FORUM 0862
INTEGRATION OF PV WITH EE DR AND ES

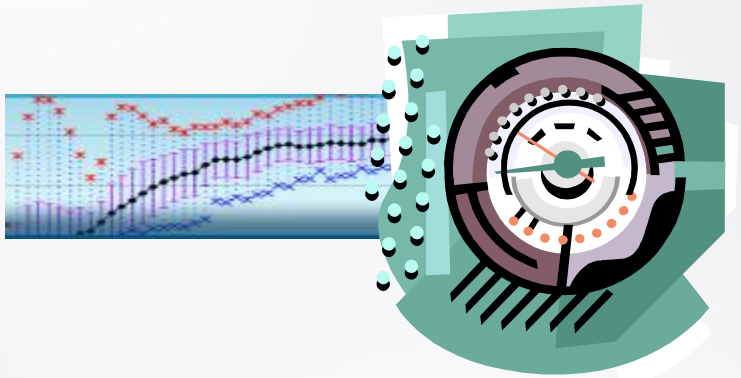
Tools and Approaches towards ZNE

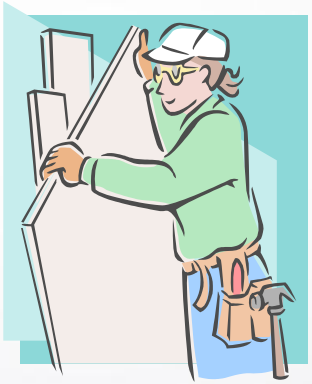
Itron CSI RD&D Program Manager

PUBLIC UTILITIES COMMISSION · EUREKA · STATE OF CALIFORNIA

GO solar CALIFORNIA

INTEGRATION OF PV WITH EE DR AND ES





CALIFORNIA POLICY

- California Solar Initiative
  - Distributed Generation - Solar PV
  - Grid Integration of Solar
  - CSI RD&D Program
- Energy Efficiency Strategic Plan
  - ZNE 2020 -2030
  - Loading Order

AGENDA

Time	Topic	Presenter
4:15 – 4:20 pm	Introduction to the forum	Smita Gupta (Itron)
4:20 – 4:30 pm	IEP Model	Devan Johnson (kW Engineering)
4:30 – 4:40 pm	BEopt-CA (Ex)- A Tool for Optimal Integration of EE/DR/ES+PV in Existing California Homes	Craig Christensen (NREL)
4:40 – 4:55 pm	**Discuss tools**	
4:55 – 5:05 pm	Low-Cost, Smart-Grid Ready Solar Re-Roof	Victoria Doyle (ConSol) Rob Hammon (ConSol)
5:05 – 5:15 pm	UC Davis West Village Project: Integrating PV & EE	Michele Chait (E3) Mary Hayakawa (UC Davis)
5:15 – 5:30 pm	**Discuss approaches**	

TOOLS THAT ADDRESS INTEGRATION

IEP Model

Devan Johnson, PE
kW Engineering

Towards Integration

- Energy efficiency (EE) and Demand Response (DR) measures often more cost effective than PV
- EE audits are often prerequisite to solar incentives
- Common info required for evaluating EE/DR/PV
- Integrated approaches reduce data collection redundancies and facilitate integrated projects

Integrating Focused Tools

- Numerous tools exist for evaluating EE and PV
- Lack of tools for evaluating comprehensive projects, or facilitating implementation.
- Interoperability between specialized tools will facilitate more integrated energy projects (IEP).
- Overall ROI on IEPs better than PV only creating potential for higher sales and deeper PV penetration.

Solution: A Common Language

Introduce a set of XML schemas that will become a comprehensive, standardized definition of:

- An Integrated Energy Project (EE/DR+PV)
- How stakeholders communicate between each other

Provide a open means for passing electronic information among the parties through various software and web-based applications.

IEP Model – XML Schemas

High level elements that are described by IEP XML:

- Site and Building information
- Energy systems (HVAC, Lighting, Appliance, PV, etc.), equipment specifications, and operating schedules
- Utility service and energy consumption data
  - Modeled after ENERGY STAR ABS schemas
- Project participants (customers, contractors, acct reps, etc.)
- Measures (EE, DR, DG)
  - Including savings, cost, affected systems, and details

Schema documentation is available online at **http://www.iepmodel.net/**

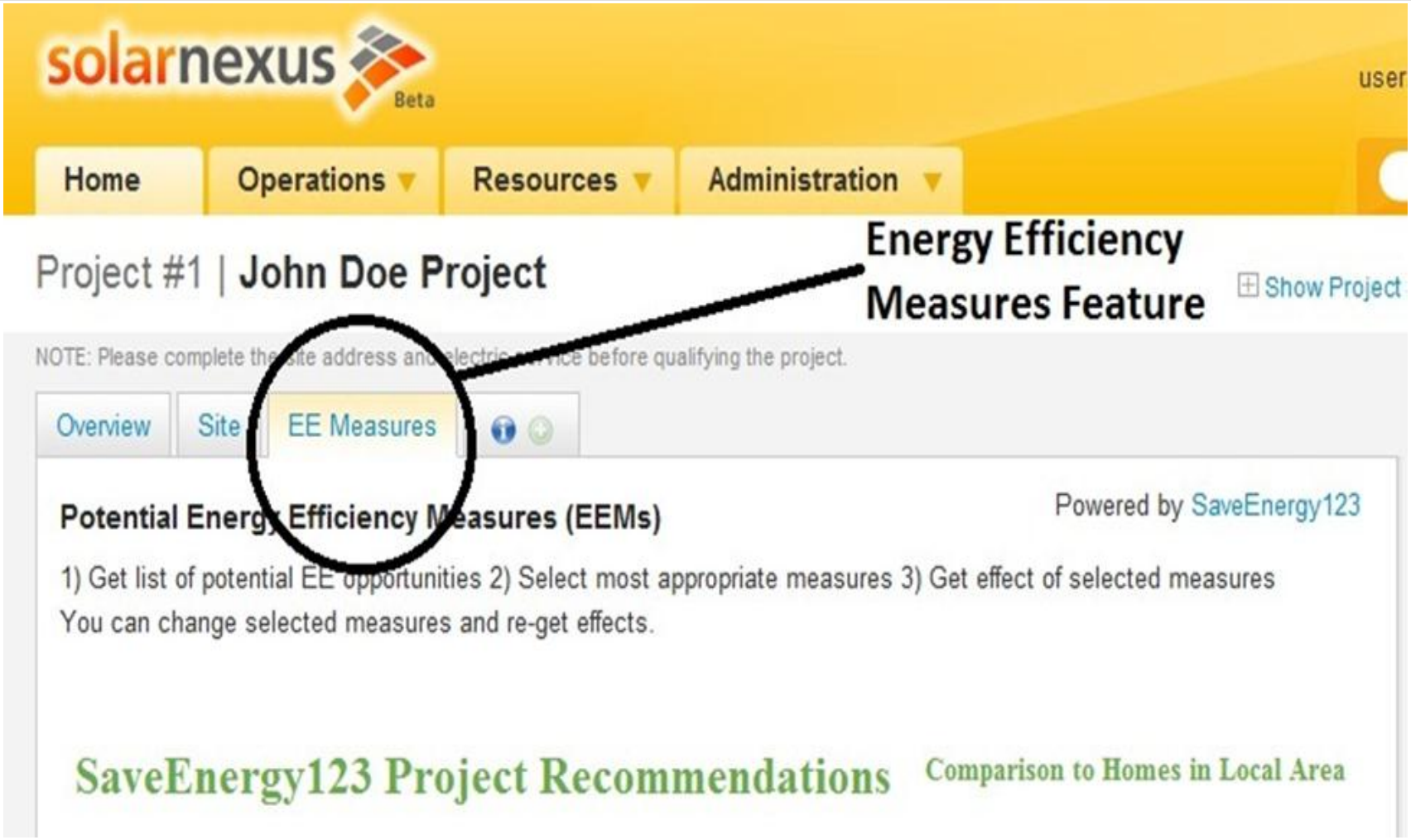
IEP Model – Initial Integration

Integrated SolarNexus solar project management tool with SaveEnergy123 energy efficiency audit tool

SOLARNEXUS ⟷ Save Energy 1·2·3

Contractor-facing solar project management tool	Customer-facing residential energy efficiency audit tool

IEP Model – Initial Integration



IEP Model – Initial Integration

Building loads information gathered by solar contractor during site assessment

SOLARNEXUS

Energy loads information entered by solar contractor

IEP Model – Initial Integration

Building loads sent as IEP XML in request for energy efficiency measure (EEM) recommendations

SOLARNEXUS → Save Energy 1 2 3

Request EE evaluation from SaveEnergy123

IEP Model – Initial Integration

EEM recommendations sent as IEP XML in response

SOLARNEXUS ← Save Energy 1 2 3

Respond with EEM recommendations for building

IEP Model – Initial Integration

Solar contractor can perform what-if scenarios with different combinations of recommended EEMs

SOLARNEXUS ⟷ Save Energy 1·2·3

Contractor selects EEMs to include in integrated proposal

Estimated energy impacts and costs returned for selections

What's the Value?

Value of data exchange is huge

- With IEP XML we can greatly speed collaboration by minimizing redundant data collection and entry
- Collaboration can take the form of integrating tools, manual export/import of data in common format, or data aggregation from multiple sources

Integrating functionality of other tools

- Integrating tools will encourage integrated projects
- Software tool developers can focus on their core strengths instead of trying to develop all features themselves

Thank You

Contact

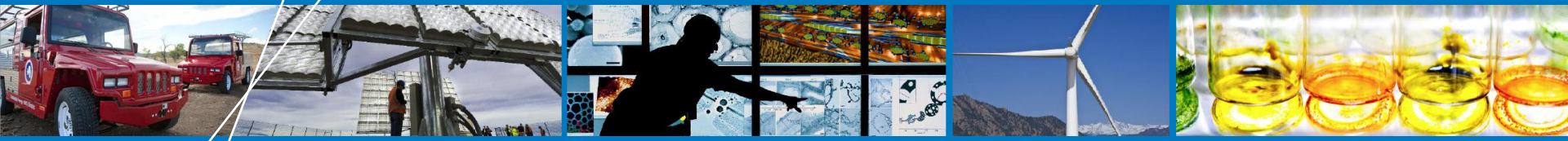
Devan Johnson, P.E.
johnson@kw-engineering.com

www.iepmodel.net

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

BEopt-CA (Ex)

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



Craig Christensen

May 15, 2012

World Renewable Energy Forum
Denver, CO

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.

Objective

- Develop a software tool to provide utility program managers with a means of balancing and integrating energy options in existing homes:

EE – Energy Efficiency

DR – Demand Response

ES – Energy Storage

PV – Photovoltaics

New Capabilities for BEopt:

Existing Homes Analysis

Retrofit Costs, Equipment Sizing, Remaining Life, Standards, Retrofit Timing

Detailed Utility Tariffs

Tiered, Time-of-Use, Real-Time-Pricing

Utility Cost/Benefit Tests

Ratepayer, Participant, Utility, Total Resource, Societal

Demand Response

Peak Shaving, Peak Shifting, High Penetration RE

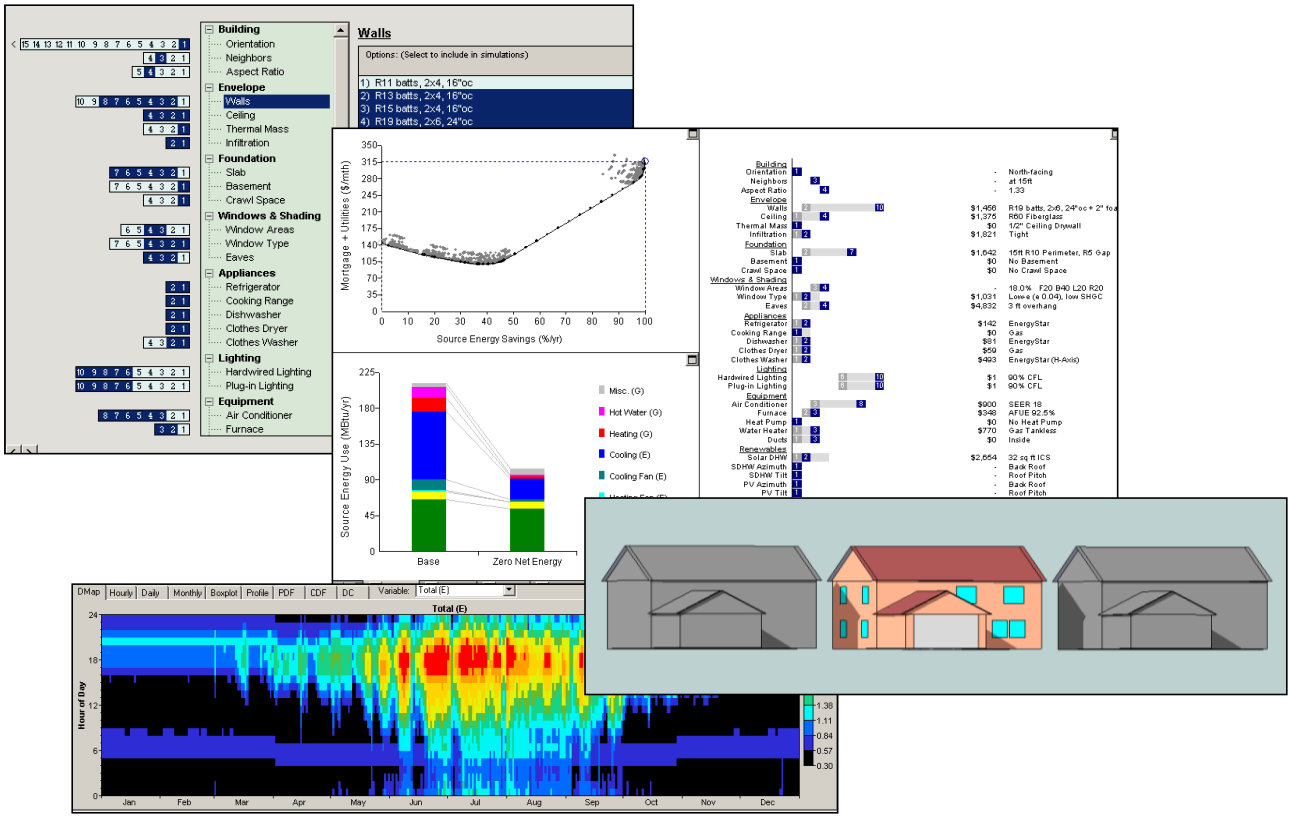
Energy Storage

Batteries, Thermal (Passive and Active)

BEopt

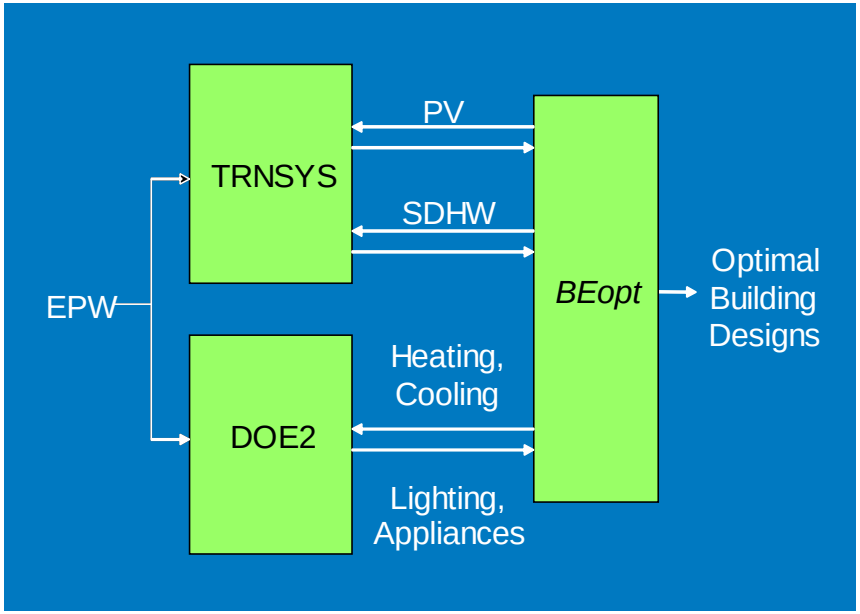
Building Energy Optimization Based on Hour-by-Hour Simulations

beopt.nrel.gov

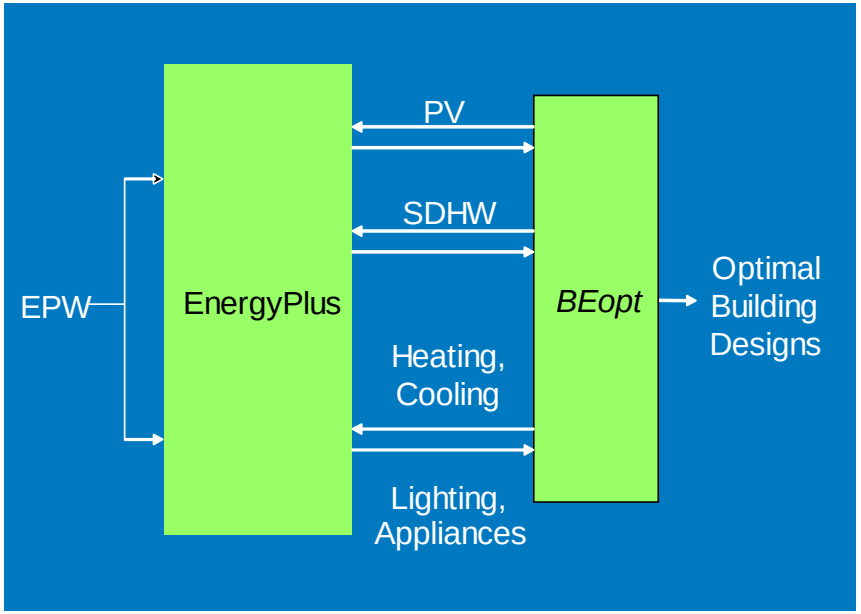


BEopt can run different simulation engines

BEopt (TRNSYS + DOE2)

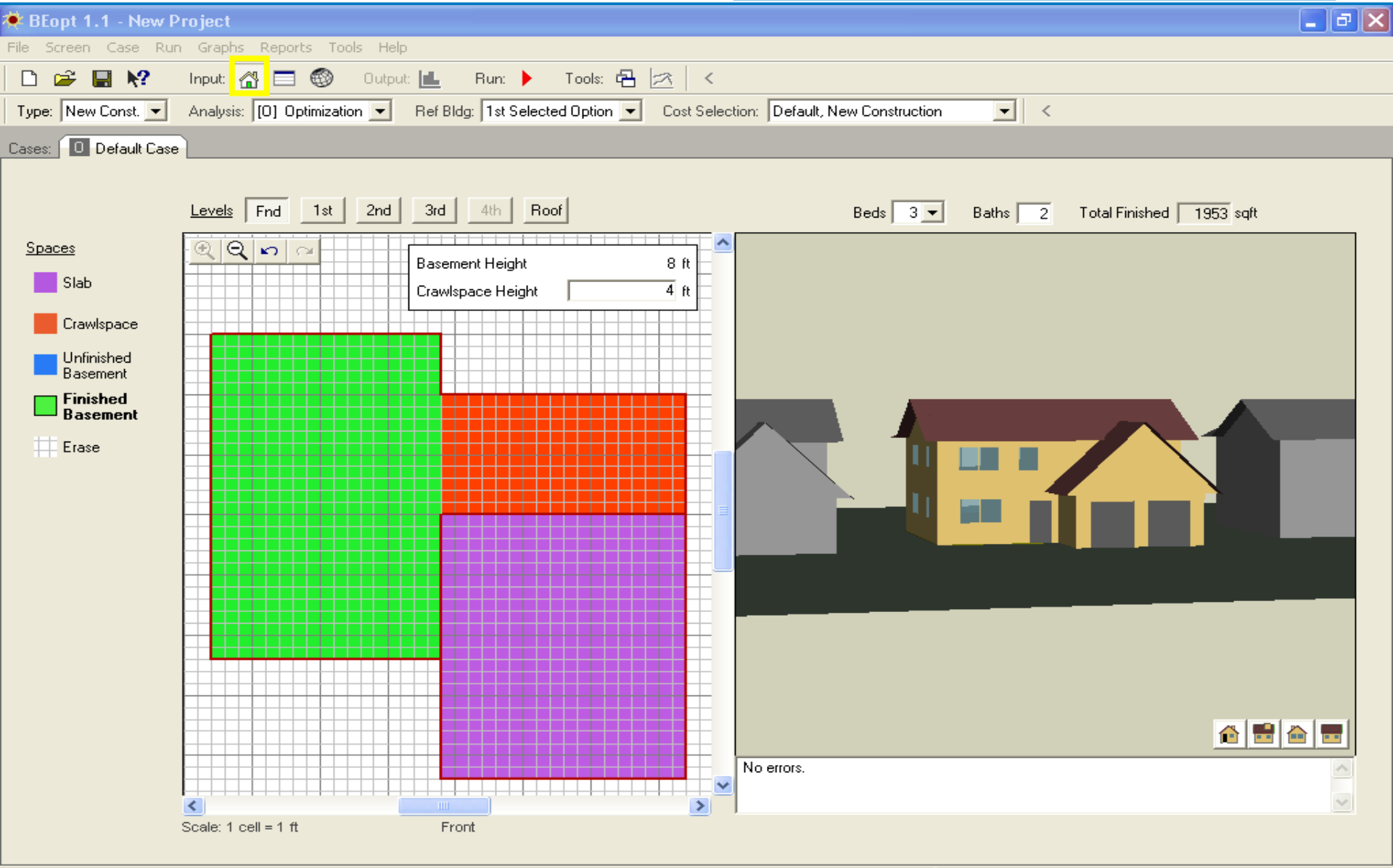


BEopt (EnergyPlus)



BEopt input (1)

Drawing Tool – quick/accurate input of detailed building geometry



BEopt input (2)

Options – operation, envelope, equipment

BEopt 1.1 - New Project

File Screen Case Run Graphs Reports Tools Help

Input: Output: Run: Tools:

Type: New Const. Analysis: [0] Optimization Ref Bldg: 1st Selected Option Cost Selection: Default, New Construction

Cases: 0 Default Case

- **Building**
  - Orientation: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
  - Neighbors: 1 2 3 4
- **Operation**
  - Heating Set Point: 1 2 3 4 5 6 7 8 9 10 11 12
  - Cooling Set Point: 1 2 3 4 5 6 7 8 9 10
  - Misc Electric Loads: 1 2 3 4 5 6 7
  - Misc Gas Loads: 1 2 3 4
  - Misc Hot Water Loads: 1 2 3 4
  - Natural Ventilation: 1 2 3
- **Walls**
  - Wood Stud: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
  - Double Stud: 1 2 3 4 5 6 7
  - CMU
  - SIP
  - ICF
  - Other
  - Exterior Finish: 1 2 3 4 5 6 7 8 9 10 11
  - Interzonal Walls: 1 2 3 4 5 6
- **Ceilings/Roofs**
  - Unfinished Attic: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
  - Roofing Material: 1 2 3 4 5 6 7 8 9 10 11 12 13
  - Radiant Barrier: 1 2
- **Foundation/Floors**
  - Finished Basement: 1 2 3 4 5 6 7 8
  - Crawlspace: 1 2 3 4 5 6 7 8 9
  - Interzonal Floor: 1 2 3 4 5
  - Exposed Floor: 1 2 3 4 5 6
- **Thermal Mass**
  - Floor Mass: 1 2
  - Ext Wall Mass: 1 2 3 4

Category

Wood Stud options	R Assembly [hr-ft²-°F/Btu]	Total Framing Factor	Lifetime [years]
1) None	-	-	999
2) Uninsulated, 2x4, 16"o.c.	3.8	0.250	999
3) R7 batts, 2x4, 16"o.c.	9.0	0.250	999
4) R11 batts, 2x4, 16"o.c.	10.5	0.250	999
5) R13 batts, 2x4, 16"o.c.	11.4	0.250	999
6) R13 loose-fill, 2x4, 16"o.c.	11.4	0.250	999
7) R15 batts, 2x4, 16"o.c.	12.2	0.250	999
8) R19 batts, 2x6, 24"o.c.	16.3	0.218	999
9) R11 batts, 2x4, 16"o.c. + 1" foam	16.9	0.250	999
10) R21 batts, 2x6, 24"o.c.	17.2	0.218	999
11) R13 batts, 2x4, 16"o.c. + 1" foam	18.0	0.250	999
12) R19 batts, 2x6, 24"o.c. + 1" foam	23.1	0.218	999
13) R21 batts, 2x6, 24"o.c. + 1"	24.2	0.218	999
14) R19 batts, 2x6, 24"o.c. + 2" foa	29.4	0.218	999
15) EnviroWall, 24"o.c.	19.3	0.218	999

Options

Standard wood stud framed walls with cavity insulation. The total framing factor includes studs, top and bottom plates, corners, and framing around windows and doors.

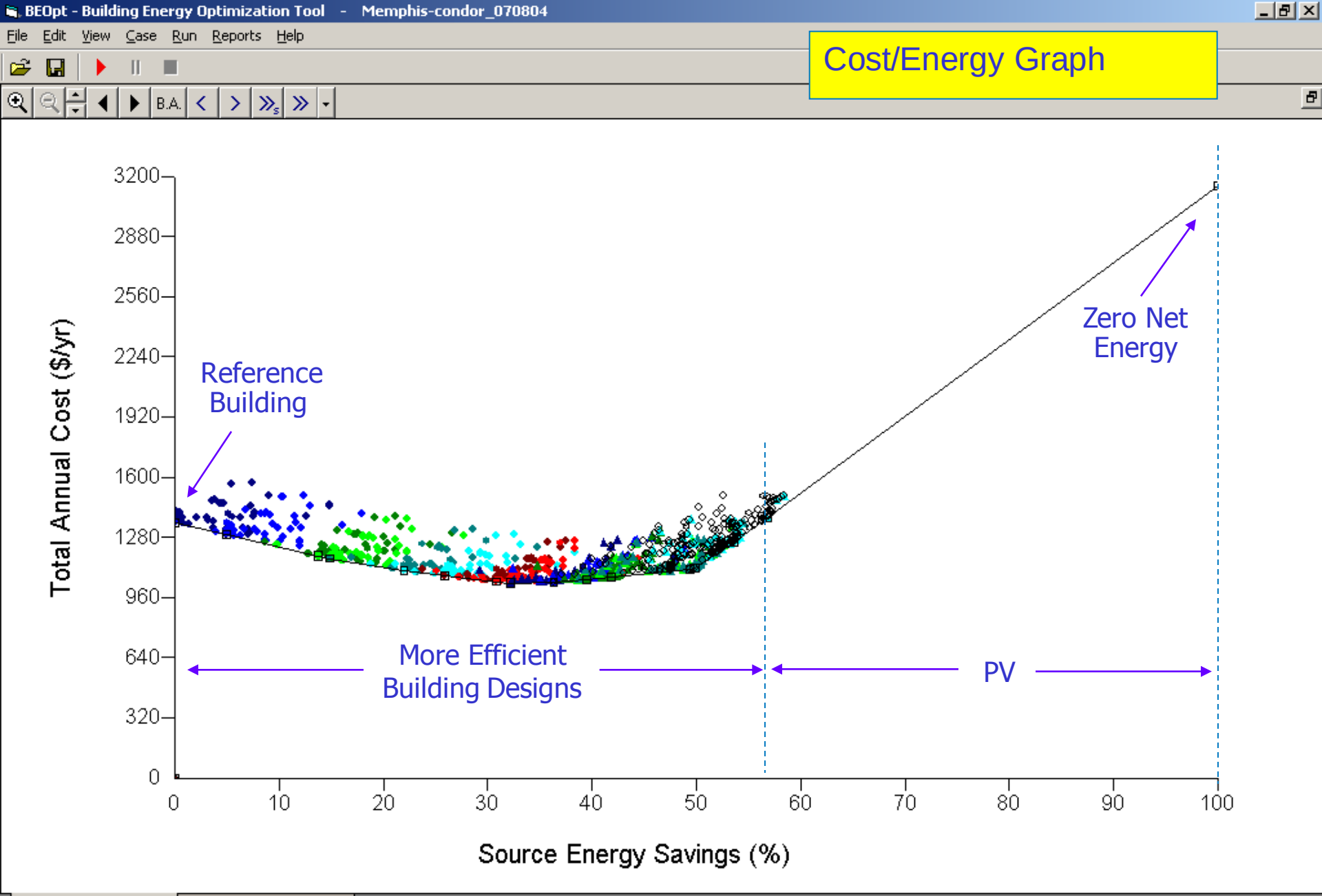
NOTE: Displayed assembly R-values include inside and outside air films, 1/2 in. of OSB sheathing (optional), 1/2 in. of drywall, and a stucco exterior finish.

~500 options

(in ~50 categories)

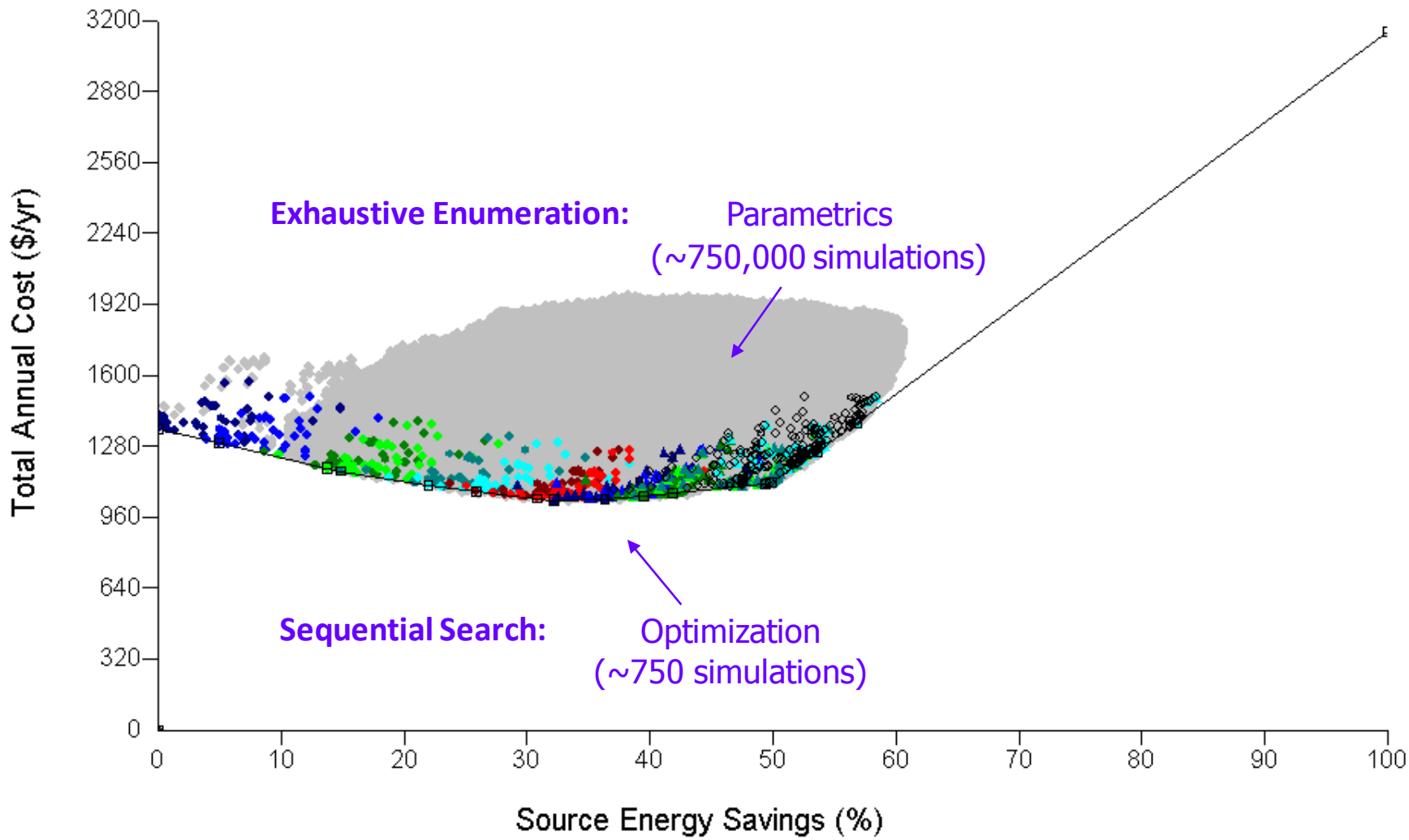
start 10:04 AM

Cost/Energy Graph



BEOpt - Building Energy Optimization Tool - Memphis-condor_070904

File Edit View Case Run Reports Help

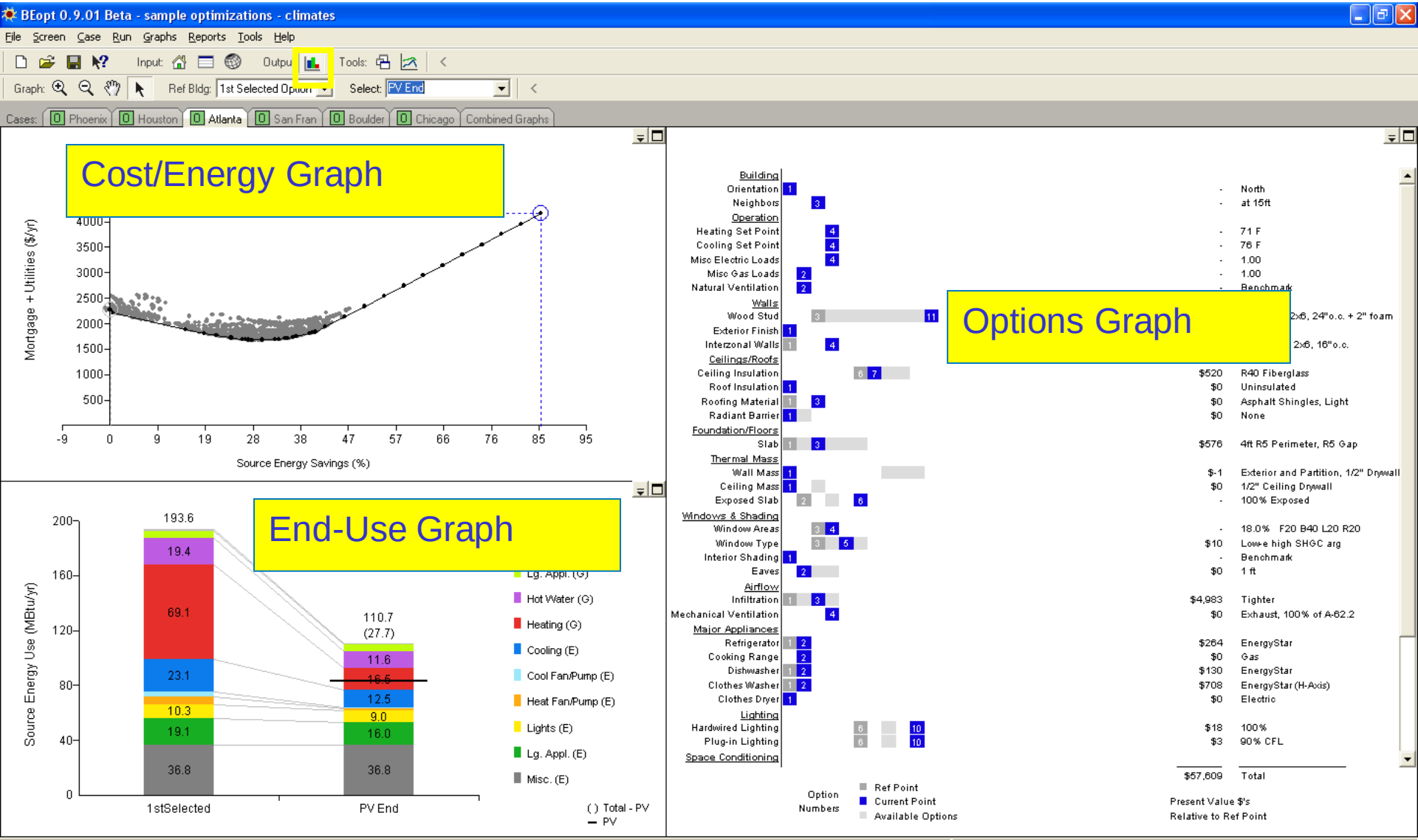


Memphis-Condor

Click and drag to zoom, click on a point for details, or right-click for graph options.

BEopt output

Results – multiple designs, selected individual designs



For More Information

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beopt.nrel.gov

DISCUSSION

Tools that deal with integration

APPROACHES - DEMONSTRATIONS

GO solar CALIFORNIA

Low-Cost Solar & Energy Efficient Retrofits

ConSol

SDGE
A Sempra Energy utility™

GE Global Research

Itron

PUBLIC UTILITIES COMMISSION
EUREKA
STATE OF CALIFORNIA

Low-Cost, Smart-Grid Ready Solar Re-Roof Project Overview

Goal:

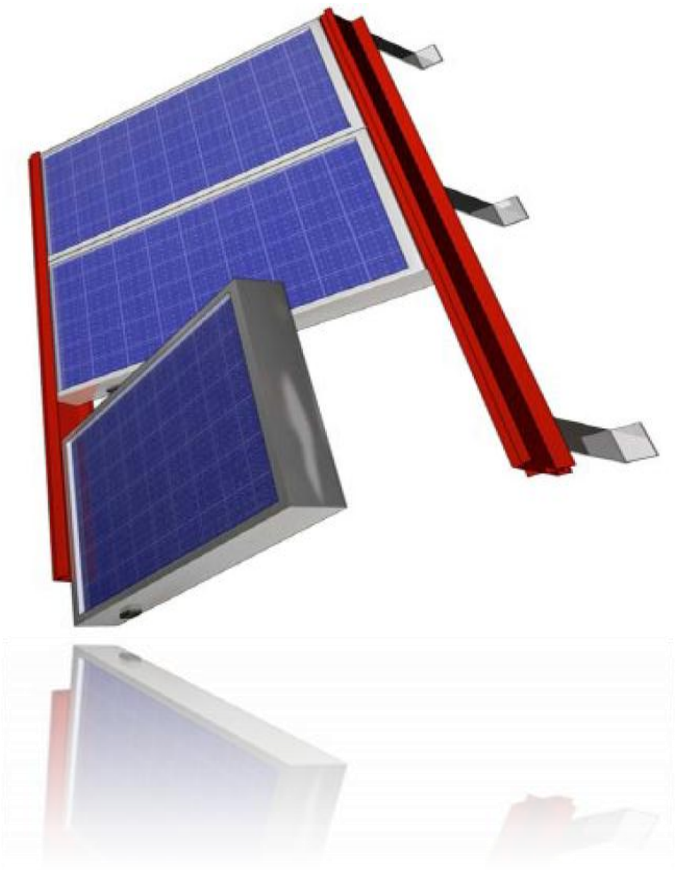
Reduce first-cost barrier for zero energy homes (ZEH) through a new business model where a low-cost solar system is coupled with energy efficiency improvements, demand response (DR) and a home energy management (HEM) system. Achieve install cost goal <$4.25/W.

Method:

Seven demonstration installations in the San Diego Gas and Electric (SDG&E) territory

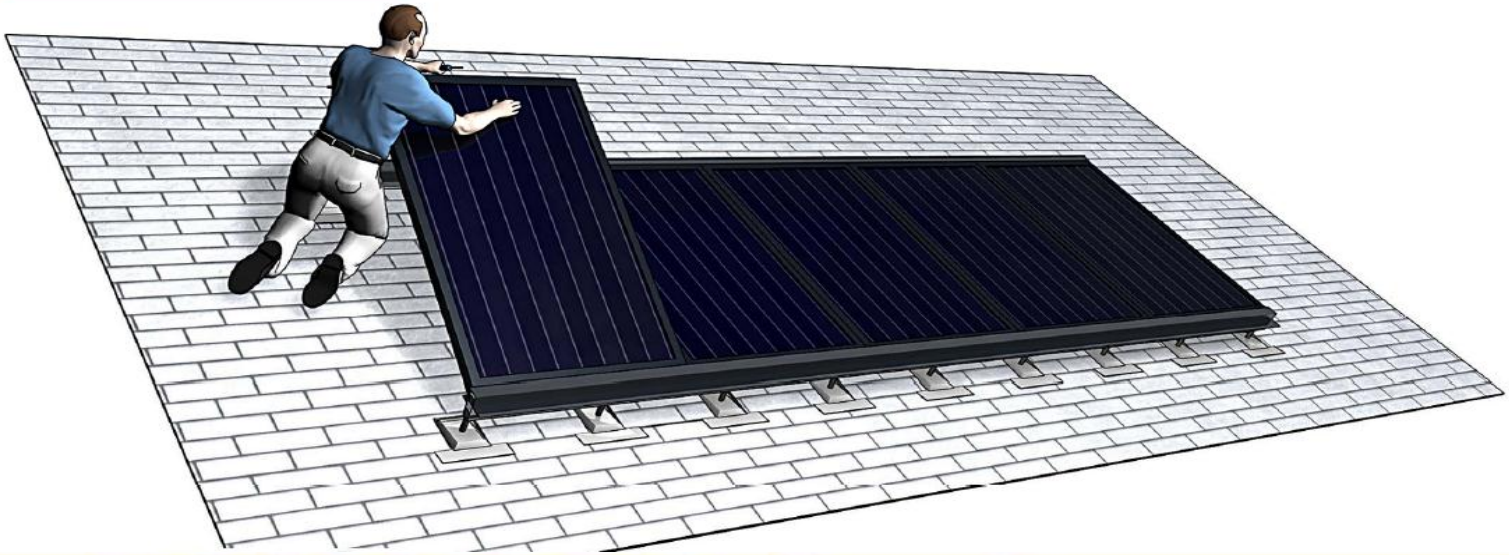
- One (1) roof-on-the-ground prototype installation for training purposes
- One (1) initial demonstration home retrofit installation
- Five (5) test installation homes in different markets with different levels of energy efficiency, including one zero energy retrofit

General Electric (GE) "Plug-and-Play" Photovoltaic (PV) System



- Designed for coordinated installation with asphalt re-roofing materials by standard roofer and electrical contractor **without extensive training and special tools**
- PV system features a **simplified** "insert and capture" mechanical mounting assembly
- **Reduced assembly part count** and "plug & play" $240V_{AC}$ micro-inverter PV system
- **No penetrations** of asphalt shingles roof
- Target installed PV system cost is less than **$4.25/Watt**, including:
  - An AMI-ready home energy monitor (HEM)
  - Demand response (DR) controller

GE "Plug-and Play" PV: Differentiating Feature- Ease of Installation



Chula Vista Sustainable Energy Showcase Home

- Evaluate installation for structural, design, permitting, warranty issues
- Demonstrate emerging technologies
  - Including a 2.4 kW GE "plug-and-play" photovoltaic system
- Perform field evaluation, monitoring of retrofitted home
- Evaluate performance, operation of PV and HEM systems
  - Compare to historic, modeled performance
- Create a showcase for energy efficient home retrofits
  - Open to public and available for EE training

CV Sustainable Energy Showcase Home:
Energy Efficiency Measures & Energy Savings Goal

- Single-family, detached home
- 1,900 sqft. CFA
- 3 Bed/2 Bath

Retrofit Building Measures

- Additional Ceiling Insulation
- Asphalt Singles, White/Cool
- Radiant Barrier
- Low-e Windows
- Hot Water Heater- Condensing Tankless
- High Efficiency Furnace
- Demand Response Appliances
- Lighting: 100% LEDs
- Solar Thermal- Integral Collector Storage
- Home Energy Management System

Demonstration PV & 30%+ WHES

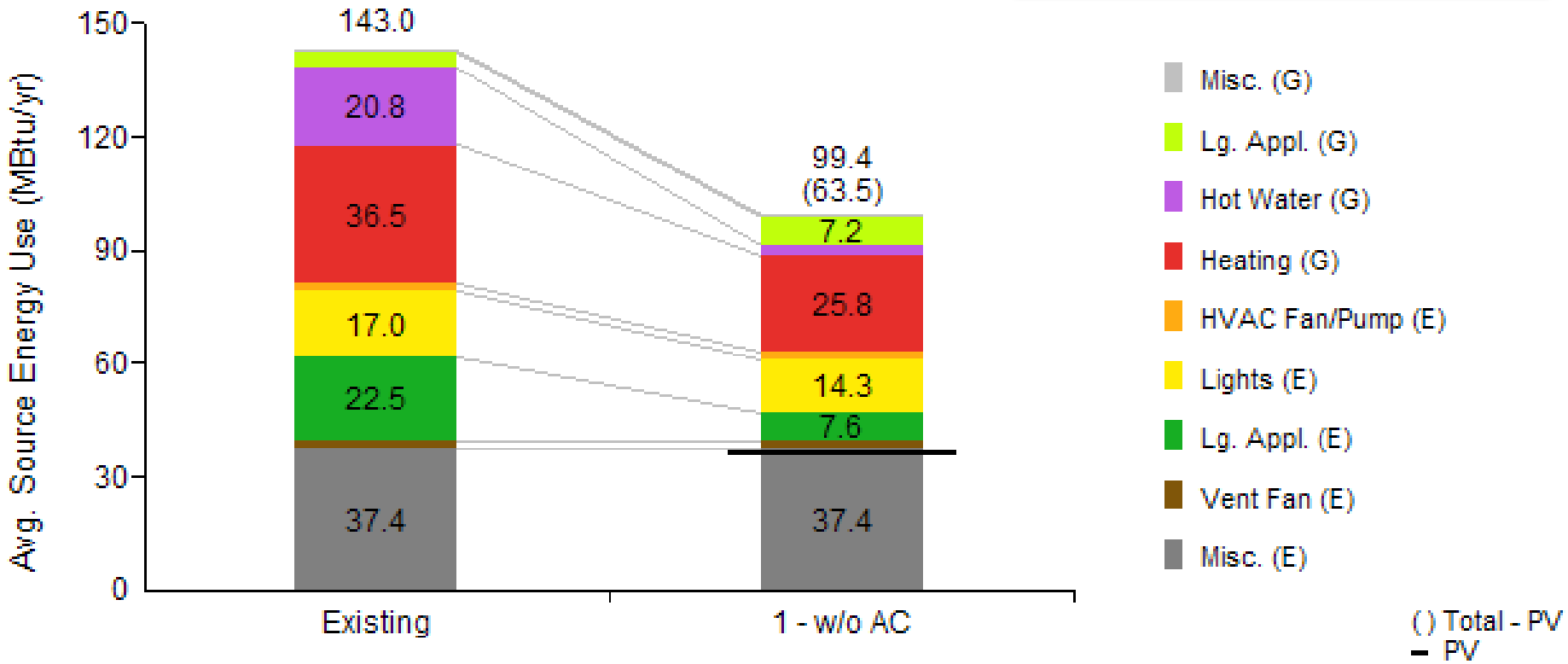
CV Sustainable Energy Showcase Home:
2.4 kW PV System Installation

- Cost-savings from installation during reroof process

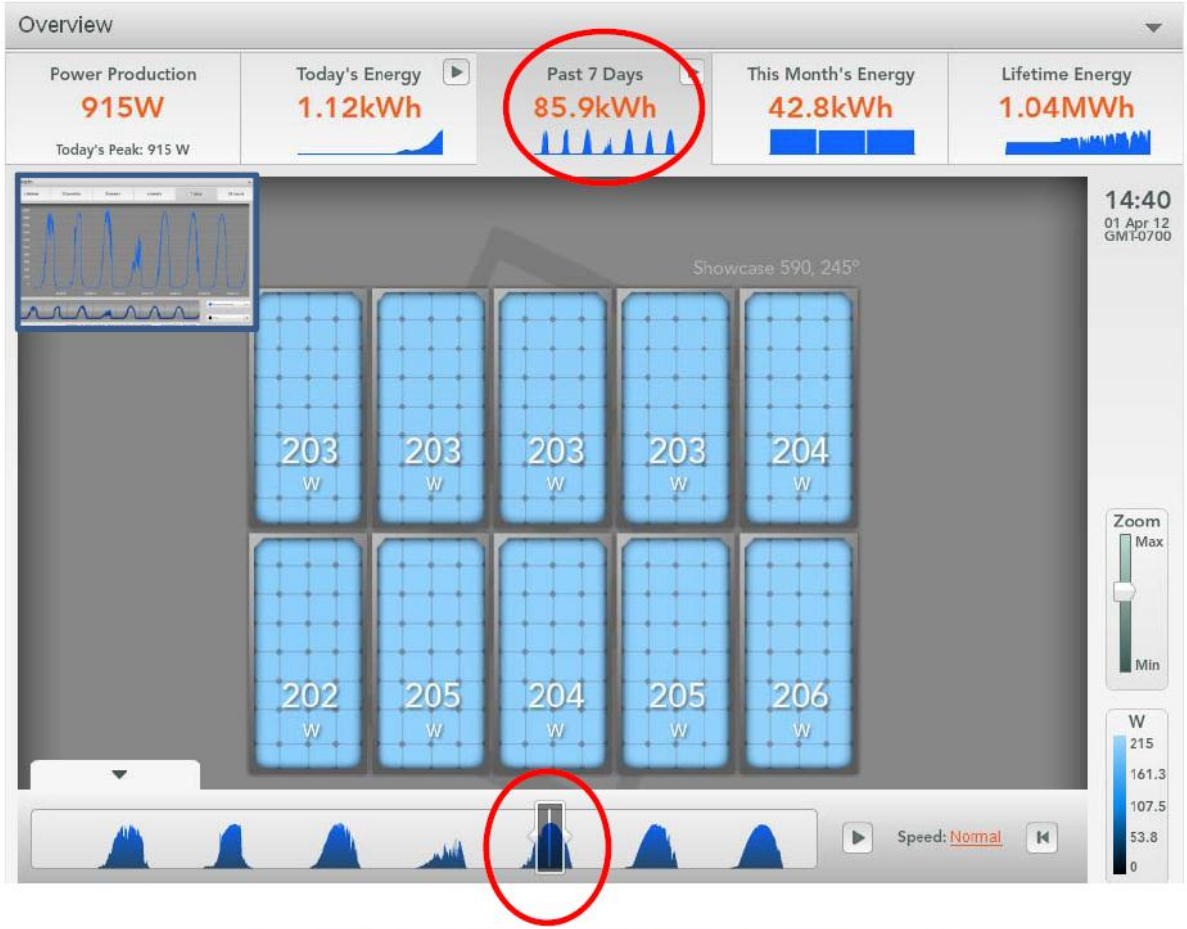
- Time-savings from simplified system design (less than 3.5 hr.)

CV Sustainable Energy Showcase Home:
Energy Savings (Modeling Pre- vs. Post- Retrofit)

- 30.5% WHES (w/out PV)
- 55.6% WHES (w/PV)



CV Sustainable Energy Showcase Home: PV Energy Production (Dec 2011-April 2012)



Based on actual system performance, DC-AC derate factor is 0.87

Annual projection for this 2.35kW system is 4472kWh

=1902kWh/kW

PV Watts = 1740kWr/kW

THIS REPRESENTS A 10% IMPROVEMENT

Thank You

Tori Doyle
vdoyle@consol.ws

Energy+Environmental Economics

UC Davis West Village Project: Integrating PV & EE

15 May 2012

ASES - Denver, Colorado

Michele Chait
Senior Consultant, E3

Overview of Project Goals

- **Determine roadmap for achieving zero net energy at 343 single-family homes at U.C. Davis's West Village, while achieving business objectives**
  - No higher cost to developer
  - No higher cost to owner
  - Integration of multiple renewable technologies
- **Describe potential pathways under future economic, regulatory & business scenarios**
  - Accommodating regulatory, cost, & technology changes over time
    - Best plan under existing regulations
    - Identification of high-value changes to existing regulations

Strategy for Implementing EE & PV

- **Include natural gas uses (vs. all-electric home)**
- **Implement as much EE as economically feasible**
- **Supply remaining usage with PV & Biogas**
- **Held "Design Charrette" to bring stakeholders together**
  - Shrunk window space
  - Revised truss and dropped ceiling - ducts and HVAC equipment moved from attic to conditioned space
  - First-pass elimination from consideration of measures that are not feasible

EE Measure Evaluation Methodology

- Evaluated each potential EEM versus cost of onsite renewables
- Utilized range of levelized costs for PV & biogas
  - Advanced Package A: $0.14 per kWh PV & $2.00 per therm biogas
  - Original EE Package: $0.21 per kWh PV & $2.20 per therm biogas
  - Advanced Package B: $0.30 per kWh PV & $2.40 per therm biogas
- Assumptions
  - EEMs financed through mortgage at 5.5%
  - At end of useful life, measures are replaced with identical measures at same cost
  - Lifecycle evaluation term of 25 yrs
  - Base Case Home: 1753 sq. ft., 3 bedroom
    - Scalars for mix of plan types: 1400-2500 sq ft
- 8760 home usage modeled with BEopt (DOE-2.2) based on predominant lot orientation (N/S)
  - Orientation variance in use up to 3.6%

DAVIS ENERGY GROUP INCORPORATED

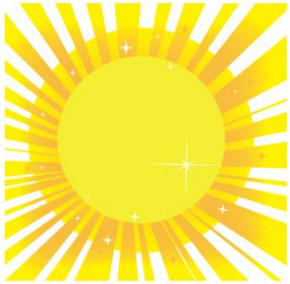
Package Savings versus Title 24

Package	Annual Electricity (kWh)	Annual Nat Gas (therms)	kWh Savings vs. T-24	Therm Savings vs. T-24	Net Cost vs. T-24
Title-24	6,734	721	-	-	-
Original	5,248	499	22%	31%	$ 5,395
Advanced – A	4,949	443	27%	39%	$ 5,052
Advanced - B	4,756	418	29%	42%	$ 10,080

- Results shown for base case home
- Advanced A package is most economic
- Net cost includes 15% developer carrying charge for EEMs

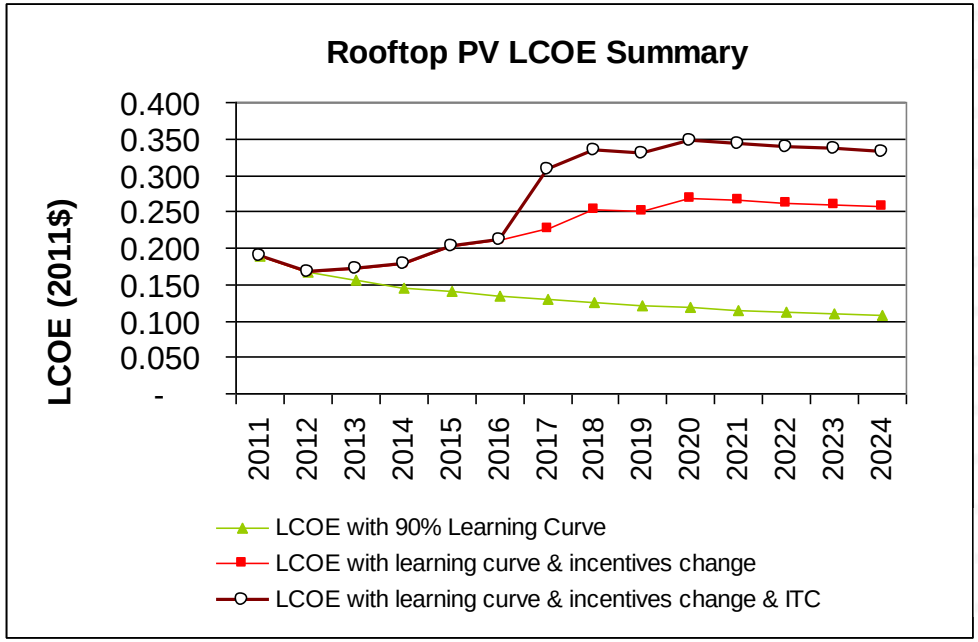
Measure Category	Original Package	Advanced A
Envelope		
Window Area - % of Conditioned Floor Area	26%	**22%**
Exterior Wall Construction	2x6 16"oc	**2x6 24"oc Advanced Framing**
Exterior Wall Insulation	R-21	
Foundation Type & Insulation	Slab on Grade - Uninsulated	
Floor Over Garage/Open	R-19 Batt	
Roofing Material & Color	CRRC Certified Roof, (0.28 Reflectance, 0.91 Emittance)	
Ceiling Insulation	R-49 Blown Cellulose	
Radiant Barrier	Yes	
House Infiltration - Blower Door Test (HERS)	SLA 1.8	
Thermal Bypass Inspection - QII (HERS)	Yes	
Windows & Patio Doors	Dual Non-Metal 0.32 / 0.23	
HVAC Equipment		
Heating Type & Efficiency	Gas Furnace / AFUE 92%	**Combined Hydronic**
AC Type & Efficiency	AC / SEER 15, EER 12.5	
Duct Location & Insulation	Conditioned Space, R-6	
Duct Leakage Verification (HERS)	Yes, <6% of system airflow	
Verify Refrigerant Charge Credit (HERS)	Yes	
Verify High EER (HERS)	Yes, 12.5	
Verify Cooling Coil Air Flow (HERS)	No	**Yes**
Verify Fan Watt Draw (HERS)	No	**Yes**
Verify Cooling Right Sizing (HERS)	No	
Mechanical Ventilation	ENERGY STAR exhaust - ASHRAE 62.2	
Water Heating Equipment		
Water Heater Type & Efficiency	Gas Tankless, EF 0.82	**Condensing Tankless, EF 0.96**
Tank Capacity/Gallons	0	
HW Distribution	PEX Piping, Engineered Design, Kitchen Pipes Insulated	
Appliances, Lighting & MELs		
Appliances	ENERGY STAR Dishwasher	**ENERGY STAR Dishwasher, Fridge & Clothes Washer**
Dryer, Oven Fuel	Gas	
Fluorescent Lighting Package	100% w/ Controls & Ceiling Fans	
MEL Controls	None	

Best Business Model: Rooftop PV + NEM



- **PV system installed on roof of each single-family home**
- **NSHP $2.35 per watt incentive**
- **PV sized to achieve first year annual home usage**
  - Assumed no changes in home-owner usage over time
  - Incorporated annual degradation of PV output
- **Usage/Generation uncertainty:**
  - Generation shortfall procured at PG&E retail rate + REC ($0.05 / kWh) (total of ~ $0.19 per kWh)
  - Net surplus compensation = approx. $0.04 / kWh

Rooftop PV LCOE Over Time with 90% Progress Ratio



- **Brown line shows final LCOE trajectory after taking into consideration learning curve (progress ratio), changes in state incentive levels, and ITC stepdown from 30% to 10%**
  - Assumes rooftop systems financed with third-party PPA
- **Construction Scenarios: 30, 60, or 100 homes per year**
  - Construction rate drives installed cost of rooftop PV

Summary of Analysis

Construction (Homes per Year)	Learning Curve	Levelized Annual ($ per home)	Overall NPV ($MM)
30	75% 90%	196 -65	0.9 <0.3>
60	75% 90%	349 -19	1.8 <0.1>
90	75% 90%	467 112	2.5 0.6

- **Zero Net Energy homes are possible with little to no incremental cost, given current state of incentives and smart development**
  - **Negative value indicates ZNE homes more expensive than Title 24 home**
- **Home construction rate drives results**
- **No electric vehicles assumed**

What if we add electric vehicles?

Homes per Year	Learning Curve	Annual ($ per home)	Overall NPV ($MM)
30	75% 90%	457 217	2.1 1.0
60	75% 90%	660 252	3.4 1.3
90	75% 90%	785 336	4.2 1.8

- **NPVs increase because gasoline is more expensive than electricity from PV, more than offsetting the higher purchase price of the EV**
- **There are many potential future EV scenarios**
  - This scenario reflects medium penetration, controlled charging pattern, 35% "soccer mom" / 65% commuter usage
- **Assumes PV systems sized to cover EV usage**

Storage: Uses Evaluated & Results

- **Modeled two Advanced Electrical Storage (AES) potential uses:**
  - Arbitrage time-of-use retail rates
  - Backup power during grid emergencies or interruptions
- **Other AES uses do not benefit households directly (PG&E value)**
  - Community-level load following resource
  - Smooth intermittent resource output
  - improve grid reliability
- **Arbitrage of retail rates + backup power**
  - Modeled charge during off-peak and discharge on-peak
    - Need to assume PG&E TOU rate schedule
  - Backup power attributes residential outage value
- **Storage not currently economic for these two uses, hence storage not assumed implemented at West Village**

Continual Reinforcement of Energy Efficiency Goals

- **Need to provide regular feedback to occupants**
  - In-house displays – real-time energy use feedback
  - Provide tools to control "leaking" energy use
- **Limit owner-provided energy hogs**
  - Appliances, Electronics, Lighting
- **Ways to engage the community**
  - Education – seminars, workshops (engage university community)
  - Community events, contests
  - Additional fees for excessive use
  - Continued / ongoing community feedback
  - Lab House (technology showcase, test bed, student research)
  - Car share program

Conclusions

- **ZNE is possible with little to no incremental cost to home owners, given current state of incentives and smart development**
- **Economics enhanced through**
  - Work with developer & architect to optimize home design
  - Implementation of as much EE as economically feasible
    - Take advantage of incentives for high levels of EE
  - Natural gas end uses, supplied with biogas via offsets
- **Community-scale generation (~1MW+) is lower cost but challenging to implement given current regulatory rules.**
- **Under current regulatory rules, individual rooftop PV systems are more economic.**

Thank you!

- **Energy and Environmental Economics, Inc. (E3) has provided analytic and regulatory support on key issues facing electricity sector clients since its founding in 1989.**
- **E3 is uniquely positioned at the nexus of technical innovation, transmission, market, and regulatory arenas.**
- **Michele Chait – Senior Consultant**
  - 15+ years in energy industry
  - Leads valuation, regulatory finance, project finance, contract structuring, utility cost of service, and tax.

DISCUSSION

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CSI RD&D Program	Smita Gupta (Itron)	Smita.gupta@itron.com
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BEopt-CA (Ex)- A Tool for Optimal Integration of EE/DR/ES+PV in Existing California Homes	Craig Christensen (NREL)	Craig.Christensen@nrel.gov
Low-Cost, Smart-Grid Ready Solar Re-Roof	Victoria Doyle (ConSol) Rob Hammon (ConSol)	vdoyle@ConSol.ws rob@consol.ws
UC Davis West Village Project: Integrating PV & EE	Michele Chait (E3) Mary Hayakawa (UC Davis)	michele@ethree.com mghayakawa@ucdavis.edu

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