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NEW CONSTRUCTION

One Large Builder's Energy Evolution: What Worked, What Didn't

by Steve Andrews

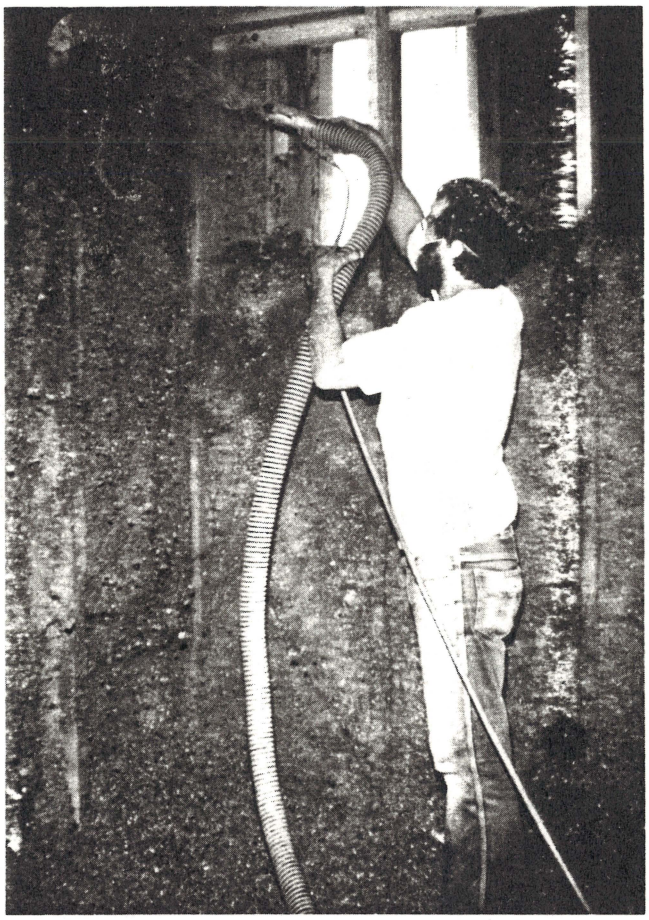
Going against the conventional wisdom, a builder in Colorado built—and sold—more than 700 extra-energy-efficient homes. The homes' owners now spend half as much on space heating as their neighbors do.

Large production builders are often the last to adopt new energy-efficient building practices and products. They'll readily tell you that few entry-level or mid-range buyers come to them asking for an energy edge. Yet ironically, production builders are also best positioned to explore the effectiveness of new approaches; they have the resources and can easily compare standard buildings to energy-efficient homes in large samples.

Every now and then, a large builder breaks the mold and takes a radical departure from the pack. Between 1985 and 1987, Denver-based Columbine Homes made a strong move to improve the energy features of their homes. A careful analysis of the costs and performance of the homes it built during that time shows how well that strategic decision turned out, even during the early stages of a serious regional housing depression. Columbine built over 700 homes with annual heating bills less than half that of average new-home construction. Savings on heating bills more than covered the higher mortgage payments required by the energy upgrades.

By late 1989, Columbine opted to leave the crippled Denver housing market. Their previous commitment to build more energy-efficient homes had no bearing on their action. In fact, Bill Richardson, construction vice-president, said that if anything, their focus on energy "helped us hang on longer than we could have without it. We had built up a really good reputation, thanks in large part to our energy package."

Steve Andrews is a residential energy consultant and writer living in Denver, Colo. He consulted with Columbine Homes, and went on to further analyze the data independently.



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Sprayed cellulose in wall cavities.

Company Commitment to Energy Efficiency

Columbine entered the highly competitive and relatively healthy Denver housing market in 1982. They concentrated on homes in the $75,000 to $95,000 price range. Early on, President Bill Butler sought a quality edge and marketing advantage. Beyond some differentiating interior features—better standard kitchen cabinets and the like—Butler leaned towards energy efficiency. This path offered an opening that no one else seemed to be pursuing in his price range.

During its first two years, Columbine offered extra attention to tightness and slightly higher R-values (R-38

ceilings, R-13 walls) than the competition (R-30 ceilings, R-11 walls). In 1984, the contractors began attending both passive solar and superinsulation seminars in hopes of finding a major, cost-effective upgrade. Since they planned to build on previously subdivided land, limited solar access presented too many problems to passive solar. Conservation made sense, but they were frustrated by disagreements among the experts (mostly about how to tighten and ventilate) and a lack of cost-consciousness among those they labeled as "energy purists." They eventually made a deliberate and strong commitment to conservation improvements, but their final package was two years in development.

Silver, Gold, and Refined Silver

By 1985, Denver's Homebuilder Association had developed a voluntary home energy rating system called the Energy Saver Homes program. Participating contractors building to the guidelines could choose from either a prescriptive list or a performance-based approach. Three levels, shown in Table 1, were designed to provide Energy Saver buyers with large reductions in their heating bills.

Initially, Columbine opted for the level labeled "Silver." The 50 needed performance points—each corresponding to 1 million Btus saved per year—can be gained by such things as HVAC efficiency, R-value, and the level of tightness as measured by blower doors. One of the easiest ways to reach the Silver level is through tightness. A builder can earn up to 21 tightness points, or 27 with a heat-recovery ventilator. At this point, Columbine aimed for 21 tightness points.

While searching for the best tightening and insulation upgrades, Columbine discovered a double-duty product:

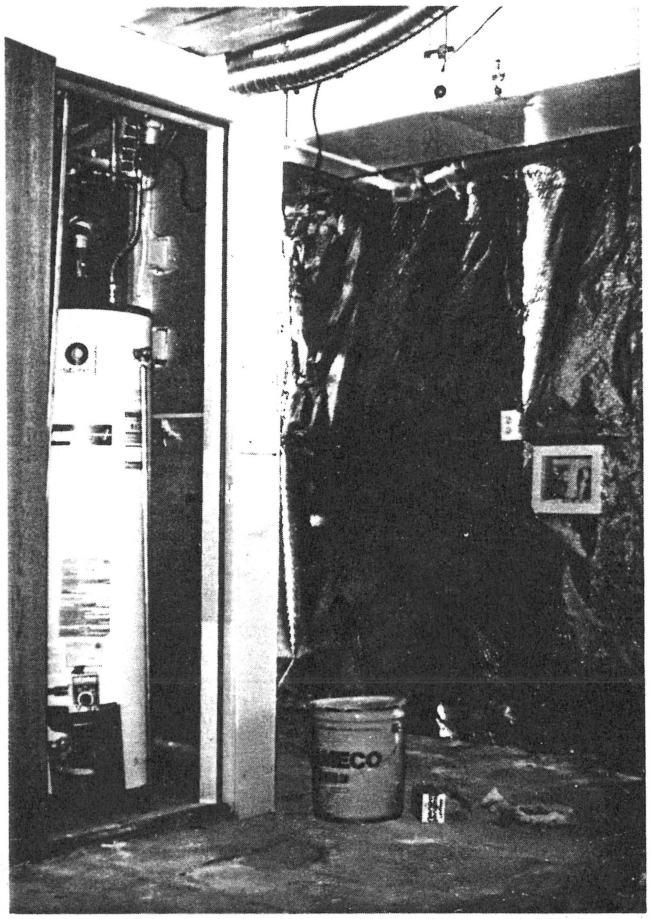
Table 1. Energy Saver Home Performance Standards.

	PERFORMANCE GOALS		ATTAINMENT METHOD
Level	Heating Energy Savings	Btu/ft²-HDD	
Current practice	n/a	7–8	n/a
Bronze	35% savings	4.5	prescriptive list or performance
Silver*	55% savings	3.2	menu list or performance
Gold	70% savings	2.0	performance only (computerized)

* also allows points for avoided electric load.

sprayed cellulose wall insulation. In 15 experimental homes, Columbine tested different products and techniques. Bill Richardson reported that the switch to blown insulation tightened up the shell more than any other single air-sealing step. Infrared scans indicated that the cellulose provided more effective wall and cantilever coverage than batts. When combined with 1-inch foil-faced polyisocyanurate foam sheathing, the scans showed no weak points in this 2x4 framed package. Basement walls—normally uninsulated in production housing—were also sprayed with cellulose and covered with a fire-rated foil product.

In-house sales staff began showing comparison thermal scans to prospective buyers. It proved to be an effective way to sell an unseen quality feature. Claimed Richardson,



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Walls sprayed with cellulose were also covered with a fire-rated foil product.

"Looking through a thermography scanner, our wall images looked black. Fiber-glass batted walls had heat short-circuits. And you could pick out the studs when we didn't use insulating sheathing."

To achieve further tightness, Columbine avoided the airtight polyethylene wrap, settling instead on a 3-stage foam sealing package: sealing before insulation, after drywall, and after trim. They hired an air-sealing specialty firm, which also blower-door tested every home and supplied a certificate to the home buyer specifying the degree of tightness attained. They aimed for a leakage ratio (LR—a measure of tightness developed by Denver-based blower door operators, equivalent to the number of square inches of leakage area per 100 ft² of exterior building shell) between LR-2 and LR-3. This goal was significantly tighter than the average new home in Denver (LR-5 to LR-7). When combined with other upgrades (see Table 2), the projected savings appeared to meet the stated goal of a 3.2 Btu/ft²-HDD (heating degree-day). Upgrades for this initial phase cost an additional $1,200 (about $500 for insulation upgrades, $350 for HVAC upgrades, and the rest for air sealing and testing).

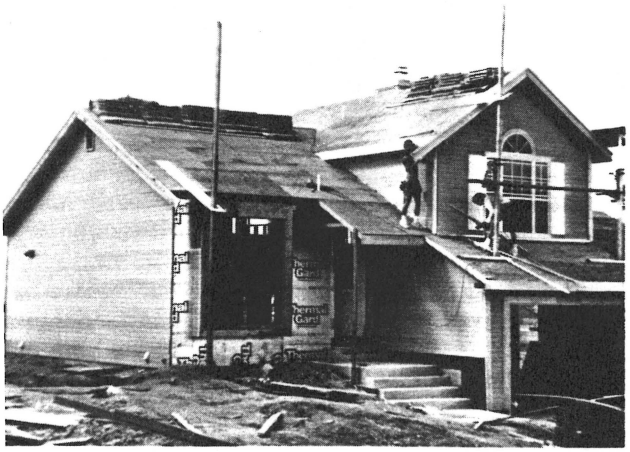
In late 1986, just after they had refined their Silver package, Columbine decided to make the "Gold" level their new standard in every home. This step required a jump up to low-emissivity (low-E) windows (though still metal-frame), further tightening to LR-1.5 or less, the

Table 2. The Composite Columbine Home

Sample Size	82	
Average house size	1,211 ft² upstairs	423 ft² basement (some in garden level)
Average annual gas bill	$335	($.42 per therm: 798 therms)
Average calculated water heating & cooking	$173	(13 times ave. summer load)
Average calculated space heating	$162	(annual bill minus water)
Average annual elec. bill	$438	($0.785 per kWh; 5,580 kWh)
Average leakage ratio	LR-2.21	(on 56 homes)
Average wall insulation	R-20	
Average ceiling insulation	R-45	
Average basement insulation	R-12	
Average window value	U-0.58	

dition of a heat-recovery ventilator and increased base-ent insulation. The ventilation system selected—manu-ctured by Engineering Development Inc., Colorado rings, Colo.—doubled as the heating system, using a n-coil unit and heat from the water heater to heat the use. But Richardson reported one major headache: the at-recovery ventilator system leakage appeared to offset olumbine's best efforts to meet its new tightness target el. Total costs of the conservation package doubled.

After building roughly 40 homes, Columbine returned the Silver guidelines in May 1987. Said Richardson, at e time: "we had intended to stay about two steps ahead



An example of a starter home in rapid construction sched-ule (30–35 days was typical).

our competition, but we found we had gone further n the competition warranted. When they make a move catch up, we can take a look at what we've learned this e around and still stay out front."

By early 1988, Columbine's energy package evolution peared to have leveled off at the moderate price of $1,500. s still met Columbine's cost-effectiveness requirement: a 7-year payback or less, or positive cash-flow (savings offset higher annual mortgage payments). The cost for low-E coated windows had dropped sufficiently to warrant their inclusion. Draft-induced furnaces with 80% efficiency offered the double advantage of increased performance and better protection against backdrafting. Tightness requirements were slightly eased, yet each home was still tested. The only thing this final package couldn't overcome was the disastrous Denver housing slump. Columbine finished their last few Denver homes in January of 1989.

Performance Results, Lessons Learned

Utility bills for 82 of Columbine's homes were analyzed using both PRISM (see p. 27) and simple subtractive methods. Since the former process generated unreliable numbers, the points about annual heating bills that follow are all based on subtracting 13 times the average summer monthly gas usage from the annual gas bill.

Annual heating bills average $162 for the 82 homes analyzed (Tables 3 and 4). Most of the homes had bills between $100 and $200 for the year (see Fig. 1). The annual $200 savings on the heating bills did indeed offset higher annual mortgage payments (to cover the $1,500 higher initial cost) for Columbine's Silver-level package.

Table 3. How several variables affected annual heating bills.

Variable	Sample Size	Average House Size	Leakage Ratio	Average Annual Heating Bill
1. Some solar gain				
Half windows face south	11	1,161 ft² upstairs 400 ft² basement	2.42	$123
2. Tightness/Heat Recovery Ventilator (HRV)				
With HRV and low-E windows	17	1,303 ft² upstairs	2.32	$154
3. Tighter vs. leakier				
Under LR-2.0 (2 w/HRV)	18	1,135 ft² upstairs 498 ft² basement	1.71	$140
Over LR-2.5 (3 w/ HRV)	15	1,161 ft² upstairs 420 ft² basement	2.88	$139
4. Variation by subdivision				
Aurora subdivision	15	1,283 ft² upstairs 295 ft² basement	N/A	$194
All other subdivisions	67	1,195 ft² upstairs 452 ft² basement	2.21	$155

The total heating will came in somewhat lower than Micropas projections (Table 5). (Micropas energy analysis software has been upgraded to "Easy Calc." See p. 39.) When they learned the results, Columbine considered offering a guaranteed heating bill—a step they had resisted for several years. Their homeowners' bills compared very favorably with average bills for comparably sized homes built to current standards, which Public Service Company of Colorado indicated were roughly $350.

Some specific observations:

- Within Columbine's experience, the 18 tightest homes did not require less space heating than the 15 leakiest homes.
- Homes with heat-recovery ventilators, designed to meet the Gold level, did not perform significantly better than

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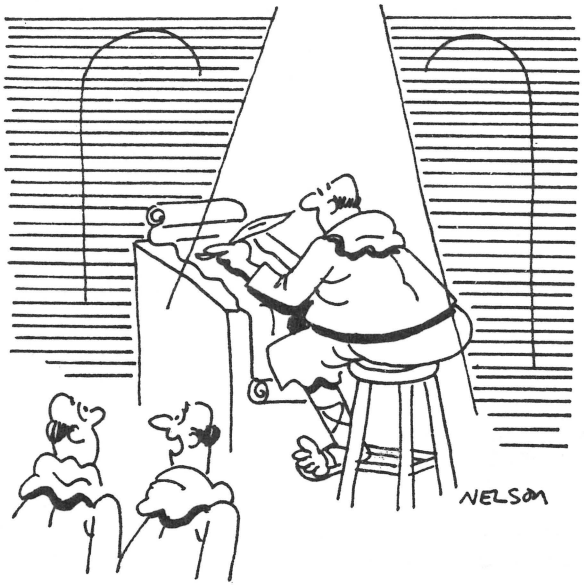


WE HAD THAT SKYLIGHT INSTALLED SO BROTHER JOSHUA COULD STOP USING THE ELECTRIC LIGHT TWELVE HOURS A DAY.

Table 4. Energy Efficiency in Three Stages.

Building Feature	Starting Point (1982)	Silver (Aug. '85)	Gold (Jan '87)	Refined Silver (May '87)
Wall Insulation	R-13	R-20	R-20	R-20
Ceiling Insulation	R-38	R-45	R-45	R-45
Basement Insulation	None	R-13	R-19	R-13
Air Leakage Ratio	LR-3.0-5.0	LR-2-3	LR-1.25	LR-2.5-3
Air Sealing	Minimal	Package	Package	Package
Combustion Air	None Supplied	Special	Special	Special
Windows	Double	Double	Triple Low-E	Double Low-E
Furnace	60%	60%	80%	80%
Blower Door Test	None	all	all	all
Infrared Scan	None	a few	all	Spot check
Avg. Cost of Energy Features	$0	$1,200	$2,800	$1,500

homes built to the Silver standard. (It should be noted that the homes did not meet the significantly tighter building standard specified for the Gold level.)

- Supervision of the building projects appears to have been a noteworthy variable. With similar model designs and sizes, homeowners in one subdivision, managed by a different supervisor, had consistently higher bills than those in the other two studied. Seven of the eight highest annual heating bills were listed in the Aurora subdivision, and only three of the 15 homes came in at or below the annual average. Of course, other variables like lifestyle, differences in models, and solar access may also affect differences among subdivisions.
- Nineteen homes without fireplaces had somewhat lower heating bills than homes with fireplaces ($141 vs $164). Yet the homes without fireplaces were slightly leakier than average, which leaves one with rather empty speculation about the lifestyles of homeowners with fireplaces.

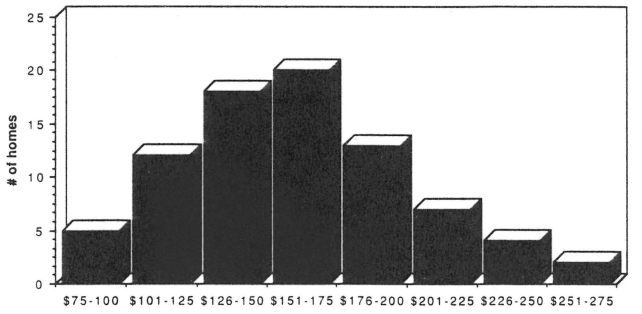


Figure 1. Distribution of Heating Bills

- Though not well-quantified, it appears that sun-tempering (window orientation) had a rather predictable impact on heating requirements. Seven of the ten homes with the lowest heating bills had more favorable access to the sun. Once heating bills are brought down into the $150 range through conservation, sun-tempering alone in a cold but sunny climate like Colorado's may cut another third off heating bills. Sun-tempering is clearly the least expensive and next obvious strategy to pursue.

Despite the few counter-intuitive results listed above, the fact remained that Columbine's approach to quality-control and energy savings revolved around using the blower door and maintaining a serious commitment to reducing air infiltration. The builders credit a great deal of their learning curve, their quality control, the low heating bills and, ultimately, their marketing success to blower-door testing early and often.

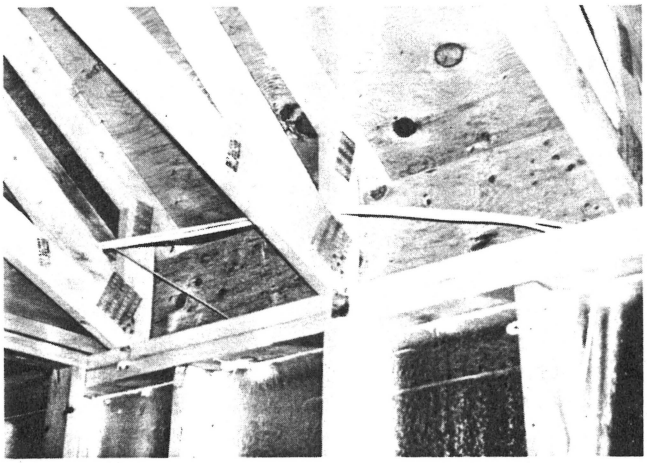
Every home sold after 1985 was tested for air leakage, which appeared to impress buyers. Twenty-five percent of the homes sold during 1986 were to buyers who sought out Columbine for this attention to energy efficiency, and another 50% listed energy efficiency as a major element in their buying decision. Only 25% claimed that energy features were not a significant factor when they bought their home.

Table 5. Computer Projection vs. Actual Heating Bill (Using Micropas)

House Size	Sample Size	Computer Calculated Btu/ft²	Projected Heating Cost ($/yr)	Actual Heating Bill ($/yr)
948 ft² 407 ft²	13	2.4	$120	$151
1355 ft² 400 ft²	24	3.2	$222	$164
1124 ft² 400 ft²	9	3.0	$158	$135
1234 ft² 600 ft²	13	3.1	$201	$162

Thermography scans also helped Columbine; though once the crew had learned to anticipate insulation and leakage problems, the boost was largely on the marketing front. During 1986, its peak production year (272 sales), most homes were scanned, with a videotape of the scan made available to the buyer. When the housing bust descended in earnest, though, scanning became an expendable luxury.

(continued on page 23)



Raised-heel trusses allow full-height insulation over outside walls. Blocking prevents insulation from being wind-washed by soffit ventilation, and prevents loose-fill from blocking soffit vents.