Beyond "Green" & "Passive vs. Active":

Benefiting people & the planet through verified net-carbon-neutral homes

Presented by:

ECOFUTURES BUILDING, INC
DESIGN & CONSTRUCTION WITH CONSCIENCE

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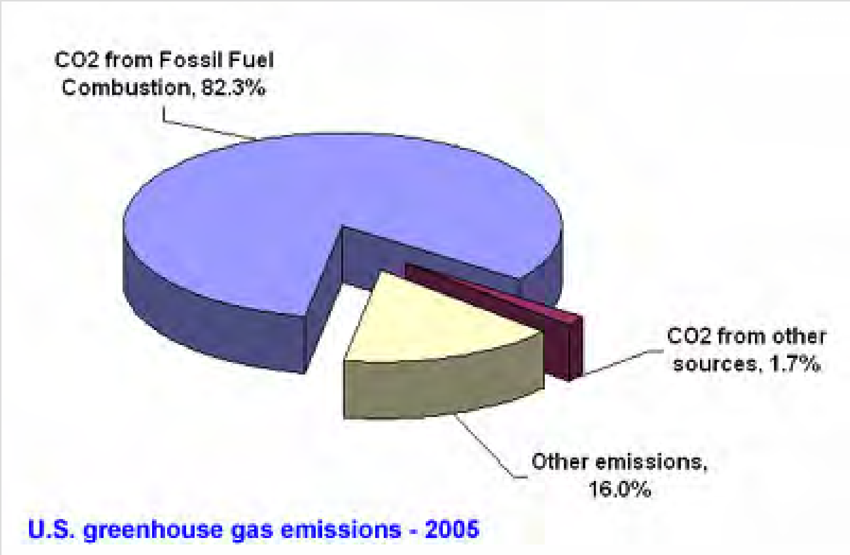
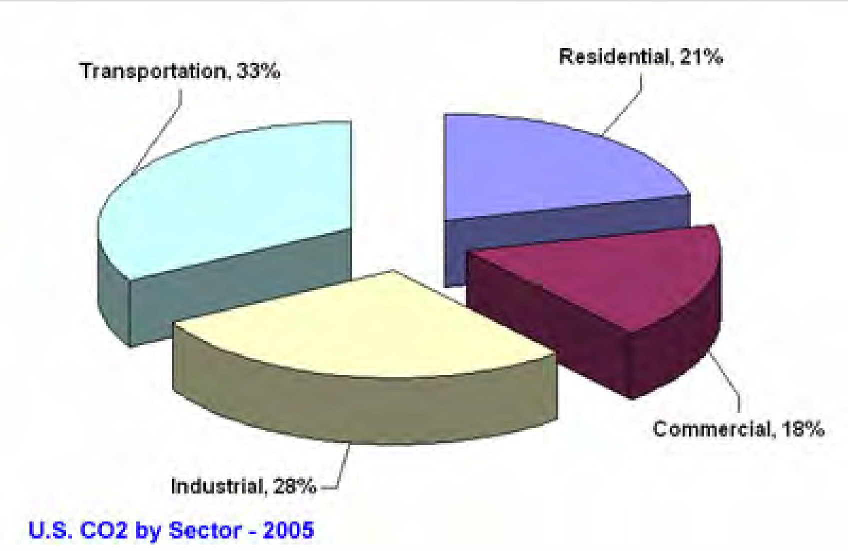
For:

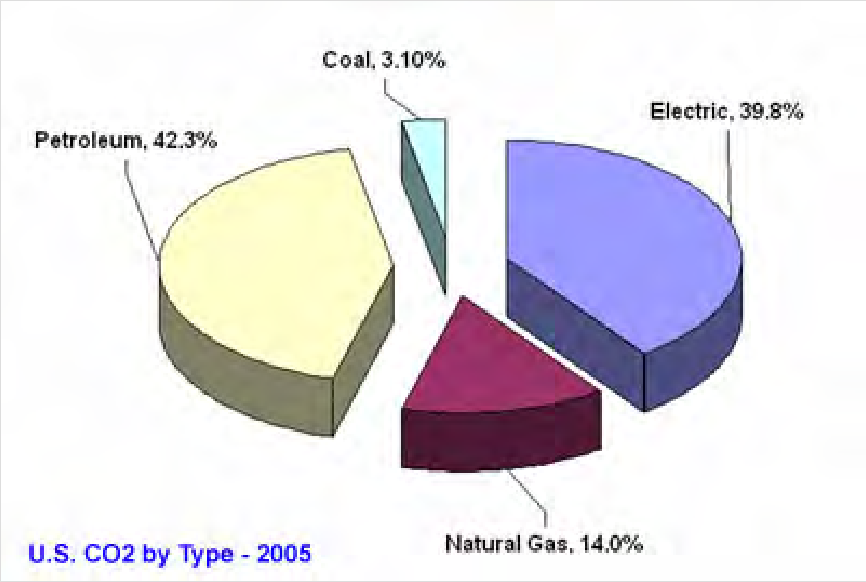
PHIUS
Passive House Institute US

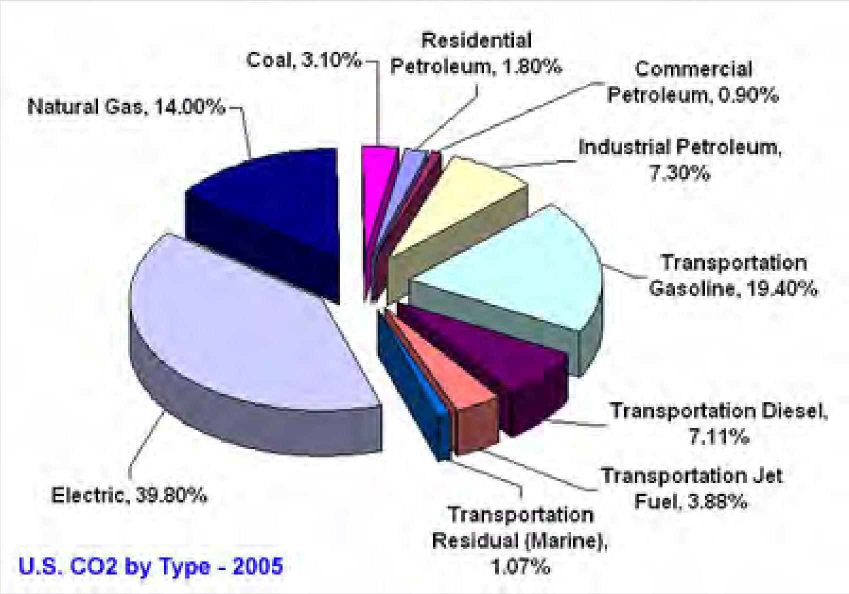
2007 Passive House Conference
Hosted by Eco-Lab
Urbana, IL

CO2 and GHG Emissions by Sector, 2005









Source: Energy Information Administration, 2007 http://www.eia.doe.gov/oiaf/1605/ggrpt/

Reducing Carbon Emissions

What are consumers currently willing to do?

- Buy RECs and offsets

- Drive hybrid cars

- Change consumption habits

- Support clean energy

On the one hand:

From a climate change perspective, we cannot afford not to afford these and other measures to move toward carbon neutrality.

But on the other hand:

Consumers have to want to afford these measures

So measures must be:

- Affordable
- Appealing
- Accessible

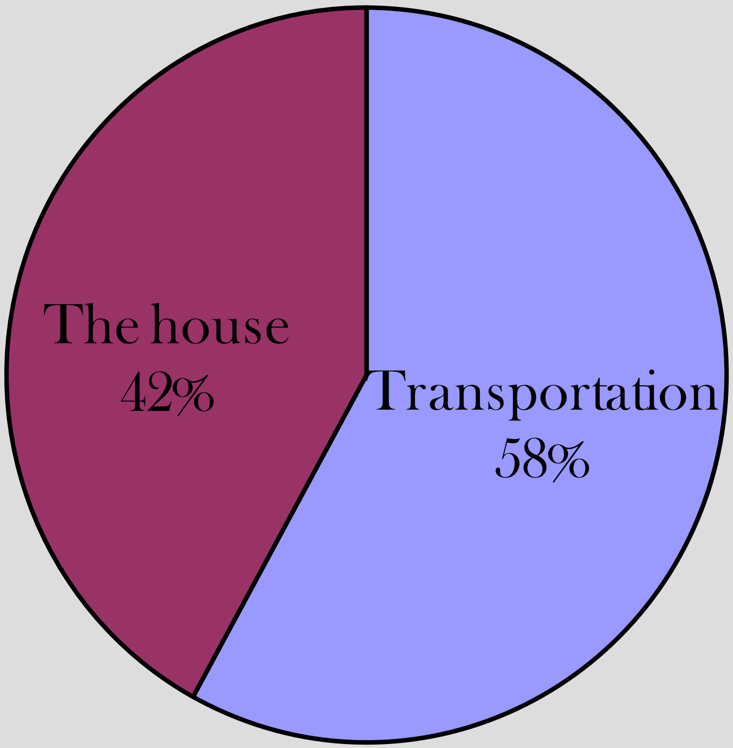
- And, Proven:
  - Lower energy bills
  - More comfortable
  - Safer

Energy Efficient & Carbon Neutral Homes Speak for Themselves

- Beautiful
- Desirable
- Comfortable
- Safer
- Healthier
- Durable
- Valuable
- Cost Neutral

"Profitably Decarbonizing" – the new lingo

Average U.S. Family's Greenhouse Gas Emissions Sources



Source: City of Boulder Office of Environmental Affairs

Future plug-in Hybrid

Solar electricity from panels on house

Cost Neutrality

Means

Same Cost of Ownership

Zero annual energy bills or less

- Principal
- Interest
- Taxes
- Insurance
- Energy
- Water

P.I.T.I.E. & W.

One city's response:

Boulder's Green Points Revision

(PASSED TUESDAY 10/30/07)

10-7.5-3 Mandatory Green Building Requirements

(a) Energy Efficiency. An applicant for a building permit for each new dwelling shall demonstrate that the building is more energy efficient than a building that meets the minimum requirements of Chapter 10-7, "International Energy Conservation and Insulation Code," B.R.C. 1981. Table 1 lists the minimum energy efficiency requirements.

TABLE 1 – Tiers for Energy Efficiency ~~and Footprint~~ Thresholds ~~Recommendations~~

Type of Project	Square Footage	Energy Efficiency Thresholds Above Code
New Construction	~~*Up to 1,500*~~	~~*15 percent more energy efficient than 2006 IECC*~~
	~~*1,501*~~ *Up to* 3,000	30 percent more energy efficient than 2006 IECC
	3,001-5,000	50 percent more energy efficient than 2006 IECC
	5,001 and up	75 percent more energy efficient than 2006 IECC
Multi-unit Dwellings	Applies to all	30 percent more energy efficient than 2006 IECC*

All new construction 5000 SF+
Will be ~ HERS 20

One county's response:

Boulder County Commissioners will soon pass the most stringent energy code in the nation

BOULDER COUNTY – BUILDSMART

a. New home construction

Size of Development in Square Feet	**Required HERS Index** for New Structures	Maximum Allowable Annual CO_2 Emissions
Up to 1000	85	20,000 lbs
1001 – 3000	60	10,000 lbs
3001 - 5000	**25 with required on-site renewable offsets, under Section 4, below**	**5,000 lbs**
5001 and larger	**Less than 10**	**0 lbs**

Every home 5001 SF+ must be zero energy AND zero carbon

Boulder County's *BuildSmart* (cont.)

Verification –

1. At building permit application - A RESNET energy model must be submitted with the building permit application showing that the proposed structure meets the required standards.

2. During construction - A certified energy rater must perform a pre-drywall verification of the energy rater's inspection to the Boulder County Building Division prior to the scheduling of a Drywall Inspection.

3. Prior to Certificate of Occupancy - Upon completion of construction, a blower door test and duct blaster test (if applicable) must be performed by the energy rater and documentation verifying that the structure meets the applicable HERS Index and carbon emissions standards must be submitted to the Boulder County Building Division prior to issuance of a Certificate of Occupancy.

Mandatory – All new construction must meet the applicable HERS Index and carbon emissions standards outlined in Table 1.

Boulder County's ***BuildSmart*** (cont.)

Dealing with Retrofits and Additions…

b. Additions and renovations to existing residential structures greater than 500 square feet in size which are not considered new construction under Section 3.a., above

For additions and renovations to an existing structure of a size greater than 500 square feet in size, which will result in either a total floor area of **less than 3,000 square feet or in less than 3,000 square feet** of the existing structure being renovated, the goal is to bring that existing home, **with the addition or renovation to a HERS Index of 85.**

This will require that a Home Energy Rating for the home must be completed and a RESNET certified energy rater must submit a report outlining the steps which would be required to bring the home, with the addition or renovation to a HERS Index of 85.

Building Homes that Last:

What Builders, owners, designers and regulators need to know

Building Science Education is a crucial element that must be included in every green building program or regulation

WHAT CAN WE DO:

- Classes, seminars and webinars for builders? A "scared straight" program?
- Mandatory yearly class attendance in order to apply for permits?
- Written test with each permit application?
- Homeowner/builder walk-through and maintenance education courses or resources?
- Mortgages & financing more readily available to homes built by "certified" builders (a dream); permit fees for builders who have completed and demonstrated training?

CERTIFICATION, CLASSES AND TESTS:

- Joe Lstiburek, Building Science Consultant www.buildingscienceconsulting.com/
- John Krigger, Saturn Resource Management www.srmi.biz/
- Building Knowledge Consulting (see below) www.buildingknowledge.com/

Building Homes that Last (cont.)

THIRD PARTY VERIFICATION and QUALITY CONTROL SPECIALISTS
Should be consulted with before building begins

- Professional Investigative Engineers (“PIE) www.callpie.com/
- The Architectural Alliance Group, LLC www.aag-adr.com/
- Ian Mackinlay Architecture (Cold and Snow Experts) www.ima-arch.com/

BUILDING SCIENCE RESOURCES

- Building Science Corporation
  www.buildingscienceconsulting.com
- Building Knowledge www.buildingknowledge.com/
- Saturn Resource Management www.srmi.biz
- HomeSmart www.home-smart.org/
- Best of Building Science www.bestofbuildingscience.com/

BUILDING AMERICA PROGRAM

- Building America Program
  www.eere.energy.gov/buildings/building_america/
- Journal of Light Construction www.jlconline.com/
- Energy and Environmental Building Association www.eeba.org/

A key resource on tough building science topics:

19-page article with decision trees, details, assembly sections, and essential guidelines on how to build walls, floors and ceilings

Vapor Barriers and Wall Design

Ideally, building assemblies would always be built with dry materials under dry conditions, and would never get wet from imperfect design, poor workmanship or occupants. Unfortunately, these conditions do not exist.

It has been accepted by the building industry that many building assemblies become wet during service, and in many cases start out wet. Furthermore, the industry has recognized that in many circumstances it may be impractical to design and build building assemblies which never get wet. This has given rise to the concept of acceptable performance. Acceptable performance implies the design and construction of building assemblies which may periodically get wet, or start out wet yet are still durable and provide a long, useful service life. Repeated wetting followed by repeated drying can provide acceptable performance if during the wet period, materials do not stay wet long enough under adverse conditions to deteriorate.

Good design and practice involve controlling the wetting of building assemblies from both the exterior and interior. They also involve the drying of building assemblies should they become wet during service or as a result of building with wet materials or under wet conditions.

Moisture Balance

Moisture accumulates when the rate of moisture entry into an assembly exceeds the rate of moisture removal. When moisture accumulation exceeds the ability of the assembly materials to store the moisture without degrading performance or long term service life, moisture problems result.

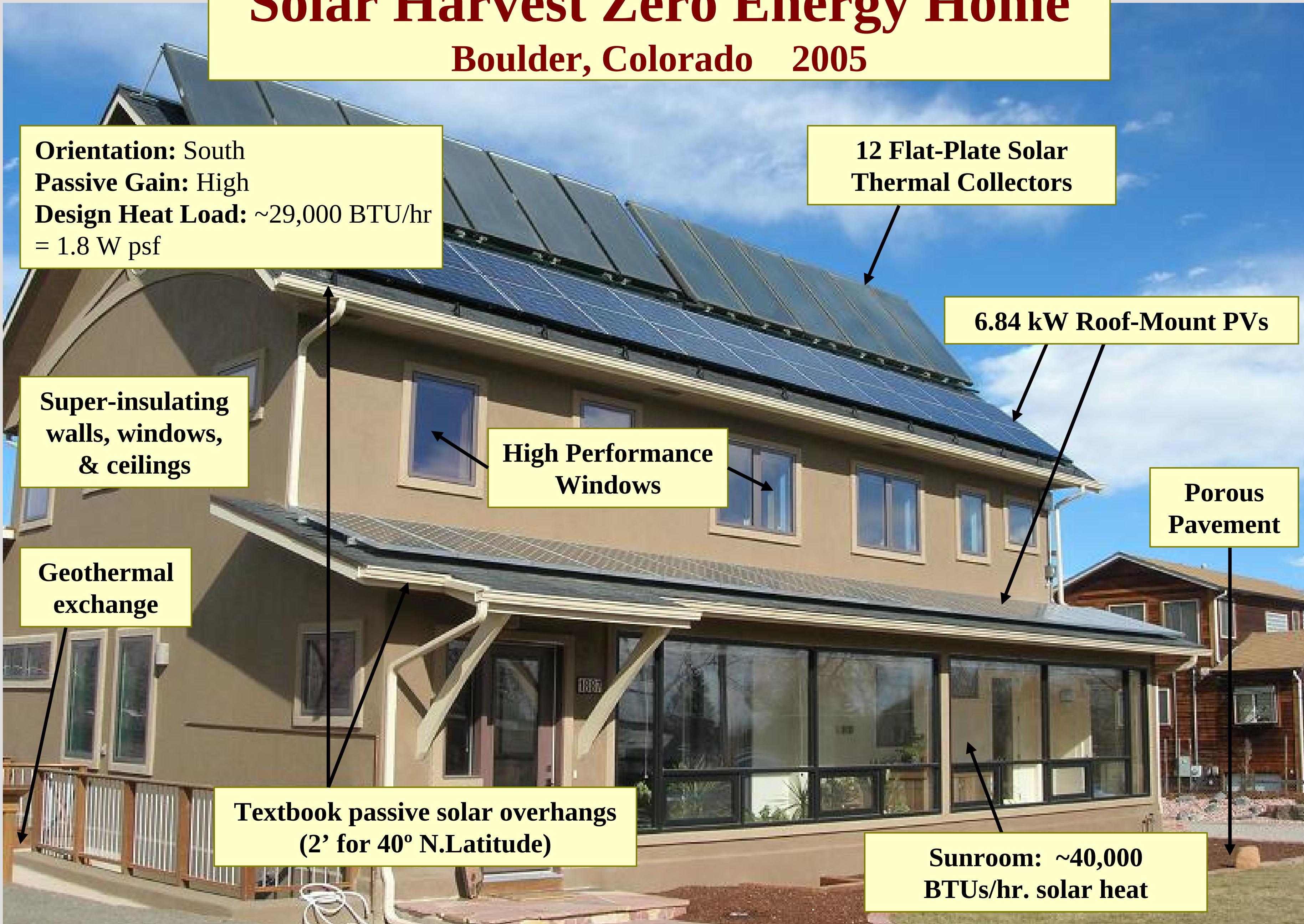
Building assemblies can get wet from the building interior or exterior, or they can start out wet as a result of the construction process due to wet building materials or construction under wet conditions. Good design and practice address these wetting mechanisms.

See their website!

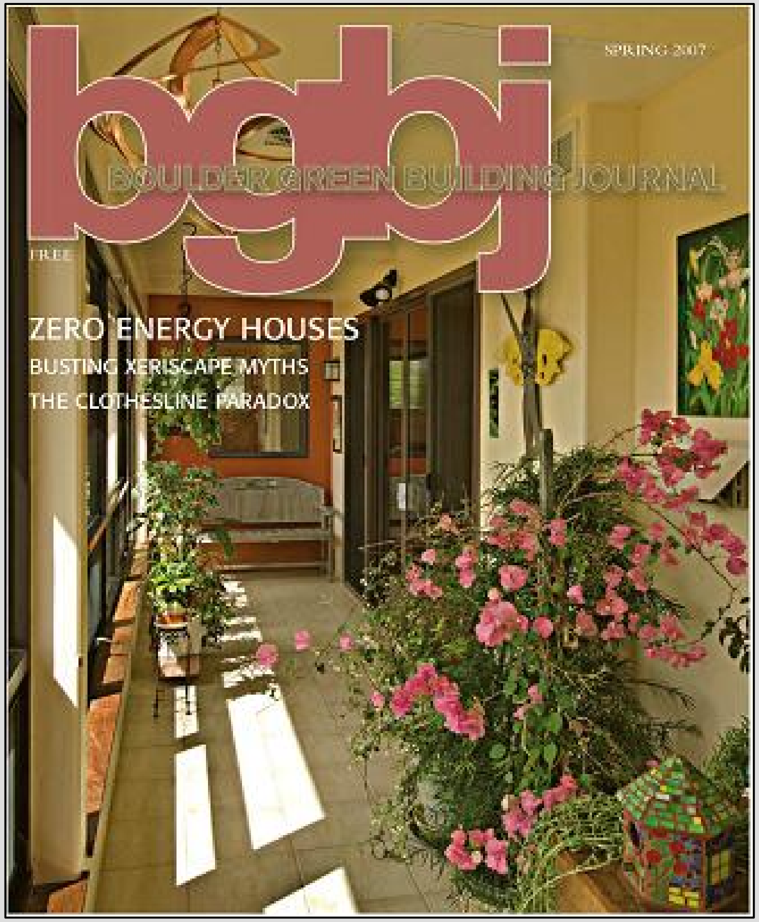
www.buildingsciencecorp.com

Solar Harvest Zero Energy Home

Boulder, Colorado 2005



Basic Principles for Comfort & Energy Efficiency



- Tight Building Envelope
- Super-insulation

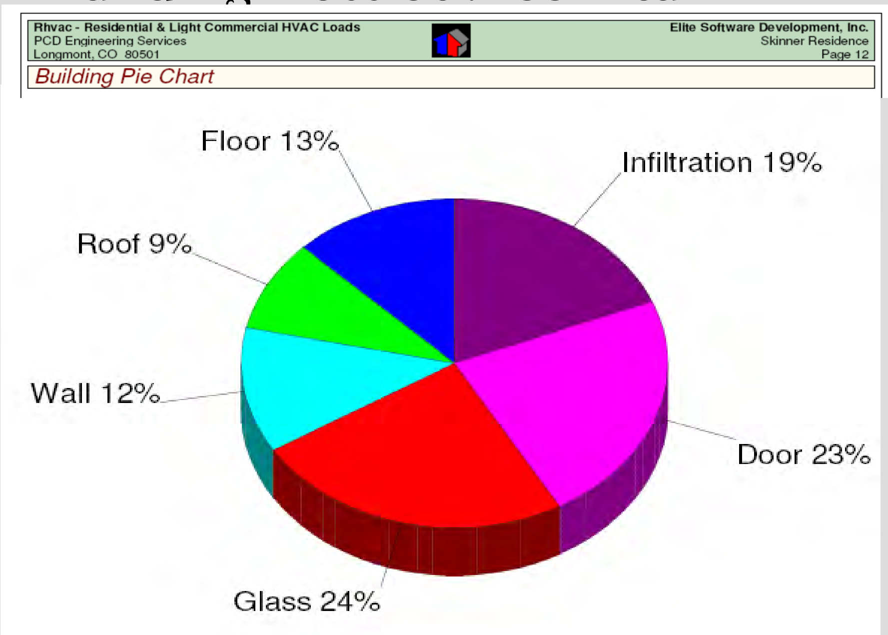
  ~1.8 W PSF
  Design Heat Load

- Continuous air barrier
- Passive and Active Solar Gain
- PVs and Electrical Efficiency
- Non-toxic construction materials and household products

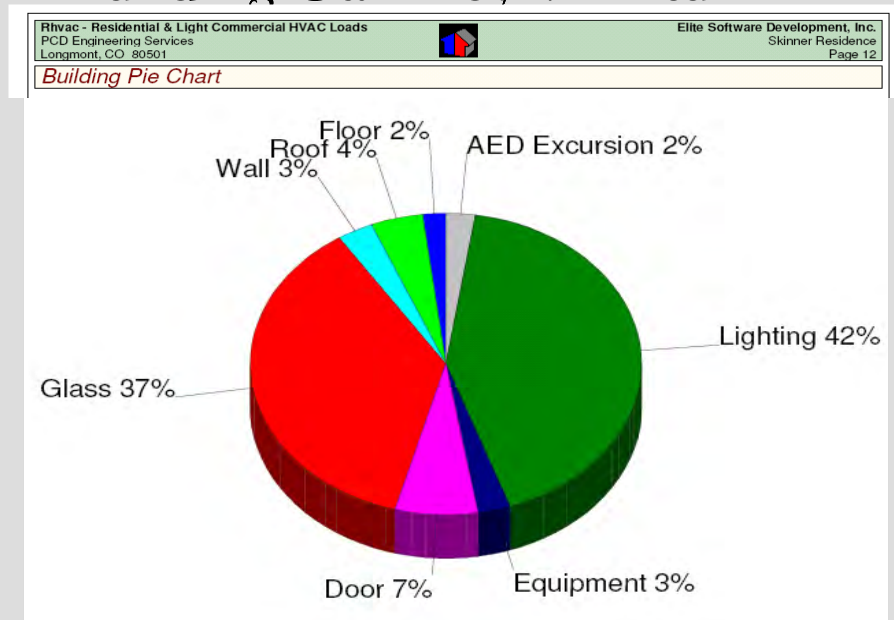
Build Tight, Ventilate Right

Doubling Insulation Value per Inch

Building Loss 59.285 Btuh



Building Gain 25,274 Btuh



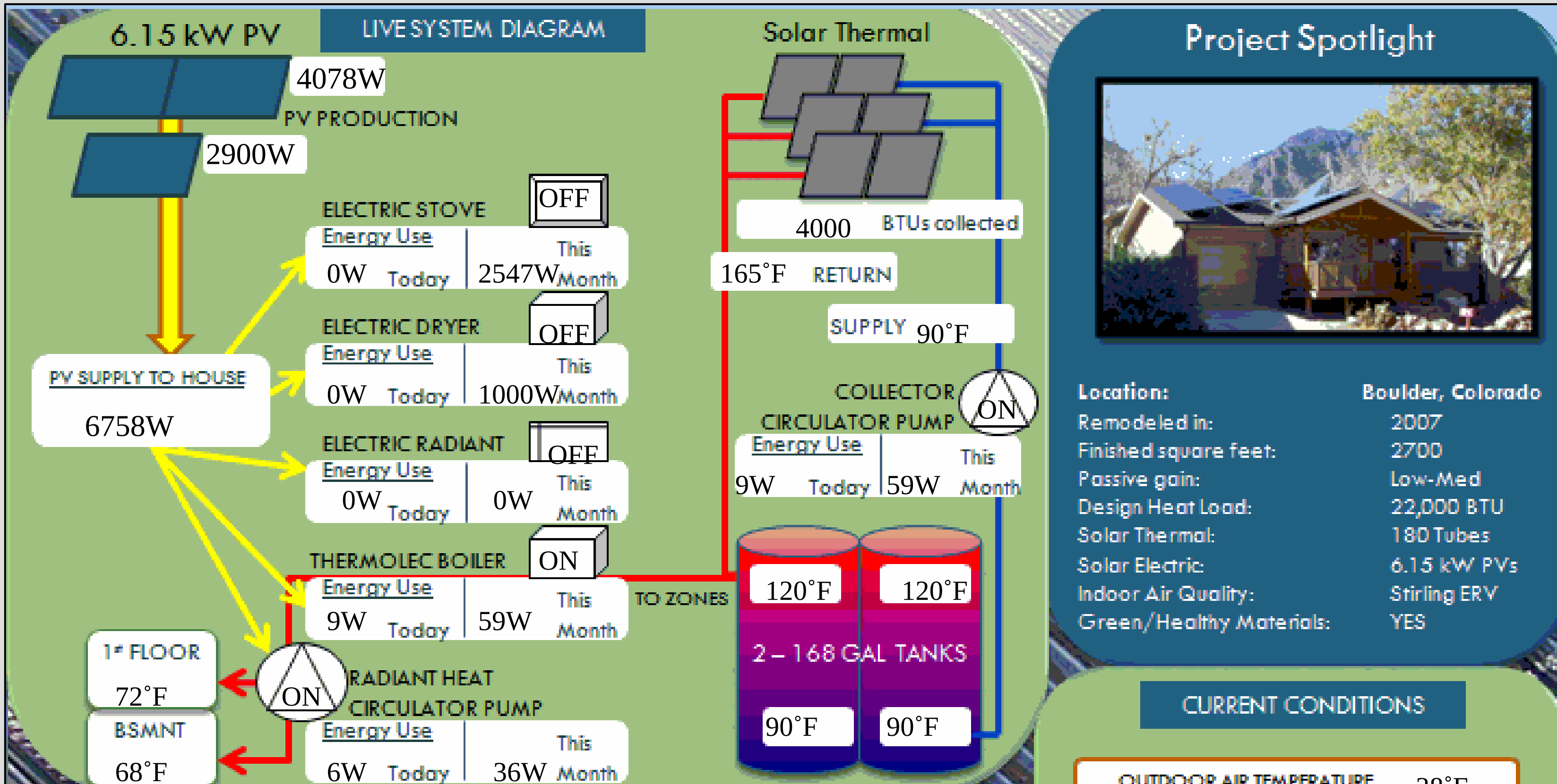
"It's all about the windows and doors!"

Reduce home's overall heat loss by about 6% in homes with already thermally broken assemblies…doesn't change mechanicals or renewables.

Actual Solar Harvest Performance, Stories 11/05 – 9/06

- Warm and toasty all winter, cool and refreshing this summer
- December dinner party: One guest heard it was a "solar house" & came prepared – long underwear and flannel shirt…but with nighttime outdoor temp at 15° after a sunny day, and with radiant underfloor heat off, at the dining room table it was 73°…offered ice packs and wet towels to help him out, and opened a window…
- February cold snap: After last sun midday Tuesday, house held heat until midday Thursday before underfloor heat engaged. Minus 18°, home stayed 68-70° and comfortable.
- 3 a.m. and minus 7°, bedrooms would stabilize at 64° – with radiant heat *off* – due to occupants generating ~400 BtU/hr.

EnergyNET Home Performance Monitor



Net Energy Balance

	CURRENT	TODAY	THIS MONTH
PV PRODUCTION	4758W	9257W	14876W
HOUSE CONSUMPTION	800W	1425W	12348W
NET BALANCE	3958W	7832W	2528W
MONEY EARNED	$00.83	$15.83	$26.83
LBS CO2 SAVED	62lbs	657lbs	1257lbs

CURRENT CONDITIONS

OUTDOOR AIR TEMPERATURE	38˚F
SOLAR INSOLATION	4000
BASEMENT AIR TEMPERATURE	68˚F
INDOOR AIR TEMPERATURE	72˚F
INDOOR RELATIVE HUMIDITY	13%

LAST UPDATED:

DATE	
TIME	

An <u>*Honest Assessment of Net Energy*</u>

- The analysis that every energy system and energy efficiency measure should be subject to…
- Home energy monitoring leads to <u>**VERIFIED PERFORMANCE**</u>. This is how to make an honest assessment.

Solar Harvest: TOTAL HOUSEHOLD ENERGY USE (Heating + Cooling + All Other) = ~2.1 kWh/sf/year

Points of Departure

From… Solar Harvest

- Passive cooling
- Flat Panel Collectors
- Whole-house radiant floor heat

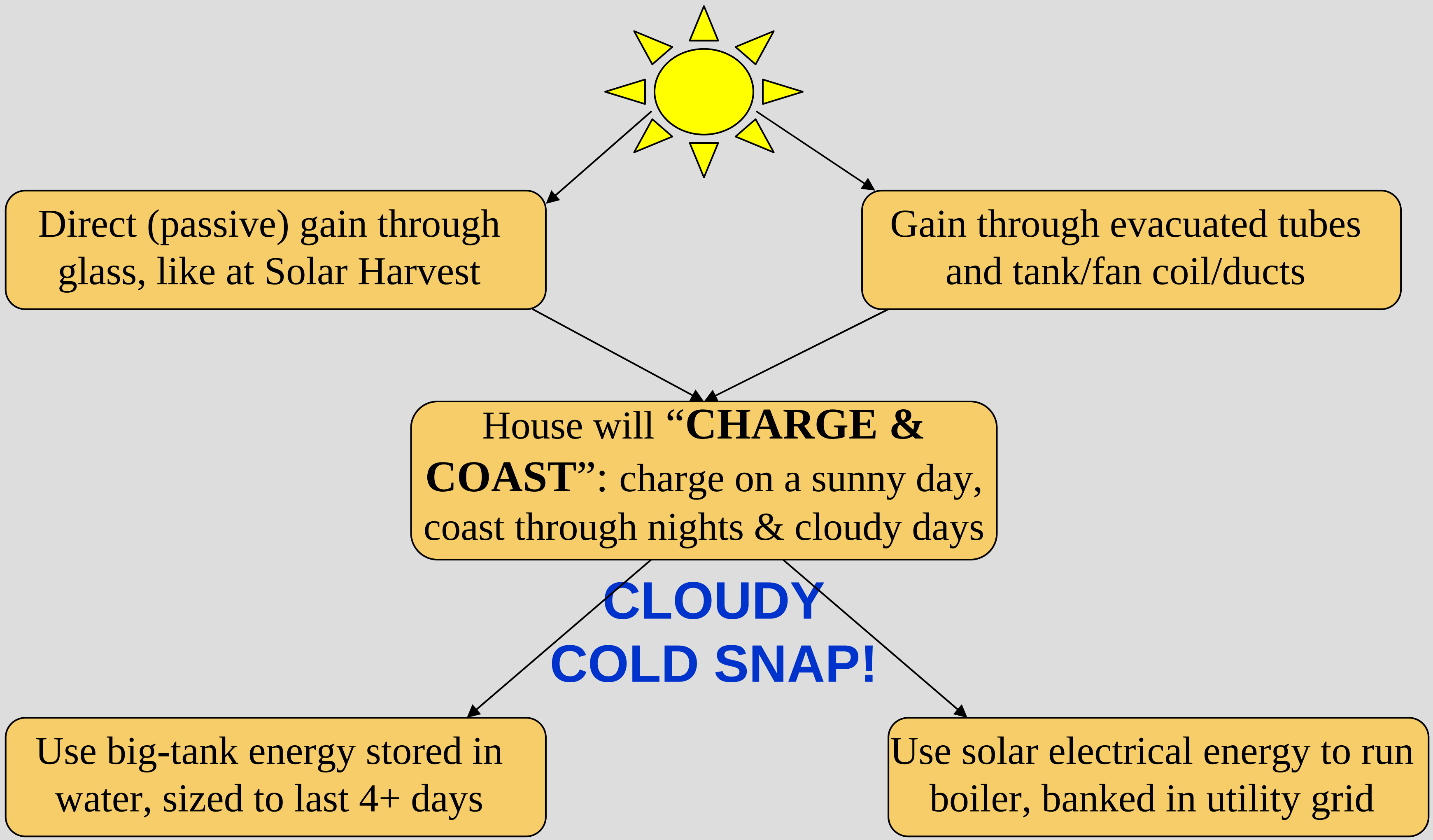
And most importantly…

- **ON-SITE** cloudy cold-snap storage
  - large tank/water

To… Broomfield ZEH

- High-efficiency mechanical cooling
- Evacuated Tubes work in
  - Lower air temperatures
  - Lousier solar conditions
- Solar-heated hydronic forced air heat
  - More responsive
- **GRID-STORED** cloudy cold-snap energy
  - **From PVs on site**

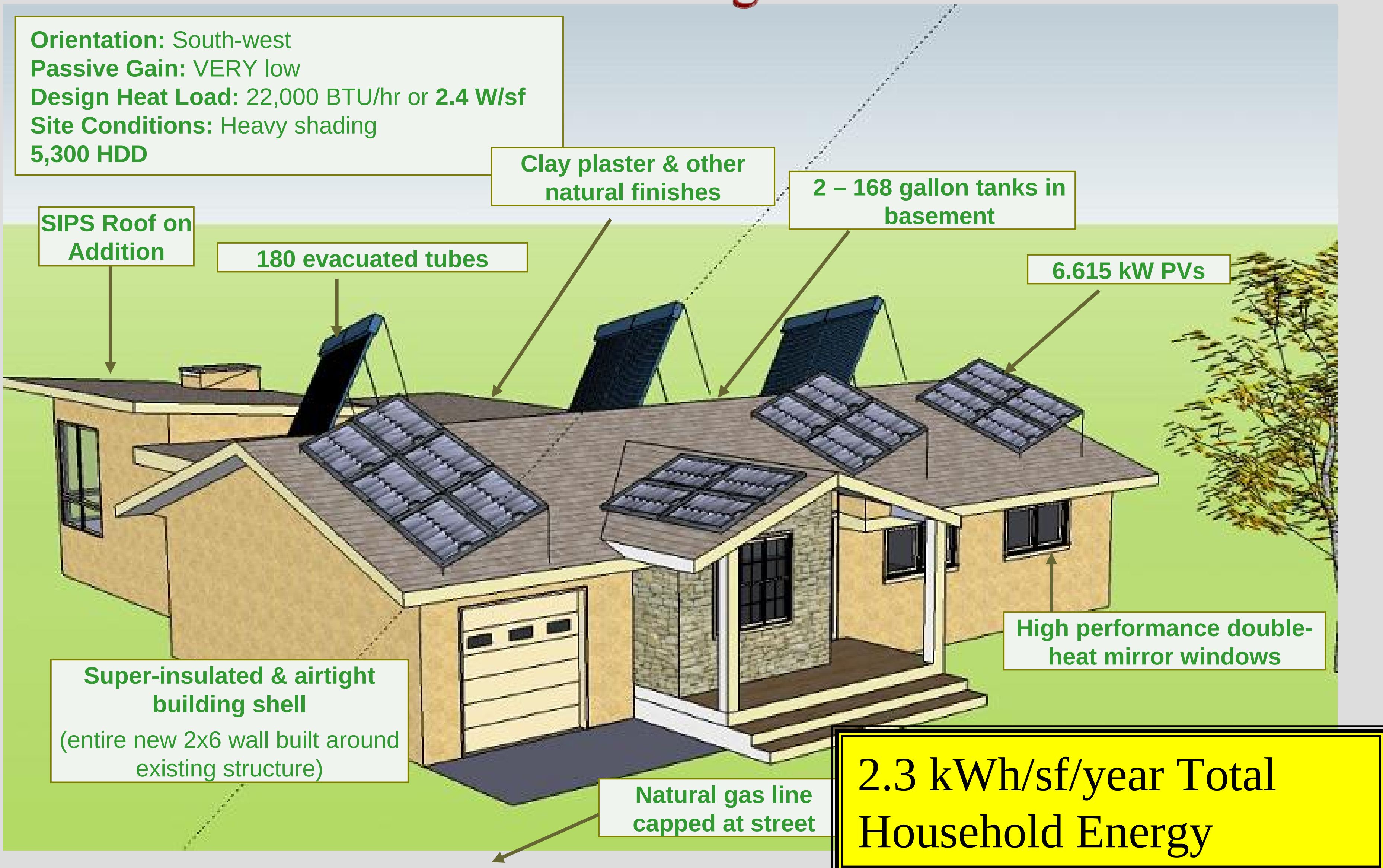
On-Site or Grid Storage?



Lessons Learned

From… Boulder Remodel		To… the future
Mfrg. Effluents +Landfill Waste	→	Cradle to cradle
High embodied energy (bamboo, quartz, recycled roofing)	→	Local materials, smaller ecological footprint
Some petro-chemical products	→	All bio-based products
Products w/ short life spans (avg. GE motor designed to last 5 yrs!)	→	Long life spans, recyclable
Shrinking greenspace	→	Intentional communities, greenroofs, small farms
Water waste & pollution	→	Greywater treatment

Zero Energy Retrofit: Powering the Home and the Car



Beyond Zero Energy:

Remodeling to Power the House and the Car

at 1247 Scrub Oak Circle, Boulder, Colorado

Major Specifications

- **Overview:** Remodel 1970s ranch home into all-electric net-zero energy home. Retrofit existing building basement and above-ground spaces for energy efficiency; 713 sf of green-built new addition; install active solar energy collection
- **Final Home Size After Remodel:** 1,700 sf above ground, 1,020 sf of basement
- **Floorplan:** Remodel existing 1,003 above-ground sf to include home office; retrofit basement into play area; add new 700 sf for new dining area, expanded kitchen & great room.
- **Deconstruction:** 90% (by weight), 70% (by volume) construction waste diverted from landfill during deconstruction of existing structure; methods included recycling and donation of salvageable materials, mulch production, and contributing to a land reclamation project (using brick and concrete removed from site)
- **Envelope:** Existing building: walls improved to ~R-28 & roof improved to ~R-46. New addition: walls at ~R-27 & SIPs roof ~R-42. See also "Building Envelope"
- **Thermal Mass:** 1½" Gypcrete floor throughout (with radiant tubes)
- **All-electric home:** 6.615 kW of roof-mount PVs. If grid goes down, when outdoor air temps are around 0ºF with cloudy conditions, home will "coast" at around 70ºF for at least a day, falling mid to high 60s at the end of day two. Home can coast for 3 days of no solar gain and no electric heat without discomfort to residents. Excellent *passive survivability*. In addition, EPA-rated high efficiency wood-burning fireplace insert will keep house warm.
- **Natural Daylighting:** utilizes 4 solar tubes, 2 skylights, & 33% more glazing by through construction of new addition. Although house was not a candidate for passive solar heating; opportunities for natural daylighting were abundant.
- **Other Green Features:** FSC-certified lumber for framing; recycled plastic decking; FSC-certified oriented strand board for subfloor; dual-flush toilet; xeriscaping and drip irrigation
- **Passive Gain:** Low – south glazing only 4% of floor area, & heavy shading by trees
- **Active Solar Thermal:** 100 Thermomax evacuated tubes @ 55 deg. tilt on flat roof with bypass for overcast days installed by Solar & Service Enterprises to substitute for low passive gain. See also "Active Solar Thermal"
- **Solar Storage:** 370 gallons in two 160-gallon tanks, insulated to ~R-60 w/ closed cell foam; one 40-gal sidearm tank for domestic hot water "boost"
- **Space Heat Distribution:** In-slab radiant tubes throughout; EPA-approved wood-burning fireplace with blower
- **Domestic Hot Water Heating:** 100% from solar storage
- **Cloudy Cold Snap Backup Heating:** Thermolec electric tankless boiler, 9 kW modulating (PVs generate excess in summer, buy back in winter: "*GRID STORAGE" of ELECTRICITY*)
- **Cooling:** Natural ventilation
- **Solar Electric:** 6.615 kW grid-tied PV by Namaste Solar. *NATURAL GAS LINE CAPPED.*
- **Indoor Air Quality:** Low-emissions building materials; ERV; NACH ~0.2; 2 direct to exterior bath fans for moisture control
- **% Net-Zero Energy Home:** Projected 152% (production vs. consumption), even with ~1,300 kWh/yr for backup heat; net excess of 3,300 kWh predicted
- **$ toward ZEH performance (beyond envelope):** $62,500 for active solar

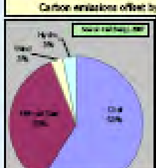
ENERGY CALCULATIONS & BENEFITS TO BUILDING NZEH

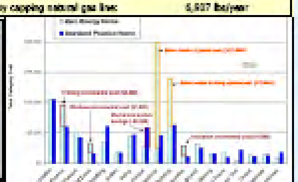
- **Net-Zero Energy Balance Calculations**

Projected energy use for elec. boiler backup:	1,300 kWh/year
Projected energy use for elec. stove, ERV & household:	5,000 kWh/year
Projected total energy consumption:	6,300 kWh/year
Projected total energy production:	9,600 kWh/yr
Projected net excess energy:	3,300 kWh/year
Expected to exceed zero-balance by:	52%/year

- **Benefits of living in this zero-energy home:**

Miles of driving an electric car *(est. 4 mi/kWh)*:	13,200 mi./year
Carbon emissions offset at the electric power plant:	17,472 lbs/year
Therms of natural gas saved by going all-electric:	590 therms/year
Carbon emissions offset by capping natural gas line:	6,937 lbs/year

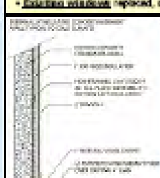


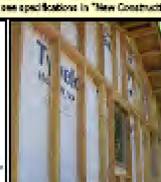


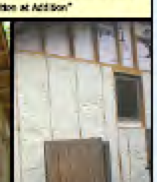
Building Envelope: *Build Tight, Ventilate Right*

Improvements to Existing Structure

- **Foundation:** Basement floor: 1½" Gypcrete with radiant tubes installed over existing 4" concrete slab; covered with 1" natural wool carpet
- **Walls, below-ground:** Basement walls lined with 1" XPS rigid foam and new 2x4 framed wall filled with cotton batts installed within basement perimeter because there was no opportunity to install exterior insulation. Estimated ~ R-17 below grade
- **Walls, above-ground:** wrapped with new 2x4 framed wall, ½" from existing wall, filled with Icynene and faced with stucco. New assembly + existing 2x4 walls with cellulose provides estimated R-28, with virtually no air leakage.
- **Attic:** Removed existing 6" cellulose insulation to install structural elements for mounting hardware in a windy climate & to achieve optimal spraying conditions for Icynene. Final assembly: 12" Icynene spray foam estimated ~ R-46, possible addition of 8½" blown cellulose in future
- **Existing windows** replaced, see specifications in "New Construction at Addition"

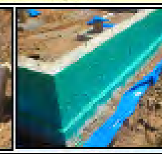


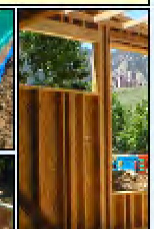


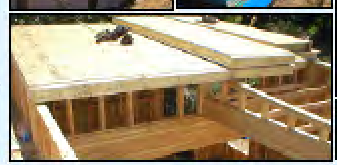


New Construction at Addition

- **Foundation:** GreenBlock Insulated Concrete Forms (ICFs) ~R-30 from foundation & crawlspace at new addition; waterproofed with Rub-R-Wall flexible membrane
- **Walls:** Exterior walls in new addition framed with 2"x6" studs and faced on interior with 1½" resilient channel to break thermal conductive path. Assembly creates a 7" wall cavity filled completely with Icynene spray-foam insulation. Estimated ~R-27
- **Roof:** 6" Structural Insulated Panels (SIPs) polyiso foam roof assembly; estimated ~R-42
- **Windows:** Deceuninck foam-filled fiberglass window frames with 2 layers TC88 Heat Mirror Low-E with krypton/argon gas glazing installed in all new & existing window openings; U-0.15 overall unit rating, with very low air leakage rates







Solar Photovoltaic

- 6.615 kW of SunPower SPR-315 high-efficiency solar panels at two different tilt angles
- 6 SPR-315 panels flush-mounted to gable roof over new porch, 18º tilt; 25º East of true south
- 15 SPR-315 panels in 3 sets of raised mounts on east roof (over original structure) tilted at 22º and oriented towards true south
- COST: $21,500 after rebates

- Recurring Benefits (every year for 30+ years)

Annual electricity production:	9,600 kWh/yr
Annual CO2 emissions reduced:	19,652 lbs/year
Equivalent reduction in vehicle miles driven:	21,507 miles/year
Equivalent number of trees planted:	756 trees (total)

- Year 1 Economic Benefits:

Annual electricity bill savings @ $0.11/kwh:	$1,056 /yr
Total increase in home real estate value:	$21,121

- Year 5 Economic Benefits *(at 5% annual increase in electricity prices)*

Annual electricity bill savings @ $0.14/kwh:	$1,340 /yr
Total increase in home real estate value:	$26,959

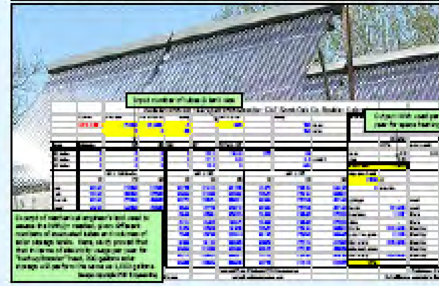
Namasté Solar Electric

Cooling & Indoor Air Quality

- **Natural cooling** by opening windows at night and closing them in the morning. ERV provides continuous fresh air year-round
- **Motorized operable skylight** and Energy Star-rated ceiling fan to prevent overheating in summer months
- **UltimateAir Recouperator 200DX ERV** (Energy Recovery Ventilator) with "Econocool" mode (heat exchanger is off) provides continuous fresh air supply. Max output: 200 cfm @ 260 watts; 40-73% moisture recovery; 95-93% apparent sensible effectiveness; 81-83% sensible recovery efficiency
- **Motorized dampers** on ERV intake and exhaust to prevent unwanted infiltration and exfiltration
- **AFM Safecoat** low- and no-VOC paints and stains; 100% natural carpet; water-based floor finishes; Marmoleum tile with low-VOC adhesives; non-offgassing cabinets
- **Natural clay plaster walls** by American Clay absorb odors, sounds, & indoor air pollutants

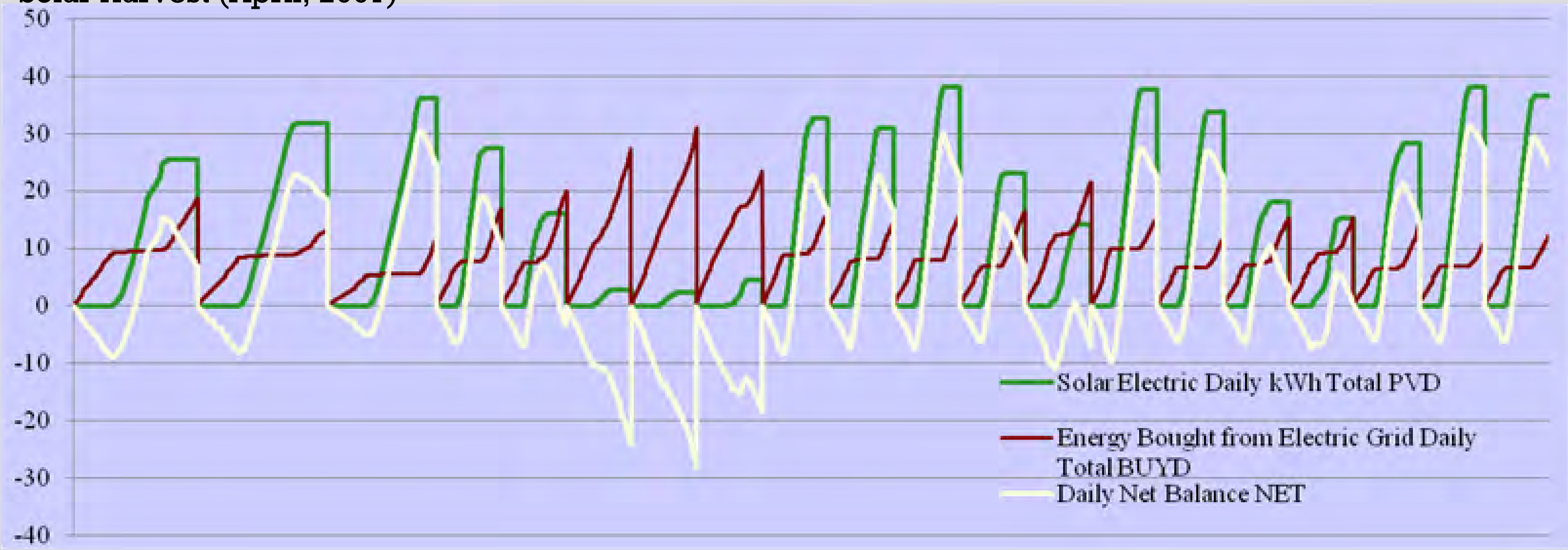
Active Solar Thermal

- **Design heat load:** 22,000 btu/hr @ peak for 2,713 conditioned SF (including garage to allow for future conversion of garage to in-law suite)
- **100-evacuated tubes by Thermomax** feed 2 – 180 gallon Steibel Eltron solar storage tanks insulated with closed-cell foam. 2 heat exchangers per tank.
- **Solar storage provides 100% of domestic hot water and space heat through in-slab radiant tubes** that can use 95ºF heat from solar storage; solar-storage bypass for delivering heat to floors directly from evacuated tubes. In weak-sun conditions, evacuated tubes provide temperatures useful for heating floors (>90ºF) and even for DHW (>125ºF). Cloudy cold-snap backup provided by on-demand Thermolec 9-kW modulating electric boiler.
- Cost: $20,000 for tubes; $6,000 tanks & insulation; $5,000 for pumps, controls, heat exchangers; $10,000 for labor = ~$41,000 for 100% DHW and whole-house solar heating system for home with almost no passive solar gain and no fossil-fuel burning backup heat



Net-Zero Energy Balance Calculations

Sample net-energy balance data from Solar Harvest (April, 2007)



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- Projected energy use for elec. stove, ERV & household: 5,000 kWh/year
- Projected total energy consumption: 6,300 kWh/year
- Projected total energy production: 9,600 kWh/yr
- Projected net excess energy: 3,300 kWh/year
- Expected to exceed zero-balance by: 52%/year

Carbon Balance Calculations

Miles of driving an electric car *(est. 4 mi/kWh)*:	13,200 mi./year
Carbon emissions saved by electric car:	11,232 lbs/year
Carbon emissions offset at the electric power plant:	17,472 lbs/year
Therms of natural gas saved by going all-electric:	590 therms/year
Carbon emissions reduced by capping natural gas line:	6,907 lbs/year
Equivalent number of trees planted:	756 trees/year

Project Costs

- $25,000 for PVs
- $34,000 for Solar Thermal
- $44,880 for Insulation & Window/Door Upgrades

- $103,880 in Direct Costs

For remodeling to power the house and the car at
1247 Scrub Oak Ave., Boulder

Ecofutures Zero Energy New and Remodeled Homes, 2005 and Beyond as of 9/11/2007

	A	B	C	D	E	F	G	H
	Doub-Childs Residence, Solar Harvest (SH)	**Skinner Residence, Broomfield**	**Graham-Jackson Residence, South Boulder**	**Gregerson Residence, Longmont****	**Leonardi Residence, Indian Hills, Denver**	**Moore Residence, Evergreen**	**Kracauer Residence, North Boulder**	**Abramson Residence, Longmont**
New or Retrofit / Yr. Built / Elevation	New / 2005 / 5,450 ft. elevation	New / 2007 / 5,390 ft. elevation	Retrofit / 1970 / 5,600 ft. elevation	Retrofit / 1995 / 5,200 ft. elevation	New / 2007 / 7,500 ft. elevation	New / 2007-8 / 7,700 ft.	New / 2007-8 / 5,450 ft. elevation	New / 2008 / 4,980 ft. elevation
Conditioned SF	4,600	6,800	2783 (2068 existing incl. basement + 713 new)	1,500	4,700	2,500	3,000	
Approx. Design Heat Load (BTUs/hr) @ degF	29,000 @ 2F	45,000 @ -5F	22,000 @ -5F	24,000 @ 0F	40,000 @ -10F (includes 30% warm-up factor)	25,000 @ -10F	26,000	
Passive Gain (Hi / Med / Low)	High, into sunspace; heat distributed w/ fans and ducts	Very Low (2 windows of 56 in house)	Low	Medium	High	Medium	Medium / High	
S Glazing: SHGC, and as % of floor area	0.62 in sunspace; 0.54 elsewhere / 7.3%	0.27 / 0.4%	0.48 / 4%	0.62 / 5%	0.62 / 8.8%	0.62 / 5%	0.52 / 10%	
E & W Glazing: SHGC; built & natural shading	0.27 / new aspen trees on E; 4 pm +, by existing neighbor's trees	0.27 / Porch overhangs on 60% of glazing; no natural shading	0.27 / 50% tree shading	0.27 / 20% tree shading	0.27 / No trees yet	0.27 / 30% tree shading; roll-down shutters on W (wind protection; traffic noise; thermal insulation; shading)	0.27; Medium shading on east side; some shading on west side from neighboring house	
Envelope: Framing, Insulation	1" ext. Blueboard; 2x6 with 1.5" resilient channel(7" Icynene	1" ext. expanded polystyrene (EPS); 2x6 with 1.5" resilient channel(7" Icynene	Remove brick; add 2x4 ext. wall; Icynene. New construction: 2x6 wall with 1.5" RC, Icynene-filled for 7" total	Dense pack walls with cellulose over existing fiberglass batts; Icynene ceiling under existing fiberglass batts	1/2" ext. expanded polystyrene (EPS); two 2x4 walls w/ 1/4" separation; 7 1/4" Icynene	2" ext. expanded polystyrene (EPS); 2x6 w/ 5.5" Icynene	Two 2x4 walls w/ 1/4" separation; 7 1/4" Icynene	
Envelope: Windows	Fibertec; Heat Mirror (dbl. on north); tuned	Fibertec; triple pane w/ LowE	Canadian fiberglass frames thru Alpen; double Heat Mirror throughout	Accent Vinyl w/ Heat Mirror	Loewen wood clad windows with triple-pane glazing, tuned	Canadian fiberglass frames thru Alpen; double Heat Mirror throughout	Canadian fiberglass frames thru Alpen; double Heat Mirror throughout	

Envelope: Air Tightness (NACH = Natural Air Changes per Hour)	Very tight: <0.1 NACH	Very tight: <0.1 NACH	Tight: ~0.2 NACH	Medium tight: ~0.35 NACH. Retrofit air sealing as possible.	Very tight: <0.1 NACH	Very tight: <0.1 NACH	Very tight: <0.1 NACH	
Indoor Air Quality / Heat Recovery	Low-emissions building materials; Stirling ERV (**Sensible Recovery Efficiency: 83-81)	Low-emissions building materials; Stirling ERV (**Sensible Recovery Efficiency: 83-81)	Low-emissions building materials; Stirling ERV (**Sensible Recovery Efficiency: 83-81)	Older materials (low toxic now); spot ventilation with programmable timers; Lifebreath HRV (**Sensible Recovery Efficiency: 63-66)	Low-emissions building materials; Stirling ERV (**Sensible Recovery Efficiency: 83-81)	Low-emissions building materials; Enerboss Clean Air Furnace with ERV core (**Sensible Recovery Efficiency: 74)	Low-emissions building materials; Enerboss ERV as air handling unit (**Sensible Recovery Efficiency: 74)	
Utilities	Natural gas for cooking & clothes drying; therms offset by net excess kWh from PVs; all-electric planned september 2007	No natural gas to home	No natural gas to home	No natural gas to home	Natural gas only for fueling vehicles	Natural gas only for cooking	No natural gas to home	
Solar Electric (rated capacity of PVs); approx. annual production	6.84 kW; 10,000 kWh; net excess 200 kWh, 1st year	10 kW; 14,400 kWh	6.615 kW; 9,600 kWh	Roof space could hold 7 kW; 10,800 kWh; will run system for one year (buying RECs), then size the PV system***	10 kW; 14,400 kWh	10 kW; 14,400 kWh	6.4 kW; 9,200 kWh/yr	
Thermal Mass	Double 5/8" drywall throughout (all walls & ceiling planes) for indirect, distributed mass	Double 5/8" drywall throughout	1.5" Gypcrete throughout (existing, with radiant floor tubes)	Existing: typical / low. Add 5/8" drywall to most ceilings and some walls	Double 5/8" drywall throughout	Double 5/8" drywall throughout	Triple drywall in selected areas	
Active Solar Thermal, w/ Collector Tilt Angle & Heat Rejection	12 - 4x8 Novan flat plate collectors, @ 55 deg tilt; sunspace air distributed w/ fans & ducts	240 Thermomax evacuated tubes, @ 65 deg tilt; summer heat rejection with roof-mounted fin tubes	180 Thermomax evacuated tubes, @ 55 deg tilt	100 Thermomax evacuated tubes @ 90 deg***	180 Thermomax evacuated tubes, @ 37 deg	120 evacuated tubes, @ 60 deg	150 tubes @ 45 deg.	
Solar Storage Tank*	6,000 gallons, Atmospherically vented	600 gallons	360 gallons	240 gallons	1,500 gallons	1,200 gallons	2,500 gallons	
Space Heat Distribution	Staple-up radiant tubes, w/ >120F water from 6,000 gallon tank; sunspace heated air w/ fans & ducts	Fan coils w/ solar- or boiler-heated water; Coolerados as Air Handling Units (blowers); Sunny Day Bypass setup	In-slab radiant tubes throughout; can use 95 deg heat from evac. tubes, w/ Sunny Day Bypass setup	Lower level: Staple-up radiant tubes, w/ heat transference plates. Upper: Fan coil in existing ductwork's airstream; Sunny Day Bypass setup	Sunspace heated air w/ fans & ducts; fan coils w/ solar- or boiler-heated water; ECM var. spd. AHU	EnerBoss + ductwork for HRV & heat distr.: Fan coil w/ solar- or boiler-heated water	Low-velocity hydronic forced air distributed through ERV/Coolerado ductwork	
Water Heating (DHW)	Heat exchanger coils in solar tank (+ 40-gallon elec. water heater as backup ~8 days during 2006-7 record-breaking winter)	Heat exchanger coils in solar tank + electric boiler to boost solar-preheated water as nec.; expected 100% solar supply of DHW	Heat exchanger coils in solar tank + electric boiler to boost solar-preheated water as nec.; expected 100% solar supply of DHW	Heat exchanger coils in solar tanks + electric boiler to boost solar-preheated water as nec.; expected 80% solar thermal supply of DHW w/ rest from PV	Heat exchanger coils in solar tank + electric boiler to boost solar-preheated water as nec.; expected 100% solar supply of DHW	Heat exchanger coils in solar tank + electric boiler to boost solar-preheated water as nec.; expected 100% solar supply of DHW	Heat exchanger coils in solar tanks + electric boiler to boost solar-preheated water as nec.; expected 100% solar thermal supply of DHW	
Cloudy Cold Snap Heating Backup (usually needed on day 3 of cloudiness; Charge & Coast system covers cold cloudy days 1 & 2)	Heat stored in tank + ~300 kWh/yr (2006-7 record-breaking winter) by 20-gal. water heater to boost radiant floor water temp. to 120F	Thermolec elec. tankless boiler, 15 kW, modulating; expected ~4,000 kWh/yr usage (PVs generate excess in summer; buy back in winter)	Thermolec elec. tankless boiler, 9 kW, modulating (PVs generate excess in summer; buy back in winter)	Thermolec elec. tankless boiler, 9 kW, modulating (PVs generate excess in summer; buy back in winter)	Thermolec elec. tankless boiler, 15 kW, modulating (PVs generate excess in summer; buy back in winter; expected usage 3 to 6 days/year)	Thermolec elec. tankless boiler, 15 kW, modulating (PVs generate excess in summer; buy back in winter; expected usage 15 - 20 days/year)	Thermolec elec. tankless boiler, 9 kW, modulating (PVs generate excess in summer; buy back in winter)	
Cooling	Open windows @ night, close in morning; earthtubes deliver 65-75F air thru ERV, for daytime IAQ; skylight; Tamarack whole-house fan	2 Coolerado units	Open @ night, close in morning; skylight; Tamarack	Open @ night, close in morning; skylight; Tamarack; use of existing AC to be minimized	Outdoor air supplied thru ductwork, to sub for opening windows; higher altitude, w/ cooler and more effective nighttime air	Outdoor air from earthtube supplied thru ductwork, + opening windows (motorized, programmed); higher altitude, w/ cooler and more effective nighttime air	21 SEER AC can be added later if desired ~500-1000 kWh/yr	
Overhangs on south (2' projection, 12-16" above glazing)	Yes	No	No	Yes on 30% of windows (created by evac tubes)	Yes on 80%	Yes	Yes	
Amenities / Notable End Uses	Outdoor spa + steam shower + fish tank	Coolerados; large home office; woodshop & electronics shop	None. Current usage ~320 kWh/mo.; w/ addition, ~375; expect <1,500 kWh/yr for backup heat	None. Current usage ~425 kWh/mo.	Outdoor spa + vehicle charging + steam shower	Outdoor spa + ice melt sidewalk	None	
$ toward ZEH performance, for active solar (beyond envelope); % of building costs	$70,000; 8%	$103,000; 7%	$59,000; NA	$50,000, including envelope improvements***	$93,000; 7%	$68,000; 8%	65,000; 8%	
Net Zero Energy Home %	99%, first year	100%, projected; if less, then remainder covered by RECs	130%, projected, with net excess >1,500 kWh/yr	95%**	100%	100%	105%	120%
*All tanks are used dairy industry stainless steel tanks, atmospherically vented, insulated to ~R-90 w/ closed cell urethane foam, except SH (site built with ICF foundation walls for structure & EPDM rubber for liner)			** **Goal is DNZEH (Darn Near Zero Energy Home)** ***Project in design; preliminary numbers shown		Sensible Recovery Efficiency (SRE) takes the actual temperature rise in the airstream into account along with all other energy used to provide a performance rating.		

Grid storage of solar energy – what if everybody did it?

- Would we make a difference on global carbon emissions, or would we still need the same amount of coal-fired power plants?
- What kinds of loads would we have in the winter? Are these loads within the range of what we have otherwise?
- ---
- 20-30% of homes with solar is when problems will happen, for now, just do what you can
- Sure, at nighttime if we put more and more houses without battery packs, there is more demand on the grid, but are we using more energy at night than most houses? Lighting better, better appliances. Uses 2/3 compact fluorescent. LED for downward facing. Probably not
- In the short run, I don't see any issue in the summer/winter. A lot of people are using A/C energy, and you're supplying clean energy, reducing that demand. So you're extra winter demand isn't such a big deal.
- When it comes to offset electricity, we are offsetting natural gas – smaller carbon footprint than coal – not really the carbon emissions from Colorado plants
- 4 pillars:
- 1. Energy efficiency
- 2. (intermittent) renewable energy
- 3. energy storage: electricity storage for large-scale utilities, utility-scale electricity (batteries in everyone's house? With longevity, cost, reliability improving) 3-5 kW in each home. Low grade heat in summertime – how to can and store it? Wind-hydrogen. Plug-in hybrids, charge when intermittent renewables are making electricity. Austin Electric – lots of wind, overwhelming system at 2am, charge when wind is blowing. Vehicles to Grid – batteries back up the grid. Car can charge grid, would use fossil fuels – if only 1-2 years per year, we're winning.
- 4. Energy management – appliances running when intermittent renewables are producing energy, don't need to run randomly, can run only 12 hrs. only run when you are producing energy.
- **Energy storage of low-grade heat
- Chemical reactions: run one way and store heat, run other way and release
- Can't do on a one-house level
Maybe on a district-level tank
- Water-source heat pump – intentionally freeze with heat pump, use heat to heat house. Really cold water is very efficient in panels. When you store heat in water 1 lb = 1 BTU per 1 deg increase. Heat infusion 144 BTUs per 1 deg heat change. Plastic balls filled with water, surrounded by antifreeze. Cold is best for thermal panels.
- Full size house = 1000 gal tank for this system   Fuel cell = flow battery
- 1 kw – 1 car battery, some toxins Flow cell = a few tanks and an expensive thing in the middle pump from one to the other double the amount of electricity you can deliver, double the fuel cell.

Grid Storage Big Picture Discussion (cont.)

- Hydrogen 1 side, water on the other, vent oxygen, makes heat and electricity and water. Limit by tank you use. Hydrogen fuel cells get poisons, very expensive (platinum as catylist), hydrogen doesn’t like to be stored.
- Vinadium Redux VRB systems – batteries. Products are relatively non-toxic, and will go back and forth 100000s of times with out
- <u>Leave space for future solutions</u>
- Money is not an issue, get a lithium ion battery
- GridPoint charge during day, discharge at night to zero out my load
- PVs as primary with ground source heat pump, small solar thermal
- Electric furnace
- Heat pump – exploits that temp under ground is stable
- Make heat pump more efficient – replace blowing air with pumping water (small amount of energy)
- Guaranteed source of 50 degree water
- Problem: 1. size of groundfield cost linear, how do you know how big of a groundfield
- 2. Run heat pump only to heat house, you can cool ground. Recharge rate slow
- 3. only really great in climates with equal cooling and heating days
- 4. extra heat in summer, drive down well to recharge ground to avoid
- 3 panels charge ground in summer, heat pump plus panels direct to house in winter
- David Crestfield
- Wind in Colorado runs more in Winter than summer therefore summer is solar, winter is wind
- Coal fired power plants – 80% base load, don’t ramp up/down. Renewables don’t interact well with base load power plants (coal, nuclear). Natural gas is great – very responsive
- Run ground source heat pump when you know when wind is blowing – Xcel doesn’t tell us. Germany there is a text message service – tells you when to do laundry/when wind is blowing

Who can benefit from these performance goals?

BEDZED zero-energy community (UK)

- Any climate
- Any state
- Single Family Developments
- Multi-Family Developments

What will the future of housing look like?

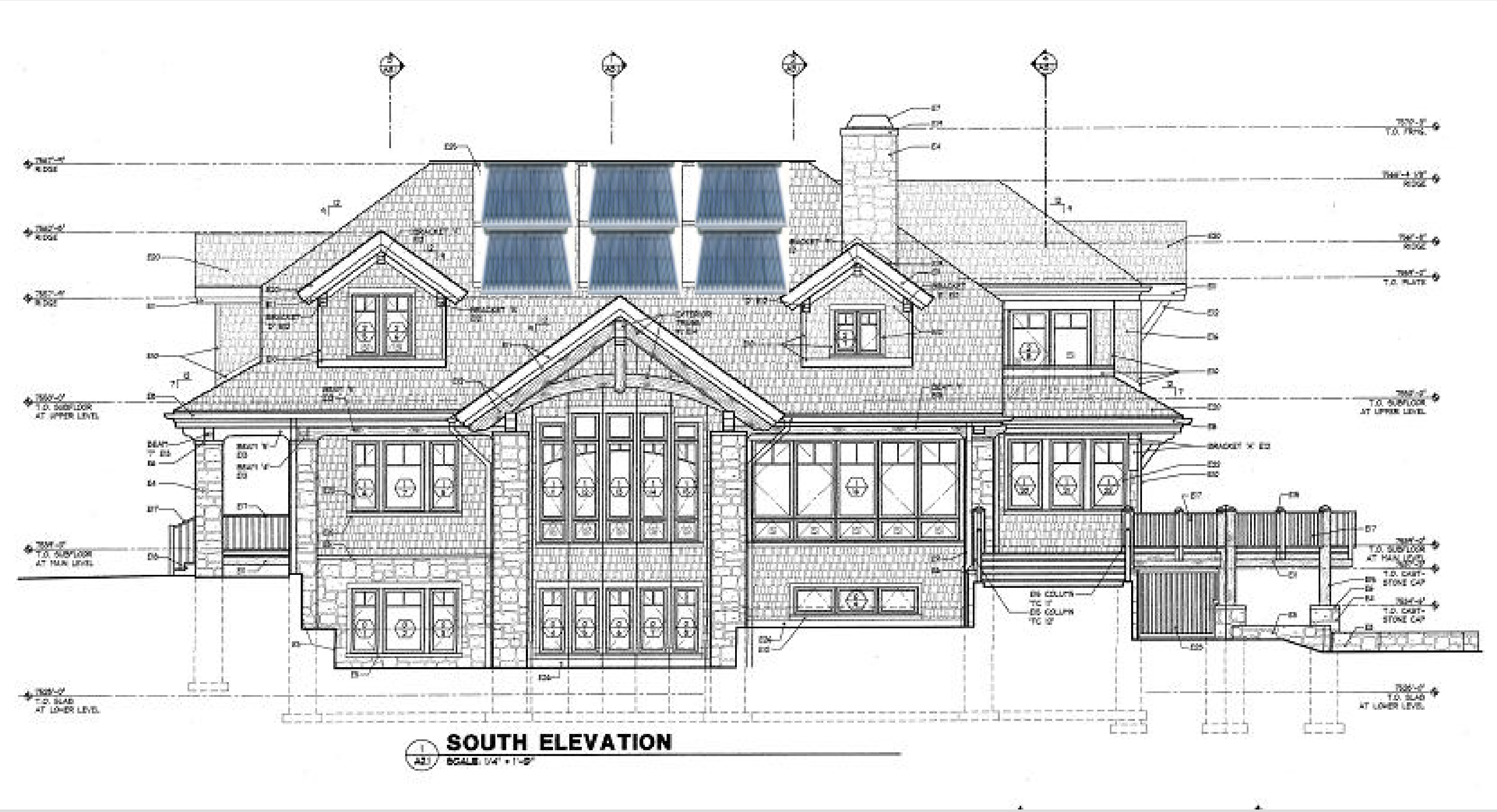
- “A house without solar collectors will be like a house without windows”
- Will the beautiful countertops of today be the avocado green of tomorrow?
- Market fairness: policies to encourage energy efficiency? “Carbon Management” will determine much of future housing
- Healthy, safe, energy efficient homes available for people of all income levels?
- Modular, prefabricated & temporary homes?
- Disaster-recovery zones; New Orleans, Louisiana

Design & rendering by:

architropic
toward sustainable design

Lee Hill Dr. & 6th St., Boulder

3000 sf Net-Zero Energy Home



Indian Hills, Denver:

4700 sf net-zero energy home

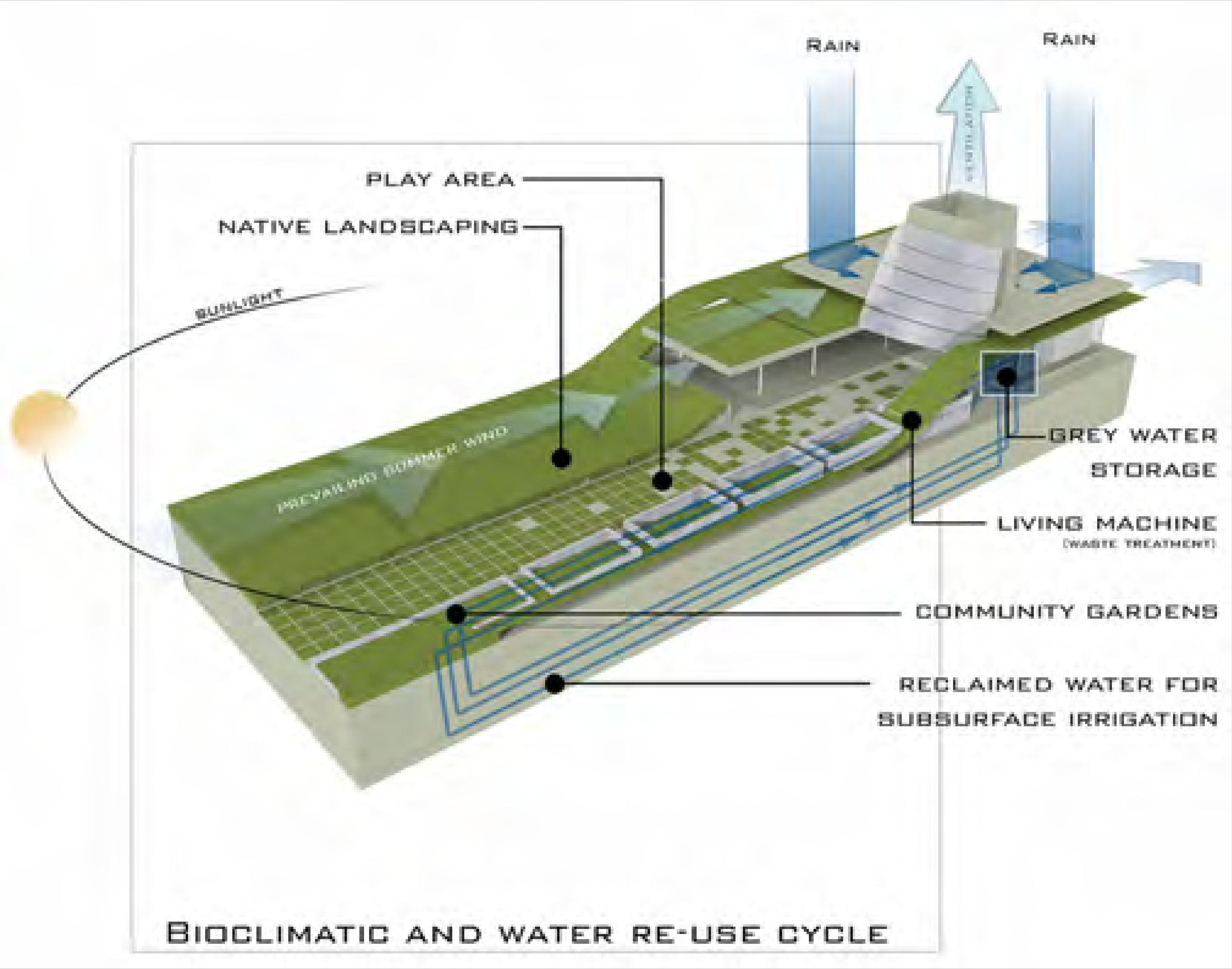
A Denver Solar Home

Appealing, Beautiful, Comfortable, and Not Affordable

NREL’s Zero Energy Habitat for Humanity Home:

A Model for the Future of Affordable Housing

Nez Perce Zero Energy Manufactured Home Project



Cradle-to-Cradle Home Competition Winner

Year Built 2005

Home Size 3300 Sq.Ft.

Contractors:

Simple Solar Systems
(see ad on page 15)

EcoFutures Building

Solar Enterprises

Solar Harvest

One Year Later: Better than Net Zero

Eric Doub & Catherine Childs

More than ever, our nation needs less violent and more sustainable resource and foreign policies. Striving to build a home that will be viable and affordable 50 years from now is one way to embrace the coming shift from fossil fuels to renewable energy.

While applying to college in 1980, I wrote that studying nuclear energy for a school paper "has been an initiation into energy research, and a synthesis of goals – of self-preservation and academics – that may be the most important thing that's happened to me yet.

Current events make it desperately clear: We're in transition to a post-petroleum civilization. War in the Middle East, the arms race, revolution in Third World countries all point to a reorganization of the planet's resources. And American lifestyles and consumption are at the center of the crisis. When good, obedient, middle-class Americans – those who guard the system – cannot buy gas or pay the heating bill or get enough to eat, our society will turn upside down. Historian Howard Zinn calls this the Revolt of the Guards. When this happens I want to be a citizen who knows, who has researched, who has hope: for a sane, decentralized, democratic energy system where the power is in the hands of the people and in biomass, efficiency, hydro, wind, solar, and cogeneration."

So, when asked how I came to start my company Ecofutures Building, I sometimes say it's not my fault – I was brought up in North Boulder and just turned out that way. In 1982 I designed and built my first solar project, an attached greenhouse on my parents' house on 9th St. In 2005, Catherine and I finished Solar Harvest, expressing the same values but on a larger scale.

Our first winter in the home was warm and toasty, with the radiant floor heat turning on only about 10 times. The record-breaking hot summer of 2006 brought Al Gore's film and also, for us, a home that was cool and refreshing inside – without an AC system or evaporative cooler. We are extremely pleased to report that the house is turning out to be better than net zero energy and are delighted to share this work and harvest with our community!

RE-USE/SALVAGE FEATURES

- Minimized and recycled constuction waste
- Salvaged hardwood flooring, doors, cabinets, sinks, and windows

Eric, Catherine & Family
Photo courtesy of Michelle Maloy Dillon
www.mmdphotography.com

ENERGY FEATURES

- 6.84 kW grid-tied PV system
- 12-panel solar thermal, drainback system
- 6,000 gallon water storage tank
- Passive solar design with sunspace greenhouse and distribution ducts and fans
- Double 5/8" sheetrock on some walls and ceilings
- Expanded foam insulation
- Extensive engineered HRV system
- Intake air to HRV through PVC pipe buried underground
- CFL lighting throughout home
- Energy Star rated appliances
- Power strips and occupancy sensors on applicable electric applicances
- 1" rigid foam insulation on perimeter walls, 2x2's and wall and ceiling members
- Greenblock ICF's in basement walls
- R-15 glass in north windows

WATER FEATURES

- Lowine water lawn
- Drip irrigation
- Xeriscaping
- Previous pavement on driveway

GREEN FEATURES

- Fly ash content concrete for foundations and slabs
- FSC certified lumber for framing
- IPE/Pau Lope decking
- Formaldyhyde free cabinets and carpet
- AFM Safecoat paint and stains
- Roofing made of 100% recycled carpet
- High-density bamboo flooring

Other ZEH Projects
for Reference & Inspiration

- Louisville, Colorado: 1,500 sf ZEH built from stock plans (2006)
- Norman, Oklahoma: first ZEH under $200K w/ 1,650 sf (2005)
- Arvada, Colorado: Geos, a 300-unit zero energy home development (2008)
- American Southwest: ZEH developments & communities on tribal lands (conceptual stages)
- "Boulder's Solar Harvest appears to be one of two or three actual net zero energy cold-climate homes in the country," (*Energy Design Update* Editor Martin Holladay, 8/06).
- ACI Summit, July 2007: "Moving Existing Housing Toward Carbon Neutrality" – how to reduce energy usage by 80% in US & Canadian homes in 15 years – see *Home Energy* Magazine, Feb. 2008, for full details

In a children's magazine (*National Geographic Kids*, 9/07)

When the kids get it, so will the rest of future society