

How Much More will BuildSmart Cost?

... it depends on the baseline, i.e. ..Compared to what?

- IECC?
- An unaffordable, leaky house with high energy costs?
- A toxic house, causing health problems for occupants?
- A national “average” that excludes local price drivers?



Most of BuildSmart is **cost-neutral**

Based on:

McKinsey Report
AEC

City of Fort Collins / Colorado New Home Choices

For example:

In a 5,000-square foot, \$1.2 million dollar home...

5% of the final budget is allocated to get to BuildSmart-mandated HERS 10 or better. This 5% includes:

- envelope upgrades
(2x6 walls with thermal breaks + Icynene)
- high performing windows
- sunspaces
(space heat collector, ~\$23,000 or ~1.6% of project costs)
- renewable energy systems for \$35,000
(solar thermal + solar electric = 2.25% of project costs)
- mechanical system efficiency upgrades (AirTap)

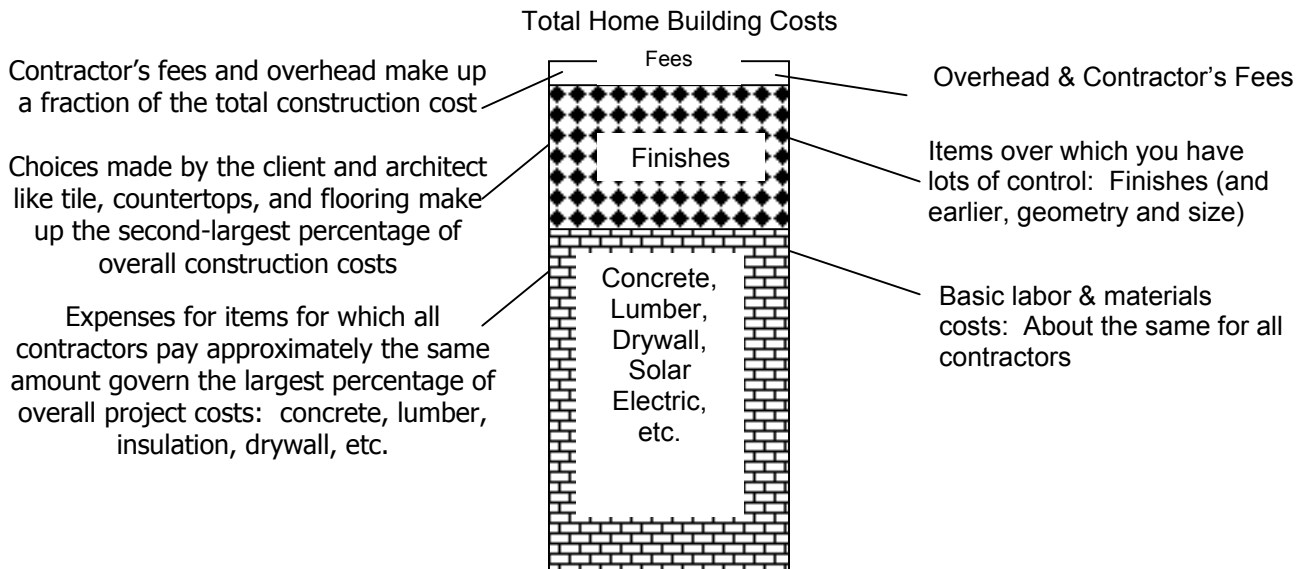
*Getting to HERS 25 is not an easy feat from a **design & engineering** standpoint, but from a **construction cost** point-of-view, those **line items** affected by **high performance** home design make up only a **tiny, single-digit percentage** of overall project costs.*

How Much Does It Cost?

Top 5 greatest factors determining construction costs:

1. Size
2. Site
3. Geometry
4. Complexity of design
5. Elaborateness of finishes

How costs break down:



Architect **John McLean** published this "Construction Cost Reality Checklist" in *Fine Homebuilding Spring, 2005* to help give prospective new homeowners an idea how construction costs break down.

It is a common misconception that the **builder** – his fees, subcontractors, and materials – are the factors that drive construction cost.

When, in fact, it is the decisions of the architect and homeowner that are the primary drivers. Decisions can range from basic design concepts (illustrated in column 1) to the most expensive building features (column 5).

Size, geometry, complexity of design, and level of finishes are the greatest influences on construction cost.

In general, mechanical systems, energy efficiency, and other performance-related factors make up a very small part of the total construction budget.

Item	EASY AND INEXPENSIVE		HARD AND EXPENSIVE		
	1	2	3	4	5
Ground-floor construction	Slab on grade	Single-level joists over minimum-height crawlspace	Single-level joists over varying-height crawlspace	Multilevel joists over varying-height crawlspace	Multilevel joists over full-height basement
Exterior-wall construction	Straight stud walls supporting 8-ft.-high ceilings and flat or gable-roof framing	Straight stud walls supporting 9-ft.- to 10-ft.-high ceilings and flat or gable-roof framing	Straight stud walls supporting varying-height flat/sloped ceilings and flat/gable/hip roof framing	Straight and curved stud walls supporting varying-height ceilings and flat/gable/hip roof framing	Straight and curved walls supporting various ceiling and roof shapes; rain-screen-wall construction
Exterior-wall finish	Stained/painted exterior plywood; wood trim at doors, windows, and corners	Stucco on front wall; painted wood or fiber-cement siding elsewhere; wood trim at doors, windows, and corners	Stucco or B-grade painted/stained wood siding on all walls; wood trim at windows, doors, corners, and eaves/soffits	Brick or A-grade stained-wood siding on all walls; wood trim at windows, doors, corners, wall base, and eaves/soffits	Stone, clear vertical-grain wood siding, or unique finishes on all walls; wood trim everywhere, including porches and balconies
Exterior doors	Brushed-aluminum sliding-glass doors	Powder-coated aluminum sliding-glass doors; painted steel and hinged wood doors	Clad-wood sliding-glass doors; fiberglass or stained/clear finish hinged wood doors	Painted or stained wood French doors with standard muntin pattern; matching sidelite panels	Clad-wood French doors with custom muntin pattern; matching sidelite and transom panels
Windows	Brushed-aluminum or vinyl sliding windows in standard sizes	Powder-coated aluminum or good-grade vinyl sliding windows in standard sizes	Painted/stained wood or fiberglass windows in standard sizes	Top-grade painted/stained wood or clad-wood windows in regular muntin pattern; standard sizes	Painted/stained wood, clad wood, or steel windows in custom sizes and shapes
Roof shape and construction	Gable or flat; rectangular plan; prefabricated wood trusses	Gable; L-, T-, H-, or U-shaped plan; solid-lumber framing	Gable, hip, shed, and/or flat roof; solid and engineered lumber	Combination of common roof forms; dormers; clerestories	Combination of unique roof forms; lumbar and steel framing
Roofing material	Asphalt shingles; built-up roof	Premium laminated shingles	Fire-treated wood shingles	Clay/concrete tile; metal panels	Slate
Skylights	Small-size fixed plastic domes	Small-size operable plastic domes	Large-size fixed plastic domes	Operable clad-wood roof windows	Custom operable steel/glass units
Subtotal	0	3	2	2	0



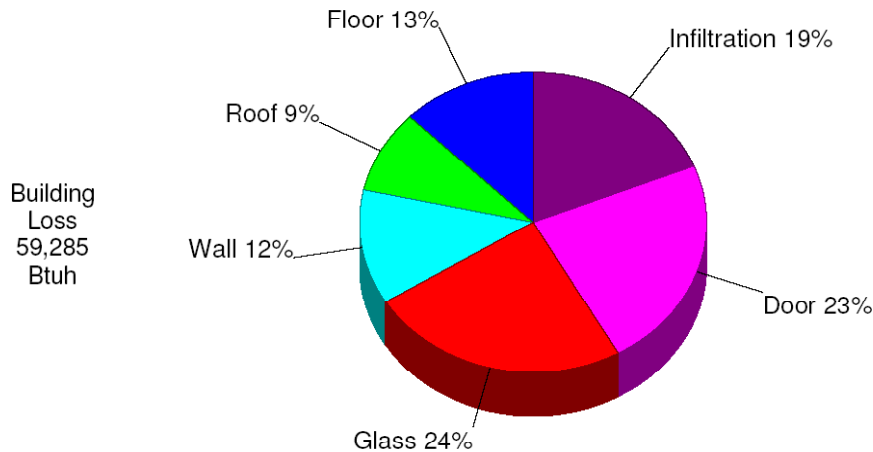
BuildSmart Food For Thought

"If you want to fill a bathtub with hot water, first put in the drain plug." -Amory Lovins

Keep in the heat you get (winter)

Keep out the heat you don't want (summer)

Building Pie Chart



65° F is the magic number for winter comfort – when surfaces are this temperature, and there are no drafts, people feel warm

Building Science is integral with building design and construction
(see "Building Homes That Last," reverse)

Build Tight, Ventilate Right...
 AND Reduce Indoor Air Emissions

Despite Our Best Efforts...

- # **Clients can later add (or allow to be added) all sorts of toxins to the home:**
 - Housecleaning products & laundry detergents & spot removers
 - Personal care products (e.g. hair sprays etc.)
 - Electronics (e.g. Comcast box or UPS for computer, giving off brominated flame retardant fumes, DecaDBE and TBBP-A)
 - Repainting or restaining with toxic products
 - Furniture with formaldehyde and other offgassing; window treatments
 - Unsustainably harvested wood in furniture and shelving
- # **And clients can add energy-hog end uses:**
 - Hot tubs
 - Incandescent bulbs where screw-base CFs were used to start
 - A second fridge, put in a hot garage, which wipes out the savings generated in specifying all the home's other Energy Star appliances

So it's whole-systems thinking that counts.

Building Homes That Last: What builders, owners, designers and regulators need to know

Our goal should be to build homes with 2 to 3 times the thermal resistance they currently have, and remodel homes to the same standard.

BUT when we add insulation, complex assemblies and new and innovative cladding products, we risk vapor and moisture problems.

Teaching Building Science should be a fundamental element to every building program seeking to mandate construction of homes that are long lasting, healthy, and energy efficient.

What can Boulder County do to mandate building science rules are followed, and continually updated?

- Classes, seminars and webinars for builders? A “scared straight” program beginning with the perils of not following of rules building science?
- Mandatory yearly class attendance in order to apply for permits?
- Written test with each permit application? 🤔
- If classes/tests not taken, 3rd Party Verification Required?
- Homeowner/builder walk-through and maintenance education courses or resources, like HomeSmart. Can Boulder County work with HomeSmart’s creators to create a customized, interactive website for our region?
- Classes are Continuing Education Credits?
- Mortgages & financing more readily available to homes built by “certified” builders (a dream); reduced permit fees for builders who have completed and demonstrated training?

CERTIFICATION, CLASSES AND TESTS

Annual and semi-annual day intensive courses can demonstrate some of the major problems that result from not following good building practice and present solutions. Key speakers could be:

Joe Lstiburek, Building Science Consultant www.buildingscienceconsulting.com/

John Krigger, Saturn Resource Management www.srmi.biz/

Building Knowledge Consulting (see below) www.buildingknowledge.com/

THIRD PARTY VERIFICATION CONSULTANTS aka. “QUALITY CONTROL SPECIALISTS”

Architectural quality control specialists are multi-disciplinary firms with expertise in many areas of building science. They provide services such as: peer review of construction documents, building code and accessibility analysis, contract review and construction observations. Having an objective third party review plans helps to ensure that no critical design elements are overlooked or incorrectly specified.

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/

ONLINE RESOURCES

Building Science Corporation www.buildingscienceconsulting.com

Building technology consulting firm internationally recognized for our expertise in moisture dynamics, indoor air quality, and forensic (building failure) investigations. Online articles include:

- "Air Pressure and Building Enclosures"
- "Water Management Details – Housewraps/Flashings/Windows"
- "Understanding Attic Ventilation"

Building Knowledge www.buildingknowledge.com/

Offering comprehensive seminar and workshop based training programs including:

- "Comprehensive Building Science Training"
- "Rain and Moisture Management"
- "Marketing and Selling a Better Built Home"

Saturn Resource Management www.srmi.biz

Consultants, trainers, publications, and curricula for raters and building professionals. Resources include:

- "Residential Energy: Cost Savings and Comfort for Existing Buildings"
- "Quick-Tips Reference Sheets"
- "Comprehensive Home Energy Curriculum"

HomeSmart www.home-smart.org/

Minnesota-based homeowner education initiative offering an interactive website with guides to maintaining and living in a healthy, efficient home. Key features:

- Monthly calendars
- Photo- and image-based "how-to" guides

Minnesota's GreenStar Program www.mngreenstar.org/

Green building standard and certification program offering a full range of benefits to certified homes and builders

- Certification can result in: tax credits, rebates on building materials, mortgage rate discounts, and more

Best of Building Science www.bestofbuildingscience.com/

Movie clips from building science leaders at national building conferences discussing basic building science rules

Building America Program www.eere.energy.gov/buildings/building_america/

Providing literature and guidelines to energy solutions for new and existing homes

Journal of Light Construction www.jlconline.com/

Journal and publications featuring the latest in building science philosophy

Energy and Environmental Building Association www.eeba.org/

Conferences, lectures, website content, networks, and publications following developments in building science

BOOKS

Green from the Ground Up: Sustainable, Healthy, and Energy-Efficient Home Construction. By David Johnson & Scott Gibson. The Taunton Press. 2008.

REGREEN Residential Remodeling Guidelines. USGBC and ASID. 2008.

"The most definitive and comprehensive guidelines published to date, and the only ones closely tied to building science."

Presentations, Lectures & Speaking Engagements

By Eric Doub

All presentations are also listed and available for download online on the Ecofutures Building website. Visit: http://www.ecofuturesbuilding.com/powerpoint_presentations_0

National Conferences

- ["South Boulder Net-Zero Energy Retrofit: Remodeling According to REGREEN"](#)
 - Greenbuild 2008, Boston MA. "REGREEN Session" Wednesday November 19, 2008.
- ["All-Electric Homes Net-Zero Energy Homes in a Cold Climate: Can it be done?"](#)
 - Greenbuild 2008, Boston MA. "Extreme Green Session" Wednesday, November 20, 2008.
- ["Increasingly Doable Net-Zero Energy Design"](#)
 - ACI Home Performance Conference, Pittsburgh, PA. Thursday April 10, 2008.
- ["Beyond 'Green' and 'Passive vs. Active': Benefiting people & the planet through verified net-carbon-neutral homes."](#)
 - ACI Home Performance Conference, Pittsburgh, PA. Tuesday April 8, 2008.
 - 2nd Annual Passive-House Conference, Urbana, IL. November 2, 2007
- ["Deep Energy Retrofit and Green Remodel"](#)
 - ACI Home Performance Conference Short Course: "Deep Energy Retrofits: Moving Toward Carbon Neutrality," Pittsburgh, PA. Monday April 7, 2008.
 - ASID Interiors08 Conference, New Orleans, LA, March 12, 2008
 - Greenbuild, 2007, Chicago, IL. November 11, 2007
- ["Profitably Decarbonizing"](#)
 - CU Bioneers Conference, Boulder, CO. October 20, 2007
- ["Increasingly Intelligent Design"](#)
 - 2007 Solar Week Conference and Expo, Boulder, CO. September 23, 2007
- ["Guiding Green & Healthy Decisions in Interior Design:"](#) Experiences of a Green Builder.
 - Presented to the first meeting of the Sustainable Residential Interiors Program, a joint venture with the American Society of Interior Designers, USGBC and national professionals. Washington, D.C. April 8, 2007
- ["Solar Harvest: Beyond Net-Zero Energy":](#)
 - ASES Solar 2006 Conference, Denver, CO. July 9, 2006

Community Events and Policy Hearings

- ["Ecofutures Building: To Net-Zero Energy and Beyond"](#): a look into the history of Ecofutures Building, and forecasting the next frontier
 - Presented to 70+ members of the Jefferson County Rotary Club, January 9, 2008
- ["Life Cycle Impact Assessments: Seeking the least-impact approach"](#): an overview of currently available metrics for assessing life cycle impacts of building products.
Presented to Boulder County Land Use Review Board, November 13, 20

Sample Mechanical Systems Comparison - BuildSmart Home, Jan. 2009 (HERS 5)

Sunspace + Solar Thermal

Geothermal

Notes	COST	Annual energy use (kWh)	System	END-USE	System	Annual energy use (kWh)	COST	Notes
HEATING								
~156 sf @ \$110 psf	\$23,000	300	Sunspace		Geothermal ground-loops*	7500	\$30,000	Loop field + compressor + AHU + digging
Hydronic coil, ERV + air handling unit	\$4,000	<i>same as geo</i>	Enerboss					
14 kW Thermolec	\$1,500	3600	Backup Boiler					
COOLING								
6-ton/2,000 cfm	\$6,800	288	Coolerado		Geothermal ground-loops	1300		<i>included in geo, above</i>
FRESH AIR CIRCULATION								
Integral to Enerboss	<i>included above</i>	<i>included in Enerboss, above</i>	In Enerboss		RecoupAerator ERV	250	\$1,500	Provides fresh air supply when geo. is off
HOT WATER								
4 panels + 500 gal. tank to pre-heat DHW	\$10,000	470	Panels + Pumps		Geothermal ground-loops	<i>included in geo, above</i>	\$2,550	Pre-heat, only operates with geo
50 gal. electric with AirTap	\$1,500	660	DHW tank w/AirTap		DHW tank w/airtap	1890	\$1,500	50 gal. elec. backup to geo
AMENITIES								
Solar-heated hot tub	\$2,000	1200	Spa		Spa	4200	\$2,000	Electric-heated hot tub
	\$48,800	6518		TOTAL		15140	\$37,550	

Notes	COST	Annual energy use (kWh)	System	END-USE	System	Annual energy use (kWh)	COST	Notes
-------	------	-------------------------	--------	---------	--------	-------------------------	------	-------

ASSUMPTIONS

Mechanical system power levels and run times:

	Watts	Hrs/day	Days/year	kWh/year
Coolerado	550	8	60	264
Enerboss	<i>kWh similar to geothermal AHU so it is omitted from this spreadsheet</i>			
ERV	100	12	205	246
Hot Tub	300	24	180	1296
Solar Thermal Pumps	260	6	125	195
Sunspace	300	8	125	300
DHW tank w/airtap	<i>assumes 6,000 kWh/year for DHW minus 90% by solar = 1,200 kWh/year, minus 55% by airtap</i>			
Thermolec Boiler	12000	12	25	3600
Geothermal system: heating**	<i>see notes below</i>			7500
Geothermal system: cooling***	<i>see notes below</i>			1300

*Comment: Loop field is very likely under-sized in this quote. It is a systemic problem the geothermal industry that bidders downsize loop fields in order to provide lower quotes and get jobs -- leaving end users to use and pay for more electricity than an independent engineer's loop field would have led to.

Sunspace cost psf counted at 100%

Solar thermal cost is estimated post-federal tax credits, not including GEO/CRC rebates or ClimateSmart (1A)

Geothermal information provided by a local geothermal company:

****Annual energy to heat a 5,500 sf home in Boulder: 7,500 kWh +/- 1,000 kWh**
 This equates to a power demand of ~3.0 kW +/- .5 kW

*****Annual energy to cool a 5,500 sf home in Boulder: 1,300 kWh +/- 1,00**
 This equates to a power demand of ~1.5 kW +/- .5 kW

These power draws include compressor and all pumps, and blowers

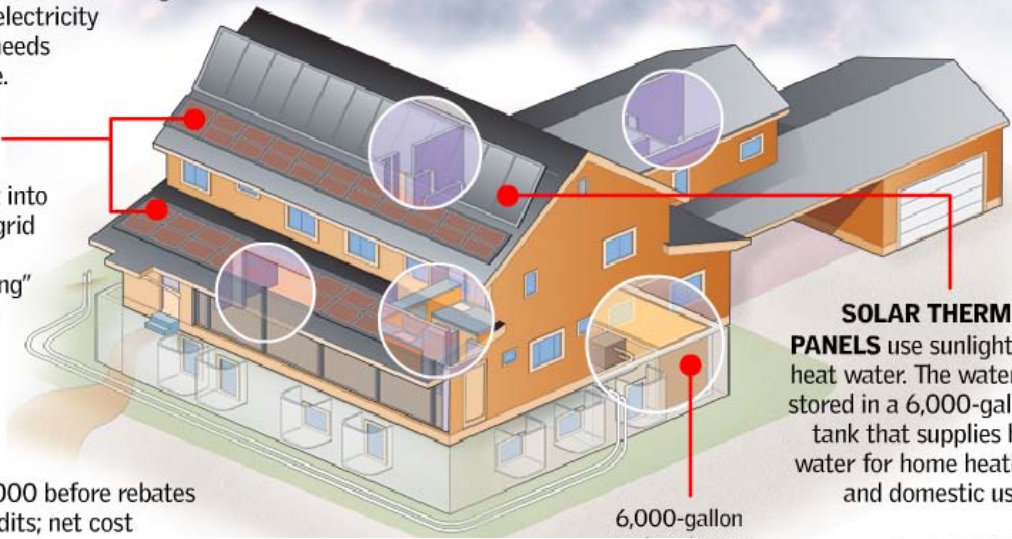
Download a copy of this spreadsheet and other materials online at:
http://www.ecofuturesbuilding.com/building_under_buildsmart

A ZERO ENERGY HOME

Solar power Capturing heat Geothermal ventilation Electricity Materials Appliances Insulation

PHOTOVOLTAIC PANELS, also known as PV, convert sunlight directly to electricity for power needs in the home. Any excess electricity generated is sold back into the power grid under a "net metering" agreement.

Cost: \$54,000 before rebates and tax credits; net cost



SOLAR THERMAL PANELS use sunlight to heat water. The water is stored in a 6,000-gallon tank that supplies hot water for home heating and domestic uses.

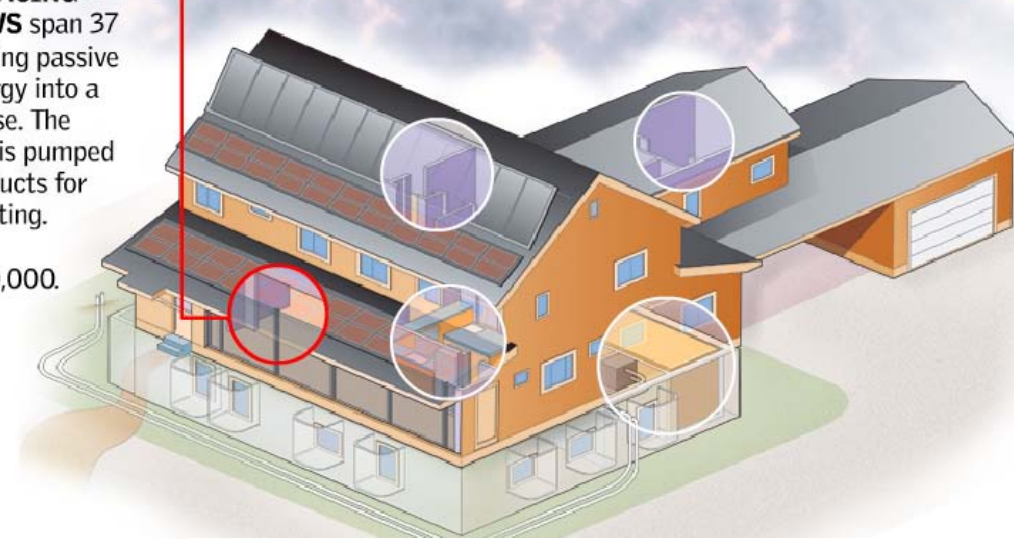
Cost: \$31,000.

A ZERO ENERGY HOME

Solar power Capturing heat Geothermal ventilation Electricity Materials Appliances Insulation

SOUTH-FACING WINDOWS span 37 feet to bring passive solar energy into a greenhouse. The warm air is pumped through ducts for home heating.

Cost: \$10,000.

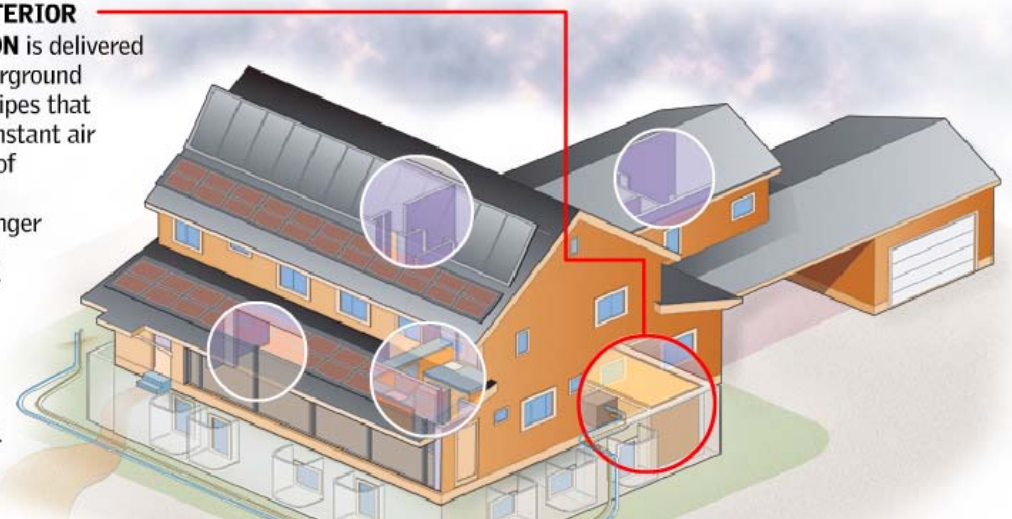


A ZERO ENERGY HOME

Solar power Capturing heat Geothermal ventilation Electricity Materials Appliances Insulation

AIR FOR INTERIOR VENTILATION is delivered through underground geothermal pipes that produce a constant air temperature of 55 degrees. A heat exchanger recovers heat from stale air to warm incoming fresh air.

Cost: \$9,000.



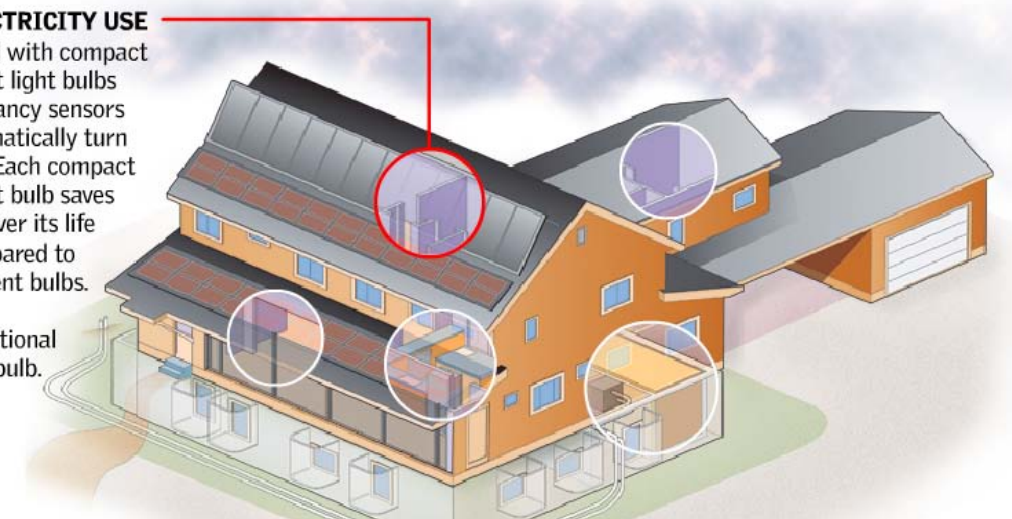
Portrait of a Net-Zero Energy Home: Solar Harvest

A ZERO ENERGY HOME

Solar power Capturing heat Geothermal ventilation Electricity Materials Appliances Insulation

LOW ELECTRICITY USE is achieved with compact fluorescent light bulbs and occupancy sensors that automatically turn off lights. Each compact fluorescent bulb saves \$55-\$75 over its life cycle compared to incandescent bulbs.

Cost: Additional \$1.25 per bulb.

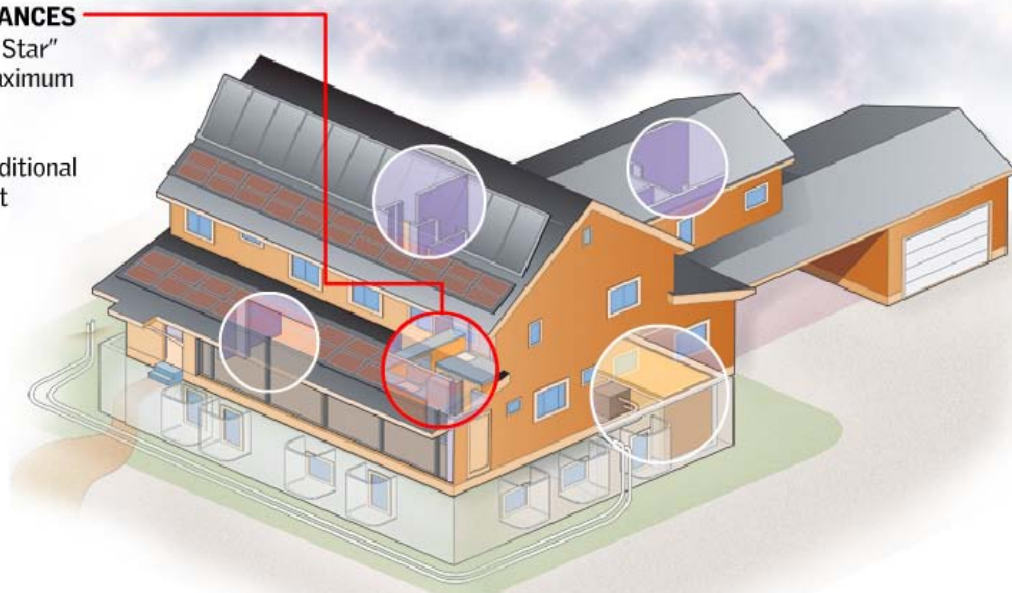


A ZERO ENERGY HOME

Solar power Capturing heat Geothermal ventilation Electricity Materials Appliances Insulation

ALL APPLIANCES are "Energy Star" rated for maximum efficiency.

Cost: No additional cost on most high-end appliances.

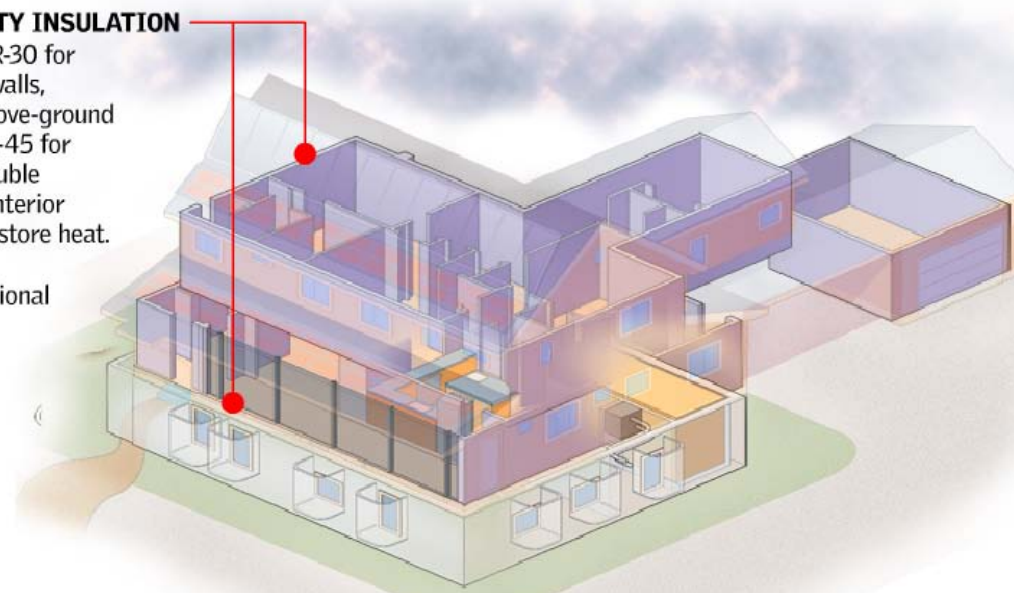


A ZERO ENERGY HOME

Solar power Capturing heat Geothermal ventilation Electricity Materials Appliances Insulation

HEAVY-DUTY INSULATION is rated at R-30 for basement walls, R-34 for above-ground walls and R-45 for ceilings. Double drywall in interior walls helps store heat.

Cost: Additional \$26,000.



Ecofutures Zero Energy New and Remodeled Homes, 2005 and Beyond as of 1.29.09

	A	B	C	D	E	F	G
	Solar Harvest (SH) North Boulder	Broomfield Nearly Net-Zero Energy	South Boulder Net-Zero Energy Remodel	Indian Hills Net-Zero Energy	Evergreen Net-Zero Energy	Longmont Net-Zero Energy Producer	Longmont Net-Zero Energy Home
New or Retrofit / Yr. Built / Elevation	New / 2005 / 5,450 ft. elevation	New / 2007 / 5,390 ft. elevation	Retrofit / 1970 / 5,600 ft. elevation	New / 2007 / 7,500 ft. elevation	New / 2007-8 / 7,700 ft.	New / future / 4,980 ft. elevation	New / 2009 in design / 5,200 ft. elevation
Conditioned SF	4,600	6,800	2783 (2068 existing incl. basement + 713 new)	4,700	3,000	7,000	5,200
Approx. Design Heat Load (BTUs/hr) @ degF	29,000 @ 2F	45,000 @ -5F	22,000 @ -5F	40,000 @ -10F (includes 30% warm-up factor)	25,000 @ -10F	50,000 @ -5F	35,000 @ 0F
Passive Gain (Hi / Med / Low)	High, into sunspace; heat distributed w/ fans and ducts	Very Low (2 windows of 56 in house)	Low	High	Medium	High, into sunspaces; heat distributed w/ fans and ducts	High, into sunspace; heat distributed w/ fans and ducts, low into S windows
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 / 8.8%	0.62 / 5%	0.72 in sunspaces; 0.53 elsewhere / 7.3%	0.82 in sunspace; 0.55 elsewhere / 9.7%
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 / No trees yet	0.27 / 30% tree shading; roll-down shutters on W (wind protection; traffic noise; thermal insulation; shading)	0.23 with electrochromic glazing yielding 0.06 (Sage Glass) / No trees yet	0.28 / high windows with overhangs, trees to be located as necessary
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	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	1" ext. EPS; 2x6 stud walls with 1 1/2" resilient channel; 7" Icynene	1" EPS foam ext; 2x6 with 1.5" resilient channel; 7" Icynene
Envelope: Windows	Fibertec; Heat Mirror (dbl. on north); tuned	Fibertec; triple pane w/ LowE	Fiberglass frames by Duxton, thru Alpen; double Heat Mirror throughout	Loewen wood clad windows with triple-pane glazing, tuned	Fiberglass frames by Duxton, thru Alpen; double Heat Mirror throughout	Loewen wood clad windows with triple-pane glazing, tuned; exterior motorized shutters; automated interior window treatments	Fiberglass frames by Duxton, thru Alpen; double Heat Mirror throughout. Avg U~.16
Envelope: Air Tightness (NACH = Natural Air Changes per Hour)	Very tight: <0.1 NACH	Very tight: <0.1 NACH	Tight: ~0.2 NACH	Very tight: <0.1 NACH	Very tight: <0.1 NACH	Very tight: <0.1 NACH	Very tight: <0.1 NACH
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)	Double 5/8" drywall throughout	Double 5/8" drywall throughout	Double 5/8" drywall throughout	Double 5/8" drywall throughout
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)	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; Stirling ERVs (**Sensible Recovery Efficiency: 83-81)	Low-emissions building materials; ERV integral with Enerboss or Lifebreath AHU
Utilities	Natural gas for cooking & clothes drying/therms offset 2005-2007; All-electric after July 2007/natural gas removed	No natural gas to home	No natural gas to home	No natural gas to home	Natural gas only for cooking	Natural gas for fireplace	No natural gas to home
Onsite Renewables: Electricity (solar et.al.) rated capacity; ~annual production	8.74 kW; 12,586 kWh; net excess 200 kWh, 1st year (with 6.84 kW array)	10 kW; 14,400 kWh	6.615 kW; 9,600 kWh	10 kW; 14,400 kWh	10 kW; 14,400 kWh	Building-integrated PVs (PV laminate): 14 kW on House, 4 kW on office; 25,500 kWh/year with hydrogen storage; future wind	10 kW PV; 14,400 kWh
Anticipated Annual Household Consumption	10,000 kWh/year thru 2007; 9,500 kWh/year 2008+	15,000 kWh/year	6,300 kWh/year	14,000 kWh/year	12,000 kWh/year	18,000 kWh/year	14,400 kWh/year
Onsite Renewables: 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	180 Thermomax evacuated tubes, @ 37 deg	180 evacuated tubes, @ 60 deg	10 flat plate solar thermal @ 30° & 8 flat plate solar thermal @ 90° in drainback. No heat rejection	4 4x8 solar thermal panels mounted in sunspace at 60 deg. tilt; sunspace air distributed with fans and ducts
Solar Storage Tank*	6,000 gallons, Atmospherically vented	600 gallons	360 gallons	1,500 gallons	2,000 gallons	3,000 gal + 120 gal DHW	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	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	Fans & ductwork from sunspaces; 4 Enerboss units and ductwork with hydronic coil for solar- or boiler-heated water	Fans & ductwork from sunspaces; Enerboss or Lifebreath and ductwork with hydronic coil for boiler-heated water
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 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	Solar w/ electric backup	Heat exchanger coils in solar tank + 50-gallon elec. water heater with AirTap backup
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)	Electric fan coil down stream of hydronic fan coil (PVs generate excess in summer; buy back in winter) expected usage ~800 kWh/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, 15 kW, modulating (PVs generate excess in summer; buy back in winter; expected usage 10 - 15 days/year)	Thermolec elec. tankless boiler, 14 kW, modulating (PVs generate excess in summer; buy back in winter; expected usage 10 - 15 days/year)
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	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	Electrochromic glazing; automatic blinds; DX AC 23 SEER ~1600 kWh/year (house) and Coolerado (fitness wing) ~40 SEER (manuf. specs)	1 Coolerado unit
Overhangs on south (2' projection, 12-16" above glazing)	Yes	No	No	Yes on 80%	Yes	Yes	Yes
Amenities / Notable End Uses	Outdoor spa + steam shower + fish tank	Coolerados + large home office + woodshop + electronics shop	None, besides vehicle charging. Current usage ~320 kWh/mo.; w/ addition, ~375; expect <1,500 kWh/yr for backup heat	Outdoor spa + vehicle charging + steam shower	Outdoor spa	Steam shower + vehicle charging + home office	Outdoor spa
\$ toward ZEH performance, for active solar (beyond envelope); % of building costs	\$70,000; 8%	\$103,000; 7%	\$59,000; NA	\$93,000; 7%	\$68,000; 8%	uncalculated; waiting for Poudre Valley REA rebates	\$60,000; 5%
Required HERS Index	<i>Had it been built under the revised Green Points, would have been required to rate: 60</i>	<i>Had it been built under BuildSmart, would have been required to rate: less than 10</i>	<i>not required (the revised GreenPoints does not address remodels)</i>	not required (Evergreen)	not required (Evergreen)	Less than 10	Less than 25
Rated HERS Index	HERS Score: 97 (Converted to post-2006 metric: HERS Index 15)	HERS Index 19	not rated	HERS Index: 14	HERS Index: 0	0	Less than 10
Project/Actual HERS Performance	0	0	0	0	0	likely -20	likely -5
Net-Zero Energy Home %	99%, first year / 112% 2007 & 2008	100%, projected; if less, then remainder covered by RECs	130%, projected, with net excess >1,500 kWh/yr	100%	100%	130%	100%
*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)					Sensible Recovery Efficiency (SRE) takes the actual temperature rise in the airstream into account along with all other energy		