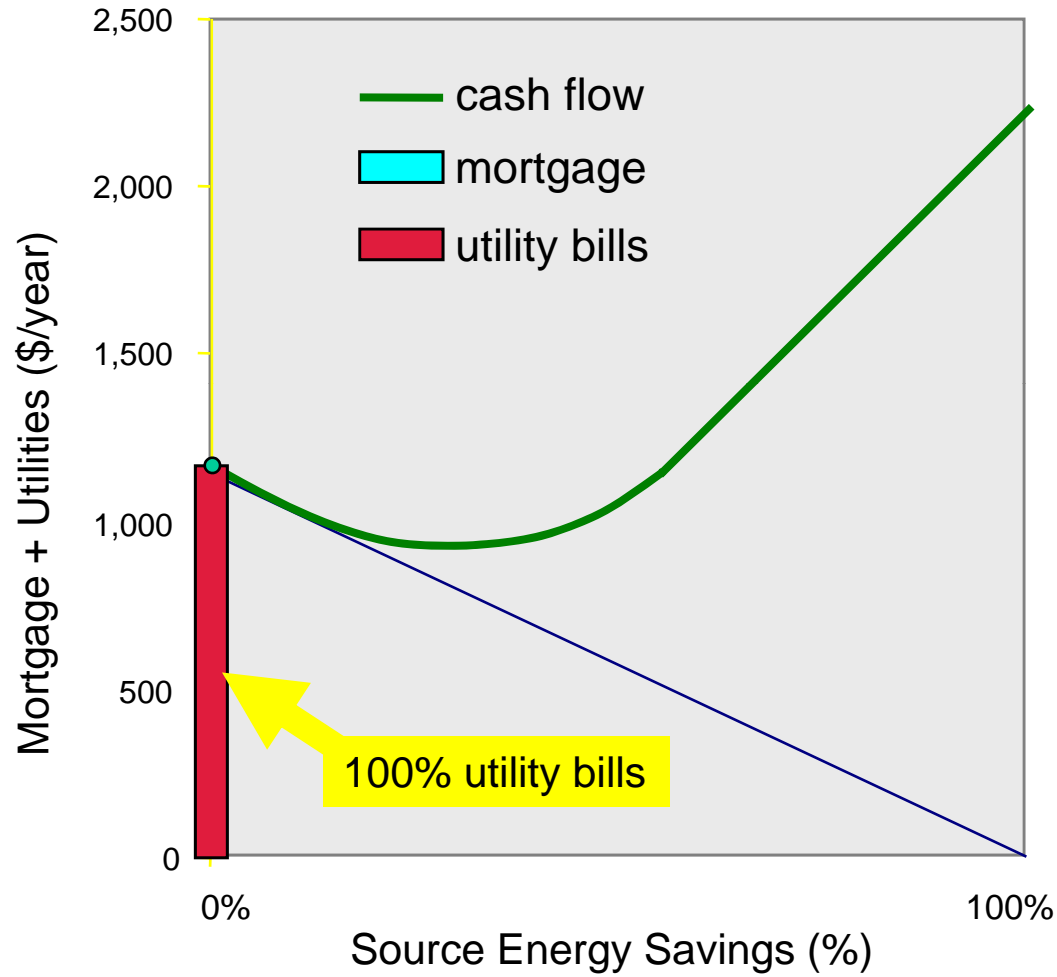
energy-related
cash flow

energy savings
relative to base



U.S. Department of Energy
Energy Efficiency and Renewable Energy

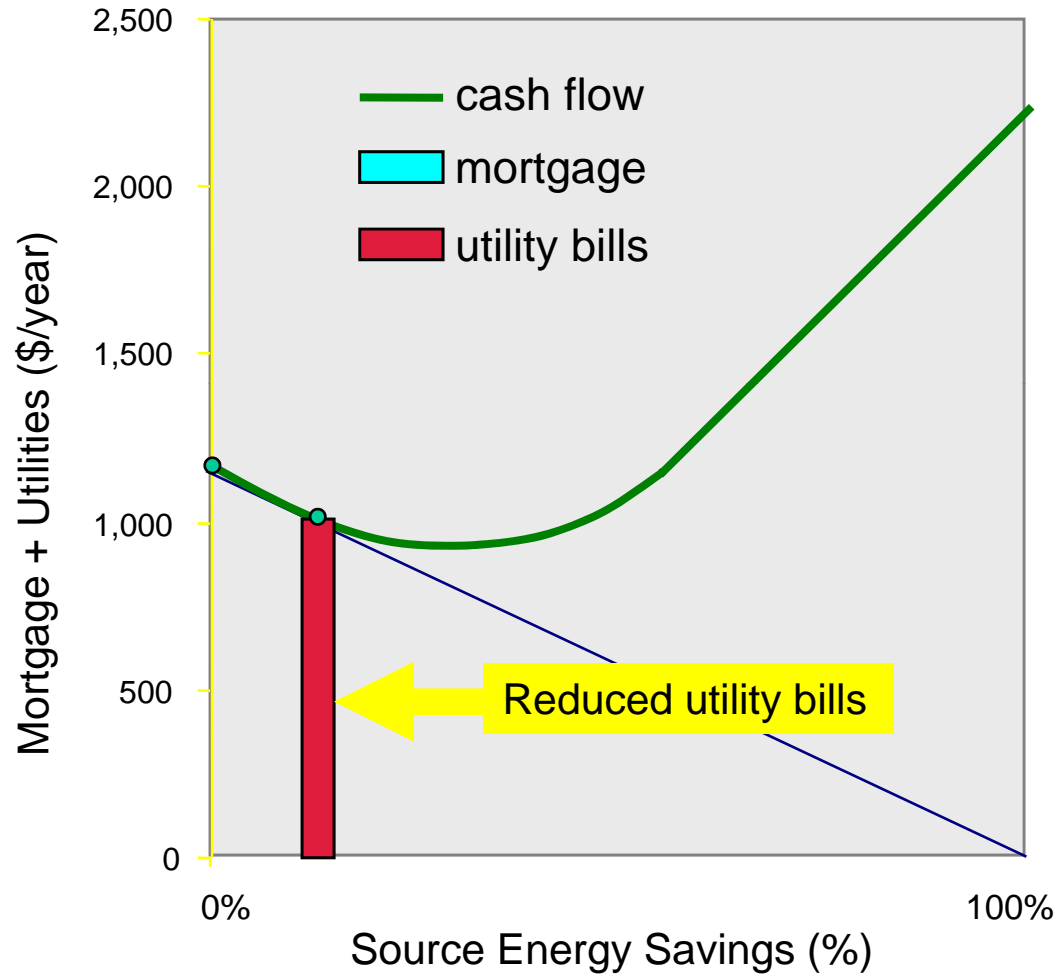
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Building Technologies Program





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Energy Efficiency and Renewable Energy

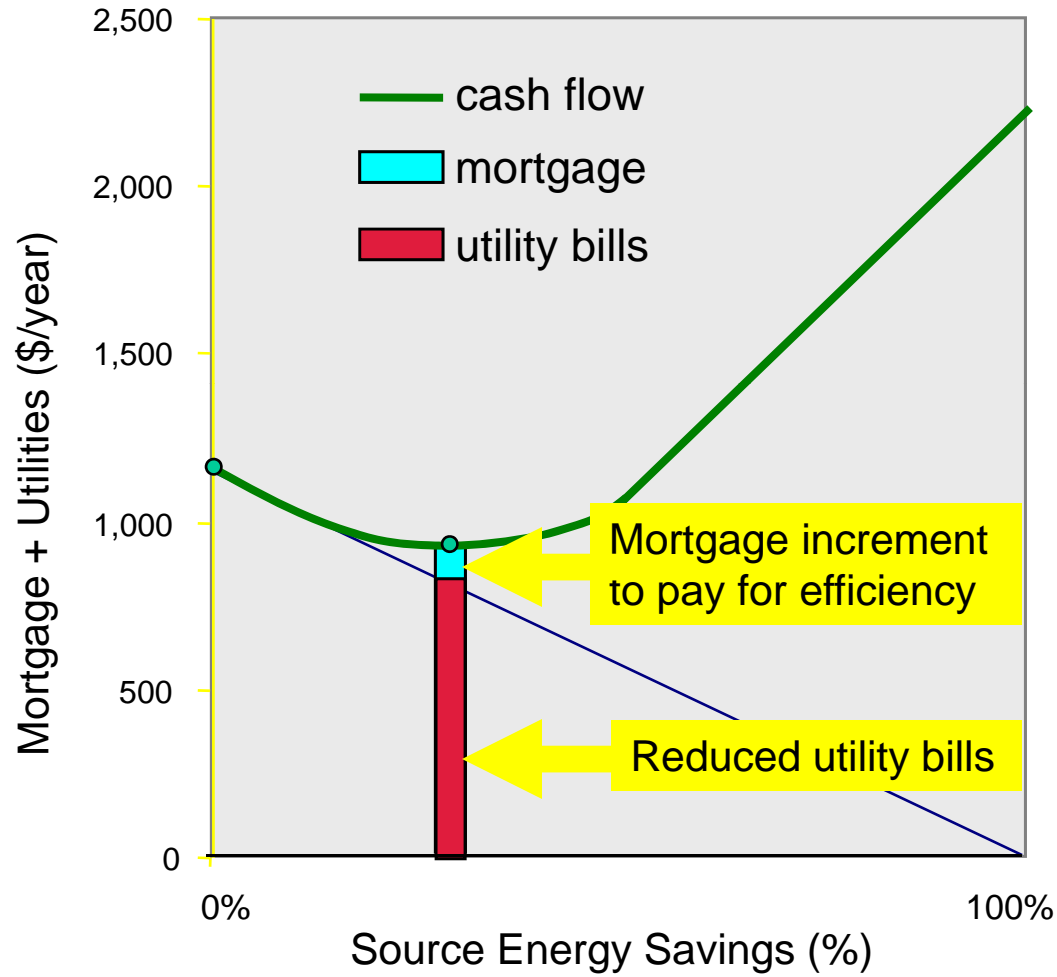
improving your home's energy future where energy is clean, abundant, reliable, and affordable
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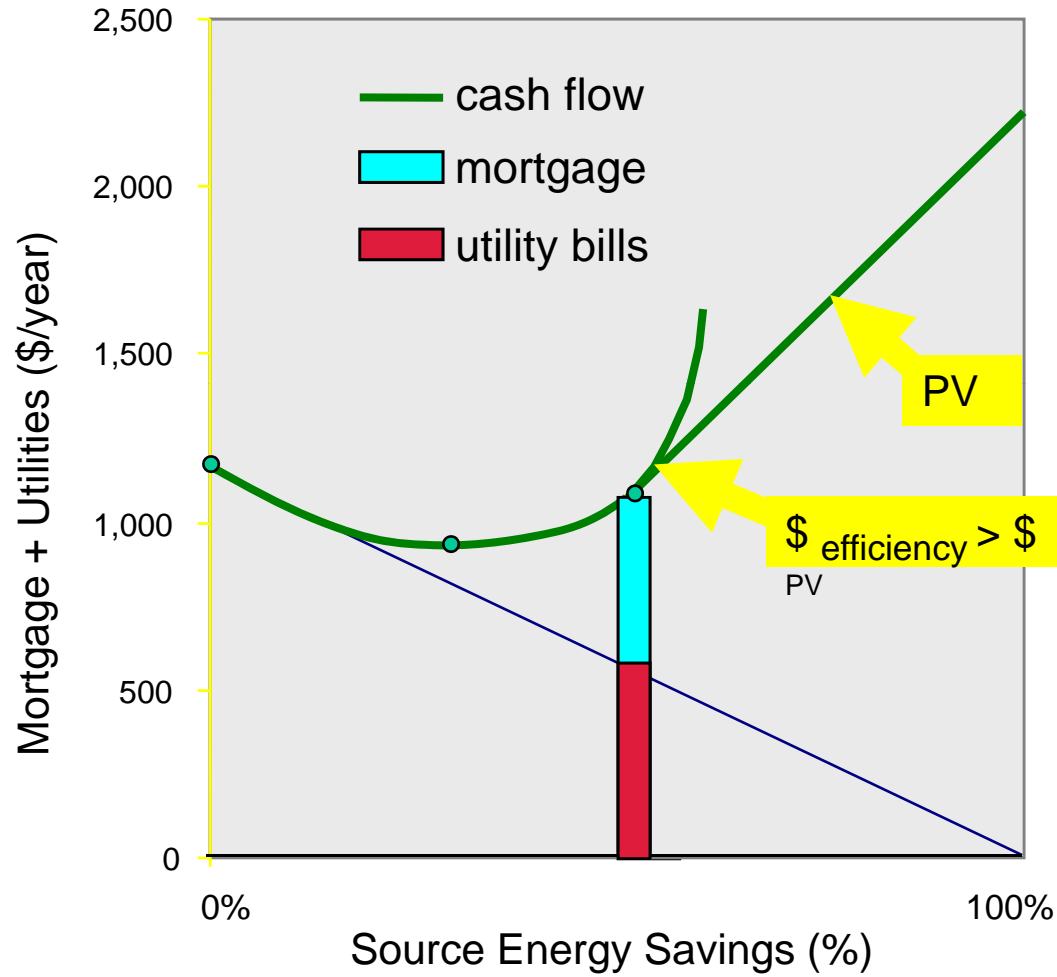


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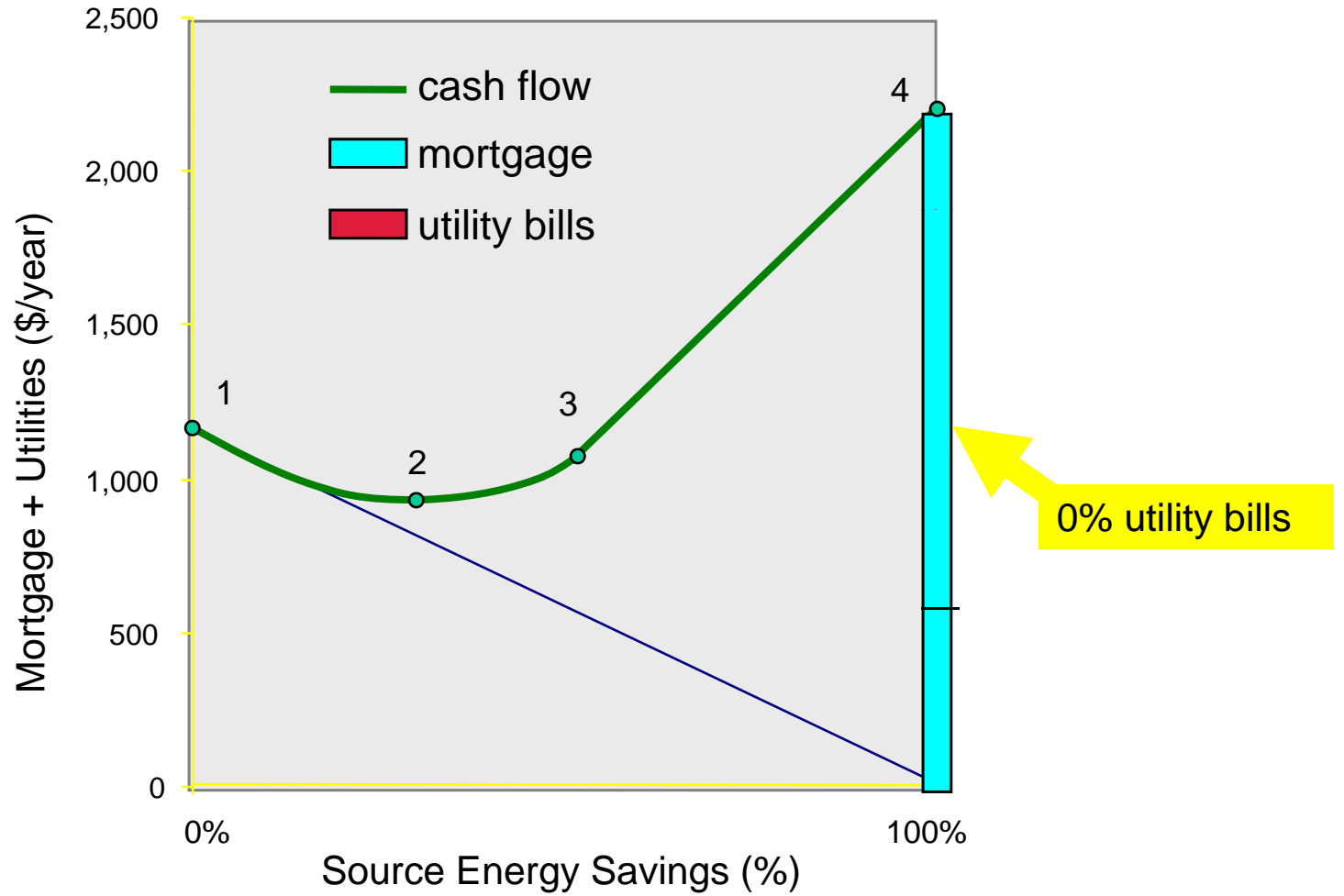


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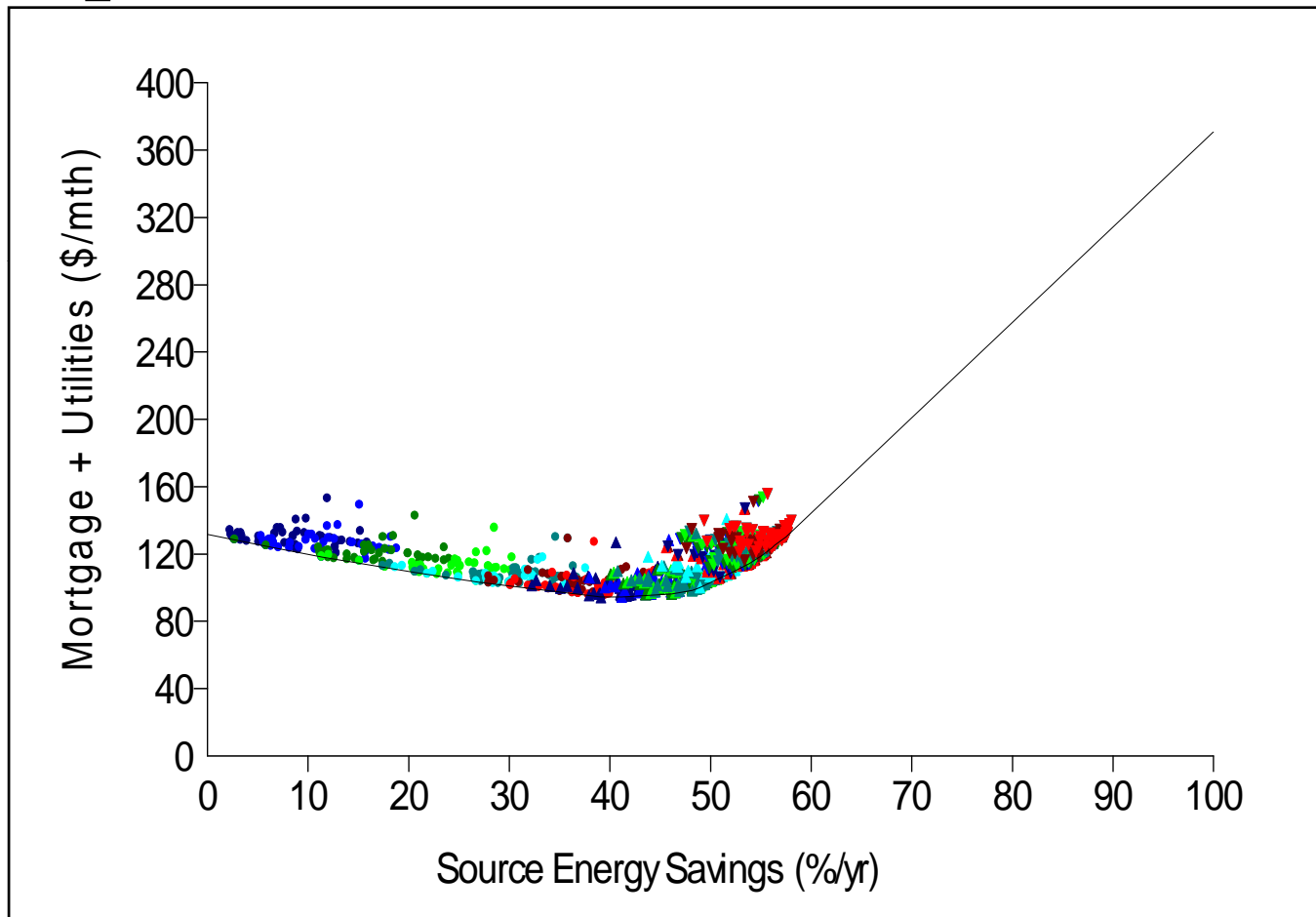


AMERICAN
U.S. Department of Energy
Research Leading to 20% Energy Savings





BEopt “Swoosh”





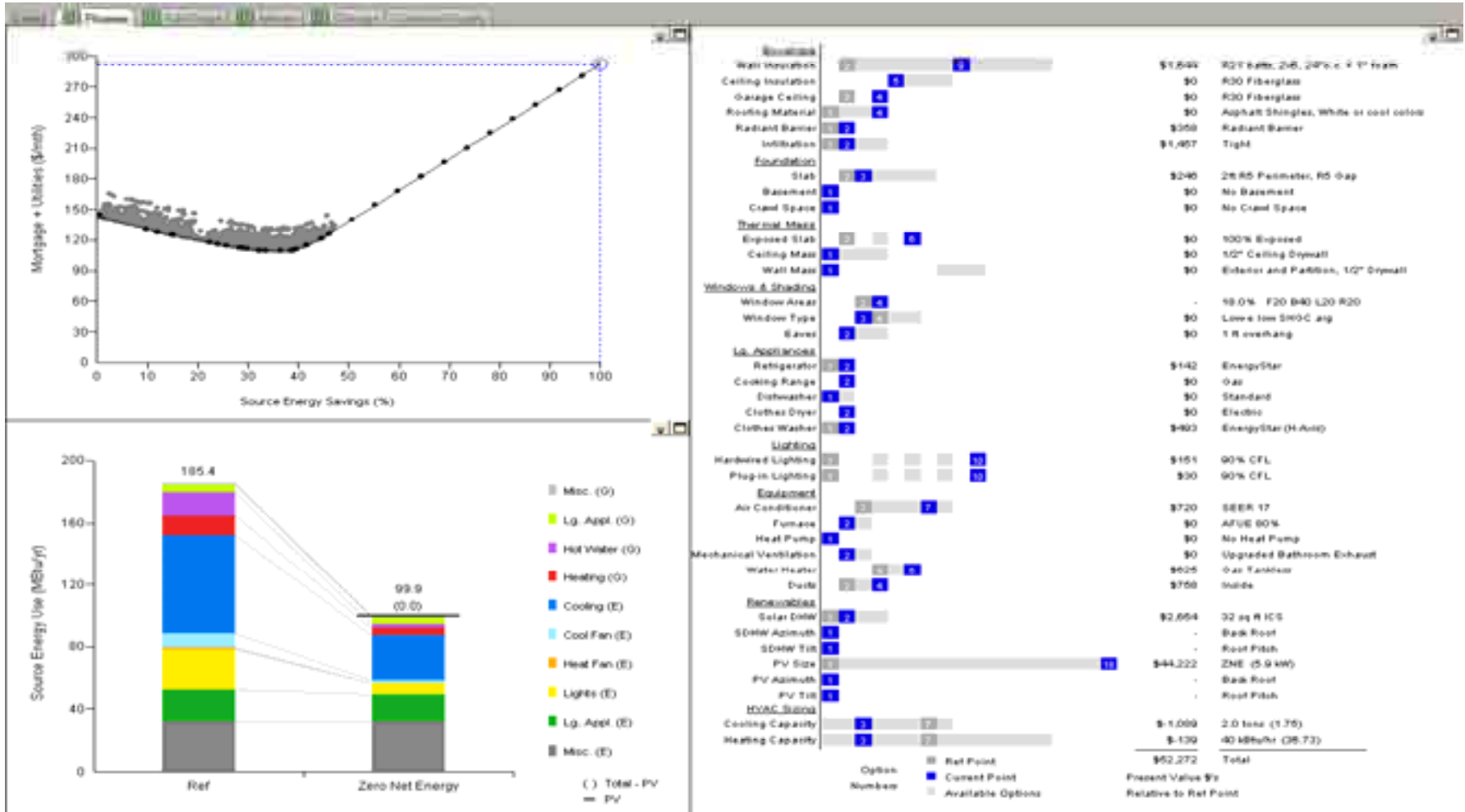
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2009
U.S. Department of Energy
Research Leading to Zero Energy Homes

Results: Phoenix



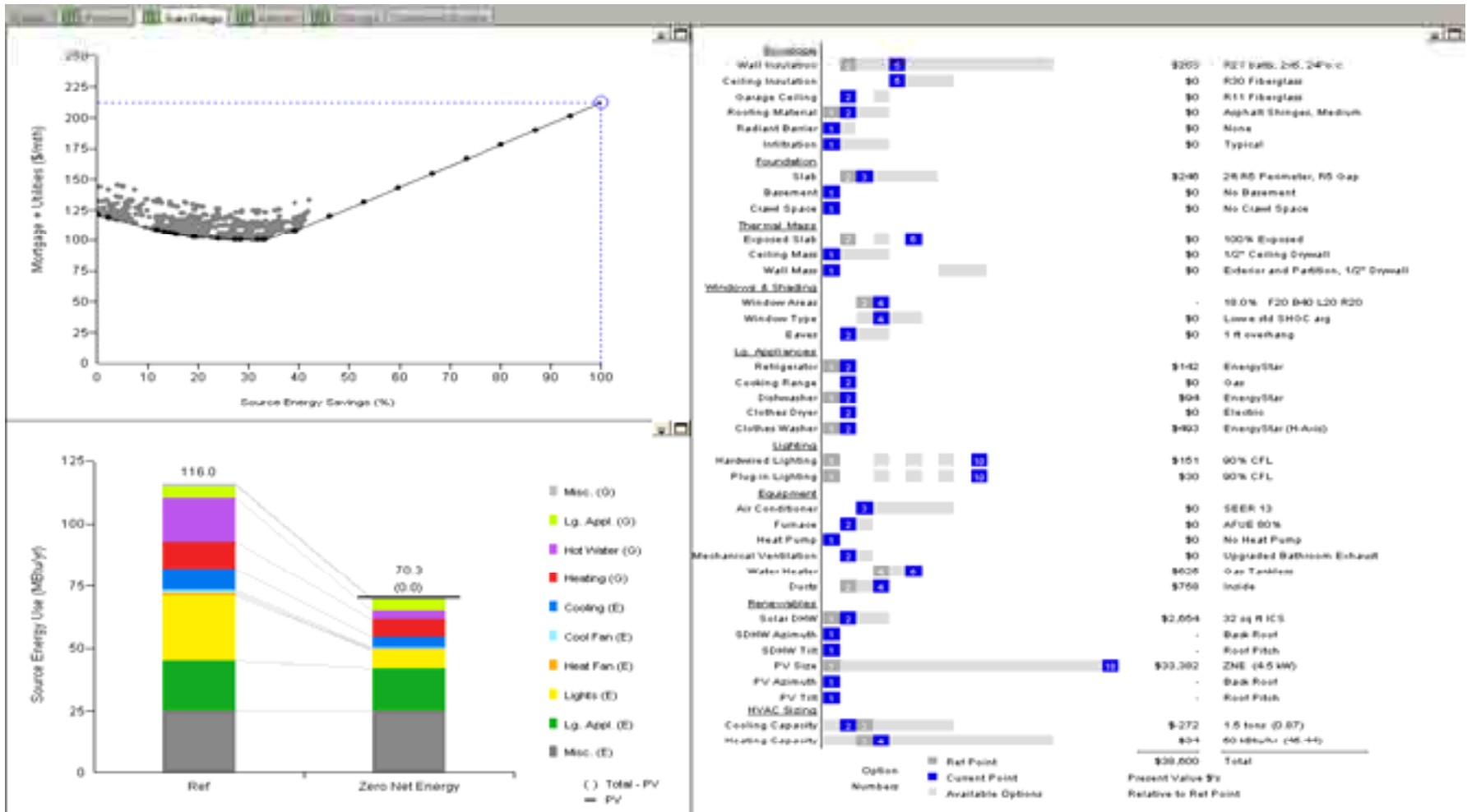


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Results: San Diego



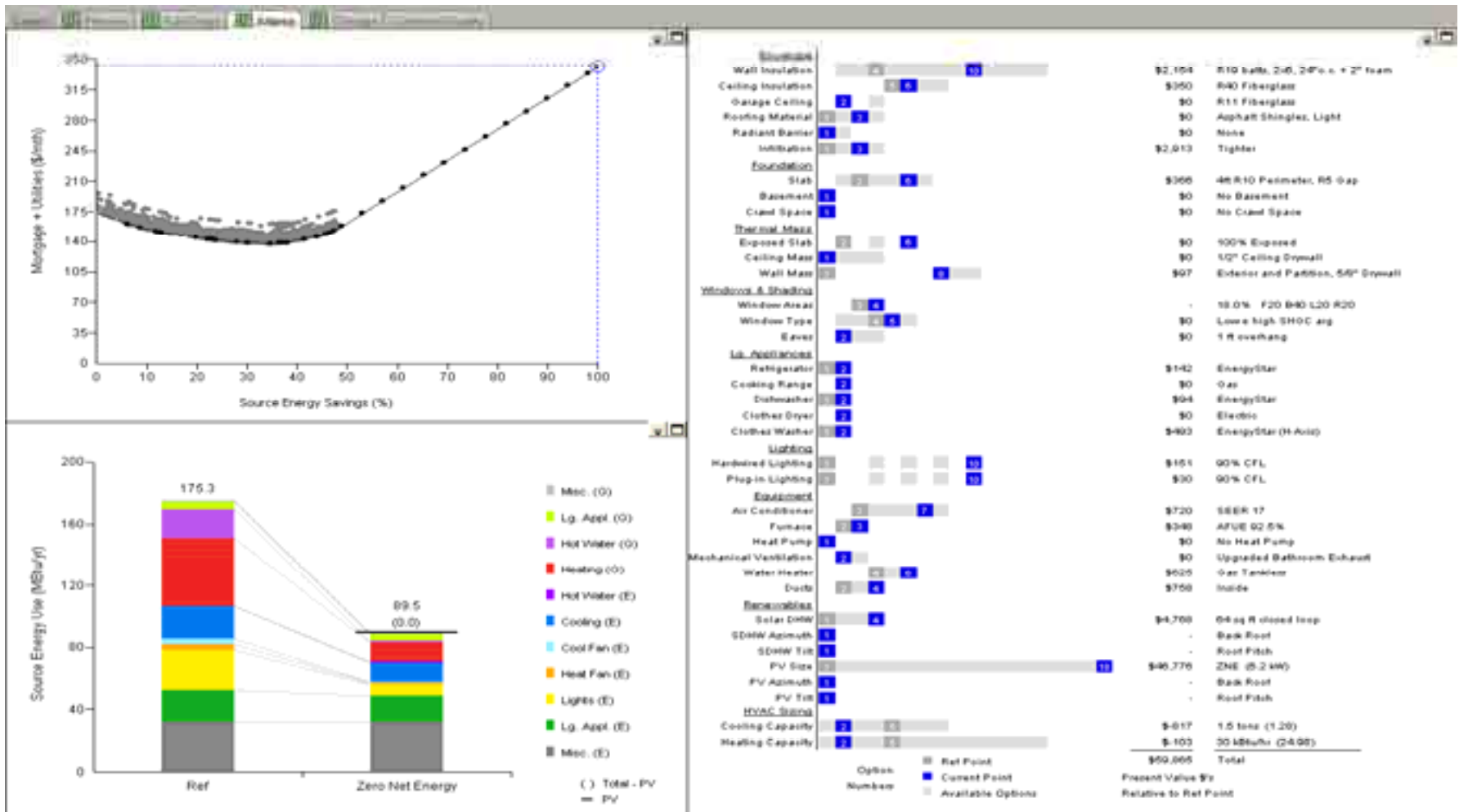


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Results: Atlanta





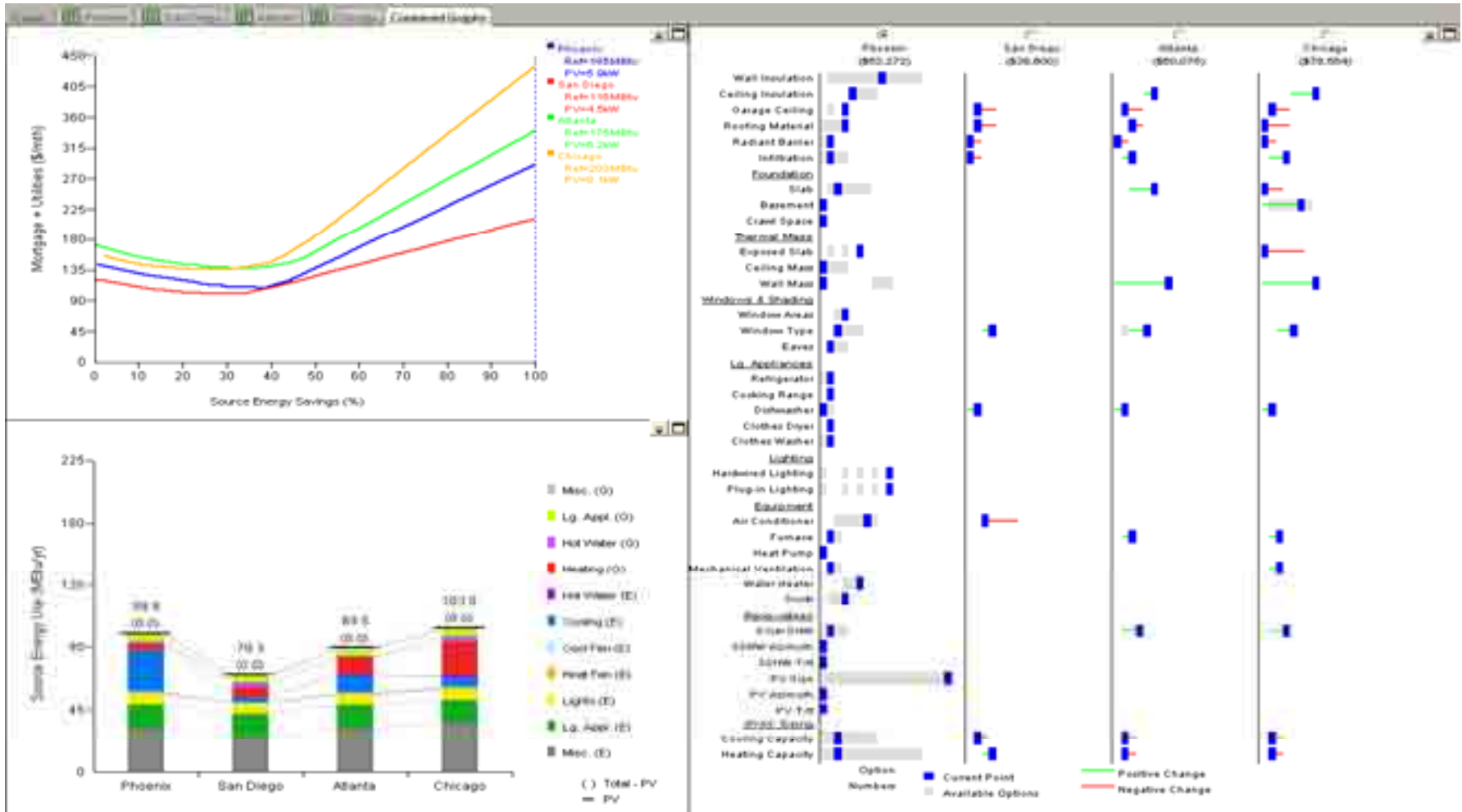
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Research Leading to 20% Energy Savings

Results: All Locations





Savings: Energy & Cash Flow

| | Reference Pt | | Min. Cost Pt | | PV Start Pt | | Break-Even Pt | | ZNE Point | | |
|-----------|------------------------|------------------|-------------------|----------------------------|-------------------|----------------------------|-------------------|----------------------------|-------------------|----------------------------|--------------------------------|
| | Source Energy (MBtu/y) | Cash Flow (\$/y) | Source Energy (%) | Cash ¹ Flow (%) | Source Energy (%) | Cash ¹ Flow (%) | Source Energy (%) | Cash ¹ Flow (%) | Source Energy (%) | Cash ¹ Flow (%) | Array Size (kW _{DC}) |
| Phoenix | 185 | 1700 | 38 | 24 | 46 | 12 | 50 | 0 | 100 | -106 | 5.9 |
| San Diego | 116 | 1450 | 32 | 17 | 40 | 12 | 46 | 0 | 100 | -76 | 4.5 |
| Atlanta | 175 | 2100 | 34 | 21 | 49 | 10 | 53 | 0 | 100 | -95 | 6.2 |
| Chicago | 203 | 1950 | 22 | 15 | 49 | -10 | 43 | 0 | 100 | -169 | 8.1 |



BEopt Summary

- Runs hour-by-hour detailed simulations.
- Evaluates realistic (discrete) options for building efficiency and solar water heating.
- Finds optimal (efficiency, SWH, PV) designs for entire range of energy savings from base case to zero net energy home.
- Identifies near-optimal alternative designs.
- Automatically implements the Building America Benchmark.
- Part of the Building America systems engineering process



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Thank You!



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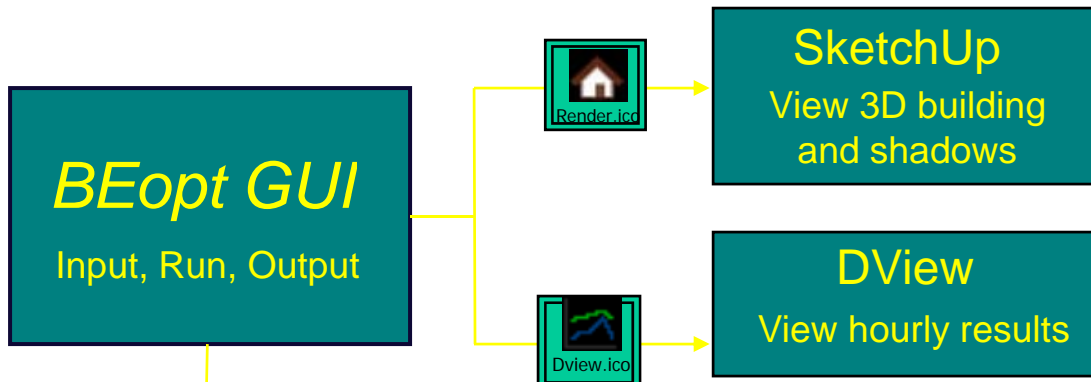


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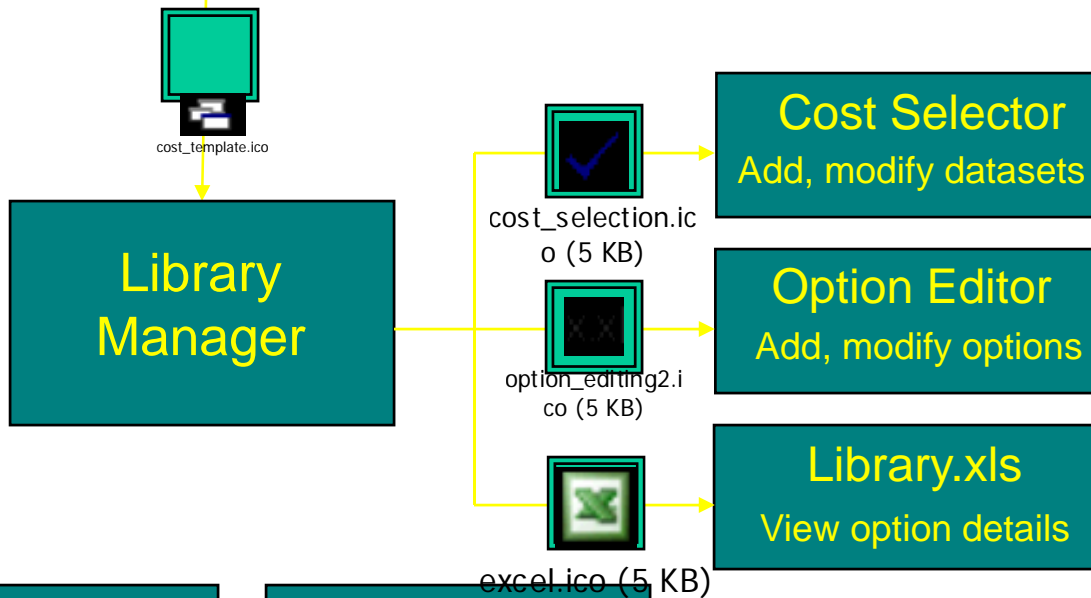
Extra Slides



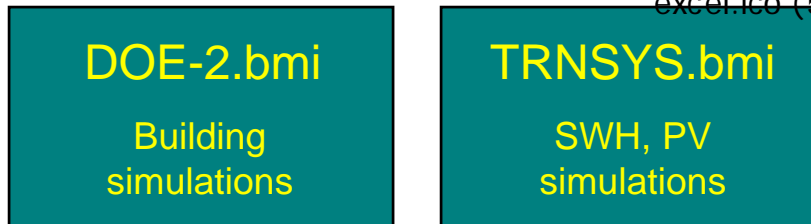
Level 1



Level 2



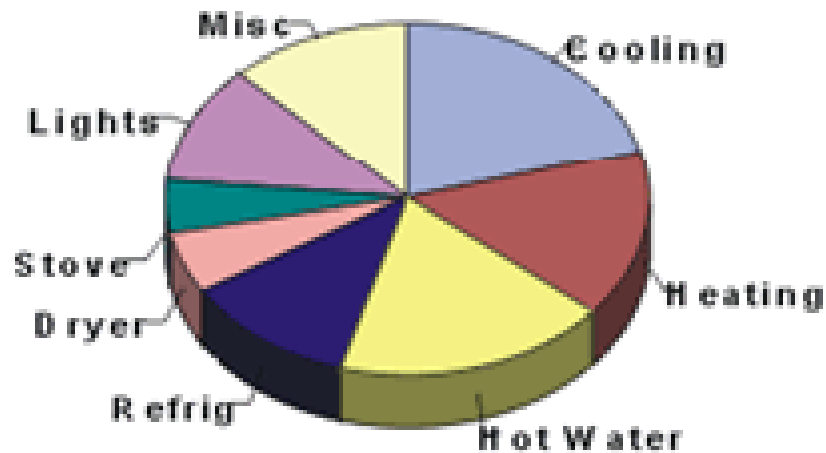
Level 3



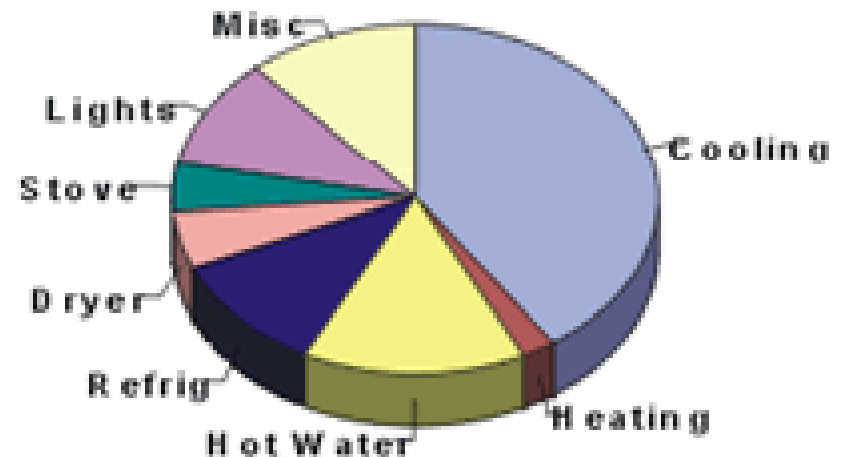


Florida Household Energy Use

**HERS Reference Home
North Florida**



**HERS Reference Home
South Florida**

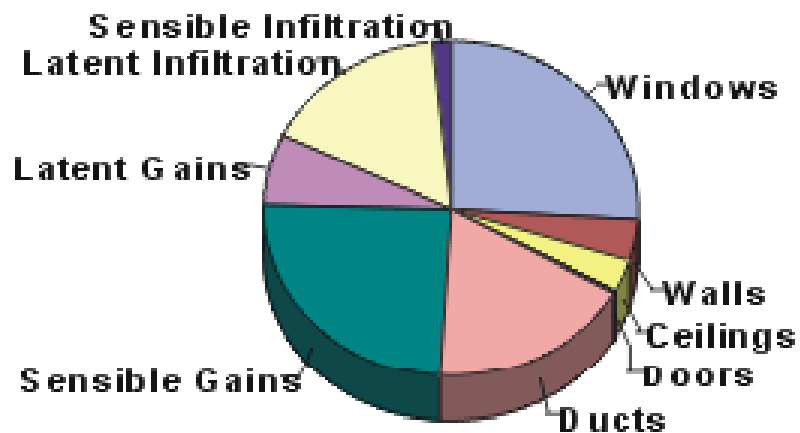


Energy end-use pie charts showing the differences in residential building energy end-uses for north and south Florida climate zones.



Florida Household Energy Use

Cooling Load Sources Central Florida



Heating Load Sources Central Florida



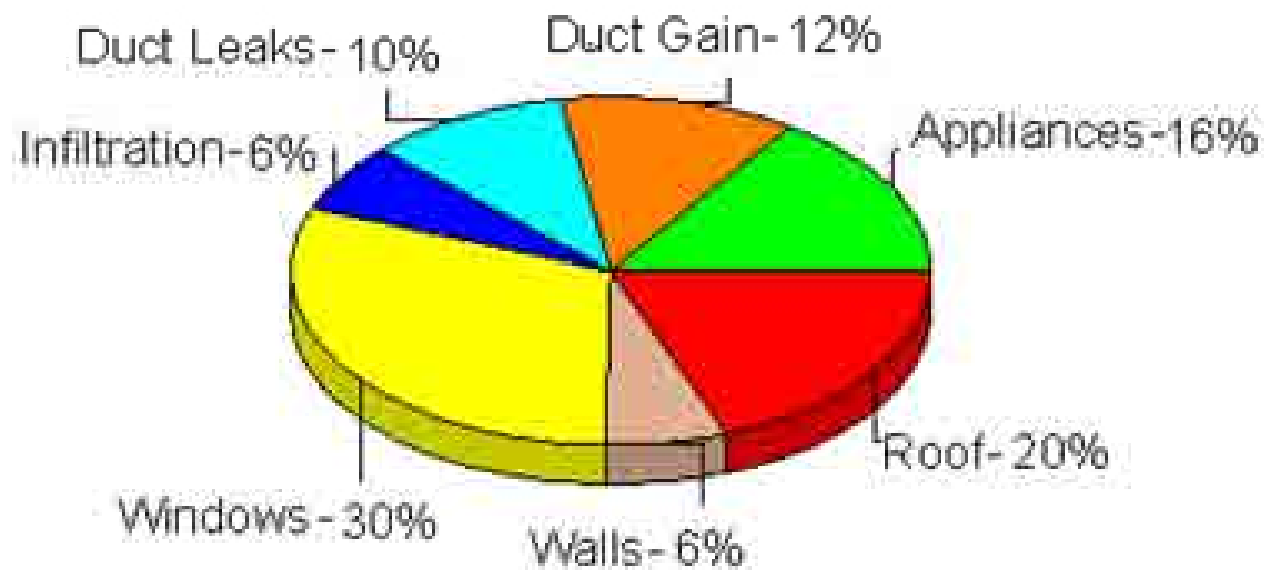
How Can Home Energy Efficiency Be Improved?

Florida Solar Energy Center



Annual Cooling Load Components

Tampa FL, 2000 sqft Residence



Priorities

Florida Solar Energy Center



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Building America - Industrialized Housing Project



FLORIDA SOLAR ENERGY CENTER

A Research Institute of the University of Central Florida

High Performance Housing

Subrato Chandra

Neil Moyer

Jay Fechtel

Karen Childress

SouthEast Building Conference July 14, 2005





Hot & Humid Design Strategies

Manage the Water

- Keep liquid water out of building
- Control water vapor

Manage the Air

- Produce dry air inside the building
- Direction of air flow (positive pressure)
- Control contaminants

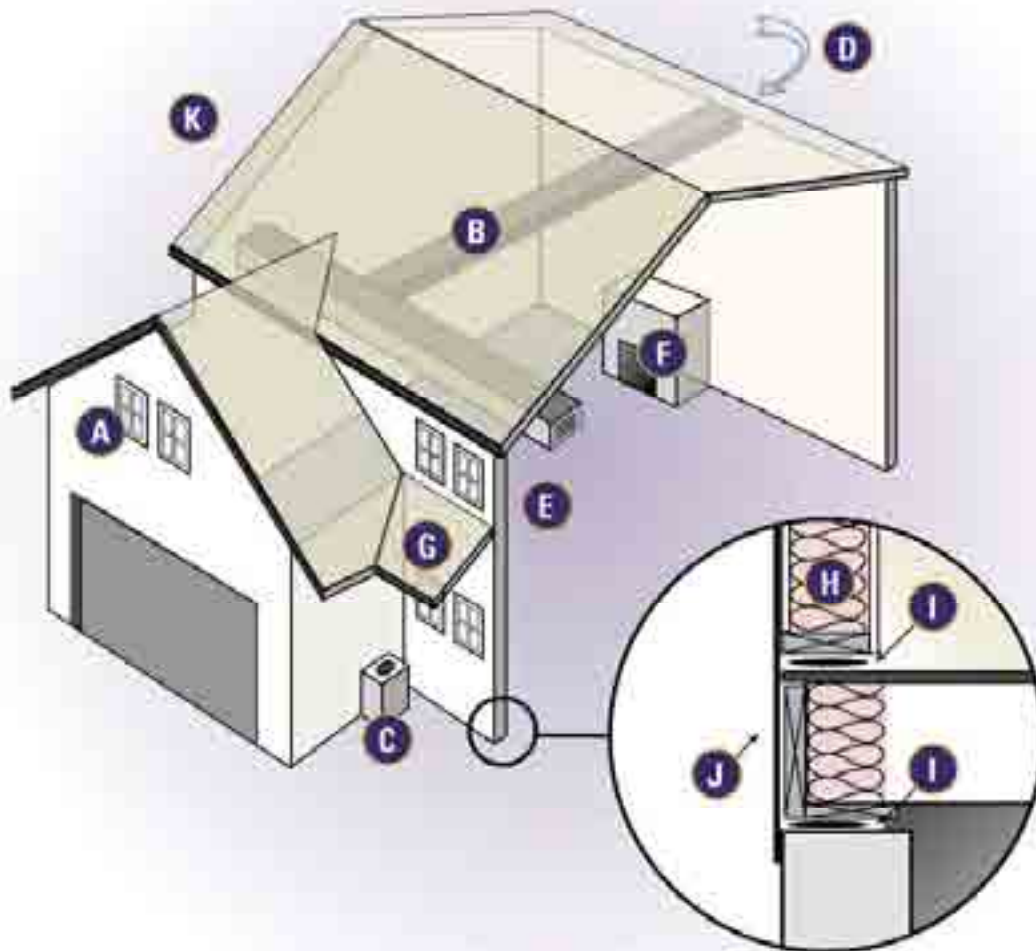
Manage the Heat (Energy)

- Building envelope
- Windows & lighting
- Heating, Cooling & Ventilation systems
- Parasitic loads
- Alternate energy sources
- Testing & Commissioning





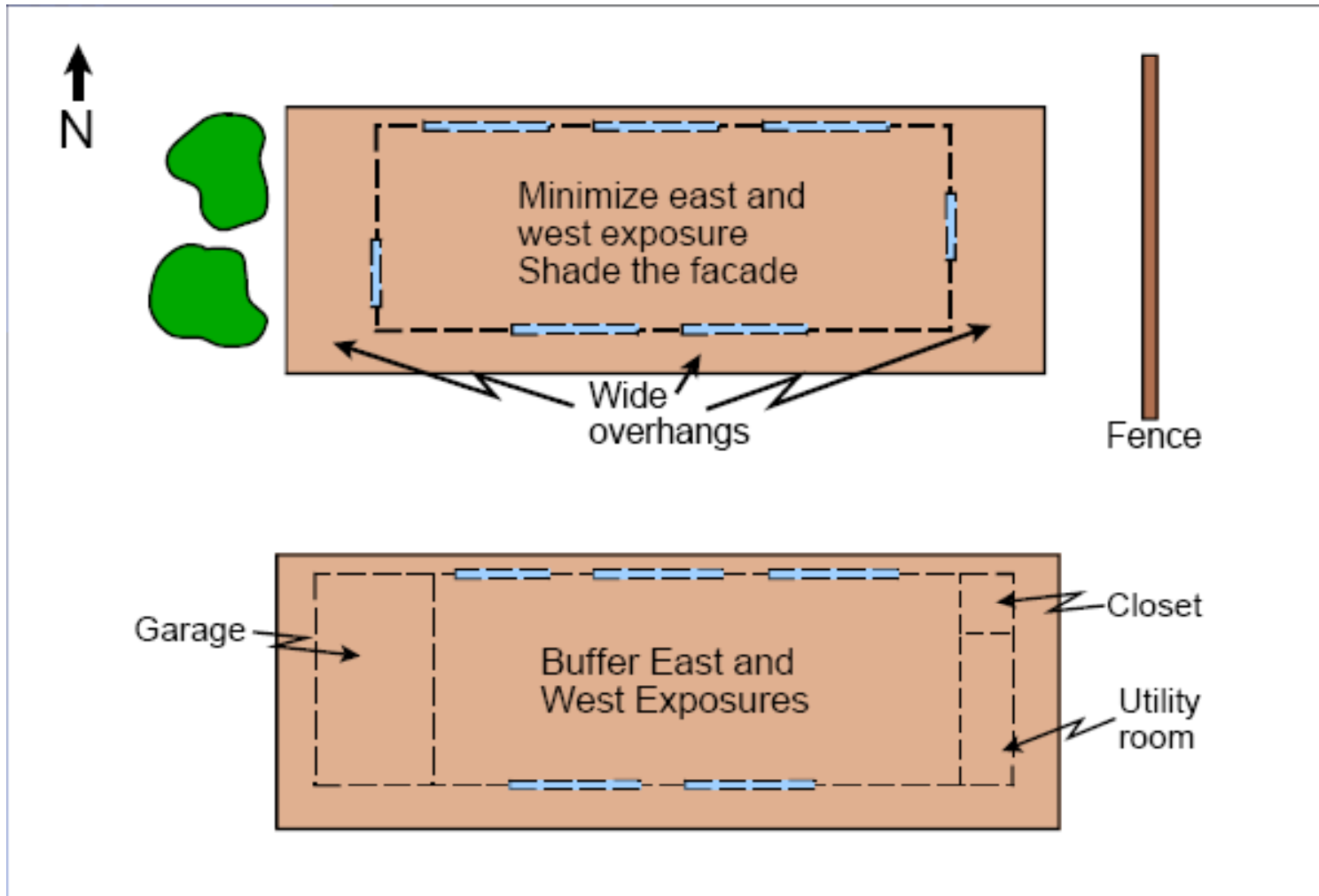
Hot & Humid Design Features



- A. Efficient Windows
- B. Compact and Tightly Sealed Duct Runs
- C. Right-Sized and High-Efficiency HVAC Equipment
- D. Ventilation
- E. Dehumidifier
- F. Sealed Combustion Appliances
- G. Overhangs
- H. Insulation
- I. Air Sealing
- J. Well-Designed Moisture Barriers
- K. Building System



Window Orientation and Shading





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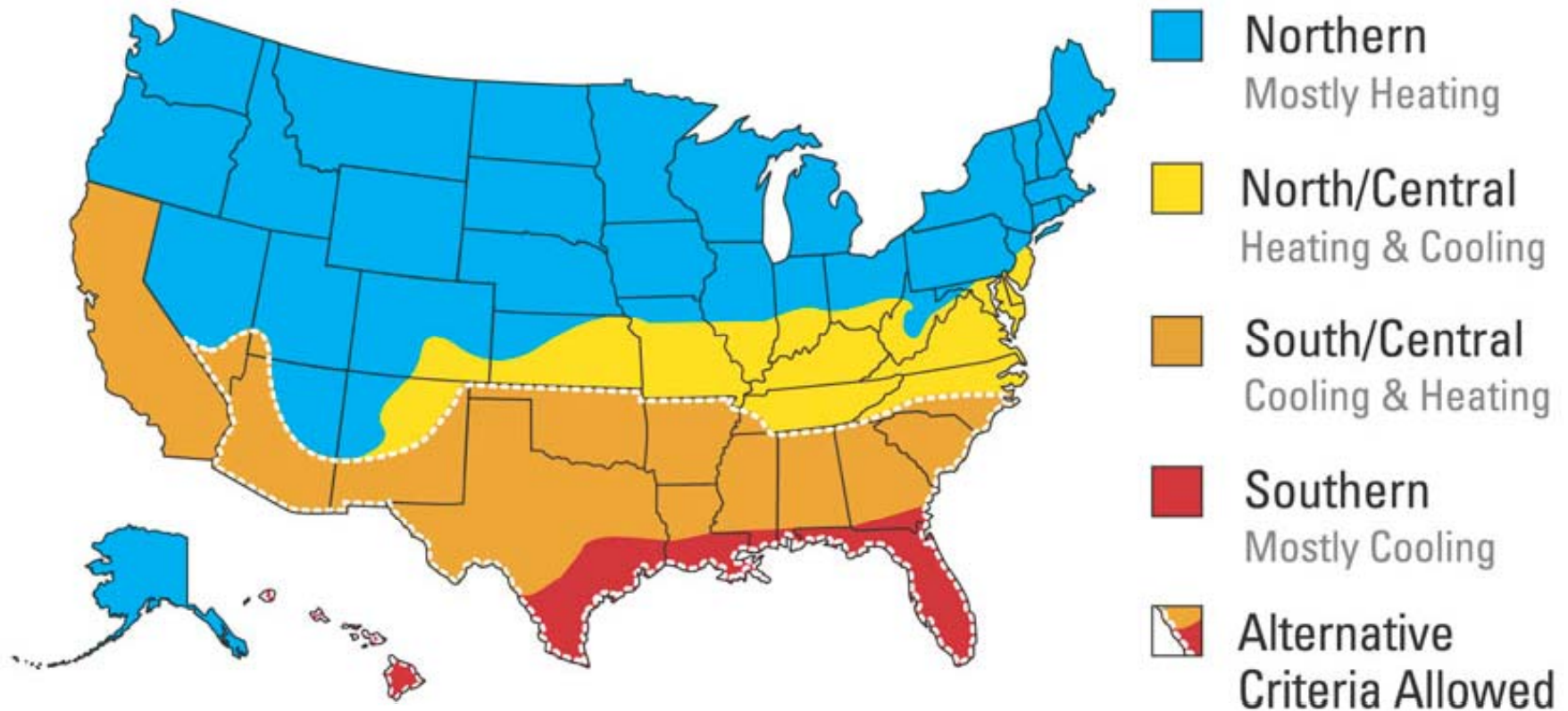
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ENERGY STAR Windows Climate Zone Map





Energy Efficient Design Features

- **HVAC System**
 - Right sized 2-speed high SEER (15+) heat pump with variable speed blower
 - Airtight tested ducts w/ returns. Keep ductwork within the conditioned space wherever possible
 - Air Handler Unit in conditioned space
 - Positive Pressure ventilation
 - Programmable thermostat
 - Zoned HVAC system
- **Water Heating/Appliances**
 - Solar water heater
 - EnergyStar Refrigerator and Dishwasher
 - Pilotless gas oven and cooktop or solid disk, radiant, or induction elements cook top



Energy Efficient Design Features

- **Lighting**
 - Energy Star labeled fixtures and use of compact fluorescent bulbs
 - Closet light switches on built-in timers
 - Light colored interior surfaces
- **Fans and Fireplaces**
 - EnergyStar ceiling fans
 - EnergyStar kitchen exhaust fans
 - Exhaust fans vented to the outside
 - Low-sone EnergyStar bath fans with timers or humidistats
 - Direct-vented fireplace with a fresh air intake



[Building America - Industrialized Housing Project](#)



U.S. DOE Secretary Samuel Bodman Announces Builders Challenge at the 2008 International Builders Show (IBS)



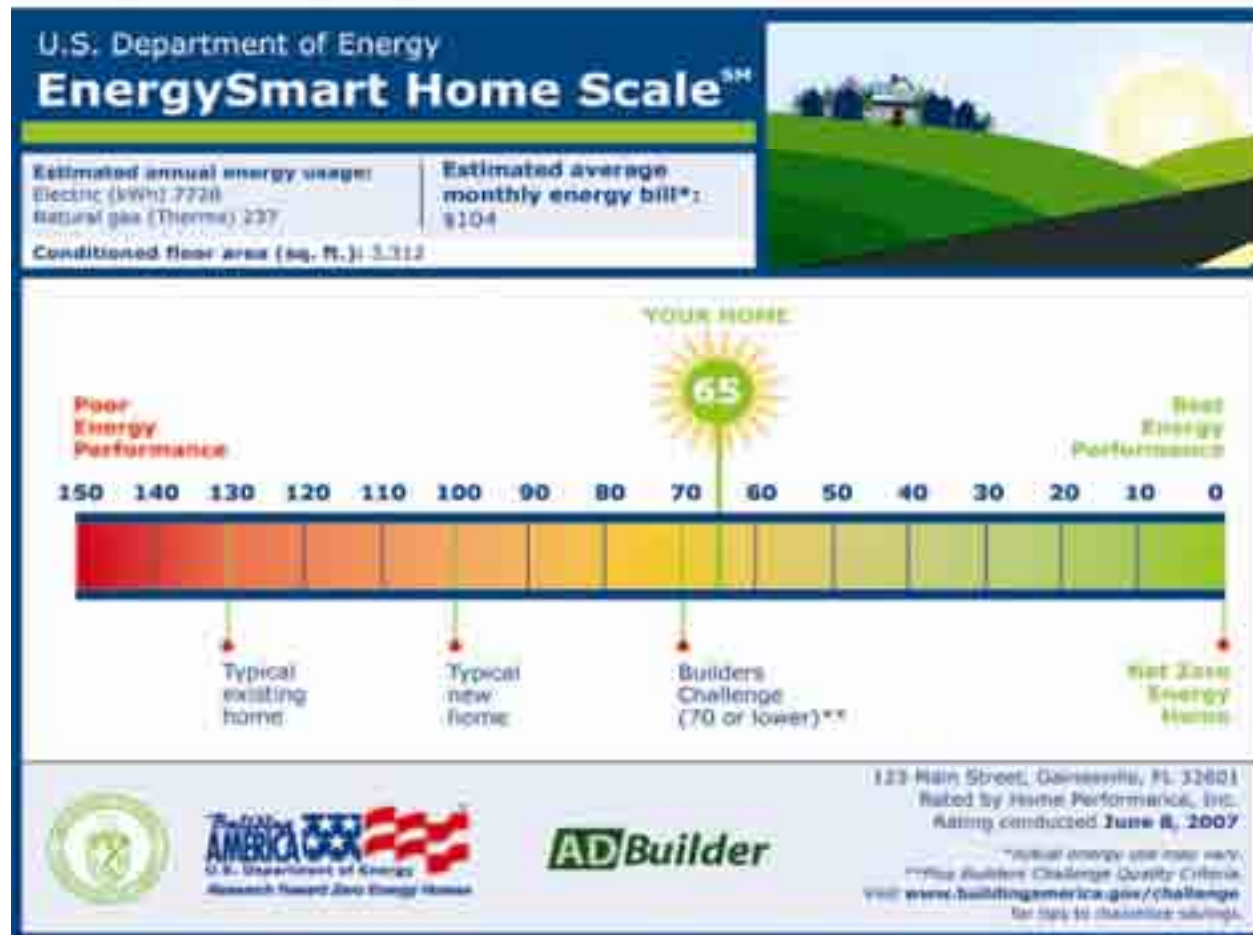
Secretary Bodman posts the first E-Scale on the Palm Harbor Green Home in the Professional Builder Show Village at the International Builders Show.

NAHB's Bob Jones shakes the Secretary's hand and helps to launch the Builders Challenge.

February 14, 2008, Orlando , FL – U.S. DOE Secretary Bodman posed a challenge to the homebuilding industry – to build 220,000 high performance homes by 2012.

Homes that qualify for the Builders Challenge must be between 70 and 0 on the EnergySmart Home Scale (E-Scale) **and meet the Builders Challenge Quality Criteria.**





The E-Scale allows homebuyers to understand – at a glance – how the energy performance of a particular home compares with others.

Builders may place the E-Scale on or near the home's electric panel to show potential homeowners the energy performance achieved by that particular home or model. Participating builders and partner organizations can also:

- Place their logo on the E-Scale label with program or product names
- Augment the rating with estimates of annual energy cost savings – which may help homebuyers get better mortgage terms
- **Include estimates of the carbon footprint associated with the energy rating**



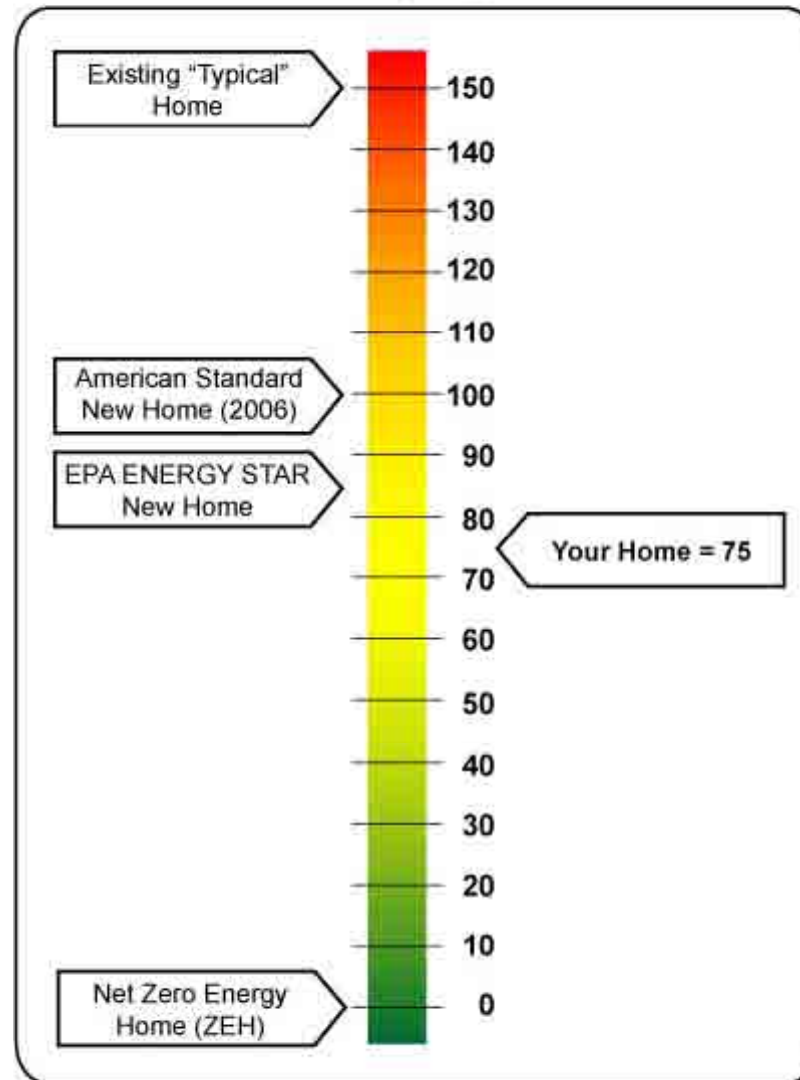


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HERS Index





Building Energy Analysis

- Florida Solar Energy Center
 - Energy Gauge



EnergyGauge - Energy and Economic Analysis Software

- Energy Code calculations and compliance reports
- Building Energy Ratings and Rating reports
- Economic analysis of building energy improvements

And for Pro versions, *EnergyGauge USA* software provides the following additional features:

- **State-by-state pollution analysis reports for SO_x, NO_x, and CO₂**



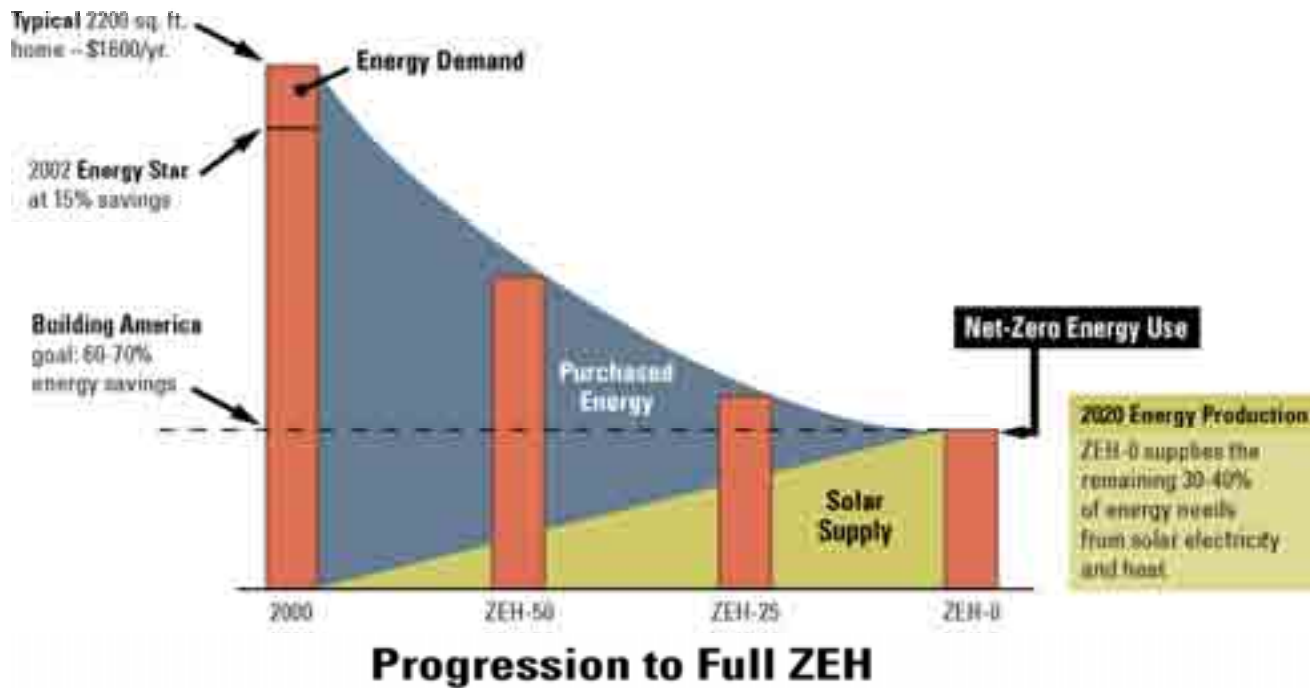
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The Affordability Factor

NAHB-RC national survey (February 2006) shows 82% consumer acceptance of ZEH when energy savings offset mortgage increase



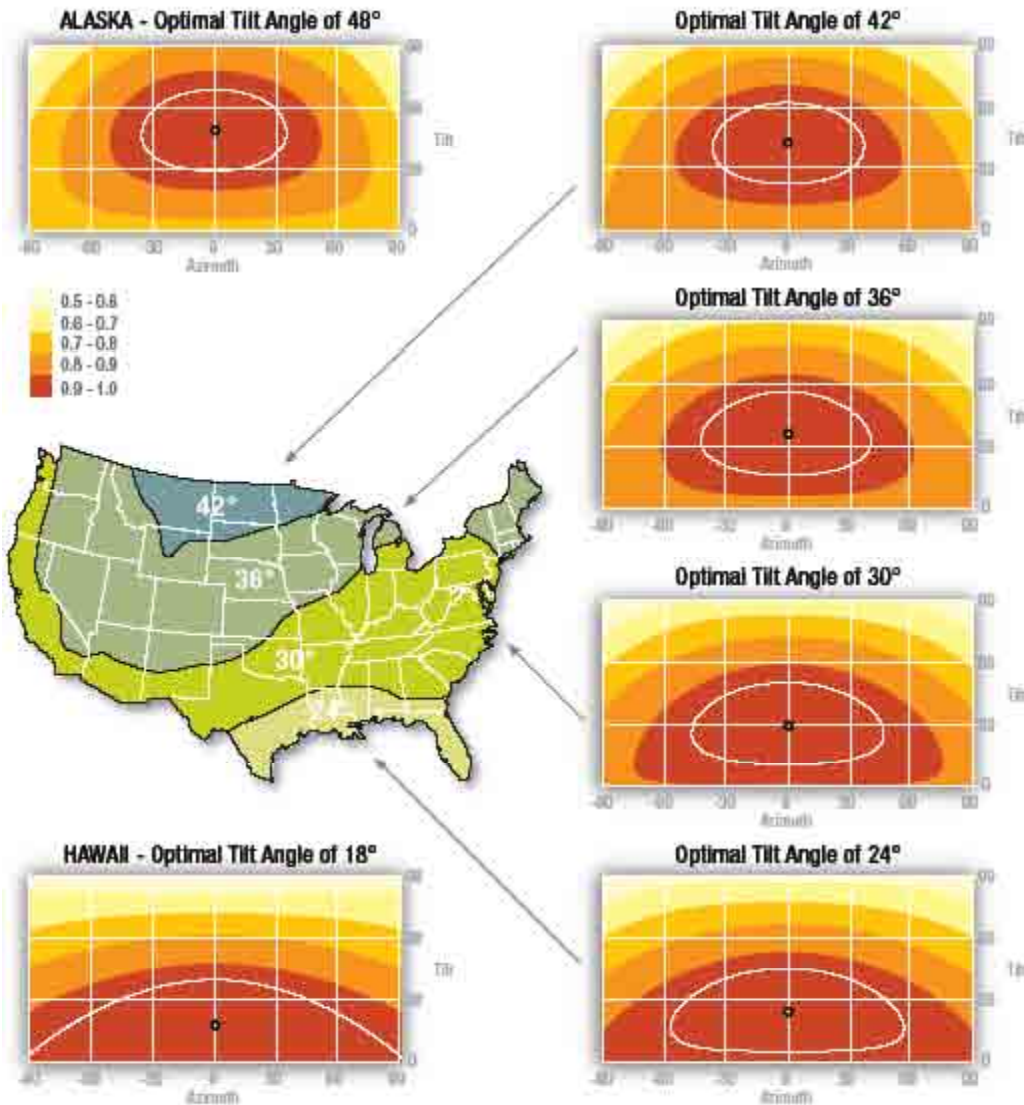


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Optimal Tilt Angle and Orientation for Solar Panels



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Zero Energy Homes



**Tim Merrigan, National Renewable Energy Laboratory
Presentation to the 2002 Southeast Building Conference
July 27, 2002**



SheaHomes



- First major production home builder in U.S. to build today's ZEHs as standard in a community
 - 306 homes sold out one year earlier
 - Homes appreciated faster than comparison homes
 - More profitable to offer as standard than as option
- Shea Home Features
 - Homes 38% more efficient than California's Title 24
 - All have 1.5 kW solar water heaters
 - 120 have 1.2 kW or 2.4 kW solar electric systems



Professional Builder (February 2001)

**Professional
Builder**

Shea to build 100 Solar Homes

"My intent was to make this the most energy efficient and largest production project that generated its own energy in the United States," says Ryan Green, Community Development Manager for Shea.





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Research Laboratory for Efficient Energy Systems

The Anatomy of High Performance by SheaHomes





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Comparison Home





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Scripps Highlands – San Angelo
Shea Homes (California)



Average Sales Prices

| Home Size Categories | SheaHomes (n= 306) | Comparison Homes (n= 101) |
|---|-------------------------------|--------------------------------------|
| $\leq 2,600 \text{ ft}^2$ | \$536,246 | \$567,471 |
| 2,601 – 3,002 ft^2 | \$590,373 | \$621,289 |
| 3,003 – 3,300 ft^2 | \$607,166 | \$627,653 |
| 3,301 – 3,376 ft^2 | \$630,091 | \$679,755 |



Property Value Appreciation

| Variable | SheaHomes | Comparison |
|---|------------------|-------------------|
| Length of ownership (range) | 9.9 – 43.9 mos. | 17 – 40.2 mos. |
| Mean length of ownership before resale | 22.5 mos. | 28.1 mos. |
| Mean \$ gain | \$306,510 | \$262,968 |
| Mean % of \$ gain | 55.4% | 44.7% |
| Mean \$ gain/month owned | \$14,492 | \$9,301 |



Original & Resale Prices

| Community | Original Price | Resale Price |
|---|--|--|
| Shea Homes (n = 15) | Range: \$483K-\$701K Mean \$556,344 | Range: \$680K-\$1.1M Mean \$862,853 |
| Comparison Community (n = 12) | Range: \$538K-\$711K Mean \$598,028 | Range: \$760K-\$995K Mean \$862,590 |



Types and Sources of Data

Three types of data were collected:

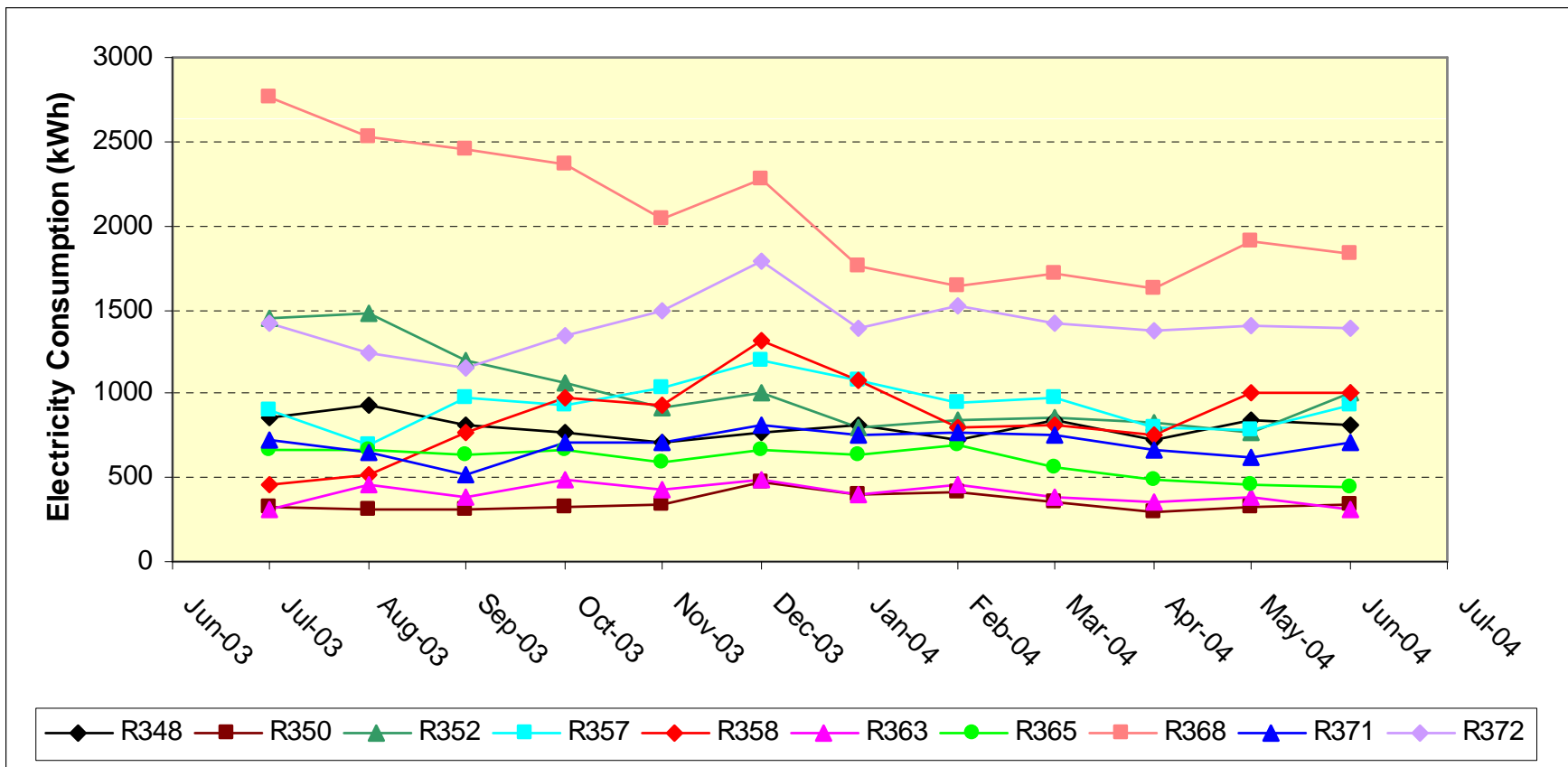
- Contextual data
- Household and homeowner data
- Utility data

Utility data for 132 homes were collected on

- Therm usage and costs
- kWh usage and costs
- Monthly combined utility costs

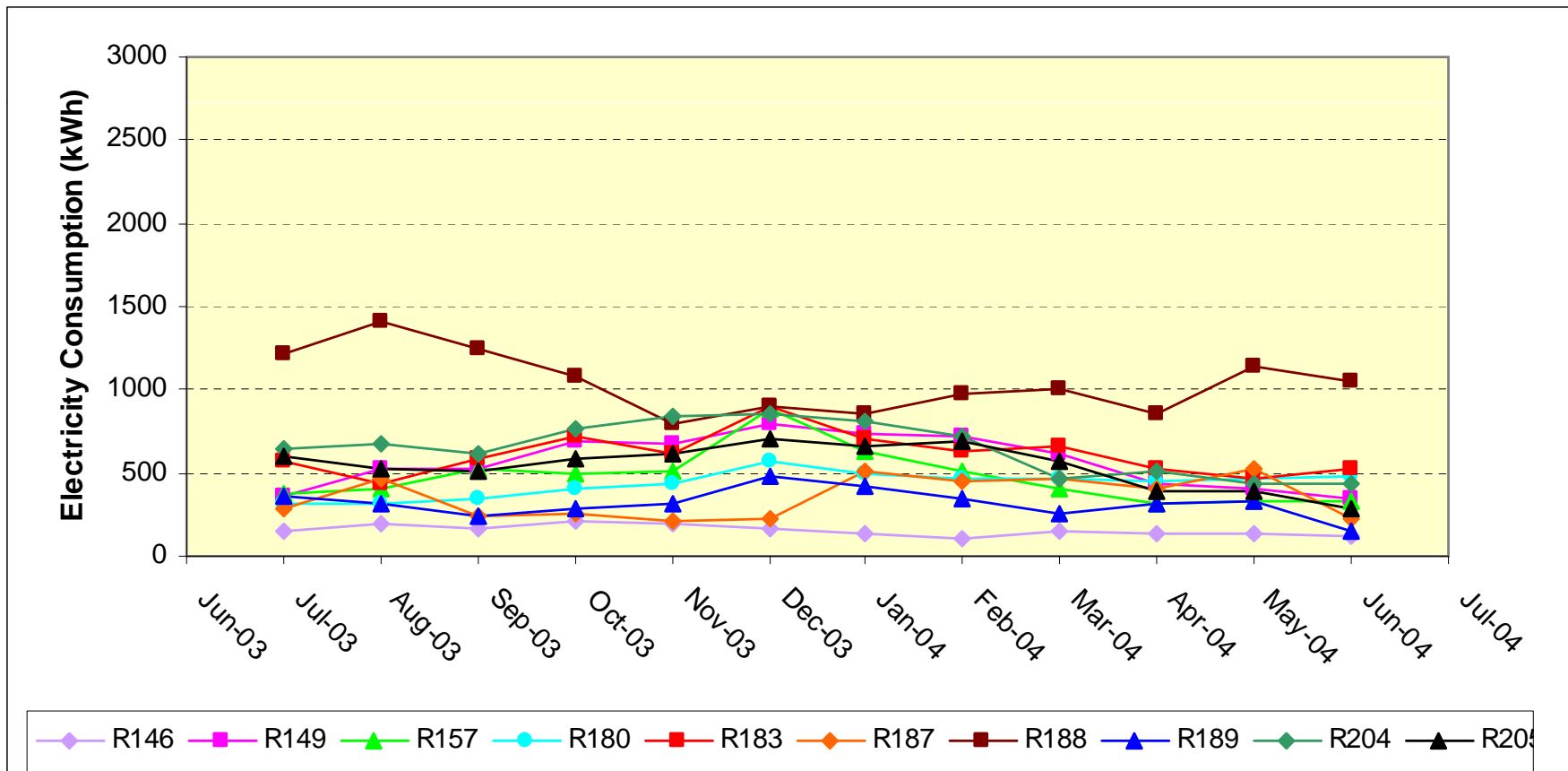


Monthly Electricity Consumption in 10 Individual Comparison Homes





Monthly Electricity Consumption in 10 Individual Shea Homes (w/PV)





Bill Savings vs. Comparison Homes **(Actual Gas & Electric Utility Bills)**

| Home Category | Avg. Monthly Bill | % Savings |
|--|--------------------------|------------------|
| Comparison homes | \$174 | NA |
| Shea energy efficiency & solar water heating (SEE) | \$149 | 14% |
| Shea SEE + 1.2 kW PV | \$123 | 29% |
| Shea SEE + 2.4 kW PV | \$ 80 | 54% |



Combined Annual Utility Bills

| Home Category | Avg. Annual Total Utility Bill | % Savings |
|----------------------|---------------------------------------|------------------|
| Comparison homes | \$2,080 | NA |
| Shea SEE + 2.4 kW PV | \$ 961 | 54% |



SheaHomes ZEH Summary

- SheaHomes showed that homebuyers will buy highly energy efficient homes with solar electric & solar water heating systems
- SheaHomes sold for less than the comparison homes – even with the ZEH upgrades
- SheaHomes buyers had greater price appreciation than the comparison community upon resale
- Today's ZEH, i.e. cutting utility bills 40-60% sells very well for homebuilders



ZEH (Standard by 2020)

- “The standards (ZEH) would be required for new residential construction projects starting in 2020 and commercial construction projects starting in 2030” Proposed by the California Public Utilities Commission, Sep 17, 2007