Building America:

Today, more than 285 occupied production homes that were built to Building America specifications have been studied in normal operation by Building Science Corporation (BSC). A recent status report includes a study of BSC's homes in Chicago and Las Vegas, where the mechanical systems and comfort complaints were tracked for three months or for a year with its proprietary "Snapshot" testing method.

The Snapshot method involves tracking utility bills and measuring how long the water heaters and ventilation systems are on, as well as monitoring return air temperatures in the first- and second-floor return ducts; basement temperatures; and how often the thermostats call for heat, cooling, or activation of air handler fans. Prior to occupancy, BSC had tested total house air leakage, duct airtightness, and duct leakage to the exterior. Perhaps more to the point, BSC tracked comments on comfort from the home owners.

Chicago Modifications

The homes in the Chicago area were built in the first large-scale Building America development to get under way. At Prairie Crossing, a subdivision in Grayslake, Illinois, 130 of an eventual 400 units have been built. The subdivision should be finished by 2002. In addition, Town & Country Homes is building the Centennial Crossing subdivision in nearby Vernon Hills. Today, 30 of an eventual 216 Building America homes have been built there.

Both developments were constructed to standards developed by BSC specifically for Chicago's cold climate (see Table 3). The standards included efficiency measures that saved on construction costs, increased energy efficiency, or improved indoor air quality. Substitution of construction materials is permitted as long as these standards are met. In return for using relatively expensive insulating sheathing, for example, the builders didn't have to buy or install house wrap and plywood or OSB sheathing. Similarly, the cost of high-performance windows was offset by a 1-ton reduction in air conditioner size. Going to 2 x 6 framing was offset by a more efficient use of framing materials, while the high-performance windows allowed shorter, smaller and less extensive duct systems.

Table 3. Cold Climate Trade-offs

Measure	Cost/Savings
24-in oc 2 x 6s in place of 16-in oc 2 x 4s	$-400
R-20 instead of R-11	+150
Insulating sheathing (R-5)	+300
Elimination of OSB and house wrap	-300
High-performance windows	+300
Savings on duct system	-300
1-ton smaller air conditioner	-500
Interior air-flow retarder	+200
No polyethylene vapor barrier	-100
Controlled ventilation system	+100
Basement insulation	+600
Direct-vent gas water heater	+150
Total incremental cost	**+200**

Chicago Results

These changes raised builders' eyebrows. To allay their concerns, from March 1997 through February 1998, BSC monitored 15 of the Chicago homes, examining some by Town & Country and some at Prarie Crossing.

The Chicago houses saved energy beyond their designers' expectations. According to BSC, the homes have shown an average of approximately 50% savings on heating energy, which translates into an average of about 40% savings on the gas bill (see Figures 1 & 2). The homes averaged a savings of only about 2% on air conditioning energy use, but the average cooling setpoint has been reduced to 72°F, much lower than the 78°F prescribed by the designer based on a computer model with the same setpoint temperature.

Because they were built without a vapor barrier, skeptics questioned whether excessive moisture would become a problem inside the walls of the Chicago houses. BSC engineer Joseph Lstiburek has maintained for years that so little moisture is carried by diffusion that all one needs to do is limit infiltration into the walls, keep a low indoor relative humidity, and use insulating sheathing (which warms the cavity) or semi–vapor permeable sheathing (which allows the cavity to dry). In the Chicago homes, indoor relative humidity remained around 40% throughout the monitoring period, thanks to controlled mechanical ventilation. And the walls were all air sealed by gluing the drywall to the framing—BSC's airtight drywall approach. The walls had vapor diffusion retarders, but not 6-mil poly vapor barriers. "Paint provides a permeance rating of about 2 to 3 perms," Lstiburek says. "With 1 inch of insulation sheathing [R-5], or with a semi-permeable noninsulation sheathing [plywood, oriented strand board, or fiberboard], there is no problem."

Lsiburek's ideas were borne out in the Chicago homes. Moisture content on the outside of the studs and inside the plywood sheathing should be below 16% to prevent mold, and below 20% to prevent decay. "We're running between 6% and 11% seasonally on the studs," he reports.

Las Vegas Modifications

Las Vegas is one of the country's hottest housing markets, both in sales volume and in temperature. With about 500 homes built every week in a climate where $200 per month cooling bills are considered a cost of living, this is a market in serious need of energy efficiency. And with high-speed production builders dominating the market, any measures that reduce callbacks are sure to be appreciated.

As in Chicago, BSC brought to Las Vegas a combination of simple improvements and slightly more unusual measures. Some of the simple improvements involved modification of the HVAC system. The number of ducts was reduced, and the ones that remained were shortened. The air

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Real-World Results

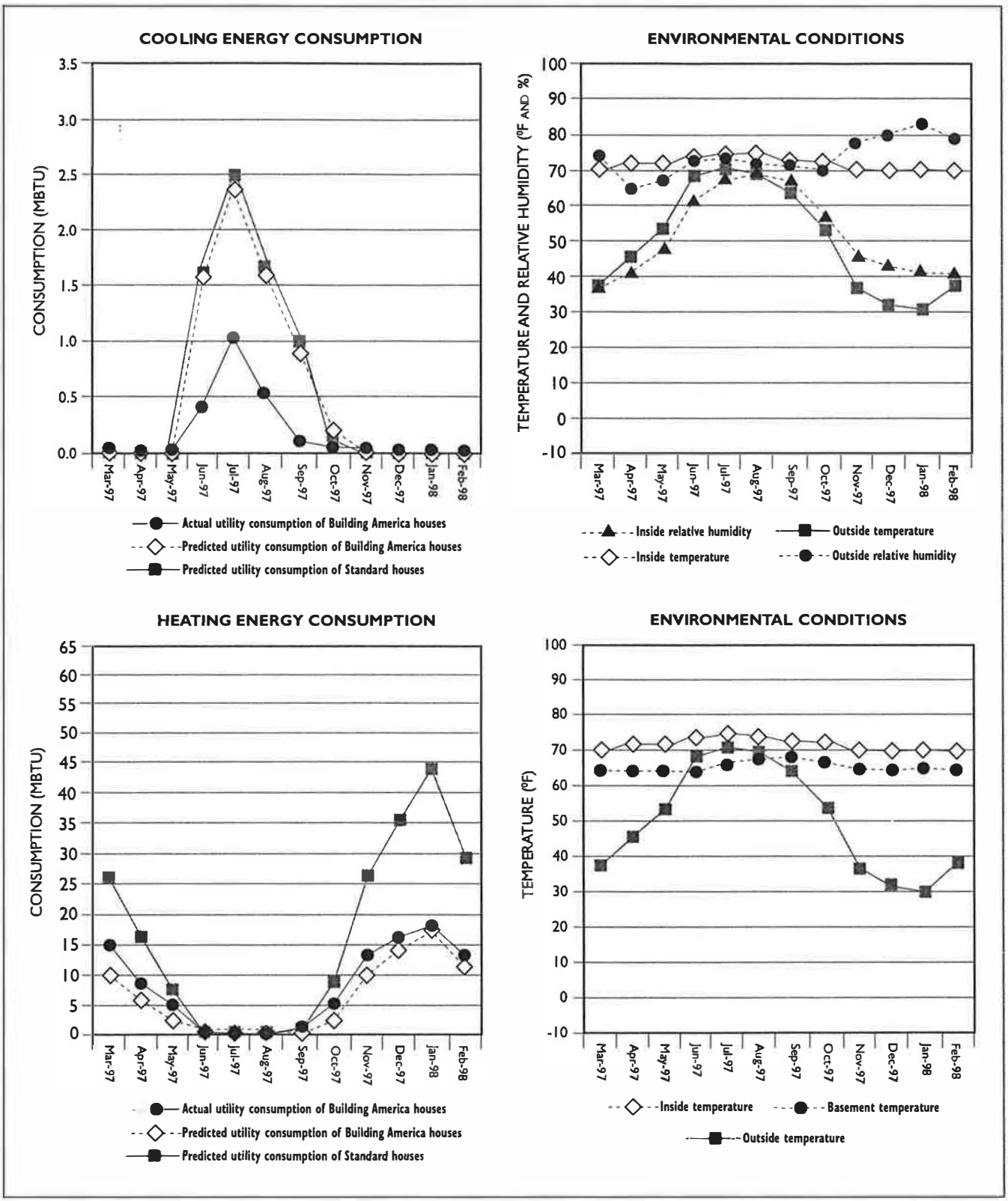

Figure 1. Average long-term (one year) data logging for 10 Building Science Corporation homes, averaged over square footage, showed that actual energy consumption was far less than would be predicted for a home built with standard construction.

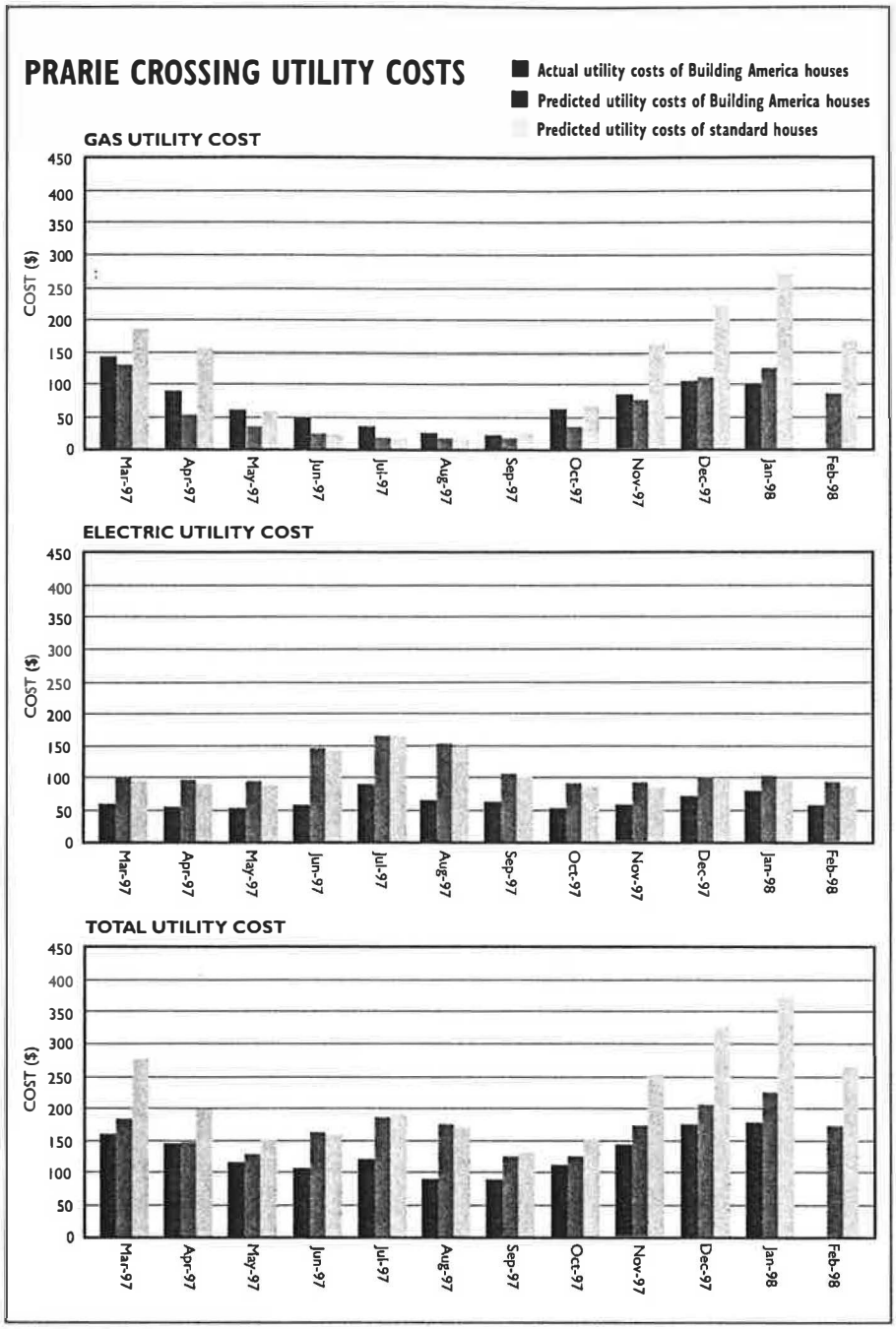

Figure 2. Data from utility bills of 40 Prarie Crossing houses over a year, standardized for square footage, showed that, although actual gas utility costs were slightly higher than predicted, electric costs were much lower than predicted, bringing the total costs lower. The fact that the total costs were fairly close to the predicted utility costs means that BSC can predict with reasonable accuracy the actual utility bill savings that will occur when systems engineering is done.

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handler and all the ductwork were located inside the thermal and pressure boundaries of the house, and no ducts were located in outside walls. Furthermore, all the returns were fully ducted (there were no panel joist spaces or stud cavities), while transfer grilles and "jump" ducts were added for pressure balancing.

Another change in the Las Vegas buildings was reducing air conditioner size by about 2 tons compared to the ones the builder usually installed. The smaller sizing was due to the envelope modifications and correct load calculations, and the units have since proved themselves more than adequate for the task of cooling.

One of the most controversial design changes was to use unvented roofs, so that all the ducts and mechanical systems (except the outside coil) were located within the conditioned space. This increases the amount of conditioned space and makes builders worry about excessive heat on the roof deck. The advantage was that, through having the air handler located within the conditioned space, there was no duct leakage to the outside, and therefore no energy penalty for duct leakage.

Analyses show that the total cost of the Las Vegas efficiency measures was only $200 higher than the cost of a barely code-compliant house. And with the latest round of refinements, these measures will actually save builders $200 on the cost of a standard, code-compliant house. The $700 extra in labor costs for unvented roof construction was partly offset by the $250 savings from not buying and installing roof vents. The remaining expense was recouped—the unvented attic accounted for half of the 2-ton reduction in air conditioner size.

Las Vegas Results

As of October, 1998, 134 Building America homes were on the ground in Las Vegas, built by two of the BSC members, Pulte Homes and Watt Homes. Twenty of the homes were monitored from January through April 1998. Again, BSC sought to determine if the HVAC systems were correctly sized and if the houses were durable. BSC monitored the following items: supply and return air temperatures; supply and return water temperatures of the combined domestic hot water and heating system; attic temperature; roof deck temperature; water heater on-time; and thermostat calls for heat, cooling, and ventilation by the air handler fan.

The results are promising. Energy use in the new homes was compared to that in homes of almost the same size that Pulte and Watt built using their usual techniques. At Pulte's Cypress Pointe development, heating energy use in the Building America homes was about 50% below that in Pulte's standard-construction houses, while cool-

Table 4. Hot & Dry Climate Trade-offs

Measure	Cost/Savings
24-in oc 2 x 6s in place of 16-in oc 2 x 4s	$-400
R-19 batt wall insulation instead of R-11	+150
Unvented roof: labor	+700
Unvented roof: elimination of roof vents	-250
High-performance windows	+300
2-ton smaller air conditioner	-1,000
Controlled ventilation system	+100
Larger gas water heater	+150
Total incremental cost	-$250

ing energy use declined by about 25%. The gas bills also fell about 30%, though electric bills held steady, while the mechanical ventilation increased the electricity use by approximately $35 for the entire year.

At Watt's Four Seasons development, heating energy savings were approximately 25%–45%, and cooling savings were about 10%–25%. The lower energy savings may have been due to Watts's decision to go with conventional 2 x 4 framing, rather than the 2 x 6 framing used at Pulte's development. Neither builder elected to use the 2 x 6 optimal value framing suggested by BSC, as they were both concerned about using stucco over 24-in centers. (At that time, they had not found a manufacturer who would test stucco with 24-inch centers for code compliance, although they have since found such a manufacturer.) The 2 x 6 framing system saves energy because it uses less wood, which allows for less thermal bridging.

Climates and Costs

BSC found that cost increases or savings depended on what specific measures were required for houses in different climates. The average cost for cold-climate efficiency measures is now $200–$1,000, although reduced callbacks recoup $200 of this amount. The home in hot-dry climates initially cost $200 more than conventional homes, but the current list of trade-offs leaves builders in those regions $250 ahead (see Table 4).

To bring cold-climate costs into line, BSC allowed the measures that were least effective and had the longest payback time to be changed to "buyer optional." It no longer requires the exterior foam sheathing to be glued in an attempt to increase airtightness (the airtight interior drywall is enough), and gone is the condensing gas furnace. Also gone are the "wood window returns"—BSC's term for the extra wood detailing that is necessary when building with 2 x 6 rather than 2 x 4 framing. "Most builders now do not use wood window return in conventional [base] construction," says Lstiburek. "They now return the drywall." The extra cost of high-perfomance windows increment has been cut from $500 to $300, mainly because more builders are using these windows, and so prices are dropping.

—Steven Bodzin