System Integration Research Leading to Zero Energy Homes

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NREL Residential Research Team Leader

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Residential Best Practices:
Integrating Building Science with Above Code Programs
2006 National Workshop on State Building Energy Codes

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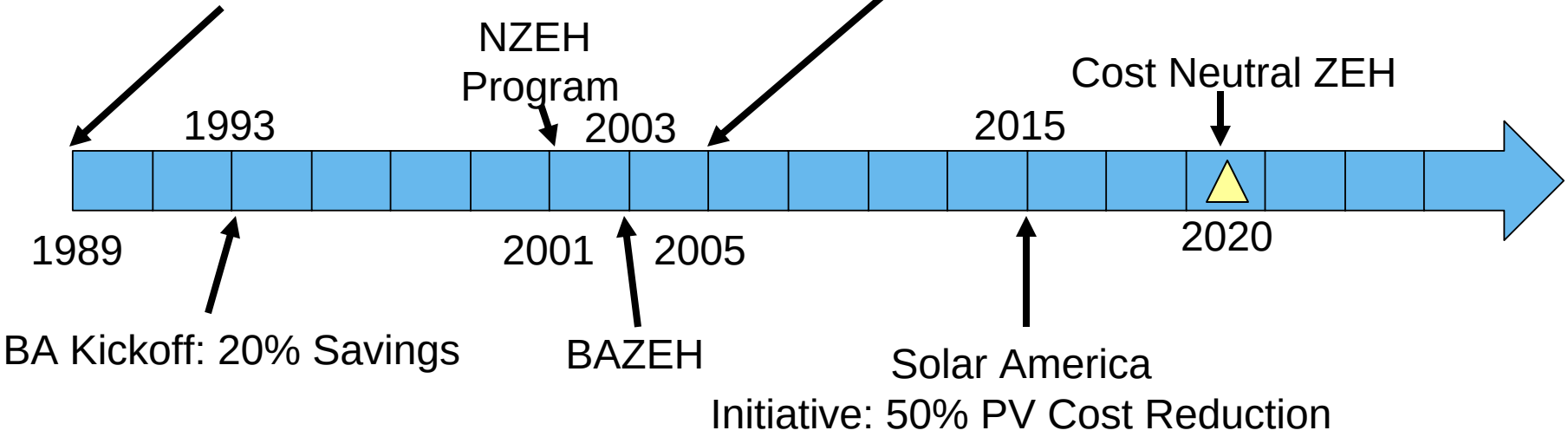
Long Term Goal: Homes that Produce as Much Energy as they Use on an Annual Basis.

Brief History of BA Residential Innovation

GE Living Environments

Denver Habitat ZEH

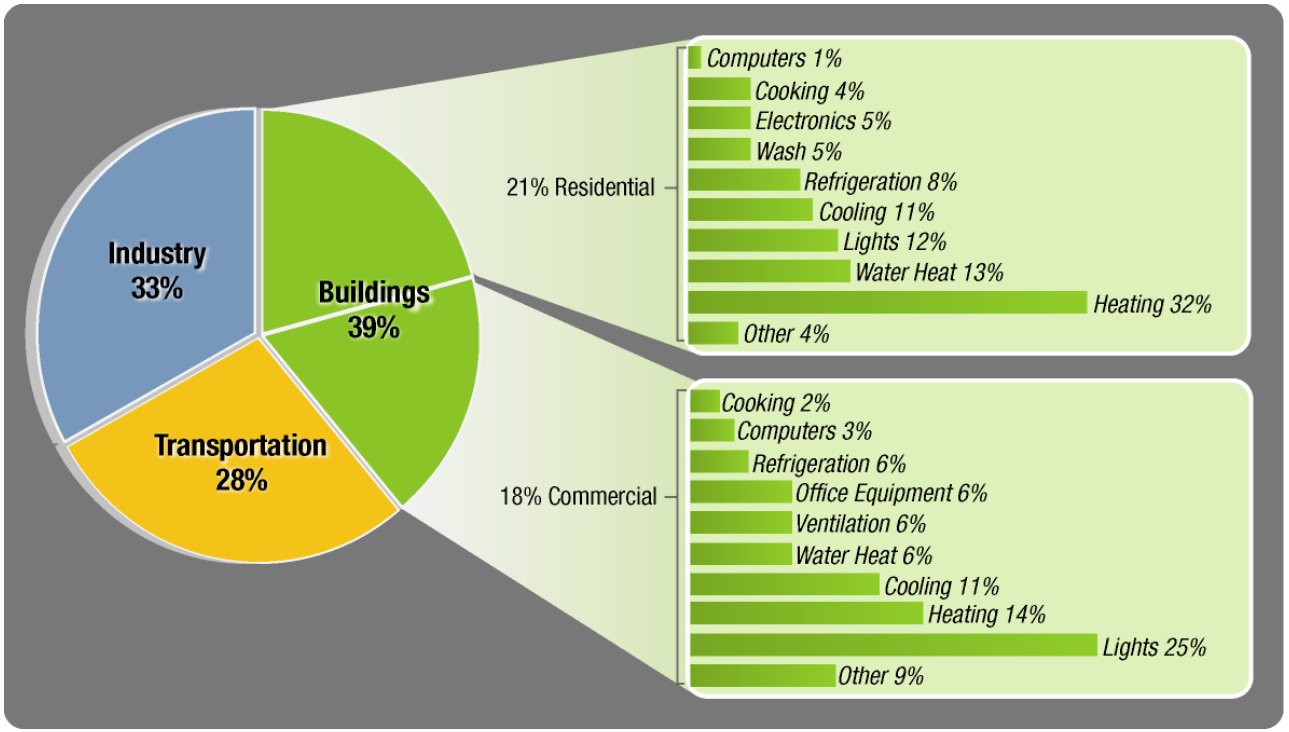


Over 30,000 BA Homes Completed

Why Are We Interested in Low Energy Homes?

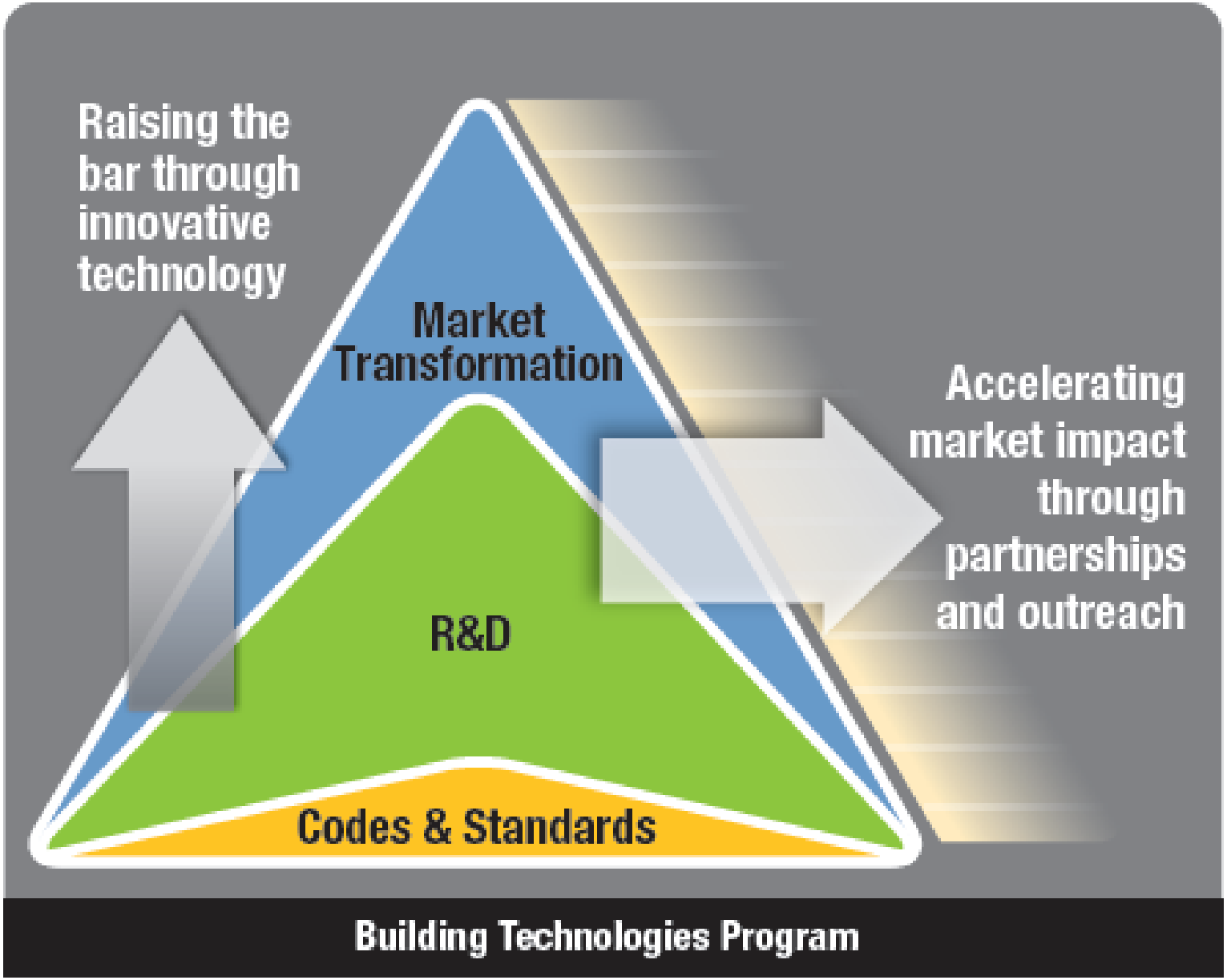
Buildings consume 39% of total U.S. energy

- **71% of electricity**
- **53% of natural gas (primary consumption)**



Development of <u>cost neutral</u> Zero Energy Homes (ZEH) is a critical part of ongoing DOE efforts to increase the efficiency of US energy use.

Building America is a Voluntary Program!



Key System Integration Questions to be Answered:

- What combinations of energy saving features provide customers with the most bang for the buck?
- What is the least cost required to achieve different levels of energy savings?
- What are the estimated costs to achieve different levels of energy savings?
- What R&D is required to reach future goals?

Market Accelerators for Above Code Programs: Builders Tend to Embrace Changes That

- Reduce risks,
- Reduce costs,
- Reduce complaints,
- Reduce training requirements
- Increase the reliability of suppliers, materials and equipment, and
- Reduce planning steps or approvals

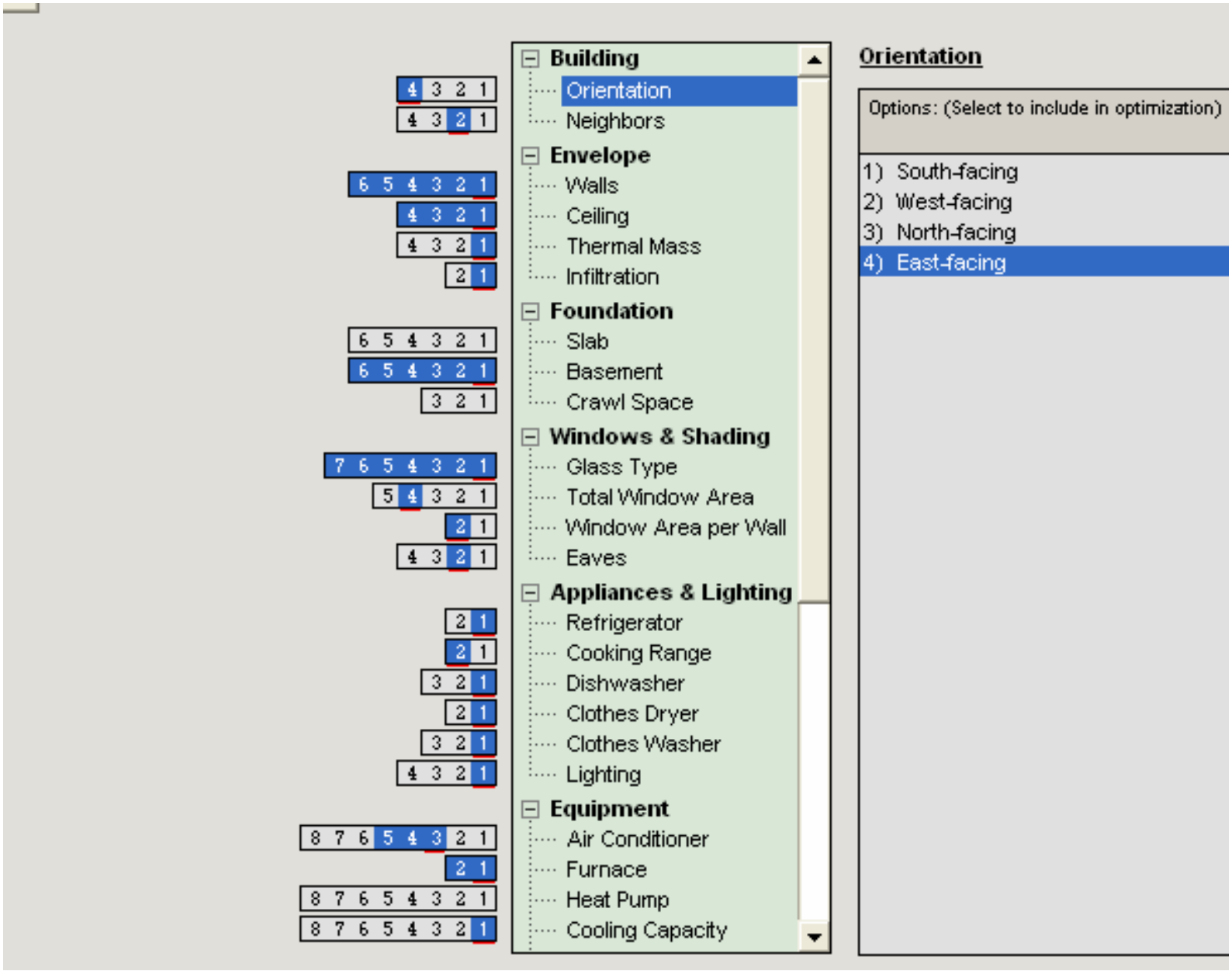
Discrete Optimization Techniques Offer An Approach to Answer These Questions :

Researchers at NREL have implemented an optimized discrete optimization technique (BEOpt) using hourly energy simulations to facilitate the innovation process.

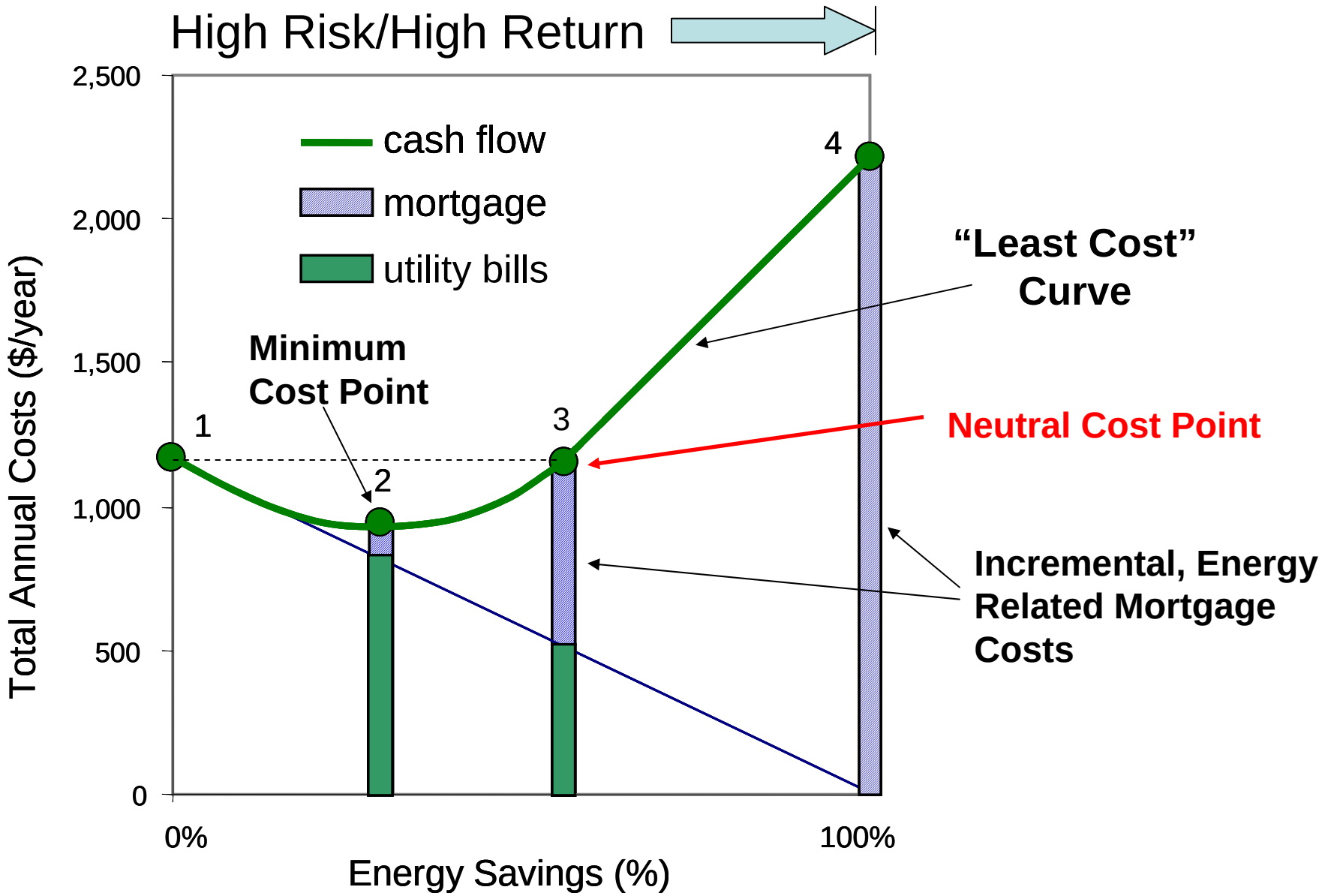
BEOpt Analysis Approach

- Uses a Consistent Framework for Evaluation of Incremental Costs and Benefits for Energy Efficient Homes
- Considers Specific Residential Energy Saving Options
- Defines the Least Cost Curve
- Retains Information on Near Optimal Solutions

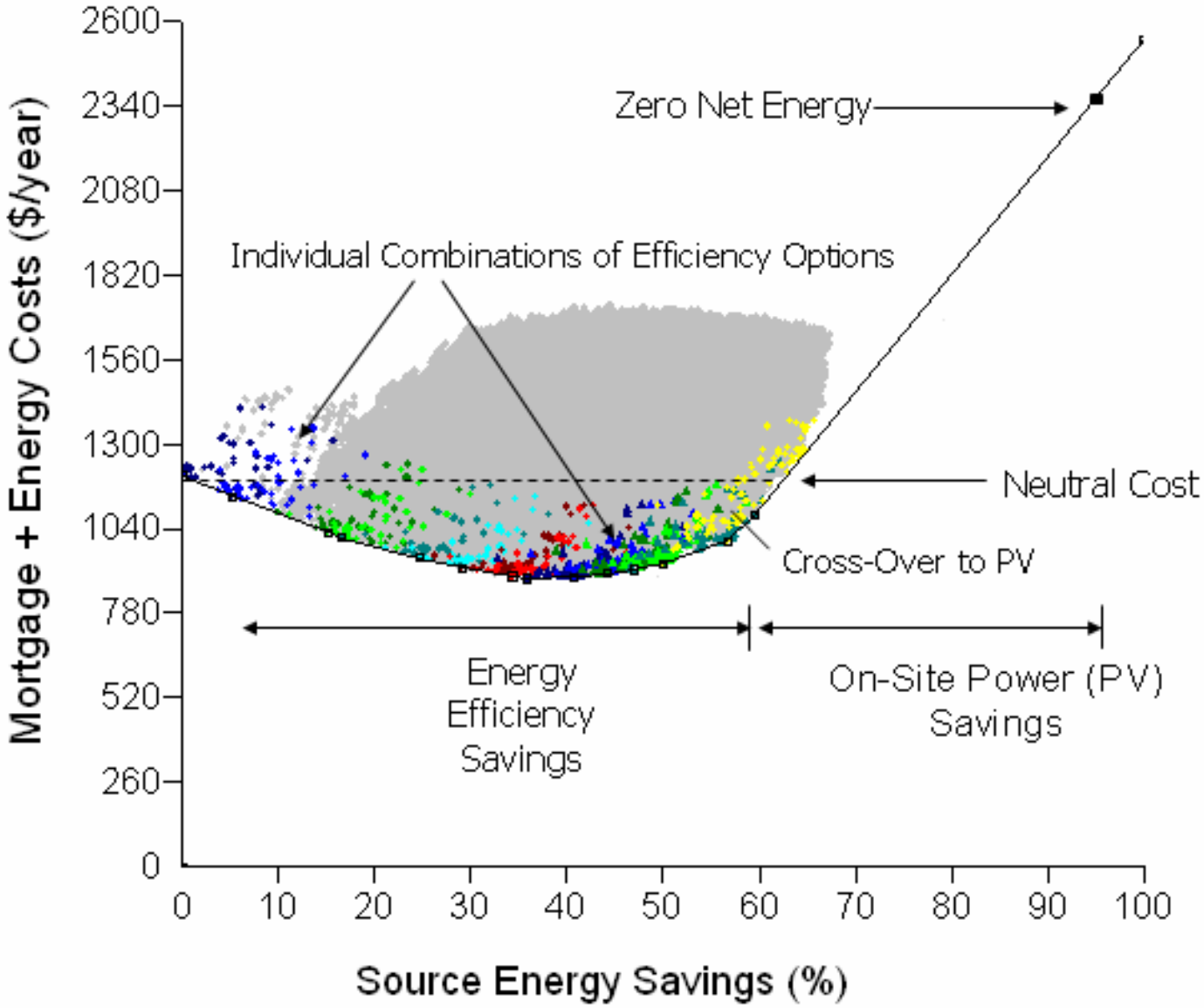
Discrete Energy Savings Options



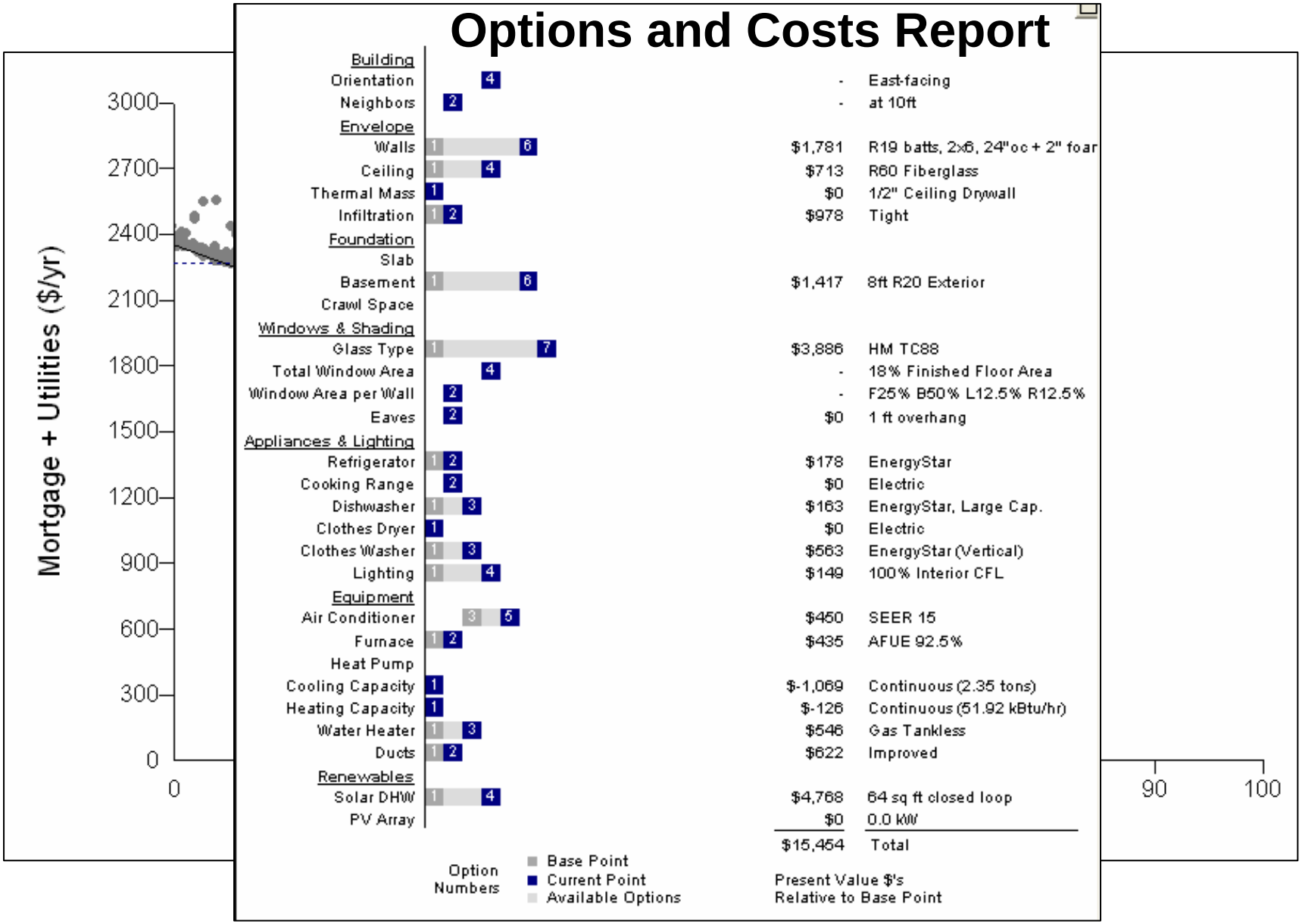
Overview of Key BEopt Results



Example Results: Costs and Energy Savings of All Possible Combinations of Options



Determining Incremental Costs and Benefits for Energy Efficient Homes



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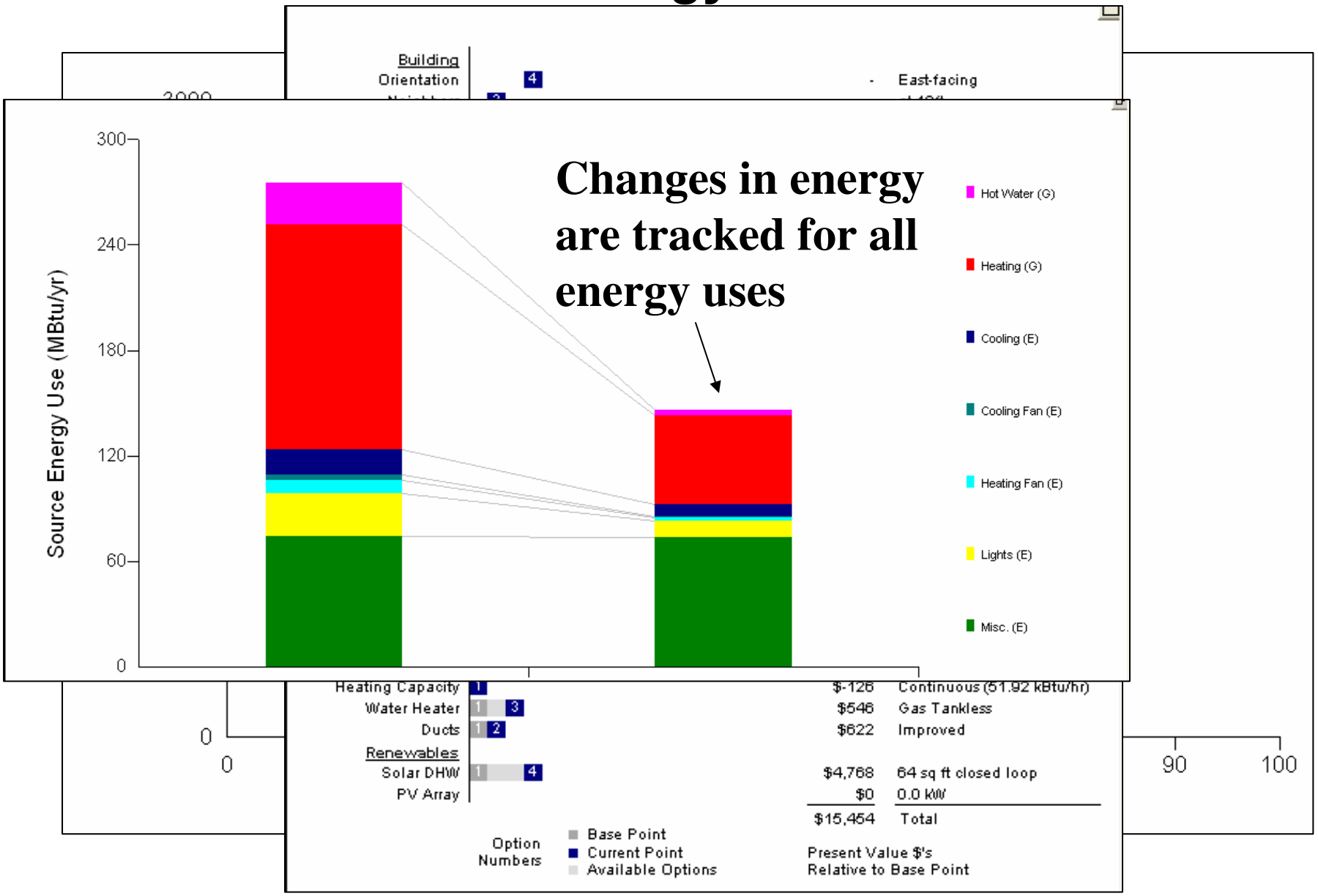

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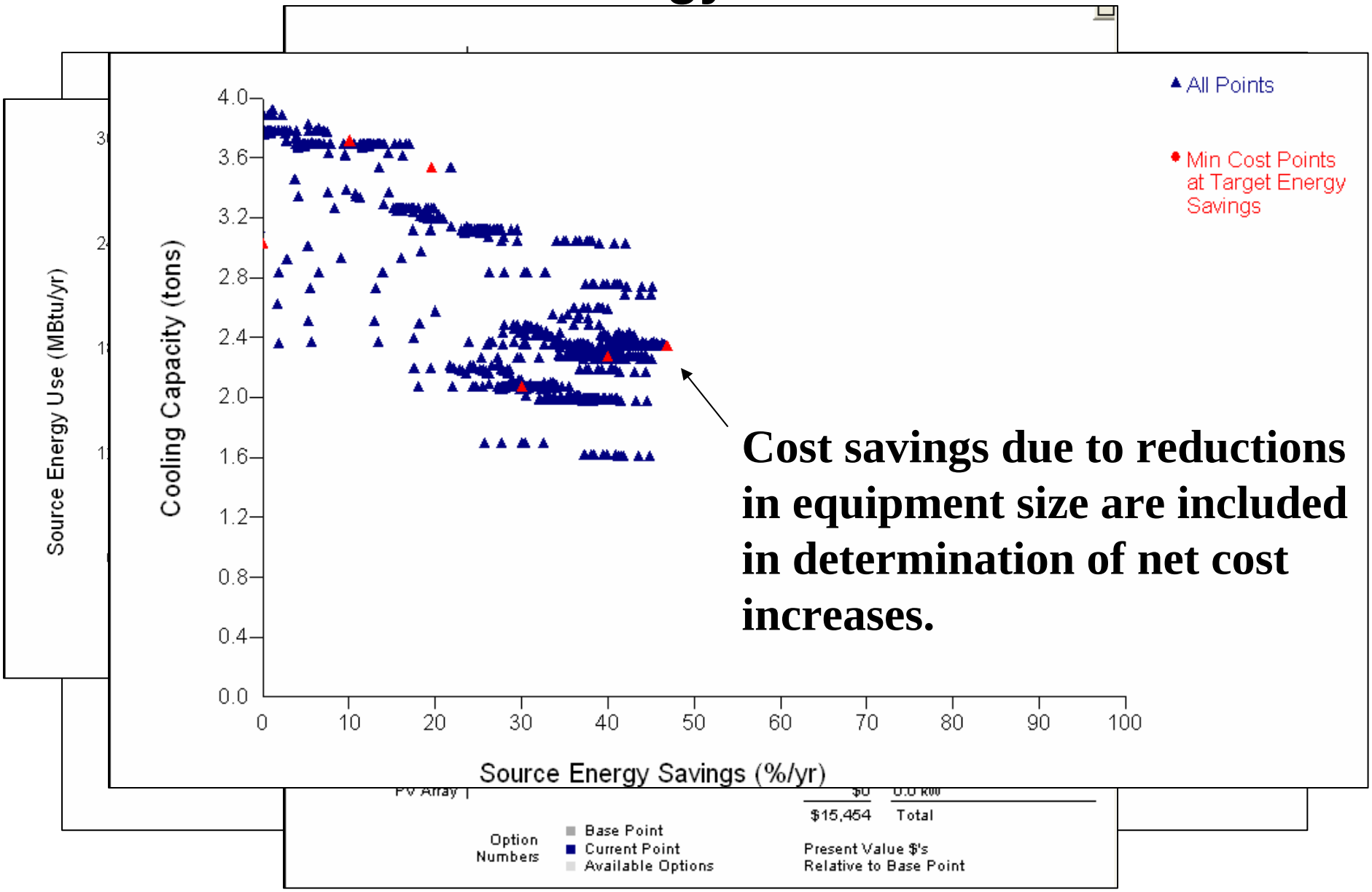
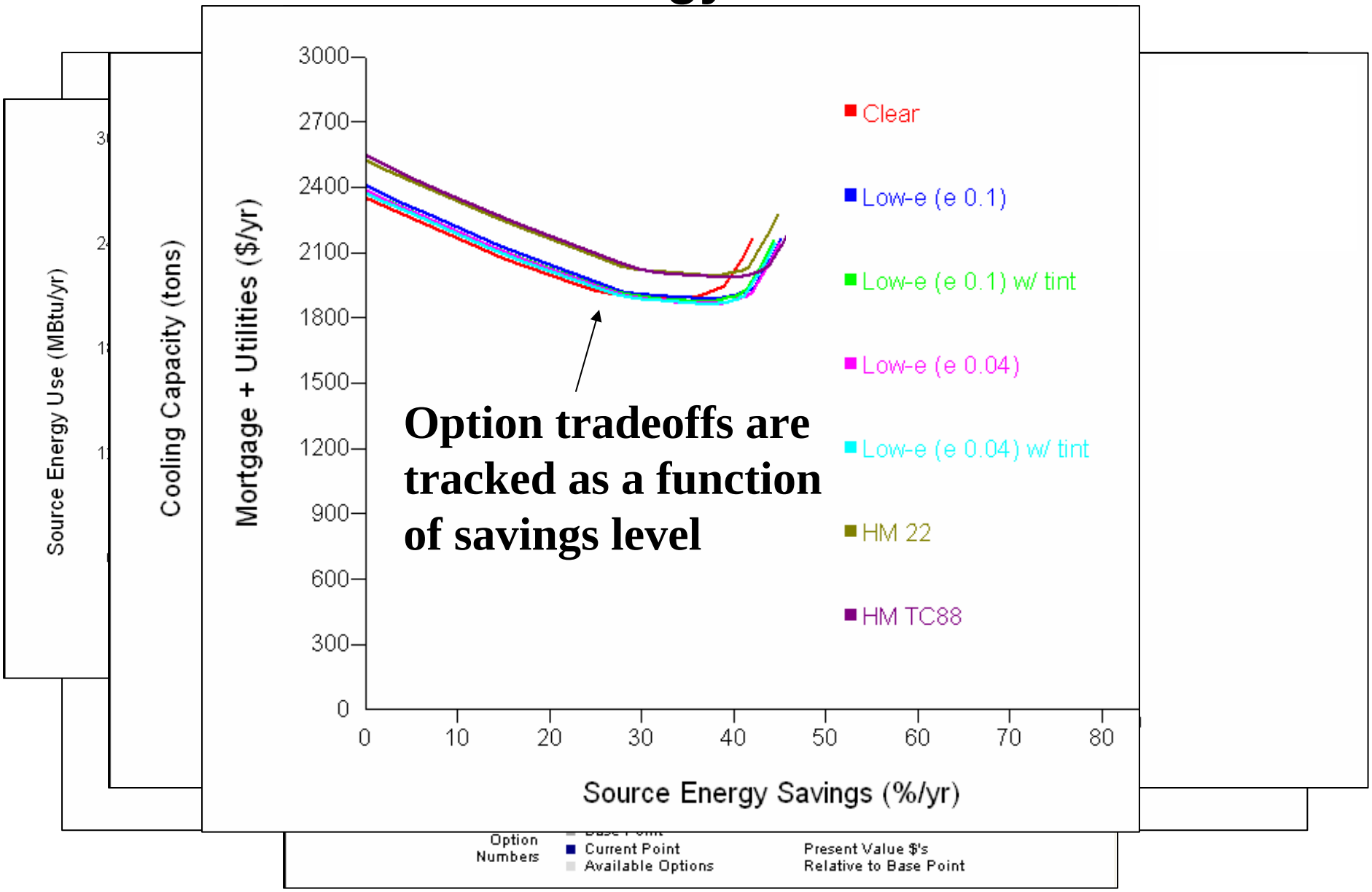
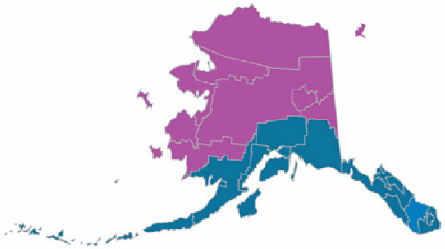


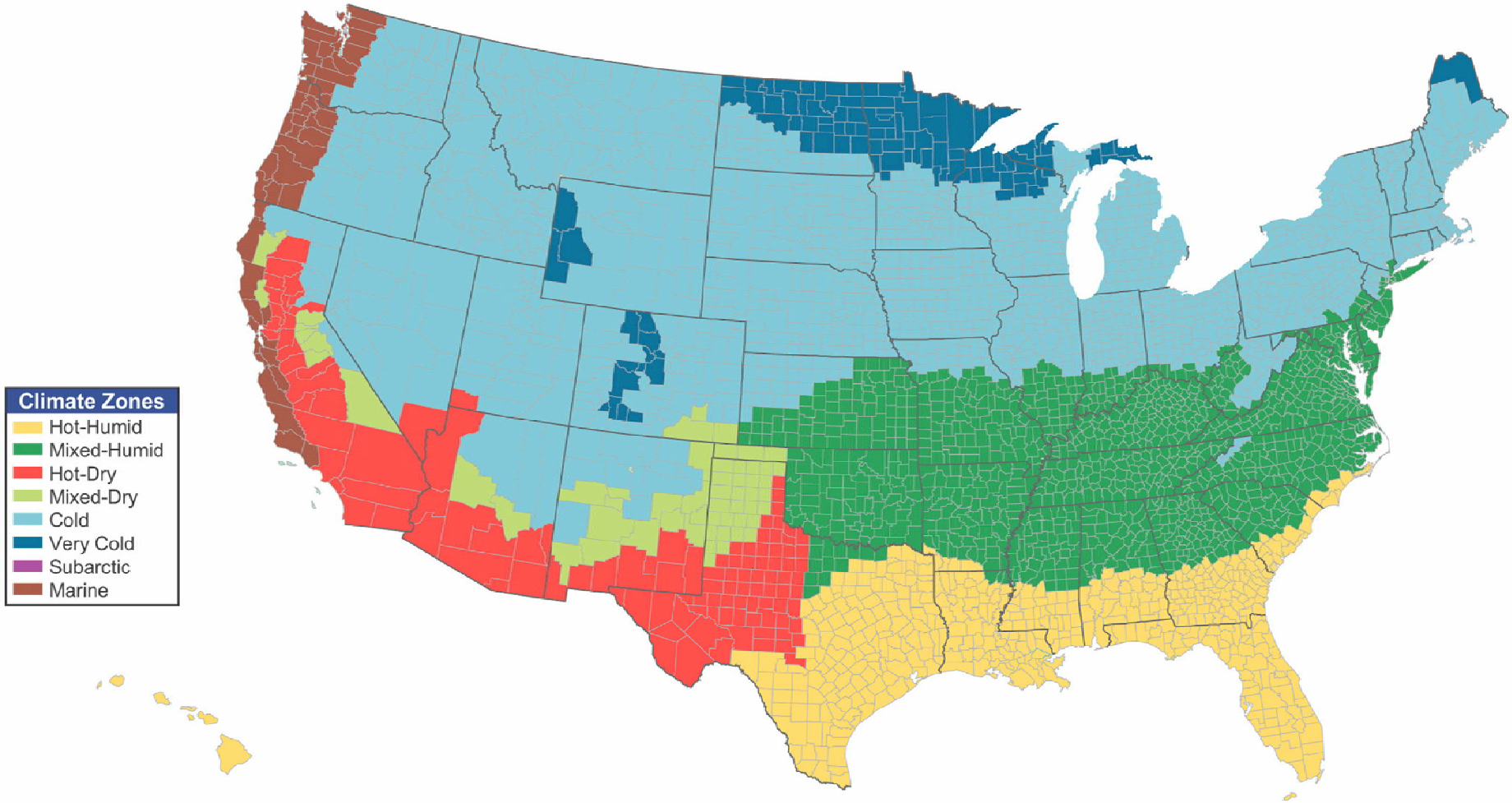
Cost savings due to reductions in equipment size are included in determination of net cost increases.

Determining Incremental Costs and Benefits for Energy Efficient Homes

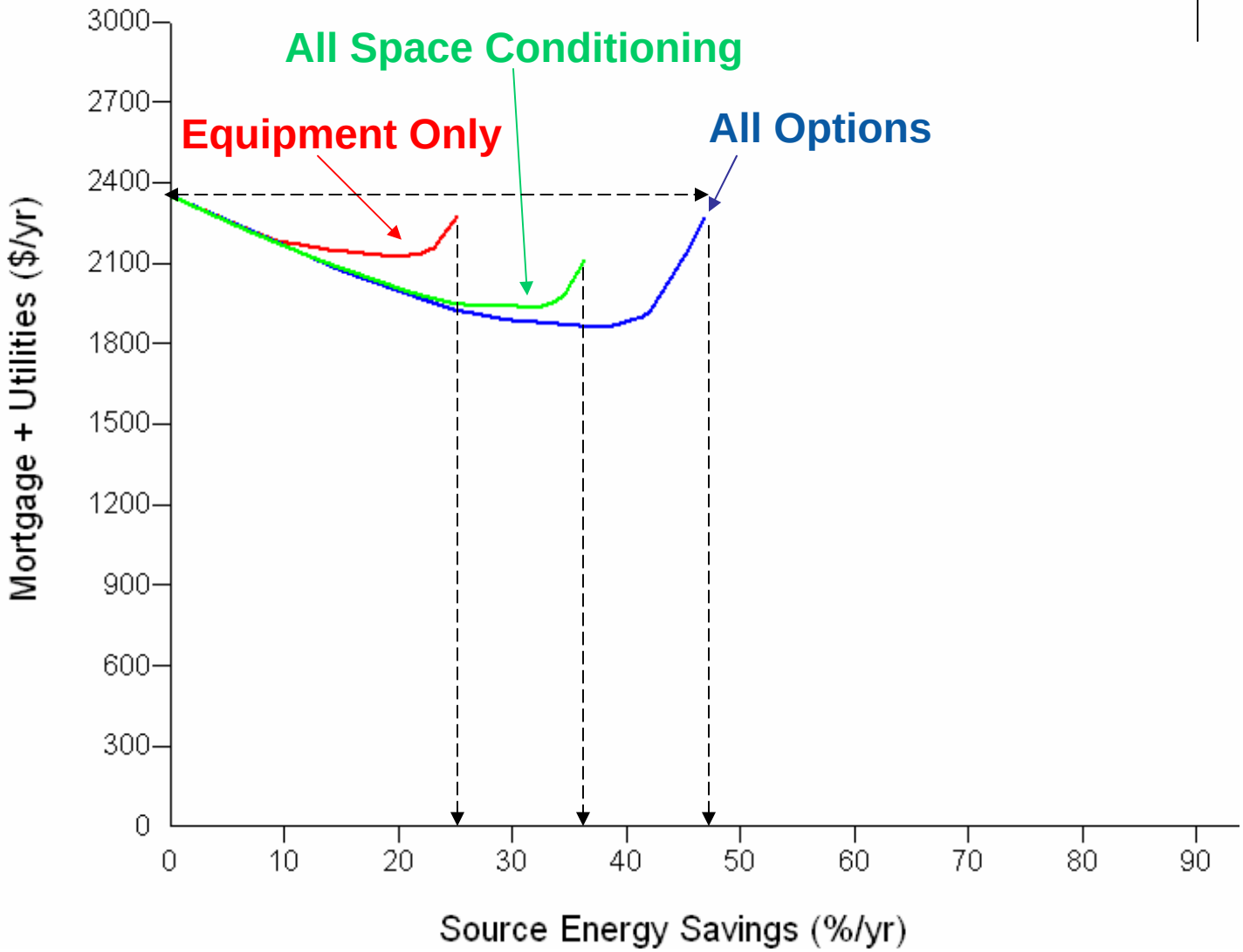


Research Focus:
Major US Climate Regions

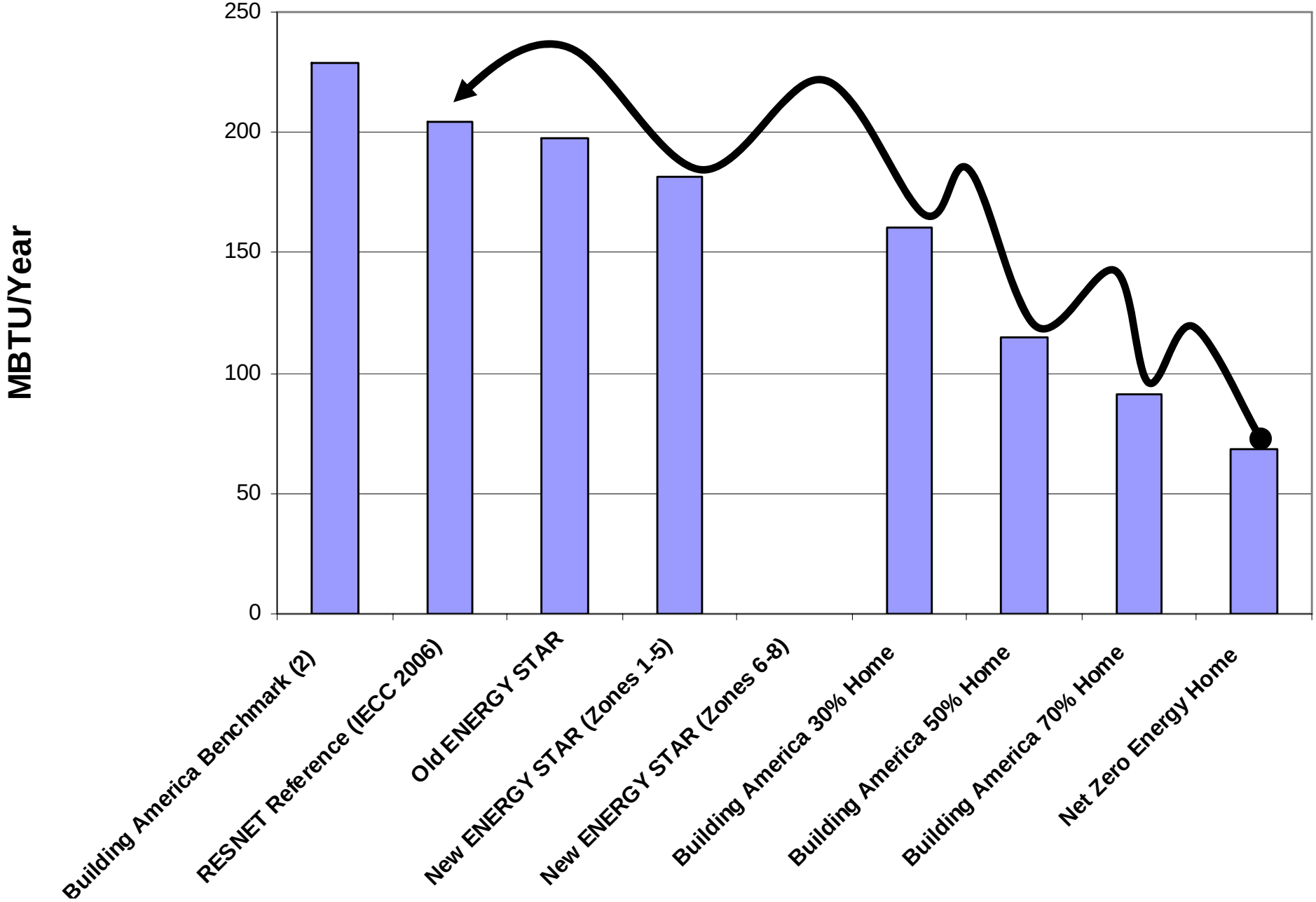




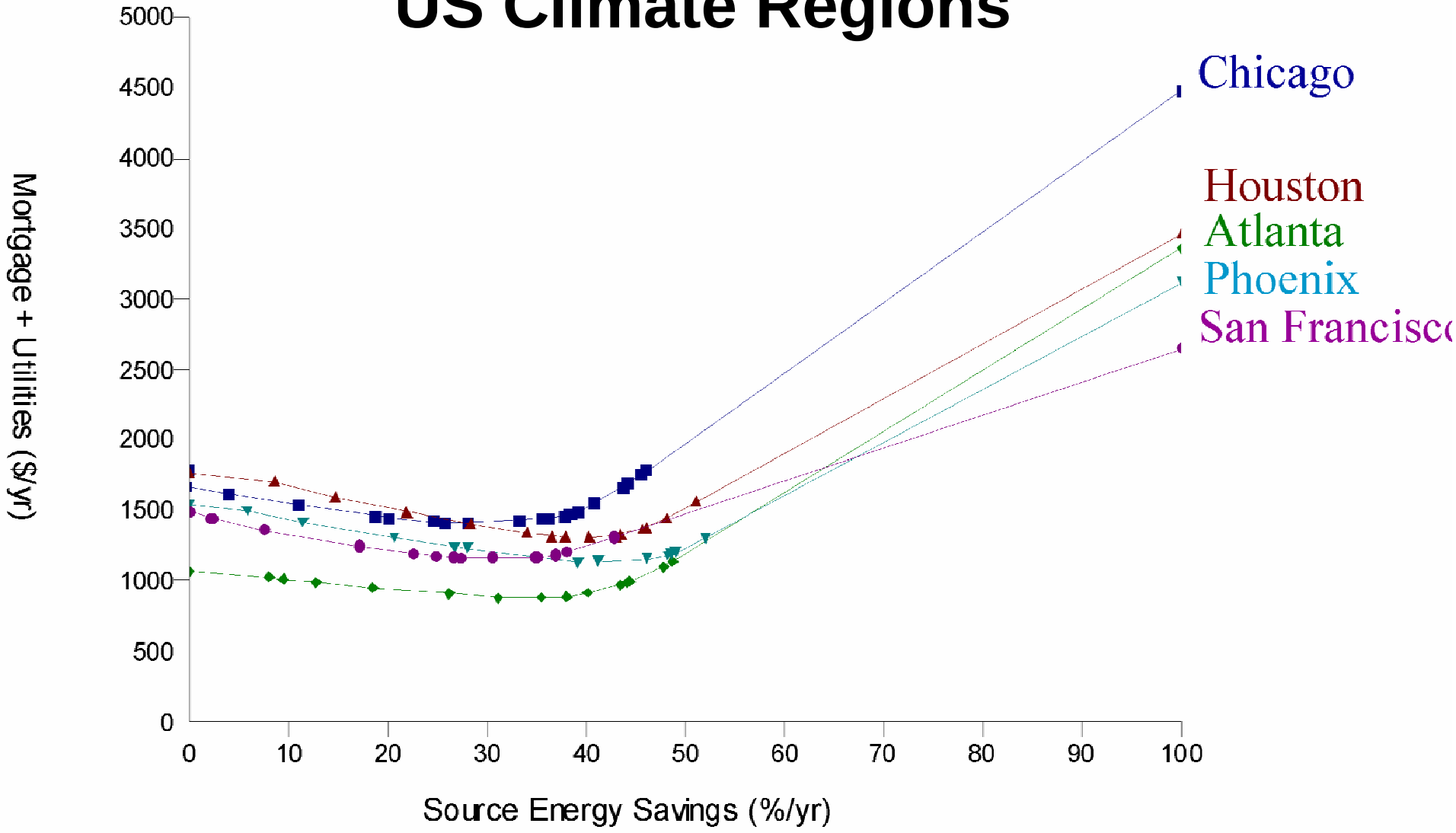
Key Point:
Whole Building Approaches Provide the Largest and the Most Cost Effective Energy Savings



Relative Efficiency (Orlando Source Energy Without PV)



Least Cost Curves for Five Major US Climate Regions



1800 ft2 House

Investment Required to Achieve Minimum Cost

Location	% Whole House Energy Savings at Minimum in Least-Cost Curve	Corresponding Present Value of Investment in New Home Energy Efficiency
Atlanta	32%	$1749
Chicago	28%	$3899
Houston	38%	$2585
Phoenix	39%	$2585
San Francisco	27%	$1337

PV Capacity Required to Reach ZNE

Location	Crossover Point	PV Capacity Required to Achieve ZNE (kW)
Atlanta	49%	5.6
Chicago	46%	7.6
Houston	51%	6.2
Phoenix	52%	5.4
San Francisco	43%	4.8

1800 ft2 house with net metering agreement at wholesale electric cost, $7.50/W PV.

Key Conclusions

•Modest investments ($2-4k) can reduce energy use by about 30% relative to the BA Research Benchmark

•$8-15k in efficiency investments are required before the marginal cost of saved energy is equivalent to the cost of energy from site PV (@ $7.50/W)

•Cost neutral savings of 40-50% can be achieved in the near term, <u>assuming resolution of technical and market barriers to integration</u>

Additional ZEH Benefits: Reduced Peak Loads

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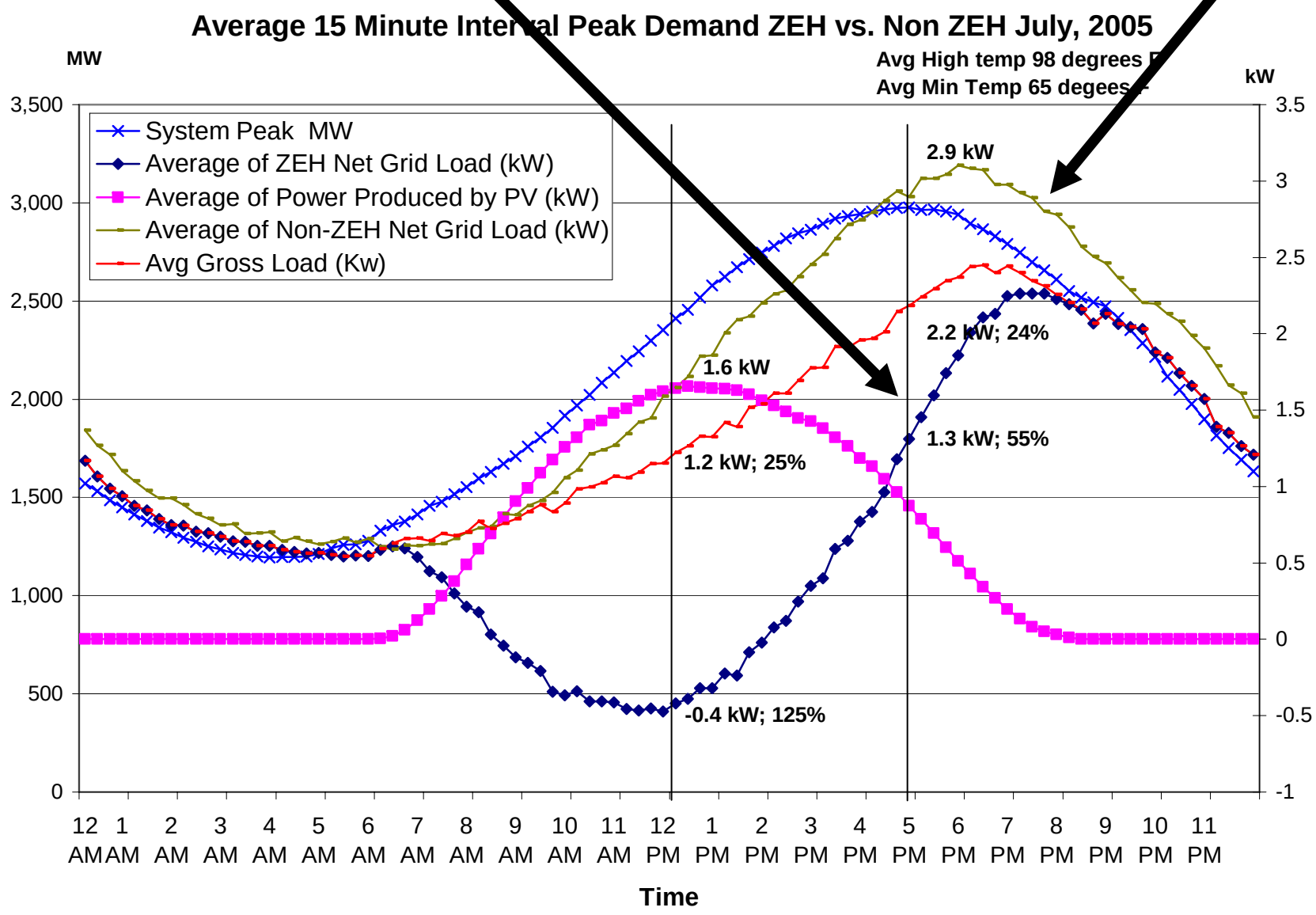
Premier Gardens

SMUD Premier Gardens ZEH Homes

SMUD Comparable New Homes



Questions?

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Economic Assumptions

- 30 year analysis period
- 3% inflation rate
- 5% discount rate (nominal)
- 7% interest rate (nominal)
- $7.50/watt PV (installed cost)
- $1/Therm natural gas
- State average electric costs (EIA 2005)
- National average efficiency costs