Case Study 3100 sq. ft. home
Lafayette, CO

CASE STUDY: Ranch Home with Ground Based Heat Pump (GBHP)

Location: Lafayette, CO 80026 Elevation 5221'

Climate: Approximately 6100 F Degree Days heating, 1000 F Degree Days cooling

House: EPA 5 Star Plus ranch with full basement 1550 sqft up and 1450 sqft down, 3000 sqft heated

Insulation: Attic R38 blown in cellulous; Walls R19 bats, Foundation walls R11, Slab, R0.0 at edge, R10 under slab. Attached 2 car garage R11 walls, insulated steel garage door, insulated ceiling

Windows: Amsco double pane vinyl VLS low-E, U factor 0.34, solar gain 0.31. South facing 5 =103 sqft includes 2 patio doors; East facing 6 = 33 sqft; North facing 1 = 19 sqft + entrance door; West facing 3 = 28 sqft, 2 skylights = 13 sqft

Heat: 3.5 ton Econar 2000 ground based heat pump (GBHP) with desuperheater COP 3.7 to 4
Loop field: 3 loops 800' in length buried 5' below basement = 13' below ground level. Two inch R10 insulation under slab to isolate from loop field. Slab temperature typically 65 F

Hot water: 50 gal natural gas with desuperheater assist from GBHP, under counter *instant* hot water

Appliances: All Energy Star rated except late model upright freezer

Miscellaneous: Master bath has radiant heated floor @ 82 F

Heating performance 0.031 Therms/Heating F Degree Days

Cooling performance 0.037 Therms/ Cooling F Degree Days

ENERGY USAGE 12/19/2006 to 12/19/2007
Heating F Degree Days 2007 = 6068, Cooling = 968
House Temperatures: Winter 68 F nights, 73-75 F Days; Summer approx 76 F

Use	EPA Model Estimated	Actual	Difference	EPA Model	
	Therms	Therms	Therms	Est Cost $	Act Cost$
Heating	228	187	- 41	559	386
Cooling	23	36	+13	59	98
Hot water	210	150	- 60	191	116
Lights/Appliances	347	223	-124	796	608
Service charges				195	121
Total	**808**	**596**	**- 212**	**1800**	**1337**
Wind Adj. for Electricity					97
Totals					**1426**
Actual- EPA Model			**-27%**		-21%
	Total Cost without wind Adj. $1337				
	Total Cost with Wind Adj. $1426				

A Case Study: Ground-Source Heat Pumps
Heating a 3,000-square-foot house for $1.25 a day

By Fred L. Walls, Ph.D.
and Kay Turnbaugh

As his house was being built in Lafayette, Colorado, Fred Walls installed the loop field for a ground-based heat pump (GBHP) 5' under the basement. His research on GBHPs indicated they were the most energy-efficient means of heating and cooling, so he talked the developer of his neighborhood to dig a little deeper and allow him to install the necessary pipe work before pouring the foundation for his new house.

Walls, a physicist and Fellow of the American Physical Society and IEEE, documented his energy savings during the first year he and his wife lived in their new house.

During the first year his GBHP was on line, 2007, the energy usage for heating his home was only 21% of comparable homes with gas heat. His total energy usage is less than 50% of comparable homes. His average heating costs in 2007 were $38 per month, which included 100% wind adjustment for electricity.

Heating/cooling consumes roughly 45% to 70% of the energy in a typical home. GBHPs have efficiencies of 350% to 500% compared to a fuel-based furnace, which is typically 65% to 92% efficient. “Replacing an old 65% gas furnace with a new GBHP would reduce energy consumption for heating by an astounding 85%,” Walls says.

“GBHPs also provide very efficient summer cooling and can provide pre-heat for the hot water.”

Walls also points out that the gas that is saved by using a ground-source heat pump (GHP) can then be used to displace coal used in the generation of electricity. “This is important because gas generators produce 45% less CO2 and much less heavy metal pollutants than coal, and electrical output of gas generators can easily be controlled to accommodate changes in load and/or generating capacity of intermittent renewables such as wind or sunlight.”

“It’s a value-added system,” Walls says. “Investments in selected energy conservation projects show a savings in utility costs of roughly 5% of investment. The expected increase in energy costs should create an additional return of roughly 3% to 10% per year due to appreciation in the value of the energy conserving projects. Total rates of return could easily approach 8% to 15%. These factors make it feasible, in most cases, to reduce energy consumption, reduce the average monthly cost of ownership, and at the same time increase the value of your home.” Walls expects the value of his house to increase faster than the rate of inflation because of its energy-saving GHP system.

According to the National Renewable Energy Laboratory (NREL) and Colorado’s Xcel Energy, geothermal heat pumps, also known as ground-source heat pumps or GeoExchange systems, are the most energy efficient way to heat and cool a home and provide hot water. The Environmental Protection Agency (EPA) says that GeoExchange systems are the most energy-efficient, environmentally clean, and cost-effective space conditioning systems available.

Ground-source heat pump systems typically show a savings in utility costs of roughly 5% and add value to the home of about $20 for every $1 reduction in yearly home energy costs. (See *The Appraisal Journal*; “More Evidence of Rational Market Valuation for home Energy Efficienty,” October 1999.)

There are federal tax rebates for some energy conservation projects, including ground-based heat pump systems, and many utility companies offer large rebates for the installation of a GHP system. More than 1 million GHP systems have been installed in the United States, including over 1,000 at colleges and universities, according to NREL.

HOW IT WORKS

A GHP system moves the heat from the earth, or a groundwater source, into the home through a heat pump/exchanger in winter and pulls the heat out of the house and discharges it into the ground in the summer. Underground piping loops serve as a heat source in the winter and a heat sink in the summer. A pump circulates temperature-sensitive fluid through the ground loop.

Walls' system is installed under his house, which makes it more efficient than a system that is detached from the structure. Of course, if you're retrofitting a system to an existing structure, the pipes have to be buried in the yard or a field. Another idea for a retrofitted system is to install it under a driveway or other narrow strip of land. In this case, the system would consist of several wells that are drilled to approximately 200 feet.

A few feet below the earth's surface, the ground temperature remains at a relatively constant temperature. Depending on latitude, ground temperatures usually range from 45 degrees F to 75 degrees F (7 degrees C to 21 degrees C), even when temperatures outside can range from sub-zero in winter to scorching highs in summer. A GHP system can take advantage of this constant temperature by exchanging heat with the earth through a ground heat exchanger.

Walls has plotted the inside temperature and the outside temperature over the course of a year. As the first year of using his system progressed, it got more efficient. To see a graph of Wall's data for a day during the GBHP's first month of operation, click here.

COST and SAVINGS

A geothermal heat pump system averages about $5,000 per ton of capacity. A three-ton unit, at a cost of roughly $15,000, works for a typical residence. Xcel Energy estimates that other systems would cost about $4,000 with air conditioning. "When the cost is included in the mortgage, the homeowner has a positive cash flow from the beginning. For example, say that the extra $11,000 will add roughly $95 per month to each mortgage payment. But the energy cost savings will easily exceed that added mortgage amount over the course of a year. The cost savings of roughly 800 to $1,000/ year in utility costs adds about $16,000 to 20,000 to the value of the house. Therefore, the homeowner can typically reduce total monthly costs, increase the value of the home, and reduce total energy consumption with its associated CO_2 production.

Xcel Bills and Energy Usage						
Date	Elect kWhr	Bill $	Wind included $	Gas Therms	Bill $	Total Utilities $
28 Sept to 18 Oct	551	47.83	0	7	11.29	59.12
10/18/06 to 11/16/06	1238	103.77	0	23	26.43	130.2
11/16/06 to 12/19/06	1510	125.16	0	36	40.47	165.63
Calendar 2007						
12/19/06 to 1/22/07	1794	158.5	0.92	20	27	185.5
1/22/07 to 2/20/07	1507	140.06	1.47	22	29.01	169.07
2/20/07 to 3/21/07	1061	101.31	1.47	21	28.91	130.22
3/21/07 to 4/20/07	972	107.87	16.28	22	27.93	135.8
4/20/07 to 5/21/07	674	71.44	6.49	19	25.06	96.5
5/21/07 to 6/20/07	412	39.43	3.97	8	16.21	55.64
6/20/07 to 7/20/07	670	73.59	10.32	7	14.81	88.4
7/20/07 t0 8/20/07	916	97.95	16.76	8	16.31	114.26
8/20/07 to 9/19/07	796	86.16	14.56	8	16.75	102.91
9/19/07 to 10/18/07	415	47.54	5.22	17	20.93	68.47
10/18/07 to 11/16/07	738	77.64	6.71	26	27.45	105.09
11/16/07 to 12/19/07	1412	141.61	12.83	28	32.85	174.46
Total 2007	**11367**	**1143.1**	**97**	**206**	**283.22**	**1426.32**

Here are Walls' conclusions for his 3,000-square-foot home with a 3.5-ton ground-based heat pump for its first 12 months:

(1) Use of the ground-based heat pump reduced energy usage for heating by approximately 79% per square foot versus a conventional 80% efficient furnace.
(2) Total energy usage was reduced approximately 55% per square foot when compared to a conventional home.
(3) Cost savings were approximately $800 to $1,175 ($67/mo to $100/mo depending on rate structure). This is roughly $19/mo to $29/mo per ton of heating/cooling.
(4) Cost savings typically are enough to finance loan and still save on total monthly costs.
(5) The cost of the system added to the value of the house.
(6) The cost to install a system is very roughly $5000/ton.
(7) The size needed is roughly 1 ton to 1.5 ton per 1,000 square feet.
(8) Ground loop lifetime is 50 years guaranteed; expected lifetime is 200 years.

The following graph is for Walls' home in Lafayette, Colorado, for the 12 months from December 19, 2006, to December 18, 2007. Heating costs were about $1.25/day when all services charges including 100% offset with wind energy are included. Note that the heating energy consumption is only 21% of the comparison house when adjusted to the same square footage. Note that the comparison house energy usage was measured from January 1, 2007, to January 1, 2008. The Degree days are similar for December 6 (1028) and December 7 (1181) so the comparison should be valid to within 5% of December usage or a few dollars.

12 Months December 19 2006 to Dec 18, 2007

3000 SqFt Lafayette, CO 19 Dec 2006 to 19 Dec 2007 Heating/Cooling with Ground Based Heat Pump (GBHP) 3.5 tons Winter ≈75 F, Summer ≈76 F.				Comparison house 3600 SqFt Lafayette, CO 1 Jan 2007 to 1 Jan 2008 Gas Furnace, Traditional Air Conditioning Winter ≈ 69 F, Summer ≈ 76 F			
Heating Elect GBHP	Cooling Elect GHP	Cooking-gas Hot Water-Gas+ Elect GBHP	Lights Appliances Elect	Heating Gas	Cooling Elect Air Conditioner	Hot Water Gas	Cooking Lights Appliances Elect
Therms	Therms	Therms	Therms	Therms	Therms	Therms	Therms
187.2	35.8	149.6	223.7	1055	46	228	249
Gas Therms 210		Electrically Therms 386		Gas Therms 1259		Electrical Therms 319	
Total Therms 596.3				Total Therms 1578			
#Cost		$1426 = $119/mo		*Approximate Cost		$2055 = 171/mo	
#Includes surcharge for wind energy of $97				*Includes surcharge for wind energy of $87			

1 therm = 100,000BTU. 1 Therm = 29.2 kWhr

Graph by Fred L. Walls, Ph.D.

30-year fixed loan amortizations:

Monthly payments/ $5,000 versus Interest Rate

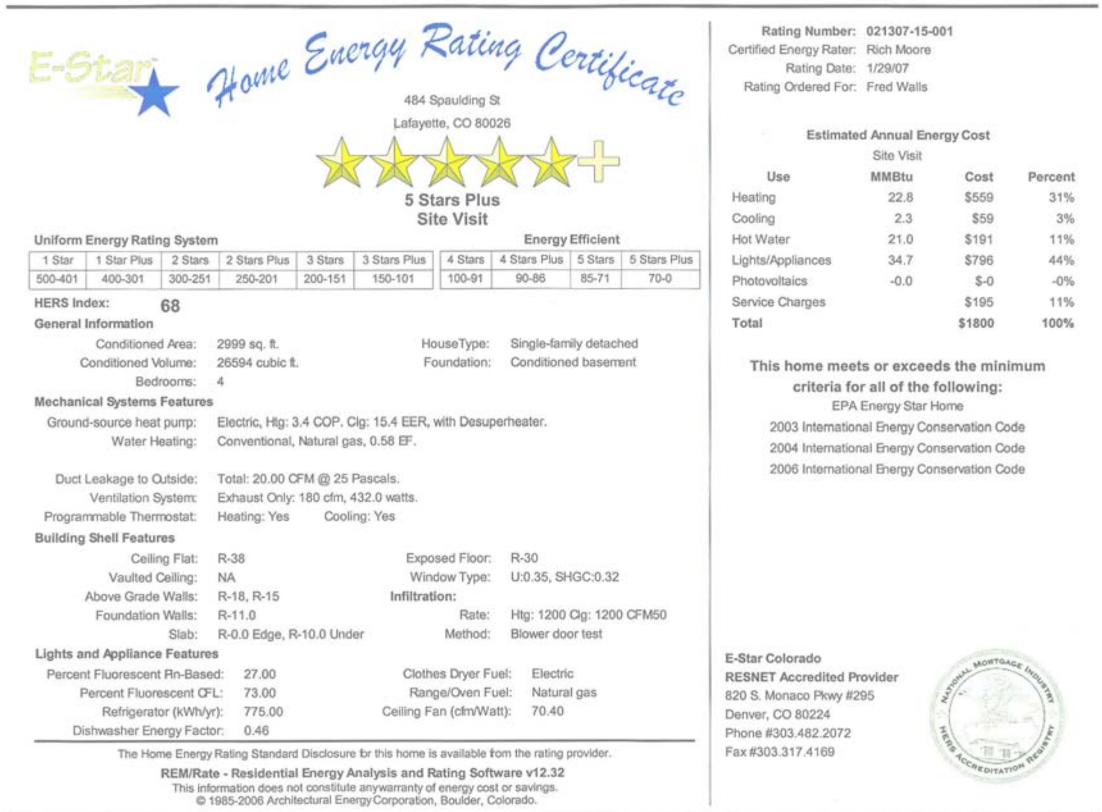
Interest Rate	6%	6.5%	7%	7.5%
Monthly Payment	$29.98	$31.61	$33.27	$34.96
Monthly Interest	$25	$27.08	$29.16	$31.25
Tax refund 32% Bracket	-$8.00	-$8.67	-$9.33	-$10
Net initial mo cost	$21.98	$22.94	$23.94	$24.96

Graph by Fred L. Walls, Ph.D.

One of the reasons Walls' system is so cost-effective is that he installed it under his house. He can't allow the ground under the house to freeze, because then the house would heave, so he installed enough pipes in the ground to keep it from freezing. The pipes are buried five feet below the basement, which is 13 feet below ground level, and, on the advice of a friend in Alaska, Walls took the extra precaution of adding two inches of Styrofoam insulation between the pipes and the house.

The house itself is insulated with R38 blown-in cellulous insulation in the attic and R19 bats in the walls. The foundation walls are insulated to R11, and under the slab is R10. The attached two-car garage has R11 insulation in the walls, an insulated steel garage door, and an insulated ceiling. Windows are Amsco double-pane vinyl VLS low-E, U factor 0.24, solar gain 0.31.

Walls hired an EPA-certified inspector to evaluate his home. He gave it a 5 Star Plus rating, which certifies that expected energy usage was less than 50% of comparable homes. Based on this rating, Walls qualified for a $2,000 tax refund.



E-Star Home Energy Rating Certificate

484 Spaulding St
Lafayette, CO 80026

5 Stars Plus
Site Visit

Uniform Energy Rating System — Energy Efficient

1 Star	1 Star Plus	2 Stars	2 Stars Plus	3 Stars	3 Stars Plus	4 Stars	4 Stars Plus	5 Stars	5 Stars Plus
500-401	400-301	300-251	250-201	200-151	150-101	100-91	90-86	85-71	70-0

HERS Index: 68

General Information

Conditioned Area: 2999 sq. ft.
HouseType: Single-family detached
Conditioned Volume: 26594 cubic ft.
Foundation: Conditioned basement
Bedrooms: 4

Mechanical Systems Features

Ground-source heat pump: Electric, Htg: 3.4 COP. Clg: 15.4 EER, with Desuperheater.
Water Heating: Conventional, Natural gas, 0.58 EF.

Duct Leakage to Outside: Total: 20.00 CFM @ 25 Pascals.
Ventilation System: Exhaust Only: 180 cfm, 432.0 watts.
Programmable Thermostat: Heating: Yes Cooling: Yes

Building Shell Features

Ceiling Flat: R-38
Exposed Floor: R-30
Vaulted Ceiling: NA
Window Type: U:0.35, SHGC:0.32
Above Grade Walls: R-18, R-15
Infiltration:
Foundation Walls: R-11.0
Rate: Htg: 1200 Clg: 1200 CFM50
Slab: R-0.0 Edge, R-10.0 Under
Method: Blower door test

Lights and Appliance Features

Percent Fluorescent Pin-Based: 27.00
Clothes Dryer Fuel: Electric
Percent Fluorescent CFL: 73.00
Range/Oven Fuel: Natural gas
Refrigerator (kWh/yr): 775.00
Ceiling Fan (cfm/Watt): 70.40
Dishwasher Energy Factor: 0.46

The Home Energy Rating Standard Disclosure for this home is available from the rating provider.

REM/Rate - Residential Energy Analysis and Rating Software v12.32
This information does not constitute anywarranty of energy cost or savings.

Rating Number: 021307-15-001
Certified Energy Rater: Rich Moore
Rating Date: 1/29/07
Rating Ordered For: Fred Walls

Estimated Annual Energy Cost
Site Visit

Use	MMBtu	Cost	Percent
Heating	22.8	$559	31%
Cooling	2.3	$59	3%
Hot Water	21.0	$191	11%
Lights/Appliances	34.7	$796	44%
Photovoltaics	-0.0	$-0	-0%
Service Charges		$195	11%
Total		$1800	100%

This home meets or exceeds the minimum criteria for all of the following:
EPA Energy Star Home
2003 International Energy Conservation Code
2004 International Energy Conservation Code
2006 International Energy Conservation Code

E-Star Colorado
RESNET Accredited Provider
820 S. Monaco Pkwy #295
Denver, CO 80224
Phone #303.482.2072
Fax #303.317.4169

MAINTENANCE

Xcel Energy says that geothermal heat pump systems have fewer maintenance requirements than most other systems. The underground components are virtually worry free. Walls' says the only maintenance he has to do for his system is to clean the filter every couple of months. Unlike regular furnace filters, his GBHP filter can be washed.

LIFESTYLE

Walls and his wife have not had to change the way they live to accommodate the geothermal heating system. "We can save 70% to 80% on gas consumption and not change our lifestyle," Walls says. They maintain their house at 73 degrees F in the winter and 76 degrees F in the summer.

When they leave the house for a few days or for a vacation, they enable the back-up electric strip heater within the geothermal system in the remote chance there is a failure in the loop field or compressor.

Some geothermal systems use radiant floor heating rather than a forced air system. The Walls' master bathroom floor is heated in the winter by electrical radiant heat.

Walls' data shows that the payback for a geothermal heat pump system is approximately twice as fast as a photovoltaic system, even with the rebates usually associated with a PV system. In 2007, the cost for heating Walls' house was $456.

CASE STUDY: Ranch Home with Ground-Based Heat Pump (GBHP)

Location: Lafayette, Colorado 80026; elevation 5,221 feet

Climate: Approximately 6100 F Degree Days heating, 1000 F Degree Days cooling

House: EPA 5 Star Plus Ranch with full basement; 1,550 square feet up and 1,450 square feet down, 3,000 square feet heated

Insulation: Attic R38 blown-in cellulous; walls R19 bats; foundation walls R11; slab R0.0 at edge, R10 under slab. Attached two-car garage: R11 walls; insulated steel garage door, insulated ceiling.

Windows: Amsco double-pane vinyl VLS low-E, U factor 0.34, solar gain 0.31. South-facing 5 = 103 square feet, including two patio doors; east-facing 6 = 33 square feet; north-facing 1 = 19 square feet, plus entrance door; west-facing 3 = 28 square feet; two skylights.

Heat: 3.5-ton Econar 2000 ground based heat pump (GBHP) with desuperheater, COP 3.7 to 4. Loop field: 3 loops 800 feet in length, buried 5 feet below basement = 13 feet below ground level. Two-inch R-10 insulation under slab to isolate slab from loop field. Slab temperature typically 65 F.

Hot water: 50-gallon natural gas with desuperheater assist from GBHP.

Appliances: Energy Star, except freezer

Heating performance: 0.031 Therms/Heating F Degree Days

Cooling performance: 0.037 Therms/Cooling F Degree Days

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Heating F Degree Days 2007 = 6,068; Cooling = 968

House Temperatures: Winter 68 F nights; 73-75 F Days; Summer approx. 76 F

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LINKS

Information on Energy Efficient Mortgages:
http://www.natresnet.org/alabama/mortgage.htm

Energy Efficiency & Building Technology:
http://www.icfi.com/Markets/Community_Development/cd-expertise-3.asp

International Ground Source Heat Pump Association:
http://www.igshpa.okstate.edu/

Geothermal Resources Council:
http://www.geothermal.org/index.html

Tennessee Valley Authority:
http://www.tva.gov/products/business/geothermal.htm

Geothermal Heat Pump Consortium (includes information about incentives by state):
http://geoexchange.us/