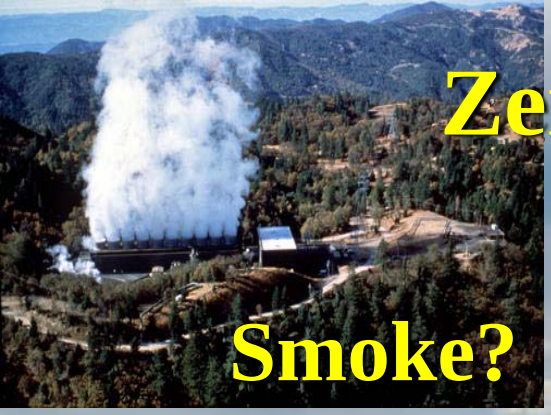


Zero Energy Buildings:

Smoke?

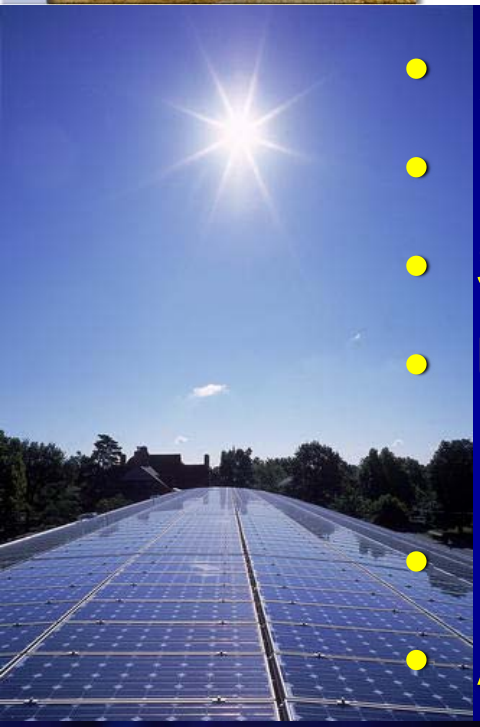
Mirrors?

or What?

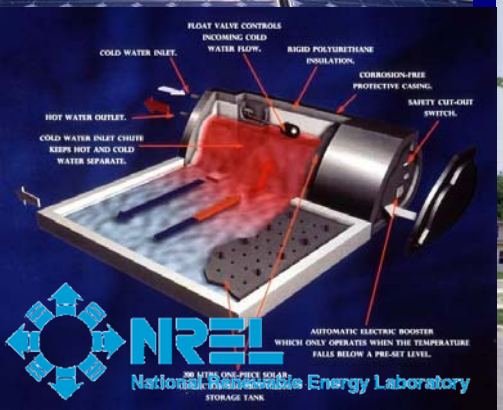
R Judkoff, Principal Program Mgr: Buildings R&D
National Renewable Energy Lab (NREL)

NREL STF: 1st LEED Platinum Federal Bldg

NREL Buildings R&D

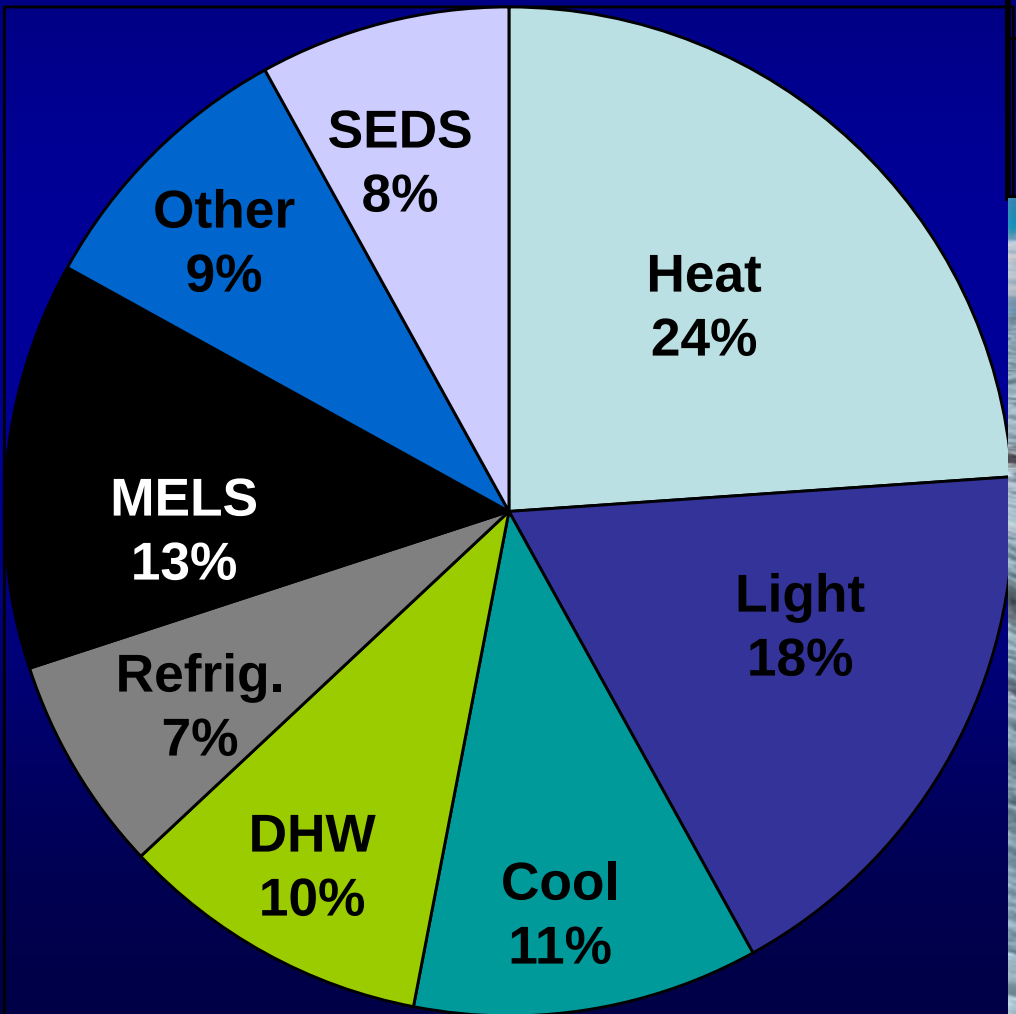


- Measurement and simulation
- Energy Optimization software
- Systems Integration
- Ultra energy efficient Design
  – Zero Energy Buildings
- Passive/Active Solar, & BIPV
- Advanced HVAC & Windows



US Building Energy Use (2006)

40% Carbon Emissions



Primary	39% (39 quads)
Electric	74% (29 quads)

Whole Building Optimization and Systems Integration Research

Goal: ZEH by 2020, ZECB by 2025

Energy Design Process

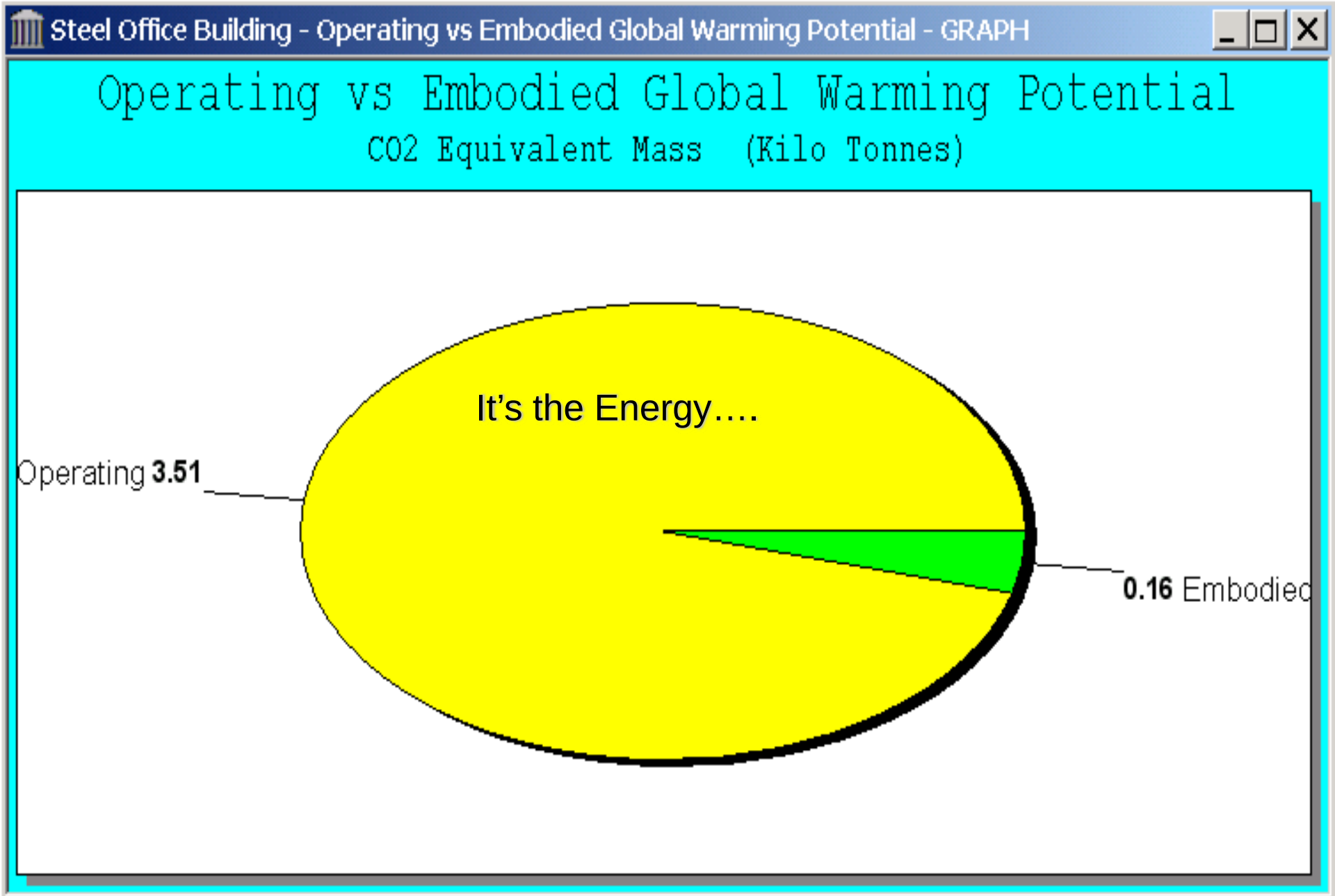
Simulate

Construct

Test/Monitor

www.nrel.gov

Example Building LCA, Athena EIE

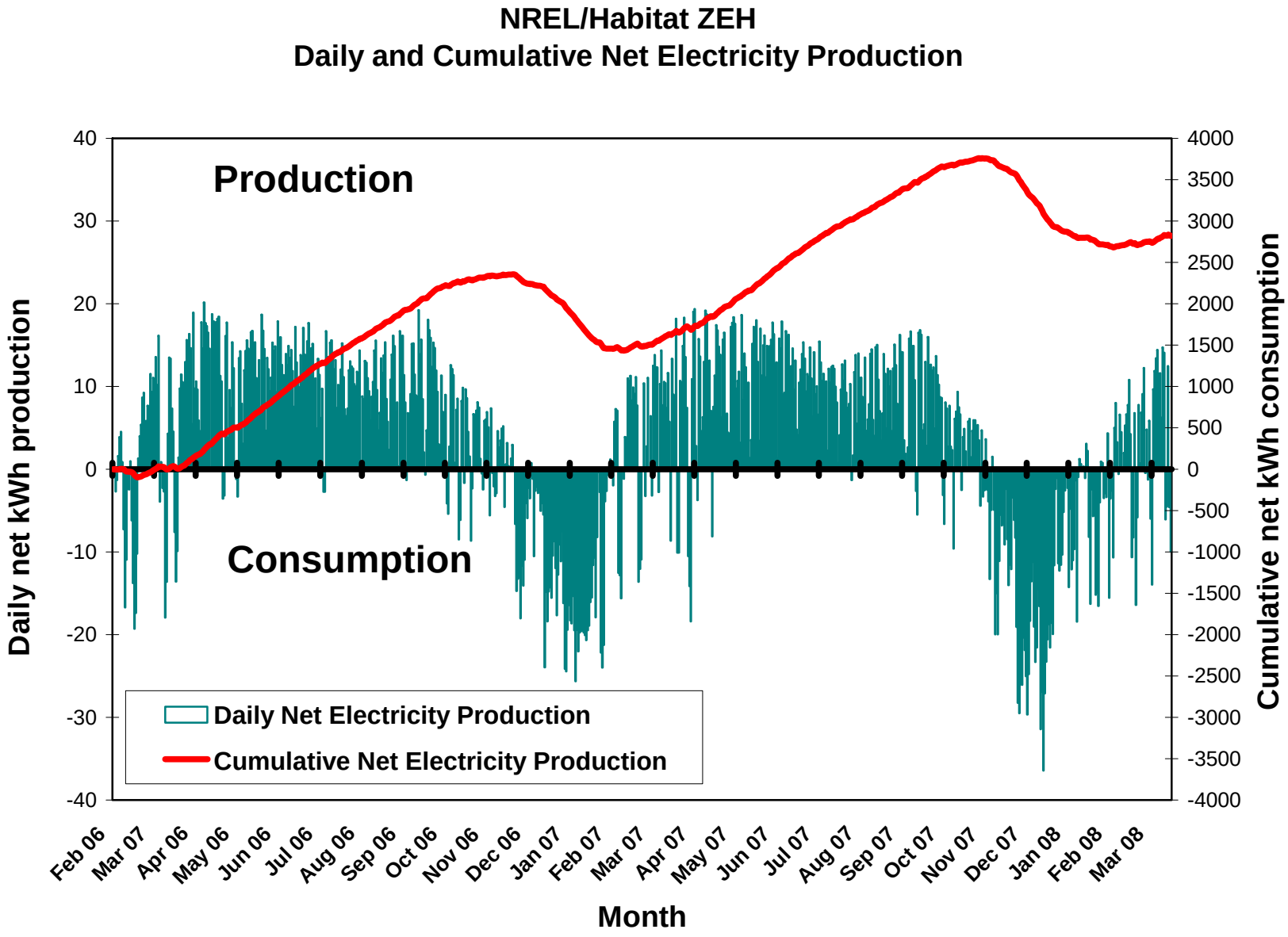


Building AMERICA
U.S. Department of Energy

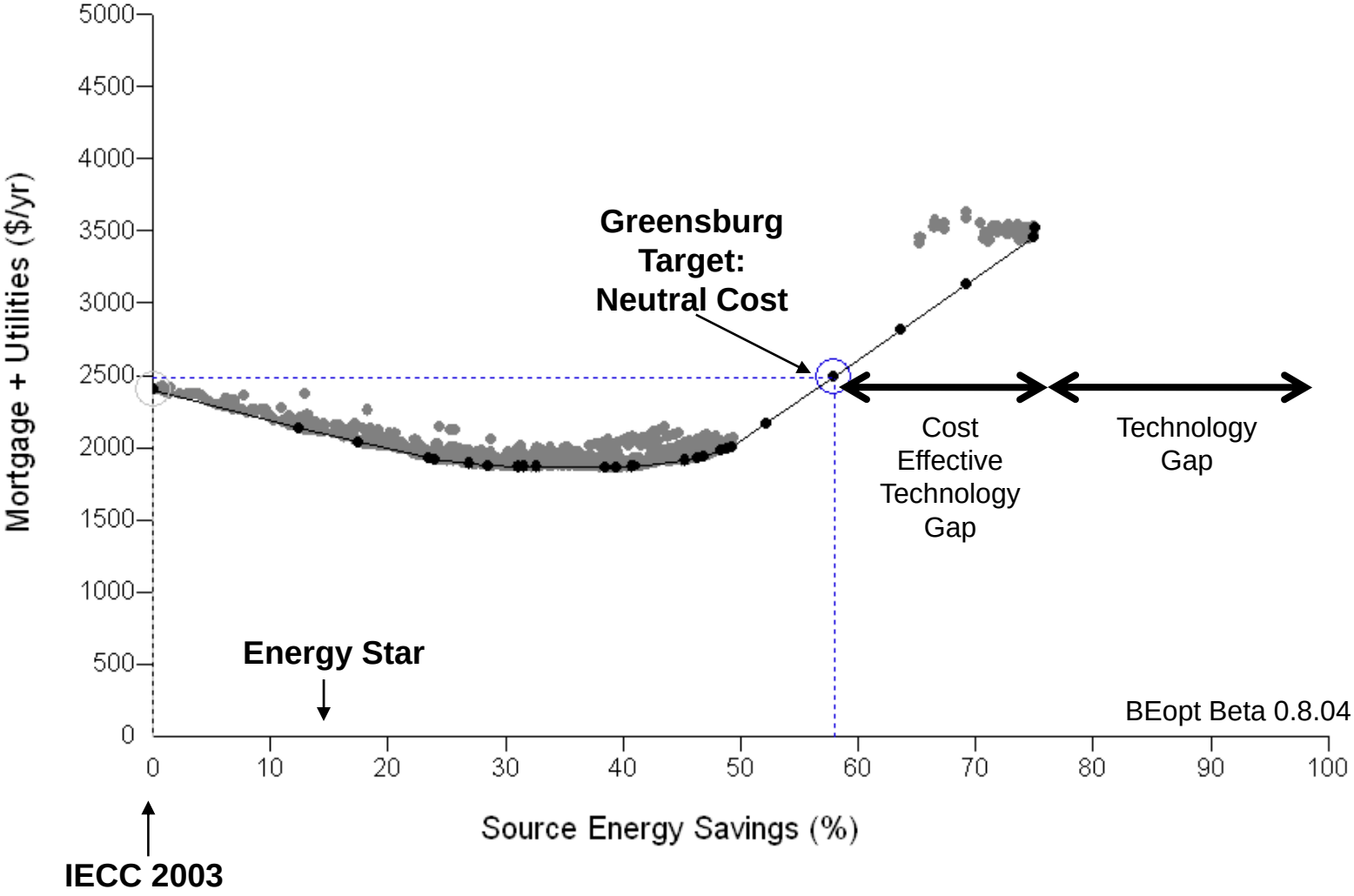
NREL Zero Net "Site Energy" Habitat House

-Walls: R40
- Roof: R60
- Passive
- SDHW
- PV: 4 kW
-Heat Recovery

Denver Climate


NREL/Habitat ZEH
Daily and Cumulative Net Electricity Production
Production
Consumption
Daily net kWh production
Cumulative net kWh consumption
Month
Daily Net Electricity Production
Cumulative Net Electricity Production
40
30
20
10
0
-10
-20
-30
-40
4000
3500
3000
2500
2000
1500
1000
500
0
-500
-1000
-1500
-2000
-2500
-3000
-3500
-4000
Feb 06
Mar 07
Apr 06
May 06
Jun 06
Jul 06
Aug 06
Sep 06
Oct 06
Nov 06
Dec 06
Jan 07
Feb 07
Mar 07
Apr 07
May 07
Jun 07
Jul 07
Aug 07
Sep 07
Oct 07
Nov 07
Dec 07
Jan 08
Feb 08
Mar 08

Neutral Cost Point: Greensburg BEopt Analysis



(2000 ft2, 2-story, 16% window to floor area ratio, unconditioned basement)

Example: Greensburg Neutral Cost Package[1]

- R22 wall assembly (2x6 + R-19 batts+ foam sheathing)
- R50 ceiling assembly
- R10 basement
- .0001 SLA (2 ACH_{50}): Approx = .12 nACH
- Low e/low SHGC glazing, Argon Fill (0.28 U-value, 0.37 SHGC)
- 80% CFL Lighting
- SEER 18 AC
- AFUE 90+ furnace
- Gas tankless hot water, EF 0.8+
- Tight ducts (Mastic, 5% Leakage), in conditioned space
- Energy Star Appliances
- 1.5 kW_{DC} PV System
- BA QA (moisture control, air quality, etc.)

Estimated cost increase relative to standard home[2,3]: +$10.00-$13.00/ft2

Notes:
1. Equivalent packages may be substituted, based on specific builder preferences
2. Does not include costs associated with builder/contractor training and changes in business practices.
3. Incremental costs will depend on current builder practice

Estimated Annual Costs: Neutral Cost Target

	Greensburg
Estimated Incremental First Cost Relative to Standard Practice	$26,000
Annual Amortized Cost of Energy features (7%, 30Year mortgage[1)]	$1386
Annual Utility Bill Savings	$1386
Net Annual Cash Flow	**$0**

(2000 ft2, 2-story, 16% window to floor area ratio), unconditioned basement

[1] Assumes 28% marginal tax bracket and includes present value of future replacements of equipment over 30 year life of mortgage.

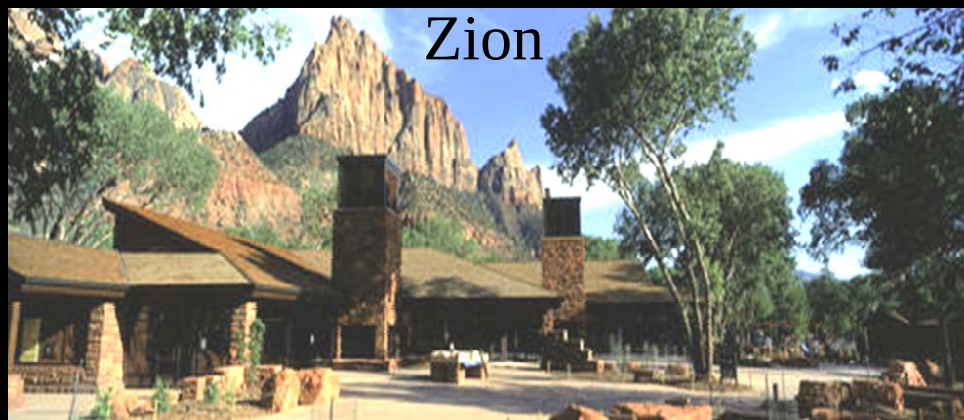

BigHorn

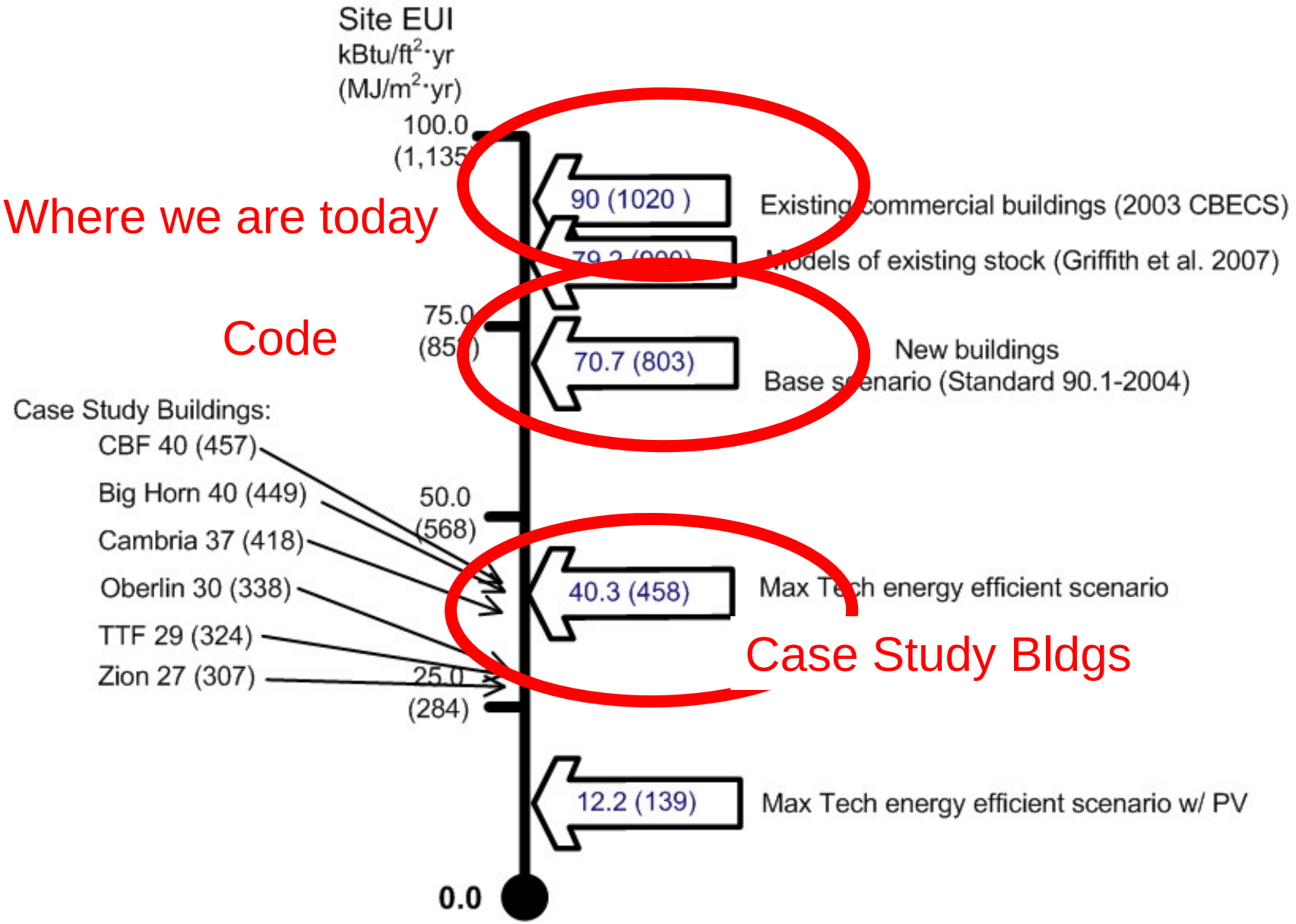

Cambria


Oberlin


Chesapeake


TTF


Zion


Site EUI
kBtu/ft²·yr
(MJ/m²·yr)
100.0
(1,135)
90 (1020)
Existing commercial buildings (2003 CBECS)
Models of existing stock (Griffith et al. 2007)
Where we are today
75.0
(85
Code
70.7 (803)
New buildings
Base scenario (Standard 90.1-2004)
Case Study Buildings:
CBF 40 (457)
Big Horn 40 (449)
Cambria 37 (418)
Oberlin 30 (338)
TTF 29 (324)
Zion 27 (307)
50.0
(568)
40.3 (458)
Max Tech energy efficient scenario
Case Study Bldgs
25.0
(284)
12.2 (139)
Max Tech energy efficient scenario w/ PV
0.0

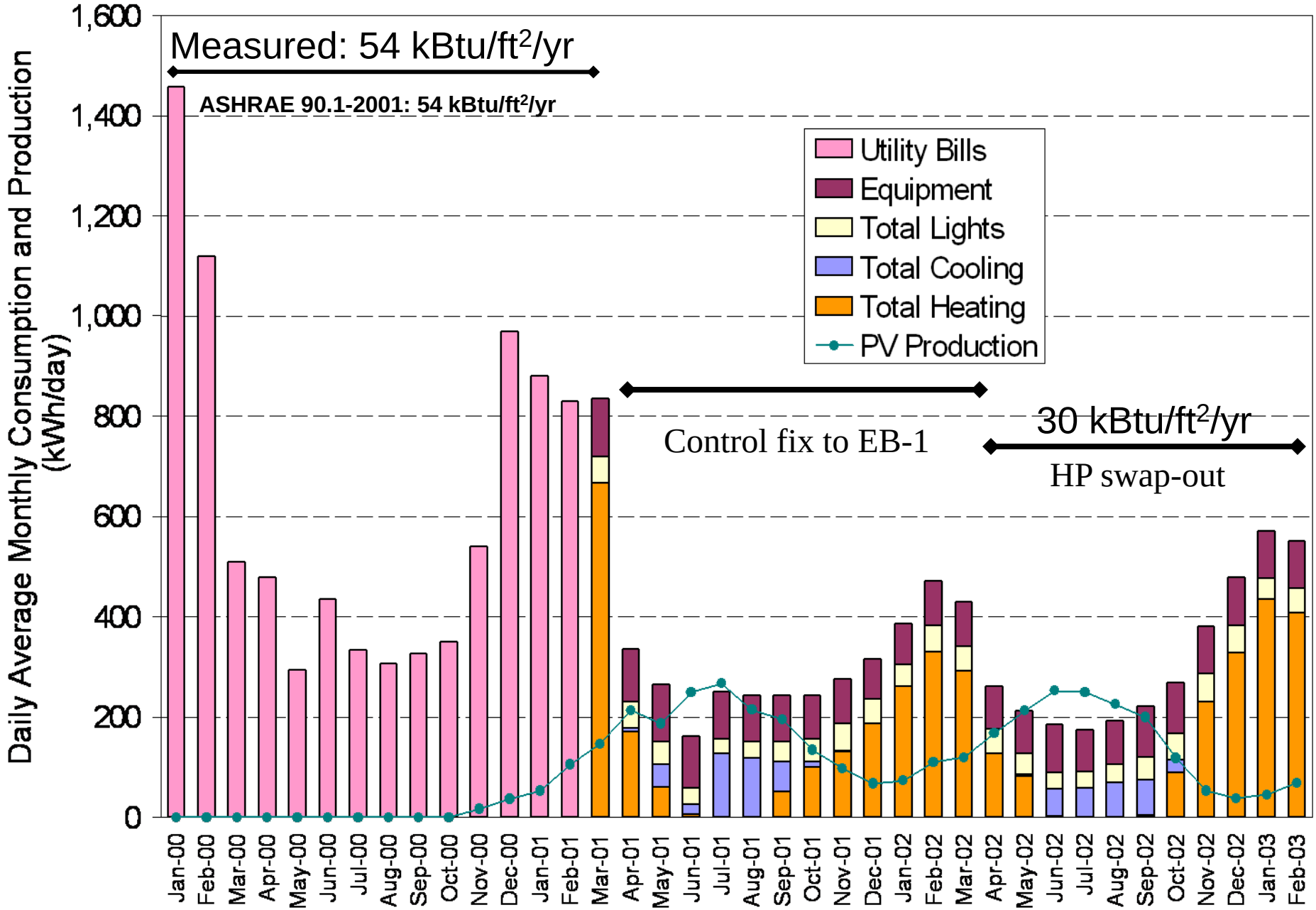
On the Path to Commercial ZEBs

Oberlin Lewis Center for Environmental Studies

-14,000 ft2 Classroom and Offices

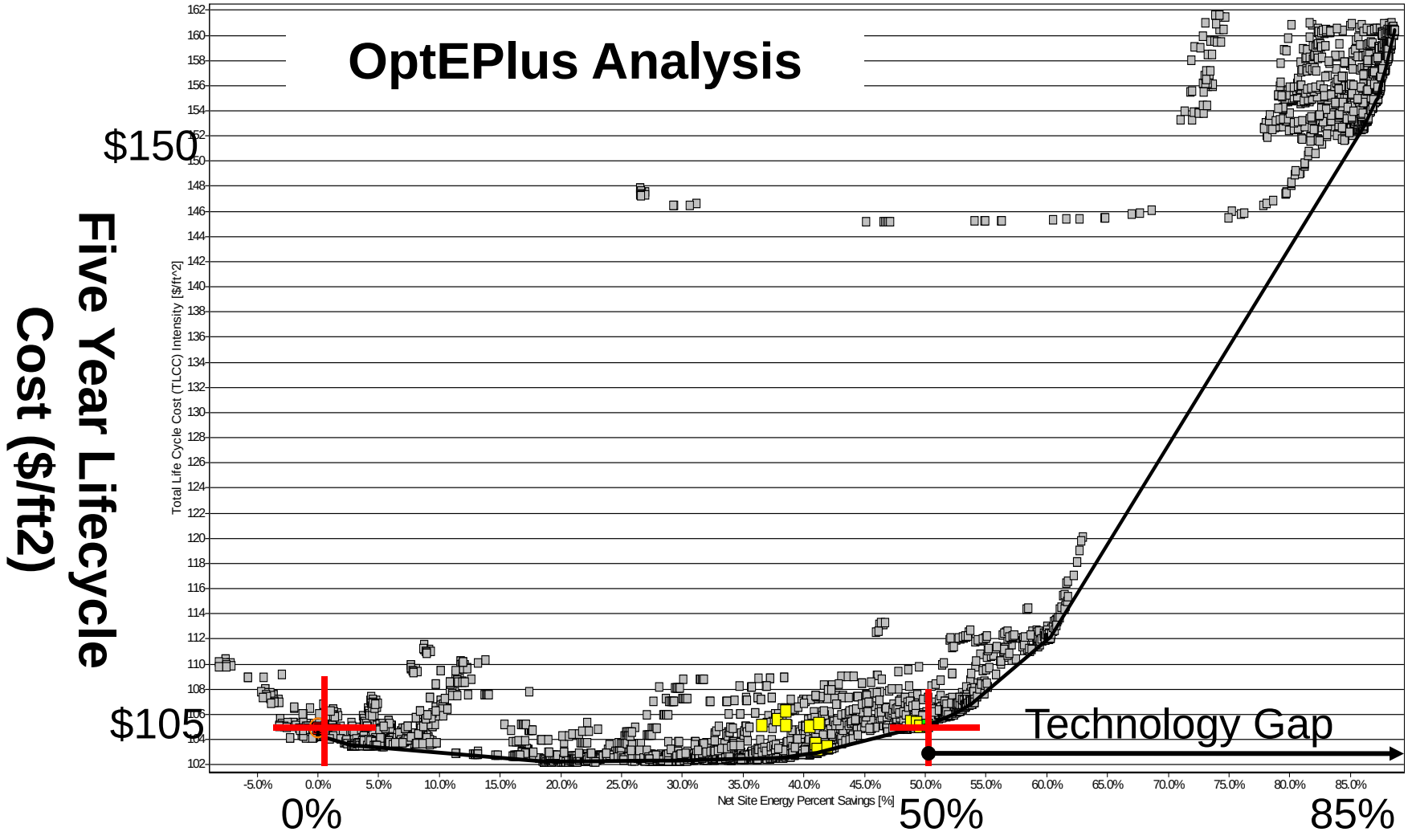
- 60 kW PV
- Daylighting
- Natural Ventilation
- Ground Source Heat Pump

Oberlin Before & After Fixes

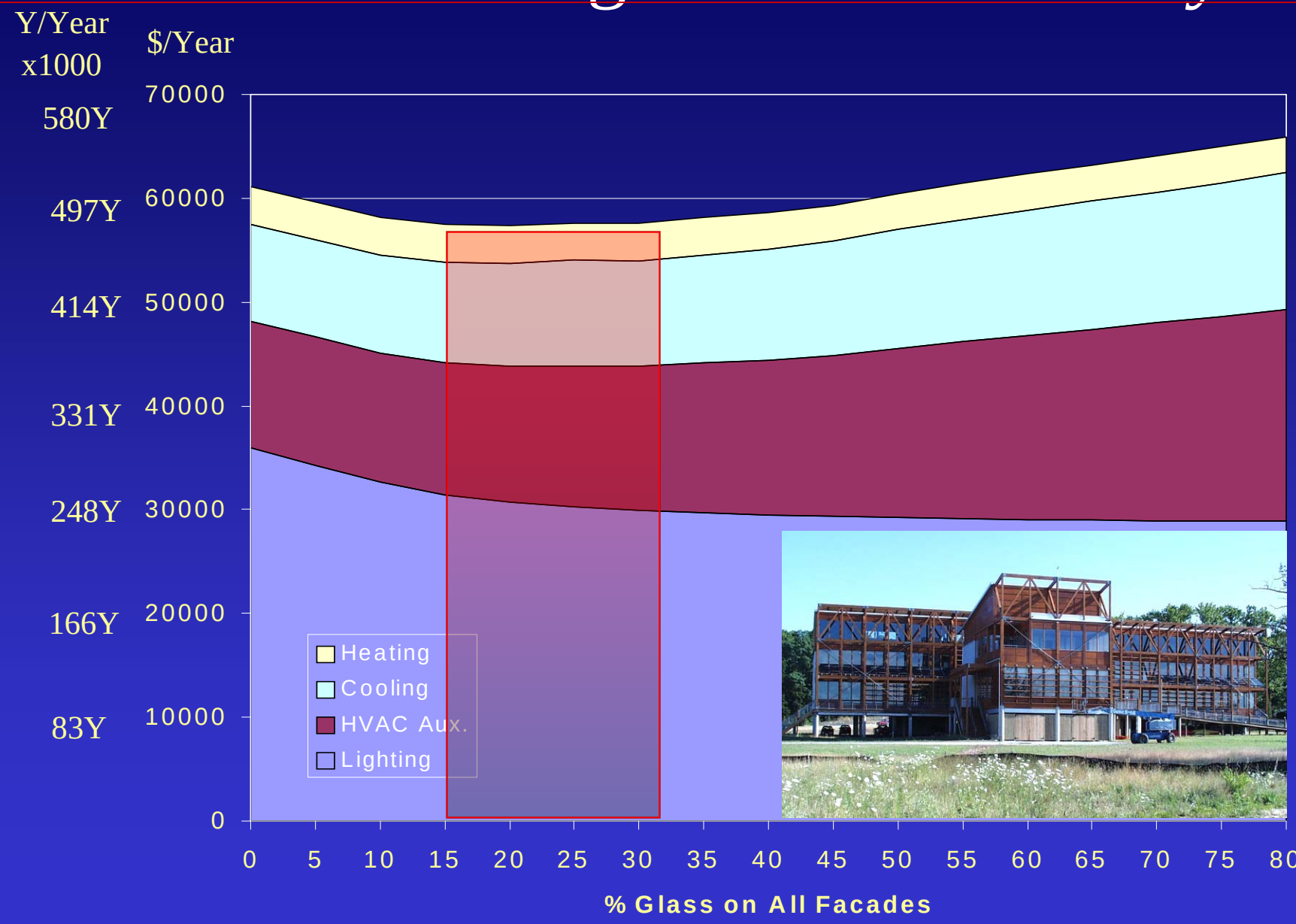


Oberlin PV Carport

Mid Size Retail Box, Boulder, CO



Low-E Glazing - *Economic Analysis*



Signature Center Denver West


NREL
National Renewable Energy Laboratory

Lessons: Get an A&E that uses Energy Design Process

- In house energy modeling or consultant
- Energy simulation used early and often throughout design process
- Charettes: whole design team in sync
- Commissioning: pre and post occupancy
  - Innovative system controls and interactions will take awhile to perfect
- Beware of A&Es who use daylighting as a license to glaze!
- Use “aesthetic” budget to pay for architectonic energy features

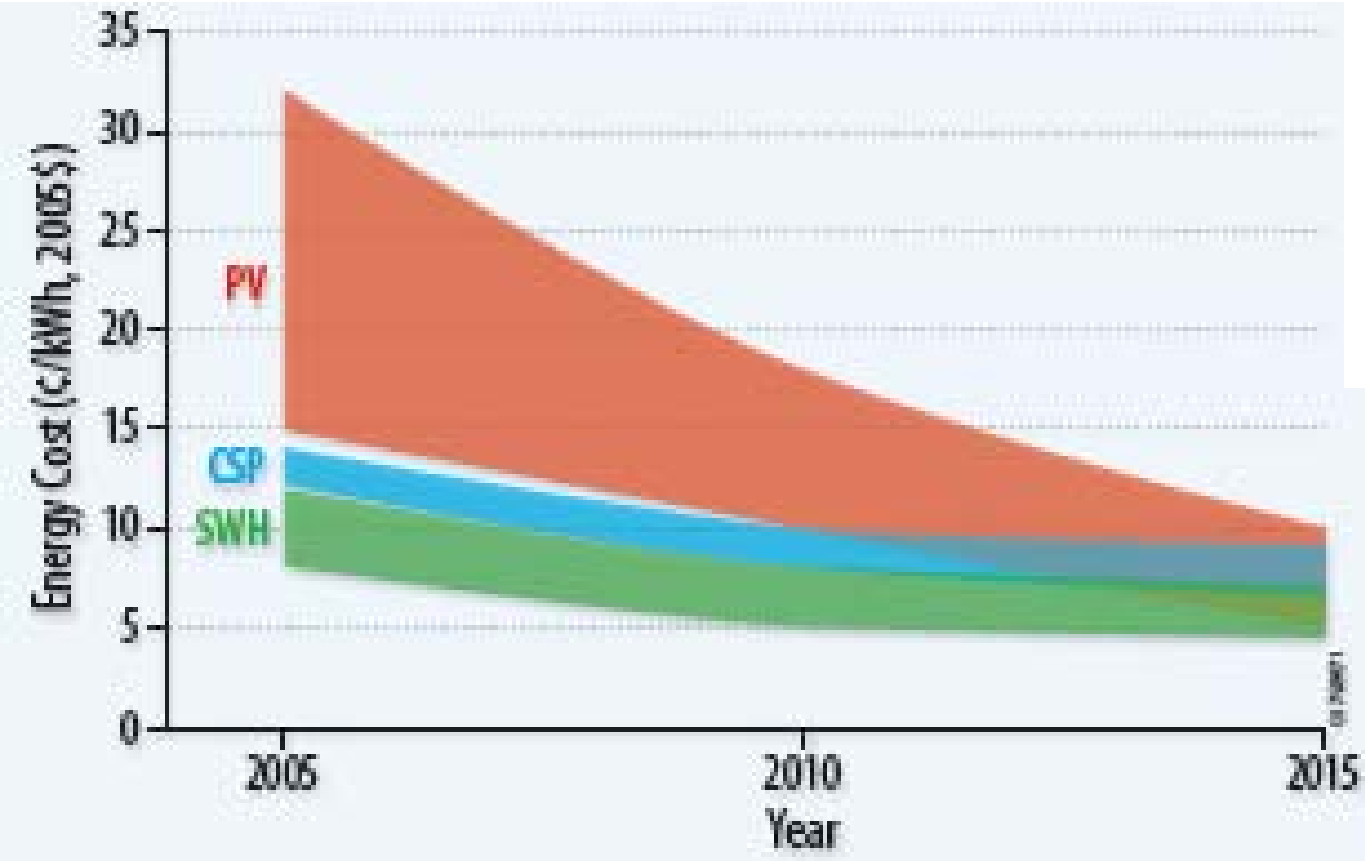
How to Achieve ZEB…

1. Envelope and Orientation to Reduce Loads
   - Well Insulated roofs, walls, floors, windows (with shading)
2. Envelope and Orientation to Meet Loads
   - Daylighting
   - Passive Solar Heating, Trombe walls
   - Natural Ventilation
   - Cool Towers
3. Lighting design to utilize day-lighting
4. Plug loads
   - Design vs. owner loads
5. Climate specific HVAC designed for the remaining loads
6. Commissioning (making sure the building works)
7. Metering and evaluation
8. Make it Simple

9. Site Specific Renewable generation within footprint, site, off-site
10. Small amounts of RECs

Where are we now?

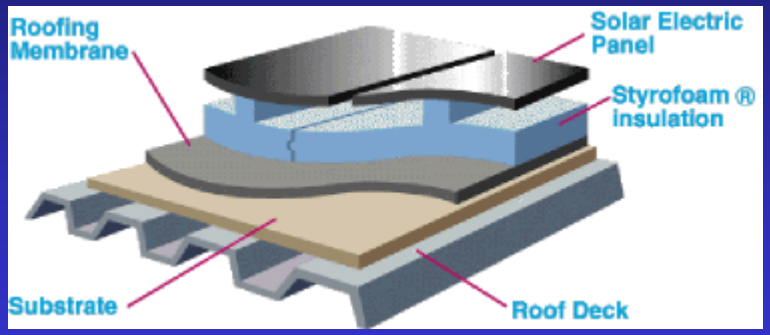
Solar Technology



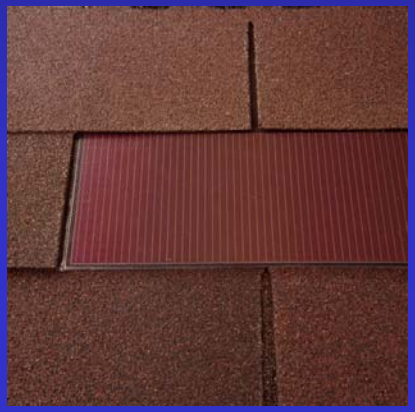
SAI Research Targets

BIPV Product Examples

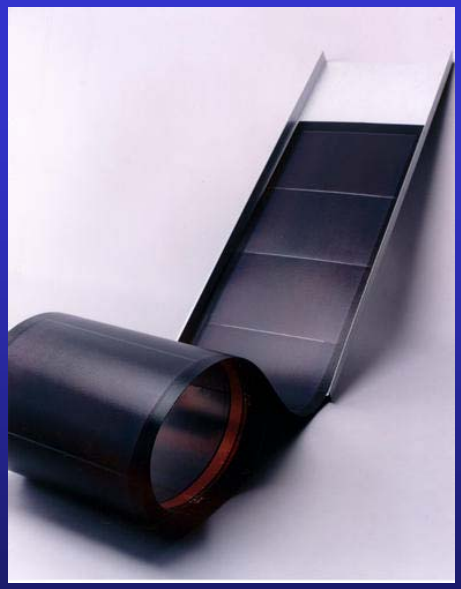
Flexible roof-top PV shingles



PowerGuard® system



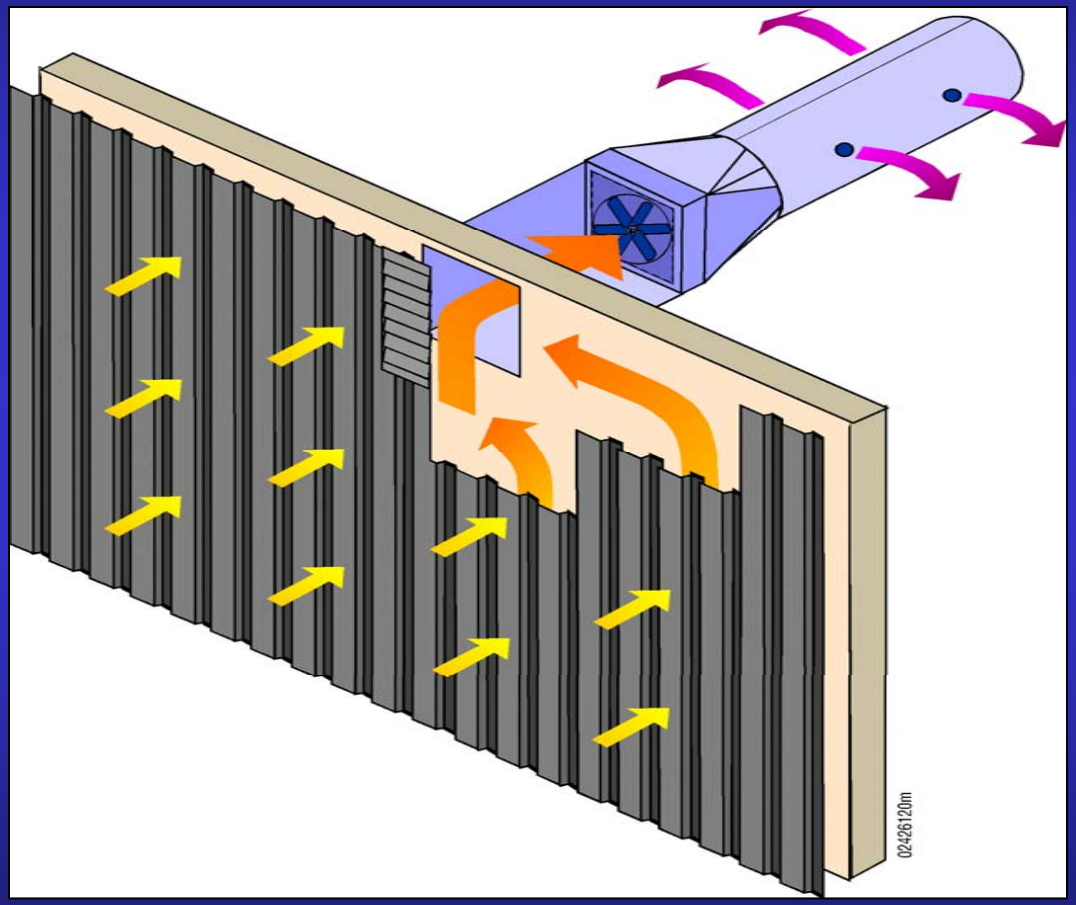
Light, flexible PV roofing shingle for direct rooftop mounting



Building-integrated PV metal roofing modules

PV roofing shingles

Solar Ventilation Preheating

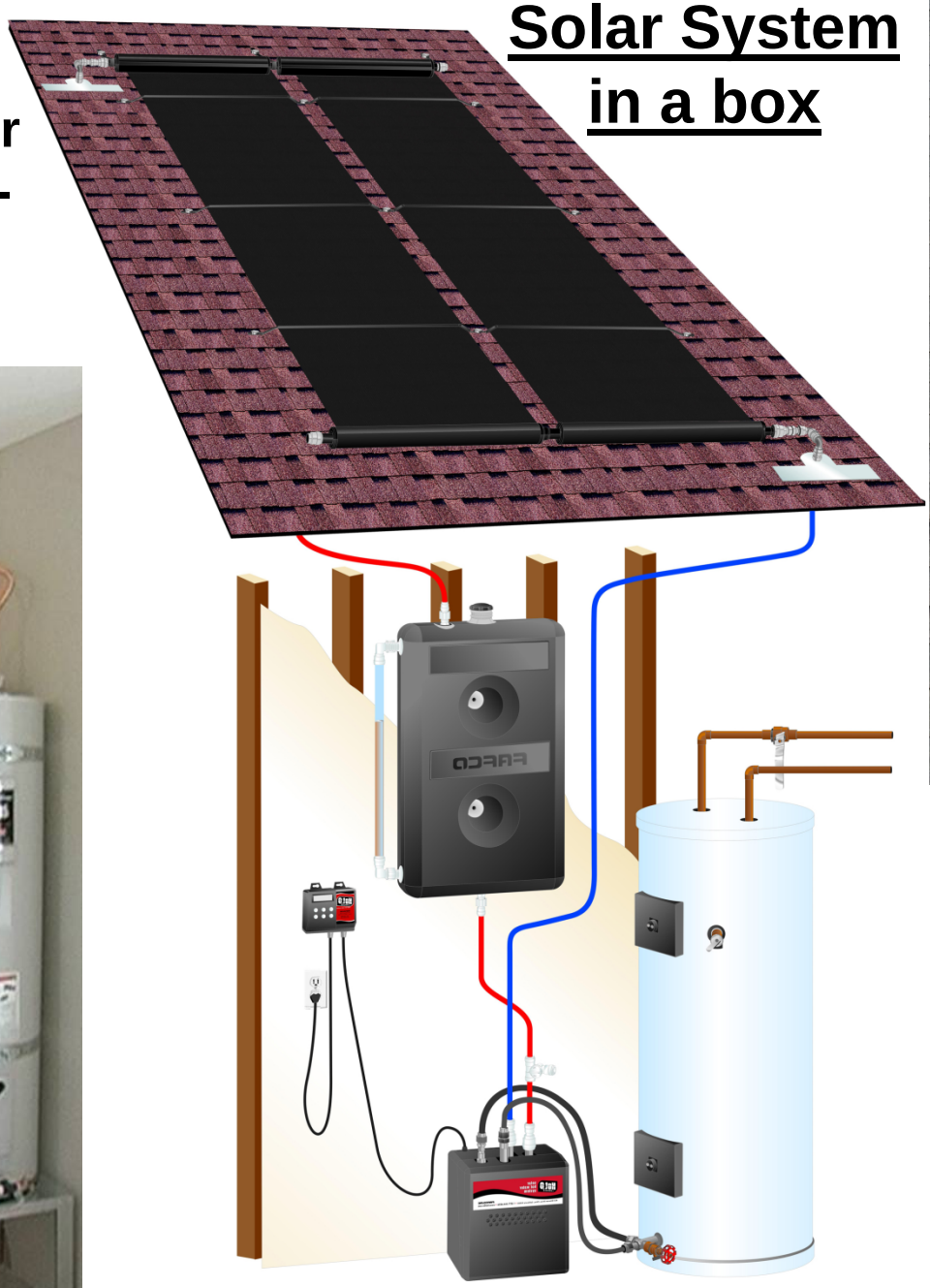


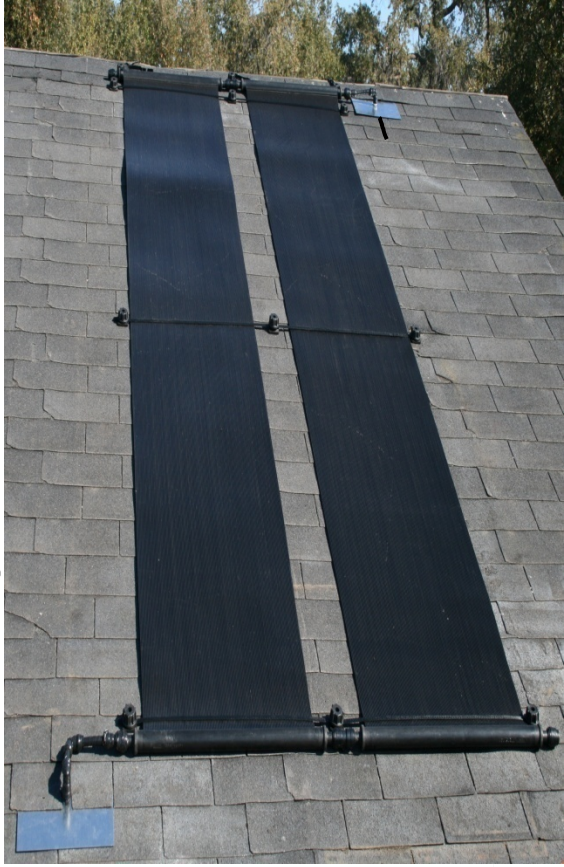
Federal Express -- Package Handling
Denver, CO

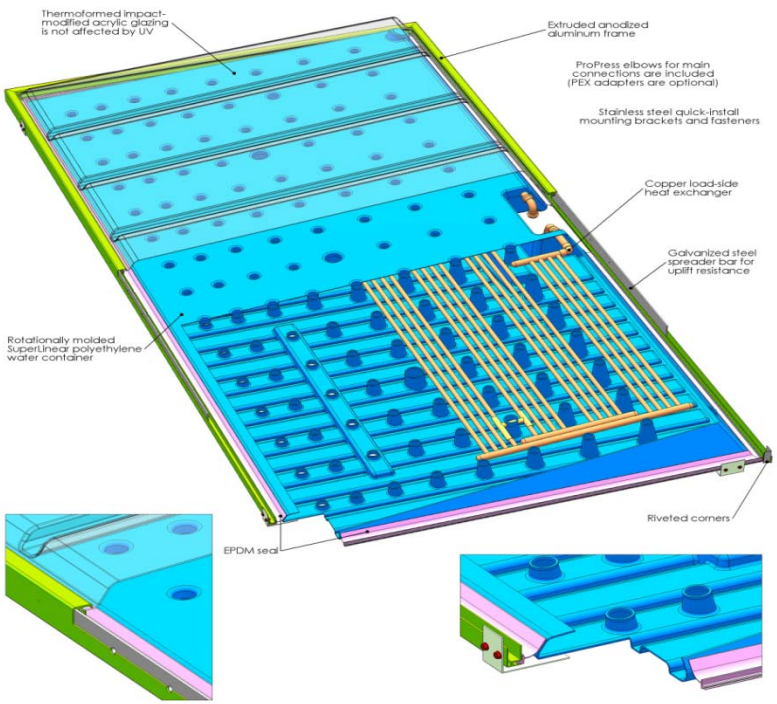
Collector Area:	5000 ft^2
Air Flow:	45,000 cfm
Heating Fuel:	natural gas

Solar System in a box

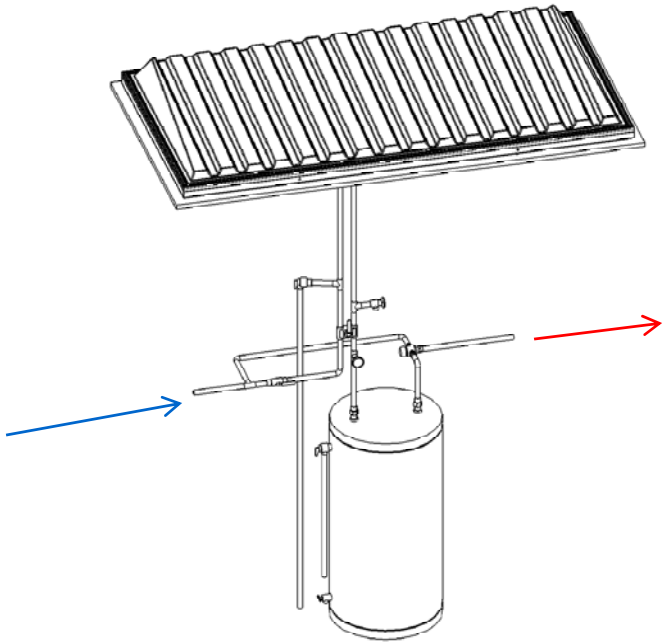
FAFCO polymer unglazed drain-back solar hot water system





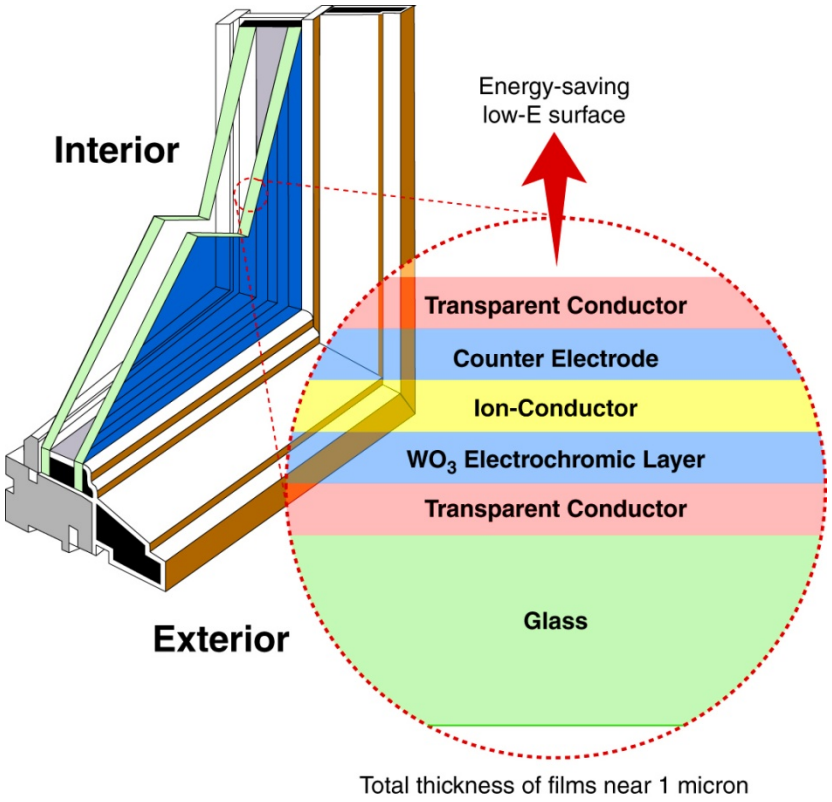

Thermoformed impact-modified acrylic glazing is not affected by UV
Extruded anodized aluminum frame
ProPress elbows for main connections are included (PEX adapters are optional)
Stainless steel quick-install mounting brackets and fasteners
Copper load-side heat exchanger
Galvanized steel spreader bar for uplift resistance
Rotationally molded SuperLinear polyethylene water container
Riveted corners
EPDM seal


Sun-Cache polymer glazed solar hot water system



SunEarth / PVT Solar Combined PV/Thermal Array

Electrochromic Windows



It’s not smoke. It involves some mirrors. We can do it if we have the national will!

End