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# A FORTIFIED, LEED HOME FOR THE US GULF COAST: The How's and Why's of a *Building System* That Makes Sense

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## INTRODUCTION

*Houston is a city where the residential home building industry is dominated by tradition. There are good traditions and bad traditions. And, unfortunately, the traditional Houston approach—wood framing, fiberglass insulation, ventilated attics, etc.—I feel, lies in the bad tradition category. Traditional builders will tell you that they are building what the buying public demands. And, to a point, that is correct, but you could argue that the buying public doesn't demand better because they don't know better exists and therefore aren't looking for it. The buying public sees the moldings and finishes and "flow" of the home. What's behind the sheet rock doesn't usually get on the home buyer's radar when the decision to buy is made. The purchase cost of the house, but not the living cost of the house is considered. It's only later; when they get the utility bills, that they feel the sting of the lack of efficiency of the traditionally built home. Tradition is also felt when homeowners are faced with tens of thousands of dollars in repairs after a hurricane, or termite or rodent infestation, or HVAC system or duct replacement.*

*There is a better way to build and, in our opinion, a best way to build for the U.S. Gulf Coast. Here is what we believe it is and how we got there.*

About three years ago my wife and I bought a lot in a nice neighborhood in Houston. We planned to build a house, but being a "form follows function" guy I began looking at how houses are built and out of what materials. I have always been "green," and I always look at "value" when I buy something. I also knew that, someday, Houston would have another hurricane (this was before Ike), and I wanted a house that I could be reasonably sure would survive a hurricane. Knowing, as we all do, that resources are not getting any cheaper, I also wanted to minimize my utility, maintenance, and upkeep costs.

This got me started on what quickly became a research quest. If I were going to fund the building of my house, I was going to have some significant impact on what went into it. My research answered some questions but, in the early stages, it raised more questions than it answered. The learning curve was steep but exciting. The conditioned envelope, air quality, solar energy, wall systems, windows, hurricane resistance, heat transfer, radiant barriers, insulation, HVAC, roofing, and other building factors, all became part of my everyday vocabulary.

After about six months of research, phone calls, and conversations—with any number of experts—I realized that: a) there are lots of divergent and conflicting opinions about all sorts of building and green issues, and, b) the traditional bricks, sticks, and fiberglass insulation home construction techniques are not even close to the way a house should be built. It had become clear that traditional home building is done for the day of sale, and I was looking to build for the long haul.

About then, I talked to Brad Lindsey (who invented a phenomenal radiant barrier I will introduce later) who referred me to Texas A&M University's Energy Systems Lab. My conversations with them were inspiring, and it became clear that there was a golden opportunity here. Subsequently, Texas A&M committed to a project where we would design, build, and study a complete *Building System*. We then methodically researched all of the sub-systems in a house (e.g., walls, windows, attic, roof, HVAC, electrical, etc.) and considered over 300 different products and technologies. From this sea of information we distilled a list of products and

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technologies that function together. We sized each system in the context of the Building System, and we strove for synergies wherever feasible. We aimed at what should be built, not what can be built.

### WHAT MAKES SENSE?

That question became the benchmark for our decisions. It asks “what makes sense” in the context of what we are trying to achieve (build the best house for the US Gulf Coast) but also “what makes sense” from a cost/benefit (investment/return) perspective.

Once the Building System was defined, we took it to Todd Rice of Rice Residential Designs. This firm has great expertise and experience in ICF construction and green home building. Todd embraced the concepts of our *Building System* and designed a home incorporating the Building System and a house that is very much in line with other new homes in the neighborhood. Through Rice Residential we partnered with The Interfield Group. This engineering firm has a working relationship with Rice residential and is comfortable with ICF construction. Mike Quaddumi and Interfield were also able to take us through the critical Fortified rating process. This will be the first house in Houston to achieve the Fortified rating.

As an aside, we understand that while the size of this house is generous; our Building System is specifically designed so that it can be scaled up or down and thus is applicable across a wide range of home sizes, design styles, and building footprints.

With the Building System, the design, and engineering completed, we then went looking for a builder. After a number of interviews, we found out that builders have their comfort zone, and they like to do what they know. Even the local green builders were reluctant to take on the project—unless I paid them well over \$300 per square foot—build cost. By this point in the project I knew that the cost should be far less than that, and I wasn’t willing to fund their learning curve and pay a daunting premium to boot.

Unable to find a suitable builder, I formed a building company of my own, Durable Residential Builders, LLC, and lined up some expert help, sub-contractors, financing, and many of the products and technologies called for in our Building System, fully ready to be my own general contractor.

Ker Thomson and Jim Kuchenbrod of Durable Residential Builders, as the house nears the landscaping stage.



That was the moment Todd Rice insisted I meet Jim Kuchenbrod. I was reluctant to talk to another builder, but Todd insisted. After a phone conversation and several face-to-face interviews, it became clear that Todd was right. Jim has 30 years of experience in all aspects of the building industry. He has built ICF homes in three states during his career. He also holds residential and commercial building licenses in Florida (no small accomplishment). Jim also saw what I saw, brought expertise and know-how that I did not have, plus enthusiasm that matched mine. Jim became my partner in Durable Residential Builders, LLC and suddenly we were a new company with 30 years of experience.

From there we built the house. We stayed true to the Building System, with a few practical changes as we worked through getting the house off the prints and onto the ground. We stayed on schedule and we followed the USGBC’s LEED for Homes guidelines. Along the way we attracted the attention of the TV news and talk radio. We’ve created a buzz around town and perhaps our house is the seminal event that will bring a new way of building in Houston.

Before we get to the whys of the Building System allow me to briefly define the mind-set, or mission statement, of the project.

**It’s good to be green, qualified** (or common sense and the green movement and why what makes sense is so important):

While it is true that green is very popular and a hot item these days, what is hot can also be senselessly expensive. There are lots of astonishingly

green projects where cost was of no apparent consideration. These projects are good to show people what can be done. BUT, the practical application and conversion from “can be” to “what should be” done today gets lost. You can buy bragging rights with the budget-less approach, but not many people can afford to follow your gilded footsteps. Even worse, these projects often intimidate consumers—who, reasonably, draw the conclusion that because it’s green then it must be unaffordably expensive. The “what makes sense” mantra commits you to the should approach both functionally and financially. It finds followers in its simple logic.

**Green, defined:** The United States Green Building Council’s (USGBC) Leadership in Energy and Environmental Design for Homes (LEED-H) program looks at home building from a broad view. It considers not only where the house is located but how, and out of what, a home is constructed. The LEED-H certification process requires site management, recycling, and waste management during construction. It gives credits for energy efficiencies, water conservation, air quality, product choice, etc. Under the program there are many ways to achieve these, but to get to the top of the ladder (the Platinum rating) requires that you address all aspects of the multifaceted program. While we lost points for the size of the house, we more than made up for those by the very design of the Building System and how we built the home. For more information regarding the USGBC and LEED for Homes, please see: [www.usgbc.org/](http://www.usgbc.org/).

**Our guiding principles for the U.S. Gulf Coast homes**—what makes sense in the context of:

**Strength and Durability:** Specifically hurricane resistant—hurricanes bring wind, water, and utility failure. Thus strength was the core of our system. Walls, windows, and roof are the core of the strength. Utility failure, which lasted up to three weeks after Ike, dictated that we have backup electric power and water. Durability also speaks to longer term maintenance issues.

Along these lines, we pursued a Fortified rating from the Institute for Building and Home Safety (IBHS). This is a designation awarded to homes of exceptional strength and threat resistance. In addition to meeting other criteria, this house was engineered to withstand

winds 20 mph *over* the FEMA wind speed zone designation for this location. For more information on this see: [www.disastersafety.org](http://www.disastersafety.org).

**Efficiency:** Energy in versus energy out. Energy in means solar electric (PV) and solar thermal. Energy out translated as a sealed building envelope, immense insulation, and radiant barriers.

**Security:** Keep the bad guys out and your stuff in.

**Livability/Health/comfort:** This addresses a variety of issues from air quality to humidity; to the choice of appliances, lighting, and finishes; to more subtle things like the bathroom exhaust fans.

**Affordability:** Understanding that owning a house is a two-fold proposition: a) the cost to buy and b) the cost to operate. This is where the “what makes sense” rubber meets the proverbial road.

**Green:** LEED-H platinum rating was our target.

Obviously, many of these areas overlap and many of our choices serve us well across the spectrum of our intent, the Building System.

## THE DETAILS

From here we will go through the sub-systems generally from the outside in and the top down. We will try and detail synergies and the logic behind the choices and the conflicts and resolutions.

### *The Building Envelope*

This is the backbone of the Building System. It is also where the outside and inside environments conflict. Here is where convection, conduction, and radiation (the big three energy maladies of residential construction) attempt to follow the natural gradations of high to low and hot to cold.

In a hot, humid environment that also has the dubious luxury of being just up-stream from any number of chemical plants, convection, the movement of air, is the bearer of many ills. Our leaky homes, blessed with fiberglass insulation, ventilated attics, and recessed lighting, are plagued with convection. In my opinion this is the worst of the big

three and carries humidity, heat, pollution, pollen, spores, and bugs into our ostensibly conditioned living space.

Convection was our first target, and our first line of defense against convection is the wall system.

We looked at wood framing, steel framing, SIPs (Structural Insulated Panels), Concrete Molded Units (CMU), and ICF (Insulating Concrete Form). Wood was the cheapest but left us with the issues of thermal bridging every sixteen inches and susceptibility to termites, mold, and rot. Furthermore, wood required, as does steel framing, insulation. The quality of wood is not what it once was and its longevity, or lack thereof, played into our decision (Remember, we are looking at the house for the long haul.).

Steel framing is better, but substantially more expensive. Finding crews to do the steel framing is difficult relative to wood framing crews. Fire risk and waste issues come down on the side of steel relative to wood, but the thermal bridging is worse.

As a sidebar, **insulation:**

If we called for wood or steel framing, insulation becomes a critical element of the wall system. Insulation is also critical in the attic system so this is as good a place as any to discuss this.

We looked at a plethora of types of insulation but only seriously considered fiberglass batts (the industry standard), cellulose, and spray foams, open or closed cell. The trouble with apples-to-apples comparison of insulation products is that there isn't a true apples-to-apples measurement. R-value is defined under a specific lab-controlled set of circumstances that has limited applicability to the real world environment in which insulation lives. It does not consider convection nor does it consider conduction through the structural (non-insulation) elements of the wall. We'll expand on this later when we discuss effective R-value; for now understand we often found the R-value more confounding than helpful.

Our insulation conclusions:

**Fiberglass Batts** are cheap, easy to install, and widely used. However, it has been said when air moves through fiberglass batt insulation it becomes little more than an "air filter with an R rating." Convection can destroy fiberglass as an insulator. Fiberglass batts do not fill gaps well and are notoriously

difficult to fit into the framing and around pipes, wires, and tight or angled corners. The R-value of fiberglass also varies depending on the degree of compression it suffers. Over time it can sag and is easily displaced. There are also some concerns about off-gassing. We consider fiberglass the worst of the bunch for these and other reasons.

**Cellulose** makes a strong case, especially with its treatment with boric acid as a fire retardant and insect repellent. This environmentally attractive and low-cost insulation has an R-value of 3.7/inch, which is comparable to open cell foam. However, the possibility of moisture absorption and its inability to dry out—along with potential time related product degradation—are drawbacks. Furthermore, cellulose is not an air or moisture barrier, making it vulnerable to convection.

**Spray Foams** seemed to be the next logical insulation product to evaluate, especially since we were closing in on ICF blocks for the building envelope. There are primarily two types of spray foam insulation: closed and open cell. While the complaint of off-gassing has been made about the current foams (especially by the cellulose installers), there doesn't seem to be any real substance to this issue at this time. (Early closed cell foams from the 1970's had formaldehyde which is no longer a consideration.) Today's open cell foams are water blown and contain no CFCs, PBDEs, nor detectable VOC emissions.

**Closed cell foams** have an R-value of 6.2/inch and are a true air and moisture barrier when applied in thickness over one inch. However, they always require an ignition barrier coating or sheathing. An intumescent paint can be almost as expensive as the foam insulation and requires certified installers and inspections. The closed cell foams are substantially more expensive for the same insulation value as open cell foams. Thus, in an attic setting when fully installed, closed cell foam can be up to three times more expensive than open cell foam after the additional step (the ignition barrier) to meet code.

**Open cell foams** have an R-value of 3.7 per inch. In the hands of a skilled installer, they are fast and easy to install. They expand into hard-to-reach gaps and around pipes, ducts, and wiring. They are considered an air barrier with air permeance 0.009 L/S-m<sup>2</sup>. They are neither a moisture nor a vapor

barrier, which has its own pros and cons. Most open cell foams will not degrade due to humidity or time. Critically, Icynene meets the fire code requirements (*flame spread index of* <20 and smoke development of <400) without the addition of an ignition barrier in the attic.

When all was said and argued we concluded Icynene open cell foam was the right insulation in the right place and at the right time.

**Back to the envelope:** Regardless of the insulation chosen, the minimum wall thickness to achieve an acceptable level of insulation in Houston, Texas, in our opinion, requires 2 × 6" framing and that increases the labor and material costs of both wood and steel.

With the limitations of wood and steel in mind we turned our attention to SIPs and the ultimate winner, ICF.

When we came to SIPs (Structural Insulated Panels) we were suitably impressed. They are easy to manufacture and provide admirable insulation and suitable strength. They can be made in a wide variety of sizes and can have window openings and chases precut. To make SIPs more attractive they are easy to assemble, and, once you get over a higher than expected shipping expense, deport themselves well in the speed with which they go together. The roof system can also be SIPs and, with modest trusses, allows for open and attractive interior spaces. Furthermore, they do not suffer from thermal bridging (except at the window bucks) and convection is negligible. So, what's not to like? First of all, they are limited, practically speaking, from a design point of view, and are best used in a simple gabled design with relatively few corners. The design of the house and especially the roof worked against SIPs. Beyond that, Time of Day (TOD) electrical meters and absolute strength lead us to ICF.

**Another brief aside:** Time of Day (TOD) or Time of Usage (TOU) electrical pricing is up-and-coming. It is currently widely used in California and is as close to us as Austin, Texas. It is promoted as a way to encourage electrical consumers to voluntarily shift electrical usage to off-peak periods. The politics and functionality of Time of Day metering is another discussion beyond the scope or intent of this paper. Just know it's coming, according to peo-

ple who have greater understanding of the electrical industry than I have.

Additionally, structural strength, absolute strength, and massive strength are attractive when it comes to a house. So between Time of Day metering and strength we turned to ICF (Insulated Concrete forms) and filled cinderblock/concrete masonry unit (CMU) walls.

CMUs are easy to do albeit heavy, can be filled with cement, and offer an excellent thermal mass, but still present insulation issues. They are troublesome to attach the exterior and interior to and are harder and slower to assemble than ICF. We also briefly considered tilt-wall construction, but logistically that was not applicable.

Enter ICF: Insulated concrete forms have been around for fifty years. There are a host of manufacturers (although the industry seems to be undergoing considerable consolidation as I write this). This form of construction is widely used in Canada and many northern states. It carries with it the sheer force of being five inches foam insulation sandwiching six and one half inches of reinforced concrete. Convection is no longer an issue of any kind, and I pity the termite or insect that takes on the challenge of such a wall system. Furthermore, the thermal mass (capacity of the cement to hold heat or the time the cement takes to heat or cool) can be a worthy adversary to TOD electrical pricing. If they chose, the homeowners could cool the house (thermal mass) at night, when the rates are a fraction of the day rate, and let it slowly warm through the day, when electricity rates skyrocket). The R-value of the ICF wall system stands at near 25. But when you take into account the thermal mass, the lack of convection or conduction, and add in the radiant barrier/moisture barrier and air spaces—plus add the exterior (stucco, stone or brick) and the sheet rock in the inside of the wall—you have an “effective R-value” of perhaps as much as 50!

So what is effective R-value? As we discussed above, the R-value is essentially resistance to the movement of heat. It measures the resistance to heat movement through a product when the temperatures on each side of the tested material are held constant. It does not consider the temperature fluctuations the real world experiences. It also fails



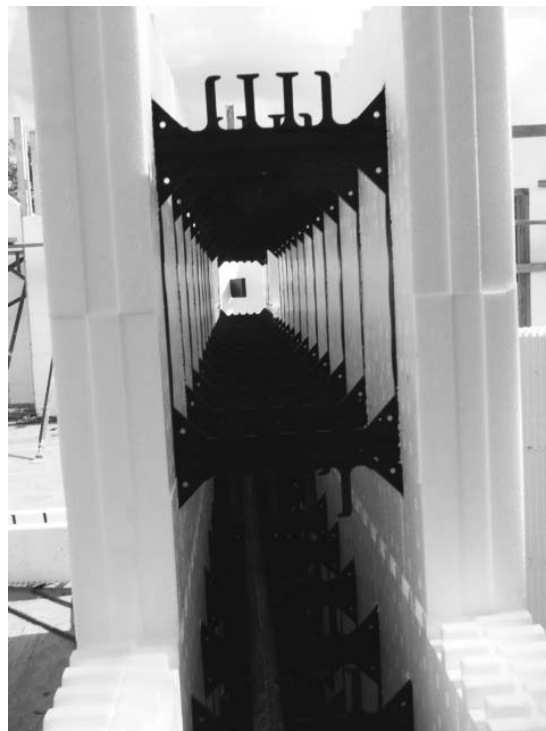
to account for convection (our regional bad guy), or thermal bridging (essentially conduction) in the context of the entire wall system—exterior, framing, insulation, windows, electrical boxes etc. R-value cannot account for air gaps from poor, compressed, or inadequate installation. So while somewhat helpful, R-value can be utterly deceiving (as in the case of convection through fiberglass insulation). For example, a builder will sell a house based on R-13 insulation in the walls (the DOE recommendation for wall insulation is between R-13 and R19). This meets code, strictly speaking, but the function of the walls may be only R-10 when thermal bridging and convection are considered. That's a problem.

So to address insulation in a real-world setting, some thoughtful insulation-types coined the term “effective R-value” (or “relative R-value,” “performance R-value,” or “mass effect R-value”). This term/approach, is holistic in its view and refers to the resistance to heat movement across the entire wall or roof system (less the windows) as temperatures change. The drawback is that “effective R-value” lacks a scientific consensus as to the actual calculation thereof. So, in the context of this project, it is based more on the additive properties of the materials in the entire wall system, with a nod to the mass effect of the high mass ICF wall.

**Back to ICF.** ICF is not, by itself, a true vapor barrier. But the 11.5" of extruded polystyrene (5") and cement (6.5") that is then wrapped in a radiant/vapor barrier (TCM4-RW) makes the migration of moisture into the house (especially compared to the natural opening and closing of doors) probably immeasurable. Plus, there aren't any seams (like SIPs), and our window bucks are integrated into the cement wall. There are secondary benefits of the 14" thick wall system. A quiet home comes from the inherent noise barriers in the walls and windows. In our experience, there is no comparison between exterior noise levels in a wood frame (good) or SIPs (better) house with an ICF (best) home. In a car there is no substitute for steel and in a house it's hard to beat cement.

Now consider: massive strength; the thermal mass; the tremendous resistance to heat movement; TOD electrical pricing; sound dampening; the resistance to convection, moisture, bugs, wind,

Inside the BuildBlock ICF, demonstrating the every 6 inch cross webbing, providing the ICF excellent protection against blowouts during the cement pour.



fire, etc.; and our choice of ICF makes sense. Cost is higher with ICF, no doubt, but not hugely. ICF added about \$3/ft to the build cost vs. wood framing. In our view, it was money well spent. We chose BuildBlock ICF for a number of reasons that include the ease of use, customer service, reputation, and the fact that it's produced here in Texas. We were very impressed with the ease of use and speed, plus the superior quality of the product.

Then put BuildBlock ICF in the context of our carefully considered wall-system. From the outside to the inside, we called for:

- The exterior (stucco, stone or brick)
- An air gap (maintained by  $1 \times 1.5$ " battens every 6 inches and screwed into the ICF).
- The radiant/vapor barrier (TCM-4RW)
- The ICF wall (BuildBlock)
- Five eighths inch fire rated drywall.

### **Radiant Barriers (RBs)**

This was a point of lengthy consideration and conversations, simply because there is so much information, misinformation, and myth-information regarding this potential leap in building technology. The controversies range from the superiority of one RB vs. another (paint, board, film, sheeting), to ideal placement (on top of the insulation, under the rafters, over the rafters, etc.). That leads to the which barrier/which location combination question. The details of this raging controversy are beyond the scope of this article, but suffice it to say that radiant barriers need air above (to the unconditioned side of) them to work at their best. The consequences of bad placement/choice can work counter-intuitively, e.g., when RB reflects heat back into an attic assembly and traps it over the living space (bad in Houston, where cooling days outnumber heating days 2:1). RBs are a surprisingly tricky technology whose science needs to catch up with the hype before they get a bad reputation.

Simply put, radiant barriers range from the useless (in my opinion) silver paint option to single layer radiant barriers to multiple layer radiant barriers. Single layer radiant barriers are all well and good, up to the point where they get dusty. When dust happens, the single layer RB falls victim to conduction and its effectiveness decreases dramatically.

Into this controversy steps the inventor of TCM-6 and TCM-4RW: Brad Lindsey of Horizon Energy Systems, Inc. of Arizona. His several patented RBs are multilayer radiant barriers where the first layer is sacrificed and the radiant barrier property is maintained by the sequential RB layers. There is a growing body of scientific evidence that this is the best way to produce RB of lasting function (while not answering the location debate). There is documented support for the incredible assertion that TCM-4RW alone offers an R-value of 24! Extraordinary to be sure and further study will tell, but the effectiveness and quality of the radiant barrier is probably unmatched in the industry, and TCM-6 and TCM-4RW have garnered worldwide attention—plus they are vapor barriers, thus killing two birds with one product, and at a cost not dramatically more than a good vapor barrier.

Thus, all things considered, our wall-system conceivably has an effective R-value between 40 and 60. Welcome to the cave!

### **Windows**

Of course a wall is only as good as its windows. We carefully considered 3 top window manufacturers and settled on Pella's Architect Series HurricaneShield casement, argon filled, windows. Here, again, one product served us in multiple ways. We installed these Impact Zone 1, (IZ-1) rated windows with their reinforced frames and triple laminated exterior glass elements (think car windshield plus one), which were then hurricane clipped to the metal bucking system. These Pella aluminum clad all-wood windows have a low maintenance exterior and paintable/stainable interiors. The choice of IZ-1 windows gives us security from the periodic

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This picture details the window install. The Hurricane Shield Pella window is screwed into the metal Buck and then sealed with closed cell foam and water proofed.



hurricane or attempted break-in. The windows and doors are extremely difficult to break or pry open. They have remarkable R and U values and unparalleled sound dampening. They are windows as well matched to our walls as any could be. In addition to the basic quality and beauty of the windows, customer service, product support, and a wide variety of design choices factored into our choice of Pella of Houston's custom built product.

The upgrade for the IZ-1 window is not insignificant. We spent an additional 50% on the cost of the windows and doors, but with the advantages noted and the fact that windows of this quality are required for the Fortified Rating from the IBHS; our HurricaneShield windows and doors should pay us back financially and emotionally for years to come.

### ***The Roof/Attic Assembly***

This was no small task in that we found dramatically conflicting information from a wide variety of sources. Our first big task was to decide between a ventilated attic and a sealed unventilated attic. There was much to consider. Warm weather conditions carry heat, humidity, and a variety of airway irritants, allergens, bugs, and others into a ventilated attic. In Houston our traditional ventilated attics can reach 140°F and 100% humidity on any given summer day. This puts a tremendous heat and moisture load above the ceiling for the 200 cooling days we have each year. Meanwhile, cool/cold weather is not free of molds, irritants, and pollutants, and still carries high humidity a large percentage of the time. Cold ventilated attics create a heat sink above the conditioned living space.

Despite blown or batt insulation on the attic floor, all these bad actors find their way into the conditioned living space via our old enemies conduction and convection. Remember that attic insulations (typically cellulose or fiberglass) are not moisture barriers or air barriers. Over time, heat and moisture will follow the gradients—high to low and hot to cool—through and around the insulation. Then the only thing between the heat and humidity and the living space is half inch sheetrock.

Furthermore, in-ceiling lighting, electrical chases, switches, electrical plugs, plumbing, or AC registers that are either not sealed or less than

perfectly installed creates another ready conduit between conditioned living space and the attic. Not insignificantly, a ventilated attic can also open the home to varmints that can die in the walls (since the tops of the walls are rarely sealed), nest in your insulation, and gnaw on all the “stuff” in the attic (I know this first hand).

If that were not enough, storms can drive rain, or at least excessive moisture, into the attic via the soffits and ridge vents. And in the event of a severe storm or tornado, a ventilated, more than a sealed, attic can negatively pressurize and lead to a catastrophic roof failure.

Furthermore, in Houston many of the mechanical sub-systems (water heater, air handlers, and ducting) live in the attic. From a long haul/maintenance/performance perspective it seems logical that putting these expensive system components in an environment that sports these trying conditions is a bad idea.

Finally, since we don't typically have basements in Houston, the attic becomes the primary location for storage of all things, and the hostile environment of a ventilated attic is hard on grandma's quilts. All-in-all a ventilated attic, while traditional, and expected in the Houston housing market, is, in fact, an unhappy, sub-optimal situation.

When we considered the sealed, unventilated attic approach, it raised questions regarding the energy cost of conditioning, albeit passively, the un-air-conditioned attic space. It also puts some additional stress on your rafter/roof assembly in that, insulation under the roof deck and adding a radiant barrier arguably increases the heat load on the shingles and raises the possibility of dry or wet rot in your rafters.

The argument was advanced that AC ducting is insulated (a whopping R-6 duct insulation is typical), and the mechanicals are designed to withstand the hot/humid conditions. I figure that you can make the similar argument that cars are designed to operate in New York City, but they seem to last longer in California, makes sense.

We decided an unventilated attic was clearly a better choice. Thus, during our insulation meetings, we had already decided on Icynene open cell foam. The Building System calls for it to be applied to the underside of the roof deck and cover all the wood elements of the roof (rafters, etc.). Icynene,



Notable here is the water lines (before insulation) that will carry hot and cold water to the water-filled coils in the air handlers. These airhandlers maximize air quality with media filters and UV technology and are coupled with Fantech ERVs that will turn over the air in the house seven times per day while minimizing energy losses.



not being a moisture barrier, should not increase the likelihood of dry or wet rot in the rafters. We partnered with Energy Efficient Insulation (EEI), a certified and experienced Icynene dealer and installer, who sprayed 5–7 inches of foam. EEI was meticulous in getting into all the tight angles and recesses of the complicated rafter assembly.

Once we committed to a sealed attic and foam under the roof deck, we then considered the attic system's impact on the rest of the Building System and specifically on the roof assembly. One controversial issue we encountered was the increased heat load on the shingles, when placed on our insulated roof deck. In this configuration the roof deck cannot conduct heat away from the underside of the shingles.

Another critical issue was the requirement that the roof of a Fortified Rated home must be engineered for winds 20 mph higher than the wind speed zone designated by FEMA for the home's location (110 mph, in this case) so we called for a roof engineered to 130+ mph. The Interfield Group engineered the structural elements that were up to the task.

No small long-term consideration is the fact that replacing a roof is very expensive. And a replacement roof adds a truckload, or more, of poorly biodegradable materials into our landfills.

The strength and durability required from our roof, and a timely referral, led us straight to DECRA Roofing Systems and their stone coated horizontal metal roofing panels. They are installed on battens that allowed us to place TCM-4RW above the roof deck. We then asked the roofers to stagger 4–6 inch gaps in the battens in such a way that we have a semi-ventilated roof, not attic. This allows heat accumulating under the panels to move with the air currents up the slope of the roof and out the top cap as well as around the panels. DECRA backs its products with a 50-year transferrable limited warranty and has tested the installed product to 150 mph wind speeds (although the warranty is only to 120 mph). Again there is a cost for the better roof, but amortized over the life of the roof (2–3 times the life span of the traditional asphalt shingle roof), the increase in the cost of the roof pays back over the long haul.

Finally, it is our contention that, on the U.S. Gulf Coast, using thirty-pound roofing felt under shingles of any kind borders on irresponsible. The advent and availability of adherent and sealing products like Grace Ice and Water Shield should have signaled a sea change in the roofing industry. For the addition of a very modest cost—pennies per square foot—the shingles become the primary water barrier, and the underlying water barrier becomes a secondary water barrier that is integral to the roof deck—thereby dramatically increasing the roof's impermeability. (Why this isn't code evades me.)

In summary our unventilated un-air-conditioned roof-attic assembly came together as follows (from outside to inside):

- DECRA Shingle Plus roofing panels, screwed into the battens, 8 screws per panel.
- 2 × 2 treated battens that are screwed into the roof deck and rafters.
- TCM-4RW radiant barrier/vapor barrier.
- Grace Ice and Water Shield applied to the entire roof deck.
- 5/8 inch roof decking that is independently screwed into the rafters.
- Rafters that are hurricane strapped to each other and the anchored to the ICF wall system.
- Icynene open-cell foam sprayed under the roof deck and covering all the wood elements of the roof assembly.

Here the roof is being installed. Note the Grace Ice and Water Shield. The TCM4-RW radiant barrier is inverted closest to the photographer to allow the reader to visualize the undersurface and see the layered construction. Each DECRA panel is screwed into the battens seen in the top left hand corner of the photo. The battens are screwed into the roof deck and rafters and the roof deck is screwed into the rafters.



While the argument can be made that this is an expensive roof system and more complicated to install than the traditional shingle/roofing felt nail down approach, I submit that the roof assembly is one of the critical elements in the performance of the house. Speaking again of effective R-value estimates, our roof assembly varies from R-25 to R-40, depending on how you do the math. Furthermore, this roof should not require replacement in my lifetime. Plus, the proof being in the pudding, entering this attic on a 104 degree day in August, you will encounter a temperature that is within three degrees of the conditioned living space and only fractionally more humid. That translates to very usable storage space and, almost certainly, a longer functional life expectancy of the mechanical systems that labor in the attic. The attic is where this Building System becomes palpable: you can see, feel, and touch it. As we have seen, it is where the Building System sells itself.

## HVAC

Having designed the envelope and defined the conditioned space, we turned our attention to the MEP systems (mechanical, electrical, and plumbing).

First we looked at the HVAC. Geothermal is on the front page these days, but remains impressively expensive. Furthermore, in Houston (which is arguably built on a swamp), with our clay soils, flooding, soil movement, and high water table, geothermal struggles to make sense. Empirical evidence speaks to wells that heat up and moisture issues that are beyond the scope of this article. Suffice it to say that we chose to put our money into the envelope of the house, which worked synergistically with the rest of our system(s), as you will see.

Any discussion of HVAC centers on EER (Energy Efficiency Ratio) or SEER (Seasonal Energy Efficiency Ratio). These ratings, defined in the 1970s (when the average HVAC had a SEER rating of about six), attempt to offer a direct comparison between systems. However, actual climate dramatically impacts the effective ratings and, as such, here (like R-values) again we ran into confusion trying to interpret claimed rating values.

EER is based on testing at 95°F outside, 80°F inside; with a humidity of 50% out and in. These are not realistic numbers and are hard to apply to Houston where we see 100+°F and 90% humidity on a regular basis. Nobody I know keeps his house at 80°F. Plus dehumidification can take a huge amount of energy and is not even considered in the EER calculation.

SEER should be better, but our problem with SEER stems from where we live, the hot and humid gulf coast. SEER is calculated based on seasonal climatic conditions found in New York that are scarcely applicable to Houston. It also fails to account for dehumidification; thus SEER, like EER, deceptively raises the efficiency ratings of the systems in my opinion. Generally speaking: as the temperature rises higher than 80°F, the functional SEER rating drops 2 points for every 10 degree rise—meaning that at 100°F, your 14 SEER system is functioning at SEER 10.

So while we are told we are buying an HVAC system with a stellar SEER rating, for most of the cooling season we suffer with AC systems that perform below our expectations. This should not be overly surprising, in that AC is essentially the physics of heat transfer and dehumidification, and there is only so much additional heat hot humid Gulf Coast air can absorb.

Additionally, a refrigerant based system (CFC or HCFC) has a coil that remains cold only when the compressor is compressing. Even with variable speed fans, right-sizing the system and getting the zones correct can be tricky and often beyond the ability of many AC installers. (Everyone I know has at least one AC nightmare story.) Furthermore, in the winter, the HVAC components are coupled with gas or electric furnaces that roast the air and balance differently on the warming days than they did during the cooling days.

There had to be an easier and better way, and the huge efficiencies of the envelope helped us get there.

Enter Gary Parr with HVAC Direct to You here in Houston, and Mac Word of Thermalflow, LLC out of Austin, Texas. Mac is pioneering the use of chilled water systems (akin to universally used commercial systems) for residential HVAC. Thermalflow produces a water chiller based HVAC system (where the coil is filled with chilled water) with an estimated SEER performance of between 15 and 19. The system is much less affected by the weather. As ambient temperatures rise, the efficiency drop-off is only about 10% of the decline of traditional refrigerant home systems. Our system is the first like it in Houston (although Mac has installed similar systems across the southwest and in California). We required a local HVAC contractor with the knowledge to integrate the water based components with high quality, UV light, media filter, variable speed fan equipped air handlers, and the willingness to soldier through the learning curve. We also needed local support and maintenance. Lucky for us, for Gary, the learning curve was short. Additionally he brought expertise, enthusiasm, and a willingness to partner with Durable Residential Builders and Mac Word. Gary's participation was essential and allowed the team to put the system together, match it to the house, understand the system, and install and fine tune our HVAC. HVAC Direct to You participated in the project at a number of critical junctures including air exchange and electrical backup.

The chilled water system has other advantages that dovetail perfectly with our system. First of all we have multi-speed fans on the evaporative cooling tower and the air handlers. This allows the system to match the demand with great precision and obviates the risk of over-powering the cooling needs and

short cycling, which can lead to disastrous humidity and moisture related issues. It also allows us to link the system to humidistats and, for very little energy cost, maintain the 43°F temperature in the cold water coils. The air handlers then function as a 24/7/365 dehumidifier, if needed. Humidity problem solved. We also make elegant use of the dehumidification waste water by using it for irrigation.

In the winter, our coil becomes a hot water coil, obviating the need for a furnace and reducing the severe drop in humidity that a furnace provides. This folds into our renewable hot water sources for even greater efficiencies, which we will soon address.

As we noted earlier, the thermal mass and tremendous insulation/efficiency of the envelope comes into play by allowing simplification of the HVAC system. Once the house reaches a steady state, there is really no need to program the HVAC system. The house gains and releases heat very slowly, and once your target temperature and humidity are reached, the amount of energy needed to maintain them is minimal. Set it and leave it. The system easily and precisely responds to the natural ebb and flow of family life and the gradual creep of energy from the outside (on cooling days) or to the outside (on warming days).

It is worth noting that a traditionally built house in Houston of this size would typically use 12–15 tons of AC and be divided into 3–5 zones, each with its own programmable controller. The Manual J load calculations (by which a system is right-sized to the home) for this house called for a total of less than 6 tons of AC. We, knowing this would be a showcase, model (high traffic) home, increased that to 8 tons, but the variability of the system allows us to do that without the risk of wrong-sizing the system.

Thus we were able to use only a two-zone system with two, 4-ton compressors, one water pump, one evaporative tower, and one 6 gallon chilled water reservoir. Additionally, all the parts for the system are commercially available, making maintenance and repair easier. The icing on the HVAC cake is the fact that the hot water system is designed to scavenge waste heat from the AC compressors and use that energy source for hot water production.

To summarize, the synergies of the system are founded in the hugely efficient walls and attic assembly. The envelope allows for a simpler and

The two compressors, the chilled water holding tank and the evaporative cooling tower. This system is akin to water chiller commercial units and provides 42 degree water to the air handlers. The chilled water coils also function as active dehumidifiers if the set temperature is reached but the humidity is higher than desired. The Allied Thermal System (Austin, TX) is far more efficient than their conventional HVAC competitors. The immense efficiency of the building envelope allows a smaller and simpler system, where the homeowner can just "set it and go."



substantially smaller HVAC system. The compressors are an energy source for heating water, and the dehumidification is a grey water use opportunity. Living in the home is easier and potentially complicated systems have been simplified.

### **Hot Water**

Since we have already mentioned hot water, let us continue in that vein. Heating water can account for up to 30% of the total energy consumption of a house, and as such, was another domestic need that prompted considerable debate. What makes sense?

There are hot water recirculating systems, a variety of tank-less or hybrid hot water heaters, solar thermal systems, storage tanks, and items like our compressor based heat source.

Our Building System calls for hot water as the heat source in the coils in the air handlers. That makes it critical that we have ample hot water, regardless.

Solar thermal has a financial payback—thanks to the tremendous heat capacity of water and the enormous energy required to heat it—that makes sense today. Depending on your usage the payback could be three to five years or less, so solar thermal with an eighty gallon storage tank is the backbone of our hot water supply. That is supplemented by the heat scavenged from the AC compressors, thus in hot and rainy or hot and sunny days we should be fine. But what about hot water when the weather is cold (not running the compressors) and cloudy? We solved this by adding the Eternal Hybrid GU32DV water heater in series with the 80 gallon storage tank. The Eternal Hybrid has a 6 gallon reserve tank that speeds delivery of hot water to the point of use. The Eternal Hybrid unit has its own dedicated air intake (DV strands for Direct Ventilation) and is efficient to the point that the exhaust gases are vented to the exterior through PVC! When the water in the storage tank is hot, the Eternal Hybrid hot water heater does little, but should the need arise, the Eternal Hybrid hot water heater is the safety net that can give us 20GMP continuously. Finally, true to the Building System, Rice Residential Design located the highest points of use of hot water (kitchen and bedroom baths) to be as close to the hot water source as possible, thereby minimizing the runs of PEX tubing.

In all, we anticipate the non-renewable energy consumption for hot water to be less than 10% of the total energy used for hot water. Again, the synergy plays: renewable energy sources for usable hot water and for air warming during cold weather. Therefore the recurring costs for hot water and warm air is near zero. Again the efficiency of the envelope makes it possible.

### **Solar Electric**

Speaking of renewable energy sources, let us consider the solar electric application in this house. Photovoltaic electricity generation is, like geothermal



AC, a hot topic. It benefits from (or suffers from) the media hype of the green movement. When considered in the cold hard light of cost per kW hour and the limitations of today's solar panels, it's hard to make it work. The pay-back is too long for my tastes (10–20 years at today's electrical rates). Add in the tax incentives and it becomes more palatable to be sure, but our employment of the “what makes sense” litmus test tries very hard to avoid relying on federal incentives (governments can, and have, changed their minds and their tax incentives). Solar electric (PV) works in this house only because it is able to provide a significant percentage of the electrical requirement, and do so with a modestly sized 18 panel (3.2kW) solar array. We evaluated the feasibility of adding batteries and a larger number of panels, thus offering the opportunity to go off grid, but again, what makes sense prevailed. To do that would have tripled the cost of the system, and when you consider the average electric bill forecast for this house to be \$75.00, the payback for that is beyond the expected life span of the PV system.

As we see it, time of day (TOD) electrical pricing will mean that the PV will be working during peak times and not working during off-peak periods—perfect. Plus, if the electrical grid is down, it will be much cheaper to have a gas generator backup ready to go. Furthermore, solar is, obviously, very weather

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The solar panels installed on top of the DECRA Shingle Plus roofing panels. The DECRA roof gives the roof depth and a richness that matches the house design. The 50 year warranty and the 150 mph wind rating offer great comfort and lower long term maintenance costs to the homeowner.



dependent, and batteries are limited in the electricity they can store, while a natural gas generator is, practically speaking, unlimited in the time during which it can generate electricity, which makes sense.

Here again we partnered with a company that brought more than the single product to the table. Standard Renewable Energy added the expertise of engineers and system designers to the project that allowed us to right size the PV and the Solar thermal. They were able to work with HVAC Direct to You and integrate the PV with the RUUD backup generator and were tireless in helping us move this new approach through the city's building departments.

### **Fresh Air**

With a house as tight as this house surely is (blower door test pending) the fear of sick or stale air is real. So a fresh-air intake becomes a necessity. The problem arises when you consider that you are pumping in hot-humidified air and pumping out cool-dehumidified air that you used energy to condition. There are more expensive and less expensive ways to introduce fresh air to the home, but you pay now or you will pay later. If you pay now, the debt becomes part of your deductible mortgage payment. If you pay later it's post-tax dollars going toward every increasing utility costs. We like controlling costs and expenses and thus the logical choice was Fantech 3204N Energy Recovery Ventilators (ERVs) recommended to us, and installed by Gary Parr. Beautifully simple and highly efficient, the Fantech ERVs expose incoming and outgoing air to each other across a semi-permeable membrane. Heat and humidity follow the gradients and some percentage of each move from the high/hot (unconditioned air) in-coming side of the membrane to the low/cold (conditioned air) out-going side of the membrane. Thus, instead of adding 100°, 90% humidity air to the return air side of the HVAC system, we add perhaps 85°, 70% humidity semi-conditioned air. A dollar saved is a dollar earned.

### **Water**

Water is not in short supply in coastal Texas. But mid-Texas and the Rio Grande Valley are, at the time of this writing, in the middle of the most severe drought since the 1930s. Approximately 90% of Texas counties are under a burn-ban. Lake Travis,



near Austin, is down fifty feet. Beyond that, look at the Southwest and western regions of the U.S., and it becomes clear that the water supply is being out-paced by demand. Not one drop of the mighty Colorado River reaches the sea.

Furthermore, city water in Houston has long had a subtle but distinctive taste and/or odor and is usually not the first choice for drinking water in many families. Many municipal water supplies, while safe, have documented levels of heavy metals and other things we would rather not introduce into our bodies. Bottled water costs money and is bottled in plastic! Plus city water has sediments and calcium that corrode or clog piping and shorten the lifespan of our costly appliances by as much as fifty percent. Furthermore, after hurricanes, the water pressure is near zero, and the city authorities recommend boiling water before consumption.

So while potable and, for now, still plentiful in Houston; there are more than a few reasons to look at alternatives for domestic water. Last but not least, water-experts predict a dramatic increase in the cost of water in the next decade.

With these troubling facts in mind we evaluated rain-water harvesting. The roof of this house is substantial, measuring approximately 5,000 sq ft. Rain-fall in Houston averages from three to six inches per month; affording ample opportunity to catch and store water. But where to store it and how to 'pre-condition/filter' it? We considered above ground options like the *Rainwater HOG* system, which we liked for its ease of install and 'green-ness'. However, the system would have required 100+ units to store sufficient water to qualify for our LEED credits or be a truly adequate water source. We looked at below ground options but didn't like the idea of huge plastic tanks buried on the property. We nearly gave up on this idea when we were introduced to Jack Holm *Sparkle Tap Water Company* and the *Raintube Gutter protection system* distributed by *Rain Technologies* of Houston. When fashioned together these products and companies allowed us to easily harvest water from approximately 70% of the roof and have reasonably clean (leaves and large debris filtered by the Raintube which also keeps the gutters clean) water collecting in a sealed 11,500 gallon underground cistern.

This "underground pool" measures 10' x 20' by 10' deep. After cement and sealing it will hold roughly 11,500 gallons of rainwater for irrigation and potable use.



From there water is pumped directly for irrigation (read as much happier plants) and through a filtration unit for potable water in the home. The indoor filtration system, which will filter city or harvested rainwater, is the '*HydroSafe Triple Treat*' unit by Watts water quality products. The *HydroSafe* ultra filtration unit is a whole-house water filter that delivers NSF certified, Water Quality Association, (WQA) certified, water to all the points of use in the house. The ultra filtration membranes remove particles larger than 0.02 microns, that's 99.999% of viruses and is combined with a carbon filter to eliminate odors and tastes. The *Watts HydroSafe Triple Treat* compares favorably to other systems in that it does not rely on chlorine, and adds UV lights (254nm) to complete the decontamination process. It is unpowered when filtering the water and has a negligible effect on water pressure. This, combined with the naturally soft rainwater, provides the home with purified, excellent tasting, water. Essentially, we shower with cleaner water than you can buy in the grocery store. Furthermore, the unit is self maintaining and easily serviced. (Think of all the plastic water bottles you will not have to recycle!)

Financially is where rainwater harvesting struggles to reach the 'what makes sense' threshold. The cost is not insignificant (our system tipped the scales at nearly \$30,000). Adding in the mainte-

nance costs for the filtration unit stretches out the 'payback' period on this component of our *Building System* to between 10–20 years (at today's water prices). But, given all the issues noted above; having ten weeks of water in an underground cistern has its actual and psychological advantages. It also completes the package of hurricane readiness by allowing the house to fully function in the event of utility failure. More-over there is no question that higher water quality has health benefits and extends the life of the water consuming appliances. So while not financially obvious, we felt the system justified itself. Plus put in the context of the entire project the water harvesting added about \$5/sq.ft. to the build cost, or about 2% of the overall building budget.

And, *of course*, we have dual flush toilets, low water use appliances, faucets and shower heads.

Other non-traditional, products and technologies we felt made sense include:

### **Flooring**

We considered bamboo, recycled wood, wood from sunken old trees, a variety of species, tile, etc. Aesthetics weighed heavily here and the desires of the homeowner were critical in this high visibility item. The desired look called for wide plank Brazilian Cherry. The solution we found was engineered flooring by a German designed plant in Brazil that utilized only a 3/16 inch thick plank of the called for species. Then upstairs we used short boards, 3.5" wide of full thickness flooring. Additionally, we utilized cork flooring in lieu of hardwood in the game room and bedroom 5. Furthermore, the finish on the wood flooring is an oil based product that looks and acts like a polyurethane. The advantage in its use lies in the fact that instead of a full sand and refinish; the floor can be lightly sanded and re-oiled returning it to full beauty and dramatically extending the lifespan of the floor while reducing long-term maintenance costs. International Flooring of Houston helped us with product choices and installed our beautiful floors.

### **Paint**

All Sherwin Williams low odor, no-VOC paints. This house does not have that "just painted" smell we've come to expect from new homes. The paints

The wine room is refrigerated and the floor is recycled cooperage stock by Fontenay Flooring (California). This picture is during install and does not do justice to the true beauty of this reclaimed wood floor.



also provide high quality, long duration paints that are also anti-microbial. The paints all have the Sherwin Williams Greensure designation, denoting paints and finishes that are also manufactured using techniques that reduce the environmental impact of the product.

### **Sealers and Finishes**

Where possible Sherwin Williams Greensure, low odor no-VOC.

### **Appliances**

Almost entirely Energy Star rated Sub-Zero/Wolf appliance and Kenmore low water use, high efficiency washer and dryer. A Fantech 1200cfm exhaust fan over the stove, which required its own make-up air intake due to the tightness of the building envelope. Our bathroom exhaust fans are also

Fantech and are virtually silent, which you have to not hear to fully appreciate!

### **Doors**

Masonite Safe 'N Sound doors were a laudable addition to the finishes in the house. The unique construction of the Safe 'N Sound Emerald door, with wheat-straw based DorCor, features attributes such as: preconsumer recycled content, no added urea-formaldehyde, Forestry Stewardship Council (FSC) Certification, and low VOC Emissions. More expensive to some degree, but they are a giant leap beyond the currently available wood or other solid core doors.

### **Lighting**

Lighting is an evolving technology. We have lived and loved our incandescent lights since Mr. Edison worked out a vacuum/filament combination that worked. However, the heat they give off is all wasted energy. A more efficient fluorescent lighting is possible but it has a displeasing industrial look. We now have compact fluorescent lights (CFLs) that offer different color tones that are significantly better than the warehouse look. There is also (light emitting diode) LED lighting, which is rapidly gaining market share in everything from automotive applications, to flashlights, to lighting, to gadgets of every variety.

Then the kicker: dim-ability. Any home is well served by dim-able lighting. It sets a mood, it saves energy, and it extends the lifespan of the bulb. People expect it and for good reason. Our old standby incandescent bulb loves to dim, but the CFL with its built-in ballast responds inconsistently to lesser amperage. Additionally, LED dim-able screw-in lights exist, but they are upwards of \$70/bulb at this writing.

We looked at dim-able fluorescent cans and dim-able LED cans. They are both efficient and generate little heat. The former have a respectable lifespan but age poorly with increasingly delayed time to full brightness. They also contain mercury, which has its own issues. The fluorescent cans are relatively expensive ranging from \$150 and up per fixture, and replacement bulbs are proprietary and expensive.

LED dim-able cans are incredibly long lasting, and the potential variety of color of the light is nearly unlimited. However, as new items, they are very pricey at over \$200/fixture at this time.

The standard threaded cans are \$37, making dim-able fluorescent or dim-able LED fixtures four to six times more expensive. In hard numbers, making the leap from incandescent cans to fluorescent or LED dim-able cans represents an increased cost of \$15,000–\$20,000 on this project. This is hard to justify for two reasons: 1) when not in a room, you can turn the lights off, and 2) the lighting industry is in a huge evolutionary period. Much like Plasma screen or LED TVs, the price will come down. New and better versions of the lights will hit the market and there will be competition. We believe that LED will ultimately win the contest due to its tremendous longevity, durability, and nearly unlimited versatility. It also makes sense that threaded dim-able LED bulbs will be widely available at a reasonable price within five years. So armed with this information, we decided to install regular cans and live with CFL bulbs for now. We may compromise and install some incandescent bulbs in locations where dim-ability is critical. We anticipate being able to swap out these bulbs for LED as the price point drops to a figure we are more comfortable paying.

### **Landscaping**

LEED-H dictates significant reductions in water usage for irrigation, drought resistant plants, and encourages the incorporation of indigenous species. We worked with Moss Landscaping here in Houston. They were a natural fit for our project because of their close ties to Texas A&M University (many of the design staff are A&M graduates, even though Gary Moss is from the University of Texas). They brought enthusiasm and expertise to the table and helped us design a landscaping plan that incorporated all the LEED-H priorities. Gary Moss and his team also worked hard throughout the build process to assure the viability of three at-risk trees on the site. All survived and beautify the house today. Moss installed drip irrigation and low profile sprinkler heads. We included a number of local grasses, low water use and drought resistant plants, and others. We reduced the overall water usage by at least 30% compared to traditional landscaping. They also left us with a stunningly beautiful finished product, and I could not be more thankful for all they have contributed to the project's success.

### ***Mosquitoes***

Houston has plenty of them. We looked at pyrethrum systems, which can be tough on plants and annoying to breathe. We settled on an Envirogreen Mosquito Control system, installed by Natures Pest Control. The system uses a misted sodium based product that acts as a drying agent that desiccates the mosquito's exoskeleton, and eradicates it. It is 100% non-toxic to the point where Envirogreen is classified as a minimal risk pesticide by the EPA.

### **CONCLUSION**

What made sense was our guide and our Building System has taken a home design that had great

potential and made it into something unique. More than that, we expect the home's green features to be proved thanks to the efforts and anticipated research by Texas A&M University. Last, but not in any way least, I extend my love and thanks to my wife who listened to me when I said I wanted to build a house that "would change the world." We haven't changed it yet, but we might.

Our thanks go out to Kelly Milligan and James Sweeny who spearheaded the project at Texas A&M, and saw value in the partnership from the very first conversation.

For more information about the products and technologies chosen and employed, please see the links on our web site [www.durableresidentialbuilders.com](http://www.durableresidentialbuilders.com).