Net Zero Building Design, Construction, Operation and Costs

USACE FY 2012 Sustainability & Energy Webinars

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US Army Corps of Engineers®

ERDC

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and

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BuildEquinox.com

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Equinox House

Equinox House (located in Urbana Illinois):
-has a healthy, comfortable indoor environment
-is a 100% solar powered net zero residence
-harvests rainwater for domestic water needs
-is an economical, simple-to-live-in house

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Newell Background

-Renewable Energy
-Energy Conservation
-Energy Efficiency
-Resource Conservation

Grad school 1970's

Univ of Illinois Solar Lab 1980's

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2007 Univ of Illinois Solar Decathlon Team

Now, located at the Chicago Center for Green Technology

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Does a High Performance House have to Look Weird?

Note: Equinox House architectural design by **Jean Ascoli** (AIA, NCARB, LEED AP); formerly of Taliesin Associated Architects

No! Two story home design, same performance

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What About Cost?

Installed cost for solar energy to power 100% of Equinox House energy requirements = **$3 per day**
(our neighbors average more than twice that with "cheap" utility energy)

Extra insulation cost (~ $20k), offset by building smarter:
-no natural gas supply = $10k savings
-no air stratification = no ceiling fans = $2k to $5k savings
-efficient utility runs = $5k savings

~$100,000 less over 100 years in Life Cycle Cost than "modern" constructed home

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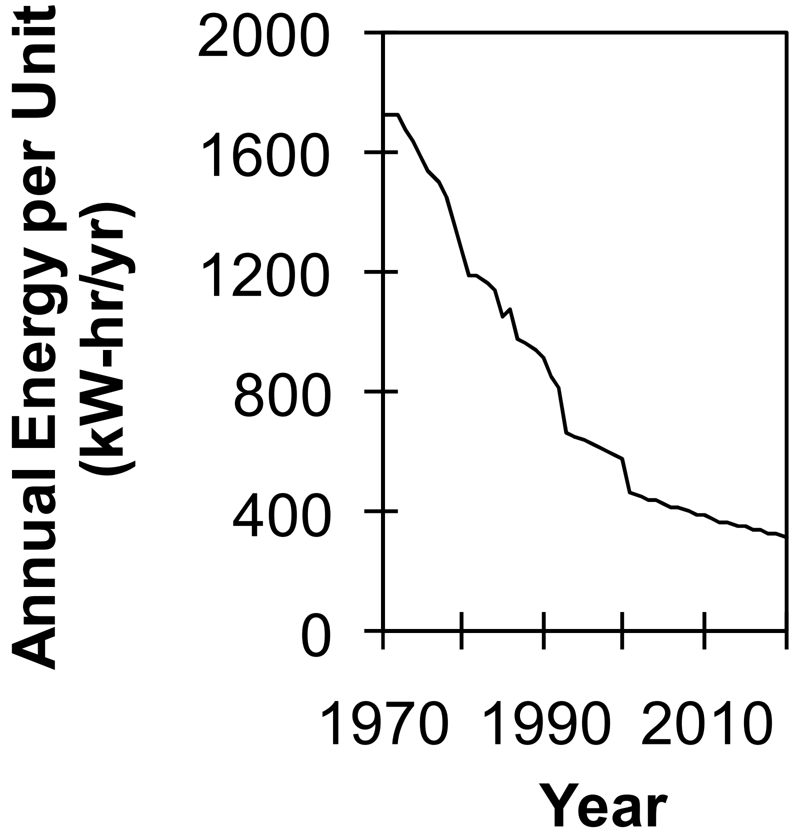
Refrigerator Analogy



A success story in energy efficiency improvement

•Approximately $2000/yr of refrigerated food per household member

•1% less food loss for family of 4 =$80/yr….twice refrig energy $

•What is the cost of an energy efficient house that makes you sick?

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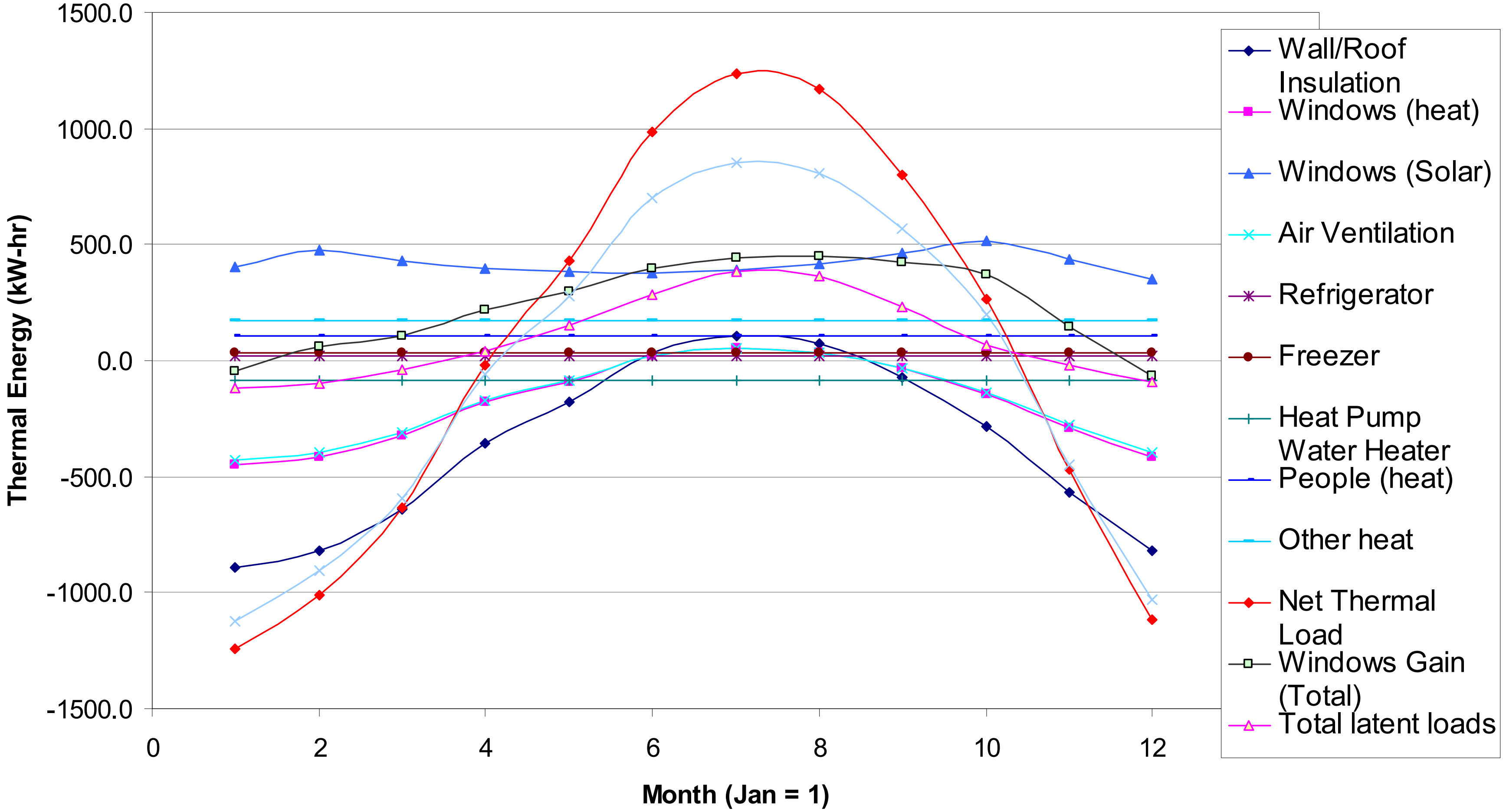
Residential Energy Interactions



More complex than commercial buildings

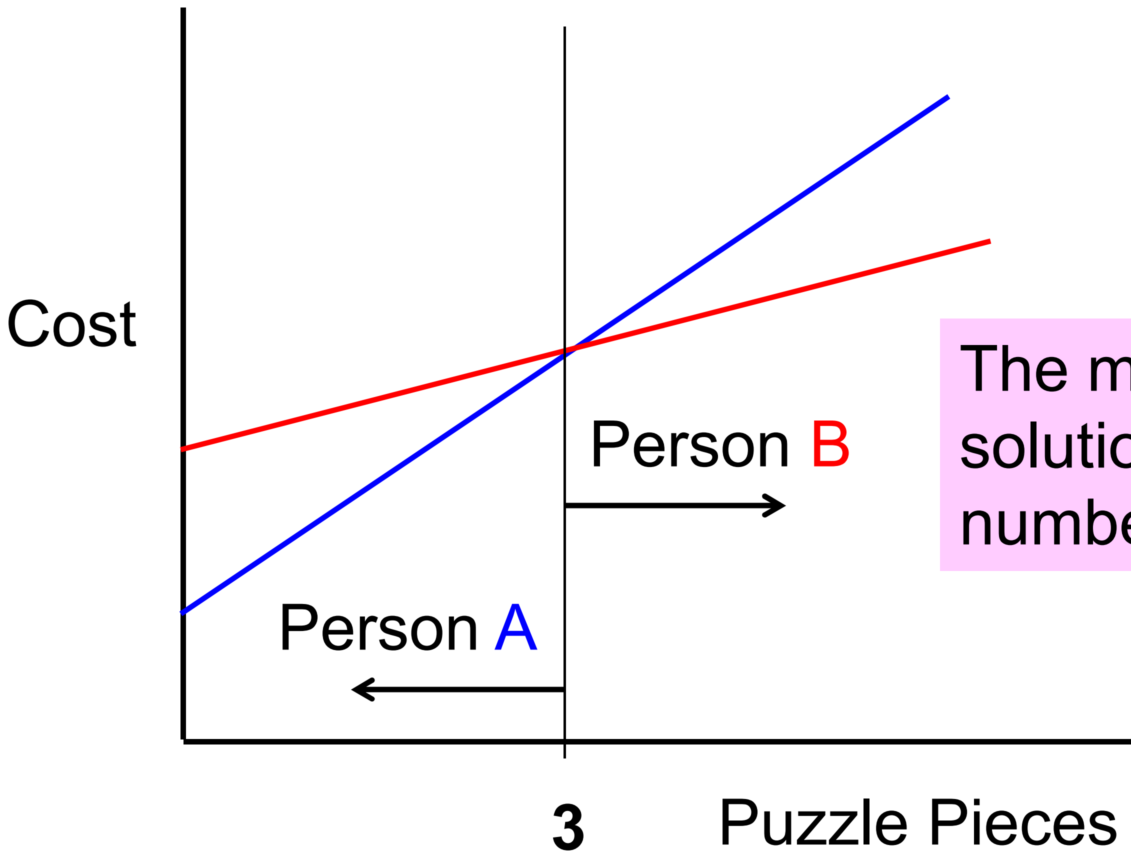
Goal

Design a Cost-Effective, Healthy, Comfortable Home

- Cost effective = optimal, minimal cost home
- Healthy = keeps air fresh (CO_2, VOC and radon control)
- Comfortable = occupant preferred indoor conditions
- Sustainable = a view toward future generations

How do we find solutions that optimize health, comfort, sustainability and cost?

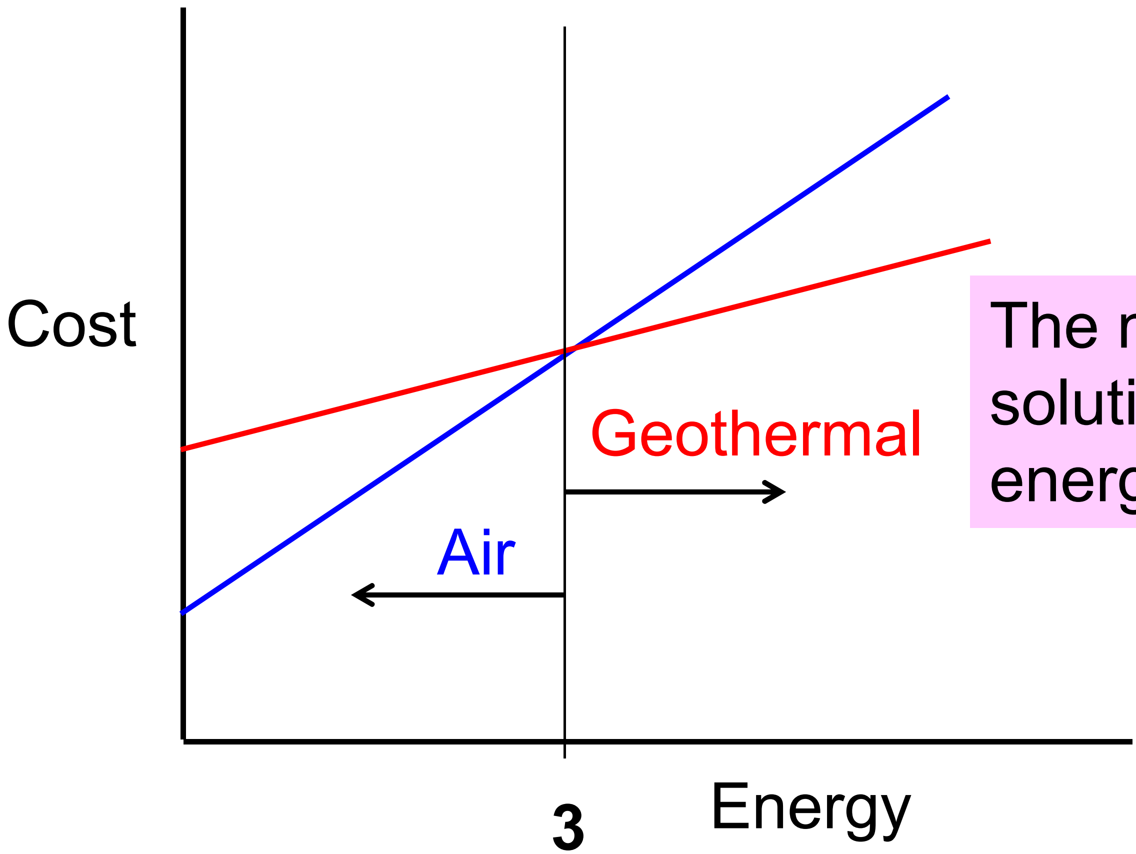
Puzzle – Optimal Solution



The most economical solution depends on the number of puzzle pieces

Person A = $1 up front and $2 per puzzle piece
Person B = $4 up front and $1 per puzzle piece

House Conditioning

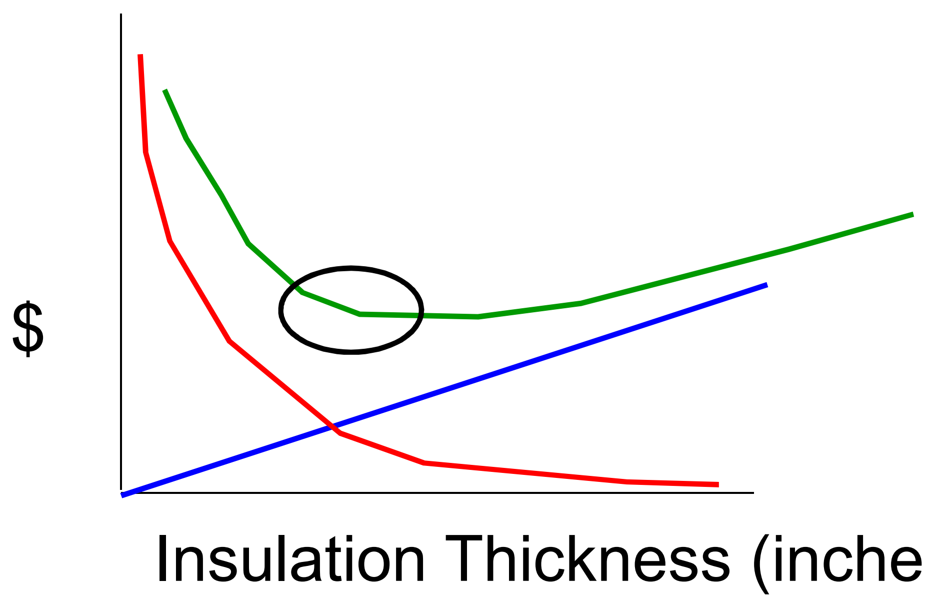


The most economical solution depends on the energy required

Air Heat Pump = $1 up front and $2 per energy unit
Geothermal Heat Pump = $4 up front and $1 per energy unit

Optimal Insulation

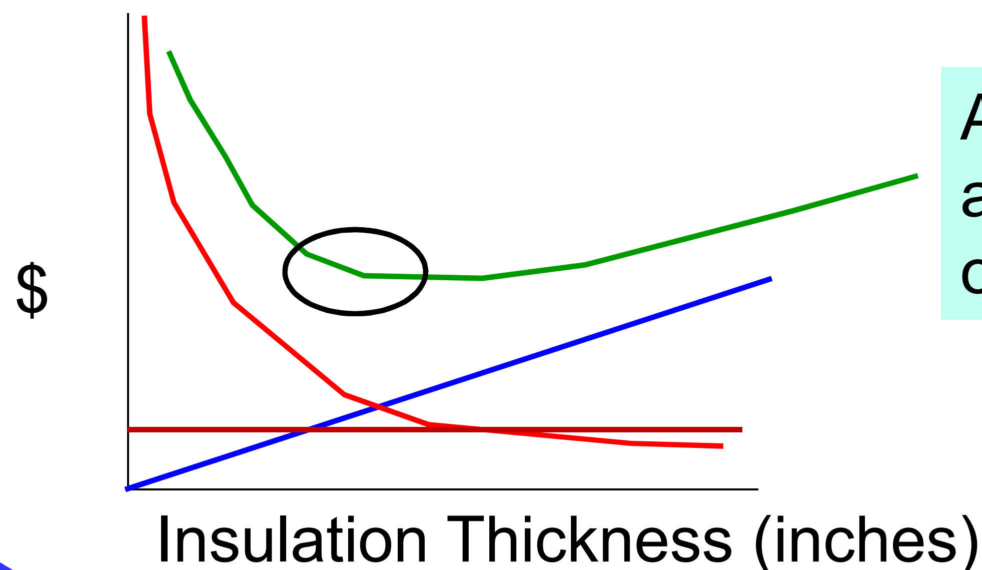
Insulation Thickness (inches)	1	2	3	4	5	6	10	20
Insulation Cost ($)	1	2	3	4	5	6	10	20
Energy Cost ($)	10	5	3.3	2.5	2	1.7	1	0.5
Total Cost ($)	11	7	6.3	6.5	7	7.7	11	20.5



The optimal insulation will be the point where the sum of insulation cost and energy cost is a minimum

Putting It Together - Geothermal

Insulation Thickness (inches)	1	2	3	4	5	6	10	20
Insulation Cost ($)	1	2	3	4	5	6	10	20
Geo Heat Pump Cost ($)	4	4	4	4	4	4	4	4
Energy Cost ($)	10	5	3.3	2.5	2	1.7	1	0.5
Total Cost ($)	15	11	10.3	10.5	11	11.7	15	24.5



Adding all costs shows an insulation thickness of 3 inches for this case

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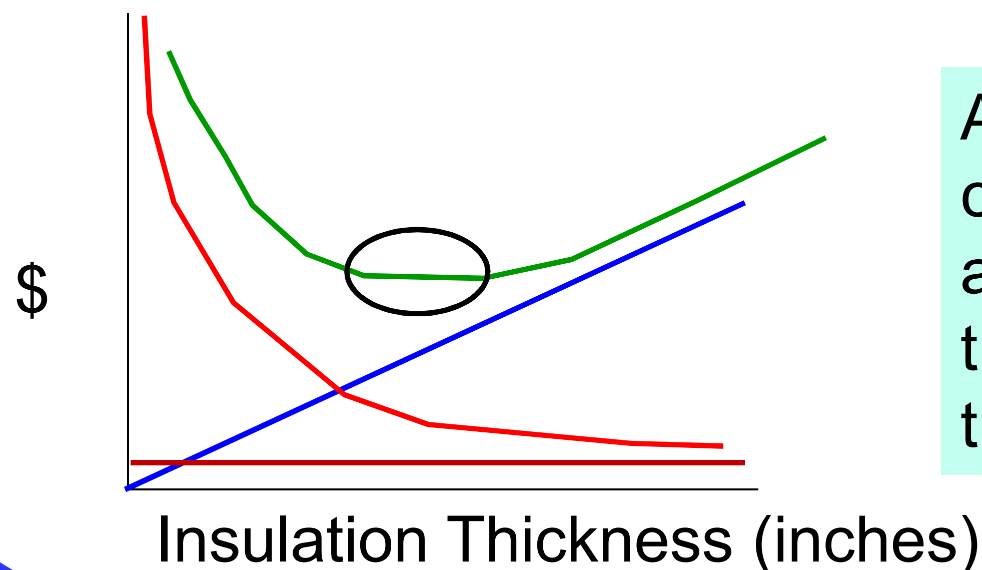
Putting It Together – Air Heat Pump

Insulation Thickness (inches)	1	2	3	4	5	6	10	20
Insulation Cost ($)	1	2	3	4	5	6	10	20
Air Heat Pump Cost ($)	1	1	1	1	1	1	1	1
Energy Cost ($)	20	10	6.6	5	4	3.4	2	1
Total Cost ($)	22	13	10.6	10	10	10.4	13	22



A change in the conditioning system cost and efficiency changes the optimal insulation thickness

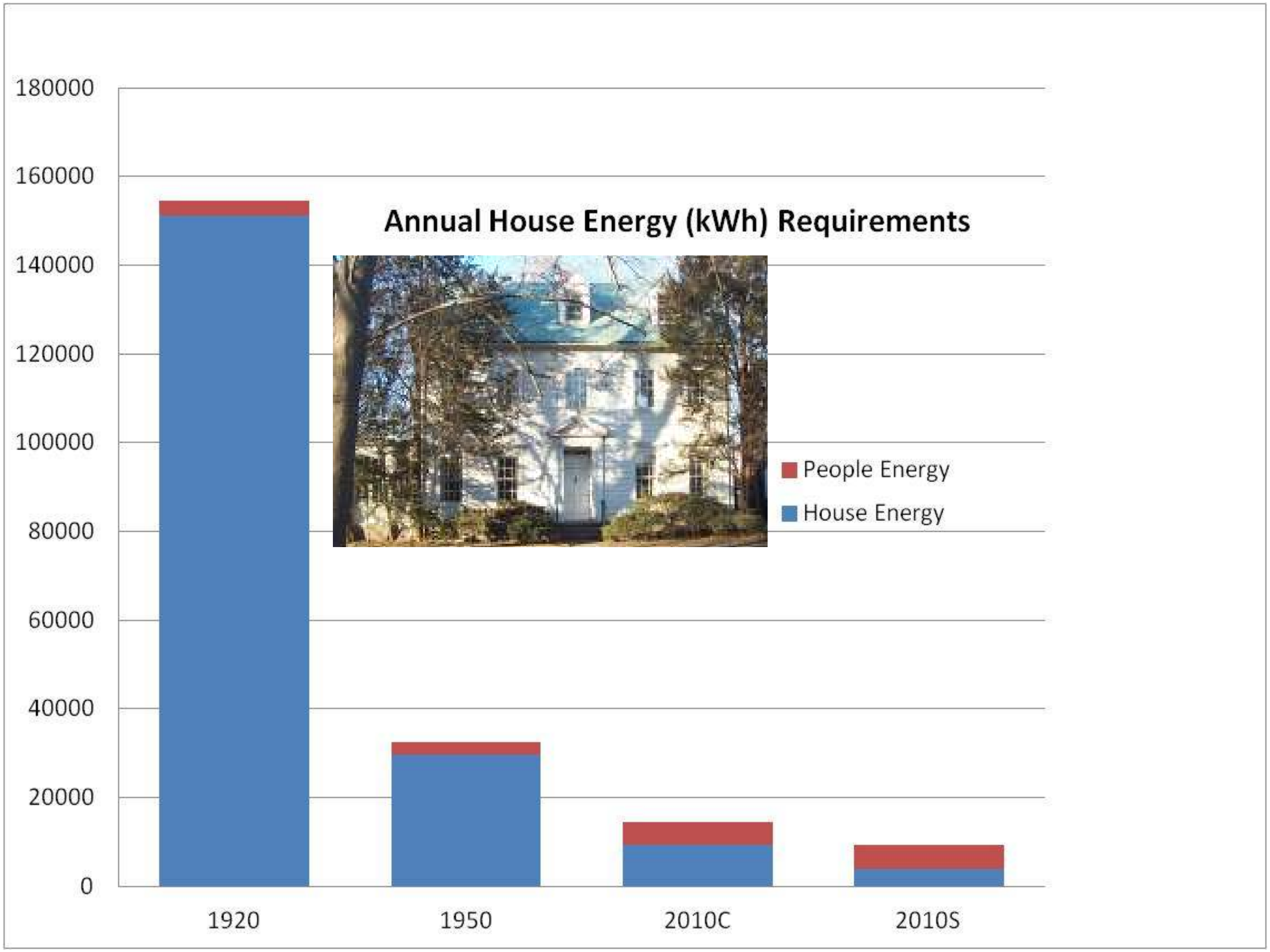
The Overall Problem

As you consider a variety of options for a building, an interdependency exists among many of the choices
- for 3 window types x 3 window areas x 3 insulation types x 3 insulation thicknesses x 3 comfort conditioning systems x 3 types of appliances x 3 occupancy levels x 3 roof insulations x 3 climates x ….. = **~20,000 + cases!!**

Fortunately, humans are good puzzle solvers

- As solution trends are observed, avoid solution regions where poor results are found
- As good choice regions appear, explore them
- This is not trivial … humans' intuition and creativity are important for finding good solutions

Home Energy Requirements



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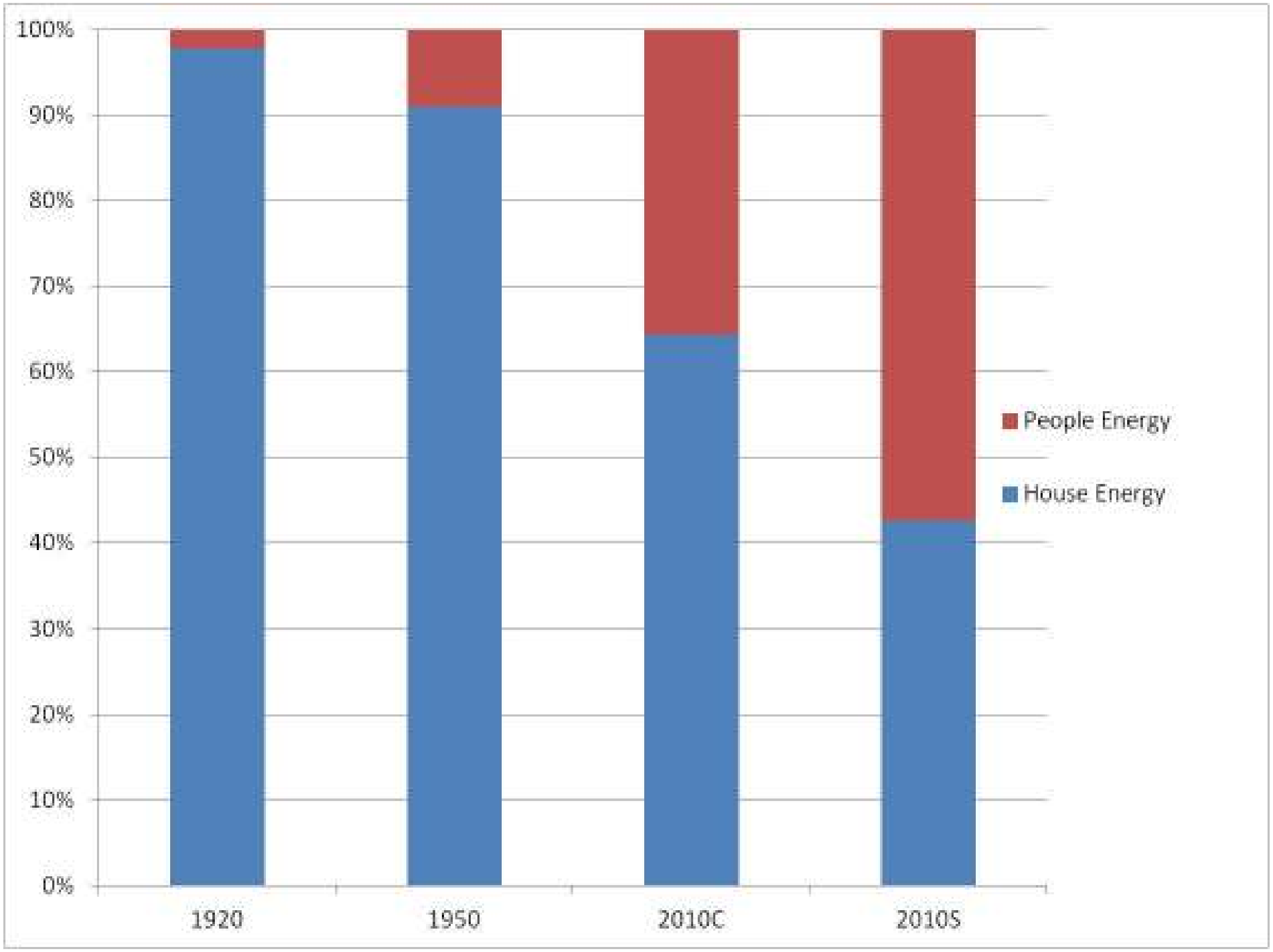
People vs Climate Energy



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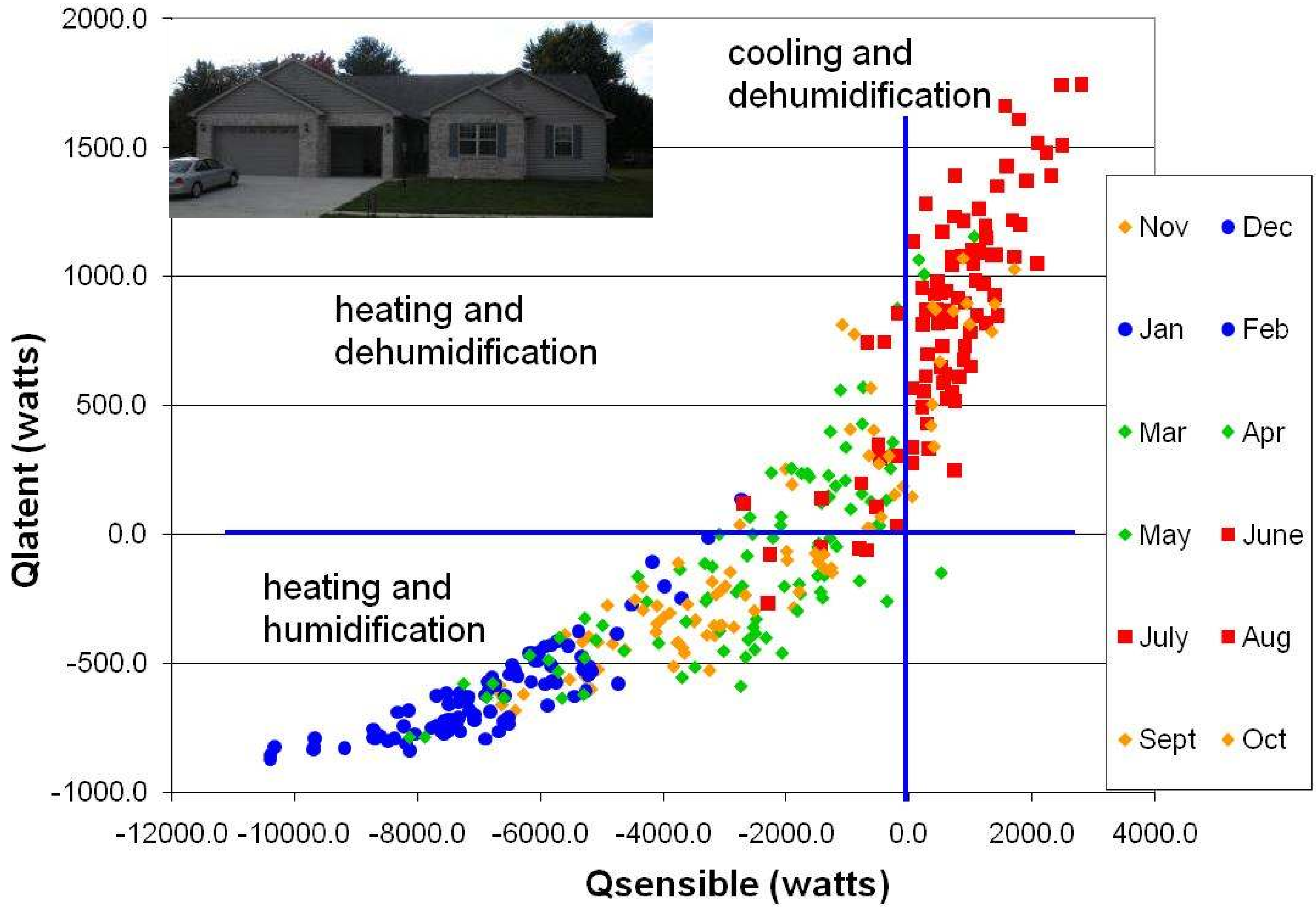
"Conventional" House 2100sqft
Climate Dominated Energy



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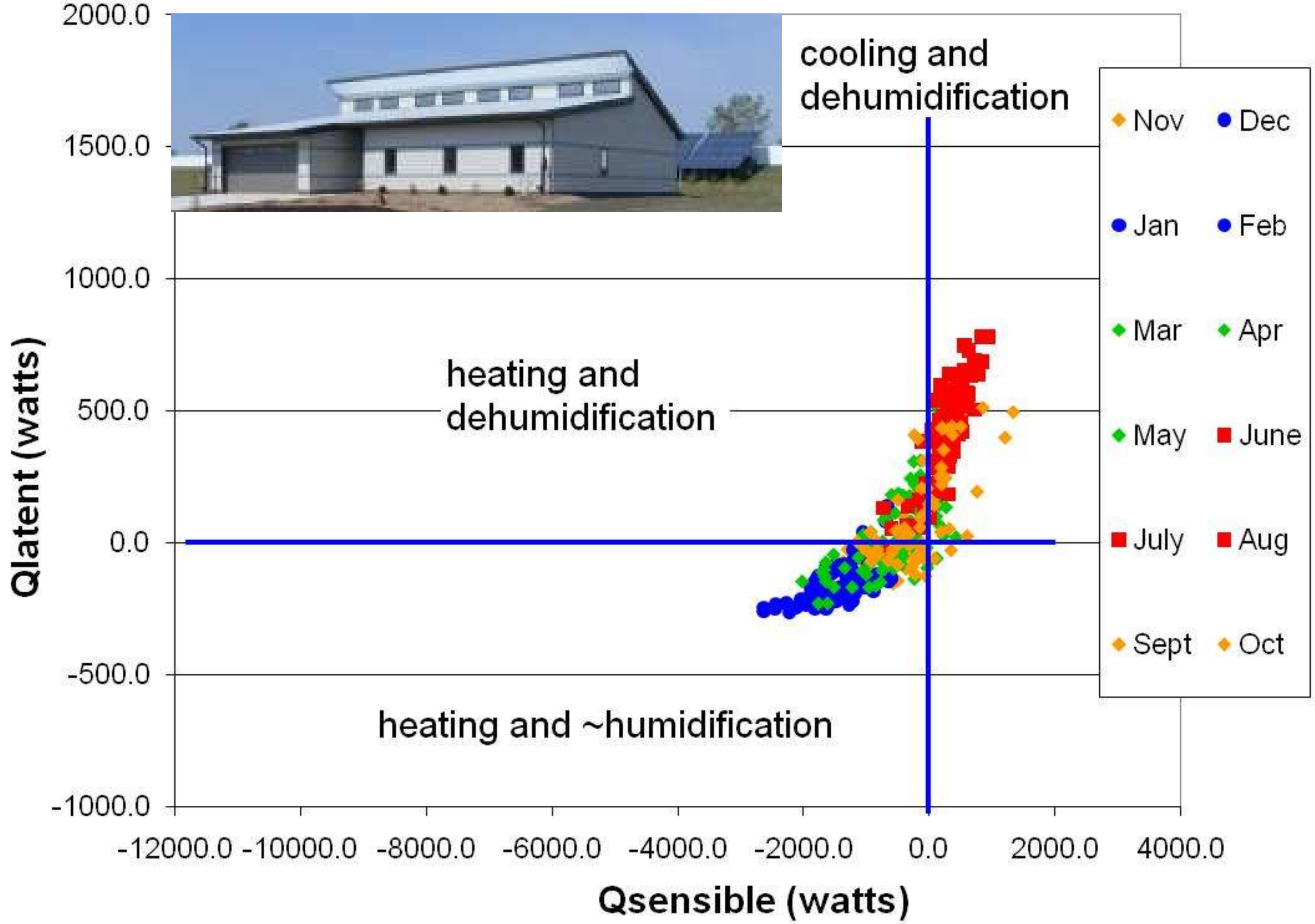
Equinox House 2100 sqft
People & Appliance Dominated Energy



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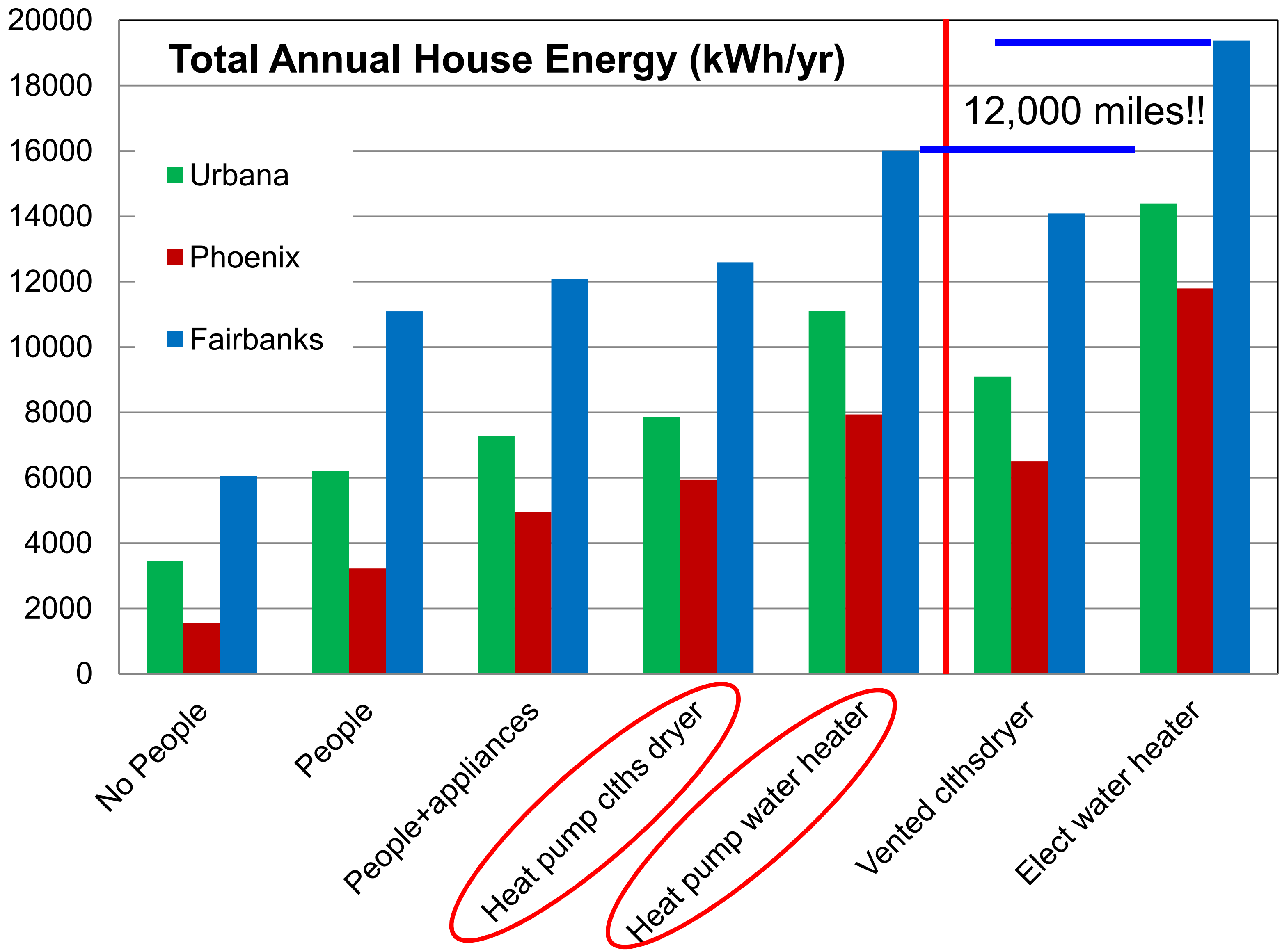
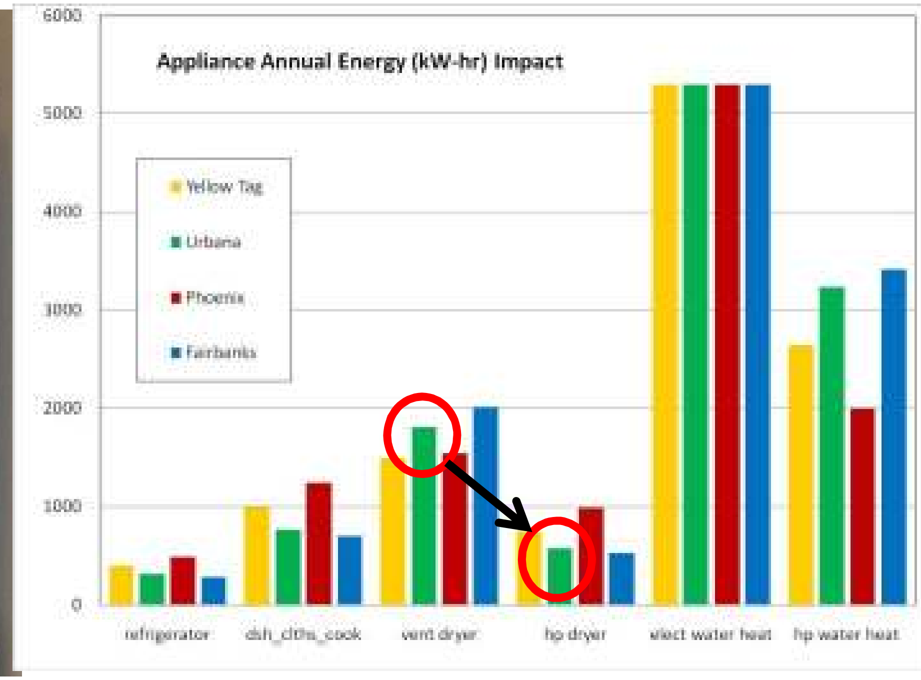
People – 2/3 House Energy



High Performance Appliances are Essential



- Ventless heat pump clothes dryer savings ~1000kWh or more per year = 4000 miles/yr EV driving!
- Savings on installation cost and house losses due to vents

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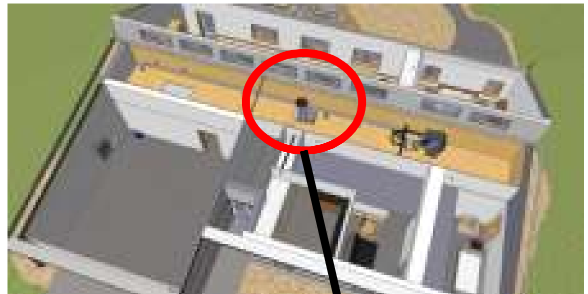
“Solar” Water Heating with Heat Pump



- Water heating important!
- COP range from 2 to 5
- ~2000kWh per savings from conventional = 8000 miles/yr EV driving
- Cooling/dehum of space added benefit…even in winter

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Solar Powered Dwelling

- Lots of insulation ….R40 to R50 (economic optimum ~12 inch thick walls and roof for our construction method)
- Adequate windows for light and view
    - Triple to quadruple glazed, low e
- Supersealed with filtered fresh air, controlled ventilation
- "Flexible" conditioning system (large variation of sensible to latent ratios)
- Details are extremely important! Construction must be monitored closely with performance/quality test validation

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Single Story, Slab Floor Construction
~2100 sqft Living ~500 sqft Garage

- •Easy-to-maintain design (accessible electric, plumbing, ductwork)
- •4 bedrooms (master and 3 small bedrooms)
- •2 ½ baths (modest size)
- •Open living space floor plan

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SIPs

Structural Insulated Panel

- 1st panel installed
- Walls and roof 12 in thick, ~R44
- Follow the numbers, ~80 panels (walls and roof total)
- Heaviest panel (8ft by 24ft) weighs ~400lb
- Minimal waste, whole house up in 1 week

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House Inspected Nov 19, 2010

Main construction completed July 2010

….but, custom Italian cabinets delayed until November

Luxury and Sustainability are not mutually exclusive

Lighting

Windows designed for “blue sky” daylighting – not for energy – **windows are not economical**

Wireless switches eliminate electrician’s holes through walls

All lighting is mercury free LEDs

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Comfort

Superinsulating and supersealing creates very uniform interior temperatures and comfort

•20 ft ceiling and concrete floor within 2-3F all year with no ceiling fans!

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FRESH AIR Conditioning

- Demand controlled fresh air ventilation for residences based on carbon dioxide and volatile organic compound (VOC) monitoring
- "Smart" algorithms for:
  - Heating/cooling/dehumidification
  - Energy "recovery"
  - Energy efficient defrosting
  - "Free" conditioning

A new generation of building conditioning systems are required for the new generation of buildings to ensure a healthy indoor environment

Clean, Fresh Air

- Continuous fresh air and exhausted stale air
- All fresh air is filtered
- Maintain low levels of CO2, VOCs and radon
- Use “free” conditioning when outside is “nicer” than inside

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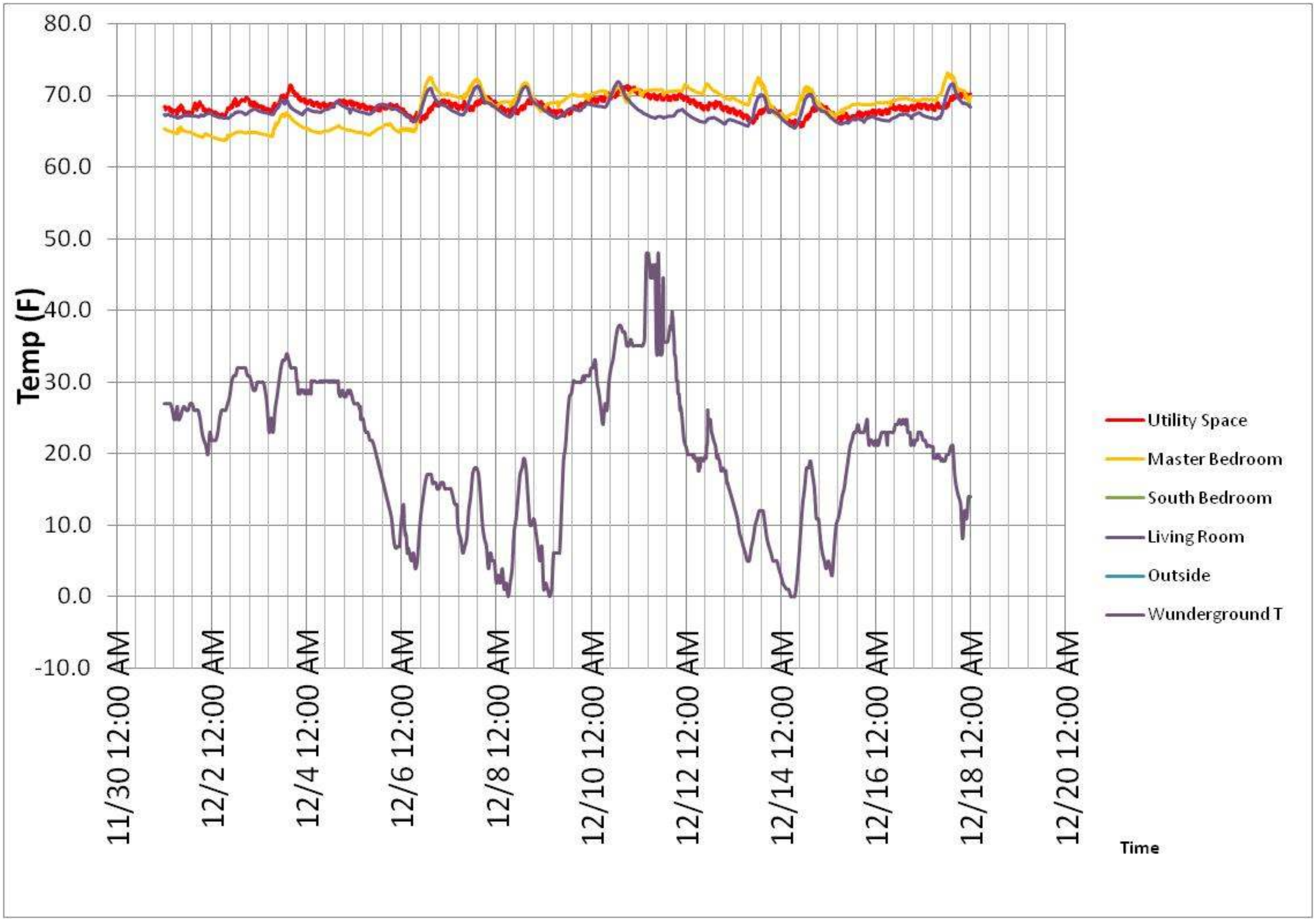
Comfortable Temperatures



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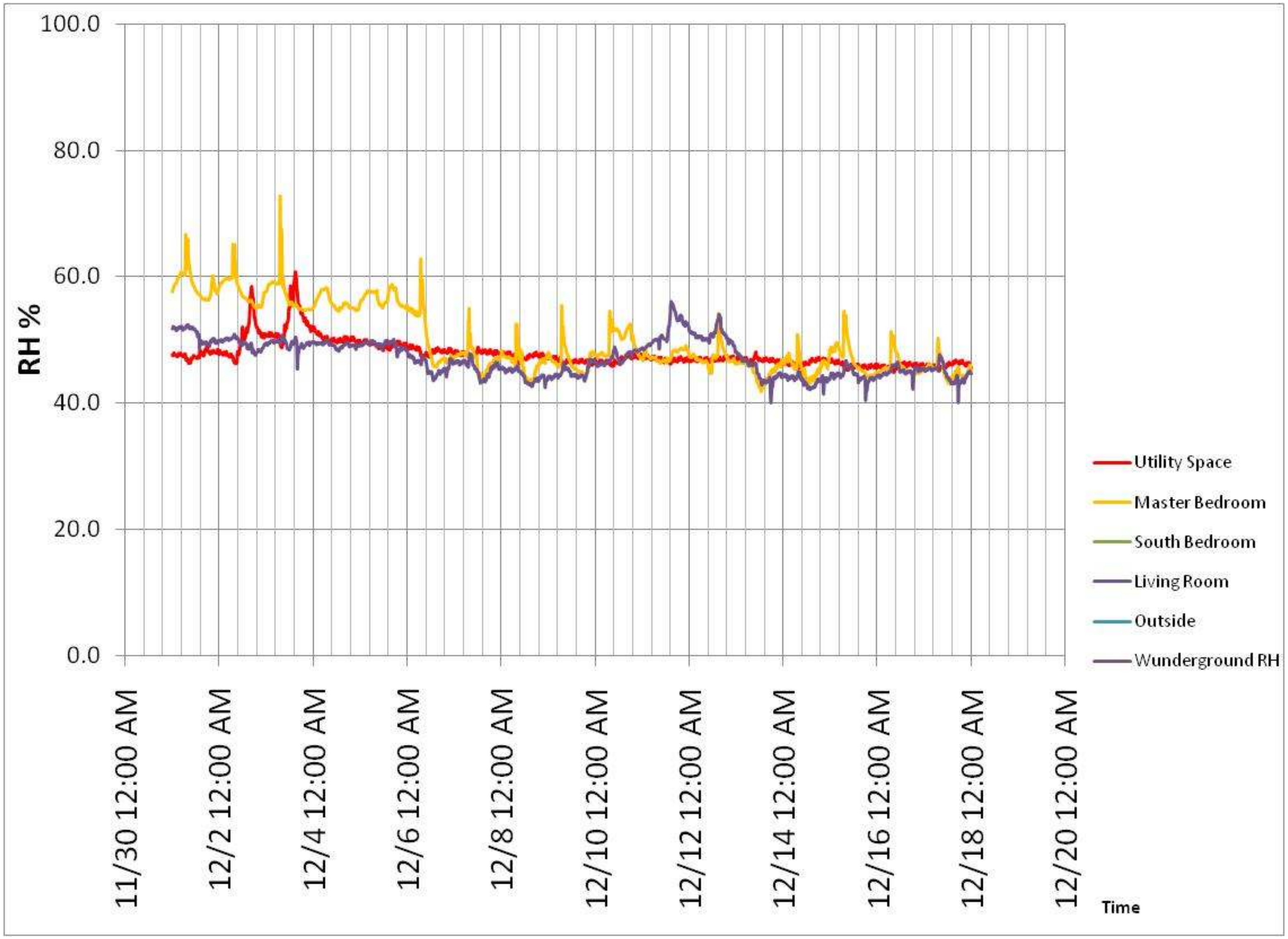
Comfortable Humidity



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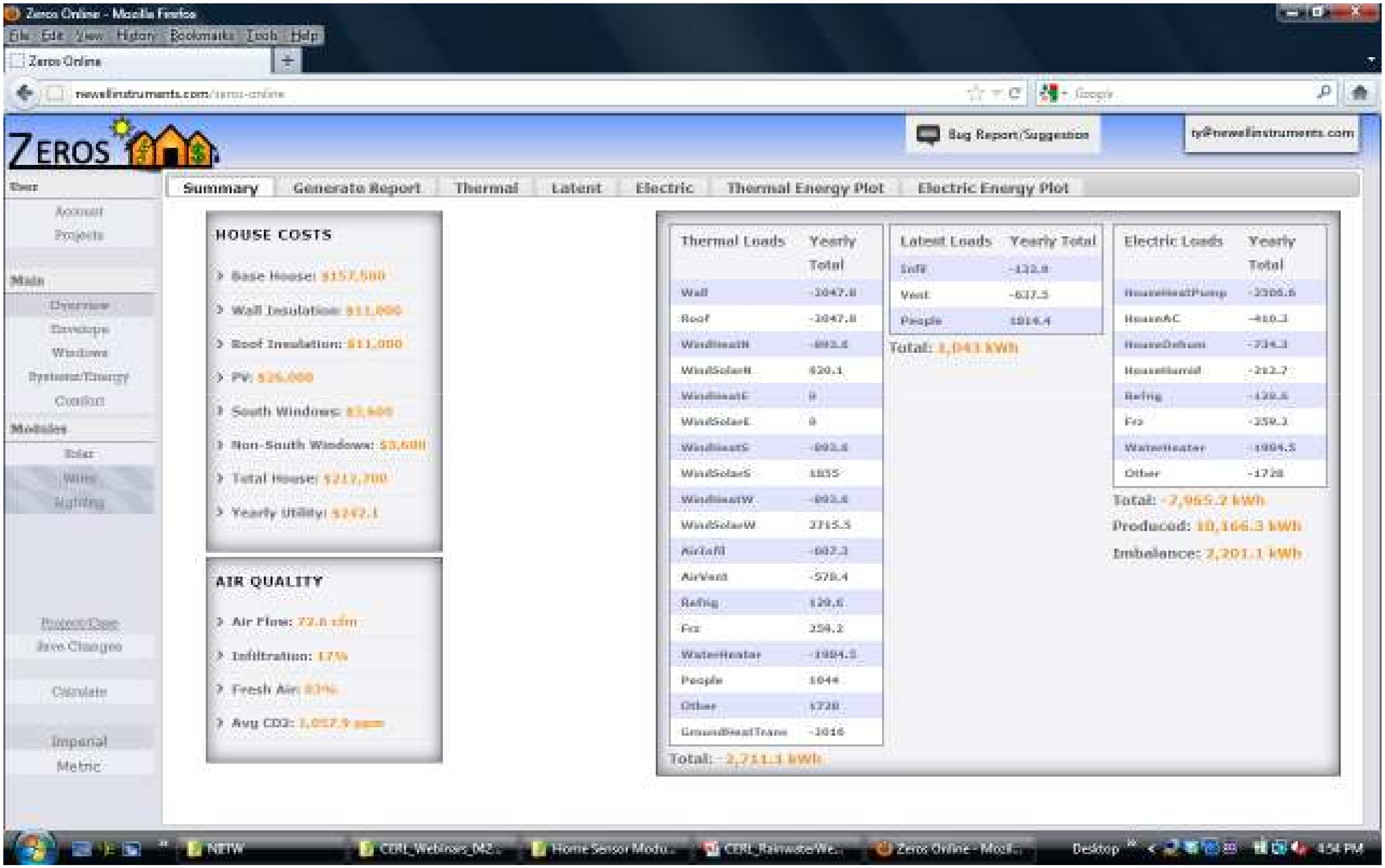
ZEROs

Zero Energy Residence Optimization software



Watch for ZEROs on BuildEquinox.com

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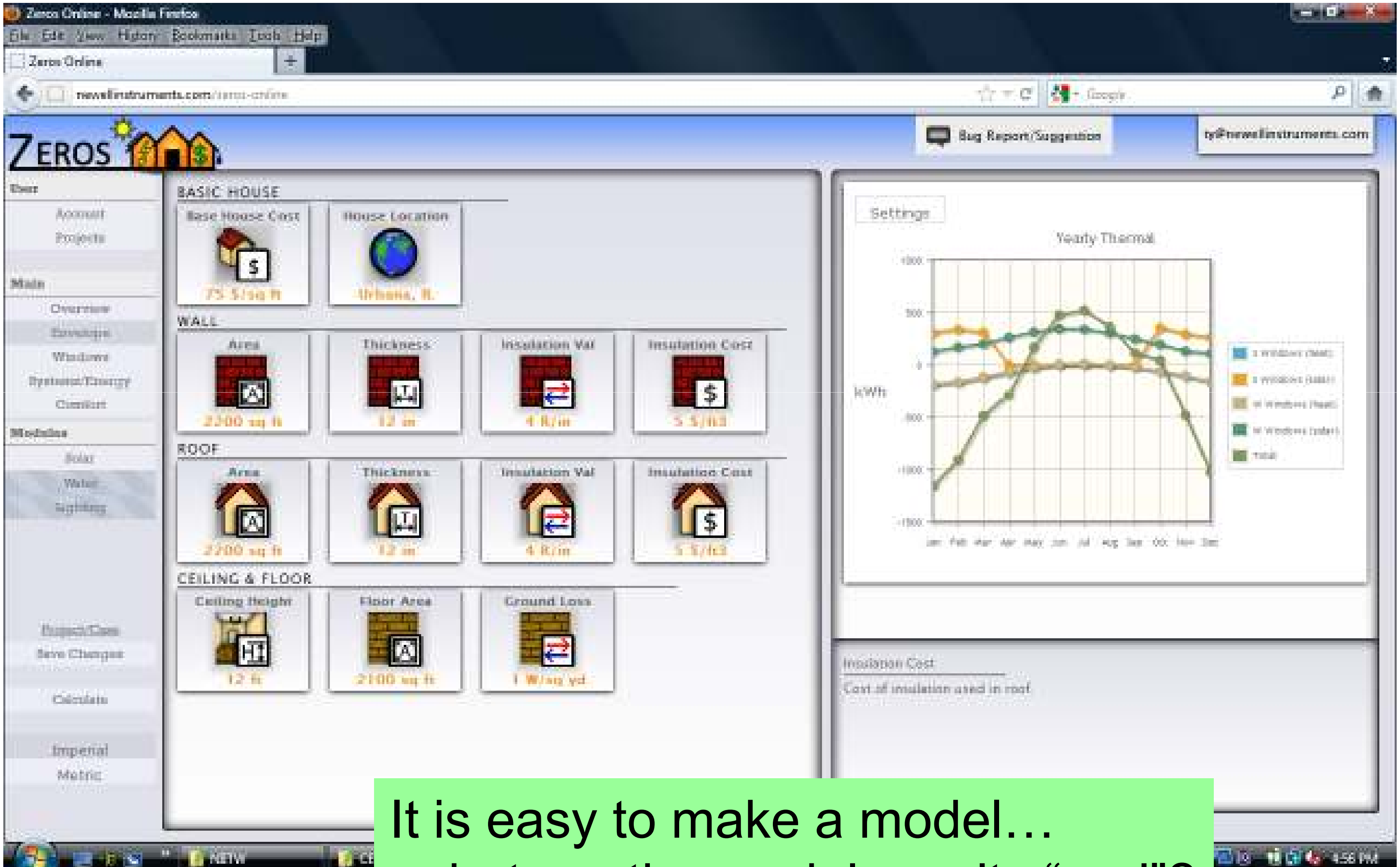
Zero Energy Residence Optimization software



It is easy to make a model…

…but are the model results “real”?

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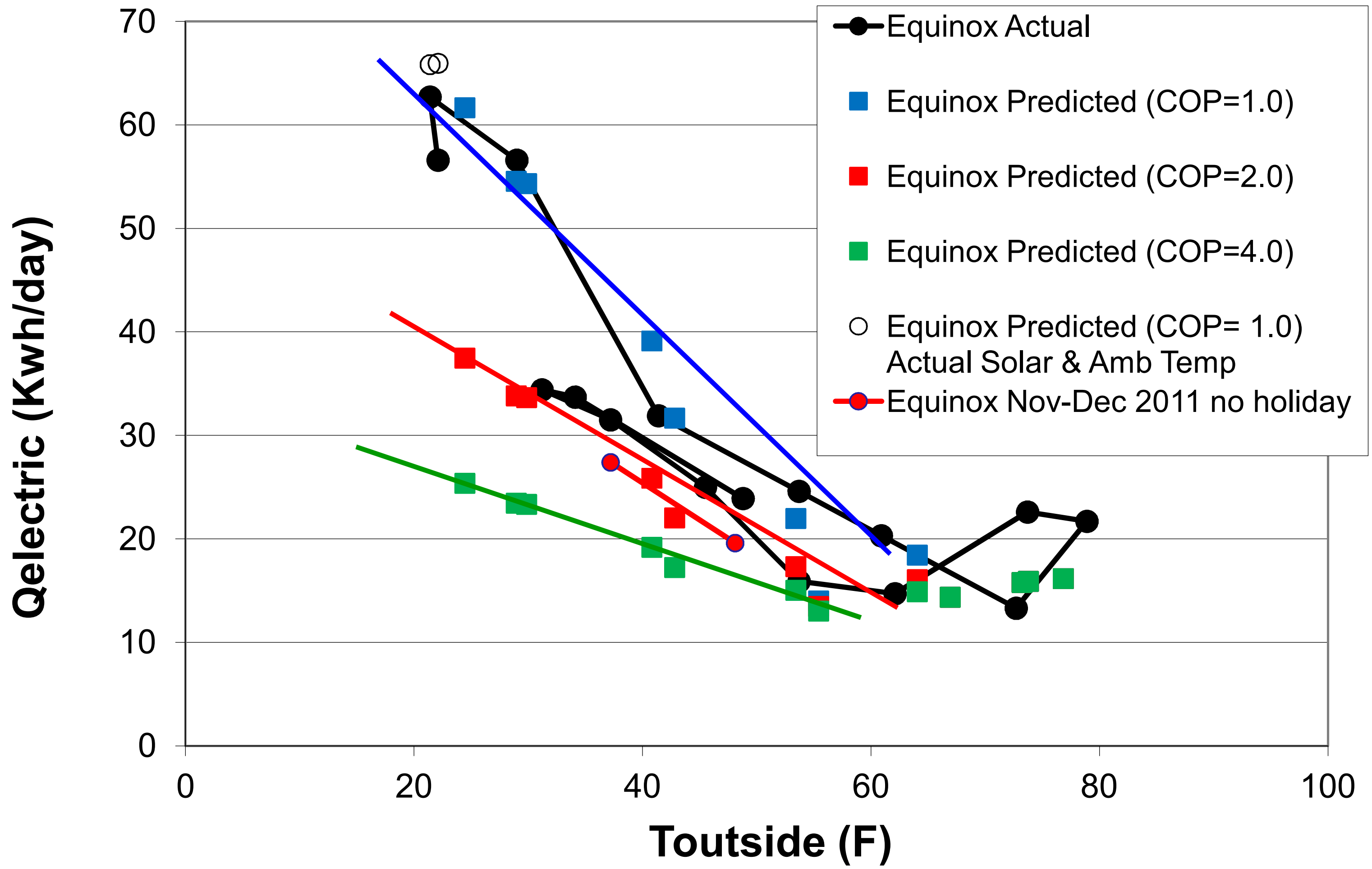
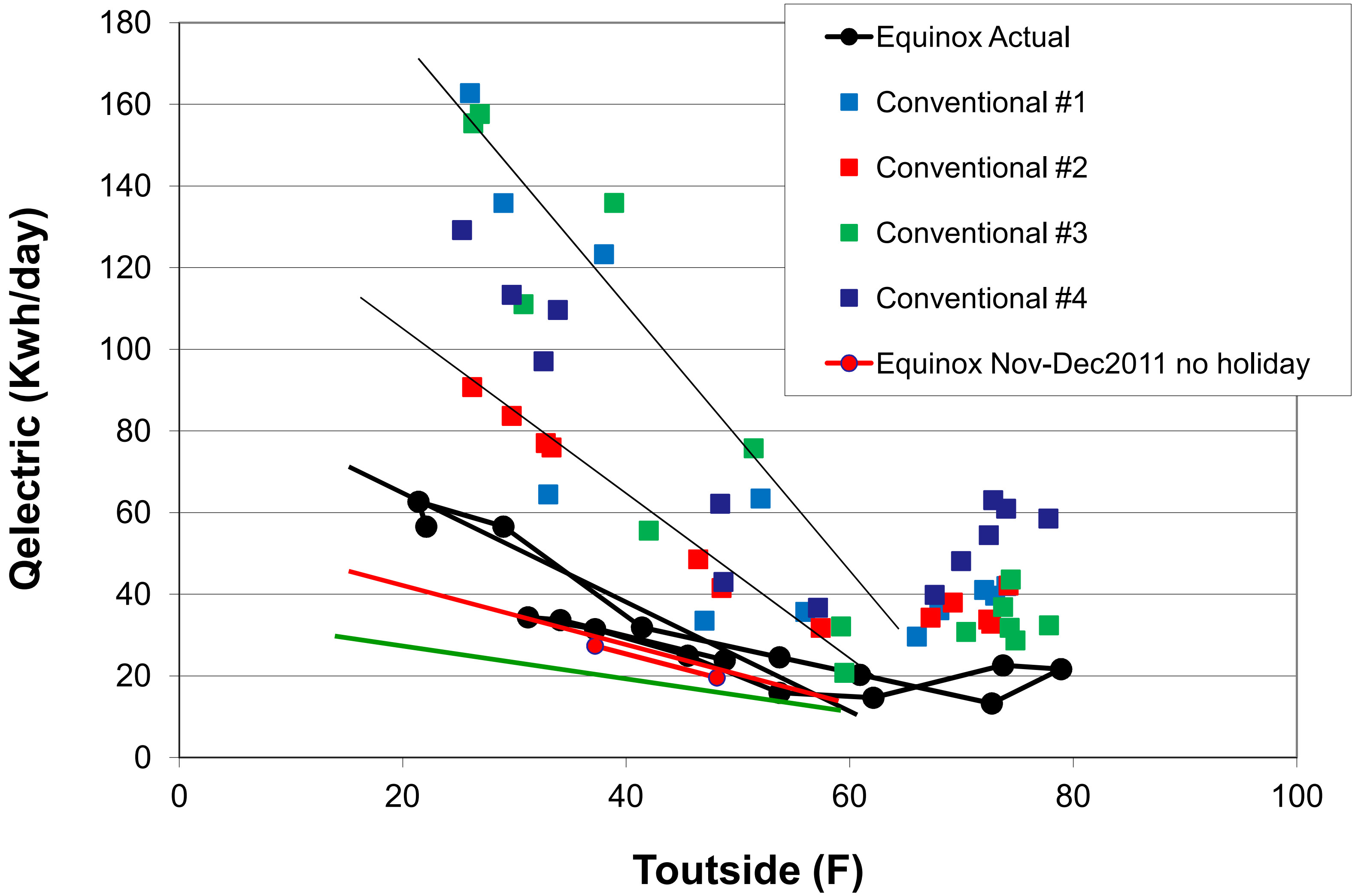
Modeling versus Reality



COP = 1 = electric resistance heat
COP = 2 = air source heat pump
COP = 4 = ground source heat pump

Equinox vs Neighborhood



Equinox Dec 2010 – Mar 2012

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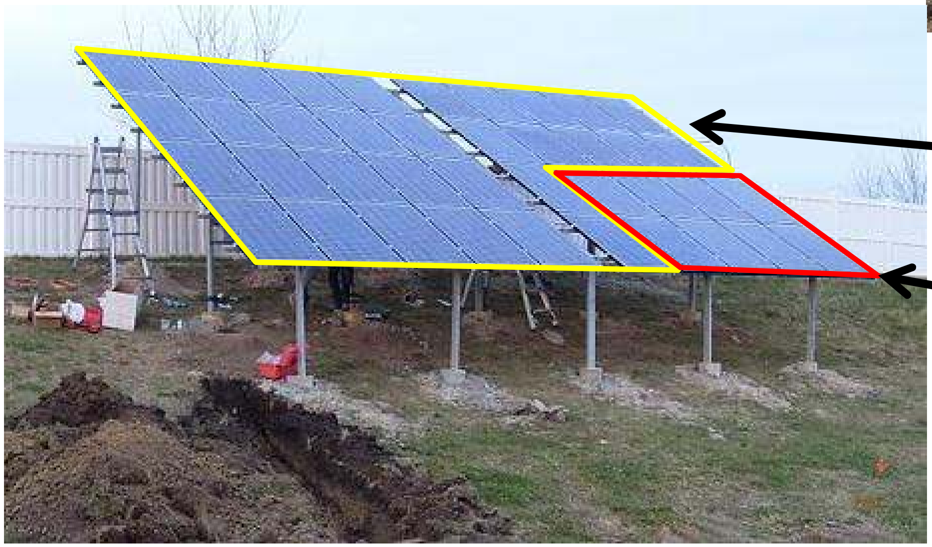
Solar System Installation

8.2kW nominal system size
~4 days to install rack and panels
~750 sqft
~11,000kWh per year
9000kWh for house
2000kWh for electric car



House panel area

Car panel area (8000 miles per year)

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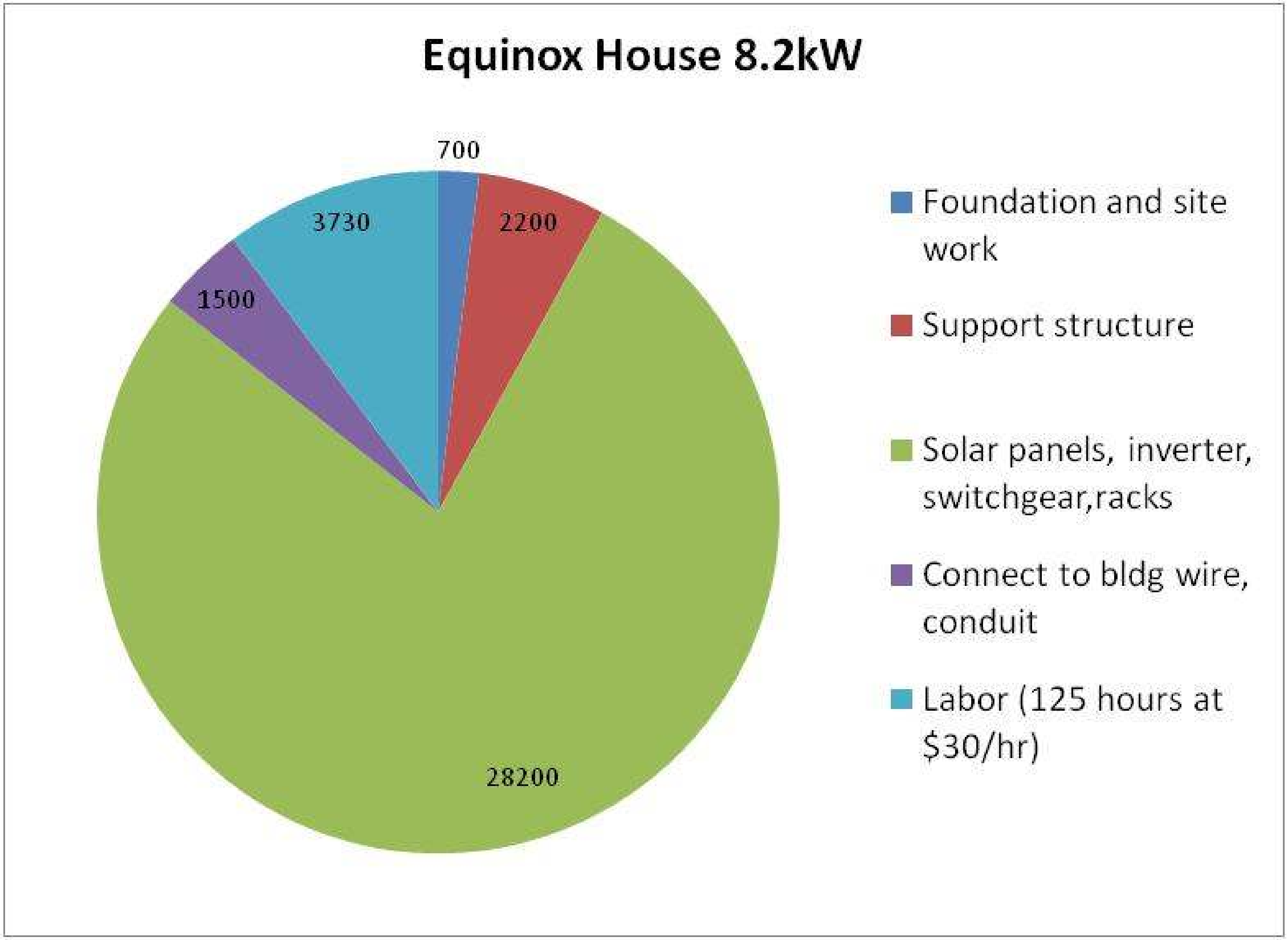
Equinox House Solar PV ~$36,000 (~$4.43 per Watt)
$25,000 after US Tax Credit



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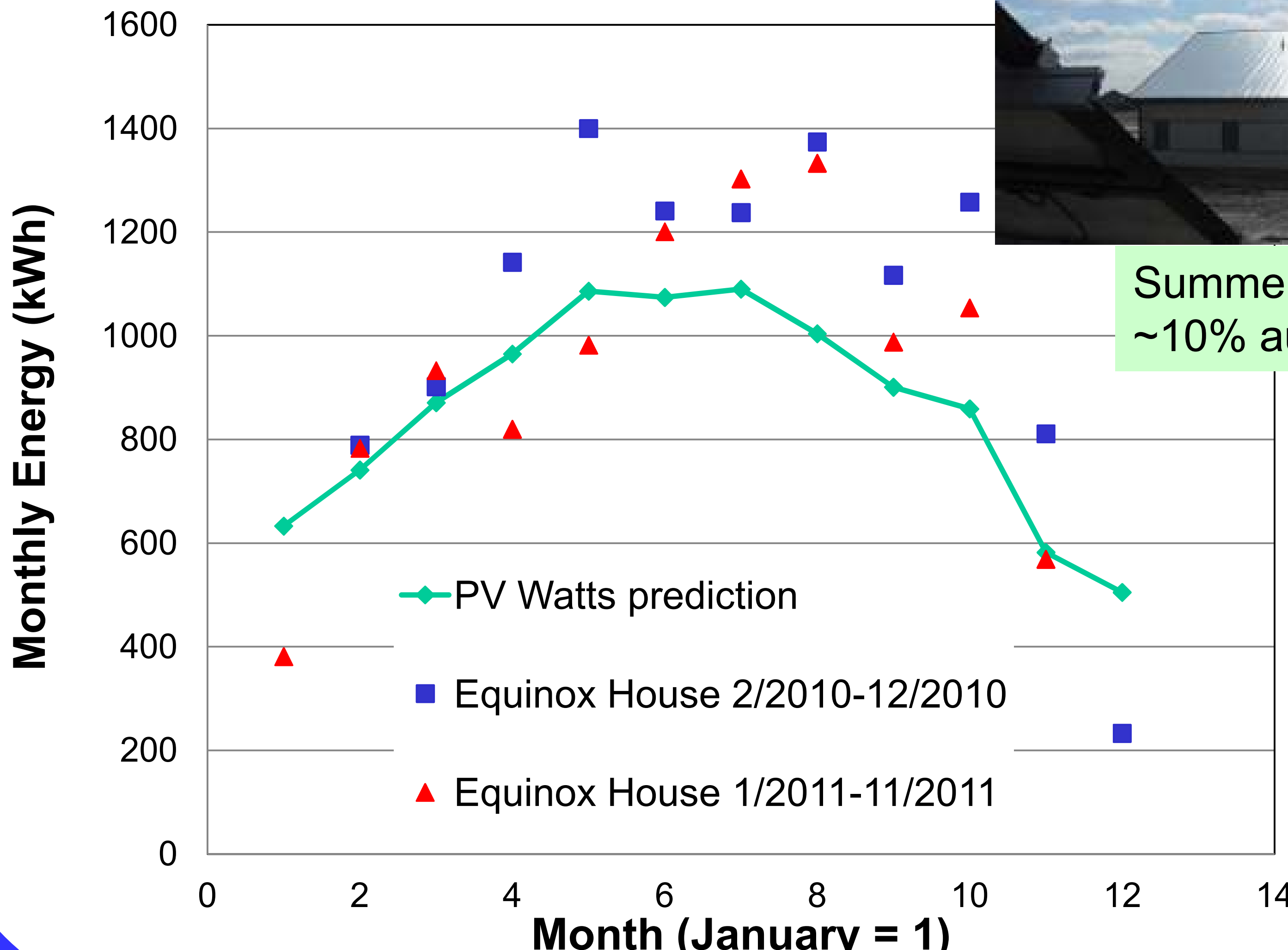
Solar PV Performance – Predicted vs Actual



Summer roof reflection
~10% augmentation

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Transportation

- Electric vehicles (EV) = 4 miles per kWh
- 80-100 mile range will be typical initially
- 30 miles per day average = 11,000 miles/year

+

= 12,000 miles of EV transportation per year!!

Heat Pump Dryer and Water Heater

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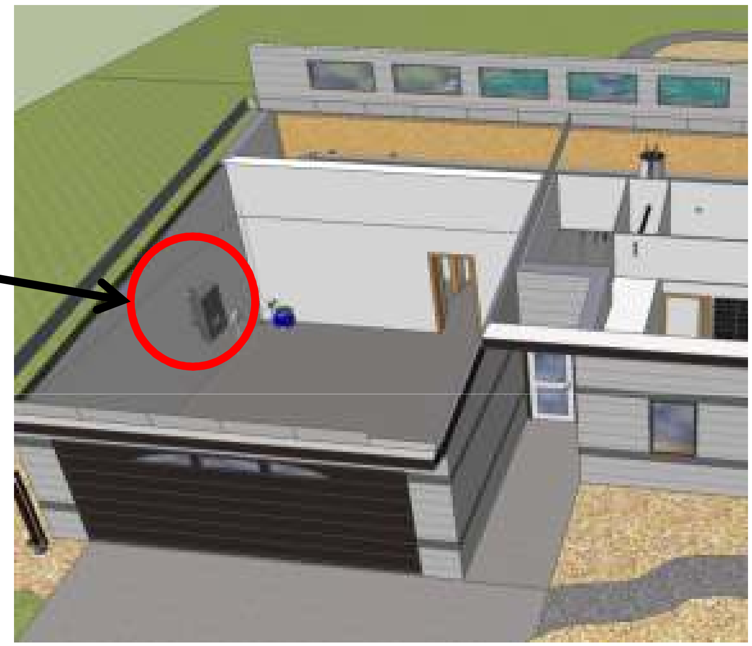
Solar Powered Electric Vehicles

- 4 miles per kWh
- Solar electric cost ($0.125/kWh)
    - ~$0.03-0.04 per mile
- Gas car cost ($4/gal)
    - ~40mpg=22km/liter
    - ~$0.10 per mile

Solar powered EVs are already less expensive than gasoline

And, you will not spend 12 hours per year pumping gas and breathing fumes

“Smart” Electrical System
Monitoring and Control



- Monitor activity anytime from anywhere
- Control circuits based on time-of-day
- Control circuits based on cost
- Monitor “health” of house, health of people

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Last, But Not LEAST
Ease-of-Living, Accessability

In the US, our population is getting "old"

- People need to be in control of technology
- Equinox has 36 inch wide doorways and no steps, stairs or barriers throughout its living area, including the shower area
- We need simplified, robust house designs that allow our elderly to live independently longer

The biggest cost savings of Equinox House may be deferred elder care and minimizing accidents

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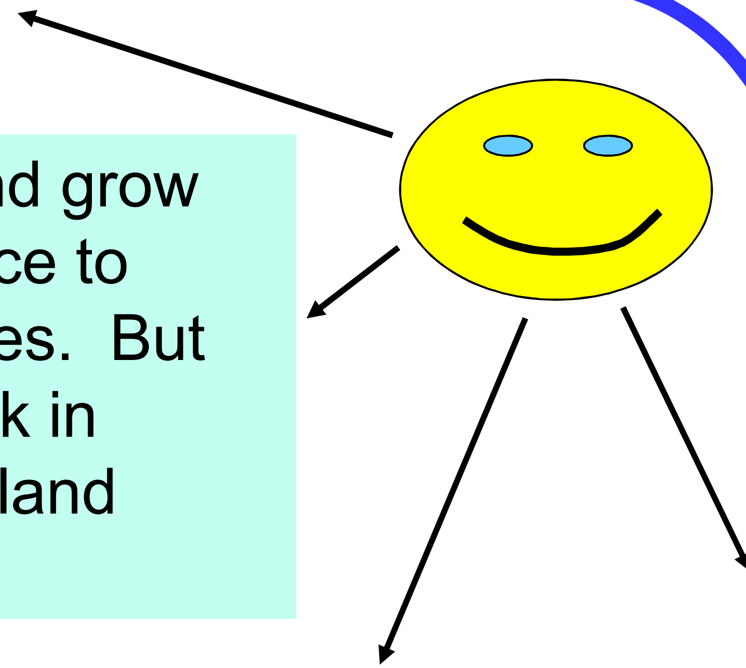
“our tools are better than we are, and grow better faster than we do. They suffice to crack the atom, to command the tides. But they do not suffice for the oldest task in human history: to live on a piece of land without spoiling it.”



Professor Aldo Leopold; 1938
University of Wisconsin
Engineering and Conservation speech

Thank you!

For further reading, see ASHRAE Journal; September 2010 through August 2011 articles “Solar NZEB” by Ty Newell and Ben Newell

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