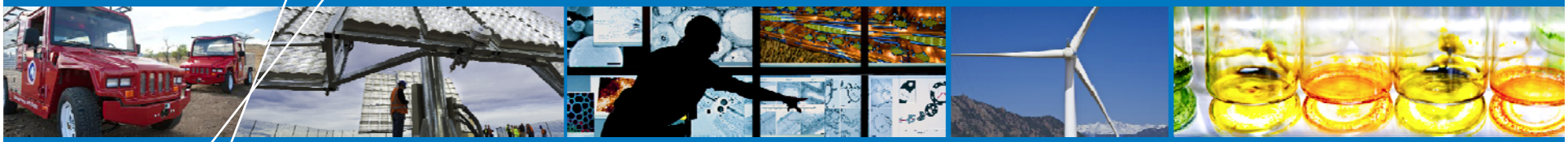
BEopt-CA

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



National Renewable Energy Laboratory (NREL)

Davis Energy Group (DEG)

Energy + Environmental Economics (E3)

January 23, 2013

Oakland, CA

NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

Agenda

Introduction

Project Overview

New BEopt Features

- What is BEopt?
- Retrofit Analysis
- Demo BEopt

Utility Cost Tests

- Background and Implementation
- Demo BEopt Utility Cost Tests
- BEopt Utility Cost Test Examples

Ongoing and Future work:

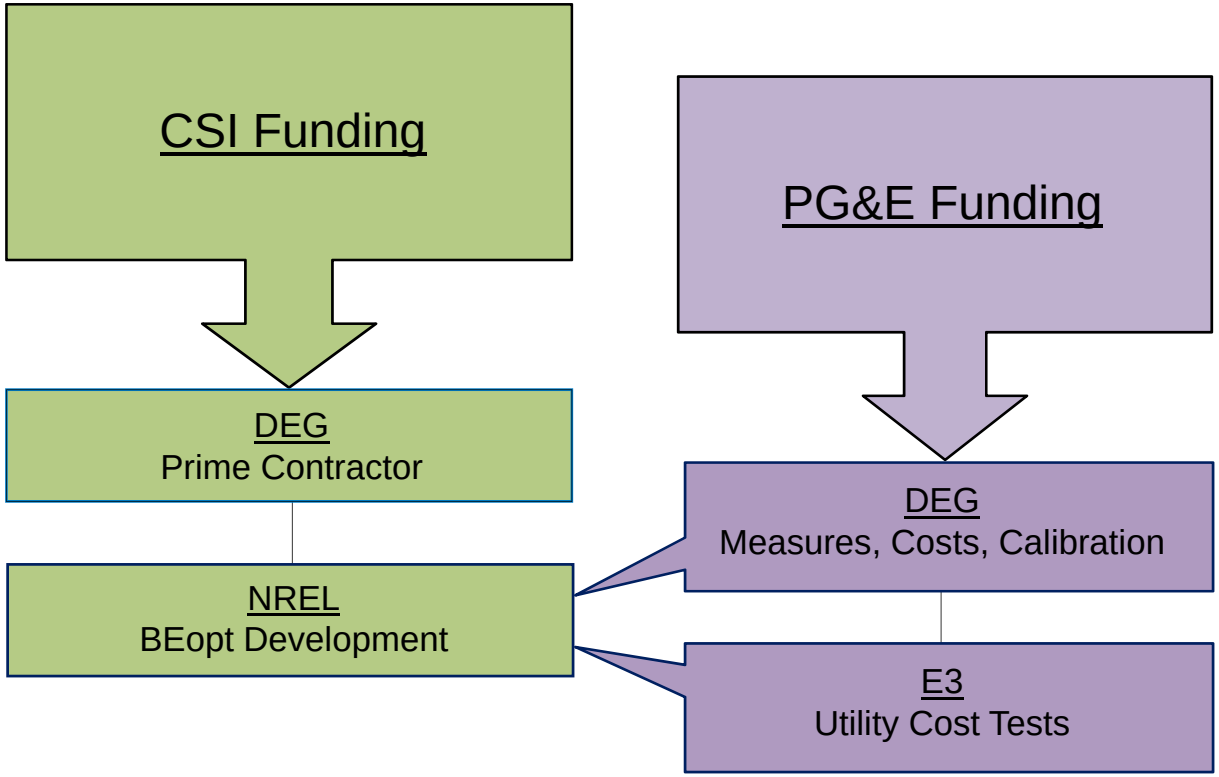
- DR and Energy Storage
- Calibration
- Connecting to CSE
- Community-Scale Analysis

Feedback and Discussion

Objective

- Develop a software tool to provide utility program managers in California with a means of balancing and integrating energy options in existing homes:
    - EE – Energy Efficiency
    - DR – Demand Response
    - ES – Energy Storage
    - PV – Photovoltaics

Team/Roles


CSI Funding
PG&E Funding
DEG
Prime Contractor
DEG
Measures, Costs, Calibration
NREL
BEopt Development
E3
Utility Cost Tests

Technical Approach

I. Model Development

1. Modify *BEopt* analysis methodology to apply to **retrofit analysis**
2. Add energy **efficiency measures** that are retrofit-specific and California-appropriate
3. Add **cost library** data for EE/DR/ES+PV measures for California retrofit markets
4. Add California **utility tariff** capabilities
5. Add methodology and outputs for **utility benefit-cost tests**
6. Add methodology and measures for **demand response** and **energy storage**
7. Modify the **user interface** to include additional inputs, outputs, and reports
8. Connect *BEopt* to **CSE** (California Simulation Engine)

Technical Approach (cont.)

II. Impact Asessment

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

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

1. Develop *BEopt*-CA(Ex) results **portfolios** to inform utility residential programs
2. Training for IOU program planners and select California energy professionals.

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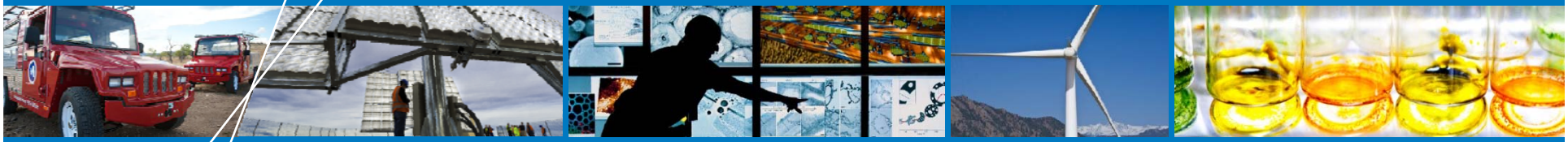
New BEopt Features

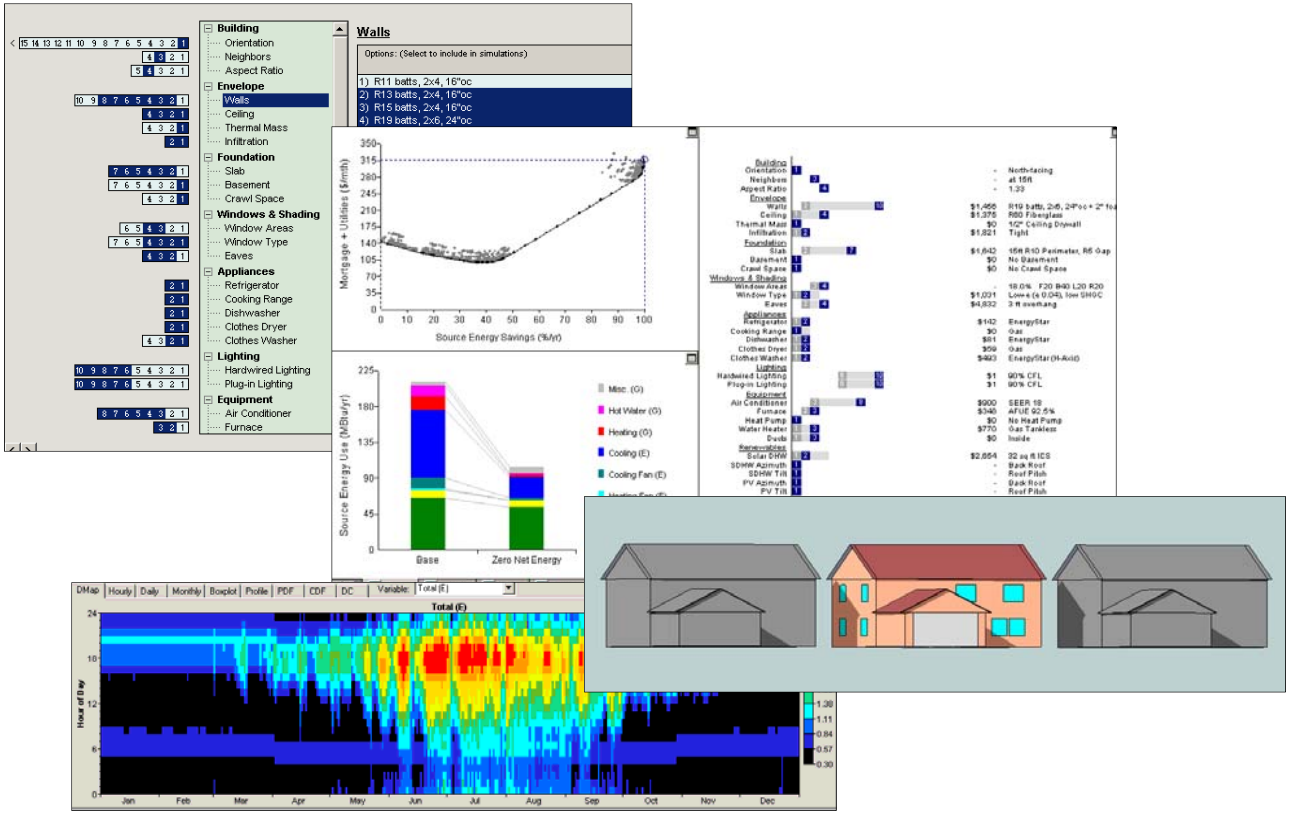


- What is BEopt
- Retrofit Analysis
- Demo

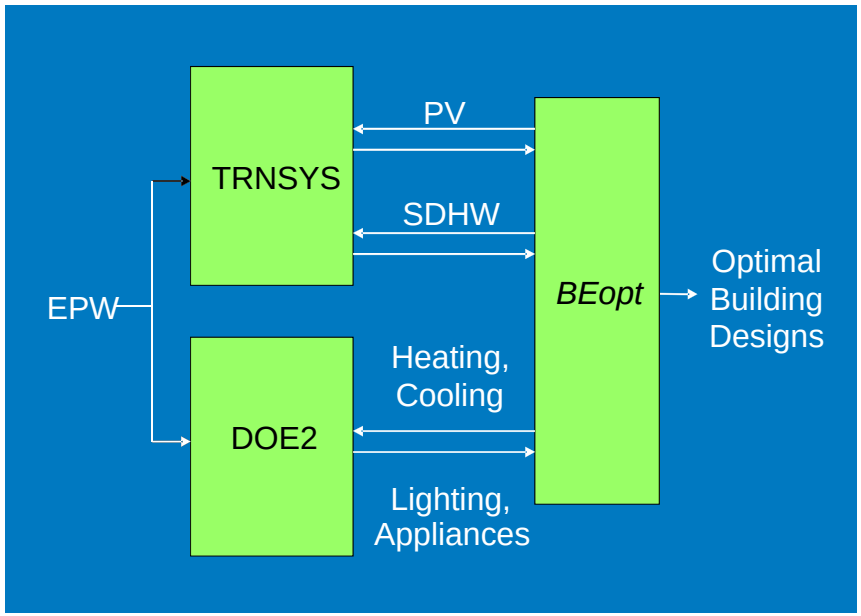
BEopt

Building Energy Optimization Based on Hour-by-Hour Simulations

beopt.nrel.gov



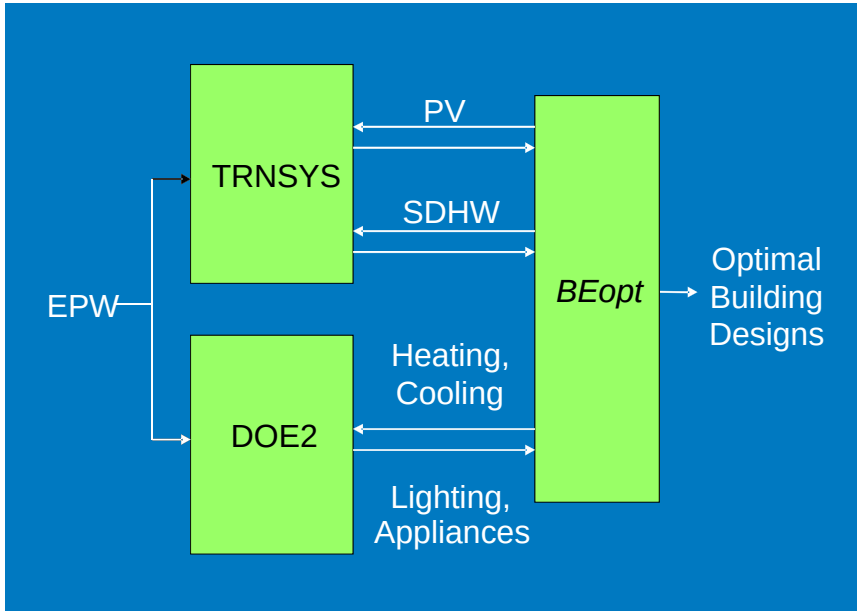
BEopt (TRNSYS + DOE2)



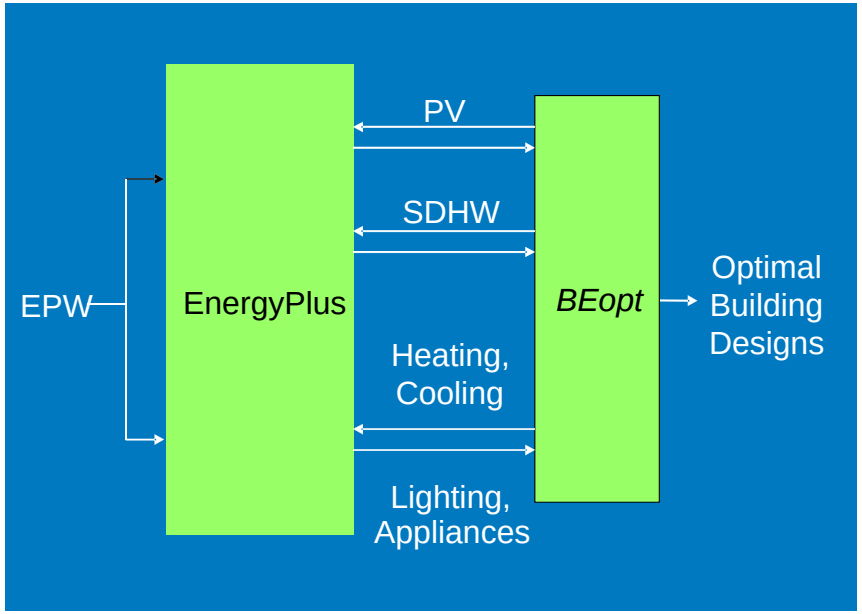
- **Runs detailed hour-by-hour simulations**
- **Accurately accounts for interactions (e.g., glass type and HVAC)**
- **Evaluates realistic (discrete) options**
- **Finds optimal designs from base case to zero net energy**
- **Identifies near-optimal alternative designs**
- **User-specified or Building America occupancy/operating assumptions and climate-specific reference buildings**

BEopt can run different simulation engines

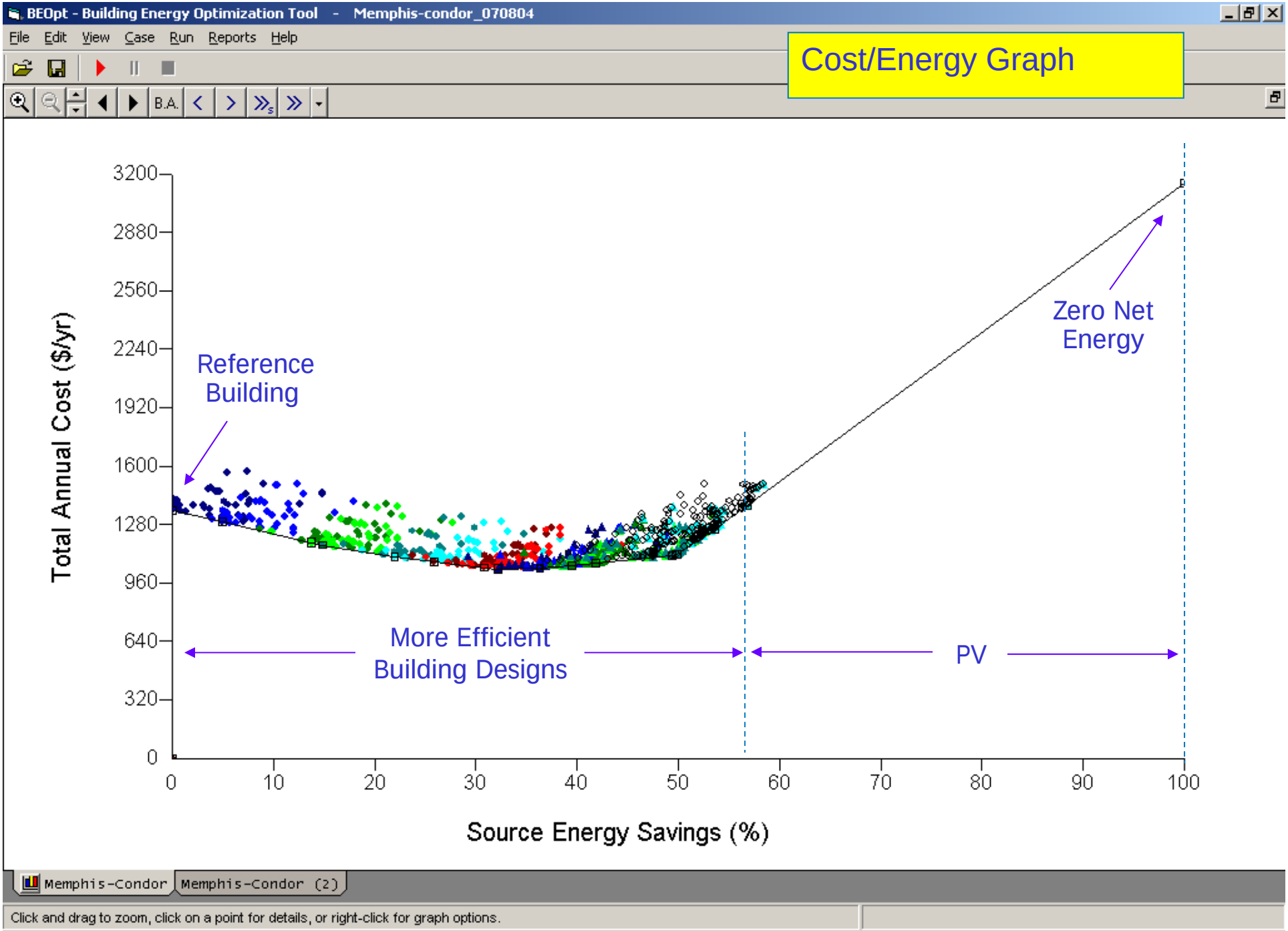
BEopt (TRNSYS + DOE2)

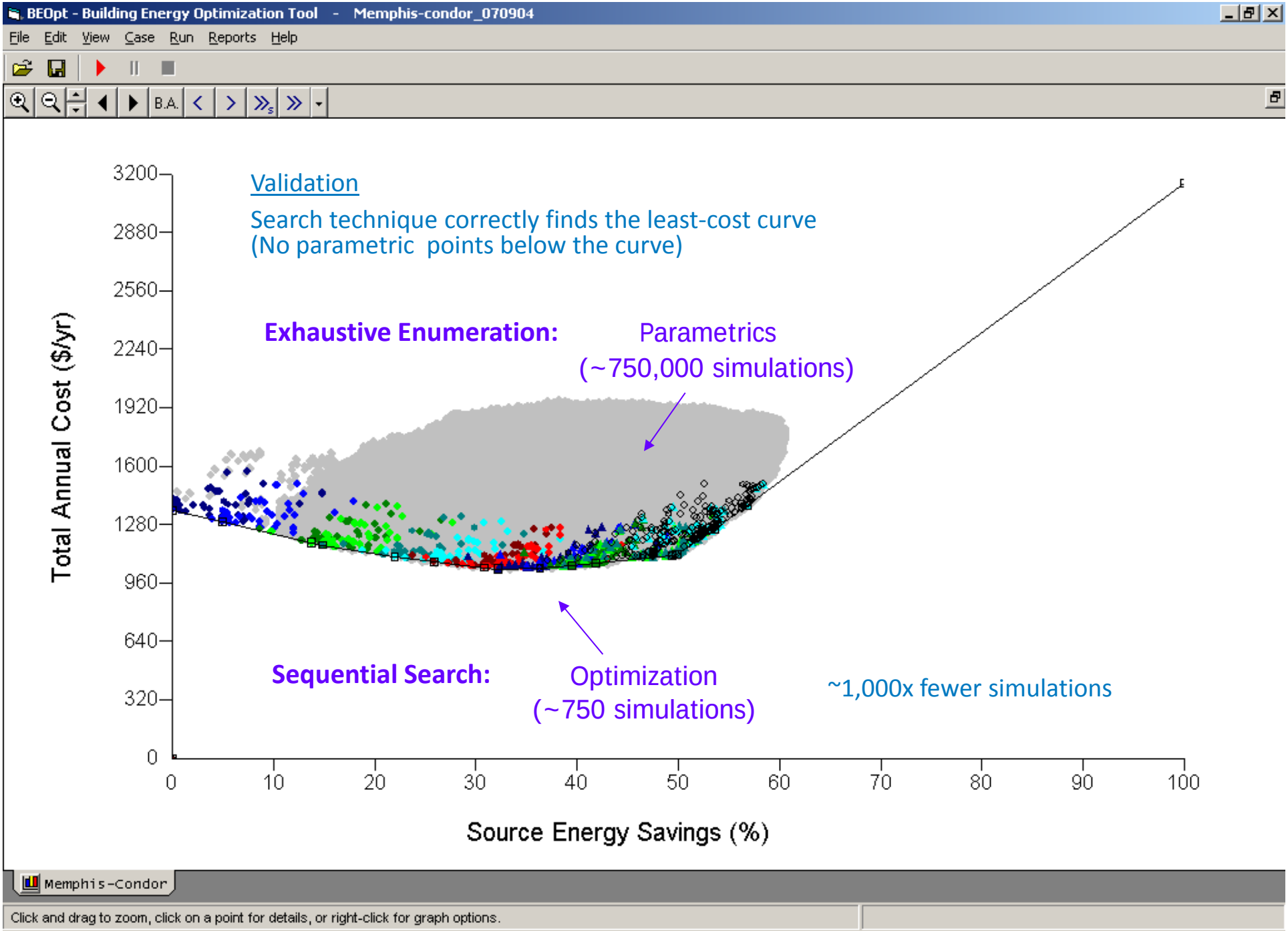


BEopt (EnergyPlus)



Cost/Energy Graph




BEOpt - Building Energy Optimization Tool - Memphis-condor_070904
File Edit View Case Run Reports Help
Validation
Search technique correctly finds the least-cost curve
(No parametric points below the curve)
Exhaustive Enumeration:
Parametrics
(~750,000 simulations)
Sequential Search:
Optimization
(~750 simulations)
~1,000x fewer simulations
Total Annual Cost ($/yr)
3200
2880
2560
2240
1920
1600
1280
960
640
320
0
0
10
20
30
40
50
60
70
80
90
100
Source Energy Savings (%)
Memphis-Condor
Click and drag to zoom, click on a point for details, or right-click for graph options.

Retrofit Analysis

- **Retrofit timing**
  - Age of existing options => remaining life
  - Upgrade today or upgrade at wear-out
- **"Minimum Upgrades"**
  - Comply with code, available on market
  - Reference building at wear-out
  - Design building at wear-out or today
  - Cost of upgrade included, at time of upgrade
- **Multiple energy simulations if upgrade at wear-out**
  - For years before upgrade
  - For years period after upgrade

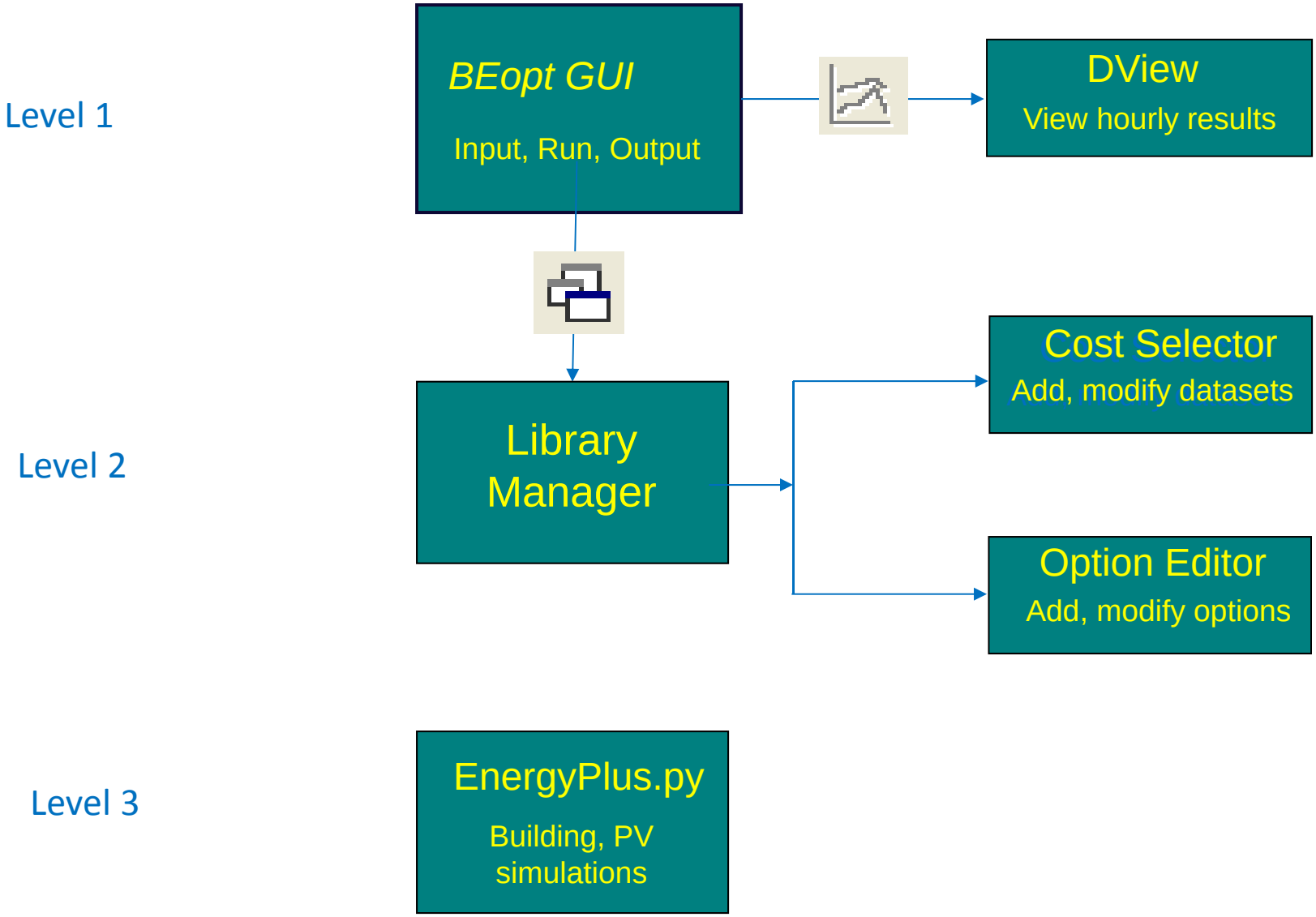
Retrofit Measures and Cost

- Include measures that are most likely to be used in standard California retrofits
- Where possible apply cost data from local sources and use California labor assumptions
- Retrofit specific labor costs include details not included in other cost data
- Compliments NREL's National Residential Efficiency Measure Database (www.nrel.gov/ap/retrofits/group_listing.cfm)

Retrofit Modeling

- **HVAC sizing**
  - Set size of existing equipment
  - Only downsize if HVAC is being replaced
- **Non-central space conditioning systems**
  - Window ACs, mini-splits
- **Heat transfer sensitive to highly-conductive components**
  - Uninsulated walls/ceilings
  - Single glazed windows

BEopt: simple or detailed to use (open architecture)



BEopt Demo

- Measures
- Costs
- Retrofit Analysis
- Utility Tariffs

For More Information

BEopt 2.0 currently available in Beta
(Official release in February 2013)

beopt.nrel.gov

craig.christensen@nrel.gov

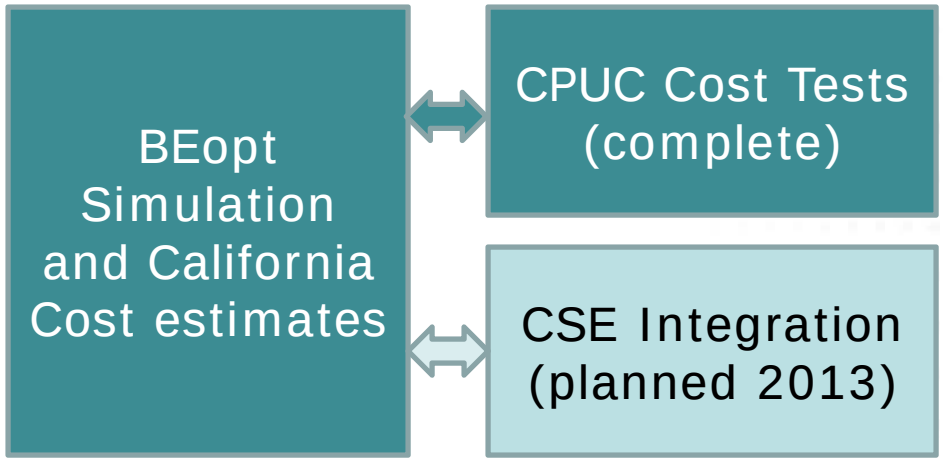
UTILITY COST TESTS
POLICY CONTEXT & APPROACH

Broad policy context

- **Three key policy drivers that make the overall project efforts relevant**
  - Energy efficiency strategic plan and increasing pressure on the IOUs to achieve deeper EE savings
  - Statewide policy goals on ZNE (new construction)
  - Statewide near and longterm climate goals (24,200 GWh of EE by 2020)
- **Historically, it has been difficult to justify residential retrofits that go deep**
  - Cost-effectiveness constraints can be problematic: important measures like windows may not pass when evaluated independently
  - Systems approach instead of a piecewise measure approach can help achieve deeper savings

Project Objective

- Enhance the BEopt tool so that it can be used more directly in the energy efficiency program framework of the California Public Utilities Commission (CPUC)
- Team focused on the process and steps to incorporate the cost-effectiveness metrics used by the CPUC into the BEopt modeling framework



How this project fits

+ Supports existing residential retrofit programs

- Utility program managers, implementers, architects, engineers have a single tool for **integrated analysis** of incentives, measures, program costs, EE and PV
- Program design, modeling prescriptive packages, customized incentives, SPM cost-effectiveness assessment

+ Supports analysis of residential ZNE buildings

- Source or site energy savings (%) metrics available
- Additional metrics, such as TDV, potentially available

Two approaches to cost effectiveness implementation

- **Integrated approach (#1): Integrating the cost-effectiveness assessment into BEopt so that it can optimize across measures to maximize criteria such as Total Resource Costs (TRC), rather than participant costs**
- **External calculator approach (#2): Values from BEopt are exported to a version of the E3 Calculator to calculate cost test values, treating the retrofit as a single measure**
- **We implemented both approaches to provide full flexibility to users and to facilitate reporting through the CPUC process**

Approach 1: Direct integration into BEopt

+ Advantages of direct integration

- Inform program design
- Evaluate tradeoffs from multiple stakeholder perspectives
- Trade-offs are assessed in a single platform, resulting in an integrated analysis

+ Direct integration elements

- BEopt calculates the cost test results internally
- BEopt has additional optimization functionality
- BEopt provides additional program design inputs

Key features added into BEopt for cost test calculation

- **Additional optimization functionality: BEOPT can optimize along *any* cost test**
  - Example- user can optimize on TRC and look at the PCT test results; or vice versa
  - In the previous version, BEopt optimizes using the participant cost perspective
- **Incentives for energy efficiency and solar**
  - We implemented whole building based energy efficiency incentives ('performance' approach) and solar PV incentives
  - Emulates some energy efficiency retrofit programs and new construction incentives (e.g., Savings by Design, CAHP)
- **All 4 main cost tests implemented**

Cost effectiveness tests in BEopt

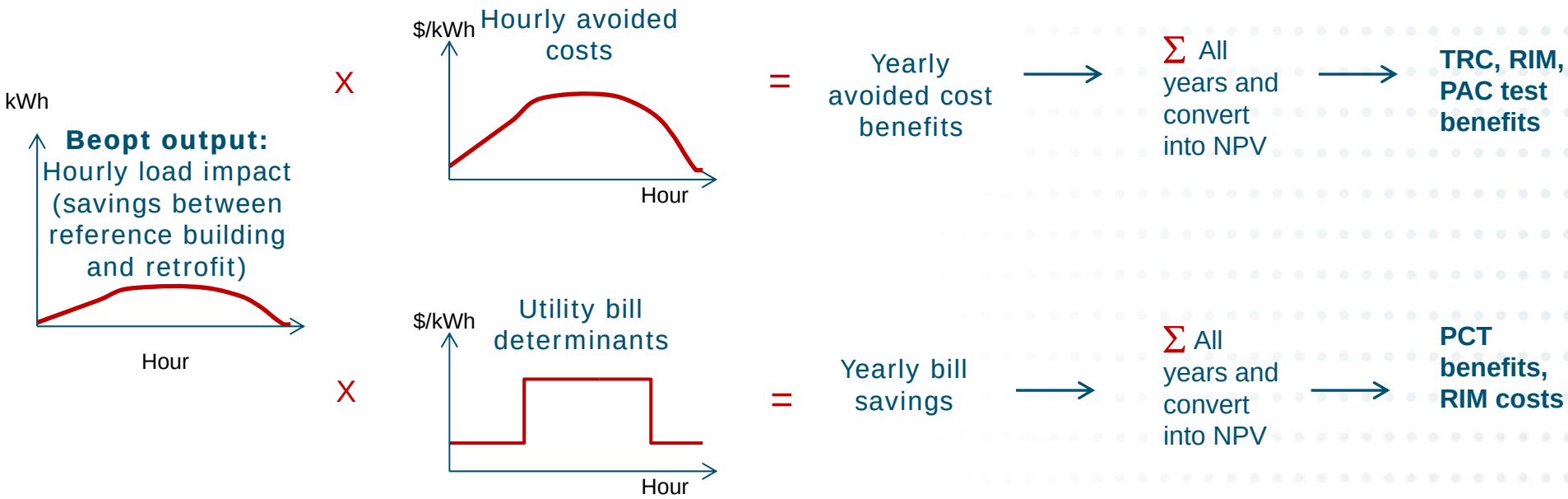
- **The 4 main cost tests are implemented**
  - Total resource cost test:
    Is the retrofit cost effective overall to society?
  - Participant cost test:
    Is the retrofit cost effective cost effective to the home owner?
  - Program administrator cost test:
    Is the retrofit cost effective to the program administrator?
  - Ratepayer impact test:
    Is the retrofit cost effective to non-participating ratepayers?
- **Note, not all cost tests are in the E3 Calculator (current program reporting tool)**
- **Avoided costs are provided for 40 years (Source: 2013-2014 E3 Calculator)**

Summary of costs and benefits

Component	TRC	PCT	PAC	RIM
Energy and capacity	Benefit	-	Benefit	Benefit
Additional resource savings	Benefit	-	-	-
Non-monetized benefits		-	-	-
Equipment and install costs	Cost	Cost	-	-
Program overhead costs	Cost	-	Cost	Cost
Incentive payments	-	Benefit	Cost	Cost
Bill Savings	-	Benefit		Cost

Cost effectiveness analysis: overall methodology

BEOPT provides hourly energy savings information about the proposed retrofit that is used to calculate avoided cost benefits & bill impacts

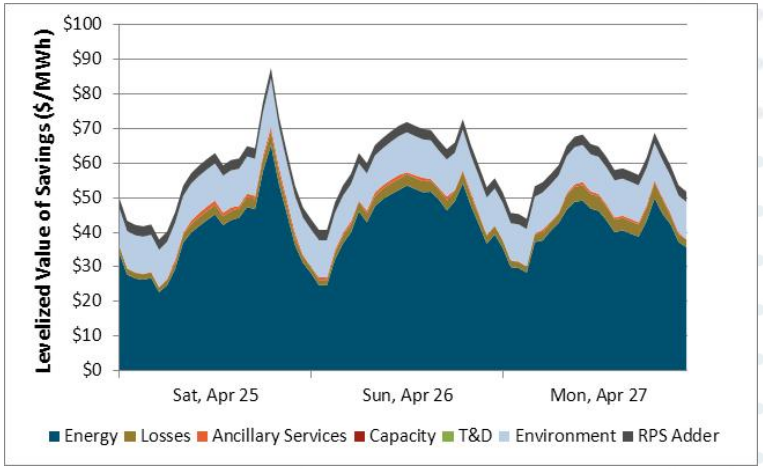


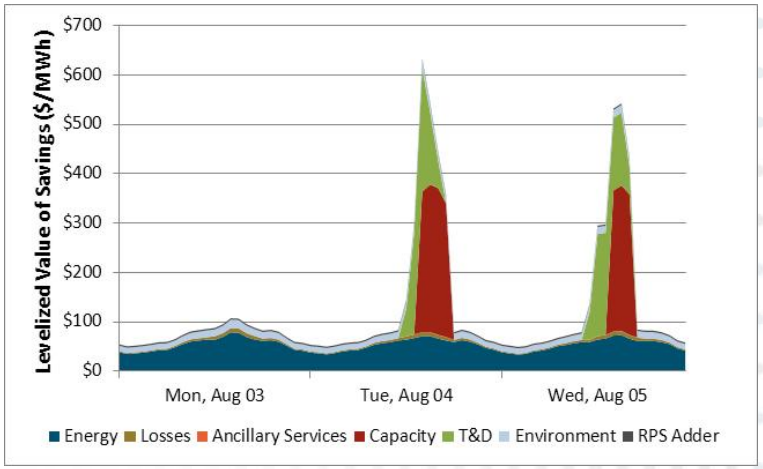
Measure cost and program information feed into the cost side of the tests.

Avoided cost benefits

- Avoided Cost Components
  - Energy purchases or generation cost
  - Generation Capacity
  - T&D Capacity
  - Ancillary Services Procurement
  - GHG Emissions
  - Losses
  - Reduced RPS procurement

Three-Day Avoided Cost Snapshots





Incentive design

- **Energy efficiency: whole home approach selected**
  - Allows for the designer to assess tradeoffs among measures
  - BEopt can emulate existing ‘performance’ style and whole home approach incentives (e.g., California Advanced Home Partnership, Energy Upgrade California)
- **Solar incentives:**
  - Upfront incentive and performance rebates can be modeled
  - NEM: user can specify end of year payouts
- **Program overlap:**
  - BEopt allows the user to evaluate many measures; some may have existing programs, such as lighting
  - BEopt can be avoid program overlap by optimizing on only the measures that do not have existing programs

Example of incentive interface

- Recognizing that programs will evolve, BEopt provides flexibility in how solar and whole-home-based efficiency incentives are entered
- CSI default values for each utility are provided in Beopt for convenience

Approach 2: BEopt version of the E3 Calculator

- **A simplified E3 Calculator takes the BEopt outputs and computes the cost tests**
- **Tool was developed mainly to support direct integration of cost tests into BEopt by providing a QA/QC tool**
- **Tool serves as a supplemental tool to the cost test reporting in the BEopt output**
- **Advantages of having a supplemental tool:**
  - Tool mimics the E3 Calculator which is the reporting tool for all programmatic filings for ensuring standardization of cost-effectiveness
  - Tool could aid future program reporting through the official E3 Calculator
  - Allows for assessment of a few sensitivities outside of BEopt: program costs, NTG ratios
- **If helpful, E3 could add features to the tool to facilitate keeping current with avoided costs and to evaluate different simple incentive structures**

"BEopt" E3 Calculator

Inputs

Climate Zone	CZ10
Utility	SDG&E
Inflation Rate	3%
Discount Rate	3%
Nominal Discount Rate	6.09%
Analysis Period (Years)	30
Net-to-Gross Ratio	90%
Loan Period (Years)	5
Cost of Equity	7%

Import Avoided Cost Data

Program Budget ($)

	NPV	NPV per Home
a. Administrative Costs		
a.i. Overhead and G&A	$ 10,000	$ 100
a.ii. Other Admin costs		$ -
b. Marketing/Outreach		$ -
c. Direct Implementation (non incentive)		
c.i. Activity		$ -
c.ii. Installation		$ -
c.iii. Hardware & Materials		$ -
c.iv. Rebate Processing and Inspection		$ -
e. EM&V		$ -
Number of Homes in Program	100	
Total	**$ 10,000**	$ 100

Cost Effectiveness (Lifecycle Present Value Dollars)

	Cost	Benefits	Benefit - Cost NPV	B/C Ratio
Program PCT ($)	$ 30,454	$ 20,978	$ (9,476)	0.69
Program RIM ($)	$ 12,139	$ 26,770	$ 14,630	2.21
Program TRC ($)	$ 27,509	$ 34,371	$ 6,862	1.25
Program PAC ($)*	$ 100	$ 26,770	$ 26,670	267.70

Program design questions

- **Individual building analysis vs. program design:**
  - What are the steps in moving from individual building analysis to program analysis?
  - How can the tools be improved to support program design?
- **Incentive approach:**
  - Is a whole-system approach for energy efficiency aligned with CPUC and utility directions for retrofit programs?
- **Program overlap:**
  - Are the features in BEOPT sufficient to deal with overlap with existing programs?
- **Standardizing inputs:**
  - Cost effectiveness results are highly sensitive to assumptions such as age of the building, measure lives, analysis period, etc.

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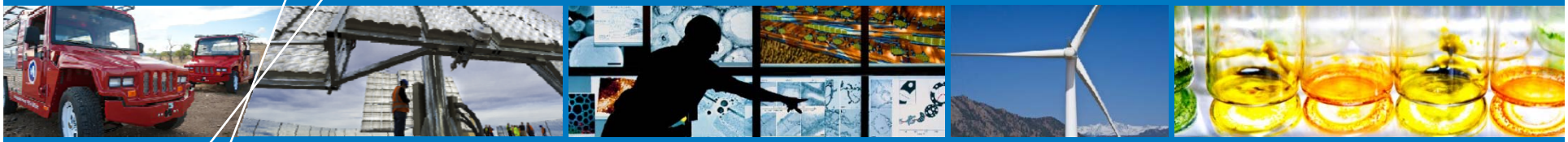
BEopt Demo



- Inputs
- Outputs

California "Switch"

BEopt California "Switch" Settings

1. EnergyPlus is set as the simulation engine (for calculation of avoided costs).

2. Only California climate zone weather files are displayed.

3. Additional inputs will now be available:
   - Net-to-Gross Ratio
   - Program Cost (Present Value)
   - CA Climate Zone Utility
   - CA Climate Zone Region

4. The marginal state income tax rate is defaulted to 9.3%.

5. The CSI PV rebate is enabled by default. The program specifies a performance-based rebate of $0.03/kWh for 5 years or a capacity-based rebate of $0.20/W AC.

6. Net-metered annual excess sellback rates are defaulted by CA utility climate zones.

7. The maximum analysis period is 40 years (Avoided cost factors are only available for these years.) Note that avoided costs are sourced from the 2013-2014 E3 Calculator.

8. Type of utility cost test is selectable for optimization and display.

California “Switch”

BEopt Demo

ILLUSTRATIVE EXAMPLES

Objective

- **We wanted to explore the new features of BEopt with a real example**
- **We were interested in the following:**
  - Exploring the cost effectiveness results for many different bundles of EE & PV, relationships between TRC, PCT, RIM
  - Exploring how BEopt can help identify incentive levels
  - Understanding the sensitivity of the results to key modeling assumptions, such as climate zone, cost test being optimized, electric vs. gas heating, measure lifetime, analysis period, rates

Case study descriptions

- **Case 1: 2150 sqft home in Stockton (PG&E, CZ 12)**
- **Key characteristics**
  - Old, inefficient & leaky home (e.g., no wall insulation, single pane metal frame windows)
  - HVAC systems (SEER 8 AC, 60% AFUE gas furnace)
  - Gas heating; E1 electric schedule, G1 gas schedule
- **Case 2: Oakland home with same characteristics**
- **Case 3: L.A. home (Culver City) with same characteristics but with electric heating**

Details of the Stockton house were provided by Davis Energy Group.

Main modeling assumptions

Common across cases

Key input parameter	Value
Analysis period	25 years
Rates	E1-region specific and G1 (from OPEN EI)
Measure lives	BEopt Defaults
Optimized over	TRC NPV of net benefits ($)
Age of systems	BEopt defaults (generally half of the measure lifetime)
Schedules	BEopt default values
Walls, roof, window properties	Walls: R-3.6; roof: R-11, windows: U 1.19, SHGC 0.83
Central air conditioner	SEER 8
Infiltration	3775 CFM (ACH50 11.7/h)

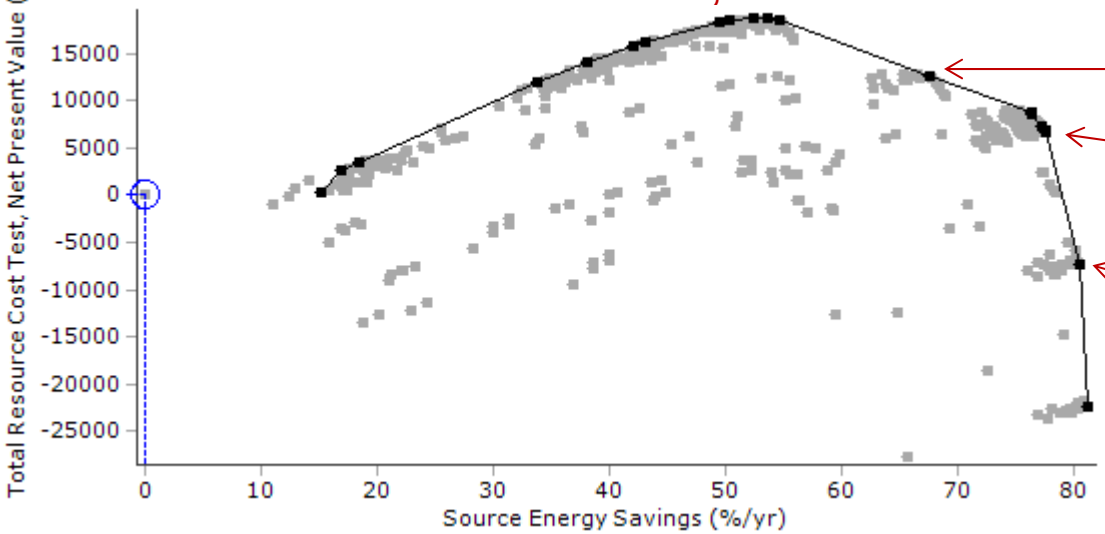
Specific to the cases

Case	Climate zone	Heating	Furnace	Water heater
1: Stockton	12	Gas	60% AFUE	0.4 energy factor
2: Oakland	3	Gas	60% AFUE	0.4 energy factor
3: Culver City	8	Electric	100% AFUE	0.9 energy factor

Main results

Stockton house: main results

TRC benefits minus costs, NPV



Adding a 3 KW PV system lowers TRC NPV (20 year system)

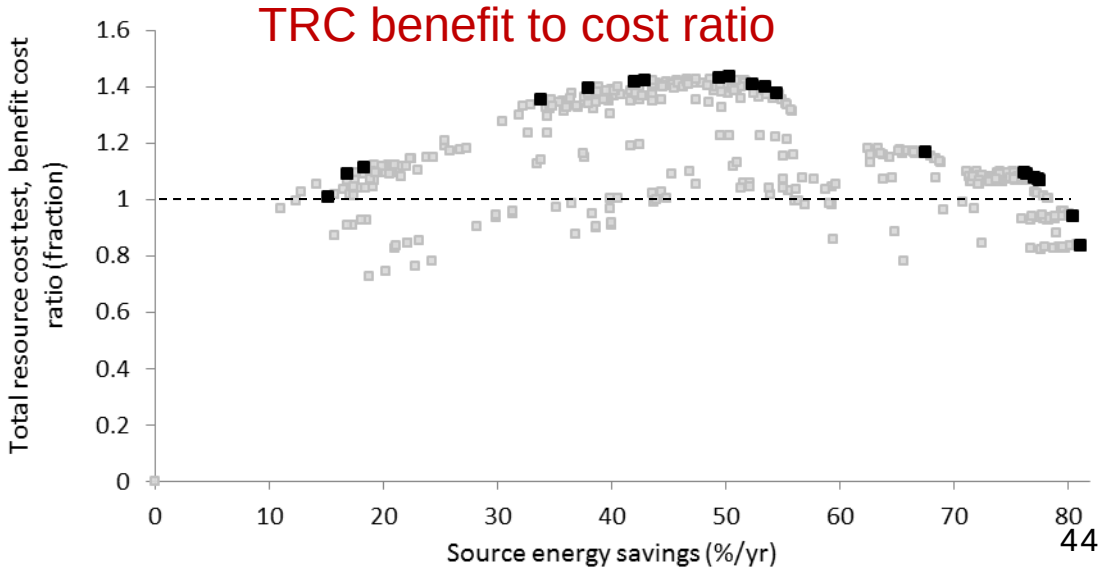
Adding a 5 KW PV system further lowers TRC NPV

Moving from a SEER 13 to SEER 24.5 further lowers TRC NPV

- **BEopt identifies several bundles of EE and PV that are more and less cost effective from a TRC perspective**

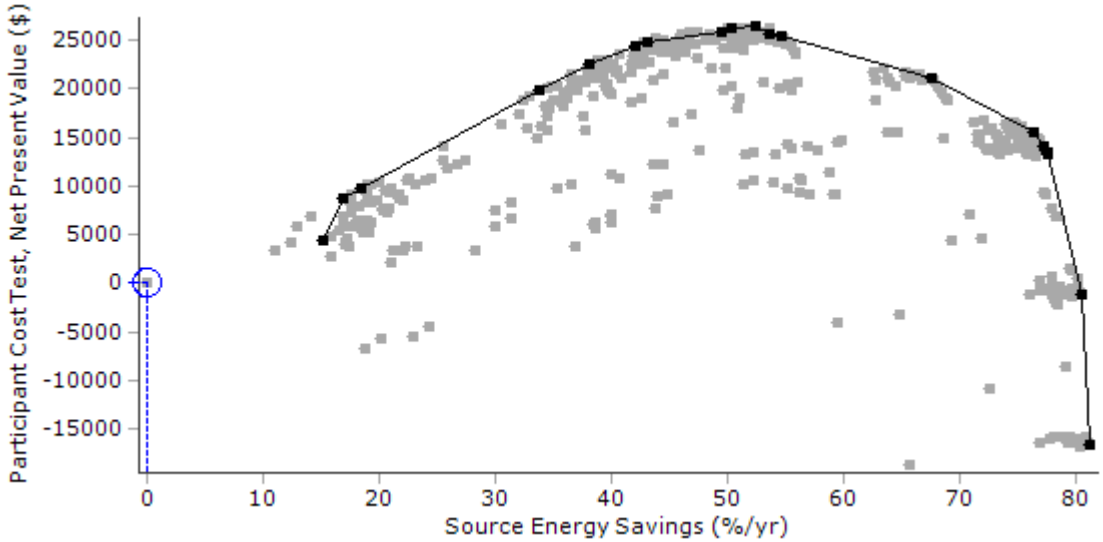
- **Range of source energy savings is covered**

TRC benefit to cost ratio



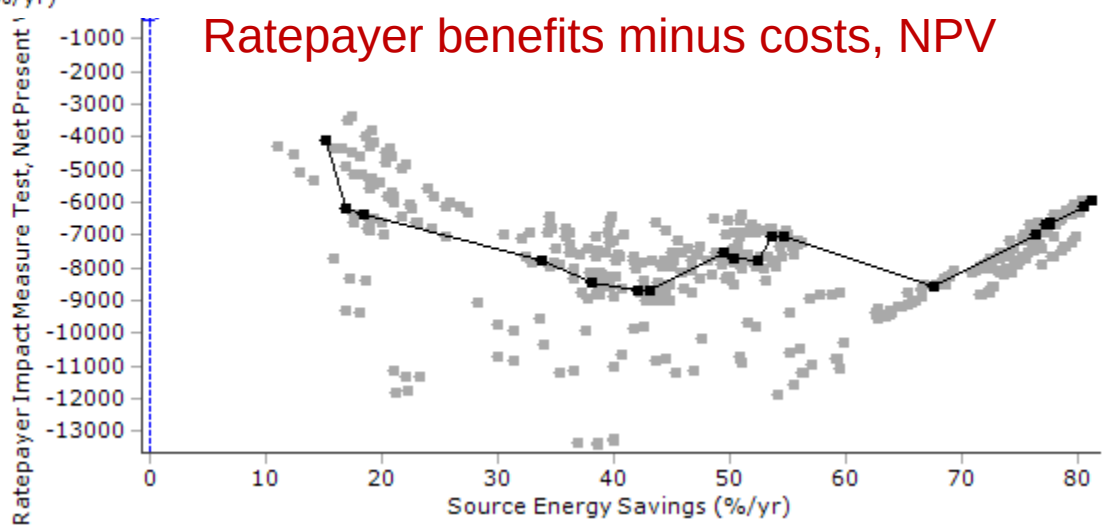
Stockton house: participant and ratepayer perspectives

Participant benefits minus costs, NPV



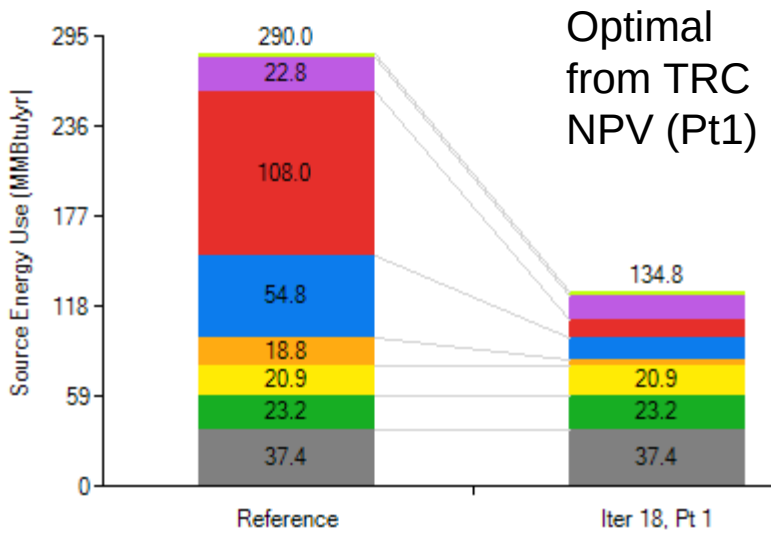
- **PCT and RIM results are intuitive**

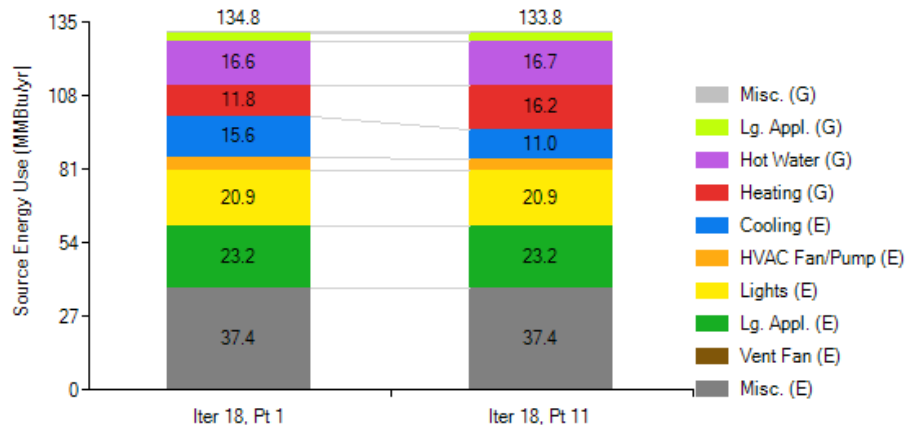
Ratepayer benefits minus costs, NPV



- **Net benefits to the participant are larger than TRC net benefits → Results in negative net RIM benefits**

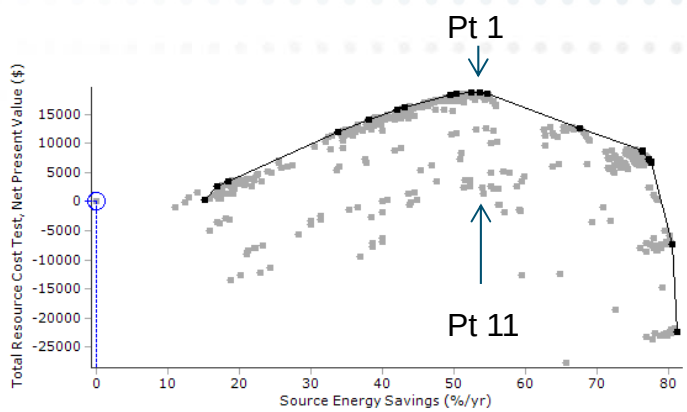
Select points: EE and PV bundles





Common measures:
Wall & roof insulation, reduced leakage, HVAC (SEER 13 & AFUE 80%), duct sealing, water heater (premium)

Main difference due to windows:
Point 1: double pane, med gain low-e windows
Point 11: triple pane, high gain low-e windows



Levelized cost calculations

Iteration 18, point 1

Levelized Costs*	Discounted Savings			
	kWh	Therms	Levelized Cost	
PCT ($/kWh)	67,472		$	0.18
RIM ($/kWh)	67,472		$	0.39
TRC ($/kWh)	67,472		**$**	**0.18**
PAC ($/kWh)	67,472		$	-
PCT ($/Therm)		12,570	$	0.80
RIM ($/Therm)		12,570	$	1.73
TRC ($/therm)		12,570	**$**	**0.80**
PAC ($/therm)		12,570	$	-

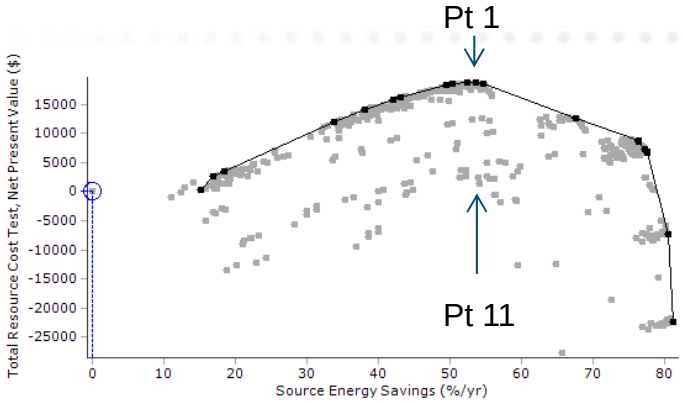
Iteration 18, point 11

Levelized Costs*	Discounted Savings			
	kWh	Therms	Levelized Cost	
PCT ($/kWh)	73,491		$	0.31
RIM ($/kWh)	73,491		$	0.39
TRC ($/kWh)	73,491		$	**0.31**
PAC ($/kWh)	73,491		$	-
PCT ($/Therm)		12,054	$	1.39
RIM ($/Therm)		12,054	$	1.75
TRC ($/therm)		12,054	**$**	**1.39**
PAC ($/therm)		12,054	$	-

Levelized costs were calculated in the BEopt E3 calculator tool using the BEopt output reports

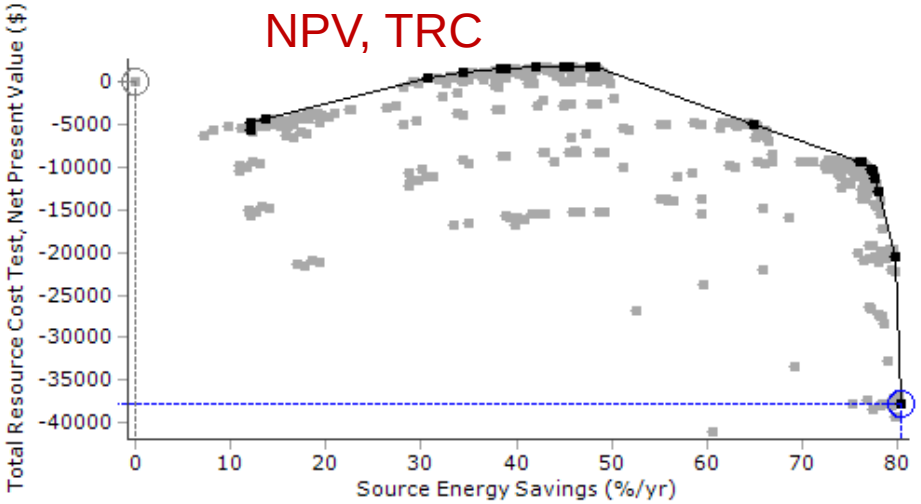
Costs are split between gas and electricity savings using the respective avoided costs (consistent with the E3 Calculator)

Did not enter program costs; NTG = 1



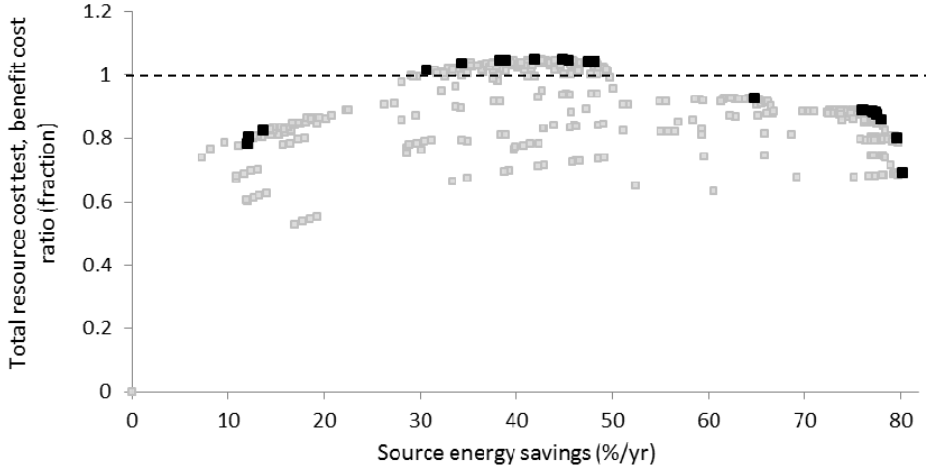
Oakland example: main results

NPV, TRC

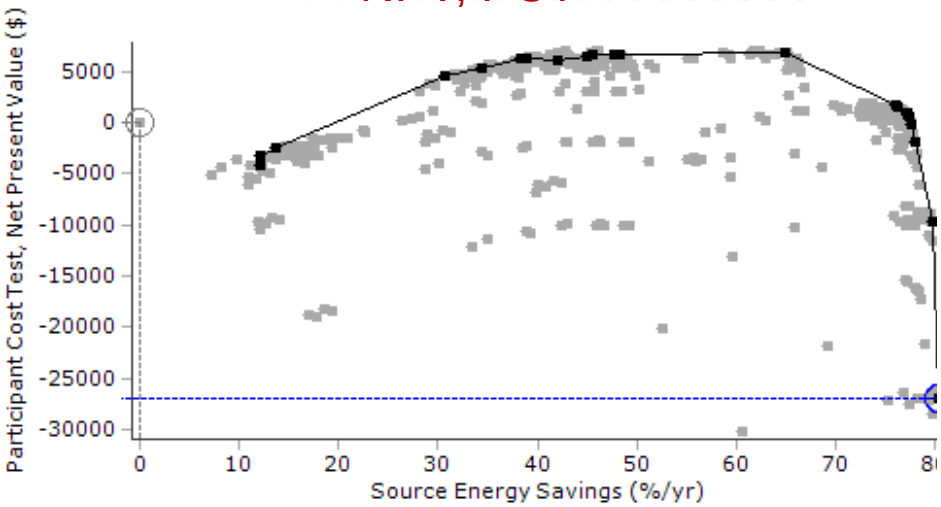


- Results are similar but NPV are shifted downwards
- Physically intuitive because Oakland has milder climatic conditions compared to Stockton
- Solar bundles no longer TRC positive

Benefit to cost ratio, TRC



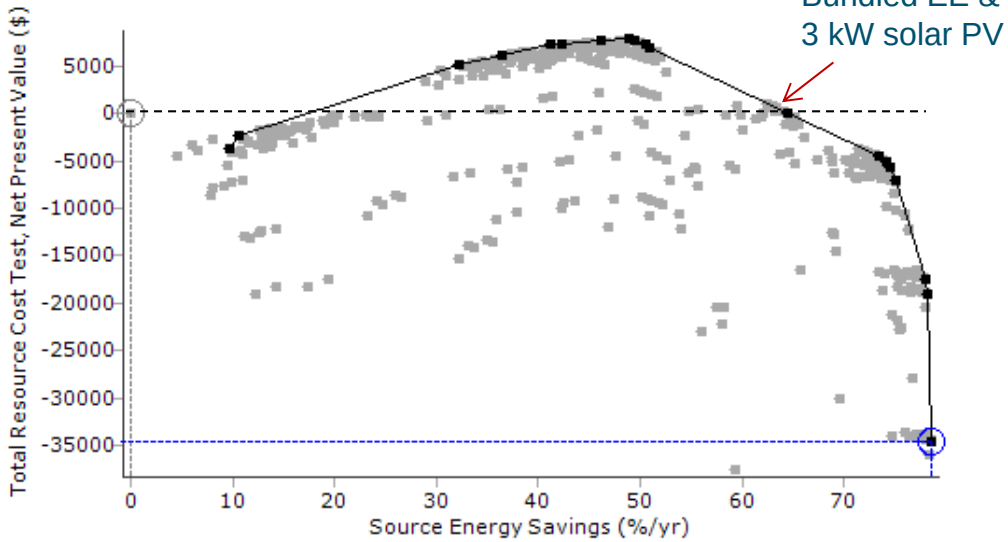
NPV, PCT



Culver City example: main results

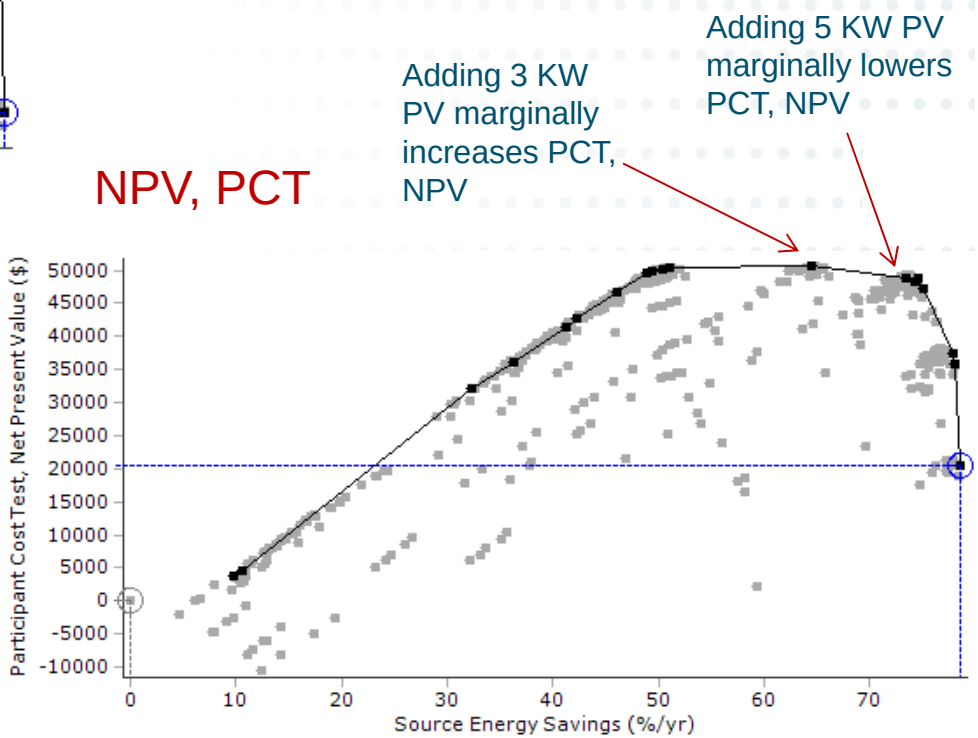
This example had electric heating and hot water

NPV, TRC



- **PCT 'plateau' due to NEM, which essentially pays for the 3 KW PV system and almost pays for 5 kW PV**

NPV, PCT



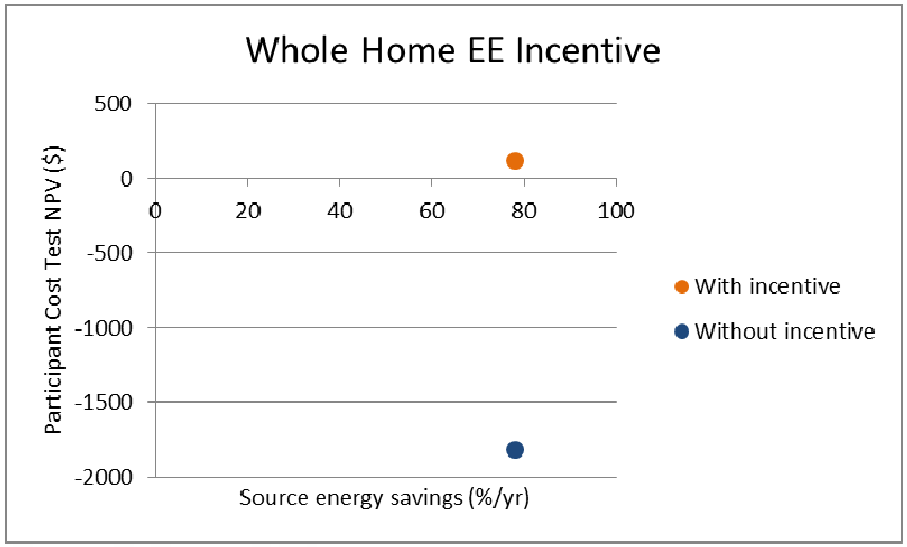
- **Higher cooling loads, avoided costs & electric heating likely contribute to higher TRC NPV, compared to the Oakland example**

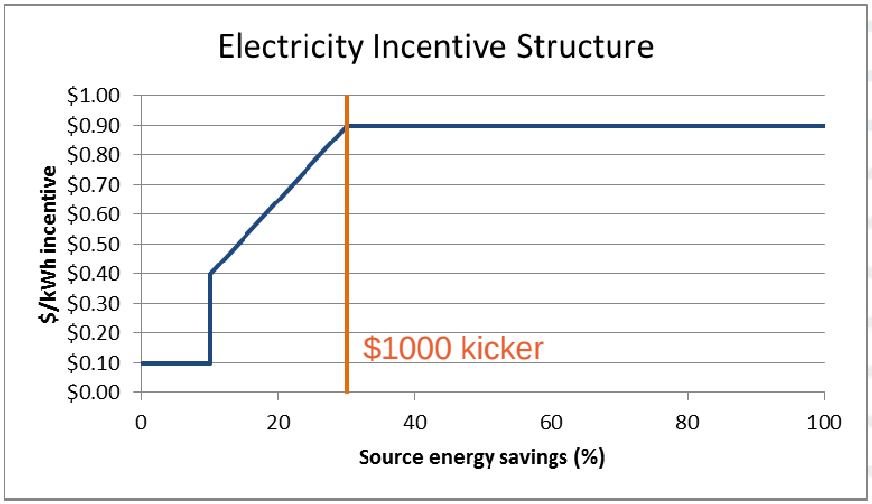
- **In bundled format, EE & 3 kW PV just passes TRC**

Exploring sensitivities: based on the Stockton case

Exploring incentive levels

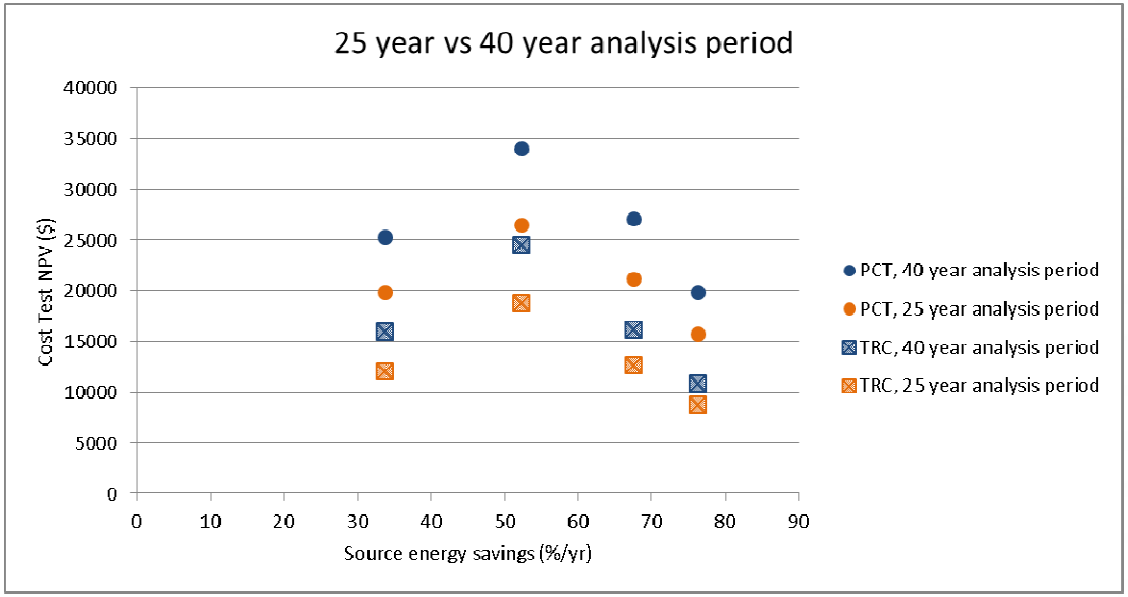
- Using an example incentive level ranging from $0.10/kWh to $0.90/kWh, with $1000 kicker, plus gas incentive $1/therm (structured similarly to CAHP)
- Case which was non-cost effective for the participant is now cost-effective
- PCT, NPV is one way of determining the incentive 'needed' to motivate investment

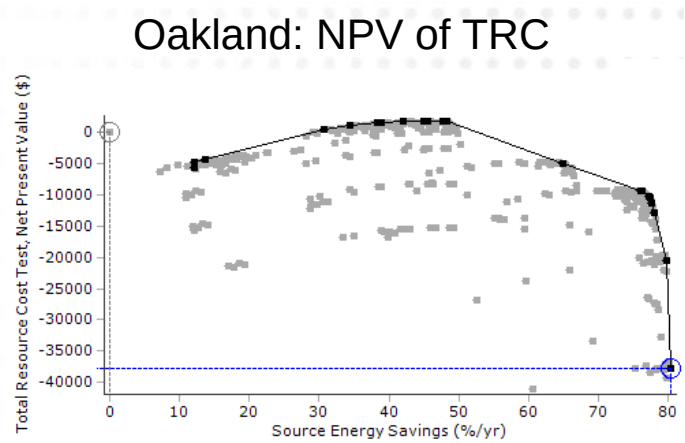




Exploring analysis period

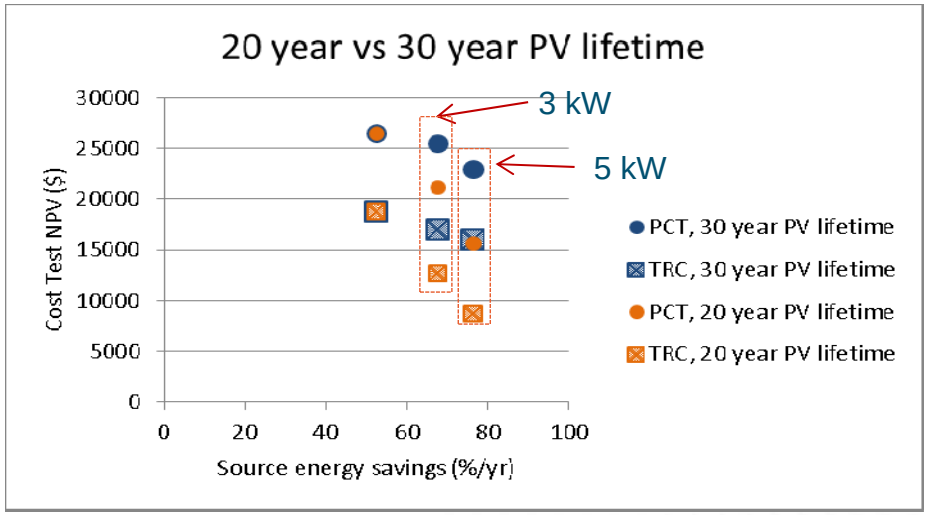
- **Extended the analysis period from 25 yr to 40 yr**
- **TRC & PCT curves are shifted upwards**
  - ↑ TRC & PCT significantly (~$5000 for TRC, ~$7000 for PCT)
- **Does not 'change the answer' for Stockton, but this may have made the Oakland case cost effective**





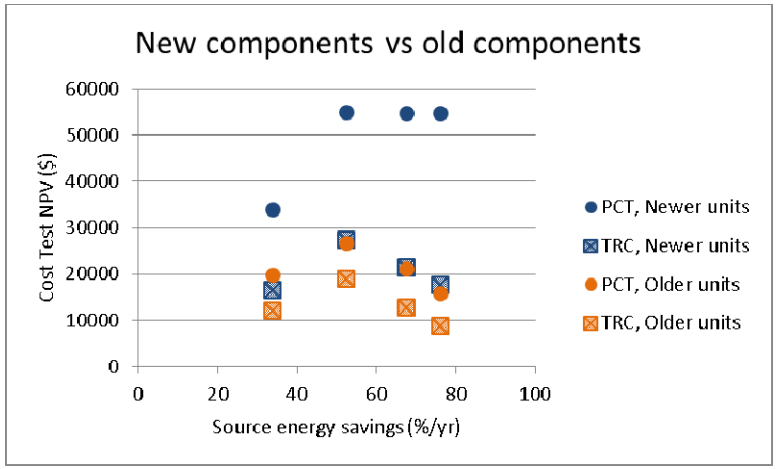
Measure lifetime assumptions

- **Increased PV lifetime from 20 yr to 30 years**
- **Increasing lifetime from 20 years to 30 years does not render PV cost effective but improves its cost effectiveness significantly**
  - Roughly doubles TRC NPV; increases PCT NPV by 25%
  - Avoided costs escalate at a higher rate in the later years, relative to rates (which affects NEM)



Age of existing components

- **Previously, windows were 15 years old; AC & furnace 10 years, and water heater 6 years**
- **All of these units were set to an age of 2 years**
- **Decreasing the age improves the TRC NPV by 40%**
  - Older units are upgraded automatically to systems that meet current standards, reducing the reference case consumption and thus, retrofit energy savings



Preliminary insights

- **BEopt tool was able to identify multiple bundles of EE and PV to inform retrofits with varying levels and patterns of cost effectiveness**
- **Example underscores importance of an integrated analysis (EE and PV, engineering and economics)**
- **Program related questions can be informed**
  - BEopt can help identify appropriate incentive levels
  - Sensitivity analysis shows importance of assumptions such as analysis period, measure lifetimes, base case assumptions
  - BEopt results can be used to set price points where current bundles are not cost effective

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Ongoing and Future Work

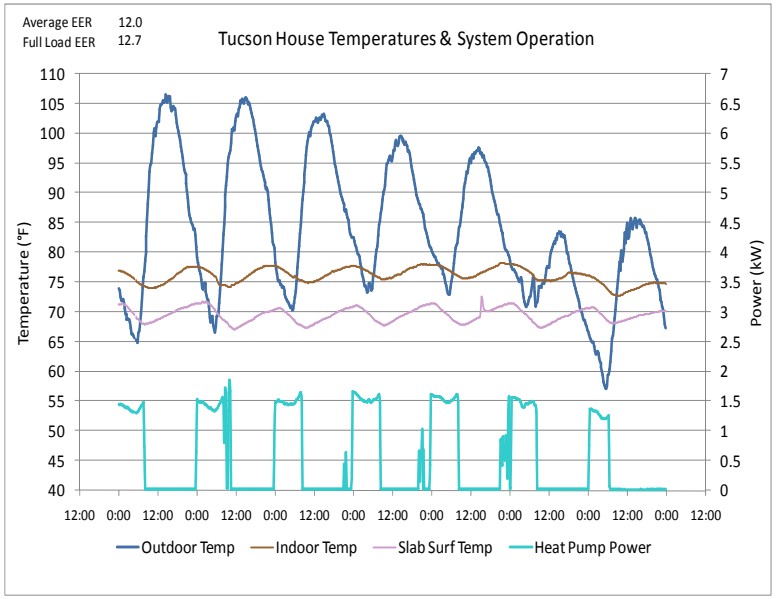
- Demand Response and Energy Storage
- Model Calibration

Demand Response

- Current California Programs
  - A/C cycling: PG&E SmartAC, SCE Summer Discount Plan, SDG&E Summer Saver
  - Voluntary load reduction: PG&E SmartRate, SCE Save Power Days, SDG&E Reduce Your Use
- Exploratory: "day ahead" or "day of" signals using:
  - Open ADR
  - Smart Energy Profile

DR & ES Potential

- Efficiency
  - Reduced loads through improved enclosures
  - Improved equipment efficiency
- Storage
  - Thermal
    - Building mass - floating temperature or pre-cooling
    - Chilled water or ice storage
  - Electric
    - Stationary batteries
    - EV batteries



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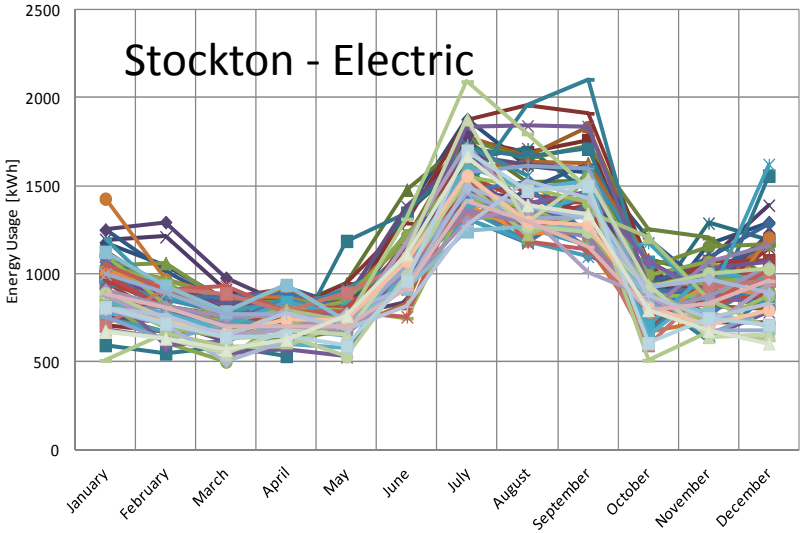
Model Calibration

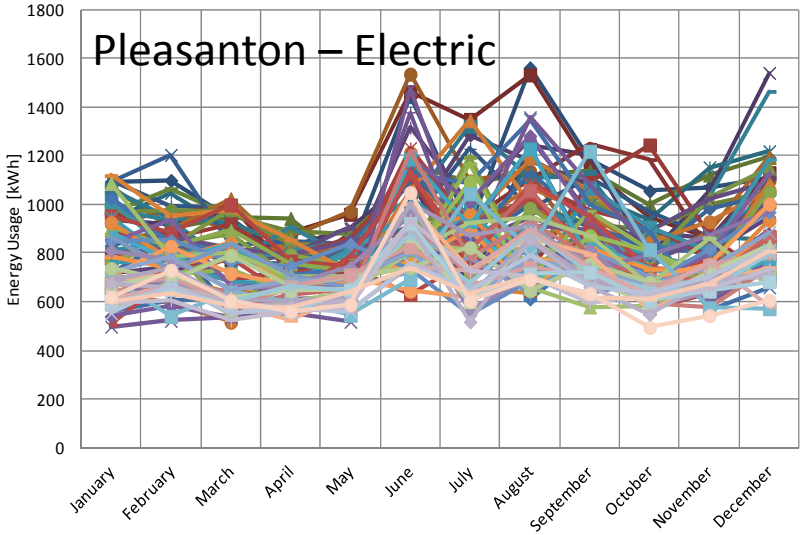
- **Issue**: How can energy savings be estimated at the *community* level with a high level of confidence to support comprehensive local retrofit programs?
  - Impractical to evaluate each house
  - HERS II software tends to over-predict savings
  - Optimal selection of retrofit measures varies by climate
  - DEER and RASS not climate specific
- **Objective**
  - Develop a process for efficiently disaggregating community utility bill data
  - Use the results to adjust program inputs to improve the confidence level

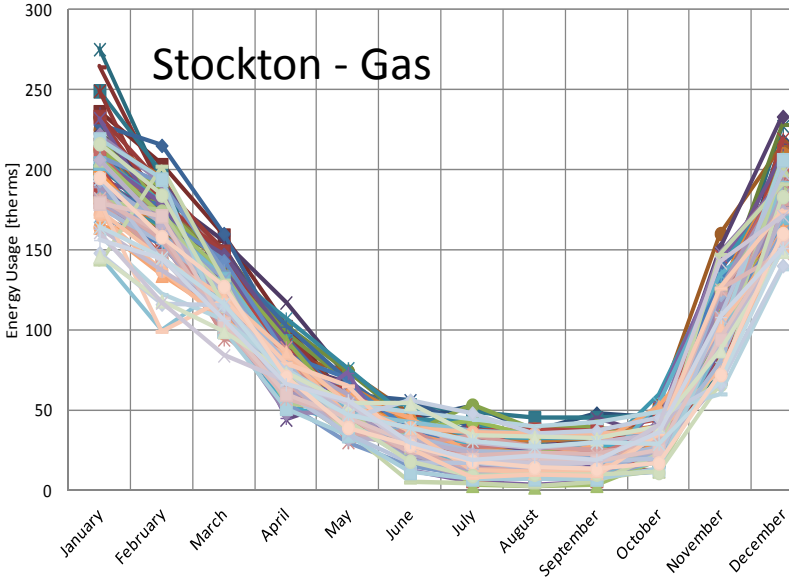
Calibration Process

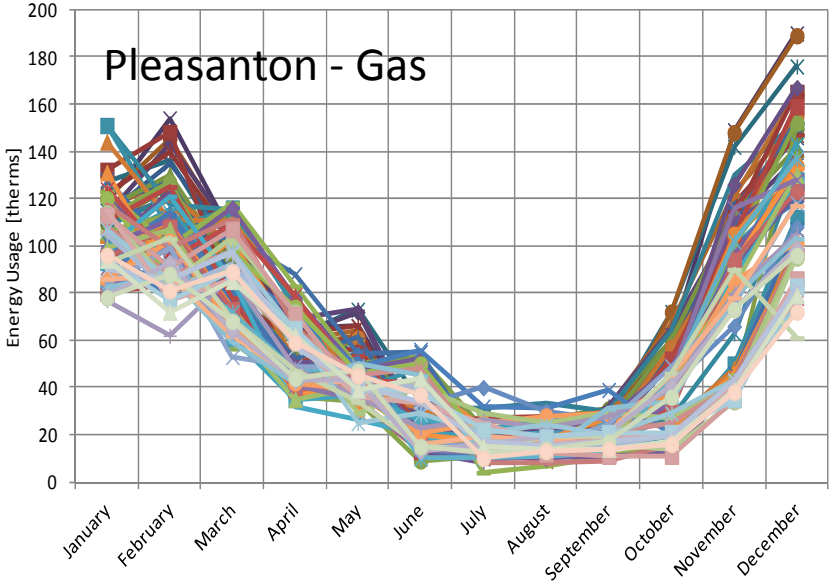
- Obtain blind utility bill data for a defined community (used Stockton & Pleasanton)
- Characterize the houses (vintage, floor area, etc.)
- Apply filters for incomplete data and outliers
- Separate base loads from heating, cooling, water heating and lighting
- Develop a BEopt model that typifies the house characterizations
- Adjust input parameters (thermostat settings, miscellaneous energy use assumptions, etc.) to achieve desired level of calibration

Calibration -- Population Variance









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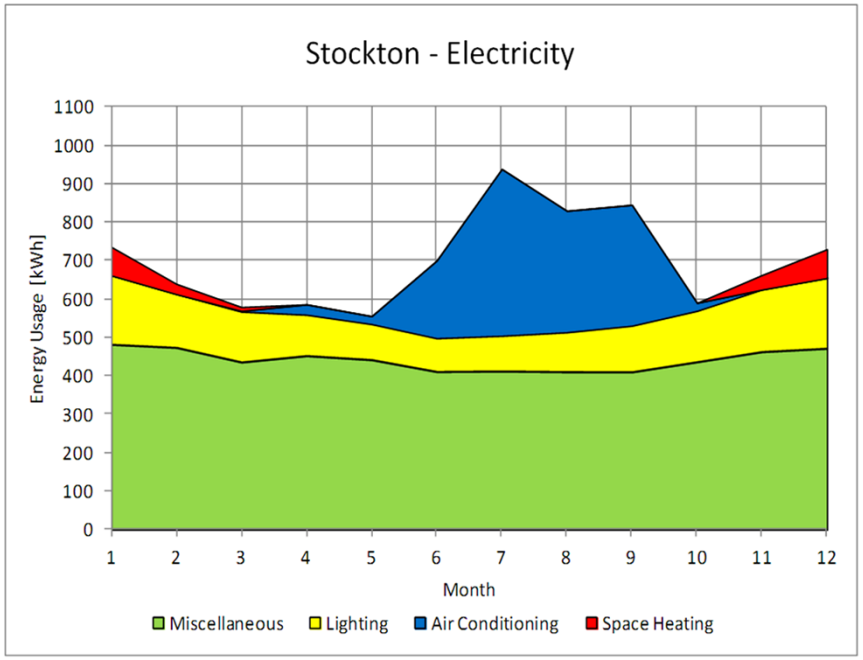
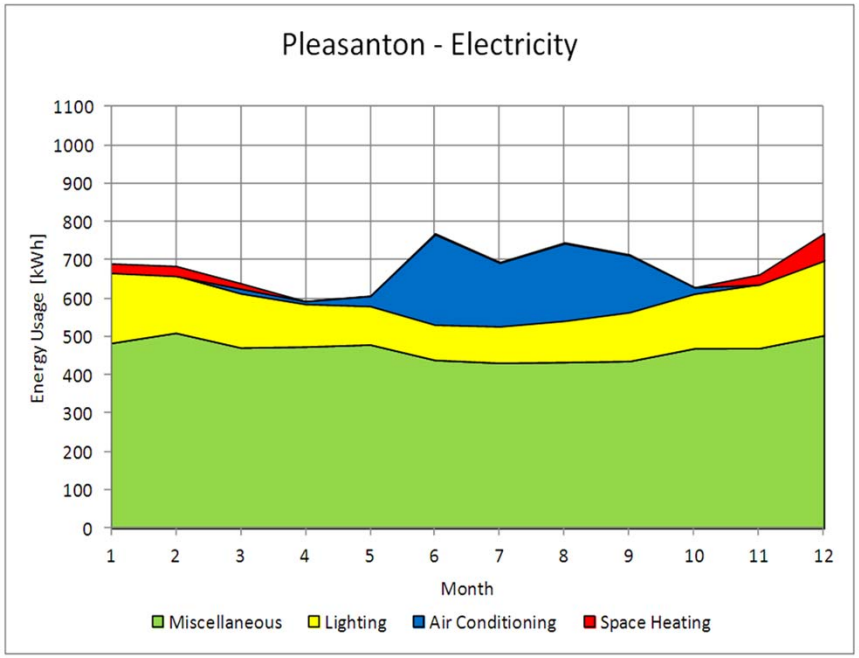
Calibration -- Climate Sensitivity





End Use	PG&E RASS	Stockton	Pleasanton
Lighting	23%	18%	20%
Air Conditioning	11%	16%	10%
Space Heating Gas	50%	59%	57%
Water Heating Gas	44%	30%	30%

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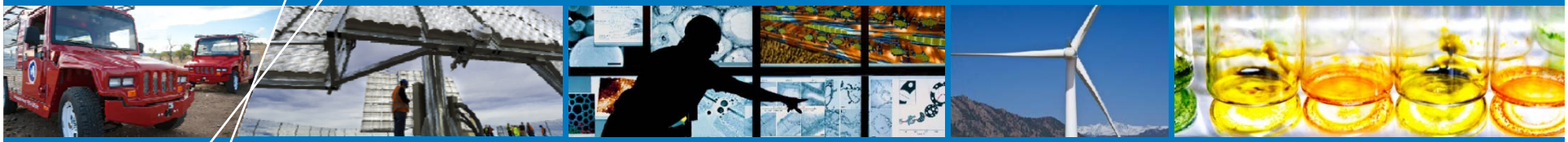
Ongoing and Future Work

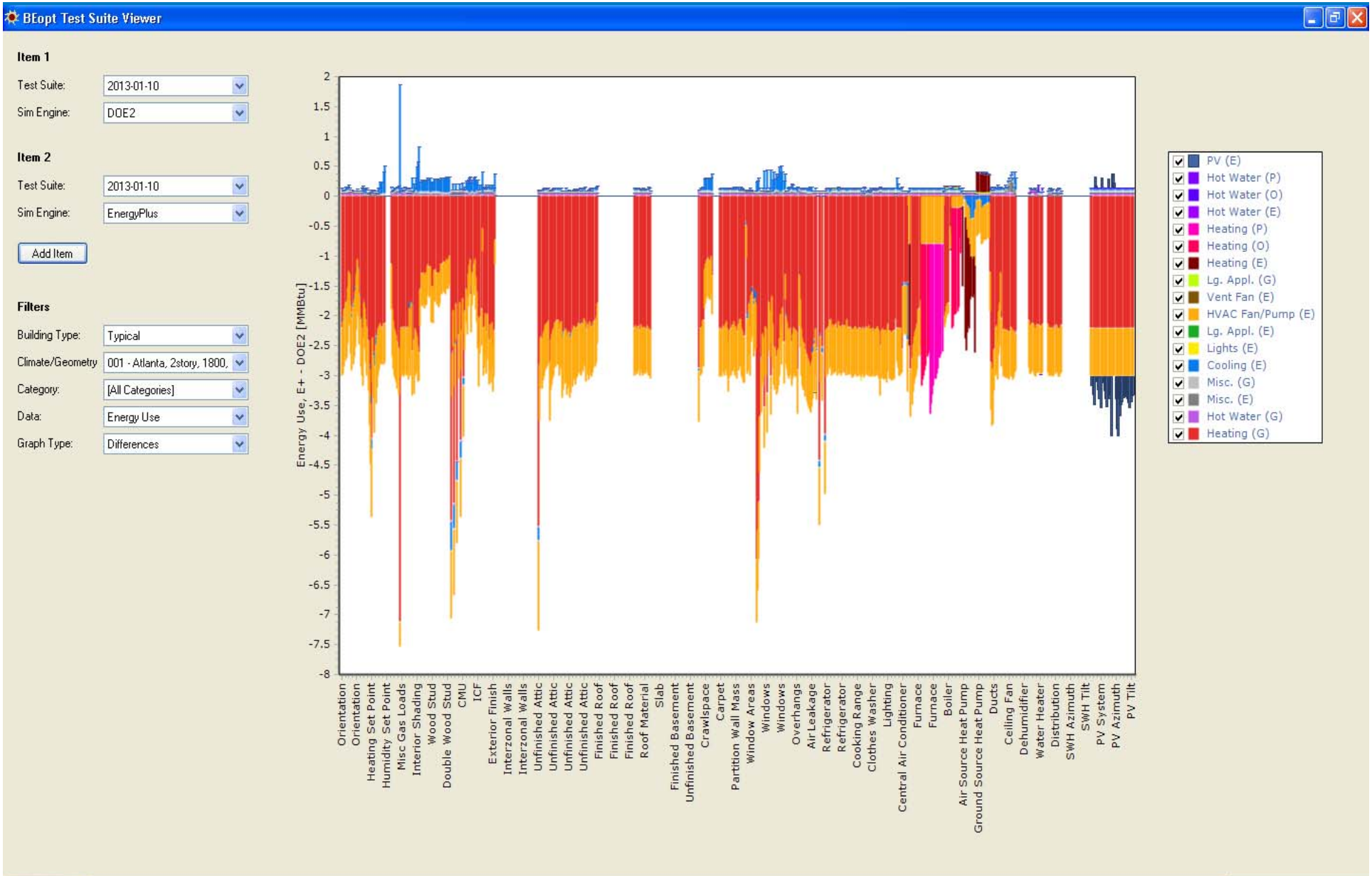


- **Connecting to CSE**
- **Community-Scale Analysis**

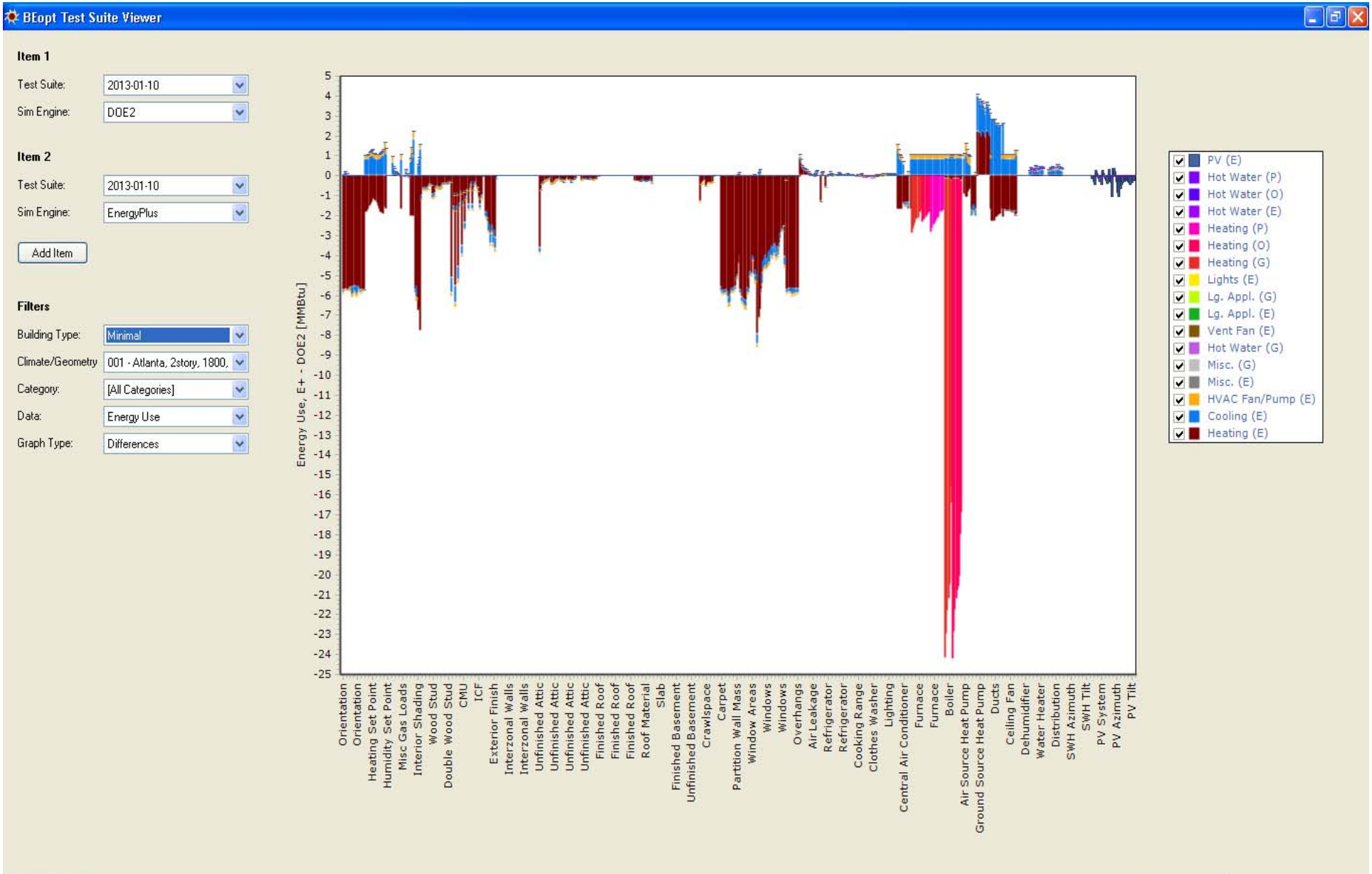
Connecting to CSE

1. CSE (California Simulation Engine) is being developed for residential compliance under the 2013 version of Title-24
   - Validate CSE via comparison with EnergyPlus/DOE-2.2 using the BEopt Test Suite
   - Mapping efficiency and renewable options from BEopt to CSE (research mode: not fully code-compliant)
2. BEopt as a front-end/user-interface for CSE?

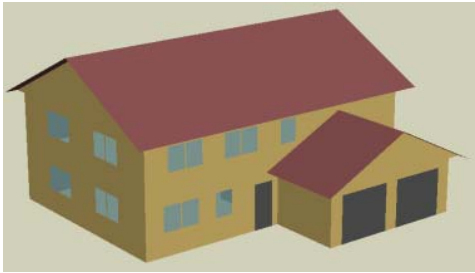
Connecting to CSE → BEopt Test Suite



Connecting to CSE → BEopt Test Suite



Community-Scale Building Energy Modeling



Individual Homes:
Detailed Simulations

?

Community
~500,000 Houses

Community-Scale Building Energy Modeling

Archetypes

5 vintages
4 floor areas
2 # of stories
2 heating fuels
2 AC system types
2 occupancy schedules
3 use levels

~1,000 Archetypes

Community
~500,000 Houses

Community-Scale Building Energy Modeling

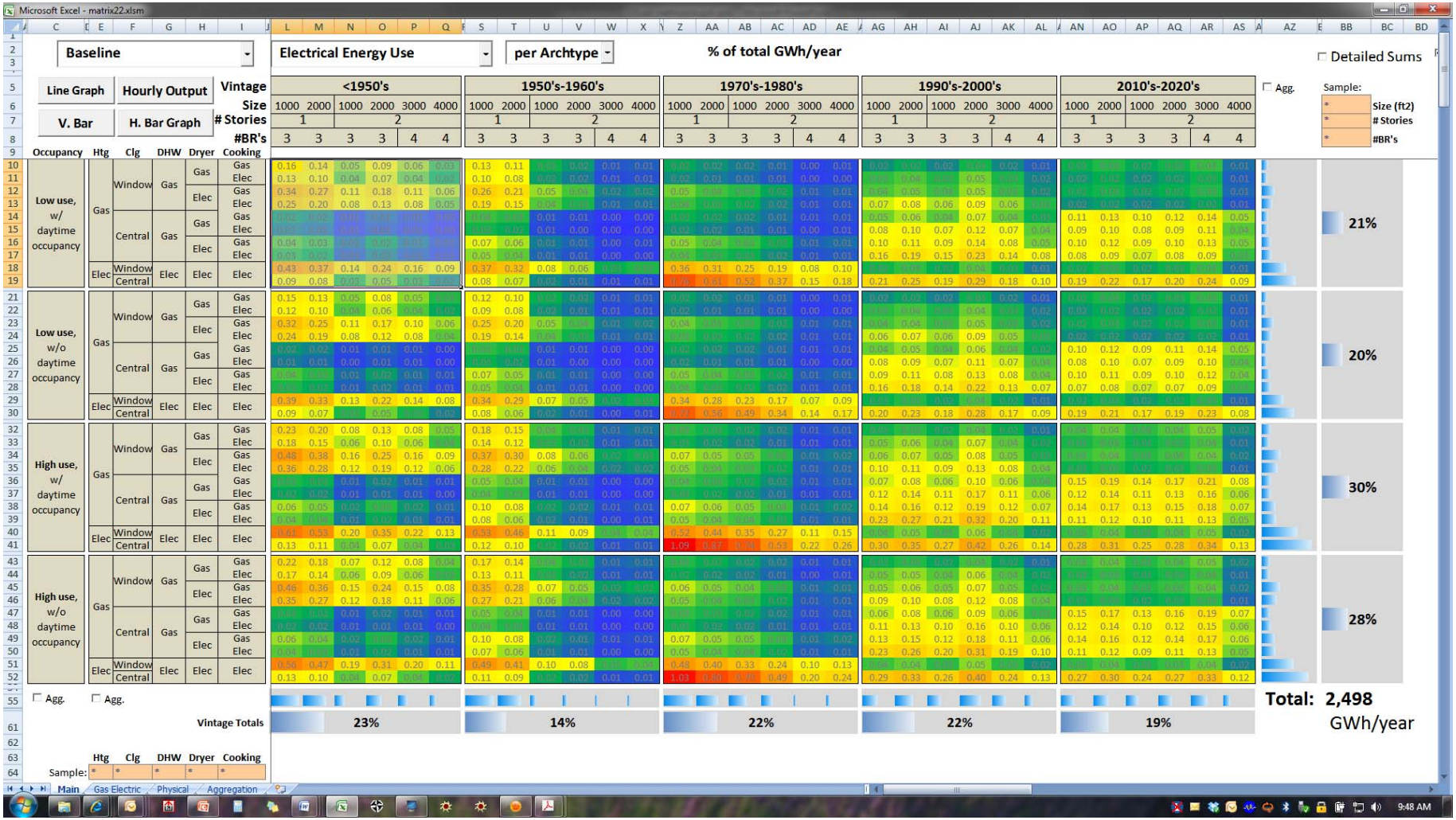
~1,000
Archetypes

$$\sum_{1}^{\sim 1000} \left[\begin{array}{c} \text{(Energy/archetype)} \\ \text{x} \\ \text{(\# houses/archetype)} \end{array} \right]$$

Community
500,000
Houses

How and where energy is used within the community?

Energy Use by Vintage, User Type, Equipment Type, and House Size



Community-Scale Modeling Tool -- Mock-Up!

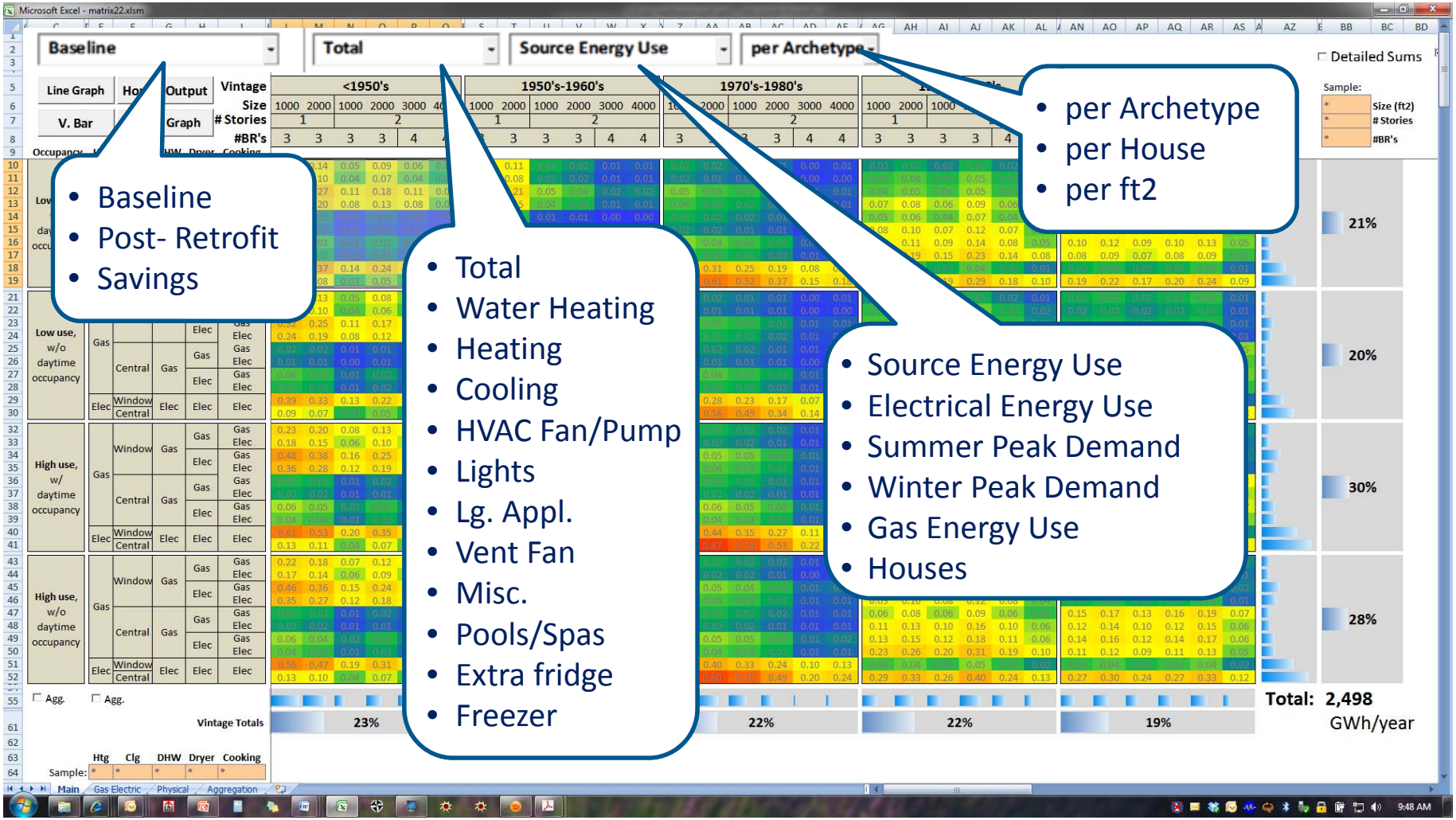
How and where energy is used within the community?

Energy Use by Vintage, User Type, Equipment Type, and House Size

Community-Scale Modeling Tool -- Mock-Up!

How and where energy is used within the community?

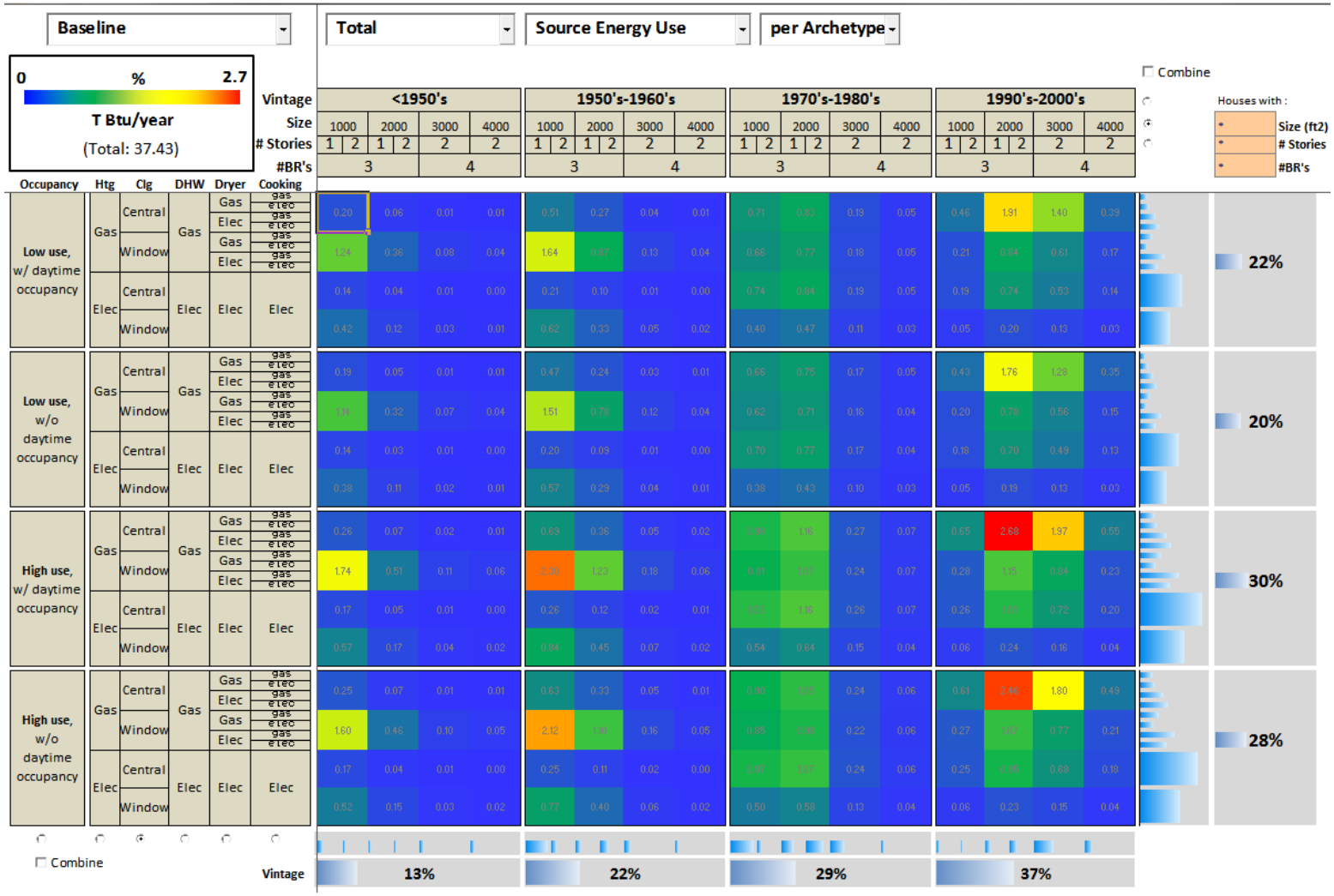
Energy Use by Vintage, User Type, Equipment Type, and House Size



Community-Scale Modeling Tool -- Mock-Up!

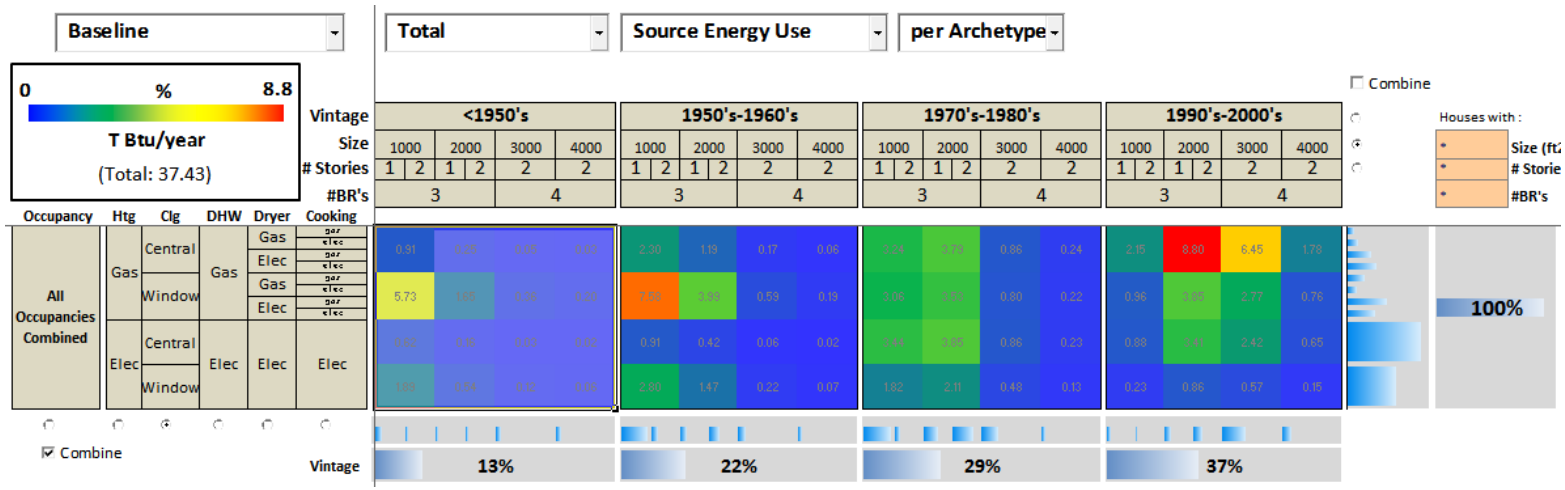
Community-Scale Modeling Tool -- Mock-Up

Energy Use by Vintage, User Type, Equipment Type, and House Size



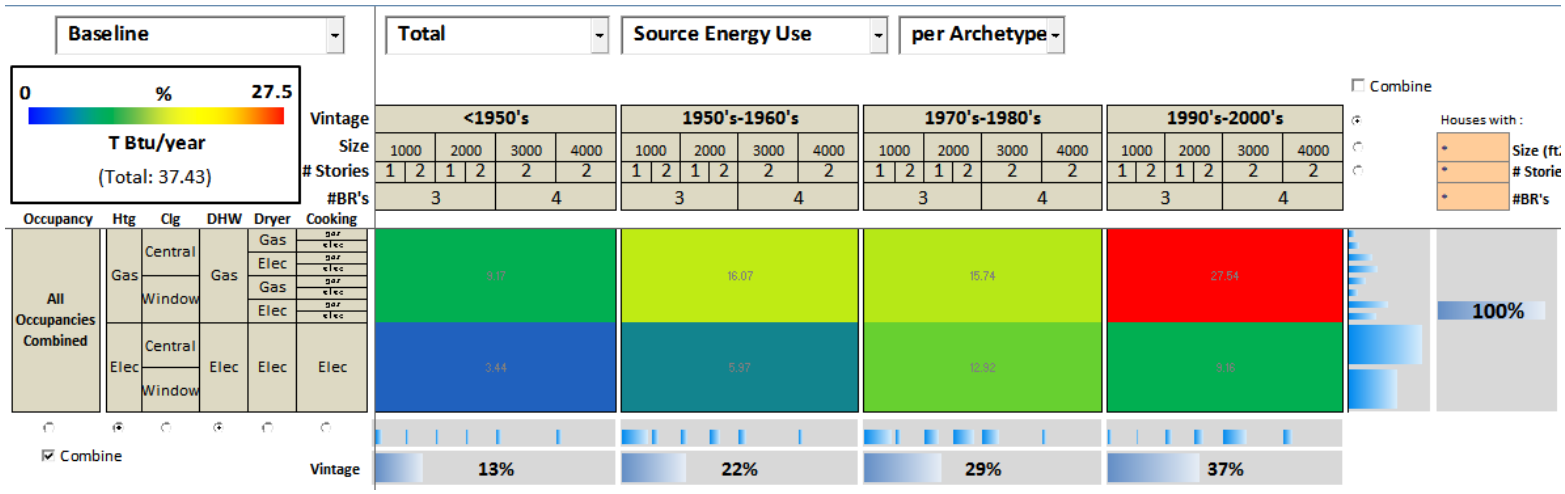
Community-Scale Modeling Tool -- Mock-Up

Energy Use by Vintage, Equipment Type, and House Size



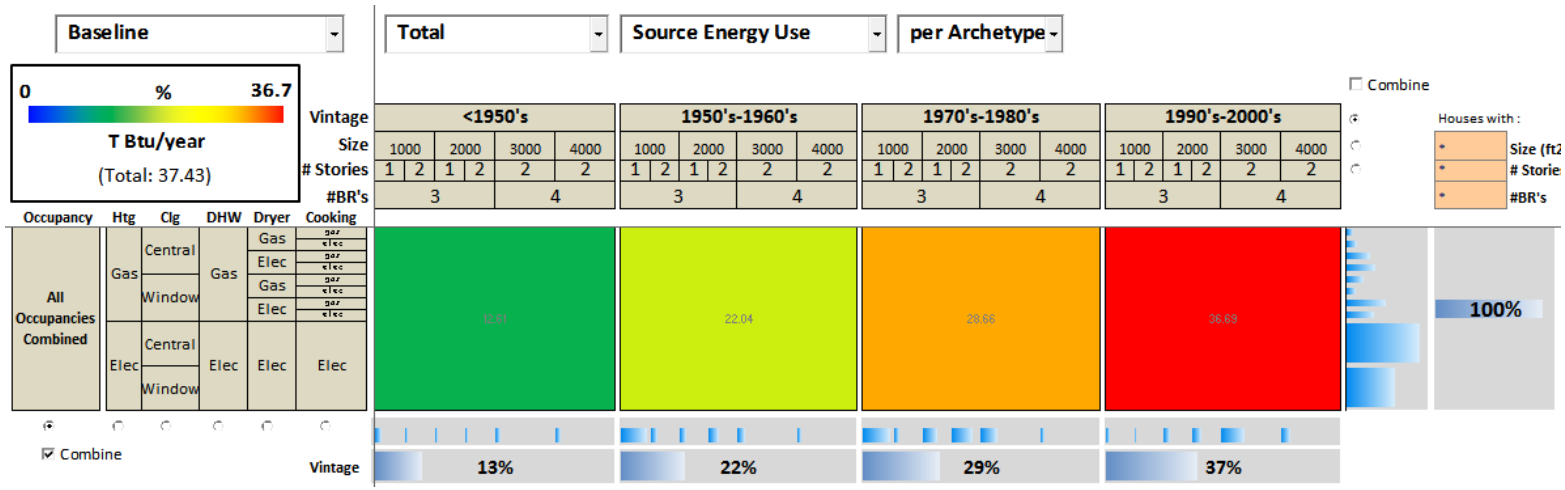
Community-Scale Modeling Tool -- Mock-Up

Energy Use by Vintage, Fuel Type



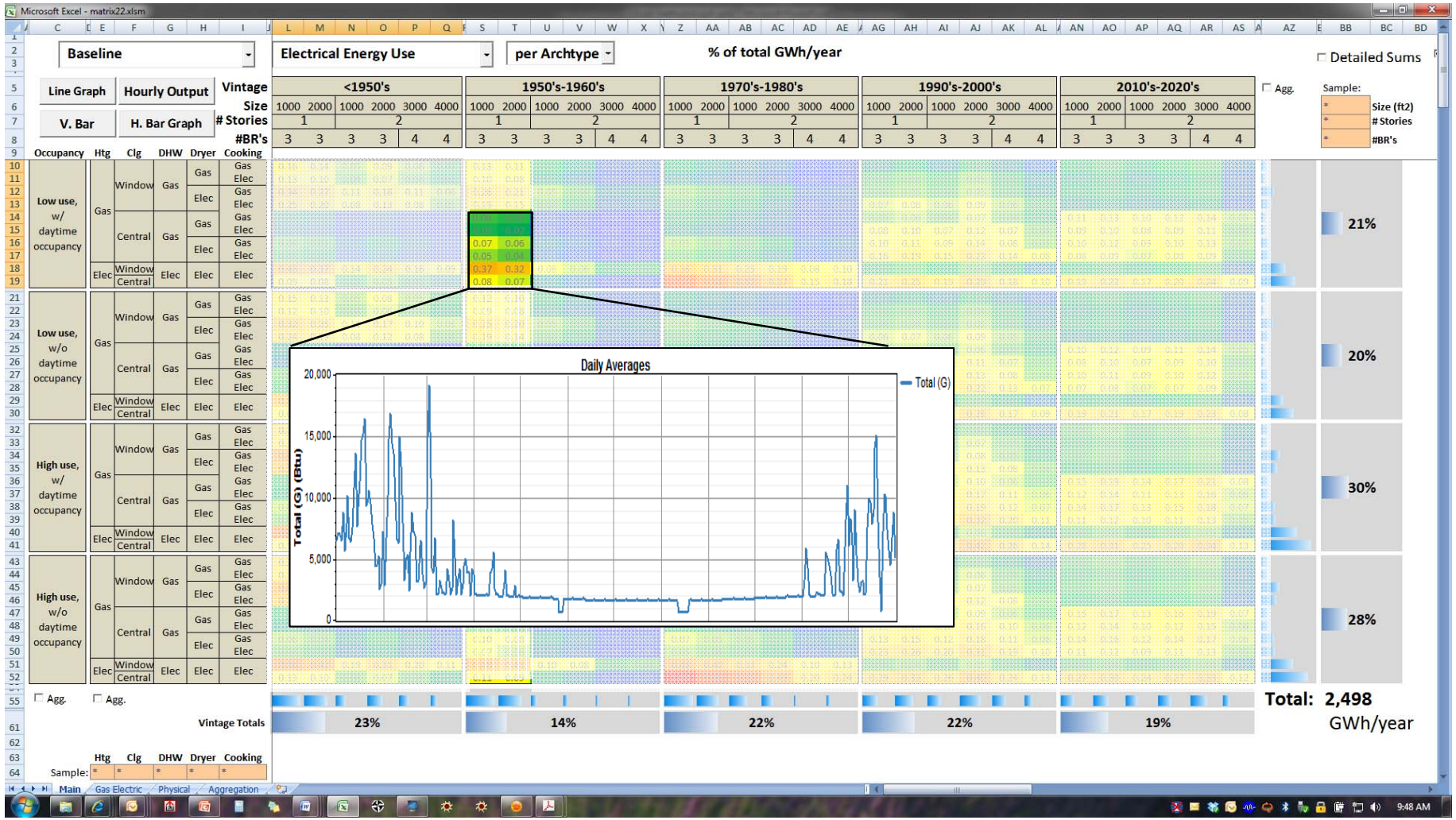
Community-Scale Modeling Tool -- Mock-Up

Energy Use by Vintage



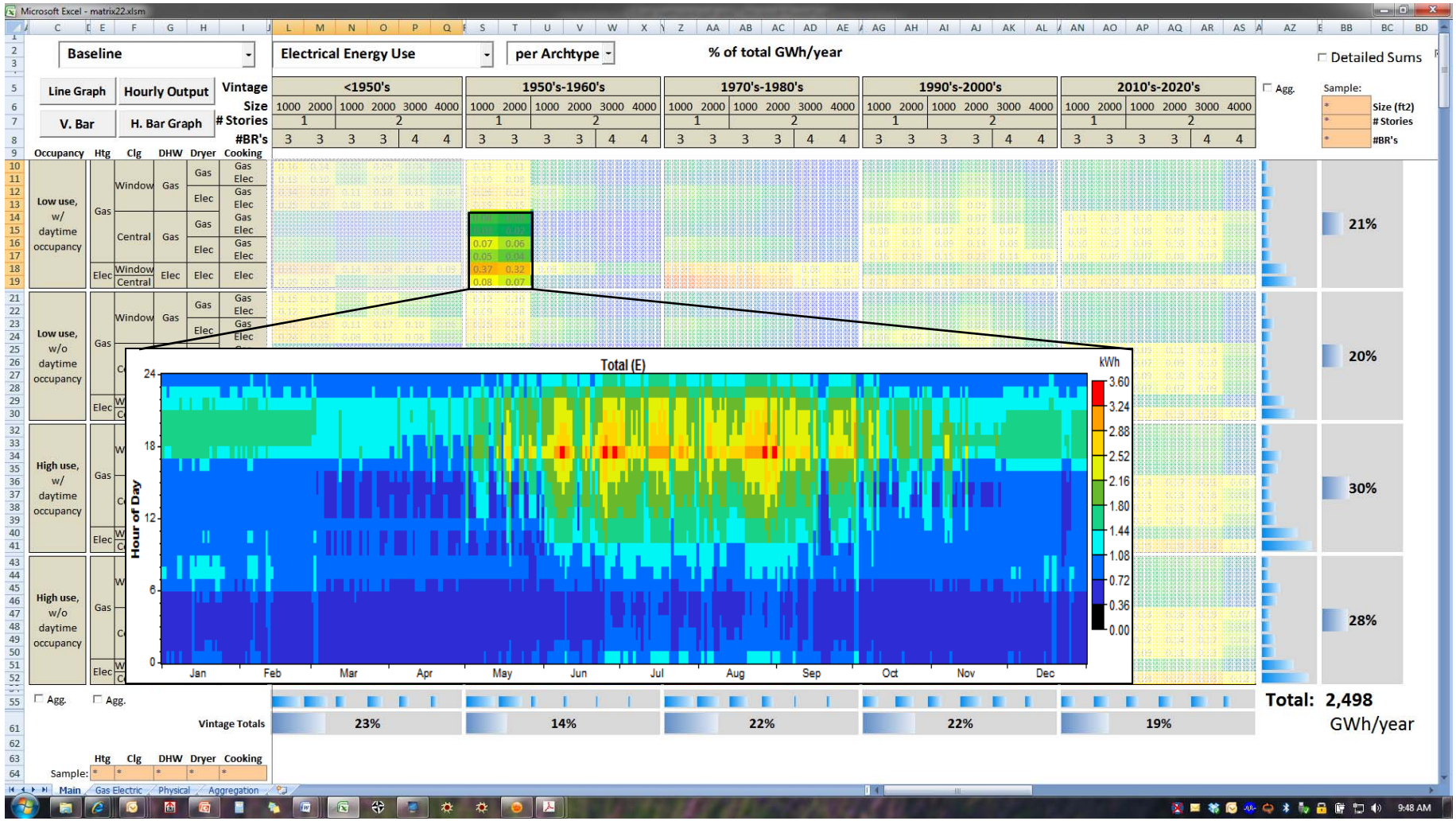
Community-Scale Modeling Tool -- Mock-Up!

Energy Use by Vintage, User Type, Equipment Type, and House Size



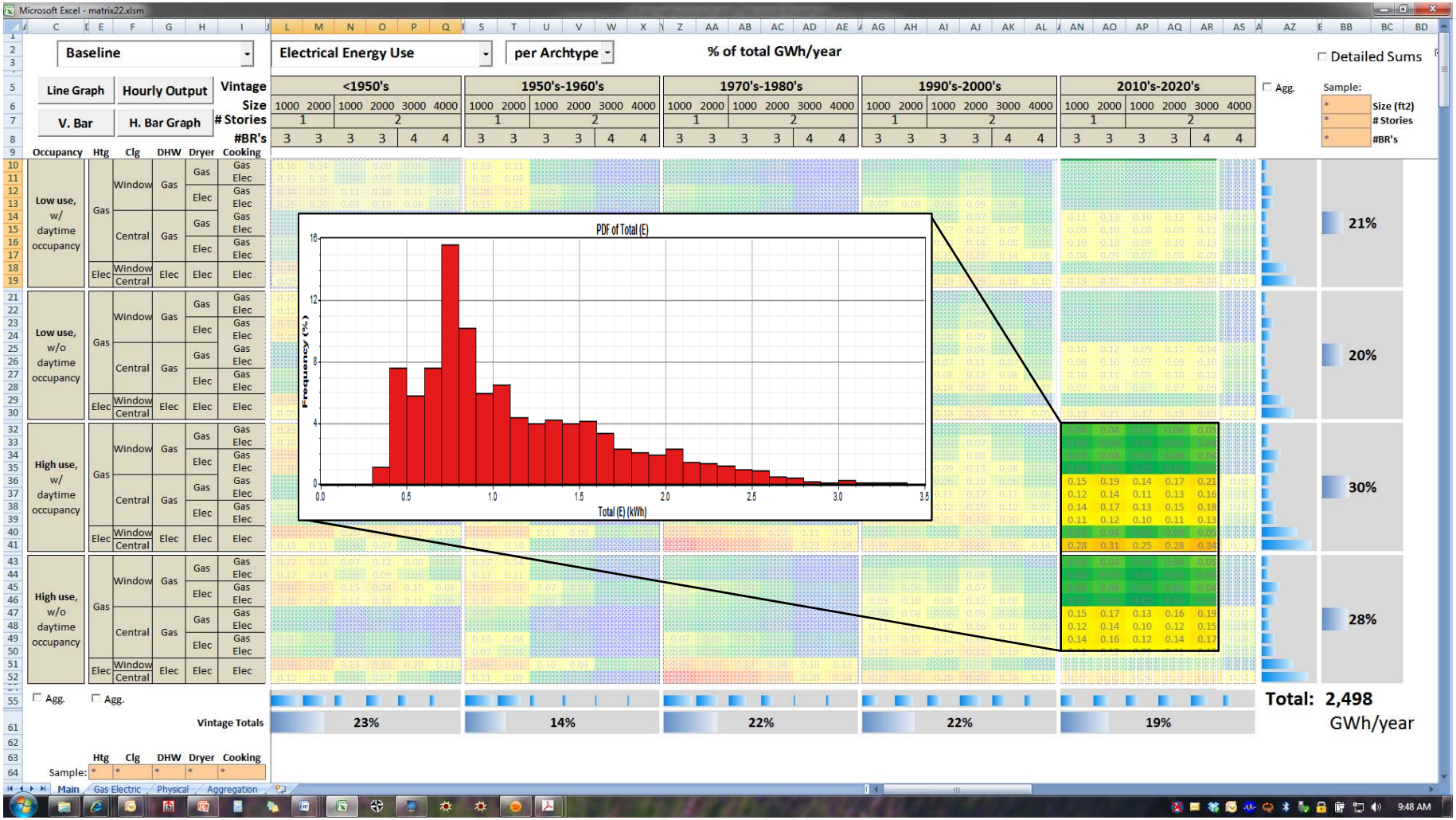
Community-Scale Modeling Tool -- Mock-Up!

Energy Use by Vintage, User Type, Equipment Type, and House Size



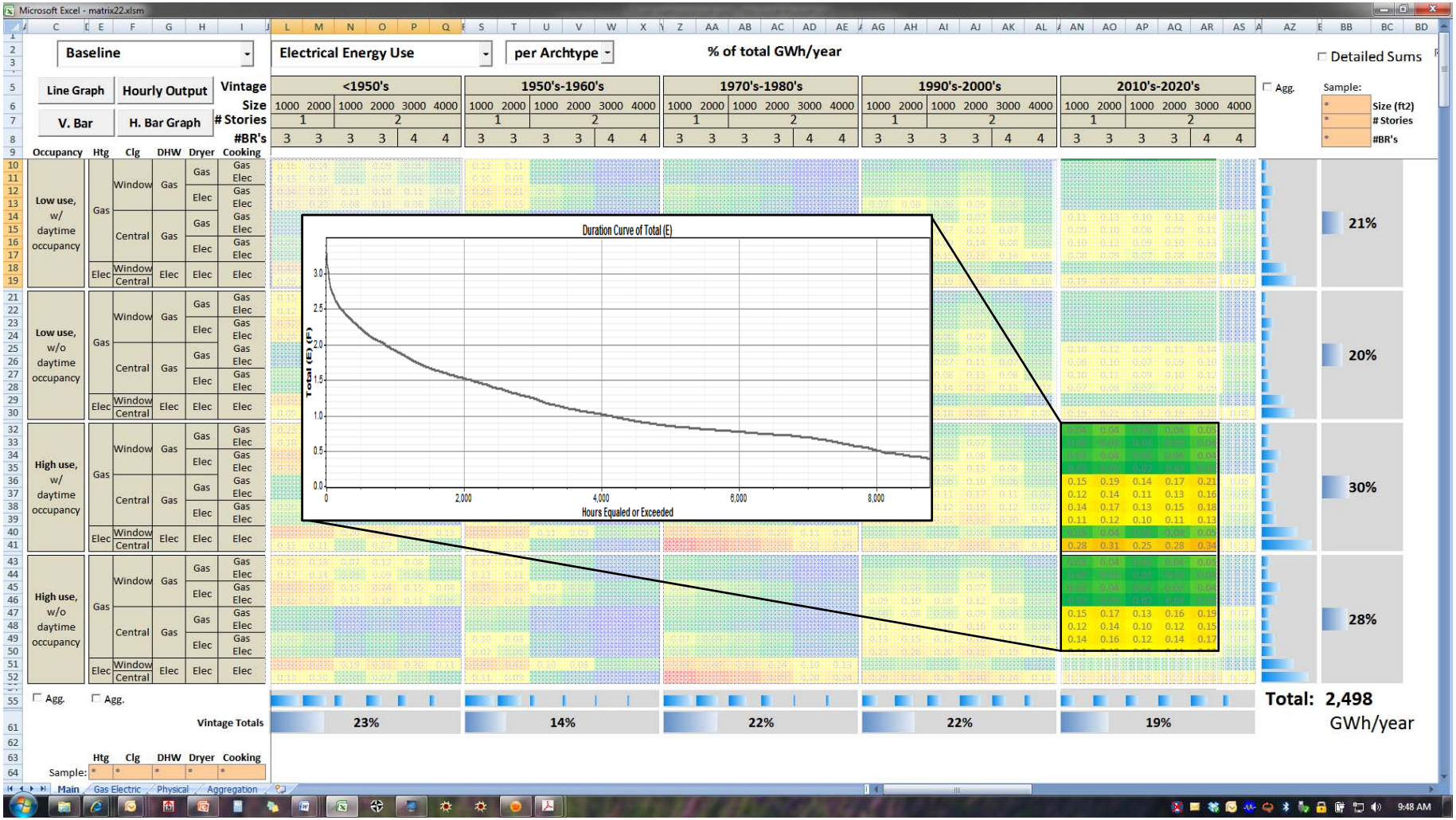
Community-Scale Modeling Tool -- Mock-Up!

Energy Use by Vintage, User Type, Equipment Type, and House Size



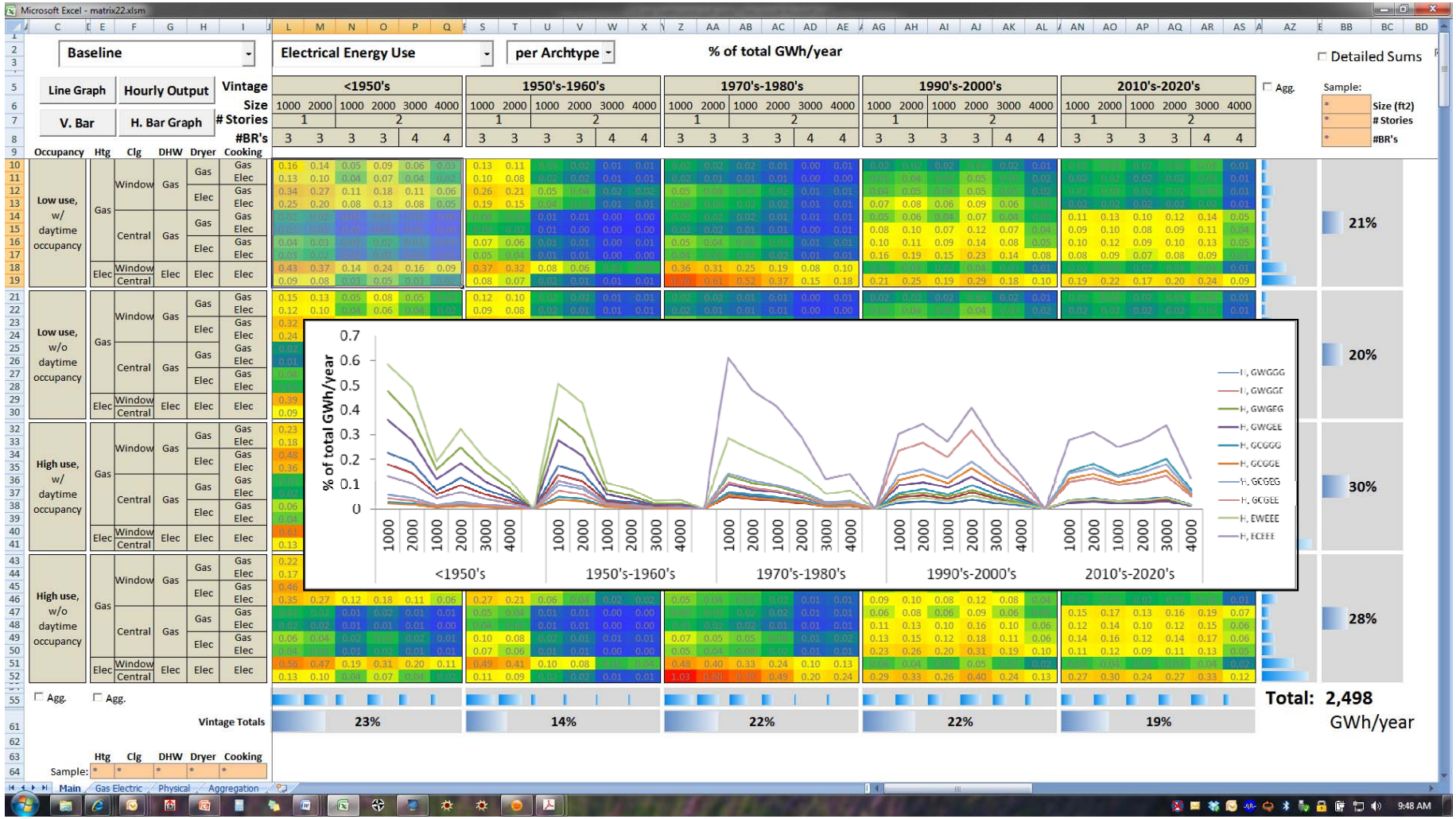
Community-Scale Modeling Tool -- Mock-Up!

Energy Use by Vintage, User Type, Equipment Type, and House Size



Community-Scale Modeling Tool -- Mock-Up!

Energy Use by Vintage, User Type, Equipment Type, and House Size



Questions, Discussion, Feedback

Agenda

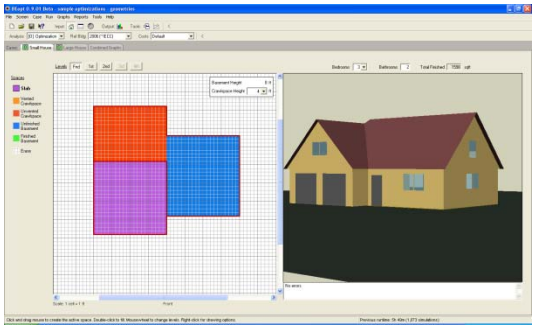
• **Introduction**	– Smita	– 5 min
• **Project Overview**	– Dave	– 5 min -
		- 10 min
• **New BEopt Features**		
o What is BEopt?	– Craig	-- 10 min
o Retrofit analysis	-- Craig	– 5 min
o Demo BEopt	-- Craig	– 10 min
		-- 25 min
• **Utility Cost Tests**		
o Background and implementation	– E3	– 20 min
o Demo BEopt	-- Scott	– 10 min
o Examples of using BEopt for utility cost test	– E3	– 15 min
		-- 45 min
• **Ongoing and Future work:**		
o DR and energy storage	– Dave	– 5 min
o Calibration	– Dave	– 5 min
o Connecting to CSE	– Scott	– 5 min
o Community-scale analysis	– Craig	– 5 min
		--20 min
• **Feedback and discussion**	– Smita	**-- 20 min**

Extra Slides

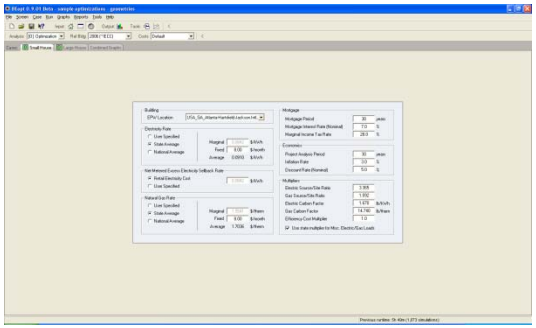
BEopt GUI (Level 1)

Input

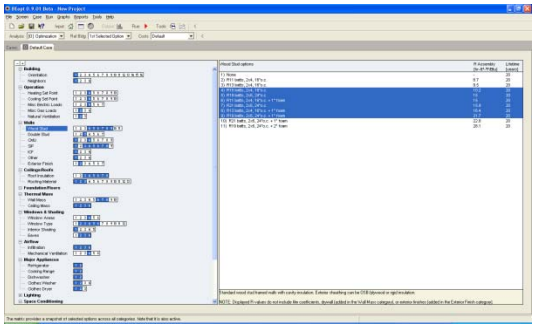
Geometry



Site

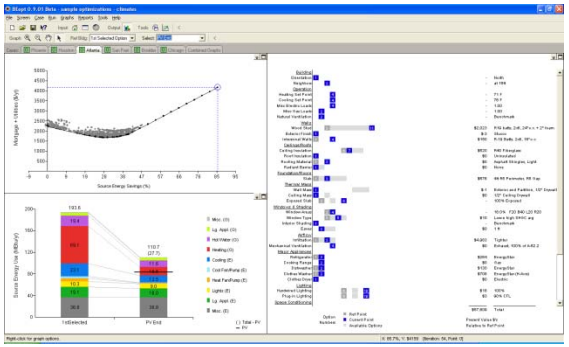


Options



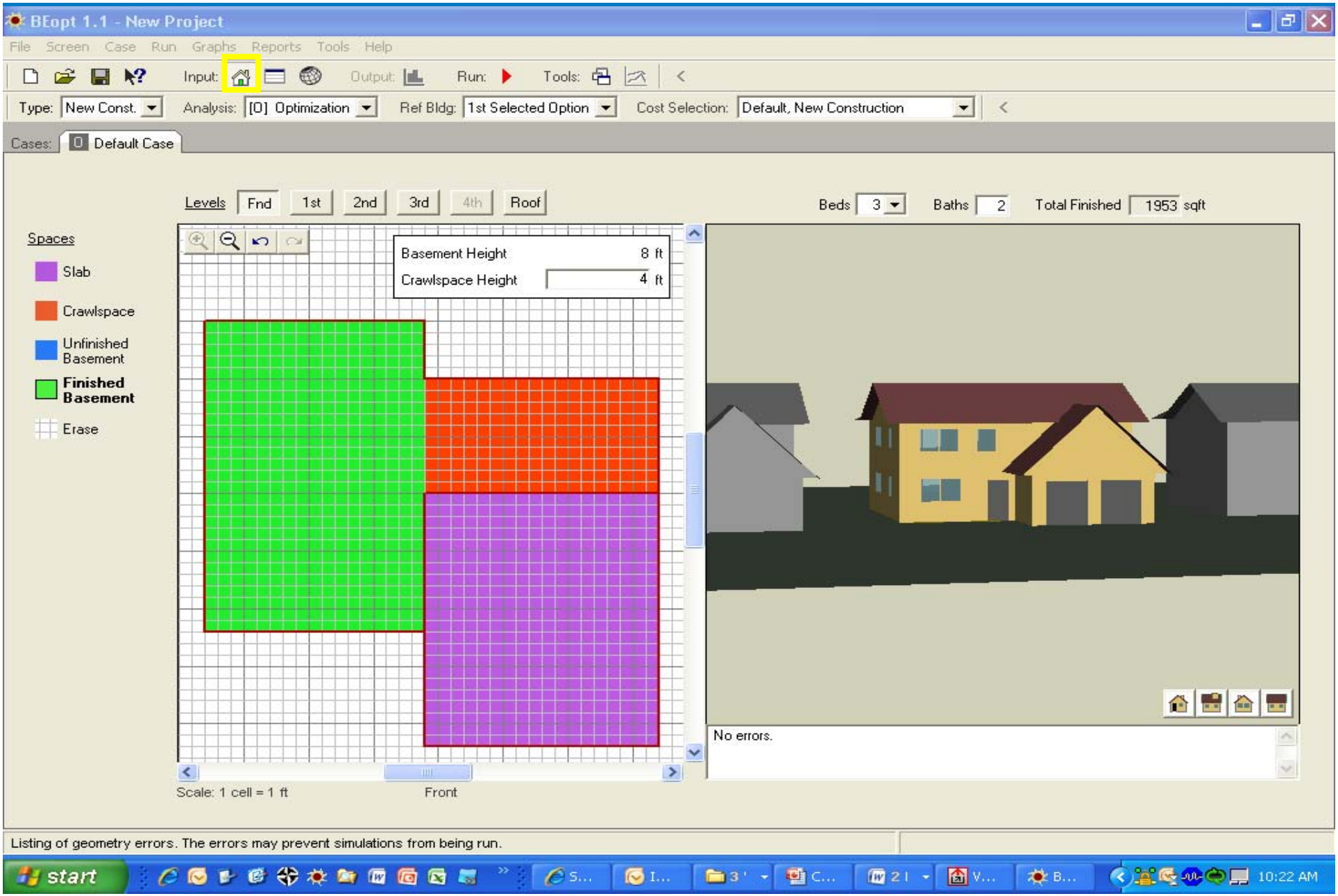
Run

Output



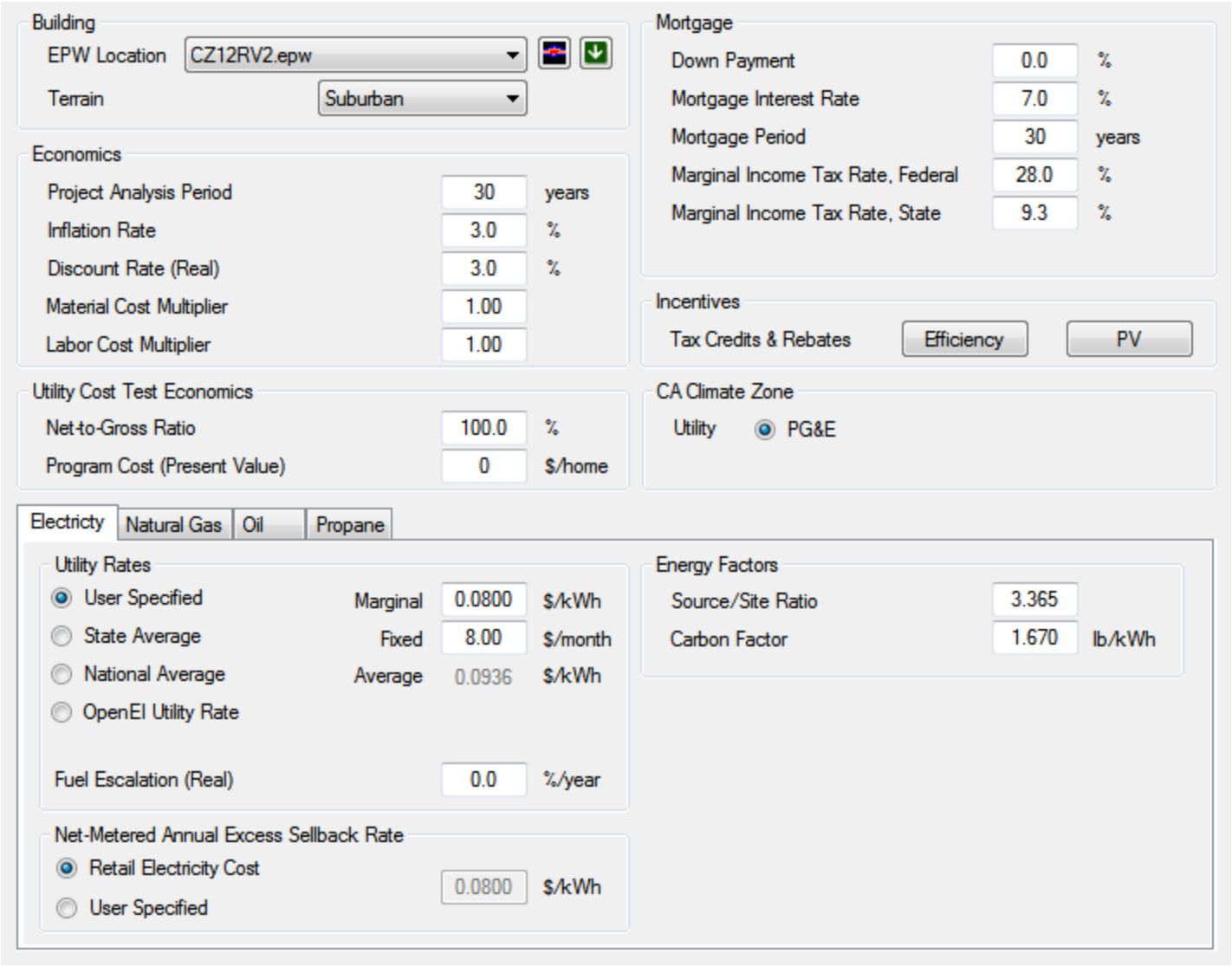
BEopt input

Drawing Tool – quick/accurate input of detailed building geometry



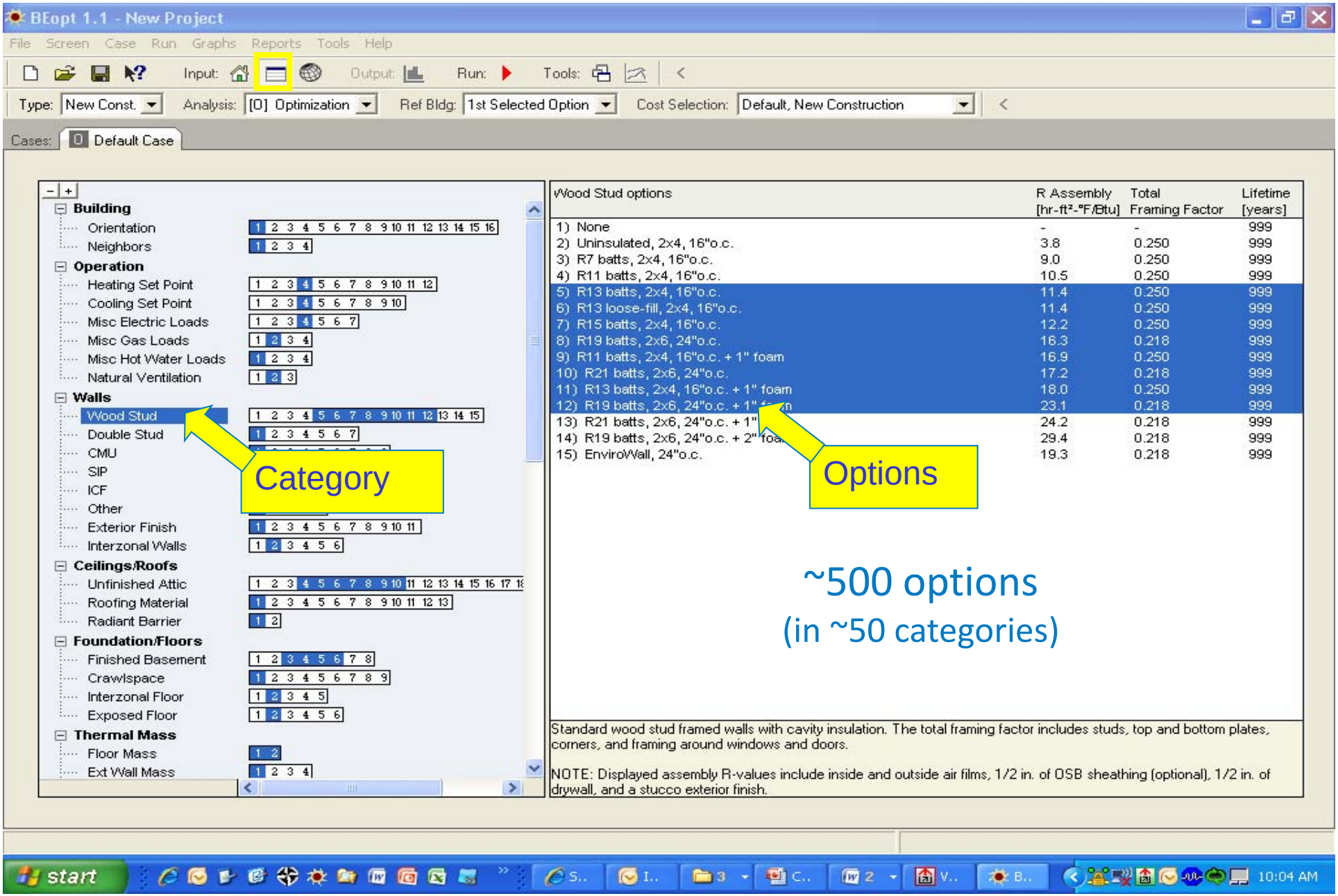
BEopt input

Site Inputs – weather, financing, utility rates, incentives, etc.



BEopt input

Options – operation, envelope, equipment

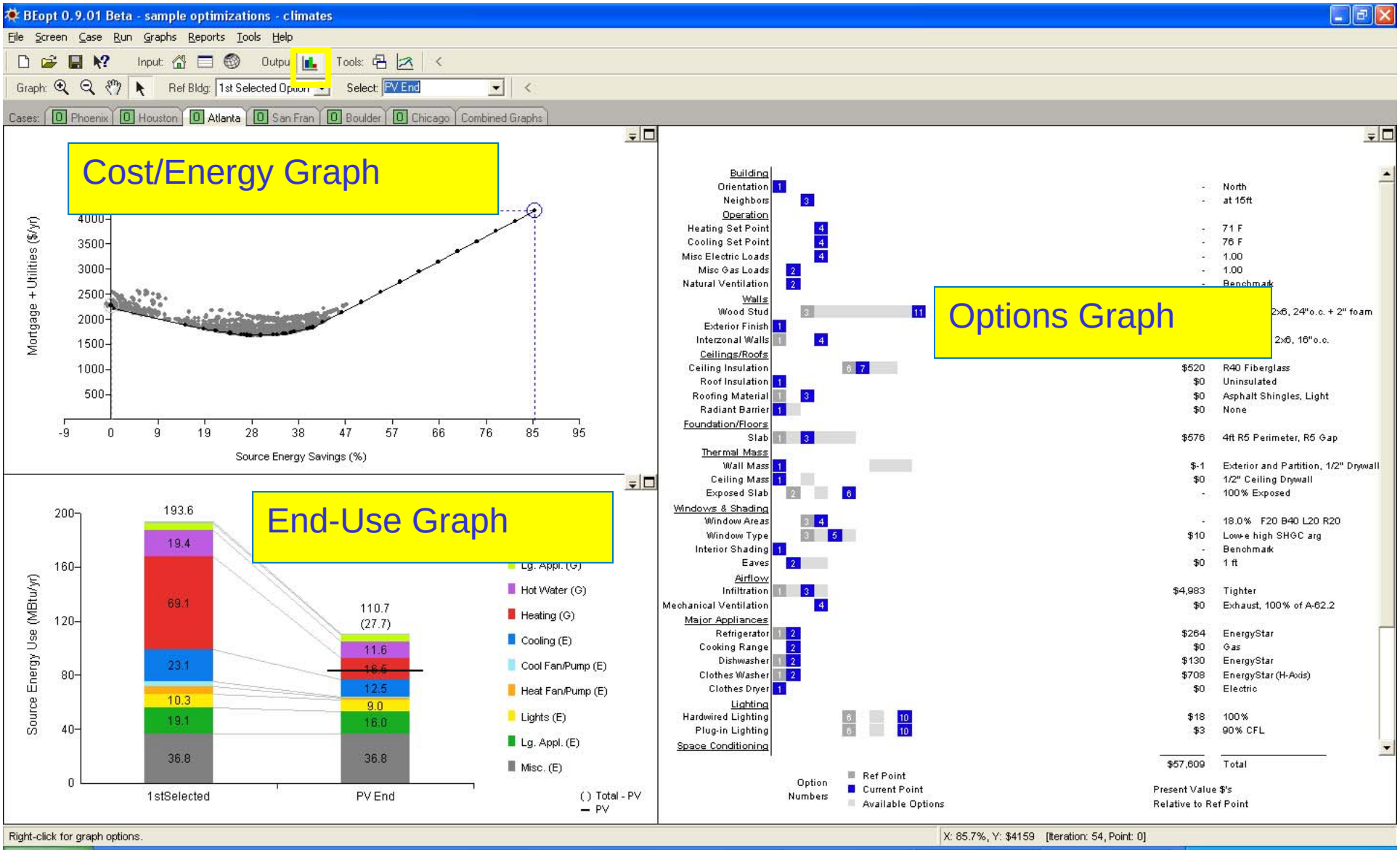


~500 options

(in ~50 categories)

BEopt output

Results – multiple designs, selected individual designs



California-Specific Cost Data

- Includes measures that are most likely to be used in standard California retrofits
- Where possible applies cost data from local sources and uses California labor assumptions
- Includes details not included in other cost data
- Compliments NREL's National Residential Efficiency Measure Database (www.nrel.gov/ap/retrofits/group_listing.cfm)

Retrofit Measures

- Include measures that are most likely to be used in standard California retrofits
- Where possible apply cost data from local sources and use California labor assumptions
- Retrofit specific labor costs include details not included in other cost data
- Compliments NREL's National Residential Efficiency Measure Database (www.nrel.gov/ap/retrofits/group_listing.cfm)