Solar Harvest: City of Boulder's First Zero Energy Home



September 2005

1887 Orchard Ave. Project Specifications

Originally Presented by Ecofutures Building, Inc. for the Boulder Tour of Solar and Green Built Homes October 2, 2005 Welcome! May your visit here both inspire and empower you, and perhaps even leave you with a sense of wonder. In my opinion, this home is only a baby step toward learning how to live, long term, on the planet. Our best effort to date, this project may look elementary in a few decades. But we start with where we are. In the coming transition to saner energy systems, and for this Solar Homes Tour destination, my wish is simple: Enjoy! S Alloub

Solar Harvest Project Information BIOTERRA CONSTRUCTORS, INC Special thanks to our sponsors:



Owners & Future Residents: Eric Doub & Catherine Childs

General Contractor: Ecofutures Building, Inc. Boulder, CO 303-415-9694

Designers: Eric Doub, Ecofutures, with Catherine Childs

Design & drawing assistance by Rachel Lavine, Ecofutures

Systems, accounting, & management assistance by Margot Rode, Ecofutures

Project Managers: Eric Keller (through foundation) 303-249-6963 Jeremy Mercier (foundation through move-in) 303-859-1437

The Amazing Enduro Crew (Ecofutures): Sean Murphy, Doug McDonald, Dan Lent, Ted Horton, Ryan Mercier, Seth Murphy, Chad Fuller, Ben Lann, Mark Bradley, Ken Sneed, Clayton Bryant, Karl Templeton, Jain Elliot, Jeremy Schick, Ali Ray

Engineers:

John Arndt, P.E., Gebau Engineering Boulder, CO 303-444-8545 JDA@Gebau.com Ken May, Industrial Solar Technology Golden, CO 303-279-8108 industrialsolar@gwest.net Peter D'Antonio PE, PCD Engineering Services, Inc. Longmont, CO 303-678-1108 info@PCDengineering.com Michael Haughey, Silvertip Integrated Engineering Consultants Westminster, CO 303-650-1080 mhaughey@earthlink.net Gary Rossen, Western Soils, Inc. Lyons, CO 303-823-6867

Healthy Home Consulting: Pete Chandler, BBEI; Living Space 1

Boulder, CO 303-442-1718 pete@livingspc.com

Overview

Description: New single family detached dwelling with 2 stories plus basement, attached garage and carport

Occupancy: Floor plan design includes 5 bedrooms; 3 full baths, one $\frac{3}{4}$ and one $\frac{1}{2}$ bath; living room; kitchen; and basement workspace.

Square Footage: 4585 ft² finished (heated) and 400 ft² unfinished (heated sports garage) & 600 ft² unfinished (unheated) carport, including 275 ft² of sunspace for passive gain with active distribution

Energy: 6.84 kW roof-mounted photovoltaic panel array for gridtied electric supply; 12 flat plate thermal collectors provide all space, water and spa heating needs; indoor air ground-cooled and heated

Design Concept:

Solar Harvest was designed and built with the overriding intentions of not only creating a safe and comfortable living space, but also of becoming a model in sustainable home construction – in this case, a Net-Zero Energy Home. Our guiding design principle was to incorporate appliances, systems and controls into a home so that throughout the course of a year the home will ultimately supply more energy to the utility than it consumes.

By meeting this net zero energy goal, we are striving to build a house that will be affordable and viable 100 years from now, when who knows how much natural gas – and electricity – will cost.

This is a showcase project but also to be our family home. We have two children, 6 and 8, and plan on adopting another child several years from now. We have also designed for the contingency of elderly parents staying with us, as well as foreign exchange students, traveling activists, and visiting relatives and friends. The home will have adequate space for meetings of all kinds – political, parenting, personal growth, or neighborhood groups. We look forward to being a community resource in this sense, in our time here. And with the home built to last several hundred years, the spaces and layout are adaptable to a wide variety of needs of future residents.

Floor Plans



The basement provides spaces accommodating play and kids' projects and a guest bedroom with private entrance. The north wall of the basement is provides storage and space for the 6,000 gallon solar tank.



Three bedrooms occupy the majority of the second floor space. Full bathrooms are adjacent to the master bedroom and the two children's rooms. The wing extending to the north allows for a guest bedroom and full bath.



Ground-level floor plan includes 37 foot-long sunspace; living and dining area; mudroom; kitchen; office; playroom; and $1/_2$ bath.



Sitework, Foundation & Framing

Quick Specs:

- Maximum allowed fly ash content in all concrete for foundations, slabs
- House & garage rest on 54 drilled piers, with basement on a suspended structural slab: expansive soils will not affect the longevity of home
- Incorporates Optimal Value Engineering framing techniques (see www.eeba.org for more information)
- Forest Stewardship Council (FSC) certified 2x6 & 2x4 wall studs
- Recycled content in steel beams and columns



Sitework Excavation & grading by Bioterra Constructors, 303-579-3569, using biodiesel in digging machines and trucks, as possible.

Landscaping: Haiku Gardens, 303-702-1925

Driveway Proprietary system by Crowder Services, 303-591-9191, using recycled concrete and SoilSement, an environmentally friendly liquid polymer

Foundation Concrete Piers by Firm Foundations, Inc. Broomfield, CO

303-465-2298 www.firmestfoundations.com

Foundation Forms & Insulation

Insulated Concrete Forms (ICFs) by GreenBlock Woodland Park, CO 1-800-816-1620 http://www.greenblock.com



Foundation Waterproofing by Jim Armstrong, Rub-R-Wall, (800) 307-3430

Framing & Steel Structural & decorative steel by Armor Steel, 303-442-3025 FSC Certified Fir and Hemlock Wood Framing from BMC West-Aspen Aspen, CO 970-925-4262 www.bmcwest.com

**Delivery Assistance from *Boulder Lumber, which has since become the first Front Range supplier of FSC lumber!*

Oriented Strand Board sheathing with no urea formaldehyde for walls and floors (FSC plywood not available at the time of construction) and engineered trusses from Boulder Lumber 303-443-0582 Floor I-joists by Roseburg Forest Products, via Boulder Lumber

Insulation & Shell Details

"If you want to fill a bathtub with hot water, first put in the drain plug." **Quick Specs:** *-- Amory Lovins, Rocky Mountain Institute*

- 2 x 6 stud wall with $1\frac{1}{2}$ " resilient channels at 24" on center
- Icynene insulation 7" thick in walls and 12" in ceiling
- Above ground walls rate R-34 and ceiling R-45 with Icynene
- Basement walls rate R-30 with GreenBlock ICFs (see Foundations)
- Fiberglass windows w/ Heat Mirror glass; e.g., North glass rates at R-15

Insulation by Icynene, installed by Arctic Insulation, Colo Springs CO 719-495-2625, 719-332-3011



Wall profile: 1" rigid foam (XPS) encased with 1/8" GrailCoat waterproofing. 1¹/₂" resilient channels at 24" on center across all wall framing members, creating 7" deep cavity for insulation; encased by double 5/8" sheetrock for added thermal mass.

Battic Door Attic Access Hatch: Critical element for shell integrity & performance. Positive Energy Conservation Products 303-444-4340

Windows & Doors

Quick Specs:

- Fibertec fiberglass windows with Alpen glazing provide overall U-values of 0.20 on the west and east, and 0.12 on the north in addition to extremely low air leakage ratings
- Solar Heat Gain Coefficients calibrated for each exposure to reduce or increase solar energy intake as derived:
 - South Glazing is 10.6% of upper level floor area
 - ➤ 0.27 on East & West
 - \geq 0.50 on North
 - > 0.67 on sunspace (east half) & 0.62 (west half)
 - > 0.54 on upper level south windows





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Fiberglass Windows and Sliding Doorsets

Window frames by Fibertec Window and Door Mfg.

Concord, ON 1-888-232-4956 http://www.fibertec.com

Glazing by Alpen Windows

Boulder, CO 303-530-1150 http://www.alpeninc.com

Pozzi swinging full-lite glass doors salvaged and purchased at Extra Building Materials Boulder, CO 303-296-8090

ThermaTru Fiberclassic ext. doors via Boulder Lumber 303-443-0582

Insulated garage door from Boulder Garage Door, Inc. 303-447-1501

Window Treatments:

Window covering and shading solutions by Innovative Openings, Inc. Boulder, CO 303-449-6465 http://www.innovativeopenings.com

Window & House Cleaning by Better View 720-771-1999

Heating

Quick Specs:

- Passive heat gain accomplished by 275 ft² of sunspace vertical glazing with active distribution ducts and Panasonic ECM motor fans, controlled by thermostats in rooms with no direct gain
- Double 5/8" sheetrock on all walls and ceilings except stairs and hallways for distributed, indirect thermal mass
- 100% of expected building heat needs achieved through passive solar gain, thermal mass, solar collectors and the solar storage tank, with staple-up tubing in upper 2 levels and in-slab basement tubes for radiant floor heat
- Design heat load of about 29,000 BTUs/hr for 3 levels totaling 4585 ft² plus 400 ft² garage, plus 360-gal. spa



Motorized dampers used for sunspace/kitchen lines, & solar tank/ERV exhaust lines



Staple-up radiant floor heating tubes The "Back-up" Heat Question



ceiling (fan units above drywall)



Engineering calculations show that no gas or electric heating system appears to be necessary. For a period of about 8 cloudy days (no solar gain) with two deg F, 24/7, the solar systems will be able to meet code of maintaining 68 deg F. Climate records for Boulder do not include any such conditions, and it was on this basis that the city of Boulder's Chief Building Official approved the system as you see it today - perhaps a national first for a home in this heating climate.

Ventilating and Air Conditioning "Build Tight, Ventilate Right."

Quick Specs:

- No air conditioning unit natural cooling provided by super insulation, nighttime intake of cool air assisted by whole house fan as necessary, shade trees on east and west, and south roof shaded by solar panels
- Summer cooling by natural "chimney" effect of airflow through operable skylight in hall of top floor and whole-house fan, with improved air flow through windows above bedroom doors, & Return Air Pathways above N BR door (baffled transfer grilles that let air through but block ¹/₄ of sound; made by Tamarack and avail. from Positive Energy in Bldr.)
- Air destratification achieved by ERV and sunspace systems
- Natural ACH expected to be 0.1 or lower
- Ground-cooled air brought into home through buried pipes air expected to be about 55 deg F, year round

Indoor Air Quality

Energy Recovery Ventilation (ERV)

Ultimate Air RecoupAerator ERV by Stirling Technologies Athens, OH



- 1-800-535-3448 http://www.ultimateair.com
- Extensive, ERV provides fresh air supplies in each bedroom and living space, direct to exterior exhaust in kitchen and bathrooms.
- 93%-96% heat recovery (rated efficiency by HVI for 32° F exterior and 70° F interior temperatures with no after-market options) – achieved in Solar Harvest by geothermal pre-warming. This winter, when exterior temperatures were 4° F, incoming air to ERV was measured at 38° F to assist maximum heat recovery efficiency.
- ERV draws fresh air through 260 ft of 6" PVC pipe buried 8 feet below grade for pre-warming (winter) and -cooling (summer)



R-38 doors open when fans turn on

Cooling

Whole-house fan byTamarack Technologies, Inc. purchased from Positive Energy Conservation Products, Boulder 303-444-4340

• HV1600-GDR -Tamarack 1600 Gold with R-38 Doors, 1600 cfm on high speed and 800 cfm on low

ERV in EconoCool mode will deliver ground-cooled air to all rooms

Solar Hot Water

Quick Specs:

- 12 salvaged Novan solar thermal flat-plate collectors mounted at 55degree angle in drainback system
- 6,000-gallon super-insulated solar storage cistern with 3 heat exchangers for domestic hot water, staple-up radiant floor space heating, and spa
- To reduce hot water demand, dedicated third recirculation line provided. Motion detectors at place of use (e.g. MBA, far from mechanical room) send wireless signals send water through recirc line. Extra insulation on pipes prevents heat loss during transit.
- In standard operating conditions, the collectors will have charged the Solar Storage Tank to a temperature that allows the household to use 8 to 10 gallons per minute, continuous

Plumbing Contractor: Norm's Plumbing, Boulder 303-447-1134

- Mechanical Contractor: Bruce Slack, Service & Solar Enterprises, Louisville, CO 303-665-6690. Solar work since early 1980s.
- **Engineering Consultant & Installation Assistance:** Six of the salvaged collectors were cleaned, pressure tested and provided by Industrial Solar Technology Corporation Golden, CO (303) 279-8108. Initial concept consulting by Ken May, IST: "...if you do this, you are engaged in an



: "...if you do this, you are engaged in an experiment. However, you could be making a tremendous contribution to the solar art."



Solar Tank

Solar-Heated Water Storage

- <u>Function</u>: The super-insulated storage tank collects hot water from roofmounted solar collectors to provide thermal mass for the entire house as well as providing all domestic hot water, space heating, and spa heating needs – effectively, the tank serves as a large heat battery.
- When fully "charged," at 190 deg F, the tank's potential energy is about 4 million BTUs. "Depleted" is considered 100 deg F.
- <u>Dimensions</u>: The 6,000 gallon solar tank measures 18' x 7' x 7'. Access hatch measures 18" x 52"
- Insulation: R-55 to R-75 (estimated) surrounding the tank
- <u>Waterproofing</u>: 2 layers of ml EPDM rubber liner on all walls; 1/8" spray-on RhinoLiner polyurethane waterproofing on tank ceiling by Rub-R-Wall Waterproofing Systems Loveland, CO (970) 667-6218
- <u>Cost</u>: \$6,000-\$7,000 for tank and heat exchangers; additional \$6,000 to \$8,000 for pumps, controls, labor and installation



Each Heat Exchanger is simply a roll of ³/₄" flex copper

• <u>The Future of Big Tanks</u>: Since Solar Harvest, big tank design has focused on reconditioned used steel tanks purchased from the dairy industry. These tanks are being installed underground, in basements, & in accessory structures. InsulSoy 1.7lb low-permeance foam superinsulates to about R-90. The stainless steel tank offers a more durable & dependable system.



Stainless steel tank being installed underground West Boulder, before insulation.

August, 2006

Photovoltaic Electricity

Quick Specs:

- 6.84 kW grid-tied PV power mounted in two arrays
- Half of the panels flush-mounted on 20-degree roof and half on 40degree roof; these different tilt angles affect electricity production only by a few percent
- When the panels produce more electricity than the home is consuming, electricity flows back out to the utility grid through a "net meter" that counts the outgoing power as a credit; when it is too cloudy or nighttime, electricity flows back through the meter and billable power is recorded by Xcel. With this size system, and low electrical demands, the home is designed to be a net power provider as can be any home with such perfect solar access. Net meter reading was minus 1000 kWh as of October 3, 2006.



Expert Design & Installation by Simple Solar Systems, Joe Callahan 303-541-9852, 303-819-7518 http://www.simplesolar.com/ assisted (one workday was 16.5 hours) by Scott Franklin, 303-638-4562 scott@lighthousesolar.us

Photovoltaic Panels

Silicon PV modules by Sharp Electronics Corp., supplied by Sunsense Solar Electric Systems Carbondale, CO (970) 928-9272

- 22 167-Watt Multi-Crystalline modules in upper array
- 18 175-Watt Mono-Crystalline modules in lower array
- Cost: \$54,000 with 50% to be covered by Xcel rebate

Inverters

Fronius IG inverters from Sunsense Solar Electric Systems Carbondale, CO (970) 928-9272

Energy & Electric Efficiency

Quick Specs:

- Low electrical demand achieved through use of compact fluorescent bulbs with occupancy sensors (manual on/timed off)
- "Phantom loads" reduced through use of power strips on switched outlets
- Energy-Star rated major appliances including fridge, dishwasher and washer/dryer. (Compared to an average 10-year-old unit, a good fridge today uses half the electricity.)
- In 2006, utility connection and natural gas costs (\$2.20 for dryer and range) have been about \$18 per month, with a check from Xcel Energy expected once per year based on net metering sales at 3 cents per kilowatt hour.
- Annual net energy bill is expected to be zero, or less.

Electric and daylighting consulting by

Nancy Clanton, PE, PIES, LC, IALD & Associates Boulder, CO 303-530-7229 www.clantonassociates.com

- Integrated design and analysis approach to energy efficiency and aesthetic by optimizing natural daylighting and low-load fixtures
- Pin-type compact fluorescents used where possible to ensure that replacement bulbs will be compact fluorescents because the ballast is located in the fixture rather than the bulb



Fixture consulting, research, specifying & supply by Front Range Lighting, 303-684-0080

Electrical Contractor: Town & Country Electric, 303-494-5939

Low Voltage Design & Installation (cable, telephone, ethernet in Structured Cable) by Harrison Home Systems, 720-298-7614

Data Logging & Monitoring consulting equipment not yet installed; future website will show energy data.

Appliances from Boulder Valley Appliance, 303-449-4440

•Range & clothes dryer use natural gas. The energy consumed for these purposes will be offset by electricity generated by solar PV panels, resulting in the designation of "Zero-net-annual site energy."

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Interior Finishes

Quick Specs:

- Formaldehyde-free cabinets and carpet and low-odor wood finishes
- Low-toxic, water-based floor finish
- Low-solvent construction adhesives
- Salvaged and environmentally preferable flooring
- Interior materials & color by Catherine Childs with Charlotte Hansen, color consultant



Painting and Staining by Tom's Painting, Boulder, CO 303-776-2063

- All paints & sill/railing varnishes by AFM Safecoat Paints and Oils, purchased from Planetary Solutions in Boulder, CO 303-442-6228
- Zero-VOC, solvent-free, food-safe polymerized linseed oil finish on all cabinets and built-ins by **Tried and True Varnish Oil** Truemansburg, NY 607-387-9280 www.triedandtruewoodfinish.com

Stairwell mural by local artist Sarah Spencer 303-661-9767

Doors All but a few are salvaged/seconds from Habitat for Humanity Outlet, Denver 303-722-5863, including interior full-lite units

Tubs are salvaged/seconds from Bud's Warehouse, Denver 303-296-3990

Flooring: High-Density Bamboo prefinished flooring from Four Winds Bamboo Boulder, CO 303-447-2389 www.fourwindsbamboo.com Now available unfinished (lower upstream health and safety costs) from

Sustainable Flooring, Boulder CO. www.sustainableflooring.com

Salvaged Oak flooring from a Boulder home demolished in early 2005, finished with Traffic by BonaKemi (800) 872-5515 www.bonakemi.com **Installation/finish** of bamboo & oak by Bldr Valley Hardwoods 303-859-0970

Marmoleum linoleum in mudroom

EarthWeave all-natural wool carpeting with Hemp/Cotton Backing supplied by Eco-Products 303-449-1876

- No dyes, pesticides or stain protections therefore no VOCs contributing to harmful indoor air conditions; biodegradable
- Hardy hemp fibers used as backing are naturally mold resistant and contribute to the its ability to naturally biodegrade

Consultant & mfr rep: EcoBuild, David Adamson, Boulder, 303-545-6255

Hypo-allergenic/non-offgassing carpet pad - by Healthier Choice Foam, supplied by Eco-Products: 303-449-1876

Interior Finishes

Cabinets & Built Ins:

Cabinet design & specifications by Rick Stone of R. Chase Design, Inc. Lafayette, CO 303-604-0177

Cabinet features include EarthSource FSC-certified Maple and Cherry wood species treated with 2 coats VOC-free Linseed oil finish; maple and cherry veneers are FSC; "WOODSTALK" hard rock Maple print 2-sided Melamine, ³/₄" & ¹/₄"; drawers prefinished with "Valspar Enviroplus" VOCfree waterborne finish www.earthsourcewood.com

Art case designed by Catherine Childs & Mark Bradley Built by Mark Bradley of Ecofutures Building

Countertops:

Hanstone kitchen countertops by Hanwha, Inc.,

by Top Shop, Denver, CO 303-421-4377 http://www.hanstoneusa.com



Engineered quartz countertops selected for aesthetic and durability.

Unlike granite, e.g., Hanstone requires no sealant.

Avonite countertops in bathrooms, by Top Shop http://www.avonite.com



Composed of reclaimed and recycled solid surfaces, contributing to a zero-waste manufacturing facility

Window sills & stair railings are "Lyptus" – plantation-grown Brazilian hardwood (30 years of sustainable Lyptus forestry to date). Sunspace sill is FSC-certified Pau Lope, from Boulder Lumber.

Drywall Hanging by Eloy Miramontes, 720-350-2185

Drywall Finishing by Francisco Martinez, 720-333-6159

Porcelain, Ceramic and Stone Tiles and Recycled Glass Grout:

Design and Supply by Capco Tile & Stone by Kim Smith 303-545-5295

Installed by Bob & Don's Tile, Don DeBacker, Boulder, CO 303-444-5394, and Fit to Be Tiled, Kris Campbell 303-588-9393 (foyer, sunroom, master bath); and Justin Snow 303-898-2125 (kids' baths, kitchen)



Roofing



Underlayment

- 1. Long-lasting Titanium UDL favored for steeper-pitched roofs, durability and longevity
- 2. Ice & Water Shield (2:12 pitch)





Roofing

Ny-Slate shingles by Nycore Atlanta, GA 770-980-0000 Contact: Marc Herubin MarcHerubin@nycore.com

- Nycore makes Ny-Slate shingles of 100% recycled post-consumer ٠ carpet -- looks and functions like slate, but is can be walked on
- Lightweight, mold- and bacteria-resistant alternative to roofing ٠ materials such as slate, tile, cedar, or asphalt.
- Warranted for 50 years, but likely will last much longer ٠
- Manufacturing processes produce no harmful vapors or materials and ٠ Nycore guarantees 100% recyclableability by taking back used material and using it again for a complete life cycle - endorsed by United Earth and Claus Nobel of the Nobel Peace Prize Family
- Stainless steel screws and copper flashing used to match the lifetime of ٠ the roofing; copper is also recyclable

Expert Installation by Saville Roofing 720-352-7423

Exterior Finishes

Quick Specs:

- Grailcoat flexible stucco for durability & enhanced waterproofing
- Exterior woodwork (stairwell railings) FSC Pau Lope; Hardiplank fascia; salvaged beams for front entry braces; ACQ low-toxic pressure-treated 6x6 landscaping ties

Stucco

- 3-Step Superflex Stucco Exterior from GrailCoat (877) 472-4528 http://www.grailcoat.com
 - Grailcoat is a flexible concrete material composed of acrylic polymer, cement and aggregate when applied provides a single seamless waterproofing membrane
 - Over the rasped Styrofoam, a polypropylene mesh is applied to the wall surface followed by two coats of Grailcoat for strength and adhesion. The final texture coat gives the wall a unique stucco-like aesthetic.
 - Perm rating of 5. Warranted for 20 years against cracking in vertical applications.

Installation by GGs Coatings, 720-939-0012 - one of 2 certified installers in Colorado. This is the first use of GrailCoat in Boulder!



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Summer Cooling





Warm, exhaust air leaves house through attic vents

Whole-house fan pulls 800 or 1600 cfm of warm air out of the house for cooling and fresh air exchange





Space Heating



Gallery









About the Design/Build Team



Eric, Catherine, Brian and Ariel

Eric Doub arrived in Boulder in 1970 and has been involved in green building and renovation since 1982. With an individually designed degree in 1988 from Stanford called "Sustainable U.S. Resource and Security Policies," he started his award-winning company, Ecofutures Building Inc., which has grown at an average of 35% per year for the last 12 years, primarily due to an ongoing dedication to comfort, health, durability and resource efficiency in residential projects.

Catherine Childs has lived in Boulder since 1981, pursuing a career in human services and, more recently, restorative justice. Since marrying Eric in 1994, she has been supporting his dedication to high-performance homes. With Solar Harvest she has launched into the world of interior design, green specifications, and finishes.

Ariel and Brian Doub are the enthusiastic and evercurious children who know their new house is kind of like a Prius – it won't pollute as much! ~107 required, 250 Green Points achieved

And highest energy star rating of any Colorado home to date! (97.7 points out of 100)



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