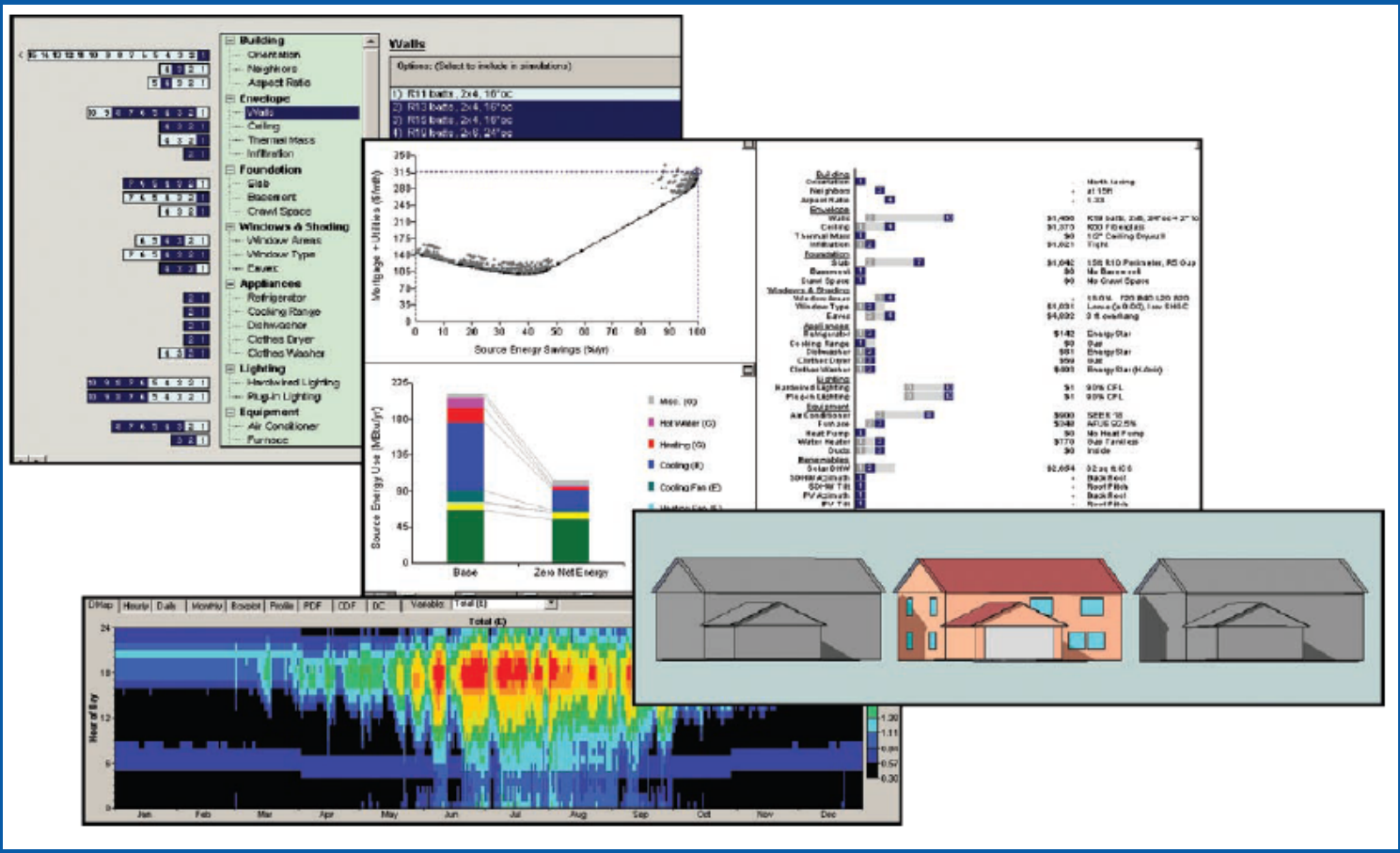
National Renewable Energy Laboratory
Innovation for Our Energy Future

Net Zero Energy Home Analysis

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



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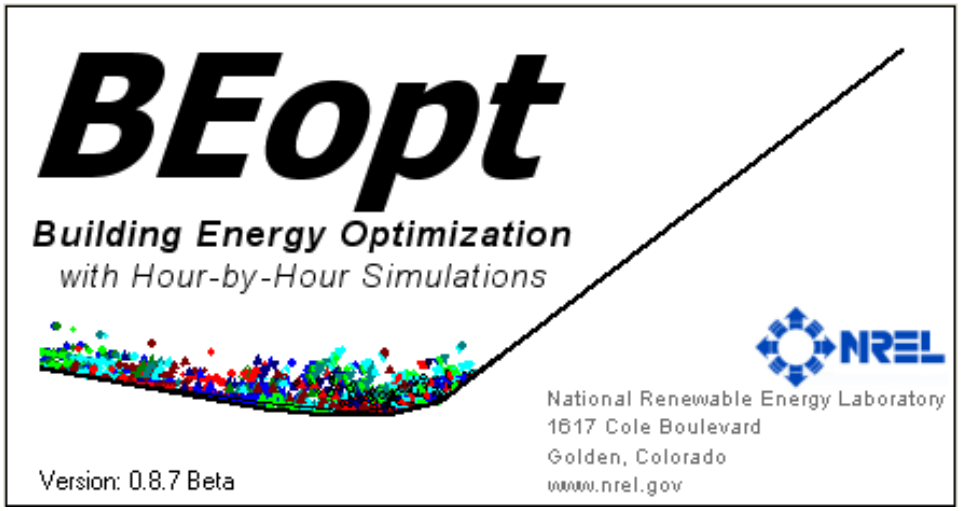
May 7, 2009

Overview

- The Net Zero Energy Vision
- A Comprehensive Approach to EE/RE
- The Energy Challenge
- A Path to NZE through Energy Modeling
- BEopt Model Description
- BEopt Model Assumptions
- Final Design Features and Cost
- The Demonstration Contest
- Future Analysis



The Vision.....

Sustainable Design

Energy Efficiency

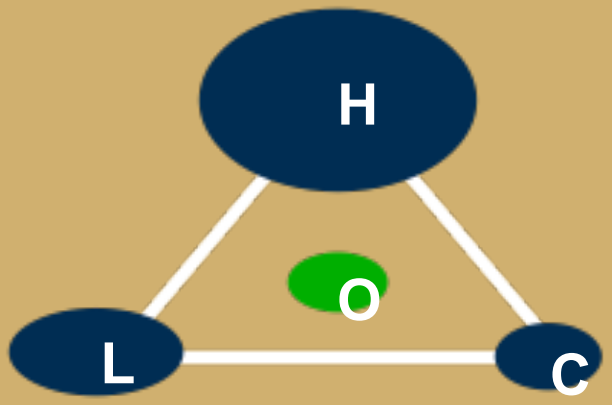
Renewable Energy

A Net Zero Energy Development

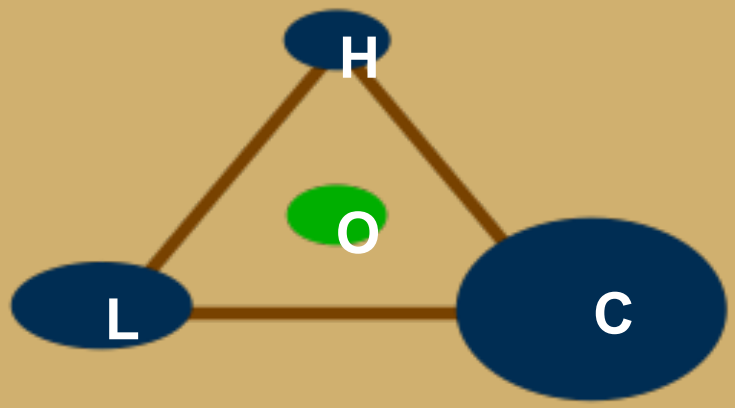
A Comprehensive Approach to Energy Efficiency and Renewable Energy Requires……

The Energy Challenge – Conventional Buildings

Skin-Load Dominated
(small building in cold climate)



Internal-Load Dominated
(large building in any climate)

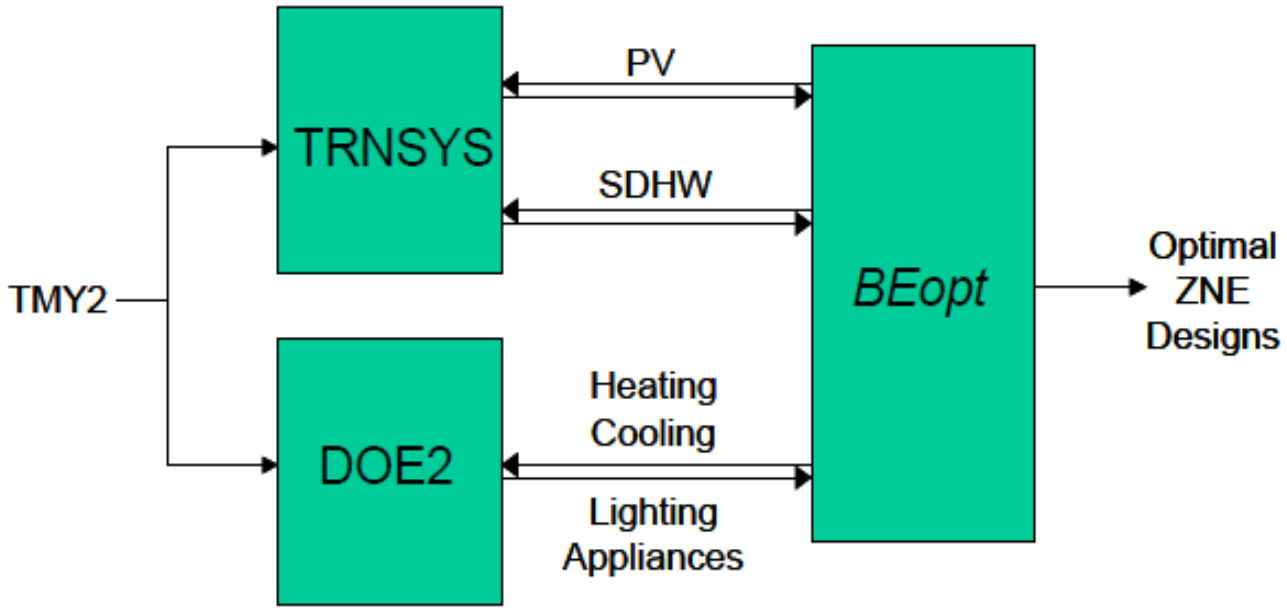


H = Heating Load L = Lighting Load C = Cooling Load
= Other, including ventilation and plug loads

Achieving Net Zero Energy through Energy Modeling

BEopt™ software program description

- The BEopt™ software is designed to identify optimal building designs at various energy-savings levels on the path to zero net energy
- Energy savings are calculated relative to a reference.
  - Uses a sequential search technique to identify optimal building designs
- Finds these optimal and near-optimal designs based on *discrete building options reflecting realistic construction options.*



BEopt - Model Inputs

Utility Information
Electric Rate, Electricity Sell Back Rate, Natural Gas Rate

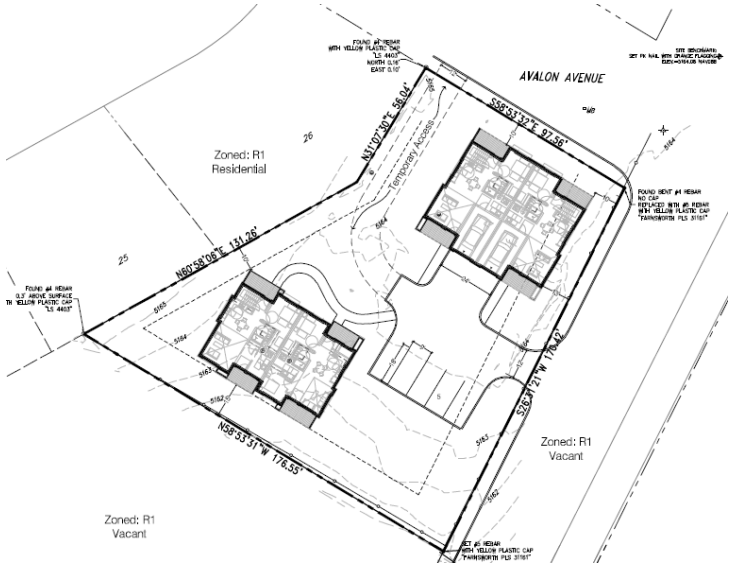
Mortgage
Mortgage Period, Interest Rate, Income Tax Rate

Economics
Project Analysis Period, Inflation Rate, Nominal Discount Rate

Building Geometry
Above Ground Finished Floor Area *(2,589 ft2)*
5 Bedrooms, 3 Bathrooms and a Finished Basement

Orientation
Azimuth – 202.5 deg

Wall Insulation
R19 *(Icynene Insulation), 2 x 6 16" O.C. +1/2" foam board*



BEopt – Model Inputs

Ceiling Insulation
Cellulose (R 50 - hr-sqft-F/Btu)

Infiltration
Effective Leakage Area – 0.85 ft2

Foundation
Insulated Concrete Form (R22 hr-sqft-F/Btu)

Window Type
Low-e double pane (U value = 0.447, SHGC = 0.547)

Appliances
Refrigerator, Cooking range, Dishwasher, Clothes Dryer, Clothes Washer – All modeled as standard efficiency electric

BEopt – Model Inputs

Hardwired Lighting

100% CFL per Energy Star Standard

Air Conditioner

No AC

Furnace

AFUE 80%

Domestic Hot Water

Standard Electric

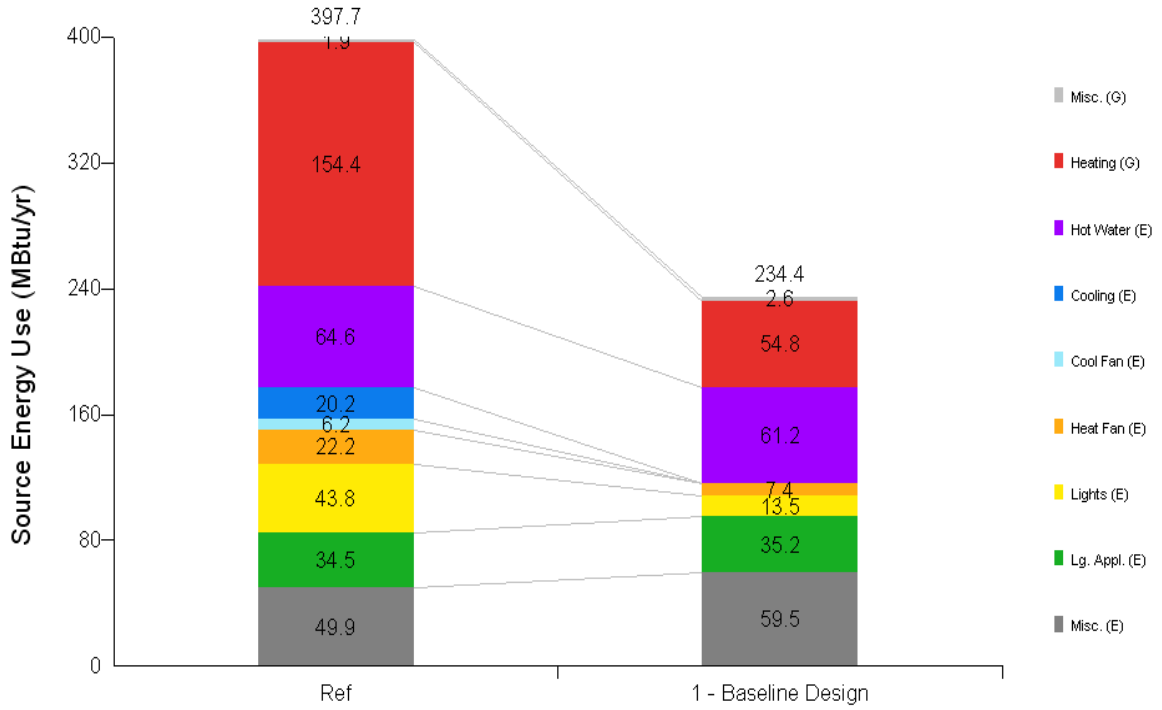
BEopt – Baseline Home Results

Mortgage + Utilities

$2,481/yr

Ref Bldg

- Typical bldg built in mid 1990's
- *42 % source energy savings over mid-1990's home*
- *$ 4,202/yr*



BEopt – Optimization Parameters

Heating Set Point	Default	BCHA	Night Setback	Day Setback
71 F	years		-	-
71 F w/ setback 65 F	30	$100.00	11pm-6am	-
71 F w/ setback 65 F (wkdy)	30	100	11pm-6am	9am-5pm (M-F)

Natural Ventilation	Default	Default	Lifetime 1	Default
	years	years	years	$
Benchmark	30	30		0.0
Smart	30	30		0

Wall Insulation	Default	DEER (RS Means)	R Assembly	Framing Factor
	years	$/sqft	[hr-sqft-F/Btu]	
R21 batts, 2x6, 24"o.c. + 1" foam	30	8	22	0.2
R19 batts, 2x6, 16"o.c. + 1/2" foam	30	7.61	21.2	25

Infiltration	DEER	Minn. Study Extrapolated	Living	Living
	years	$/sq ft	[SLA]	[ELA]
Tighter	13	1	0.0	0.84
Tightest	13	1.62	0.00008	0.45

Wall Mass	Default	RS Means 2005	Home Depot 2005	Thermal Cap.
Exterior||Partition	years	$/sq ft\|\|$/sq ft	$/sq ft\|\|$/sq ft	[Btu/F*sqft]
Exterior and Partition, 1/2" Drywall	30	$0.60||$0.60	0.6	0.42
Exterior, 5/8" Drywall	30	$0.62||$0.60	0.65	0.52

BEopt – Optimization Parameters

Window Areas	@FrontPercentOfTotal	@BackPercentOfTotal	@LeftPercentOfTotal	@RightPercentOfTotal
BCHA Duplex 1	0.25	0.46	0.05	0.24
BCHA Duplex 1 Reduced West Gl	0.28	0.52	0.06	0.14

Window Type	DEER	RMI Report	BCHA	U-Value	SHGC
	years	$/sqft	$/sqft	[Btu/fr-sqft-F]	
Double Clear	20	14	16.0	0.45	0.547
3 pane, 1 HM	20	18		0.257	0.346
4 pane, 2 HM Kr	20	24		0.20	0.324
Double Ref-C Clear-H (JD)	20	16		0.39	0.26
Triple Low-E (e2=e5=.1) Clear (JD)	20	18		0.17	0.47

Refrigerator	DEER	NAHB	sears.com	DEER
	years	years	$/unit	$/unit
Standard	18	13	1,100.0	1,052.00

Cooking Range	NAHB	Lifetime 1	sears.com	Unit Cost 1
	years	years	$/unit	$/unit
Electric	13		350.0	
Gas	15		350	

Dishwasher	DEER	NAHB	ge.com	DEER
	years	years	$/unit	$/unit
Standard	13	9	259.0	293.00
EnergyStar	13	9	329	426

BEopt – Optimization Parameters

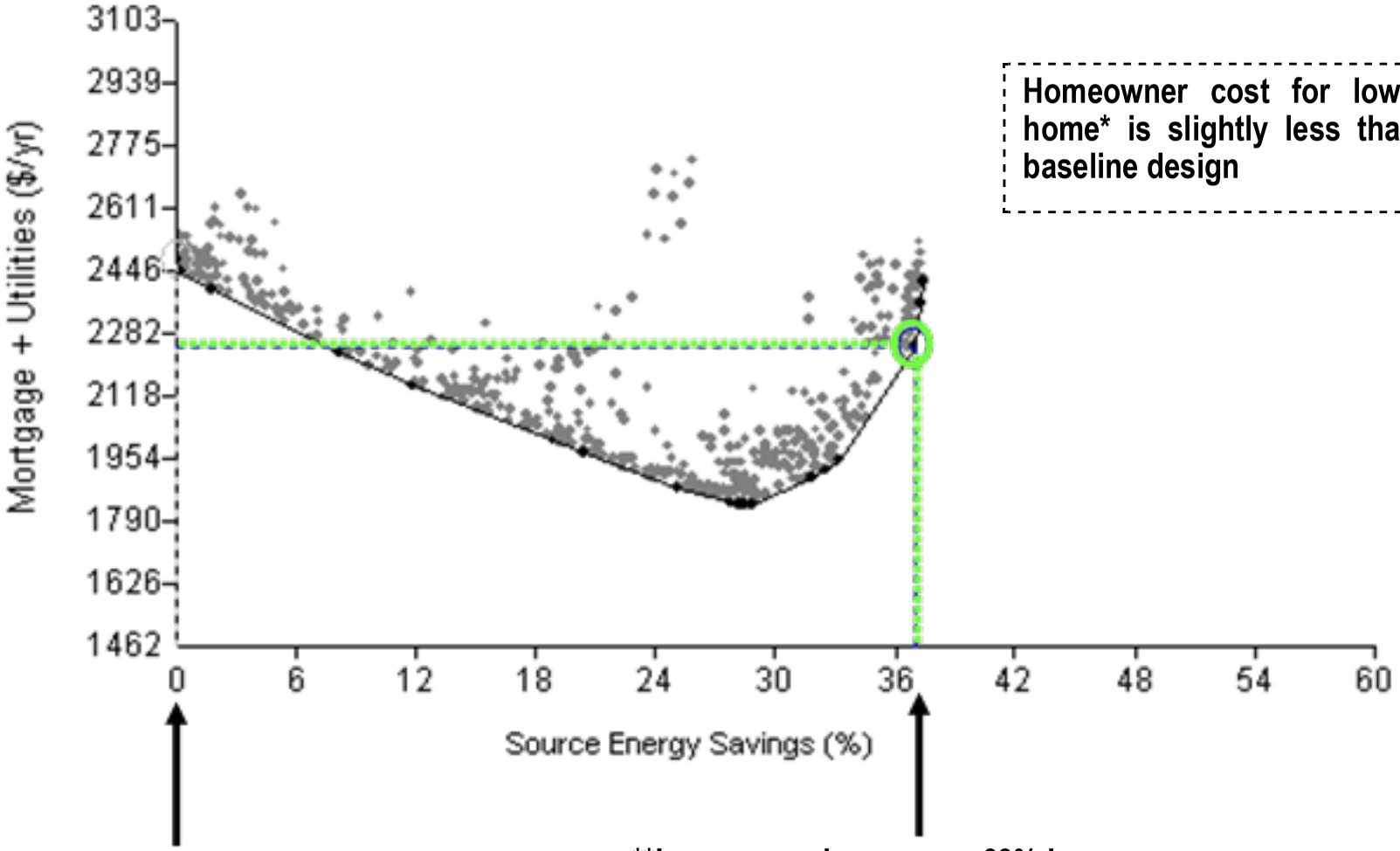
Clothes Washer	DEER	NAHB	ge.com	DEER
	years	years	$/unit	$/unit
Standard (V-Axis)	14	10	419.0	516.00
EnergyStar (H-Axis)	14	10	799	762
Standard (V-Axis) - Cold Only	14	10	419.0	516.00
EnergyStar (H-Axis) - Cold Only	14	10	799	762

Furnace	DEER	acforsale.com	DEER	BCHA
	years	$/unit	$/unit	$/unit
AFUE 80%	18	265	906.0	1,315.00
AFUE 96%	18	559	1646	2935

Mechanical Ventilation	LBNL (1998 Roberson et al.)	Lifetime 1	LBNL (1998 Roberson et al.)	BCHA
	years	years	$/unit	$/unit
Upgraded Bathroom Exhaust	20		463.0	500.00
Balanced Energy-Recovery Ventilator	20		1838	3700

Water Heater	DEER	distributor 2003	DEER	BCHA
	years	$/unit	$/unit	$/unit
Electric Standard	15	479	251.0	251.00
Electric Premium	15	570	323	369
Electric Tankless	20	1,075	1,060.0	1,194.00
Gas Standard	13		376	360
Gas Premium	13	624	551.0	551.00

Maximum Efficiency and Savings



Homeowner cost for low energy home* is slightly less than BCHA baseline design

BCHA Baseline Design

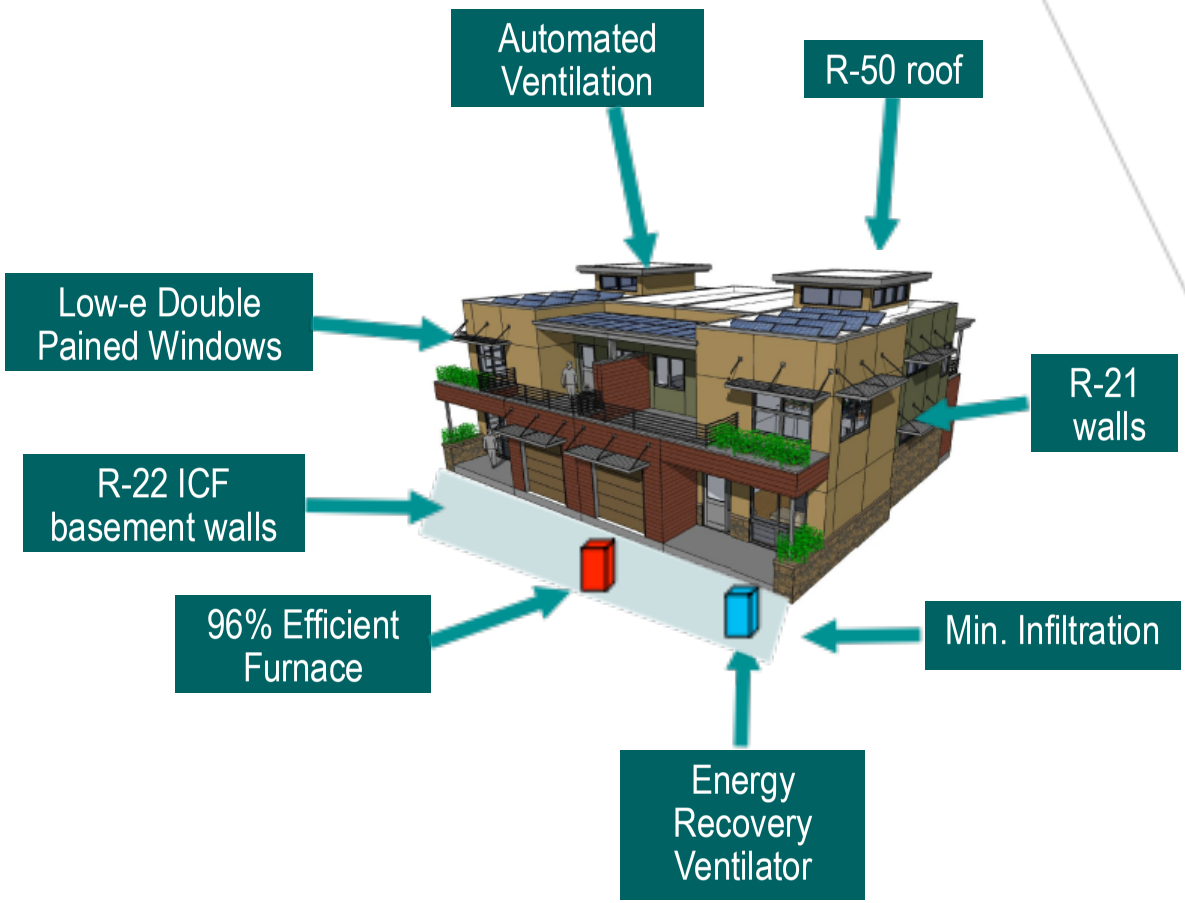
**Low energy home uses 63% less energy than a typical mid 1990's home

Beopt – Max. Eff and Savings Cost

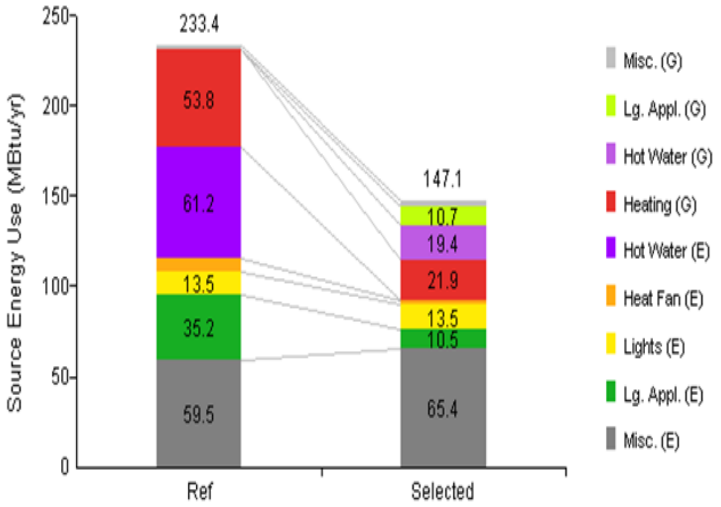
Group Name	Category Name	Delta Capital Cost (Present Value)	Current Option Name	Ref Option Name
Building				
	Heating Set Point	$100	71 F w/ setback 65 F (wkdy)	71 F
Envelope				
	Infiltration	$1,886	Tightest	Tighter
Windows & Shading				
	Window Areas	$0	BCHA Duplex 1 Reduced West GI	BCHA Duplex 1
	Eaves	$0	3 ft overhang	
Lg. Appliances				
	Refrigerator	$142	EnergyStar	Standard
	Cooking Range	($35)	Gas	Electric
	Dishwasher	$94	EnergyStar	Standard
	Clothes Dryer	$59	Gas	Electric
	Clothes Washer	$493	EnergyStar (H-Axis) - Cold Only	Standard (V-Axis)
Equipment				
	Furnace	$1,919	AFUE 96%	AFUE 80%
	Mechanical Ventilation	$3,667	Balanced Energy-Recovery Ventilator	Upgraded Bathroom Exhaust
	Water Heater	$431	Gas Tankless	Electric Standard
Total Capital Cost (Present Value)		$8,756		

Integrated Energy Efficiency

Final Building Design



Source Energy Use

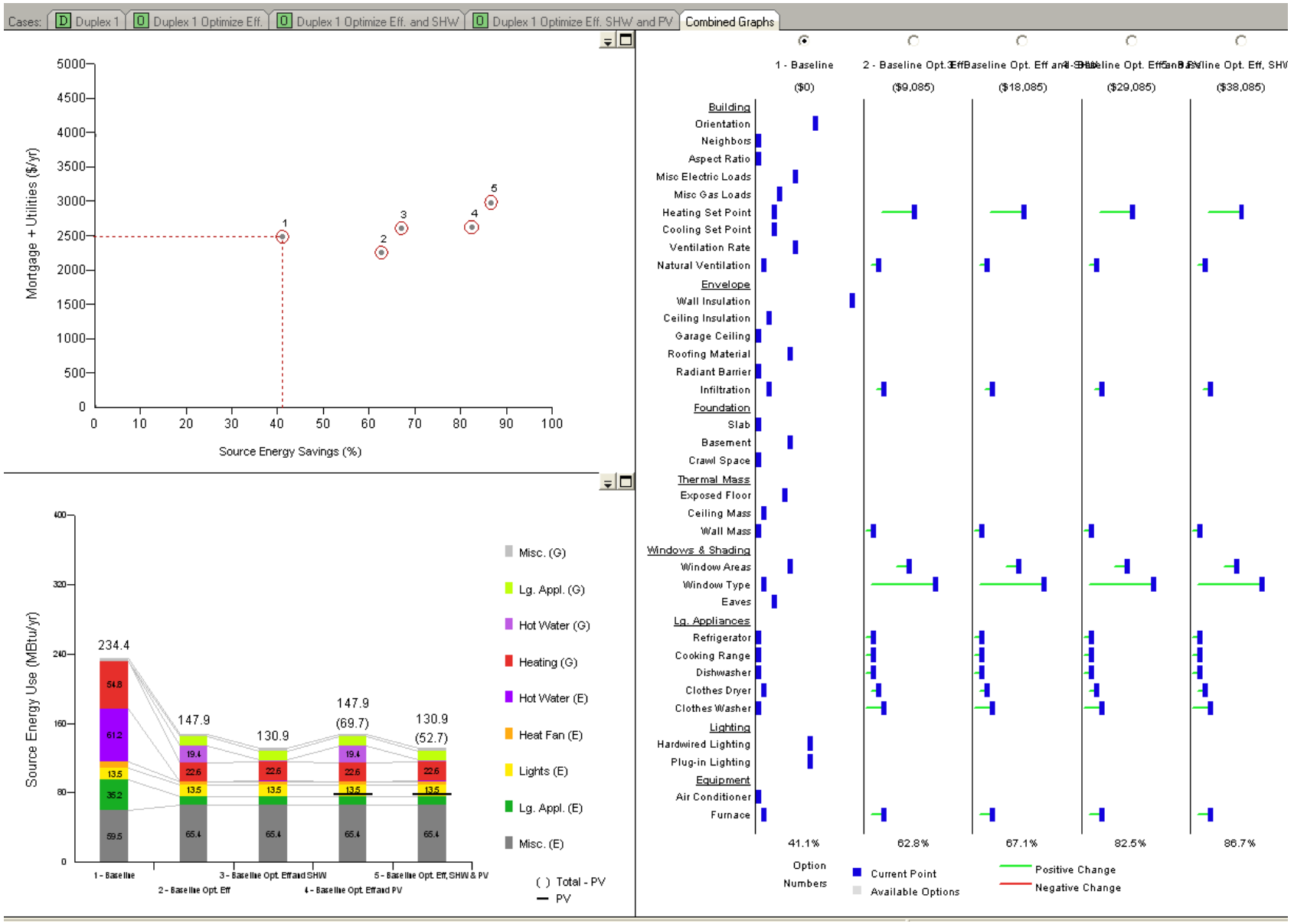


Additional Features

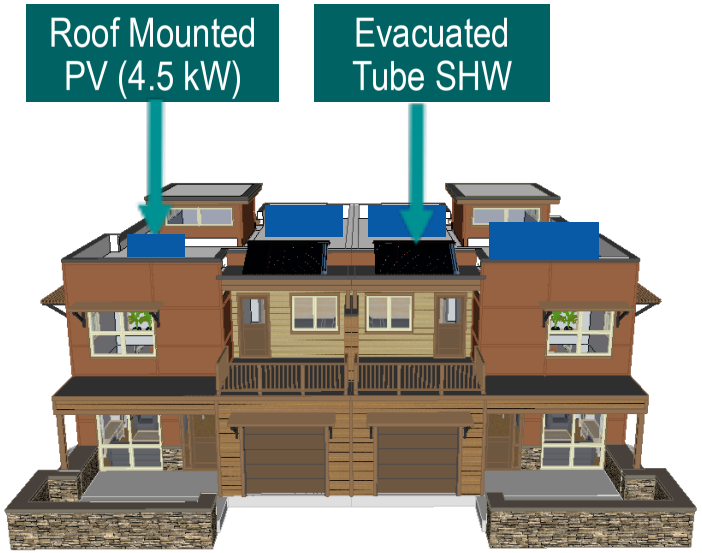
- **Programmable Thermostats**
- **100% CFL Lighting**
- **Energy Star Appliances**
- **On-demand DHW**

** Additional energy efficiency features cost $8,500 over BCHA baseline

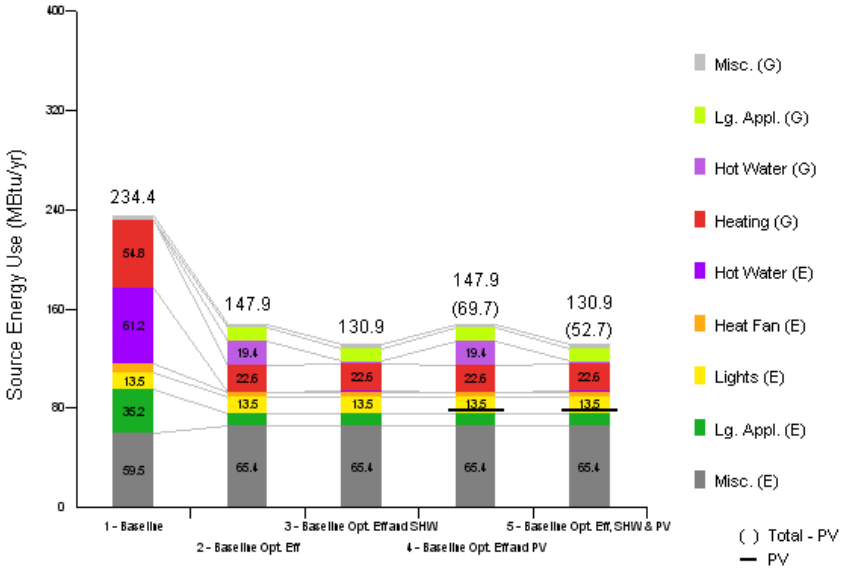
BEopt – Duplex Optimization



Integrated Efficiency and Renewables

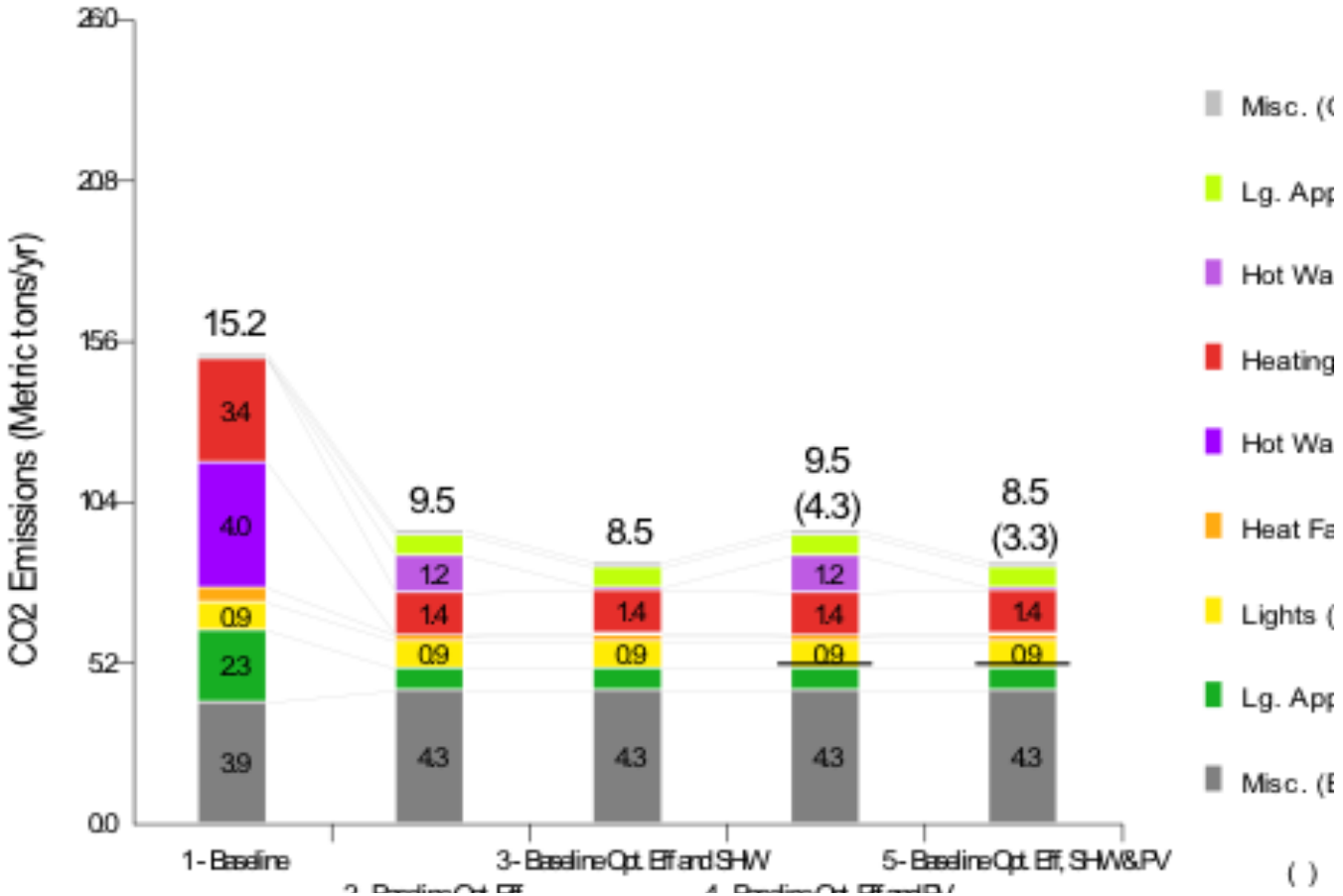


**PV system cost - $13,000
**Estimated evacuated tube SHW system cost - $9,000



** Energy use 87% lower than mid 1990's benchmark
** Net zero energy electric
** Natural gas use reduced by 76%

Net Zero Energy – CO2 Impacts

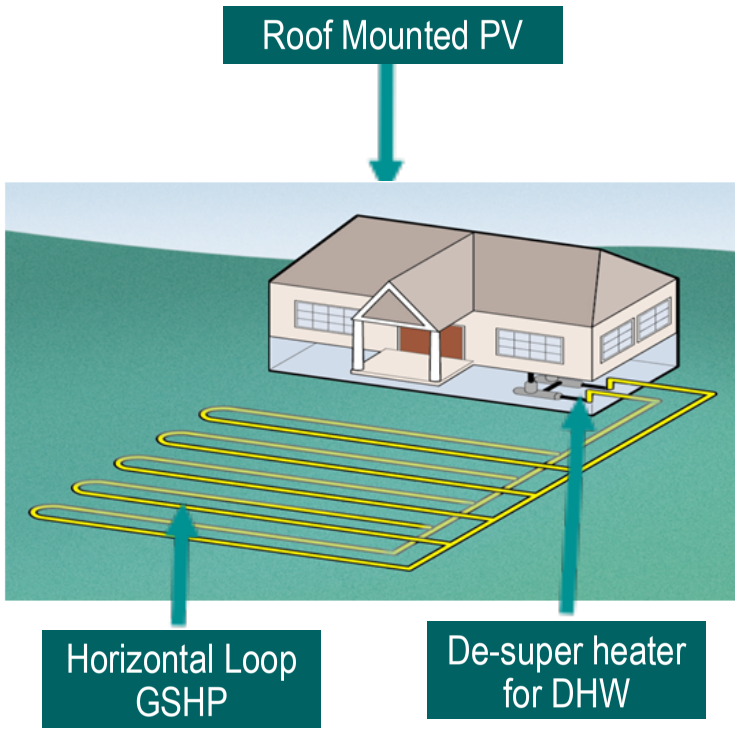


** We would need to install another 3 kW PV system to offset the 3.3 tons/yr of carbon. It would cost another $8,500.00

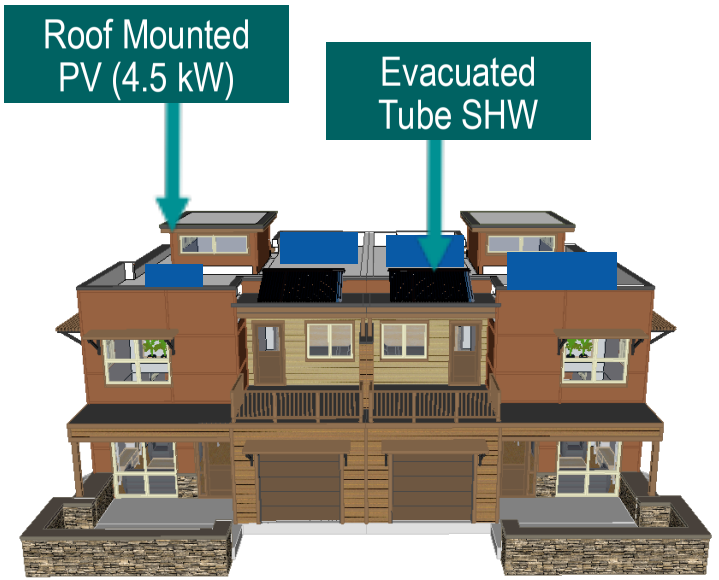
- CO2 emissions of mid 1990s benchmark is 22.7 tons/yr

All Electric Versus Electric and Gas

All Electric Home



Baseline Home



Lessons Learned for Main Development

Imperative to persistently educate all involved on life cycle cost of energy in buildings -

- Efficiency first, then renewables
- Consider all renewable resources; cost varies tremendously depending on resource and incentives
- Optimize at the system level
- Cultural change is required. Prepare for it and address it
- Data acquisition and testing equipment will be installed to test the two homes and determine the optimal design for the main site
- Future analysis will determine trade-offs between distributed RE versus central generation