Energy and Resource Efficient Communities through Systems Engineering: Building America Case Studies in Gainesville, Florida

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ABSTRACT

Two Gainesville, FL builder case studies are presented that detail the critical elements of a systems engineering process that has resulted in increased sales and fewer callbacks for several builders. Additional benefits these builders realized include enhanced customer satisfaction through improved comfort, improved indoor air quality and lower operating costs. Each of these builders chose to improve the performance and marketability of their homes taking different paths. These two approaches will be described.

In the first case the builder elected to use an incremental approach towards the process of improvement over time. In the second case a comprehensive, as opposed to an incremental approach, reduced ongoing complications and provided a better opportunity to control costs, quality assurance and enhance profits.

Introduction

The US Department of Energy Building America (BA) program works on a national basis to assist the home building industry with the implementation of systems engineering principles that result in creation of high performance homes. Typically, builders new to the concept experiment through implementation on a prototype home. Although most prototypes are deemed "successful," one challenge has been to follow through with implementation of the concept on a larger community scale. The principal issue that must be overcome is the reluctance of builders to increase the initial price of their homes. Their hesitancy is based primarily on the concern that increased price will result in decreased sales and resulting profit, and the fact that current sales of minimum code homes are very robust. Real estate agents primarily use cost per square foot to determine "value". Homebuyers are ill informed of the ramifications of the decisions made by others as to the impact on their health and the monthly cost of ownership of their home.

Our approach has been to focus on improving the quality and energy efficiency of the home, reducing callbacks for the builders, and letting the market speak for itself. As will be seen in the two case studies presented in this paper from the Gainesville, FL market, this approach has been quite successful. In Gainesville, no builder builds more than 75 homes per year, and homes which have been built to standards higher than minimum code have resulted in increased sales, quicker sales, increased profits for the builder, and less callback. Educated consumers have spurned the old cost per square foot value determination and have voted with their dollars to invest in high performance homes, which not only cost less to operate but also are more comfortable and have better indoor air quality. There is no reason to expect that consumers in other markets would respond differently once they have been educated.

Our work with Atlantic Design and Construction and GW Robinson Builder are two examples of cases where the builder realized that the appropriate way to look at "costs" involved in implementing a systems approach in a new home is to judge the efficacy of the measure within the context of its impact on their profits and the marketability of their product. For example, a builder will elect to install granite counter tops in the kitchen, not because it is the lowest initial cost option, but rather because they increase their profits and marketability. This concept held true for the upgrades related to the BA methodology- their sales and profits increased. A closely related issue with regard to the benefits and value of a high performance systems approach to design and construction is that the prospective homebuyer will not know the difference if no one tells them. With both of the case studies, the builders had on-site real estate representation that attended multiple training sessions which provided them the ability to clearly articulate the value of the systems approach to prospective buyers. In both of the case studies a significant and sustained advertising campaign was undertaken. Full page color ads in the Sunday real estate section of the local newspaper were/are being run on a weekly basis. These ads are supportive of the real estate agents' efforts in terms of communicating the appropriate message to prospective homebuyers. Typically one may assume that the location of the home, the allocation of floor space and the reputation of a builder will have more of an impact on a buying decision than the relative health, comfort, durability and energy efficiency of a home. Nonetheless, in both of the case studies, the builder's sales and profit per home went up in spite of their higher cost per square foot (obtained from privileged communication with builders). Perhaps the most important lesson learned is that consumers will make a predictable choice when provided timely, accurate and credible information.

The BA program has positively impacted the entire local construction industry. The lessons learned by the sub-contractors have been shared with the other builders they work with. Consumers increasingly insist that their health and commitment to energy efficiency be addressed. We believe we have contributed to the fact that Gainesville has the lowest per capita use of energy of any municipality in the state of Florida. (Source: Energy Information Administration - 861 data for calendar year 2002 for average residential customer use by utilities as reported in the Gainesville Regional Utilities planning documents in Dec. 2003). Gainesville also has one of the highest percentages of new homes built and tested to meet the ENERGY STAR® homes standard.

The following two case studies represent two different approaches to achieving the goal of the construction of high performance homes on a community scale. It is interesting to note that in both cases consumers have overwhelmingly demonstrated a willingness to invest in homes that utilize the systems engineering approach.

Case Studies

Atlantic Design and Construction - Mentone Subdivision, Gainesville, FL: 340 Homes Built out fully in 2006

Atlantic Design and Construction (AD), winner of 2001 US Environmental Protection Agency's (EPA) ENERGY STAR Small Builder of the Year, has achieved their current level of performance through an incremental process of improvements over several years. AD is a small, privately held residential construction company located in Gainesville, FL. Founded in 1985, the firm now directly employs 15 full-time employees and sells about 50 - 60 homes a year. See Figure 1 for a typical home. Like any business, AD is interested in both short-term and long-term profitability.

Figure 1. An Atlantic Design Home in Gainesville, FL

While having developed a reputation for building high "quality" homes, the only aspects of their homes which were greater than minimum code requirements was the use of double pane glass and R-30 attic insulation. New materials and systems have been adopted over time. Two factors lead the builder to implement quality control/energy cost changes. First, the builder genuinely had the desire to do the right thing and wanted to provide his clients with a quality home. If the quality of that product could be quantified – all the better. Second, AD had just shifted from a custom homebuilding company to a production company with this subdivision. Though they were already exceeding the minimum Florida Energy code required, they were still flexible enough in these early stages to consider practice changes if those changes could be streamlined/standardized to minimize disruption to the production schedule. Any changes to the production procedures or standard features, however, would need to be backed with proof of their efficacy.

At this point, AD was interested in determining what features would need to be added and procedural changes that would need to be made to market their product as ENERGY STAR. To make that determination, Florida Home Energy and Resources Organization (FLHERO) performed a room-by-room Air Conditioning Contractors Association (ACCA) Manual J load calculation from building plans for a model/Parade home about to begin construction. Results found that right-sizing equipment and developing and implementing strict procedural insulation and mechanical system specifications allowed the mechanical system to be reduced by a full ton. Increasing the air conditioner seasonal energy efficiency ratio (SEER) from 10 to 12 resulted in the home meeting the minimum level required for ENERGY STAR home certification (Home Energy Rating System score of 86 or greater). Savings derived from decreasing the cooling system capacity more than offset the additional $250 - $375 needed for improved duct sealing and insulation and air sealing protocol adjustments. This savings, while sufficient to offset the costs associated with improved sealing methods, was NOT enough to pay for all implemented measures. Increasing the price of the home by $1,250 - $2,500 was sufficient to cover all additional costs AND derive an excellent profit margin. In order to ensure consistent pricing and profit, part of the builder's job was to bid the criteria for insulation and mechanical specifications among multiple subcontractors. FLHERO followed up with the contractors during duct rough-in to educate workers on the specifications and ensure quality installation.

ENERGY STAR. The builder decided to include "ENERGY STAR" on the homebuyer's option checklist. If this option was selected, the builder agreed to upgrade the cooling system efficiency to SEER 12, install an electronic programmable thermostat, install sealed and verified ductwork and increase wall insulation to R-13. As one of a list of options, sales of the ENERGY STAR option were not brisk initially. After an analysis of the options program, FLHERO pointed out to AD that the ENERGY STAR option was the most profitable option on their list, based on the percentage mark-up. As a result, marketing of ENERGY STAR became more aggressive and included sales force training on selling the program. Buyers who didn't select ENERGY STAR during the closing process were contacted directly by the Project Superintendent. His goal was to explain the value of including energy efficiency, the loss of revenue from not selecting it, and to allow buyers a second chance to include the option. A study commissioned by the EPA and conducted by the University of Florida (UF) verified the energy savings from implemented improvements. By comparing the actual electricity and gas usage from utility billing information, and comparing this to similarly sized and aged code minimum homes, UF determined that the energy efficient homes built by AD resulted in an average annual energy savings of 12.7 Mbtu (savings ranged from 8.4 Mbtu minimum to 17.5 Mbtu maximum). Using this study's data to proportion approximately 50% of the energy use as electric, and approximately 50% of the energy use as gas, and applying current Gainesville Regional Utilites rates results in an average monthly savings of $23 and a maximum monthly energy cost savings of approximately $30. Finally, AD's President negotiated a deal with the preferred lender's mortgage broker that resulted in a 1/8th point discount of the prevailing rates for every home that was designated ENERGY STAR. This allowed the sales representatives an opportunity to demonstrate how much it would COST the buyer NOT to select the ENERGY STAR option! After more than 120 buyers in a row selected this option, it became a standard feature for the builder.

The value of an ENERGY STAR home in the Gainesville, FL market can now also be communicated to buyers in terms of increased resale value. An appraisal obtained on an AD ENERGY STAR home showed a $4,000 increase in appraised value over a similar home in the same area that did not contain the energy efficient features (www.natresnet.org/ratings/resources/appraiser.htm). Also, the local area Multiple Listing Service (MLS) service has become the first in the nation to include information regarding a home's status with regard to ENERGY STAR on all listings.

Building America. With ENERGY STAR so ingrained in the AD production process, FLHERO worked to ratchet-up the builder's home parameters by introducing him to Building America (BA) concepts. Having been exposed already to a systems engineering approach, the builder was primed to consider additional ways they could enhance their homes and their marketability. BA opened new avenues for them to increase energy efficiency, durability and enhance indoor air quality. Shifting their minimum standard upward to include a 13-SEER air-conditioning system, 0.90+ annual fuel utilization efficiency (AFUE) heating system and low emissivity (low-E) spectrally selective glass, the builder also embraced positive home pressurization principles through the introduction of filtered outside air to the return side of the plenum. The new upgrades resulted in this production builder's homes achieving an average Home Energy Rating System (HERS) score of 89.

Location, location, location. Blueprints called for garage air handler (AH) installations in AD's standard home. In a hot and humid climate, this architectural design element alone can cause all sorts of problems for the homeowner. In moisture laden climates, ambient conditions in a garage can accelerate rusting in the ferrous heat exchanger and increase evaporator coil sweating, both of which reduce the life expectancy of the heating and cooling system. Any air leakage especially at the blower fan, the point of greatest pressure differential, can introduce the home to moisture, outdoor irritants, automobile exhaust and toxic fumes from the substances most people store in their garage. Insufficient insulation of the AH and leaks on the supply side also lead to moisture condensation on the equipment and its associated ductwork. On the return side of the system, ductwork holes bypass all filters and create a pathway for hot moist air and/or pollen laden outside air to enter the home.

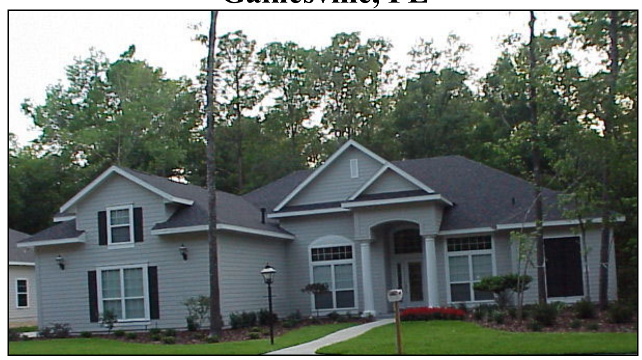
An on-site demonstration with a simple smoke stick, made invisible airflows visible and clinched this builder's interest. Armed with a clearer understanding of the ramifications of locating the AH in the garage, the builder was convinced of the value of an indoor installation. Initial design modifications forced the mechanical contractor to work in a closeted space that was simply not large enough to allow a good installation. The addition of a ductboard plenum adjacent to the furnace from an extended return, made sealing the system almost impossible. Code also required the provision of high and low combustion air to a furnace located within the thermal envelope of a home. Supply of this combustion air put the closet into communication with the attic and resulted in the movement of attic air to the living space via leaks in the duct system.

After multiple approaches were tried, an acceptable method was developed using a .90+ AFUE sealed combustion gas furnace. The sealed system eliminated the need for combustion air from the attic and allowed the equipment room to be completely sealed from the garage and the attic (Figure 3). Supply and return plenums were stubbed-out in the mechanical closet during rough in, and duct, plenum and refrigerant lines were sealed to the sheetrock with an expandable foam at all seams and penetrations. During equipment set, the supply side plenum was first affixed, then completely sealed with mastic and pressure sensitive tape. A metal tap installed in the return air plenum at ceiling height, was attached to an insulated flex duct, which was connected to a second tap on the furnace side (Figures 4 and 5). Figure 6 illustrates the typical good mastic sealed supply ductwork. An insulated exterior door for the mechanical closet with appropriate weather-stripping and threshold sealing completed the installation. Realizing that this approach would increase profits by increasing the home's conditioned square footage and provide clients with a safer and more energy efficient home, AH location changes were made to all model blueprints.

Indoor air quality. Though indoor air quality was a subject not yet broached, demonstrating the principles of air movement into a tightly constructed home was an educational experience for the superintendent. It quickly became clear to him that controlling how and where outside air was introduced into the home could make a big difference in the indoor air quality (IAQ). In many new homes it is common to have some amount of supply duct leakage resulting in the home being negatively pressurized because the ductwork is commonly located outside the home's air and thermal boundaries. In a negatively pressurized home, outside air is introduced in an uncontrolled fashion through inadvertent gaps around windows, doors or top and bottom wall plates. Installing a simple, low cost, non-mechanical fresh air system helps restrict the uncontrolled entry of hot, humid, pollen-laden air into a home and its interstitial areas. Filtering the outside air and directing it through the home's air conditioning system prior to entry ensures mitigation of the outside air's hot, humid, and pollen-laden characteristics. Including this fresh air system not only made AD's home more efficient, but more importantly it improved IAQ. This fresh air system now is a standard feature in all of the homes they build. See Figure 8.

G.W. Robinson Builder - Cobblefield, Gainesville, FL – Build out 265 homes, 241 built and Turnberry Lake in Gainesville, FL - Build out 186 homes, 30 completed

Figure 2. Home built by GW Robinson, Gainesville, FL



In contrast to Atlantic Design's incremental approach, and despite the recommendation of a market survey, it was this developer's desire to build the healthiest, most energy efficient and "Green" subdivision possible for move up buyers within reasonable financial constraints. Typical home sizes are 2,500 to 3,500 square feet with a selling price of $300,000 to $400,000. Homes implement right sized 12+ SEER air conditioners; engineered air distribution system; double pane low-E windows; radiant barrier; air handler located within the thermal envelope; programmable thermostat; cellulose insulation (Figure 7), passive outside air and new quality assurance procedures.

While recognizing that a home's most significant environmental resource impact will be the energy needed for its ongoing operation, this builder also addressed the issues of durability, health, maintenance, landscaping and irrigation. To enhance durability each home is treated with Bora-Care®, a termiticide whose active ingredient is Disodium Octoborate Tetrahydrate (DOT), which is a mixture of borax and boric acid. A 50+ year cementitious lap siding is installed over a continuous drainage plane. The entire exterior of the home receives three coats of paint which carries a ten year warranty. Thirty year architectural shingles have been selected.

To help insure better indoor air quality low volatile organic compound (VOC) paint is used in the interior, all gas burning fireplaces receive outside combustion air and all rigid duct board material used in the distribution system is a coated style to help separate the air stream from any raw fiberglass. Where applicable, alkaline copper quaternary (ACQ) wood is used, which is arsenic and chromium free.

After protecting wooded areas whenever possible, homes are landscaped with drought tolerant indigenous species which are grouped according to their watering needs. No islands of turf are created. Irrigation is provided through a municipal reclaimed water system where water that would normally be discharged via a deep well injection system is routed to the subdivision to meet the irrigation needs. It is important to note that this service is being provided to homeowners by the developer for $10 a month while a homeowner who uses the potable water for irrigation often pays $40-50 a month.

This initial broad based adoption of the high performance specifications provided the opportunity to develop formal scopes of work for each of the different subcontractors that took into consideration the interrelationship of the different components and trades. At the completion of the framing of the model center at Cobblefield, a "Team" meeting was held at this venue. In attendance was the builder, all senior office staff, the project real estate agents and representatives or owners of all subcontractors. The builder's goals, objectives and expectations were clearly articulated with the opportunity for the Team to ask questions.

In spite of the real estate agents' concern of the increased price per square foot, this BA partner chose to move forward with his vision and was rewarded by market acceptance of his high performance homes. This BA partner's success with the program has resulted in an increased level of performance for his latest subdivision, *Turnberry Lake* (Build out 186 homes, 30 completed so far) where homes feature: 14 SEER air conditioners, 0.93 AFUE sealed combustion natural gas furnaces with variable speed motor located within the thermal envelope; natural gas instantaneous water heaters, and double pane vinyl frame windows with SHGC of 0.28. See Table 1.

All of the homes built by this builder achieve a HERS score of 88.6 or better and qualify for the $2,000 Federal Energy Tax Credit. All homes are individually performance tested as part of a commissioning process. <u>*These homes are calculated to have whole house energy savings in excess of 30% as calculated by the BA benchmark methodology.*</u>

The systems engineering and commissioning process. The BA integrated systems engineering approach was used in both of these examples to optimize the performance of homes within a financial framework which enhanced the builder's profits. Our approach is that upon receipt of a floor plan, elevations and specifications for a home, we begin by reviewing the materials and characteristics to determine if there are opportunities for improvements within the context of the design. An example would be to recommend that an air handler be enclosed to bring it within the thermal envelop of the home or using low-E windows. Then a room-by-room ACCA Manual J load calculation, using Elite Software RHVAC8, is performed to determine the heating and cooling equipment size. Next, a duct system is designed using the Elite Ductsize software, which is based on ACCA Manual D criterion. Finally the duct system is drawn on a full size print. All software is continually updated. Site visits are conducted to assure quality, e.g. air barrier continuity and duct system layout without kinks. Upon completion, seven performance tests are conducted:

- A computerized multi point whole house air tightness depressurization test is performed using the Energy Conservatory Automated Performance Testing (APT) equipment. The pressure of the house with respect to the attic is performed concurrently.
- A Duct Blaster® is used to perform a duct air tightness depressurization test and quantify duct leakage (cfm25 total and cfm 25 to out).
- The home is pressure mapped using a digital manometer. All rooms with doors that can isolate them from the main return pressures with reference to the house are measured with the air handler operational, and the pressure that the home operates under with reference to the outside is measured.
- The flow of the outside air intake is measured using the Energy Conservatory Exhaust Fan Flow Meter and the damper is adjusted as required to insure that the house is operating under positive pressure with reference to outside when the air handler is operating.
- A digital manometer and static pressure probes are used to measure the pressure that the air handler is operating under and expressed as inches of water column (IWC).

- The temperature difference (delta T) across the coil is measured using digital thermometers.
- The flow of all bath exhaust fans is measured.

House characteristics such as make and model of the air handler and condenser section, water heater size, energy efficiency of appliances, and lighting types are noted and reported to the builder using a form entitled "Home Energy Rating Report" which also notes areas of deficiency. Meeting with the trades and training often occur to correct deficiencies.

Conclusions

Two builder case studies have been presented that detail the critical elements of a systems engineering process that has resulted in increased sales and profits for several builders in the Gainesville, FL market. Additional benefits these builders realized include reduced callbacks and enhanced customer satisfaction through improved comfort, improved indoor air quality and lower operating costs. To date these statements are only supported by privileged communications the first author has had with the Building America builders. On-going research in 2006 and 2007 is planned to quantify these statements by performing post occupancy evaluations, indoor environmental monitoring and utility bill analysis on a statistically valid sample of Building America and standard practice homes.

To a great extent most new homes are built “tight”. The combination of wall systems, window performance, and Florida Code requirements for air infiltration control has been successful in that regard. As a result, virtually all new homes are in need of the introduction of outside air to insure good indoor air quality and to maintain the home under positive pressure with reference to the outside when the mechanical system is operational.

An area that needs more attention is the design of the mechanical system including the air distribution system. Mechanical contractors have been reluctant to embrace the concept of “right sizing”. “Tweaking” the results of an ACCA Manual J load calculation or adding “fudge” factors is still very prevalent. Most still do not perform ACCA Manual D duct sizing, and when done, often fail to follow the specifications in the field. Additional education would be appropriate.

Following is a summation of lessons learned and ongoing challenges in achieving the systems engineering approach to new home construction:

- The first step in this process requires a clear and consistent commitment of the final decision maker, be it the builder or the developer.
- A comprehensive, as opposed to an incremental approach, reduces ongoing complications and provides a better opportunity to control costs, quality assurance and enhance profits.
- A scope of work must be developed and provided to each of the subcontractors. These need to include specific performance criteria. An example would be to include in the contract language, a provision requiring that the mechanical system will have no greater then 10% total leakage and 5% to out when using the standard cfm25 duct test.
- Effective communication of performance expectations to the person(s) responsible for implementation in the field must be performed, often in conjunction with education and demonstration activities.
- Ongoing quality assurance field inspections by either the project manager or an independent third party must be conducted to ensure consistency over time.

- Final commissioning of each home, including performance testing is an integral component of a systems approach, as it provides a timely feedback loop to the builder.

In order for the builder to achieve sales goals, the sales representative must be knowledgeable about the features and benefits that have been built into the home. A high performance home will cost more to build than a minimum code home. It has been the experience in this market that when a consumer is given the opportunity to choose, they will select the higher performing home in spite of an increase in the cost per square foot.

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Table 1. Meeting Building America Standards

Treatment	Before	After (89 HERS Score)
Windows	Double pane, clear	Double pane, low-E SHGC 0.28
Ceiling Insulation	R-30 unfaced	R-30 unfaced
Wall Insulation	R-11 faced	R-13 unfaced
Air Conditioning SEER	10 to 12	14
Natural Gas Heating, AFUE	.80	0.93+
Natural Gas Water Heating	.57 efficiency	.83 efficiency
Combustion	Unsealed	Sealed
Outside Air	None	Yes
Return Air	None	Pressure balanced
Duct Leakage to out @ 25 Pa	15% of floor area	<5% of floor area
A/C Sizing	Standard rule-of-thumb	Right sizing
Thermostat	Standard mercury	Programmable
Recessed Lighting	Standard	Air loc
Hot Water Pipe Insulation	No Insulation	½" closed cell

**Figure 3. Damp Spray Cellulose Covers Walls of
Mechanical Closet (in Condition Space) and Water Heater Cabinet in the Garage. Home Entry is on the Far Right**

Figure 4. Example of Good Mastic Return Connection Seal

Figure 5. Mastic Sealing Detail at the Air Handler Return Connection

Figure 6. Mastic Sealed Attic Supply Duct and Plenum

Figure 7. Good Insulation Detail of Blown Cellulose Installation and Foam Insulation Around Window Frame

Figure 8. Outside Air Provides Controlled, Filtered Fresh Air while maintaining Household at Positive Pressure with Reference to Outside Pressure