
BEOPT-CA (EX)

A Tool for Optimal Integration of EE/DR/ES+PV in Existing California Homes

A Response to
**California Solar Initiative
Research, Development, Demonstration,
and Deployment Program Grant Proposal
Solicitation #1: PV Grid Integration**

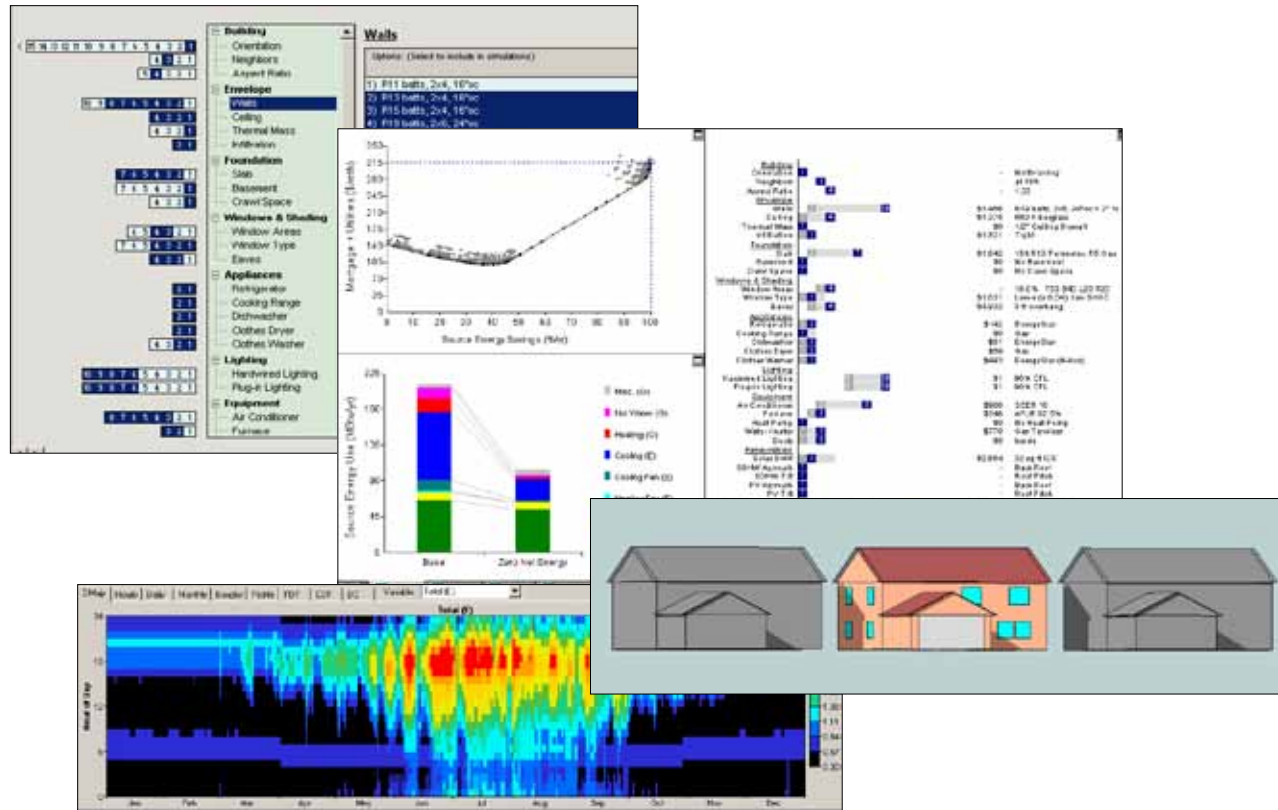
Prepared for
**CSI RD&D Program Administrator
Itron, Inc.**
Prepared by
National Renewable Energy Laboratory

**Craig Christensen
National Renewable Energy Laboratory**

**CSI RD&D Program
Coordination and IOU Outreach Meeting for Solicitation #1 Grants
July 22, 2010**

BEopt Building Energy Optimization with Hour-by-Hour Simulations

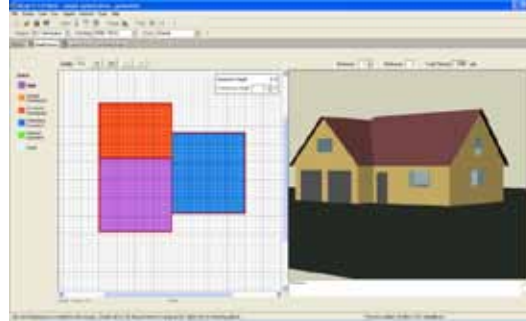
Craig Christensen, Scott Horowitz, Neal Kruis, Mike Lupton
National Renewable Energy Laboratory



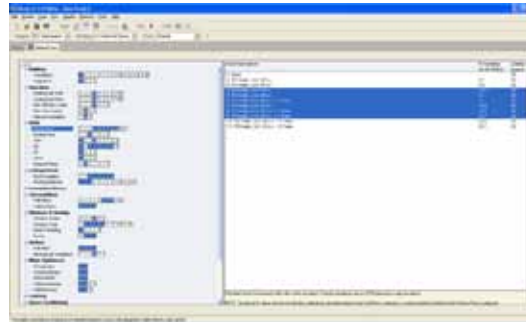
BEopt GUI (Level 1)

Input

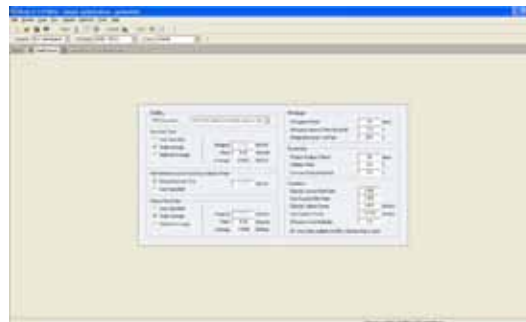
Geometry



Options



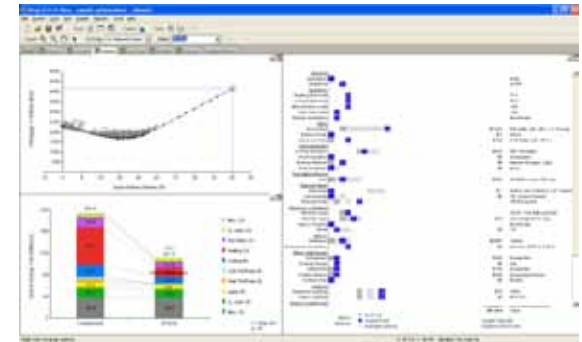
Site



Output



Run



- Cases:
- [D] Design
 - [P] Parametric
 - [O] Optimization

BEopt input

Analysis Modes:

(D) Design

(P) Parametric

(O) Optimization

- [-] +
- [-] Building
 - Orientation
 - Neighbors
- [-] Operation
 - Heating Set Point
 - Cooling Set Point
 - Misc Electric Loads
 - Misc Gas Loads
 - Natural Ventilation
- [-] Walls
 - Wood Stud
 - Double Stud
 - CMU
 - SIP
 - ICF
 - Other
 - Exterior Finish
- [-] Ceilings/Roofs
 - Roof Insulation
 - Roofing Material
- [-] Foundation/Floors
- [-] Thermal Mass
 - Wall Mass
 - Ceiling Mass
- [-] Windows & Shading
 - Window Areas
 - Window Type
 - Interior Shading
 - Eaves
- [-] Airflow
 - Infiltration

Window Type options	U-Value [Btu/hr-ft ² -°F]	SHGC	Lifetime [years]
Single Pane	0.869	0.619	20
Double Clear	0.447	0.547	20
Low-e low SHGC arg	0.285	0.266	20
Low-e std SHGC arg	0.285	0.295	20
Low-e high SHGC arg	0.298	0.417	20
Low-e v. high SHGC arg	0.325	0.511	20
Low-e, low SHGC	0.318	0.266	20
Low-e std. SHGC	0.318	0.302	20
Low-e high SHGC	0.325	0.424	20
Low-e v. high SHGC	0.352	0.511	20
Single Pane, 1 HM	0.257	0.345	20
Single Pane, 2 HM Kr	0.197	0.324	20

The U-values and SHGC's are air-to-air for the entire window assembly including frame and glazing (including edge spacer effects).

User-options require specifying the Glass-Type-Code (from DOE-2 window library), frame U-value, window framing factor, and frame spacer type (for multiple pane windows).

Argon-filled windows may not be available at higher altitudes (above approximately 3500 feet), due to issues with atmospheric pressure differences between the installation and manufacturer's locations.

BEopt input

A drawing tool for quick input of detailed building geometry

BEopt 0.9.01 Beta - sample design and parametrics

File Screen Case Run Graphs Reports Tools Help

Input: Output: Run: Tools:

Analysis: [P] Parametric Ref Bldg: 1st Selected Option Costs: Default

Cases: [D] what-ifs [P] what-ifs (2) [D] envelope, equipment designs [P] 1-category sensitivity [P] 2-category sensitivity Combined Graphs

Levels: Fnd 1st 2nd 3rd 4th

Bedrooms: 3 Bathrooms: 2 Total Finished: 1598 sqft

Spaces

- Slab
- Vented Crawspace
- Unvented Crawspace
- Unfinished Basement
- Finished Basement
- Erase

Basement Height: 8 ft
Crawspace Height: 4 ft

Scale: 1 cell = 1 ft Front

No errors.

Listing of geometry errors. The errors may prevent simulations from being run.

Previous runtime: 1m (6 simulations)

BEopt input

3) Site

BEopt 0.9.01 Beta - sample optimizations - geometries

File Screen Case Run Graphs Reports Tools Help

Input:  Output:  Tools:   <

Analysis: [0] Optimization Ref Bldg: 200b [1ECC] Costs: Default <

Cases: Small House Large House Combined Graphs

Building	
EPW Location	USA_GA_Atlanta-Hartsfield-Jackson.Intl. ▾
Electricity Rate	
<input type="radio"/> User Specified	
<input checked="" type="radio"/> State Average	Marginal 0.0842 \$/kWh
<input type="radio"/> National Average	Fixed 8.00 \$/month
	Average 0.0910 \$/kWh
Net-Metered Excess Electricity Sellback Rate	
<input checked="" type="radio"/> Retail Electricity Cost	0.0842 \$/kWh
<input type="radio"/> User Specified	
Natural Gas Rate	
<input type="radio"/> User Specified	
<input checked="" type="radio"/> State Average	Marginal 1.5541 \$/therm
<input type="radio"/> National Average	Fixed 8.00 \$/month
	Average 1.7036 \$/therm
Mortgage	
Mortgage Period	30 years
Mortgage Interest Rate (Nominal)	7.0 %
Marginal Income Tax Rate	28.0 %
Economics	
Project Analysis Period	30 years
Inflation Rate	3.0 %
Discount Rate (Nominal)	5.0 %
Multipliers	
Electric Source/Site Ratio	3.365
Gas Source/Site Ratio	1.092
Electric Carbon Factor	1.670 lb/kWh
Gas Carbon Factor	14.740 lb/therm
Efficiency Cost Multiplier	1.0
<input checked="" type="checkbox"/> Use state multiplier for Misc. Electric/Gas Loads	

Previous runtime: 5h 49m (1,073 simulations)

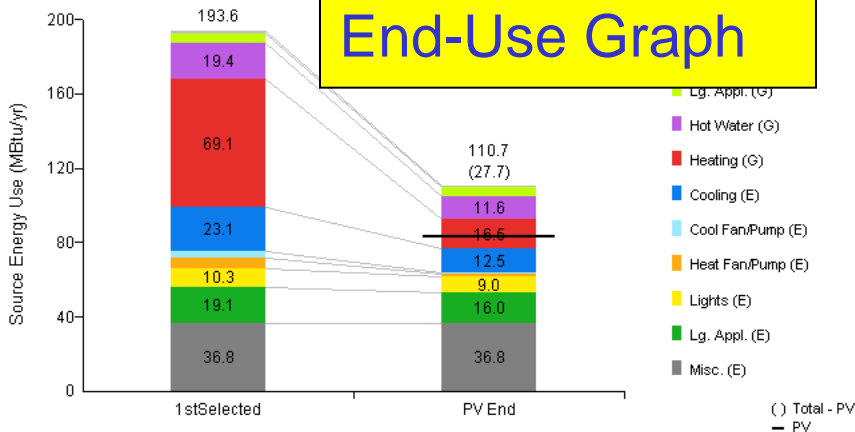
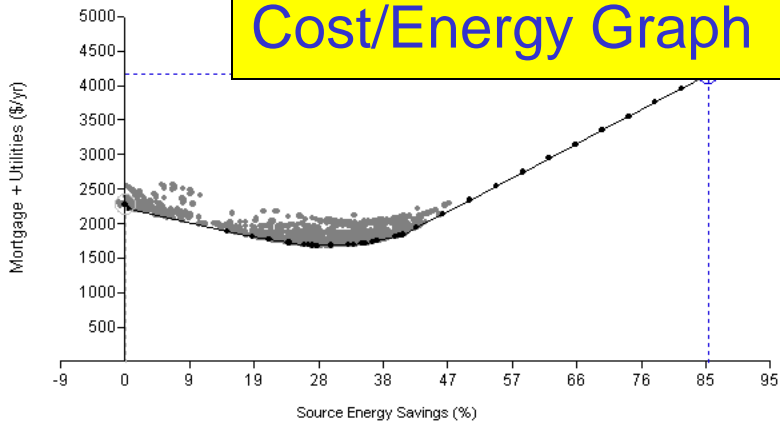
BEopt output

BEopt 0.9.01 Beta - sample optimizations - climates

File Screen Case Run Graphs Reports Tools Help

Graph: Ref Bldg: 1st Selected Option Select: PV End

Cases: Phoenix Houston Atlanta San Fran Boulder Chicago Combined Graphs



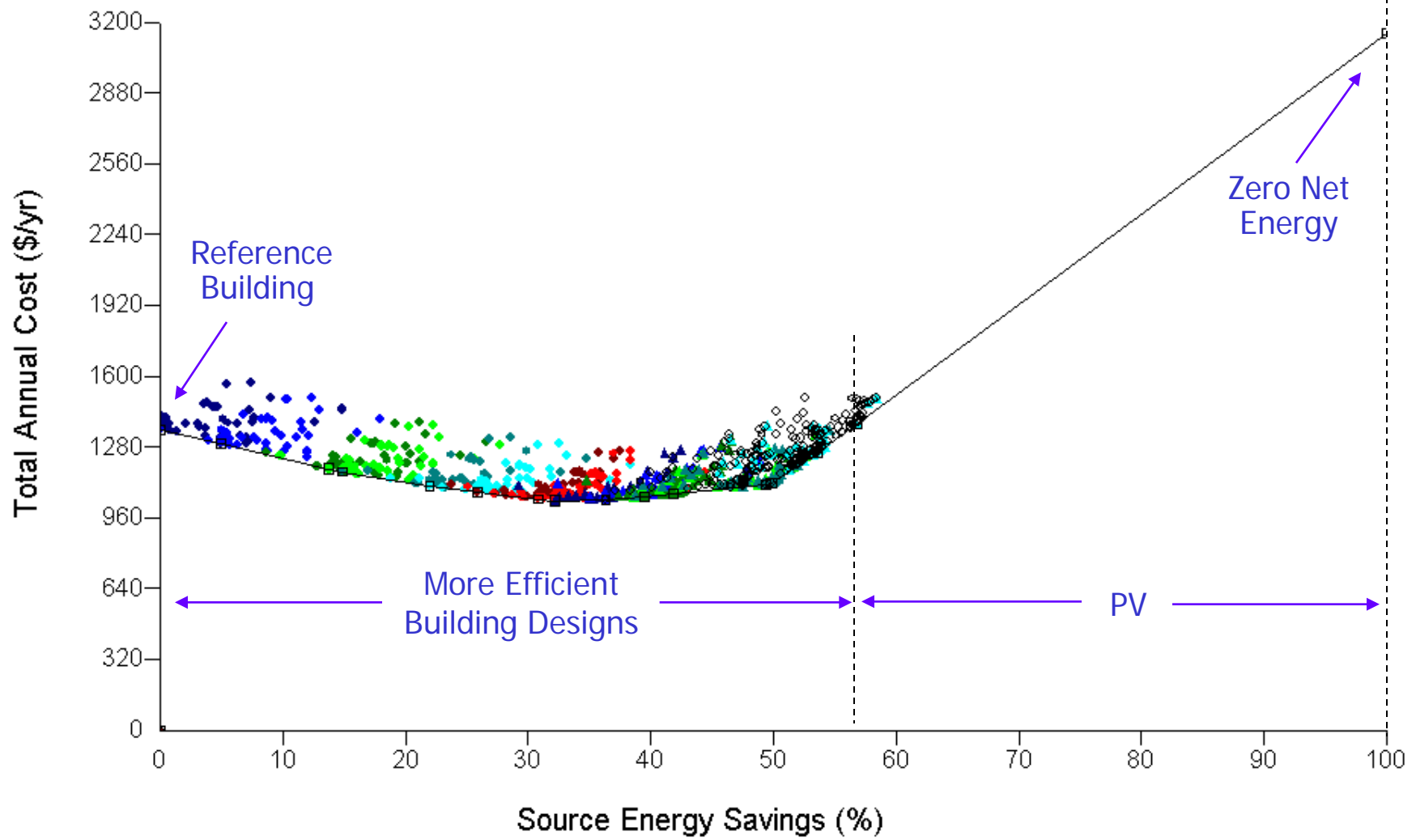
Options Graph

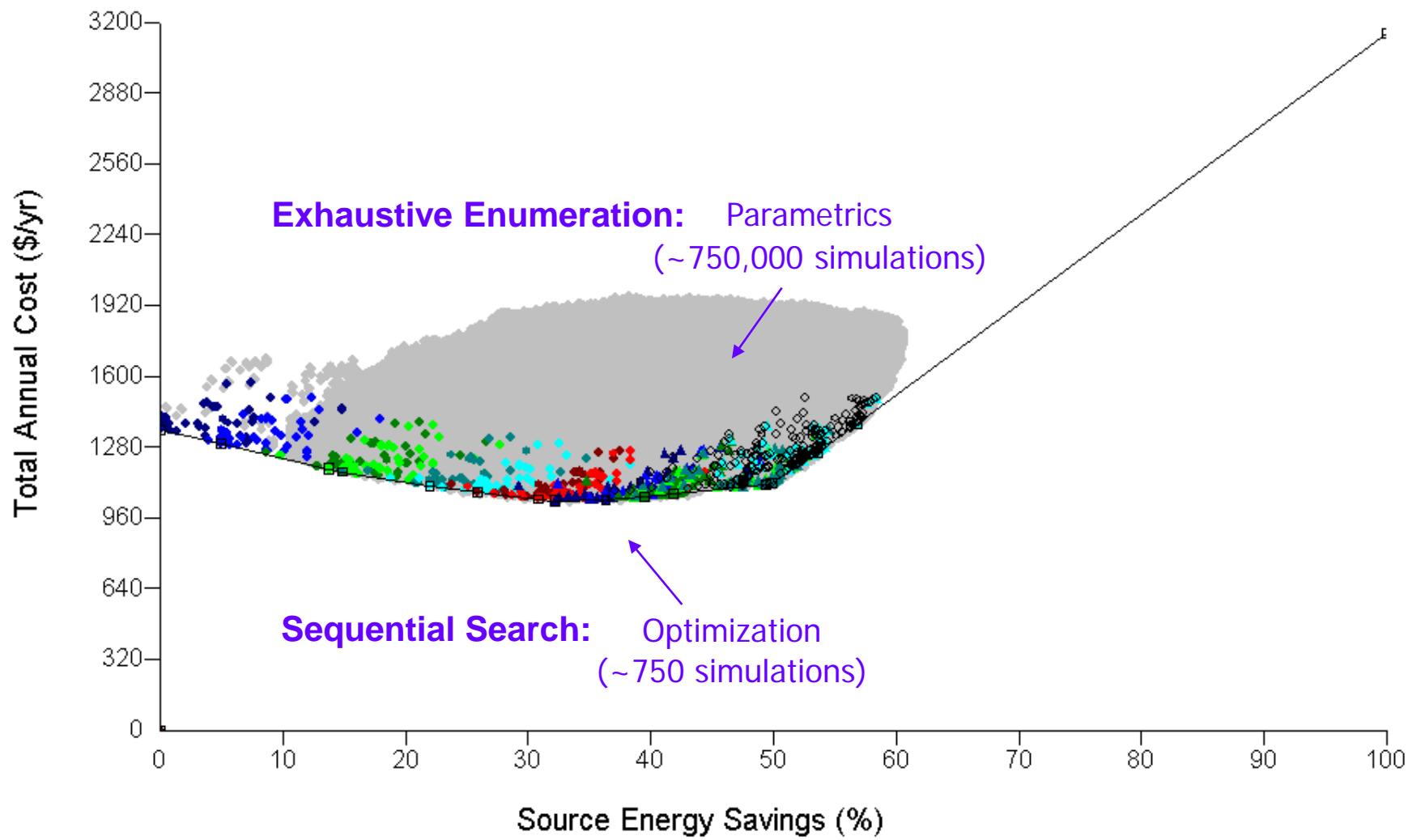
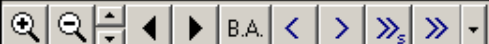
Component	Option Number	Cost	Energy Savings
Orientation	1	-	-
Neighbors	3	-	-
Heating Set Point	4	-	71 F
Cooling Set Point	4	-	76 F
Misc Electric Loads	4	-	1.00
Misc Gas Loads	2	-	1.00
Natural Ventilation	2	-	Benchmark
Wood Stud	3	\$2,023	R19 batts, 2x6, 24"o.c. + 2" foam
Exterior Finish	1	-\$3	Stucco
Interzonal Walls	4	\$150	R-19 Batt, 2x6, 16"o.c.
Ceiling Insulation	6, 7	\$520	R40 Fiberglass
Roof Insulation	1	\$0	Uninsulated
Roofing Material	3	\$0	Asphalt Shingles, Light
Radiant Barrier	1	\$0	None
Slab	3	-	4ft R5 Perimeter, R5 Gap
Window Areas	3, 4	-	18.0% F20 B40 L20 R20
Window Type	3, 5	\$10	Low-e high SHGC arg
Interior Shading	1	-	Benchmark
Eaves	2	\$0	1 ft
Infiltration	1, 3	\$4,983	Tighter
Mechanical Ventilation	4	\$0	Exhaust, 100% of A-62.2
Refrigerator	1, 2	\$264	EnergyStar
Cooking Range	2	\$0	Gas
Dishwasher	1, 2	\$130	EnergyStar
Clothes Washer	1, 2	\$708	EnergyStar (H-Axis)
Clothes Dryer	1	\$0	Electric
Hardwired Lighting	6	\$18	100%
Plug-in Lighting	6, 10	\$3	90% CFL
Total		\$57,809	

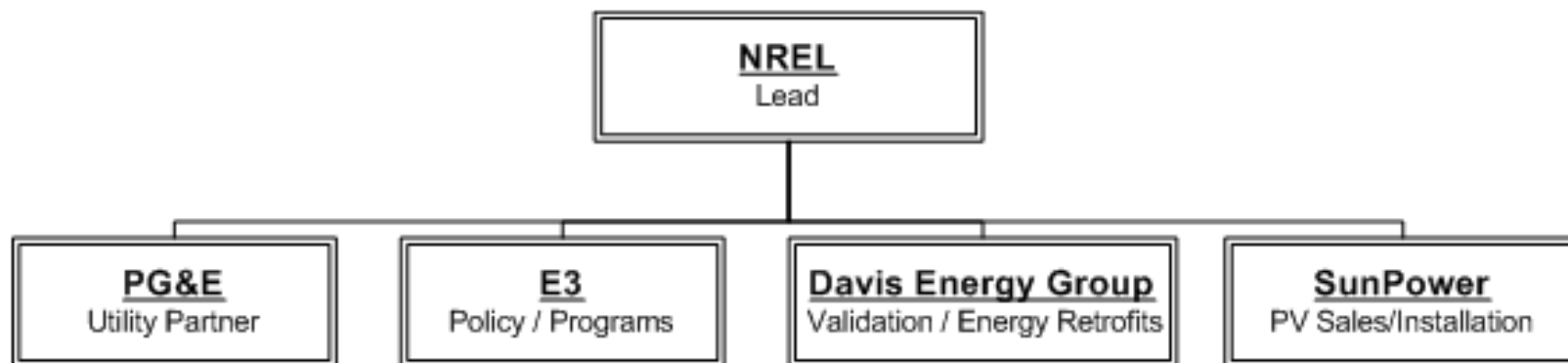
Option Numbers:
■ Ref Point
■ Current Point
■ Available Options

Right-click for graph options.

X: 85.7%, Y: \$4159 [Iteration: 54, Point: 0]







NREL Expertise

BEopt (DOE2)

- DOE-2 engine
- New homes
- DOE-funded
- Completed

BEopt (E+)

- EnergyPlus engine
- New homes
- DOE-funded
- Ongoing

NREL Residential Buildings

- Existing Homes Research
- DOE-funded
- Ongoing

BESTESTEx

- Retrofit software validation
- DOE-funded
- Ongoing

BEopt-CA (Title-24)

- MICROPAS engine
- New homes
- CEC-funded
- Completed

Collaborator Expertise

PG&E Residential Programs

- 2009-2011 Residential Programs
- Integrated Audit Tool
- Program metrics

Davis Energy Group Expertise

- Existing Home Retrofit Study
(CEC funding pending)
- Residential energy use expertise

E3 Cost/Benefit Analysis

- Developer of "E3 Calculator"
- Developer of CPUC Avoided Costs
- Standard Practice Manual expertise

SunPower Experience

- PV performance in the field
- PV cost projections
- PV market intelligence

Technical Approach

I. Integrated EE/DR/ES+PV Model Development

- Modify *BEopt* analysis methodology to apply to retrofit of **existing homes**
- Add **energy efficiency measures** that are retrofit-specific and California-appropriate
- Add **cost library data** for EE/DR/ES+PV measures for California retrofit markets
- Add California **utility tariff capabilities**
- Add methodology and outputs for **utility benefit-cost tests**
- Add methodology and measures for **demand response** and **energy storage**
- Modify the **user interface** to include additional inputs, outputs, and reports

Technical Approach (cont.)

II. Integrated EE/DR/ES+PV impact assessment

- Develop **prototypes** for existing buildings in California retrofit markets
- **Validate**/calibrate EE and PV predictions in the integrated EE/DR/ES+PV model
- Optimize and evaluate the **house-by-house potential** of integrated EE/DR/ES+PV
- Optimize and evaluate the **utility-scale potential** of integrated EE/DR/ES+PV

III. Integrated EE/DR/ES+PV Best Practices

Develop *BEopt*-CA(Ex) **results portfolios** to inform utility residential programs

Training for IOU program planners and select California energy professionals.

Key Project Outcomes

BEopt -CA (Ex)

- EnergyPlus
- Existing Homes
- CA pricing
- TRC, program metrics
- Validated

1. Portfolios of EE, DR, ES, and PV
2. Optimal packages for retrofit
3. CPUC best practices program outputs