



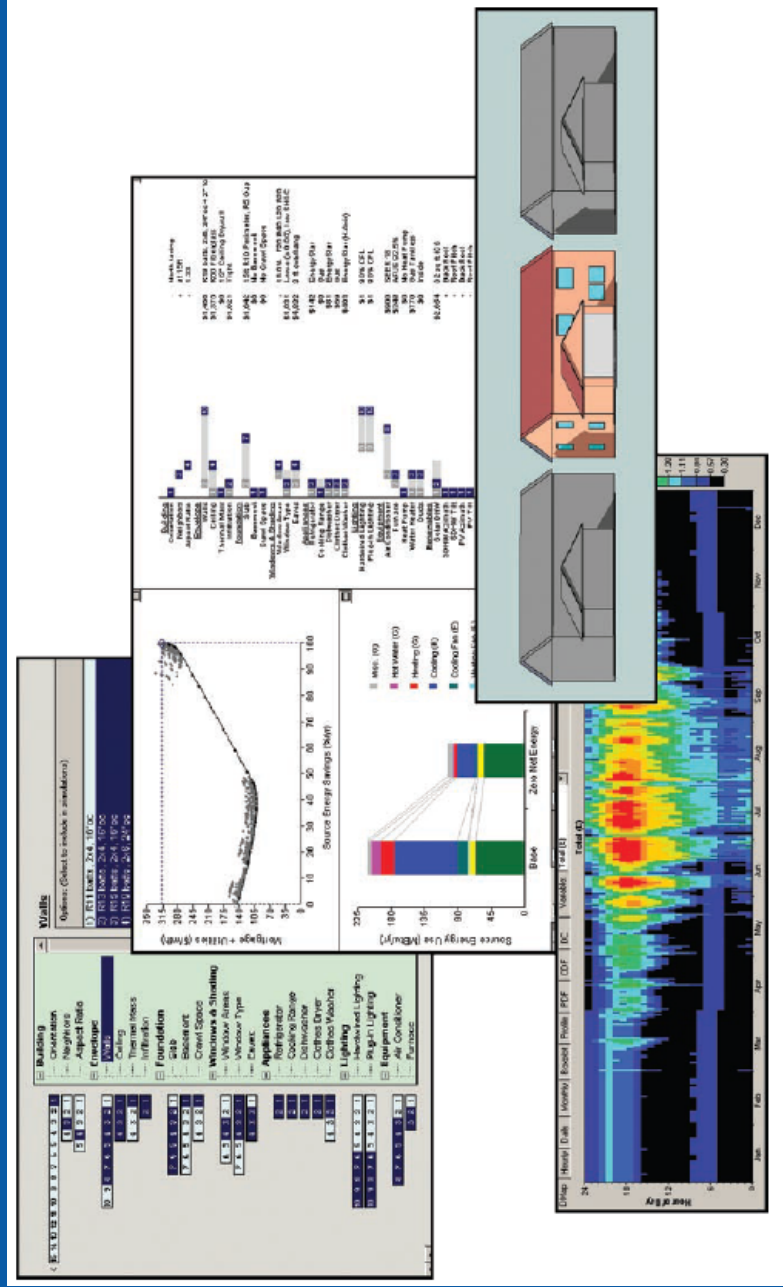
National Renewable Energy Laboratory
Innovation for Our Energy Future

BCHA Zero Energy Home Analysis

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

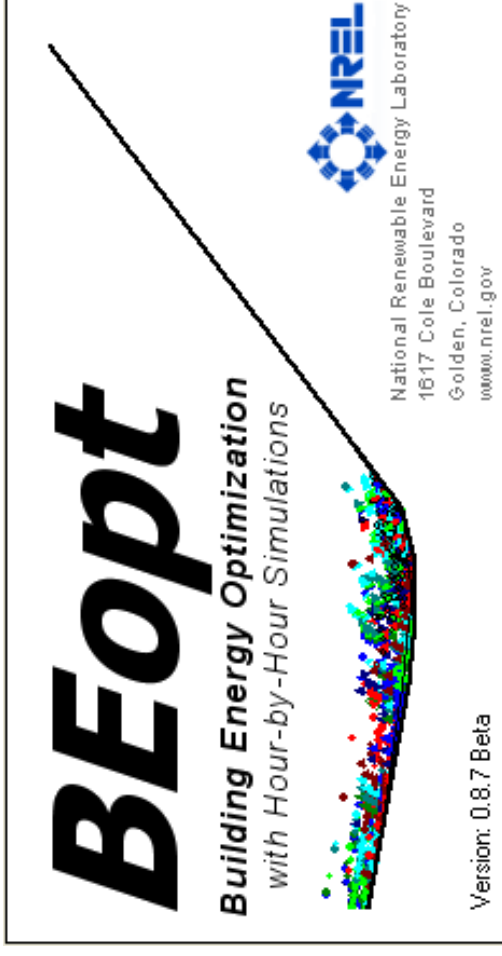
Jesse Dean
 Mechanical Engineer

February 12, 2008



Overview

- Intro to BeOpt
- Model assumptions
- Building envelope recommendations
 - Window properties
 - Window overhang dimensions
 - Wall insulation
 - Ceiling insulation
 - Infiltration
- Thermal Mass
 - Ceiling mass
 - Exterior wall mass
- Lighting system recommendations
- Large appliance recommendations



Overview

- HVAC system type recommendations
- Standard furnace versus GSHP
- HVAC duct types
- Energy recovery ventilator
- Domestic hot water heater recommendation
- SHW system recommendation
- PV system recommendation
- Building control system
- Total cost premium per duplex

BEopt Background

BEopt™ software program description

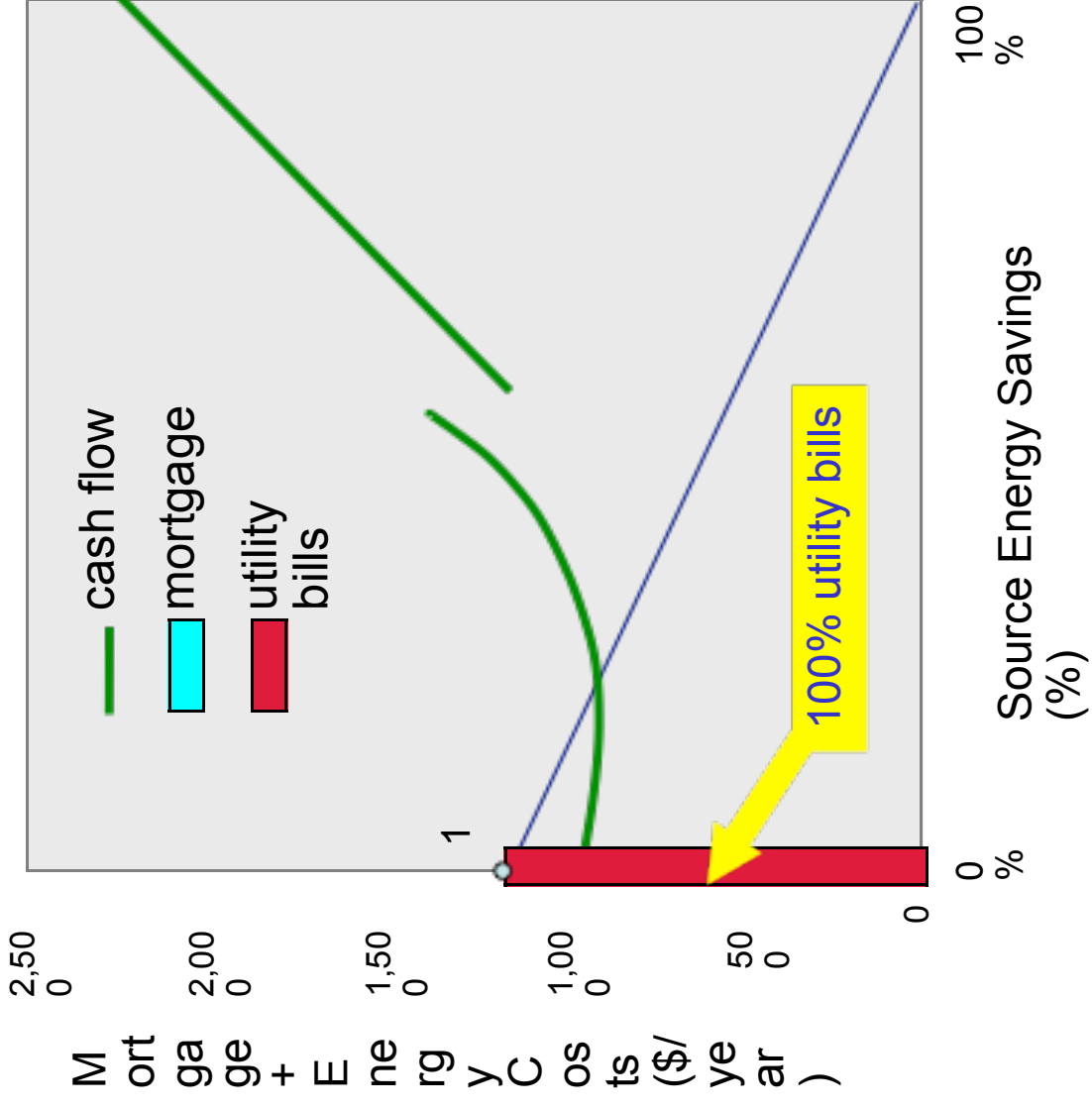
- The BEopt™ software is designed to identify optimal building designs at various energy-savings levels on the path to zero net energy
- Energy savings are calculated relative to a reference.
- The reference can be either a user-defined base-case building or a climate-specific Building America Benchmark building automatically generated by the BEopt software.

BEopt Background

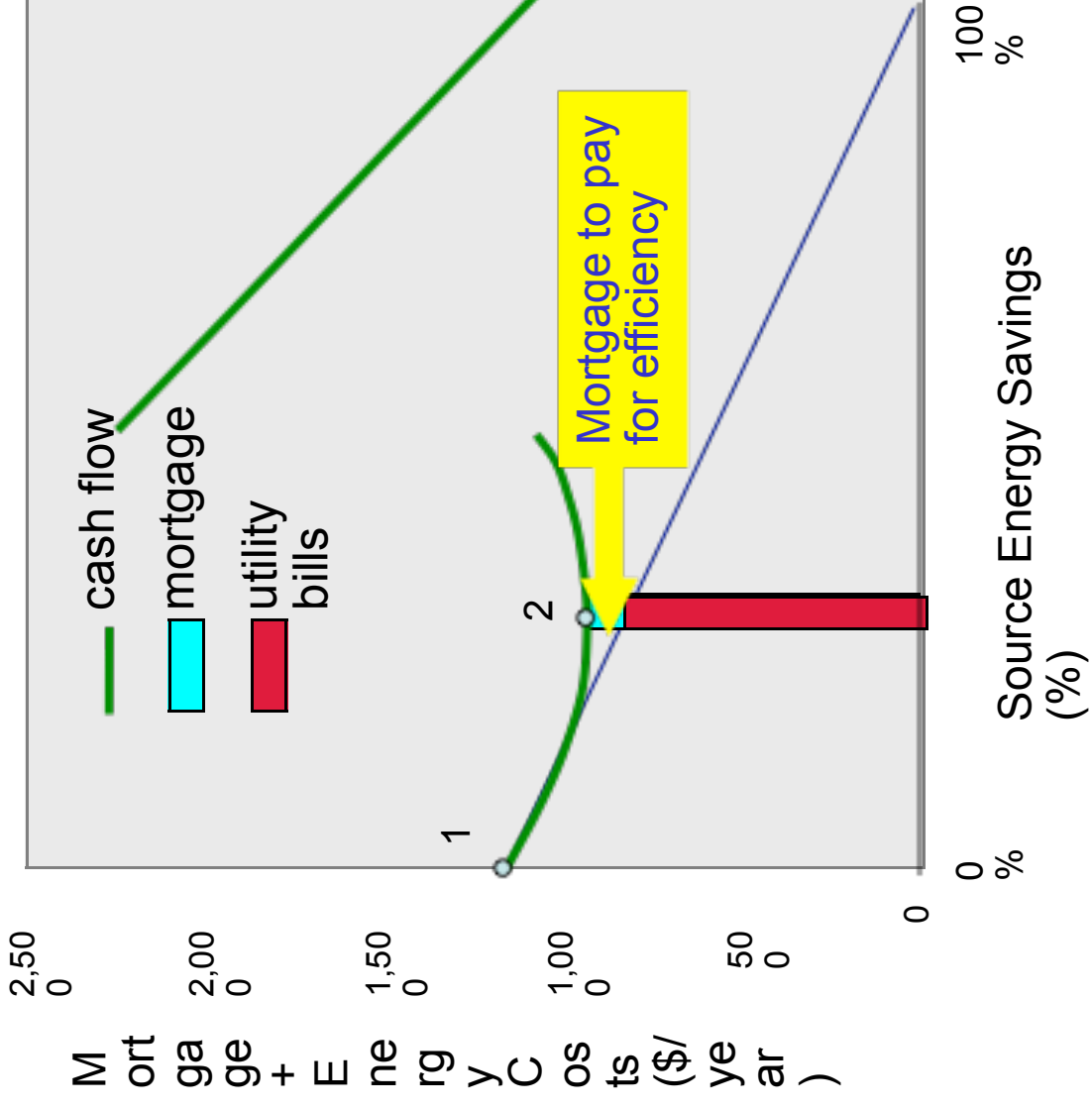
BEopt™ software program description

- Calls DOE2 and TRNSYS simulation engines
 - o 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*.
- The ZNE building uses grid-tied, net-metered PV and active solar to produce as much energy as it uses on an annual source-energy basis.

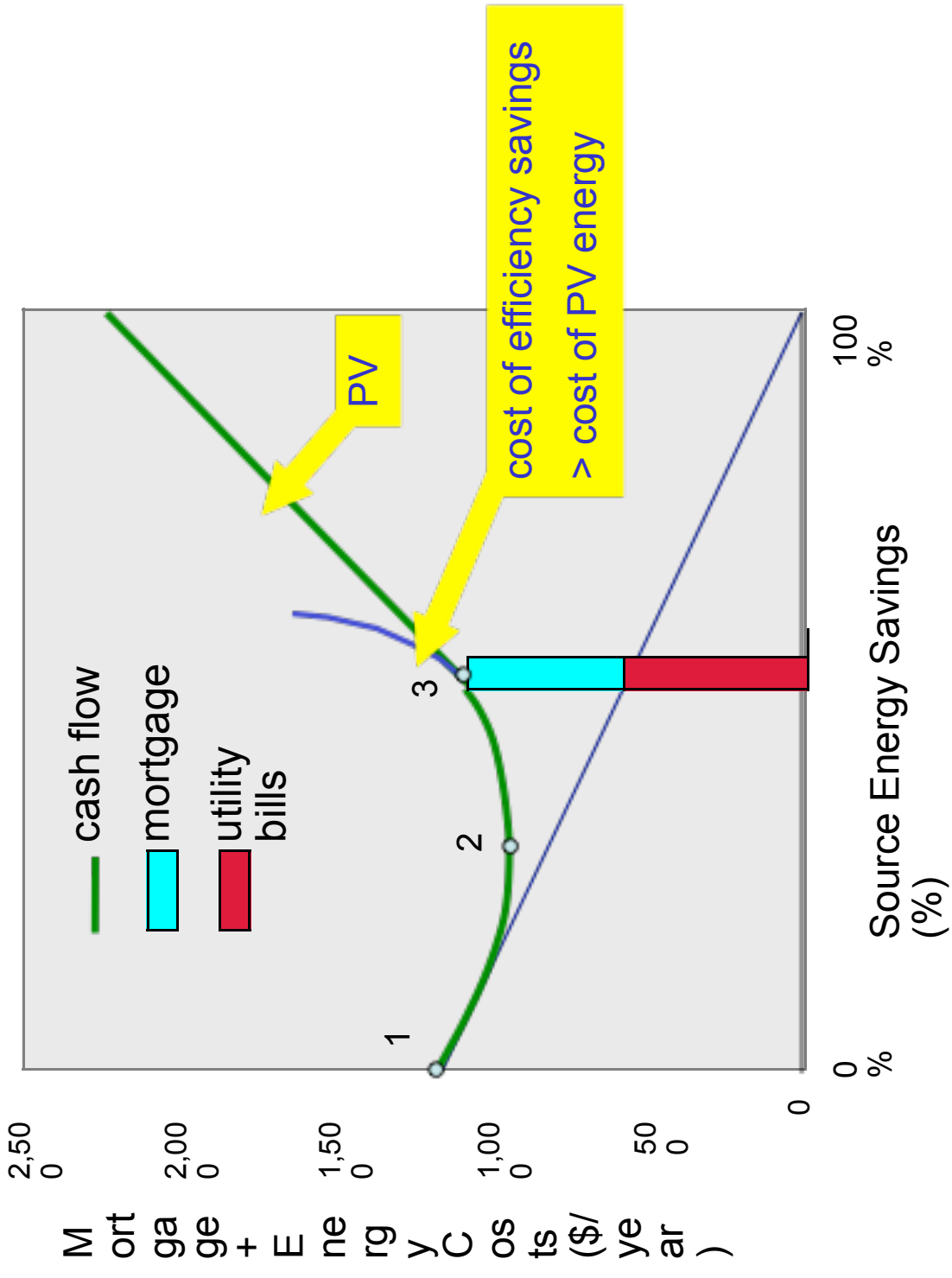
The Path to Zero Net Energy



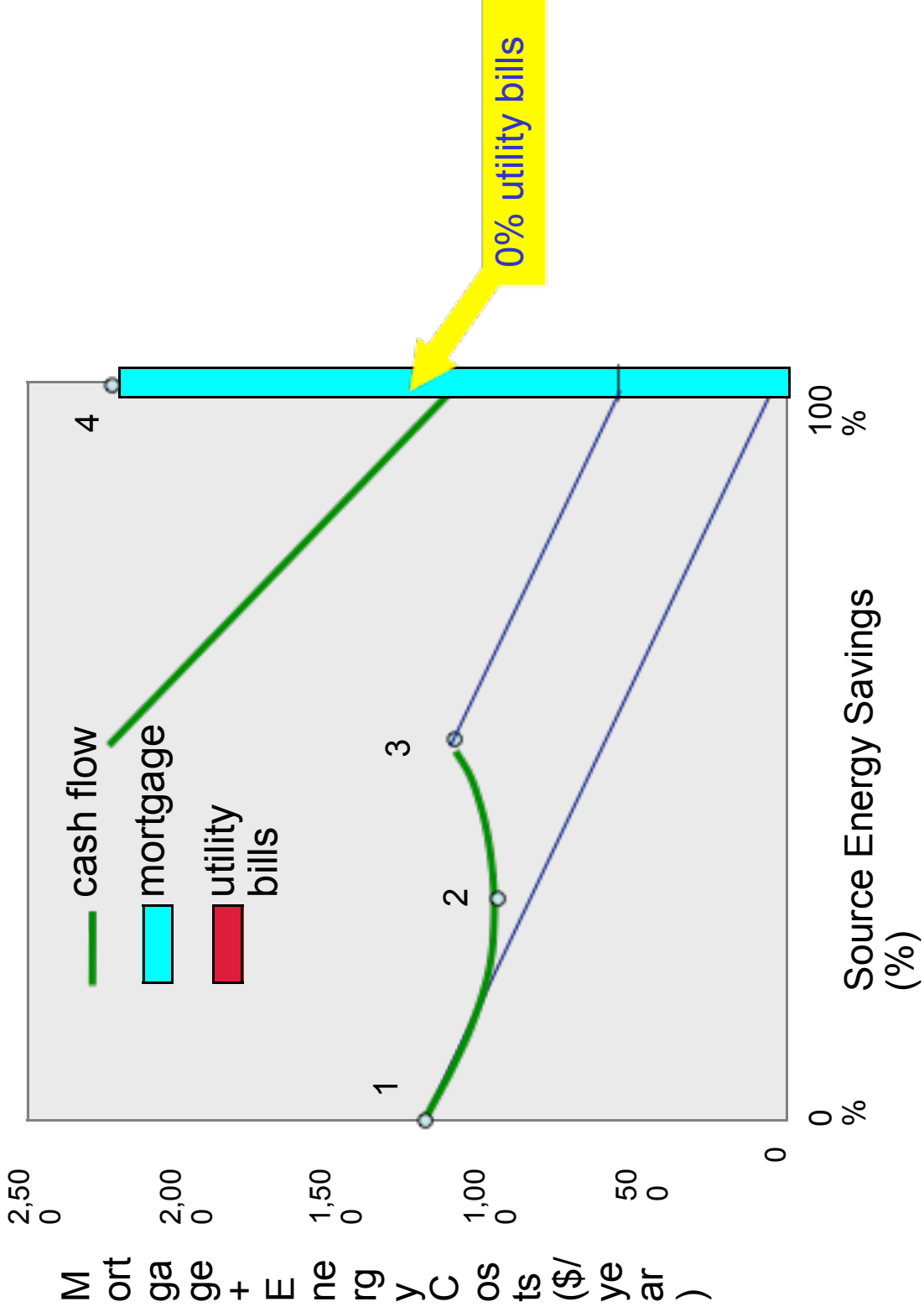
The Path to Zero Net Energy



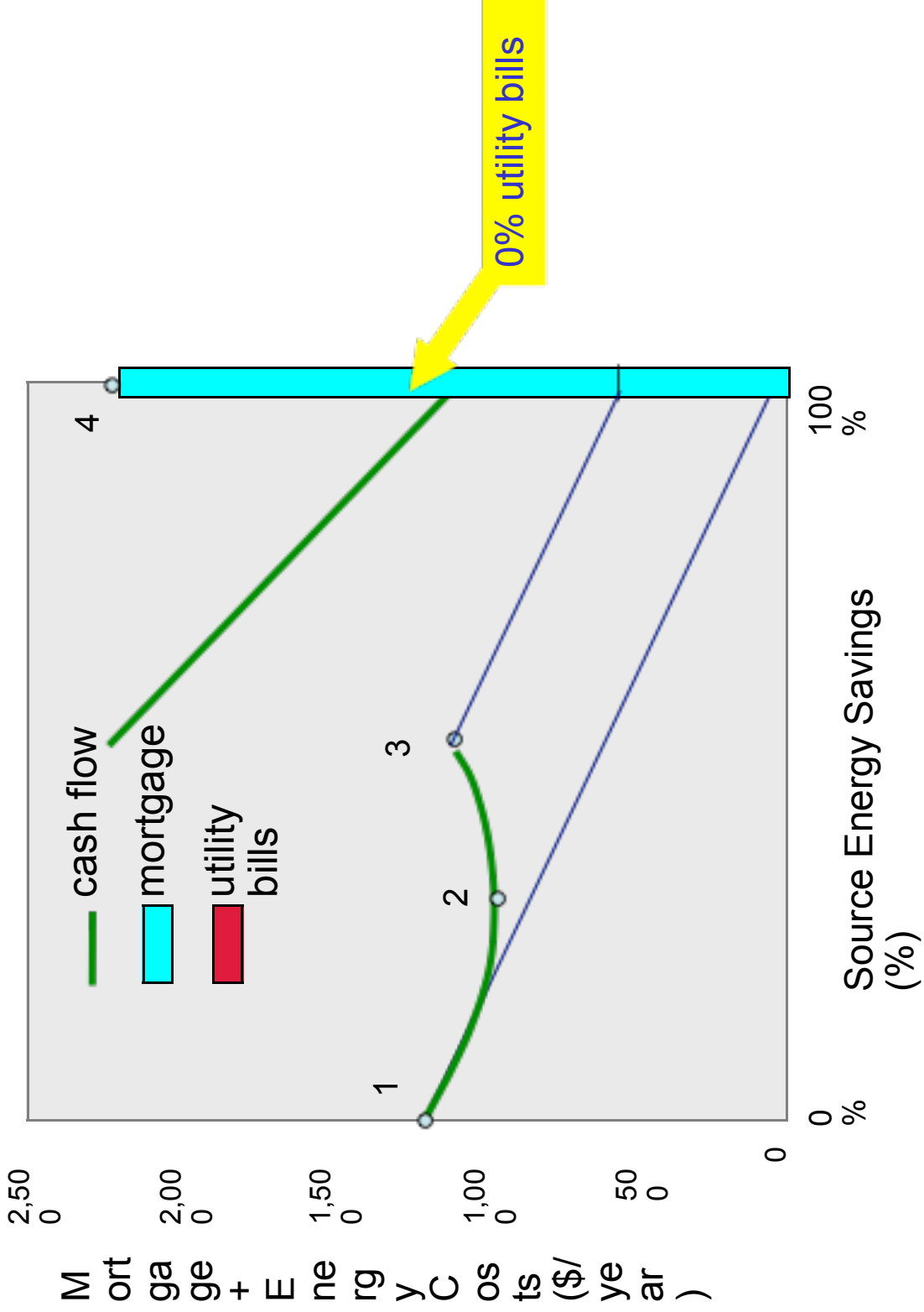
The Path to Zero Net Energy



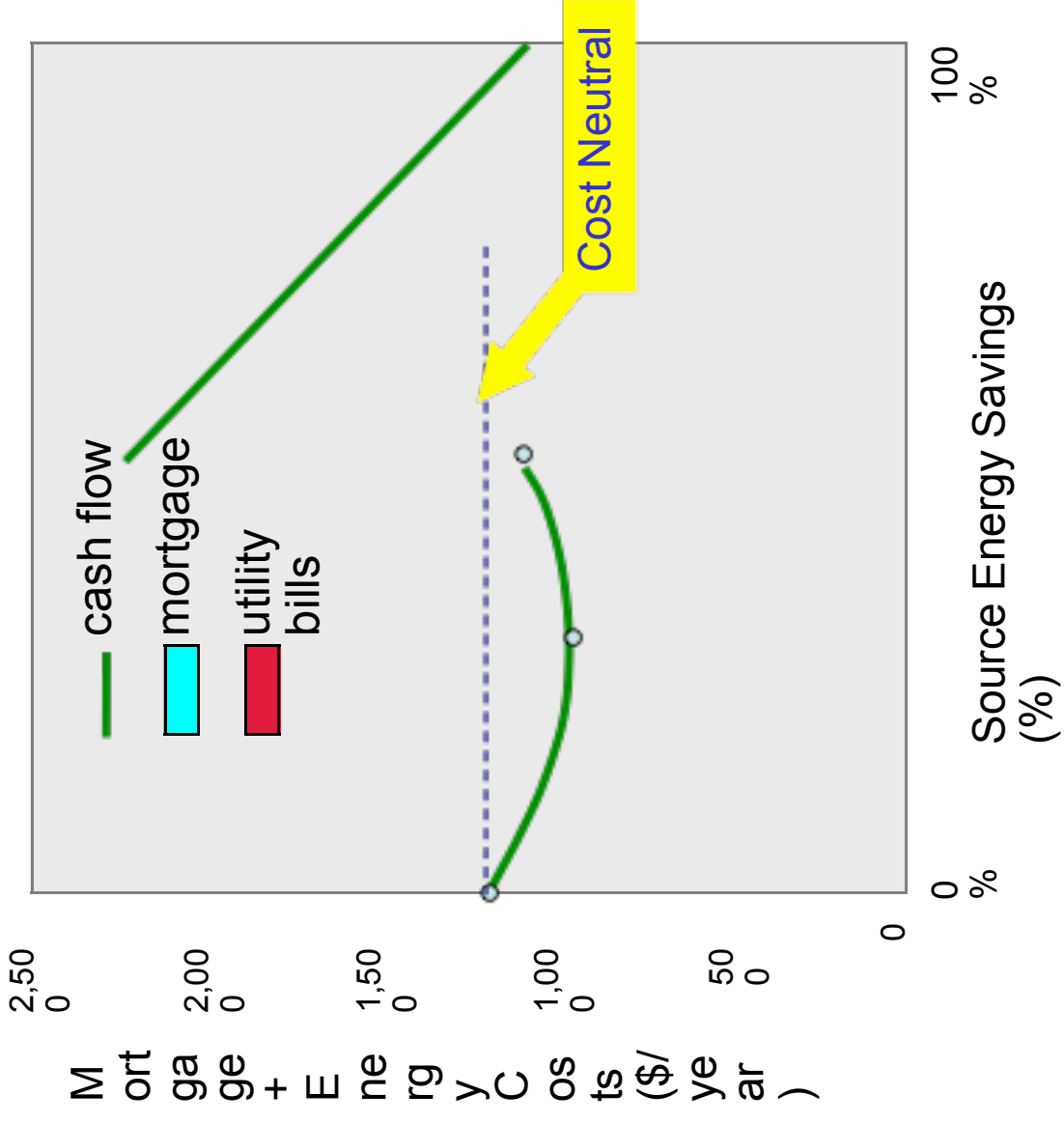
The Path to Zero Net Energy



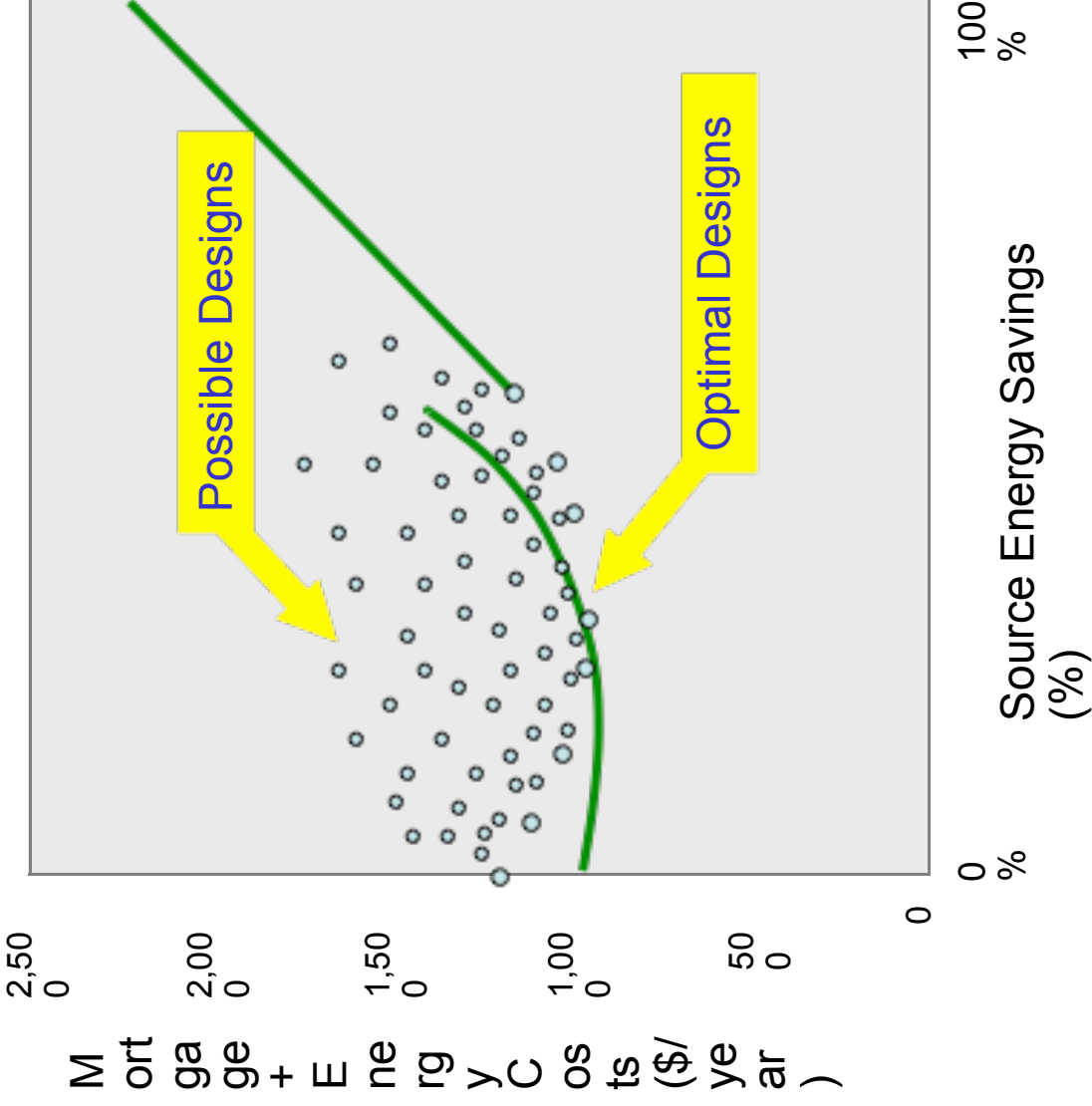
The Path to Zero Net Energy



The Path to Zero Net Energy



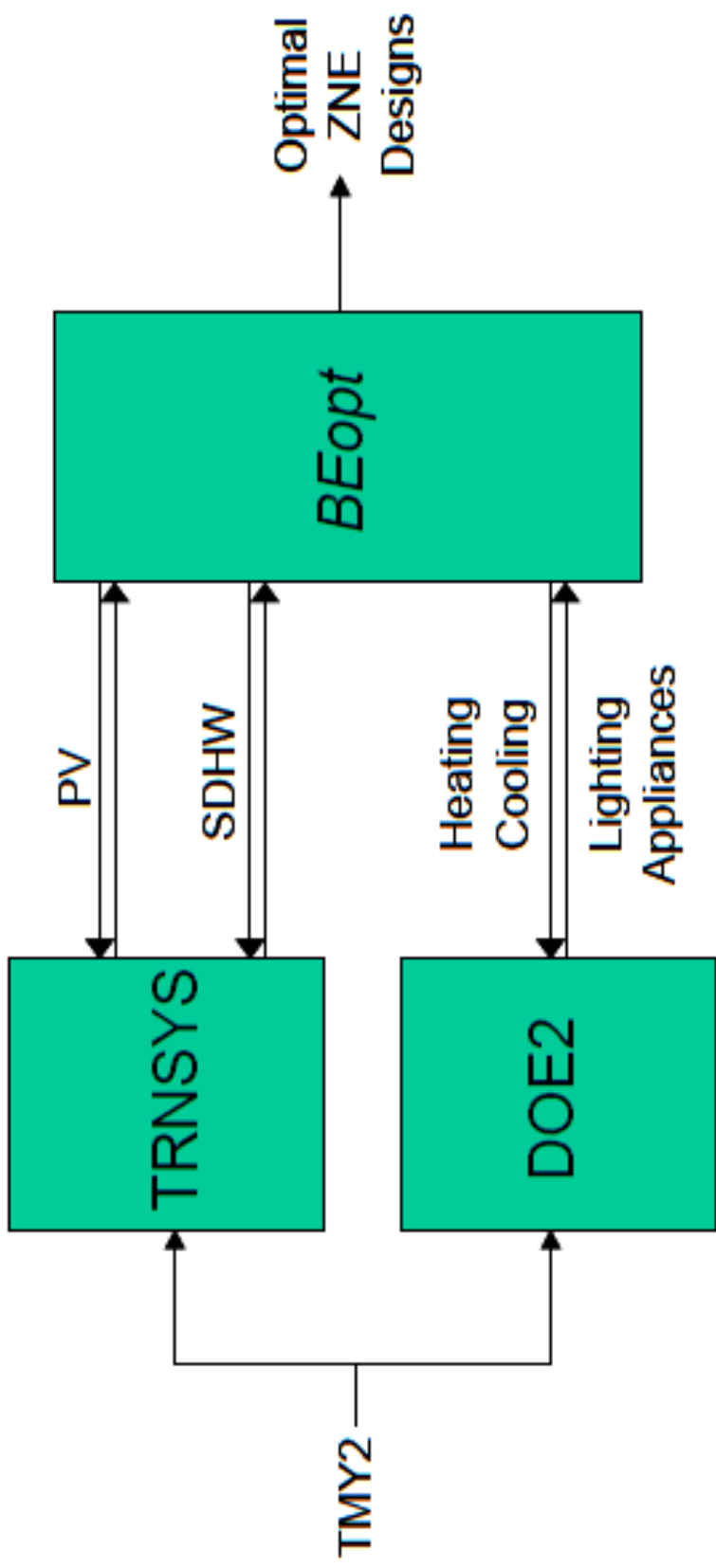
The Path to Zero Net Energy



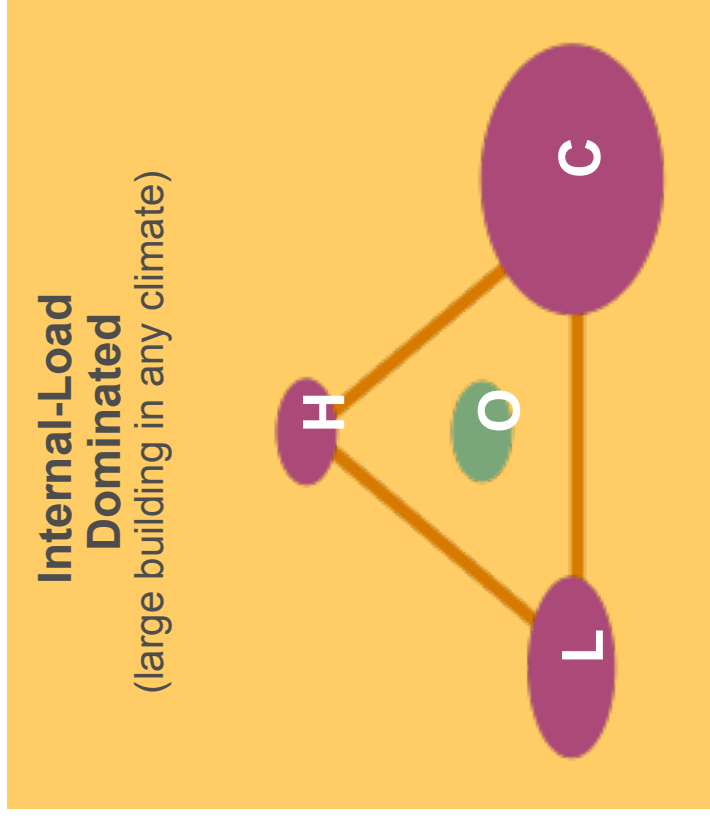
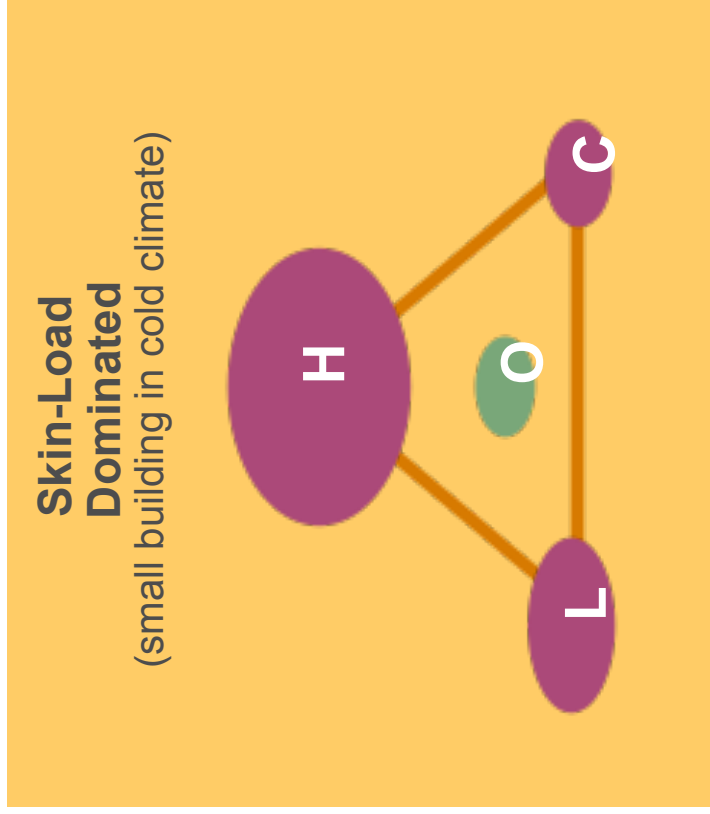
BEopt Background

BEopt™ software program description

- The BEopt software has the ability to handle special situations caused by interactions
- Finds optimal designs for entire range of energy savings from base case to zero net energy



The Energy Challenge – Conventional Buildings

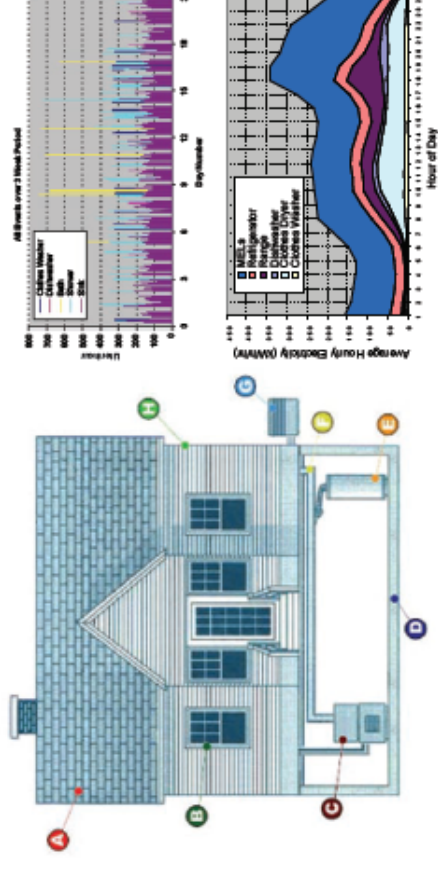


H = Heating Load L = Lighting Load C = Cooling Load
O = Other, including ventilation and plug loads

Building America Research Benchmark

- Developed to track progress toward energy savings goals of 40%–70% within the DOE Residential Buildings Program
- The Benchmark is consistent with mid-1990s standard practice, as reflected in the Home Energy Rating System (HERS)

Building America Research Benchmark Definition, Updated December 20, 2007



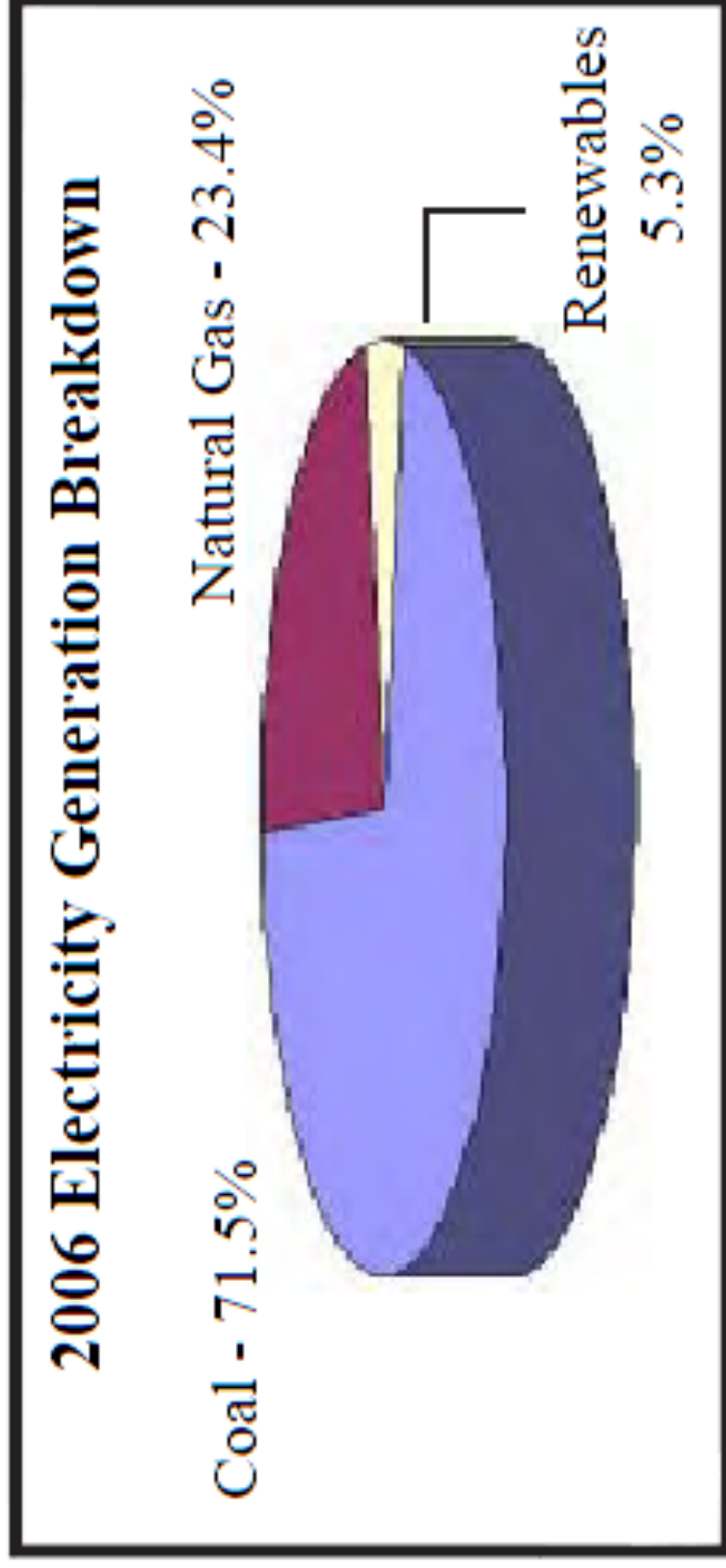
BEopt - Model Inputs

Electricity Rate <input checked="" type="radio"/> User Specified <input type="radio"/> State Average <input type="radio"/> National Average		Marginal <input type="text" value="0.11"/> \$/kWh Fixed <input type="text" value="12.00"/> \$/month Average <input type="text" value="0.1239"/> \$/kWh	
Net-Metered Excess Electricity Sellback Rate <input type="radio"/> Retail Electricity Cost <input checked="" type="radio"/> User Specified			<input type="text" value="0.035"/> \$/kWh
Natural Gas Rate <input checked="" type="radio"/> User Specified <input type="radio"/> State Average <input type="radio"/> National Average			Marginal <input type="text" value="0.947"/> \$/therm Fixed <input type="text" value="12.00"/> \$/month Average <input type="text" value="1.1158"/> \$/therm
Mortgage Mortgage Period <input type="text" value="30"/> years Mortgage Interest Rate (Nominal) <input type="text" value="6.0"/> % Marginal Income Tax Rate <input type="text" value="28.0"/> %			
Economics Project Analysis Period <input type="text" value="30"/> years Inflation Rate <input type="text" value="2.6"/> % Discount Rate (Nominal) <input type="text" value="4.9"/> %			
Multipliers Electric Source/Site Ratio <input type="text" value="3.365"/> Gas Source/Site Ratio <input type="text" value="1.092"/> Electric Carbon Factor <input type="text" value="1.670"/> lb/kWh Gas Carbon Factor <input type="text" value="14.740"/> lb/therm Efficiency Cost Multiplier <input type="text" value="1.0"/>			

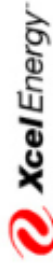
Reference Utility rates: Energy Information Administration, State Averages (Oct. 2008)

Reference Economics: Code of Federal Regulations, Title 10 Part 436

BEopt – Colorado Electricity



BEopt – Xcel Utility Bills



Bill History Report Electric Service Detail

Customer Name: GIZAW Z WOLDETSADIK	Utility Type: Electric	Address Line 1: 2506 N CENTRAL PARK BLVD 101
Account Number: 53-7386880-7	Service Number: 001	Service City, State, Zip: DENVER, CO 80238
Report Create Date: 11/19/2008	Meter Number: 000049367713	
	Multiplier: 1	

Premise Number: 304067588

Premise Description: R Residential General

Tariff Description: R Residential General

Read Date	Days	On-pk Usage (kWh)	Off-pk Usage (kWh)	Total Usage (kWh)	Avg Usage/Day (kWh)	Billed Demand (kW) On Peak	Billed Demand (kW) Off Peak	Actual Demand (kW) On Peak	Adjusted Demand (kW) On Peak	Power Factor (kVar)	Load Factor (%)	Usage Billed (\$)	Demand Billed (\$)	Other Charges (\$)	ECA/PCA (\$)	Electric Service Sub-Total (\$)	Tax (\$)	Electric Invoice Total (\$)	Invoice Date
10/16/08	29	0	0	151	5.2	0	0	0	0	0		4.98	0.00	11.12	6.08	22.18	0.81	22.99	10/24/08
06/17/08	33	0	0	144	4.4	0	0	0	0	0		4.99	0.00	11.05	7.09	23.13	0.84	23.97	09/23/08
08/15/08	29	0	0	314	10.8	0	0	0	0	0		10.89	0.00	15.44	15.46	41.79	1.52	43.31	08/20/08
07/17/08	30	0	0	126	4.2	0	0	0	0	0		4.37	0.00	10.58	5.62	20.57	0.75	21.32	07/22/08
05/17/08	35	0	0	0	0.0	0	0	0	0	0		0.00	0.00	8.83	8.83	0.00	0.32	9.15	06/23/08
05/12/08	25	0	0	55	2.2	0	0	0	0	0		59.20	0.00	99.74	50.24	208.18	7.54	215.72	05/19/08
04/17/08	30	0	0	212	7.1	0	0	0	0	0		0.00	0.00	0.00	0.00	0.00	0.00	0.00	05/19/08
03/18/08	31	0	0	313	10.1	0	0	0	0	0		0.00	0.00	0.00	0.00	0.00	0.00	0.00	05/19/08
02/16/08	29	0	0	405	14.0	0	0	0	0	0		0.00	0.00	0.00	0.00	0.00	0.00	0.00	05/19/08
01/18/08	32	0	0	588	18.4	0	0	0	0	0		0.00	0.00	0.00	0.00	0.00	0.00	0.00	05/19/08
12/17/07	16	0	0	273	17.1	0	0	0	0	0		0.00	0.00	0.00	0.00	0.00	0.00	0.00	05/19/08
	320			2581								83.43	0.00	156.75	84.49	324.68	11.78	336.46	

Blended Electric Rate - \$0.13/kWh

BEopt – Xcel Utility Bills



Bill History Report Gas Service Detail

Customer Name: GIZAW Z WOLDETSADIK	Utility Type: Gas	Address Line 1: 2506 N CENTRAL PARK BLVD 101
Account Number: 53-7386880-7	Service/Register Number: 0001 / 000	Service City, State, Zip: DENVER, CO 80238
Report Create Date: 11/19/2008	Meter Number: 000020164724	
	Multiplier: .8357	

Premise Number: 304067588

Premise Description:

Tariff Description: RG-T Residential
Unit of Measure: THERMS

READ DATE	READ METHOD	Days	Usage (Therms or MCF)	Usage Per Day	Heat Content Factor	Heating Degree Days	Cost of Gas (\$)	Distribution Charges (\$)	Other Charges (\$)	Gas Service Sub-total (\$)	Tax (\$)	Gas Invoice Total (\$)	Invoice Date
10/16/08	A	29	18	0.60	0.9857	220	10.28	1.59	11.85	23.72	0.86	24.58	10/24/08
09/17/08	A	33	17	0.50	0.9930	128	11.37	1.50	11.88	24.75	0.90	25.65	09/23/08
08/15/08	A	29	17	0.60	0.9930	12	16.16	1.50	12.02	29.68	1.08	30.76	08/20/08
07/17/08	A	30	17	0.60	0.9913	4	15.73	1.51	12.04	29.28	1.06	30.34	07/22/08
06/17/08	A	36	19	0.50	0.9880	194	17.79	1.69	14.41	33.89	1.23	35.12	06/23/08
05/12/08	A	25	26	1.00	0.9890	346	272.24	32.98	71.06	376.28	13.62	389.90	05/19/08
04/17/08	A	30	59	2.00	0.9891	682						*	05/19/08
03/18/08	A	31	79	2.50	0.9893	815						*	05/19/08
02/16/08	A	29	98	3.40	0.9883	1040						*	05/19/08
01/18/08	A	32	100	3.10	0.9910	1136						*	05/19/08
12/17/07	A	16	10	0.60	0.9932	574						*	05/19/08
		320	460				343.57	40.77	133.26	517.60	18.75	536.35	

•Blended Natural Gas Rate - \$1.166/Therm

•Blended Natural Gas Rate - \$10.83/Mmbtu

BEopt - Model Inputs

Location	
EPW Location	USA_CO_Boulder_TMY2.epw
Building Geometry	
Total Finished Floor Area (Above Grade)	2589 ft ²
# Floors (Above Grade)	2
Number of Bedrooms	5
Number of Bathrooms	3
Ceiling Height	9 ft
Basement Type	Finished
Garage	
<input checked="" type="radio"/> None	<input type="radio"/> Gable
<input type="radio"/> One Car	<input type="radio"/> Hip
<input type="radio"/> Two Car	<input checked="" type="radio"/> Flat
Position:	Left
Protrusion:	50 %
Pitch: 6:12	
PV	
PV Module	Generic - c-Si
Installed Cost	4.00 \$/W DC
Derate Factor	15.0 %

Reference PV Installed Cost: Based on Xcel Solar Rewards – Tier 1 Rebate (\$3.50/watt)

BEopt – Building Assumptions

Orientation

— North North East

- Azimuth – 202.5 Deg

Aspect Ratio

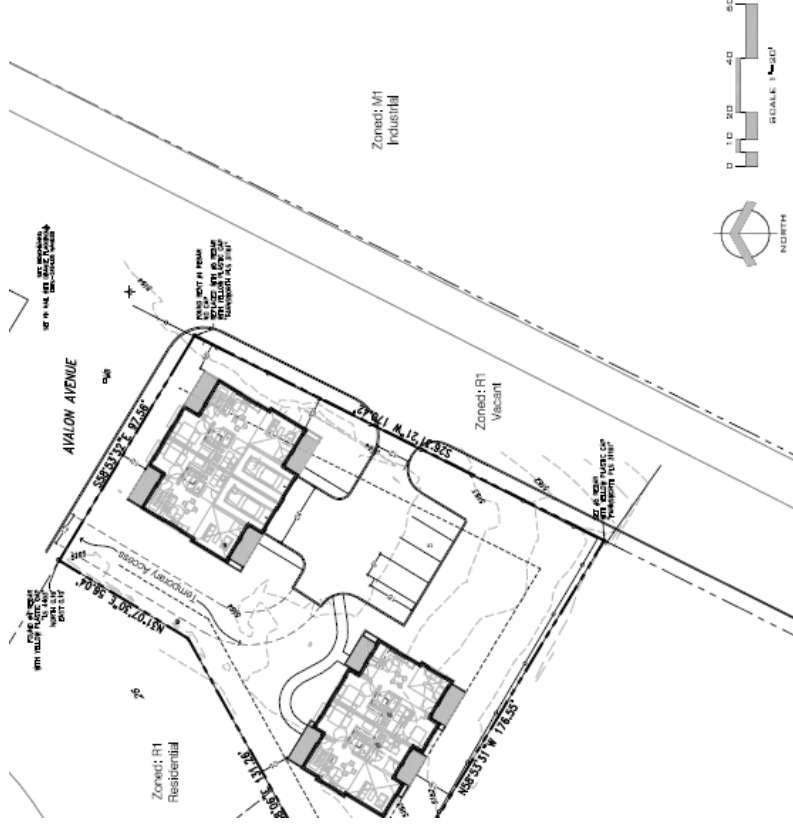
— 1.5 (44 ft x 29.5 ft)

Misc. Elec. Loads

— MEL multiplier 1.25 x BA Bench.

Misc. Gas Loads

— MEL multiplier 1.5 x BA Bench.



BEopt – Building Assumptions

Annual Appliance and Misc. Electric and Gas Loads

Appliance	Electricity (kWh/yr)	Natural Gas (therms/yr)	Sensible Load Fraction	Latent Load Fraction
Refrigerator	669		1.00	0.00
Clothes Washer (3 ft ³ drum)	$52.5 + 17.5 \times N_{br}$		0.80	0.00
Clothes Dryer (Electric)	$418 + 139 \times N_{br}$		0.15	0.05
Clothes Dryer (Gas)	$38 + 12.7 \times N_{br}$	$26.5 + 8.8 \times N_{br}$	1.00 (Electric) 0.10 (Gas)	0.00 (Electric) 0.05 (Gas)
Dishwasher (8 place settings)	$103 + 34.3 \times N_{br}$		0.60	0.15
Range (Electric)	$302 + 101 \times N_{br}$		0.40	0.30
Range (Gas)		$22.5 + 7.5 \times N_{br}$	0.30	0.20
Plug-In Lighting	$0.2 \times (\text{FFA} \times 0.8 + 455)$		1.00	0.00
Variable Miscellaneous Electric Loads (MELs)	$(1231 + 194 \times N_{br} + 0.316 \times \text{FFA}) \times F_s$		0.81	0.02
Fixed Miscellaneous Loads (Gas/Electric)	$(180 + 30 \times N_{br} + 0.047 \times \text{FFA}) \times F_s$	$(5.8 + 1.0 \times N_{br} + 0.0015 \times \text{FFA}) \times F_s$	0.13	0.25
Fixed Miscellaneous Loads (All-Electric)	$(349 + 58 \times N_{br} + 0.091 \times \text{FFA}) \times F_s$		0.13	0.25

Reference: Hendron, R. *Building America Research Benchmark Definition, Updated December 20, 2007*
NREL/ TP-550-42662

BEopt – Building Assumptions

- | | Heating Set Point | Natural Ventilation |
|---|--|--|
| – | 71 °F | BA Benchmark |
| – | Cooling Set Point
76 °F | Natural vent. rate calculated using the Sherman-Grimsrud model |
| – | Ventilation Rate | |
| – | 100% of ASHRAE 62.2 | |
| • | 80 cfm based on 5 bdrm & 3,884 ft ² | |

Thermostat based on optimum seasonal temperature for human comfort as defined in ASHRAE Standard 55-1992 (ASHRAE 1992)

BEopt – Building Assumptions

Wall Insulation

- R19 batt, 2 x6 16” o.c. +1/2” foam board
- R Value Assembly – 21.2 [hr-sqft-F/Btu]
- Framing factor – 25%
- R Value insulated cavity = 25
- R Value plates, studs & headers = 12

Ceiling Insulation

- R 50 cellulose [hr-sqft-F/Btu]

Equation 7: $SLA_{overall} = [(CFA_{bsmt} * SLA_{bsmt}) + (CFA_{a-g} * SLA_{a-g})] / [CFA_{total}]$,

where

$$SLA = ELA \text{ (ft}^2\text{)} / CFA \text{ (ft}^2\text{)}$$

$$SLA_{a-g} = SLA_{std} \text{ (where subscript 'a-g' indicates above-grade or exposed)}$$

$$SLA_{bsmt} = SLA_{std} \text{ (above-grade basement wall area)} / \text{(total basement wall area)}$$

$$SLA_{std} = 0.00057$$

Roofing Material

- TPO - white

Infiltration

- Second Tightest Option
- SLA = 0.00015

BEopt – Windows and Shading

Foundation

- 8 ft – w/ R20 exterior (similar to Insulated Concrete Form with 2 inch foam board on each side)

Window Areas

- Front – 76 ft²
- Back – 140 ft²
- Left – 15 ft²
- Right – 72 ft²

Window Type

- Standard double pane (U value = 0.447, SHGC = 0.547)

Eaves

- 3 ft overhang

BEopt – Large Appliances

Appliances

- Refrigerator – Standard
- Cooking range – Electric
- Dishwasher – Standard
- Clothes Dryer – Electric
- Clothes Washer – Standard (V-axis)

*Building America Research Benchmark - 6,000 kWh/yr
(based on square footage)*

Low Energy Case			
Appliance	Energy Usage (kWh)	Number of Units	Total Energy Usage (kWh/yr)
Refrigerator	383	2	766
Dishwasher	400	2	800
Clothes Washer	372	2	744
Television	205	4	820
Cable Box	150	2	301
VCR/DVD	122	2	244
Compact Audio	81	2	162
Microwave	159	2	318
Coffee Maker	150	2	300
Toaster Oven	50	2	100
Slow Cooker	16	2	32
Desktop PC	130	2	260
Cell Phone Charge	29	2	59
Video Gaming System	37	2	73
Iron	54	2	109
Ceiling Fan	50	4	200
Hair Dryer	35	2	71
Vacuum Cleaner	29	2	58
Totals	2,452		5,415

Reference: Hendron, R. *Building America Research Benchmark Definition, Updated December 20, 2007*
NREL/ TP-550-42662

BEopt – Lighting

Hardwired Lighting

- Adjusted to BCHA calculations
- Based on BA runtime

Plug In Lighting

- 100% CFL based on BA

First Floor						
Space	Number of Lamps	Lamp Rating (Watts)	Lamp Operation (hrs/dy)	Lamp Operation (hrs/yr)	Total Energy Usage (kWh/yr)	
Master Bedrooms	6	18	2.2	803	87	
Bedroom 2	3	18	2.2	803	43	
Kitchen 1	4	18	6.0	2,190	158	
Kitchen 2	4	18	6.0	2,190	158	
Living Room 1	3	18	5.0	1,825	99	
Living Room 2	3	18	5.0	1,825	99	
Bathroom	3	18	3.6	1,314	71	
Laundry 1	2	18	4.0	1,460	53	
Laundry 2	2	18	4.0	1,460	53	
Vestibule	2	18	3.0	1,095	39	
North Porch 1	1	18	1.6	584	11	
North Porch 2	1	18	1.6	584	11	
South Porch 1	1	18	1.6	584	11	
South Porch 2	1	18	1.6	584	11	
Total (First Floor)					900	
Second Floor						
Space	Number of Lamps	Lamp Rating (Watts)	Lamp Operation (hrs/dy)	Lamp Operation (hrs/yr)	Total Energy Usage (kWh/yr)	
Master Bedroom	6	18	2.2	803	87	
Loft	3	18	2.2	803	43	
Bathroom	2	18	3.6	1,314	47	
North Porch 1	1	18	1.6	584	11	
South Porch 1	1	18	1.6	584	11	
Total (Second Floor)					198	
Totals					1,099	

Reference: Hendron, R. *Building America Research Benchmark Definition, Updated December 20, 2007*
 NREL/ TP-550-42662

BEopt – Equipment

Air Conditioner

- No AC

Furnace

- AFUE 80%

Mechanical Ventilation

- Upgraded bathroom exhaust
 - The efficiency for each fan was set to 0.50 W/cfm.
 - The kitchen range hood is assumed to operate 30 minutes per day
 - Each bathroom fan is assumed to operate 60 minutes per day.
- Interactive effects between these spot exhaust ventilation fans and natural infiltration are included in the analysis.

Reference: Hendron, R. *Building America Research Benchmark Definition, Updated December 20, 2007*
NREL/ TP-550-42662

BEopt – Equipment

- Domestic Hot Water
- Standard Electric
- Ducts
- Typical
- Heating Capacity
- 70 kbtu/hr

	Prototype Foundation Type	Benchmark Duct Specification	
		One-Story	Two-Story or Higher
Supply Duct Surface Area (ft ²)	All	0.27 x FFA ^a	0.20 x FFA
Return Duct Surface Area (ft ²)	All	0.05 x N _{Returns} x FFA (Maximum of 0.25 x FFA)	0.04 x N _{Returns} x FFA (Maximum of 0.19 x FFA)
Supply Duct Insulation (Conditioned Space)	All		R-3.3
Return Duct Insulation (Conditioned Space)	All		None
Supply/Return Duct Insulation (Unconditioned Space)	All		R-5.0
Duct Material	All		Sheet Metal
Duct Leakage excluding Air Handler (Inside + Outside)	All	10% of Air Handler Flow (9% Supply, 1% Return) (Percentage lost to each space equal to percentage of duct area in that space, as specified below.	
Air Handler Leakage (Inside + Outside)	All	5% of Air Handler Flow (1% Supply, 4% Return)	
Percent of Duct / Air Handler Leakage Imbalance (Supply Minus Return, 5% of Air Handler Flow in All Cases) Made Up By Outside Air	Slab-on-grade or Raised floor	100% Outside air	37% Outside air
	Vented Crawl space	100% Outside air	37% Outside air
	Basement or Conditioned Crawlspace	100% Outside air	60% Outside air
Supply Duct Location	Slab-on-grade or Raised floor	100% Attic ^b	65% Attic ^b , 35% Conditioned Space
	Crawl space	100% Crawl space	65% Crawl space, 35% Above-Grade Conditioned Space
	Basement	100% Basement	65% Basement, 35% Above-Grade Conditioned Space
	Slab-on-grade or Raised floor	100% Attic ^b	100% Attic ^b
Return Duct and Air Handler Location	Crawl space	100% Crawl space	100% Crawl space
	Basement	100% Basement	100% Basement
	Slab-on-grade or Raised floor	15% Total (33% Return Fraction)	11.8% Total (42.2% Return Fraction)
Total Leakage to the Outside and Fraction on the Return Side (Calculated Based on Values Specified Above)	Vented Crawl space	15% Total (33% Return Fraction)	11.8% Total (42.2% Return Fraction)
	Basement or Conditioned Crawlspace	5% Total (0% Return Fraction)	3% Total (0% Return Fraction)

Reference: Hendron, R. *Building America Research Benchmark Definition, Updated December 20, 2007*
 NREL/ TP-550-42662

BEopt – Baseline Home Results

Mortgage + Utilities

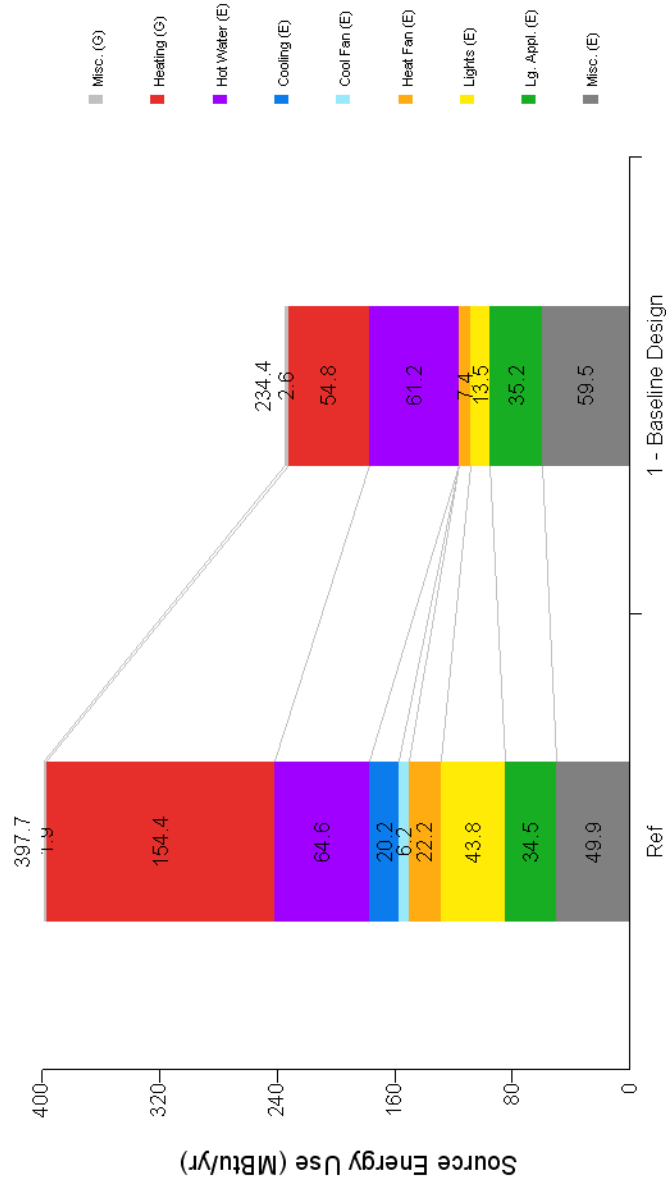
– \$2,481/yr

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.
	years	\$/sq ft \$/sq ft	\$/sq ft \$/sq ft	[Btu/F*sqft]
Exterior Partition	30	\$0.60 \$0.60	0.6	0.42
Exterior and Partition, 1/2" Drywall	30	\$0.62 \$0.60	0.65	0.52

BEopt – Optimization Parameters

Window Areas	Total	tal	al	OfTotal
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

@FrontPercentOf @BackPercentOfTo @LeftPercentOfTot @RightPercent

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)		LBNL (1998)		BCHA	
	Roberson et al.)		Lifetime 1		Roberson et al.)	
	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

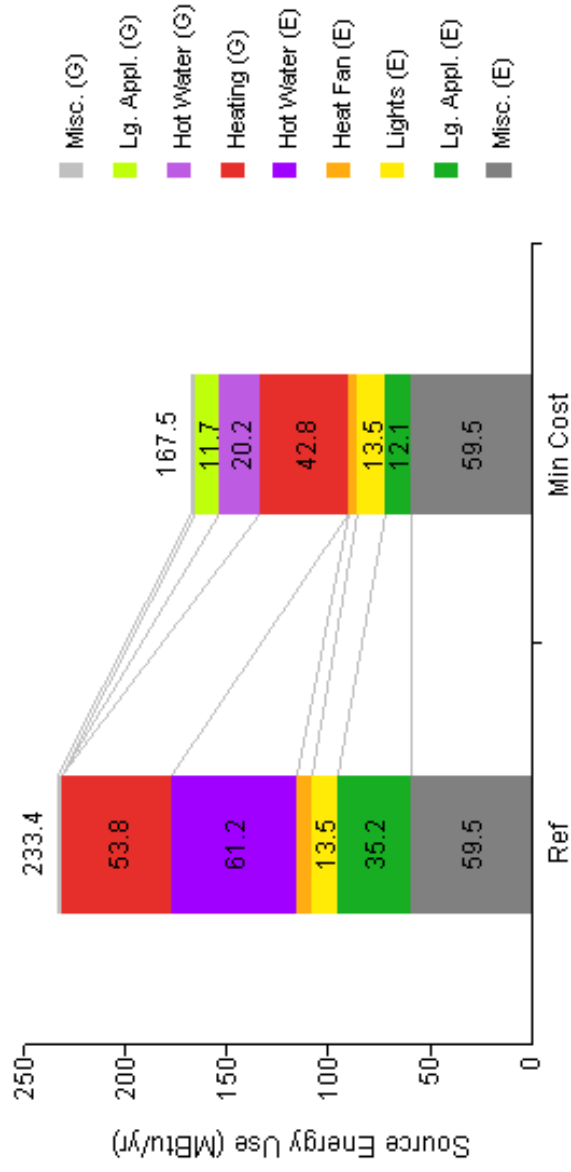
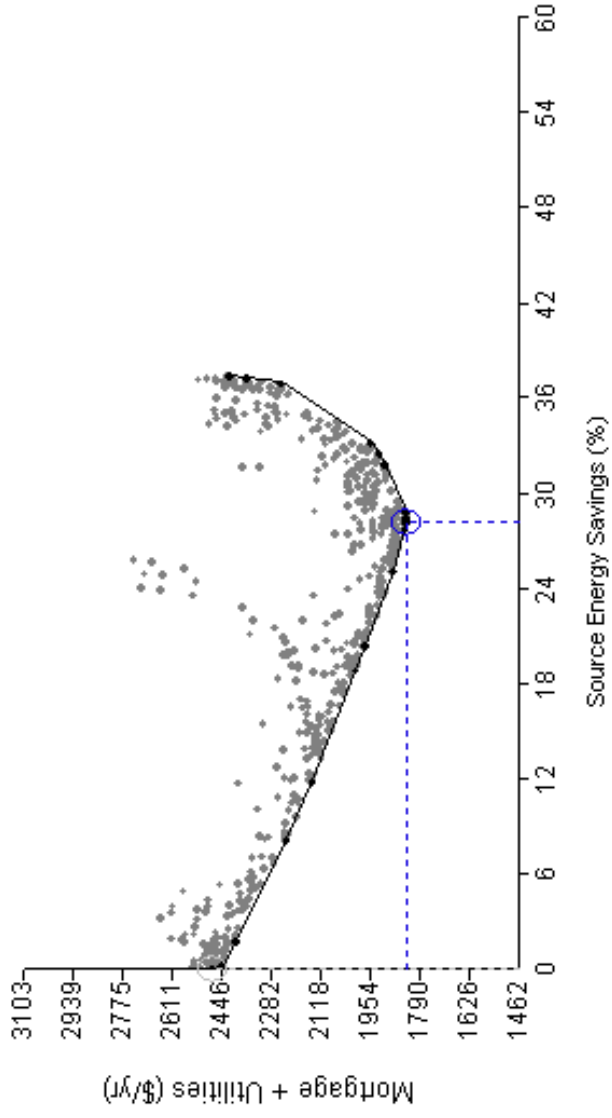
BEopt – Optimization Parameters

Ducts	DEER years	NAHB years	Lifetime 1 years	HERS default \$/sq ft
None	30	30		0.00
Typical	18	10		0.45
Improved	18	10		0.69
Inside	18	10		0.77

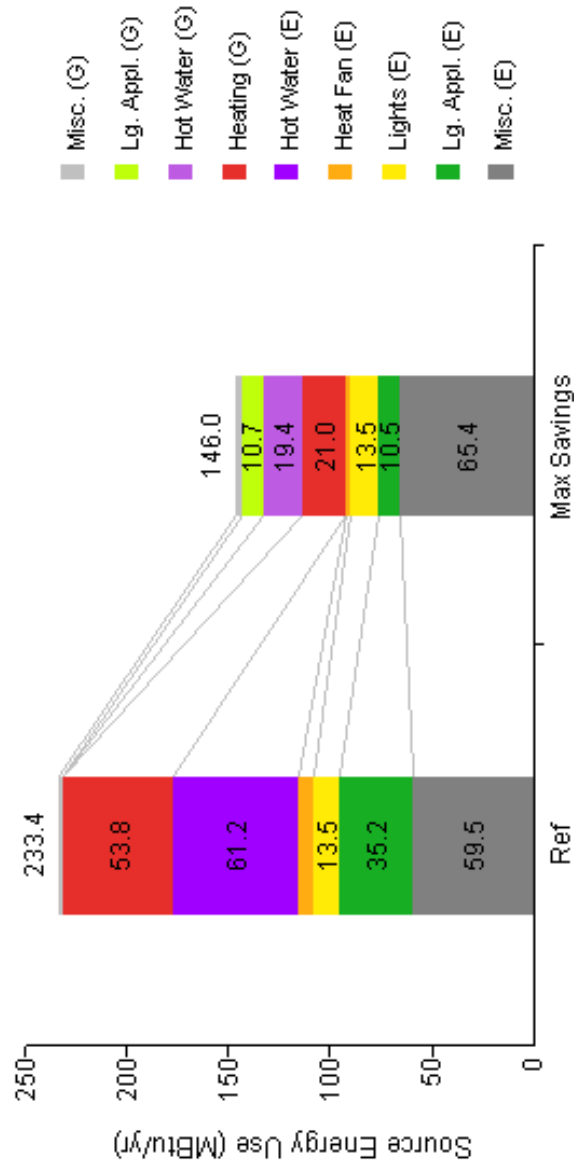
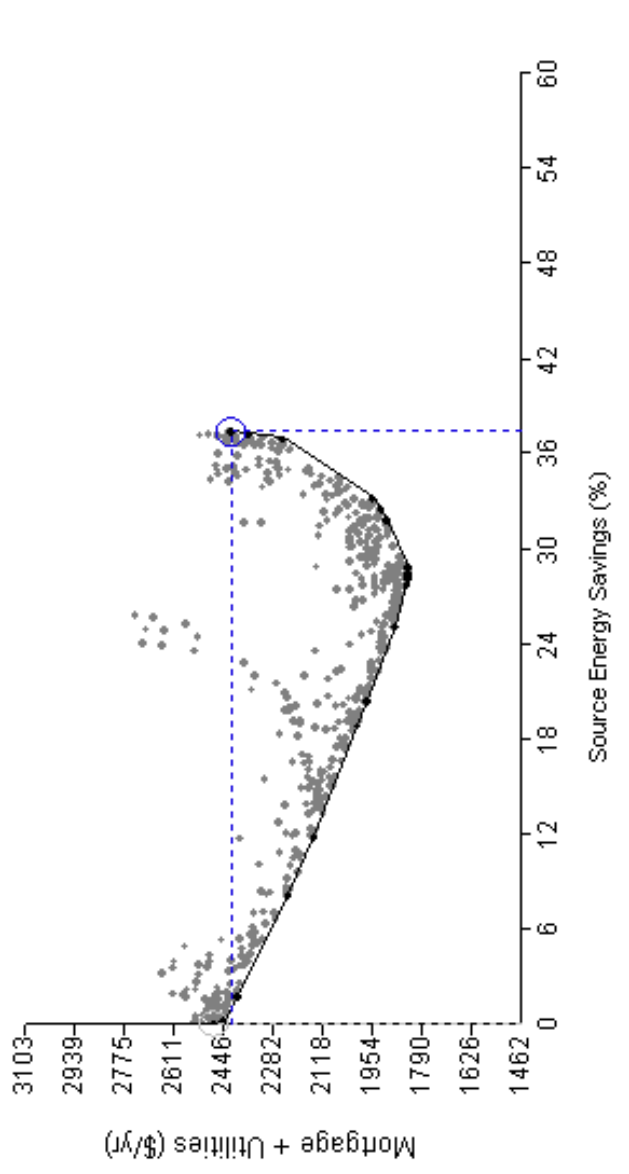
Solar DHW	Default years	Lifetime 1 years	Stoltenberg, BG \$/unit	BCHA \$/unit
No Solar DHW	30		0.0	\$
32 sq ft ICS	30		2654	100000
40 sq ft closed loop	30		4,307.0	4,307.00
64 sq ft closed loop	30		4768	4768
128 sq ft closed loop	30		4,768.0	9,000.00

Reference: Closed Loop SHW – Assumes 1.5 ft² of storage tank per square foot of collector

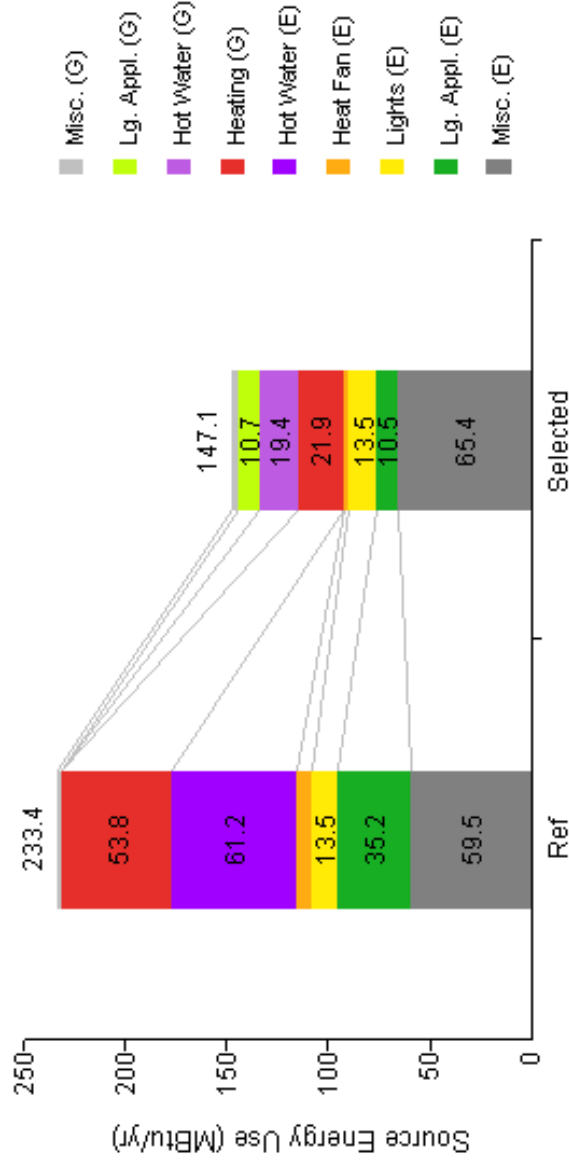
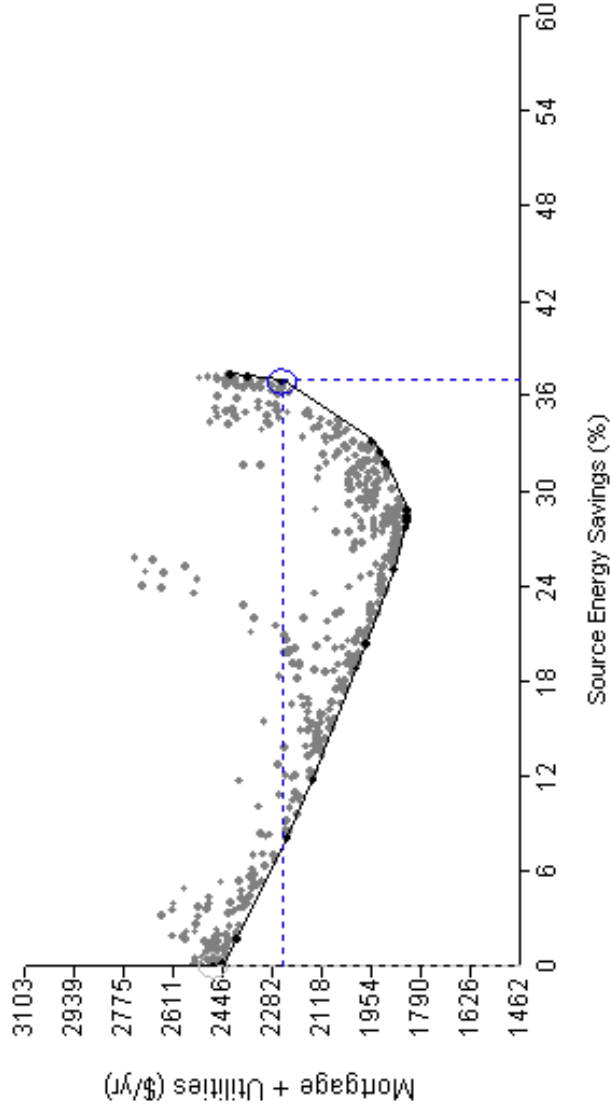
Beopt – Optimize Eff (Min Cost)



Beopt – Opt. Eff (Max Savings)



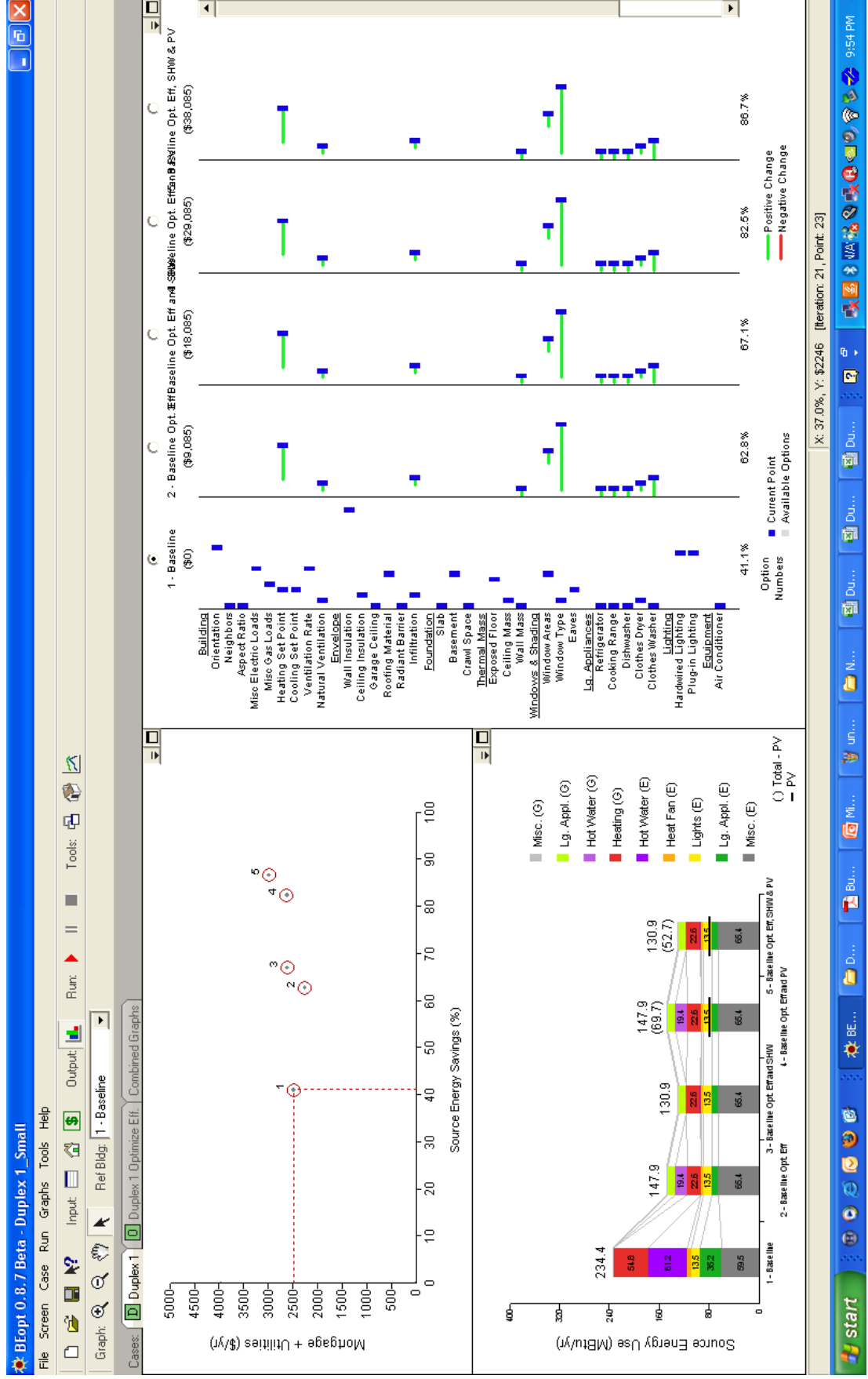
Beopt – Max. Eff and Savings



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				
	Wall Insulation	\$257	R21 batts 2x6 24"o.c. + 1" foam	
	Infiltration	\$1,886	Tightest	Tighter
Thermal Mass				
	Wall Mass	\$67	Exterior 5/8" Drywall	Exterior and Partition 1/2" Drywall
Windows & Shading				
	Window Areas	\$0	BCHA Duplex 1 Reduced West Gl	BCHA Duplex 1
	Window Type	\$6	Triple Low-E (e2=e5=.1) Clear (JD)	Double Clear
	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	AFUE96%	AFUE80%
	Mechanical Ventilation	\$3,667	Balanced Energy-Recovery Ventilator	Upgraded Bathroom Exhaust
	Water Heater	\$431	Gas Tankless	Electric Standard
Total Capital Cost (Present Value)		\$9,086		

BEopt – Duplex Optimization



BEopt – Duplex Optimization

Energy Efficiency Measures

– \$ 9,085

Solar Hot Water

– Closed loop system w/ 128 ft2 collector and 200 gallon storage
– 64 ft2 collector and 100 gallon storage per unit
– \$ 9,000

Roof Mounted PV

– 5 kW array (Will need 625 ft2 of roof space)
– 2.5 kW per unit
– \$ 20,000

Total Cost

– \$ 40,000/duplex
– 750 ft2 of available roof space

BEopt – Duplex Optimization

	Site Electricity Use (kWh/yr)									
	1 - Baseline		2 - Baseline Opt. Eff		3 - Baseline Opt. Eff & SHW		4 - Baseline Opt. Eff & PV		5 - Baseline Opt. Eff, SHW & PV	
Misc. (E)	5183	\$642	5697	\$706	5697	\$706	5697	\$706	5697	\$706
Lg. Appl. (E)	3067	\$380	916	\$113	916	\$113	916	\$113	916	\$113
Lights (E)	1180	\$146	1180	\$146	1180	\$146	1180	\$146	1180	\$146
Heat Fan (E)	648	\$80	254	\$31	254	\$31	254	\$31	254	\$31
Hot Water (E)	5334	\$661	0	\$0	93	\$11	0	\$0	93	\$11
Total	15412	\$0	8047	\$0	8140	\$0	8047	\$0	8140	\$0
PV	0	\$0	0	\$0	0	\$0	6810	-\$844	6810	-\$844
Net (Total - PV)	15412	\$1,910	8047	\$997	8140	\$1,009	1237	\$153	1329	\$165
Site Gas Use (Therms/yr)										
	1 - Baseline		2 - Baseline Opt. Eff		3 - Baseline Opt. Eff & SHW		4 - Baseline Opt. Eff & PV		5 - Baseline Opt. Eff, SHW & PV	
Heating (G)	502	\$560	207	\$231	207	\$231	207	\$231	207	\$231
Hot Water (G)	0	\$0	178	\$198	13	\$14	178	\$198	13	\$14
Lg. Appl. (G)	0	\$0	98	\$0	98	\$0	98	\$0	98	\$0
Misc. (G)	24	\$27	25	\$28	25	\$28	25	\$28	25	\$28
Total	526	\$587	508	\$457	343	\$273	508	\$457	343	\$273
Total Utilities		\$2,496		\$1,454		\$1,282		\$611		\$438
Mortgage + Utilities (\$/yr)		\$2,481		\$2,252		\$2,609		\$2,620		\$2,977
Source Energy Savings	41.1		62.8		67.1		82.5		86.7	

Programmable Thermostat

Programmable Thermostat Requirements:

Minimum of 7 day scheduling capability

EASY TO PROGRAM

Able to turn zone or unit on-off based on time and temperature

Adjustable dead-band (differential where thermostat remains neutral – no heating or cooling)

Programmable Thermostat Optional:

Multiple thermostats in multiple zones

Occupied/unoccupied control

Heating only

Cooling only

Ventilation only



Exterior Wall Construction

Wall Insulation

- Icynene insulation w/ (2x6) 24" o.c. +1/2" foam board
- R Value Assembly – 21.2 [hr-sqft-F/Btu]
- Framing factor – 20%
- R Value insulated cavity = 25
- R Value plates, studs & headers = 12
- **5% percent reduction in framing factor – reduced heat loss through walls**

Infiltration

Infiltration

- Step 1: Define infiltration requirement
 - RECOMMENDATION – Effective leakage area of 0.45 ft²
 - All trades need to take ownership of infiltration requirement
 - The air barrier needs to become as important as thermal barrier
- Step 2: Develop specification related to construction activities
 - House wrap shall be overlapped and taped correctly
 - All exterior penetrations shall be sealed
 - Gasket joints between modular units
 - Consider hiring an air sealant specialist

Duct Leakage

Duct Leakage

- Step 1: Develop duct system specifications
 - Specify duct leakage rate requirement (less than 5% of total air flow)
 - Specify mastic sealed or equivalent on duct joints and connections

Window Recommendations

Recommendation #1

North, East, West Façade
3 pane, 1 HM Low SHGC
U- Value – 0.12 [Btu/fr-sqft-F]
SHGC – 0.21

South
3 pane, 1 HM Low SHGC
U- Value – 0.13 [Btu/fr-sqft-F]
SHGC – 0.51

Alternative Recommendation

All American Spec.
2 pane, low e
U- Value – 0.33 [Btu/fr-sqft-F]
SHGC – 0.22

South
3 pane, 1 HM Low SHGC
U- Value – 0.13 [Btu/fr-sqft-F]
SHGC – 0.51

Large Appliances

Refrigerator

— Specify an energy star refrigerator

Cooking Range

— Specify a gas cooking range

Dishwasher

— Specify an energy star dishwasher

Clothes Dryer

— Specify a gas clothes dryer

— Specify a dryer with a temperature and moisture sensor

— Install a clothes line in the basement or laundry room to hang clothing

Large Appliances

Clothes Washer

- Specify an energy star clothes washer
- Specify a horizontal axis unit with weight sensing element
- Consider specifying a cold only clothes washer

Equipment

Furnace

- Specify a furnace with a 96% AFUE

Balanced Energy Recovery Ventilator

- Specify an ERV for each unit

Water Heater

- Specify a tank less gas water heater that is compatible with a SHW tank

Lighting



HOW TO CHOOSE THE RIGHT ENERGY STAR® QUALIFIED LIGHT BULB

	TABLE/FLOOR LAMPS	PENDANT FIXTURES	CEILING FIXTURES	CEILING FANS	WALL SCOFFCES	RECESSED CANS	TRACK LIGHTING	OUTDOOR COVERED	OUTDOOR FLOOD
	✓		✓	✓	✓			✓	
	✓	✓		✓				✓	
		✓							
	✓		✓					✓	
				✓	✓			✓	
				✓		✓	✓		
									✓

AVOID EARLY BURN OUT:

- Only bulbs marked "dimmable" or "three-way" will work on dimmers or three-way switches.
- Most photocells and timers are not designed to work with CFLs.



LEARN MORE AT
energystar.gov

Lighting

Exterior Lighting

- Specify LED lighting for all accent lighting

Interior Recessed Can Lighting

- Consider installing recessed can LEDs
- 12 Watt LED provides as much light as 75 Watt incandescent
- 50,000 hour life versus 10,000 hr CFL



LR6 from Cree LED Lighting Solutions
12W

Occupancy Sensors

- Install occupancy sensor in laundry rooms

Dimmable CFLs

- Install dimmable light switches and dimmable CFLs in large living spaces