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LEED FOR HOMES PILOT PROGRAM: AN IN-DEPTH LOOK AT A NEW LEED PROGRAM FOR THE RESIDENTIAL SECTOR

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INTRODUCTION

In August 2005, the U.S. Green Building Council (www.usgbc.org) announced the introduction of a new pilot-phase LEED for Homes rating system. The new system sets a national standard for environmentally responsible building in the residential sector. While there are some exceptions, most "residential green building" programs around the country have been regional in nature. LEED for Homes's goal is a national standard and certification process that encourages and regulates the green building process. Builders and consumers adopting the LEED standards will find themselves at the cutting edge of high-performance homes, as well as promoting and implementing environmentally conscious building processes.

This article discusses the implementation of the LEED for Homes pilot phase rating system in a new residence that is nearing completion in a rural setting near Charlottesville, Virginia. Specifically, this paper explores the various "decision points" as we encountered them in the actual project.

BACKGROUND INFORMATION

The LEED for Homes program, like other LEED programs, has certain elements that are "required" and other elements that are "optional." Generally, a project has to meet all requirements and have enough of the optional elements to gain enough points for certification. There are four levels of certification: Certified (30–49 points), Silver (50–69 points), Gold (70–89 points), and Platinum (90–108). After a quick review, we determined that our project would meet all required items and may have also earned a silver certification. Thus, we contacted the appropriate provider to determine if they were able to accept our project into the LEED program, even though the project had already broken ground.

A "provider" is an organization staffed with individuals who have completed the early training programs that enable them to verify and certify LEED for Homes projects. During the pilot phase of this program, there are only twelve providers around the country. This fact limits the number of projects that can be included in the pilot phase. Our provider was based in Atlanta, Georgia.

Following initial hesitation, LEED for Homes decided to include our project in the pilot program after learning that our firm had participated in another regional green building program, and that our proposed residence met many of the program's optional elements, as well as the required ones. Participation required us to attend training sessions in Atlanta and to formally register the project with LEED for Homes.

FIGURE 1. Lowe residence.

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GENERAL PROJECT DESCRIPTION

Our project, a single-family home, is located on a $2^1/_2$ acre rural lot in the Crozet community of Albemarle County, Virginia. Crozet rests at the foot of the scenic Blue Ridge Mountains and is about 13 miles west of Charlottesville, Virginia, home of Thomas Jefferson's Monticello and the University of Virginia.

The residence could best be described as a New England and/or Virginia farmhouse. The first and second levels each have about 1,600 square feet. The house includes a full basement and walk-up attic with room for about 800 square feet of finished space beneath the 12/12 pitch roof lines. The home has a double front porch and first floor side porch on the south face. These porches reinforce the architectural style, while serving as additional sources of exterior shading on the south and west sides. The heavily wooded lot has many hardwood trees that tower above the house, providing much needed natural shading during the hot summer months.

FIGURE 2. Lowe residence ICF foundation.

We built the house using ICFs (insulated concrete forms)—an ancient building material in an innovative and efficient system. ICFs provide many energy saving benefits, and solve many of the problems associated with traditional stick framing. An ICF is a sandwich of two panels of expanded polystyrene (rigid foam) and concrete. The system we used, from Amvic Building Systems, employed click-together forms of varying sizes. When filled with concrete, these forms perform a "five-in-one" function—air barrier, vapor barrier, insulation, framing, and sound barrier. In addition to cutting labor costs for both builder and owner, this system allows maximum protection against air infiltration and leakage, providing for 50% energy savings. ICFs use materials that are renewable, contain no CFCs or VOCs, are low maintenance, and are extremely durable.

Cementitious siding, our exterior cladding material, shares these benefits as well: it is durable, noncombustible, and does not contain the hazardous chemicals of vinyl or PVC. Additionally, it is readily available and is increasingly replacing vinyl siding as an industry standard. On our project, we used Hardie Plank, from James Hardie Siding Products, a

FIGURE 3. An outside corner ICF, top view. From outside (top of picture), materials are: OSB (screwed to fins that span through the ICF), expanded polystyrene foam, interior fins, steel rebar, and EPS foam.

fiber-cement lap siding product that has a 50-year warranty and virtually no maintenance requirements.

The roof is standing-seam Galvalume, a 55% aluminum/45% zinc alloy coated sheet steel with twice the corrosion resistance of galvanized steel, high reflectivity, and very low maintenance. We clad the foundation in stone, another obviously long-lasting, low maintenance material.

PROJECT CHECKLIST

The LEED for Homes rating system has eight master categories:

- Location and Linkages (LL)
- Sustainable Sites (SS)
- Water Efficiency (WE)
- Indoor Environmental Quality (IEQ)
- Materials and Resources (MR)
- Energy and Atmosphere (EA)
- Homeowner Awareness (HA)
- Innovation and Design Process (ID)

This paper will explore each of the master categories and how we implemented them in our project, along with commentary on lessons learned, contradictions in the system, and ease or difficulty of implementing the eight categories.

LOCATIONS AND LINKAGES (LL)

The first LL credit is for building a home in a LEED-ND (LEED for Neighborhood Development) certified neighborhood, worth ten points. Unfortunately, these ten points are not available during the LEED for Homes *pilot version,* since the LEED-ND program is not yet complete. Other qualifications, however, allow projects to gain up to ten points:

- Avoid environmentally sensitive sites and farmland.
- Be within $^1/_2$ mile to existing water, sewer, and roads.
- Select an infill site.
- Locate within a $^1/_4$ mile of basic community resources/public transportation.
- Locate within a $^1/_2$ mile of a green space.
- Locate on a high density site with seven units per acre or more.

Community resources include convenience stores, fire stations, banks, places of worship, restaurants, medical facilities, and other "in-town" services. "Green spaces" are defined as community open spaces that are at least $^3/_4$ acres in size, including parks, play areas, or other open space intended for recreational use.

As noted earlier, we built our project on a rural lot that is part of a small existing subdivision. We only qualified for one credit—that we did not build on an "environmentally sensitive site and/or farmland."

Clearly, the LL credits slant toward a new urbanism model. I think, however, that the LEED for Homes committee should consider both an urban model and a rural model. Many of the most advanced green homes in the nation are on rural sites; these larger sites allow the owners to introduce elements such as photovoltaic fields, wind towers, geo-thermal systems, and other features that prove difficult on small, high-density sites.

SUSTAINABLE SITES (SS)

The SS section deals with site stewardship, landscaping, shading of hardscapes, surface water management, and pest control issues.

LEED for Homes requires minimization of the site's disturbed area if the site is greater than $^1/_3$ acre. Our $2^1/_2$ acre lot is located on a small knoll; it had an already cleared area at the top when purchased. We determined that the already clear area would be an ideal site for the home. This meant that we only had to remove three trees to provide enough room for the septic field. We took down a few other dead trees at the same time; we then chipped the trees into mulch and used it on the fringes of the site.

LEED for Homes mandates that a project must maintain erosion controls during construction. This requirement worked well with our local and state requirements, which are just as strict as the LEED requirements. The county government enforces these strict state-mandated standards for erosion controls on every construction project in the area; each local project is required to designate a registered land disturber (RLD) for each building permit filed.

LEED for Homes requires that each project have a basic landscape design. The design should have drought-tolerant turf only in sunny areas and no turf in densely shaded areas. There should be no turf on areas with slopes greater than 25%. Invasive or exotic plant species cannot be introduced to the site; only native plants that require minimal water are permissible. Points can be gained for applying three to four inches of mulch around plants, limiting turf size to a small percentage of the lot.

Projects are encouraged to reduce heat-island effects by strategically installing shading plants to cover the hardscape areas. Points can be gained for shading at least 50% of sidewalks, patios, and driveways within 50 feet of the home at the five-year growth projection. Another option is to install light-colored, high-albedo materials for at least 50% of the site's non-roof impervious surfaces. If the building site is greater than $^1/_4$ acre, then it is mandatory to install or leave permeable material in place for at least 65% of the lot.

For our project, we designed the landscape with native plants that will meet the shading requirements. We contacted our local soil and water conservation office to get an official list of appropriate plantings for the area and these plants' water needs; we plan on planting these varieties after construction is completed. Finally, we decided to construct the driveway and all walkways out of permeable materials to minimize hardscaping and discourage stormwater runoff.

The LEED guidelines give different points for different precipitation areas of the country. The Central Virginia region usually receives more than 40 inches of rain per year, and is considered a "wet" region. Points can also be gained for installing permanent storm water control measures such as vegetated swales, on-site rain gardens, etc. On this project, we installed an underground cistern to store water collected from the roof; we can use this water for both irrigation and potable applications. With this system, we gained points for permanent erosion controls and water efficiency.

The final SS credit deals with non-toxic pest control. There are no mandatory requirements, but there are several opportunities for partial points. Using solid concrete wall foundation walls or topping a masonry wall with a solid block bond beam gains a half point; keeping all wood (siding, trim, structure) at least 12" above soil level also gains a half point. (Code generally requires only 8".) Other partial points come from separating concrete-to-wood connections with metal or plastic materials, and installing landscaping so that all parts of mature plants will be at least 24" away from the house. Our project incorporated all of these procedures, the most obvious being our concrete walls, which are naturally impervious to pests.

WATER EFFICIENCY (WE)

LEED mandates no water re-use requirements, but it still attempts to minimize demand for potable water. Installing a rainwater harvesting system or a grey water re-use system gains optional points in this category. Central Virginia's ample rainfall allows us to harvest and use rainwater quite easily. We built and installed an elaborate rainwater collection system consisting of two 1,700-gallon underground storage tanks totaling 3,400 gallons. We designed the system to supply all of the water needs (potable and non-potable) of the household; it will yield over 60,000 gallons per year based on the size of the roof and assuming an evenly distributed rainfall. We were very fortunate to work with Rainwater Management Systems (www.rainwatermanagementcom), based in Salem, Virginia, in designing and installing our rainwater collection system.

Installing an extensive rainwater harvesting system was one of the most difficult financial decisions we made. We drilled a well at the beginning of the project, and we did not have to install a rainwater system. Two main factors ultimately drove the decision to install the system. First, some years are quite dry, despite being in a "wet" region. For instance, the central Virginia region

FIGURE 4. Water filtration equipment. Note two different storage tanks—one for rainwater and one for the backup system, which draws water from our well. The cylinders on the wall are the carbon filters; the long metal box next to the filters is the UV sterilizer.

had a serious drought in 2002 followed by a year of record rainfall in 2003. During the drought year, many people saw their wells run dry for the first time ever. Even when we had occasional rain, it was not enough to replenish the deep groundwater supplies. With a rainwater system, we would be able to catch and use even the little bit of rain that fell, without waiting for the groundwater (and our well) to be replenished. Second, as a building company, we chose to install the rainwater system in our first LEED home as an example to our customers. We wanted to demonstrate that we are willing to lead by example and that we have the technological background to install sophisticated environmental systems.

The collection and filtration system itself is indeed sophisticated, but it works on some very simple principles. First, water is collected from the roof using gravity—instead of dumping water onto the ground, our gutters feed into underground pipes that in turn feed into underground cisterns. Before entering the cisterns, a "filtering roofwasher" removes organic material (leaves, sticks, insects), increases the life of the cisterns, and improves the taste of the water. The cisterns, made of food-grade plastic, are buried to prevent light from encouraging algae growth.

FIGURE 5. Installation of underground cisterns. The box in the foreground is the filtering roofwasher; the intake pipe at the bottom of the roofwasher will be connected directly to the downspouts.

To prepare the rainwater for drinking, it must be brought into the house and filtered carefully. A pump brings the water into a pressurizing tank; from there the water moves through two carbon filters and an ultraviolet sterilizer. The first carbon filter removes particles down to 20 microns in size; the second filter removes particles as small as 5 microns. The UV sterilizer removes bacteria, disinfecting the rainwater without using any chemicals. The newly filtered water then moves to a storage tank, ready for immediate use in the house.

LEED for Homes discourages landscape irrigation to minimize water usage. If a LEED home has an irrigation system, then LEED requires the system to have a central shut-off valve and sub-meter. LEED awards more points for following the optional measures in a dry region. Points can be gained by having at least 50% of the landscaped planting beds irrigated by a drip irrigation system to minimize evaporation, zoning turf beds by type to be watered differently as needed, using timers to irrigate specific areas between the hours of 11:00 p.m. and 7:00 a.m., and using high-efficiency nozzles and check valves in the watering heads. In any region (dry, normal, or wet), a point can be gained for installing "smart" controls that receive radio, pager, or Internet signals with "evapotranspiration" information to direct the irrigation system to replace only the moisture that the landscape has lost because of heat, humidity, and wind. This is a sophisticated and costly way to manage water, but it can be very helpful in dry regions. Alternatively, designing and installing landscaping that does not require irrigation to survive will also gain a LEED point.

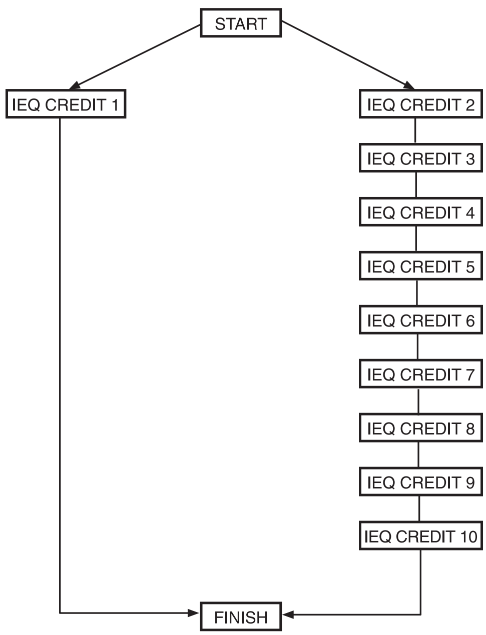
The last WE credit deals with minimizing indoor demand for potable water. There are no mandatory measures, but there are several optional measures, focused on installing "high efficiency" fixtures or "very high efficiency" fixtures. ("Very high efficiency" faucets and shower heads must use 1.5 gallons per minute or less, while "very high efficiency" toilets must use 1.1 gallons per flush (or less) on average.) We chose to use dual flush toilets, a "very high efficiency" option, in our LEED project.

INDOOR ENVIRONMENTAL QUALITY (IEQ)

Any LEED home must have an ENERGY STAR® designation. Many building professionals are already familiar with the ENERGY STAR® program, developed by the U.S. Department of Energy (DOE). In April 2005, The Environmental Protection Agency (EPA) released an elaborate set of indoor air quality guidelines to be used with the pilot LEED program. If adopted, these guidelines will recognize homes equipped with a comprehensive set of indoor quality measures. Homes that comply with these specifications can use "*Indoor Air Package*" as a complementary label to "ENERGY STAR®" for homes. The EPA anticipates that the early specification release will need refinements for cost, strength, and technical fairness prior to being released as a permanent program.

In the LEED for Homes IEQ section, a builder can choose one of two paths:

FIGURE 6. From page 53 of the LEED for Homes rating system book, this diagram shows the two paths a builder may pursue in the IEQ category.



The first path, "Credit 1," is an elaborate credit worth ten points, called "ENERGY STAR® with Indoor Air Package." The second path, called "Credits 2–10," has many of the same elements required in Credit 1, but evaluates them separately rather than as a complete package. We chose to pursue this second path, Credits 2–10. In choosing which path to pursue, a builder should consult with his rater and provider. Finally, whichever path a builder pursues, he or she needs to team up with highly qualified HVAC engineers and contractors to ensure that they carefully plan and implement the systems.

CREDIT 2: The combustion venting credit has some strict requirements to minimize leakage of combustion gases into the occupied space of the home. It is mandatory to design and install HVAC and DHW (direct hot water) combustion equipment with closed combustion (i.e., direct-vented or power-vented exhaust) if equipment is located inside the building envelope. LEED further requires that a carbon monoxide monitor be installed on each floor of the home. Installing a fireplace can prove to be a real challenge in the LEED rating system. A masonry fireplace is not permitted, with the exception of a narrowly defined "masonry heater." Factory-built wood fireplaces that meet certain UL standards, as well as specific EPA standards, are allowed. Our preliminary plan included a factory-built wood burning fireplace, but our first choice did not meet this standard. The fireplace that we found to meet this standard was expensive enough to cause us to question whether to have a fireplace. We ultimately settled for a closed combustion gas-log system installed in a wood stove in order to meet LEED's strict requirements.

CREDIT 3: There are no requirements to add a humidity control system in a LEED home, but it has been our experience that a home that is built extremely tightly needs humidity control to provide a comfortable thermal environment in the home. This is especially true in mixed-humid and warm-humid climates. Most people will feel comfortable when the humidity is in the 35% to 55% range. While an air conditioning system will both cool and dehumidify the air, a mixed-humid climate provides some challenges for the HVAC system. On a given summer day, it could be 95 degrees with 90% humidity. One day later it could be cloudy, overcast, and rainy with outdoor temperatures in the high sixties. In this scenario, the temperature is low enough that the AC will not come on, but an uncomfortable condition of high humidity exists and increases inside the home. This type of condition can lead to mold growth when left unchecked.

It has been our experience that when we use deliberate dehumidification in a residence, the occupants are more comfortable. They can even tolerate a higher set temperature, up to 75 degrees, in the sum-

FIGURE 7. Testing the house's air leakage using the blower door test.

mer, reducing cooling loads and energy demands. Our dehumidification system removes moisture from incoming air, while simultaneously filtering and purifying the air. Again, our HVAC contractors helped us specify this equipment and integrate it into the overall system installation.

CREDIT 4: Even as we build homes tighter, we must also ventilate homes to protect the occupants from indoor pollutants. LEED requires installation of a whole-building ventilation system compliant with ASHRAE standard 62.2 (see www.ashrae.org for more information). From a health perspective, a home should not be "under-ventilated," but from an energy perspective, a home should not be "over-ventilated." Section 4.1.3 of ASHRAE standard 62.2 ensures that natural and mechanical ventilation are properly integrated. A project can gain two points by installing a dedicated outdoor air supply system that complies with the ASHRAE standard and provides for a heat transfer between incoming outdoor air and exhaust air (except in very mild and dry climates), and has fully ducted supply and exhaust. Subjecting the home to third-party testing of the outdoor air flow rate into the home gains an additional point.

CREDIT 5: Local exhausts (bath fans and kitchen range hoods) should remove indoor pollutants in kitchens and bathrooms and help maintain a positive pressure in the house. LEED for Homes requires bathroom and kitchen systems be installed per ASHRAE standard 62.2 and use ENERGY STAR® labeled exhaust fans, except for exhaust fans serving multiple bathrooms. Modified switching on bath fans including occupancy sensors, humidistat controls, and timers all gain points in this category. We chose to install timer switches on our exhaust fans to meet the requirement and to gain the extra point; the timer switch prevents someone from leaving the fan on and causing the house to pressurize negatively. In a mixed-humid climate, a prolonged negative pressure would draw outside humidity into the home, whereas a positive pressure will aid in pushing moisture vapor to the exterior of permeable wall and roof structures.

CREDIT 6: Ducts must be installed carefully so that supply air is adequately distributed to conditioned spaces; they must be designed using the ACCA Manual D (see www.acca.org). It is also mandatory that every room has adequate return air flow through multiple returns or transfer grills. (There are different requirements for hydronic heat systems with passive ventilation.) A project can gain two points for testing supply air flow rates in each room of the home using a flow hood and providing balancing dampers to ensure that the supply air flow rates are within +/– 15% (or +/– 10 cfm) of calculated values from ACCA Manual J (see www.acca.org). We chose to pursue these points and perform these tests for our LEED home.

CREDIT 7: A core IEQ requirement is to filter the supply air to remove particulate matter. Mandatory measures include installing air filters with a MERV rating of 8 or better while ensuring that the air handlers can maintain adequate pressure, or installing a ductless space-conditioning system such as a hydronic heating system. Installing a MERV 10 or better gains one additional point, and installing HEPA air filters gains two more points. Again, this requires that the system can maintain adequate pressure and air flow with the advanced filtering. The air handler in our LEED home contains MERV 12 filters, and outside air passes through a MERV 14 filter on the dehumidifier.

CREDIT 8: Controlling contaminant entry into the building gains further IEQ credit. It is mandatory to seal off ducts during construction, or to clean the HVAC ducts and coils before occupancy. The LEED rating system gives one credit for installing permanent doormats inside each entry, or installing a central vacuum system with an outside exhaust. Every time someone walks into a building, that person also brings dirt, debris, allergens, and irritants along. Installing permanent doormats helps trap these particles before they make their way through the house and eventually into our lungs. During our pilot LEED training, we found out that providing a shoe storage system at the entry doors would be an acceptable alternative to the permanent doormats. Thus, we chose to install a shoe storage area within a few feet of the main entry door. Finally, third-party testing for formaldehyde, particulates, and toxic volatile organic compounds (TVOCs) gains another LEED point.

CREDIT 9: Protecting the occupants from radon and other ground contaminants is another important IEQ matter. If a home is located in EPA Region 1, then the home must have a radon mitigation system installed. (See www.epa.gov/epahome/locate2.htm for a map of EPA's regions.) Homes not located in EPA region 1 can get a point for using radon resistant construction techniques. Our LEED home is not in Region 1, but we installed several measures to aid in removing ground contaminants. We used a perforated plastic form to cast our footings. The inside form stayed in place after the footing was poured; piping can be connected to it that exhausts to the outside of the building. The outside form can have piping connected to it also, integrating it with the exterior footing drain.

CREDIT 10: The last IEQ credit protects occupants from exposure to car emissions and other hazardous fumes in the garage. No air handling equipment, return ducts, or un-sealed supply ducts may be in the garage. Occupied rooms above the garage must have carbon monoxide detectors, and shared surfaces between the garage and conditioned spaces must be carefully sealed. One point can be gained by installing a 100 cfm exhaust fan that is controlled with an occupant sensor, light switch, or garage door opening/closing mechanism. A practical solution is to put the fan on a timer that turns off after 10 to 30 minutes. One easy way to get a point is to have no garage in contact with conditioned spaces, as we chose to do with our LEED home.

MATERIALS AND RESOURCES (MR)

One of the most controversial sections of the LEED for Homes program is MR credit 1, which deals with *home size.* This is the only LEED rating system wherein a project can actually acquire negative points. The rating system creates a proportional relationship between square footage and number of bedrooms, but only up to four bedrooms. For example, a project can gain up to ten points on a four bedroom home if it does not exceed 1,150 square feet. Conversely, a project can gain ten negative points for a home that has four bedrooms, but not more than 4,150 square feet. Above 4,150 square feet, there is no limit to the number of negative points that a home can accrue using the LEED-provided calculations. I agree that building smaller homes is good for the environment, but tying that concept to negative ratings based on number of bedrooms is troublesome—and bordering on being socially discriminatory.

This credit impacted our LEED home scoring more dramatically than we had originally anticipated. The 1st and 2nd story of our home has about 3,200 square feet, which would give us about four negative points. Additionally, our home has a basement and some attic space that we could convert to living space. Given the rolling terrain in our area, most homes commonly have basements. It is less common to have finished attic rooms on top of a two story house, but we chose this because of a historical architectural precedent. Our firm routinely employs very advanced HVAC and insulation technologies, which often include basements and attics within the thermal envelope. In our home, we determined that we would have to count these areas in our square footage because they were technically conditioned areas. LEED docked us 18 points, which felt like we were starting a basketball game 18 points in the hole, hurting our chances of pulling out a win!

I believe that the rating system committee needs to work on this category. I do not offer a perfect solution, but I do have some comments and suggestions:

First, the committee needs to recognize that some terrains nearly require the building of basement struc-

tures. I suggest that unfinished (not unheated) basement space *not* be included in the square footage calculation that applies to negative points, or that at least the negative points for this type of space should not be quite so brutal.

Second, the committee needs to recognize that advanced HVAC and insulation technologies lead many to conclude that these spaces can and should be heated whether or not the space is finished. According to our mechanical engineer, if we built the house to normal industry standards with less efficient windows and ineffective insulation techniques, our house would have had six to seven tons of HVAC equipment. Instead, our house ended up with about three and one-half tons, and we were still concerned that we were oversizing the equipment. Attics and basements that are included in the thermal envelope can actually lead to smaller HVAC systems and aid in the total efficiency of the home's energy consumption.

Another MR category deals with materially efficient framing techniques. LEED forbids the use of extra framing lumber for purely aesthetic reasons, such as double thick framed walls to create deep window sills. A project can gain partial points for spacing joists and studs greater than 16" on center, sizing headers for actual loads, designing roof systems with 24" modules, using ladder blocking/drywall clips, and using two-stud corners. Conventional techniques use about 15 to 20 percent more framing material than is needed structurally, but this can be avoided with proper planning. Our LEED project was able to gain the maximum points (2) in this category. We used concrete exterior wall construction, and we had a design that created very few interior walls and header loads. We also used drywall clips to avoid excessive blocking at the ceiling intersections.

"Local Sources" is an important MR concept; it promotes the use of materials that are extracted, processed, and manufactured within a 500-mile radius of the project's location. In the LEED for Homes rating system, there are no mandatory measures in this category, but there are numerous optional points that can be gained, up to a maximum of three. For our project, we easily found products such as stone, masonry, wood, metals, and other items produced in the region. For example, we got our concrete from a local company, our wood floors were reclaimed from an old building in southern Pennsylvania, and we reclaimed our outdoor paving stones from a local demolition project.

FIGURE 8. Reclaimed pavers and FSC certified cumaru decking.

The MR "Durability Plan" credit promotes increased service life of the building envelope and its components and systems through appropriate design, materials, and installation. The Durability Plan, drawn up before construction begins, consists of four stages:

1. pre-design
2. design
3. specification
4. installation

The Plan is primarily concerned with moisture management, and thus each project must identify its climate (dry, normal, or wet). Projects in the wet region can earn up to five points in this category, while the normal region and dry region can earn three points and one point respectively. Durability, energy efficiency, and indoor air quality are inextricably linked in high-performance homes; moisture that is not controlled and managed can lead to indoor environmental problems such as mold. Additionally, improved water management at the foundation, exterior walls, roof, and site protect the structure as well as keep water on-site to limit the burden on municipal infrastructures.

The *pre-design stage* of the Durability Plan involves four steps. The first step calls for developing a statement of the intended service life of the building. This begins with the structure's major assemblies, such as the foundation, exterior walls, roof, and components (insulation, wiring, plumbing, windows, and doors). It also includes a deliberate, thoughtful approach about claddings, finishes, and mechanical systems.

The second step requires the designer to collect site-specific environmental conditions data. This includes review of the site's slope, wind, soil, ground water, pest intensity, etc. It also includes historical meteorological data that includes temperature extremes, solar radiation, precipitation, and humidity. This step should include an evaluation of the likely exposure to natural disasters such as earthquakes, hurricanes, floods, tornadoes, and wildfires.

The third step is to set a range of internal environmental conditions and intensity of use to include temperature, relative humidity, range of full-time occupants, and prohibited activities.

Having completed steps two and three, step four requires the designer to prioritize damage factors that the structure is likely to face. This becomes the basis for a design strategy to identify appropriately the likely systems, components, and assemblies that should be incorporated into the design. Collecting and analyzing this site data allows the designer to implement site-specific strategies that optimize both the site and the house, creating a compromise between land and home, as well as customizing the house to the needs of the occupants within a set of environmentally sensitive parameters.

The *design phase* of the Durability Plan first identifies an overall management/protection strategy for each of the damage functions (drainage planes, air barriers, thermal barriers, etc.) that were identified in the pre-design phase. The design phase concludes with analyzing and selecting specific technologies and practices for each strategy. This leads to developing specific details for the construction drawings, confirming that each high durability risk and each critical goal previously identified has been addressed.

The *specification phase* for each Durability Plan includes detailed specifications for materials and detailed notations on construction drawings for all related components and systems.

The *installation phase* of the Durability Plan develops scopes of work for each trade subcontractor based on the drawings and details to ensure that subcontractors implement pre-work and post-work checklists, and the site supervisor signs off on each item on the checklists.

Projects that incorporate *environmentally preferable products* can gain MR credits. The only mandatory measure in this category is that all tropical hardwoods present in the project have Forest Stewardship Council (FSC) certification. Our LEED home included the use of cumaru decking on the porches. Cumaru is a very durable and hard wood, similar to ipe, that can last a very long time without any chemical treatments. When coated with an oil or clear sealer, it has a red mahogany look. We originally wanted to purchase FSC-certified ipe wood from local suppliers, but most local suppliers had no knowledge of FSC certification. We found a Delaware source for FSC ipe, and he introduced us to the cumaru wood, which we ended up using.

Optional MR points can be gained for using a variety of environmentally preferable products. The list of possible products is lengthy, but it includes low- or no-VOC products, recycled materials, FSC certified lumber products, etc. Our LEED project included carpet that is made of recycled soda bottles, reclaimed antique heart pine flooring, and reclaimed soapstone from another project. After going to great lengths to incorporate no-VOC paints, we were disappointed with the results. The paint coverage on the walls and ceilings was uneven and bubbly. We are not sure whether the paint or the painter was the source of our problem; though the painter was experienced, he had little experience with the low-VOC paint we used. In the interest of time, we resorted to regular paints to achieve a reasonable look, and we had to forsake a credit in this area. We have not given up on using no-VOC paints, but we need to do further research before using it again.

The last MR credit deals with *waste management.* The intent is to reward those projects with lower than average waste for construction projects, up to 2 points in the LEED rating system. No more than 2.5 pounds per square foot of conditioned floor area may be sent to a landfill or incinerator. To accomplish this, our project superintendent was instructed to recycle all cardboard, metals, and plastics. We also authorized him to use scrap wood for blocking and give larger scraps to those who wanted to use it for their own projects.

As of this writing, we have not totaled our waste, but, given our efforts, it should be reasonably low. For example, we did not use lumber in our exterior walls. The foam material in the ICF exterior walls is water-based and is very light; being a "snap together" system, there is far less waste than in stick framing. Another of our strategies was to grind up our leftover drywall material and to use it on the site by mixing it with our soil. Drywall is essentially lime, and when properly segregated and ground up, it enhances the soil. This is usually only done on larger sites, rather than residential-sized projects.

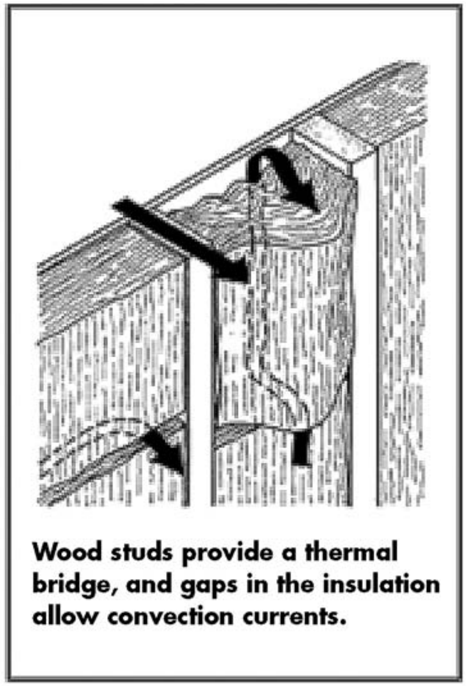
ENERGY AND ATMOSPHERE (EA)

The first EA credit is for improving the energy performance of the home by designing and building an ENERGY STAR® certified home. A qualified third party must inspect the home, and LEED points can only be gained for exceeding the minimum ENERGY STAR® ratings. The third-party rater will perform a blower door test (see Figure 4) for air leakage and will further test for duct leakage with a duct pressurizer; these tests form the basis for a project's Home Energy Rating System (HERS) score. Our project achieved a HERS score of 94 out of 100, and we were able to gain 16 points in this category for this very high score.

The builder and third-party rater must decide whether to use the HERS score as their EA credit (in which case they can skip EA credits 2–6 and 7.2) or pursue each EA credit individually. Depending upon the project, the rater will be able to determine which option will lead to the most points.

The EA *insulation* credit (EA 2) is for designing and installing insulation to minimize thermal bridging. It is mandatory to meet at least Grade II specifications (per National HERS) and to have this verified by the third-party rater, who performs a pre-drywall inspection; a project may pursue the stricter Grade I specifications for additional points. During the pre-drywall thermal bypass inspections, the third-party rater looks at the type and quality of insulation behind tubs, between floors, between conditioned and unconditioned spaces, at attic knee walls, and many other areas that builders and insulators often overlook. Essentially, a project must demonstrate that it greatly exceeds normal code requirements for insulation—both for materials and for installation.

FIGURE 9. Diagram of thermal bridging in a stud wall. (http://oee.nrcan.gc.ca)



We built our LEED home with insulated concrete forms (ICFs) which provided an R-22 rating *plus* 6–10" of concrete thermal mass. The ICF system is superior to stick construction in its insulation properties for many reasons: it forms a better seal against air infiltration, it is more structurally stable, and it achieves a much higher *actual* R-value. ICFs also minimize thermal bridging—a thermal bridge is an area within a wall that conducts heat at a much higher rate than the surrounding areas. Framing members in stick construction often act as thermal bridges, conducting away hard-earned heated and conditioned air. An ICF has no thermal bridges, and thus no ways for conduction to occur through the wall.

The EA credit for *air infiltration* (EA 3) attempts to minimize unnecessary energy consumption owing to air leakage between conditioned and non-conditioned spaces. The results of the blower-door tests determine how much outside air needs to be introduced into the building to achieve a balance between a healthy indoor environment and low energy consumption. A third-party rater must verify that the air leakage rate from the envelope is equal to or less than .35 ACH (air changes per hour). One optional point can be gained for an air leakage rate equal to or less than .25 ACH, or two points can be gained for a rate equal to or less than .15 ACH. We were able to gain two points, as our LEED project was tested at .08 ACH.

The intent of the EA credit for *windows* (EA 4) is to optimize the energy performance of windows. The minimum requirement is installation of ENERGY STAR®-labeled windows. A project can earn an additional point for installing windows that exceed this requirement by 10%; two points can be gained for exceeding it by 20%. Our LEED home included windows that exceeded the 20% requirement. The ENERGY STAR® rating system has different requirements for various regions of the country, and it is necessary to match windows to a specific region—a great window in one part of the country may not be adequate in another region.

Duct tightness (EA 5) is another important EA credit area. Leaking ducts that pass through hot or cold attics account for a huge energy loss; many homes' ducts leak 15–20%. Thus, LEED requires that a third-party rater verify that the air leakage rate is equal to or less than 5.0 cfm at 25 pascals per 100 square feet of conditioned floor area for each installed system. One optional point can be gained by getting it down to 3.0 cfm, and two points can be gained for getting it down to 1.0 cfm. In our LEED home, and in many of our other projects, we put the ductwork within the building envelope; then, if a duct were to leak, it would leak into the conditioned space rather than "outside." In this house, we installed closed-cell (rigid) foam insulation underneath the roof sheathing, and we did not vent our attic.

The intent of the *space heating and cooling credit* (EA 6) is to optimize the energy performance of HVAC equipment. Mandatory measures require the builder to design (with Manual J) and install ENERGY STAR®-certified HVAC. It also requires that the builder install a programmable thermostat and provide proof of proper refrigerant in the system. If a system exceeds ENERGY STAR® requirements by 10% this can gain two additional points, if it exceeds by 20 %, this earns three points.

Our LEED project needed $3^1/_2$ tons of HVAC equipment, and this total load was split between two systems to accommodate our floor plan. We were willing to purchase high SEER equipment, up to the 16 SEER range, but it was very difficult to find properly sized equipment. Most HVAC manufacturers do not make their smaller units in the highest SEER ratings, as the industry implements changes in its most popular (i.e., larger) sizes first. Despite our willingness to purchase the best equipment, we had to settle for equipment with slightly lower SEER ratings. If we want to get these credits in a future project, we will first attempt to design a single system with extended duct chases in our two-story structures. This may enable us to buy "normal" size units and to take advantage of the highest available SEER ratings, as well as to install "zoned" systems (one system with thermostats on both levels) that have modulated damper systems. In this case, we had to settle for the 10% increase over ENERGY STAR® even when we were willing to do better.

The EA credit for *water heating* (EA 7) attempts to optimize the energy performance of the water heating system. There are no mandatory measures for this category. The first optional measure encourages design and installation of an energy-efficient water distribution system. The rating system details three possibilities. One is a recirculation pump system with insulated hot water lines, the second is a central manifold distribution system with insulated lines, and the third involves strategic location of the heater within 20 feet of any fixture. The second optional measure is to design and install energy-efficient water heating equipment. There are several pieces of equipment that are available for a variety of points. For our LEED project, we decided to install a propane tankless water heater. Our unit will use about a third of the propane that a traditional propane water heater uses.

The EA *lighting* credit (EA 8) is intended to reduce the electric load owing to lighting. There are no mandatory measures for this category. One of the optional measures, worth one point, is to install motion detectors on all outdoor light fixtures and to include at least four photovoltaic exterior light fixtures, if exterior fixtures are installed. Another point can be gained for installing at least four ENERGY STAR® labeled light fixtures; an additional point can be gained for installing compact fluorescent lamps (CFLs) in at least 80% of the light fixtures.

Alternatively, a project can gain three points by installing an ENERGY STAR® Advanced Lighting Package (ALP). The ALP requires that a high percentage of the fixtures be ENERGY STAR® qualified models. The program distinguishes among high-use, medium/low-use areas, and outdoor lighting. For our project, we considered pursuing the ALP credits, but we were discouraged by the small range of fixtures that were available. Ultimately, we chose to take two of the possible three points by installing several interior ENERGY STAR® fixtures and by installing CFLs in more than 80% of our fixtures.

The *appliances* (EA 9) category has no mandatory requirements. In our LEED home, we elected to install an ENERGY STAR® labeled refrigerator, ceiling fans, dishwasher, and clothes washer; these machines use between 10 and 20 percent less than conventional machines. Even though LEED grants a half point for using an ENERGY STAR® clothes washer, it gives a whole point for using a very-efficient clothes washer. These typically have very low electric consumption and 50% less water usage than conventional models. Usually, the new front-load machines are the only ones that can meet this requirement.

The *renewable energy credit* (EA 10) encourages the reduction of non-renewable energy sources by installing a renewable electric generation system. There are no mandatory measures for this credit. Our LEED home did not include any system of this kind, but we are purchasing electricity from green sources through our local electric provider. Currently, we are investigating a photovoltaic system that fits well on our standing seam metal roof. This system does not require any significant modification to the roof or the underlying structure. Additionally, we are considering a twelve-month wind study to determine if there is enough wind on the site to justify a minor venture into wind generated power. James Madison University, in Harrisonburg, Virginia, has a program to lend anemometers to consumers around the state. In some cases, participation in this program has resulted in minor grants to state residents to help underwrite the cost of wind generation equipment. However, low electrical usage has been much easier to meet by using high efficiency lighting, appliances, HVAC equipment, and advanced insulation techniques. For all of our projects, we will continue to investigate renewable energy sources and seek to include them whenever and wherever possible.

The final EA credit is for *residential refrigerant management* (EA 11). There are no mandatory measures. This credit encourages the selection of refrigerants that reduce ozone depletion and do not contribute to global warming. One optional measure is simple: do not use refrigerants, and a project gains one point. For those projects using a cooling system, an optional point exists for simply using non-CFC refrigerants (commonly known as R410A) in HVAC equipment.

HOMEOWNER AWARENESS (HA)

There is only one credit in the HA section, called *Homeowner Education.* This credit makes sure that the homeowner is educated about the operations and maintenance of the equipment and features in his or her residence. Mandatory measures include providing the owner with a binder; this binder should include a copy of the LEED for Homes rating certificate, a completed checklist, manufacturer's manuals, general information on efficiency and water issues, guidance documents on occupant activities (related to watering of landscape, impact of fertilizers and pesticides, lighting issues, and appliances), and educational information on Green Power. The second mandatory measure is to provide a minimum 60-minute walkthrough of the home to identify equipment and operation and maintenance issues. LEED grants an optional point for providing a more in-depth training for the homeowner, including three additional one-hour training sessions *during* the construction process.

INNOVATION AND DESIGN PROCESS (ID)

There are no mandatory ID credits, but the intent of the credit is to provide the opportunity to gain up to four points for incorporating measures beyond those contained in the LEED for Homes rating system. Originally, we were not seeking any ID credits for our project, but we learned that we could gain points in categories we had already maximized. For example, we could only gain two points in SS 5, but we met several more optional measures based on our construction details, which allows us to apply for an ID credit.

We are also seeking an additional ID point for WE 1 for our water recovery system. Our system collects

100% of our rainwater, twice the amount required under the rating system. Our last ID point will be for obtaining a lower air changes per hour (ACH) test result than the rating system calls for. The rating system gave us the maximum score of two points for getting down to less than .015 air changes per hour (ACH). Two different tests, however, showed that our project was less than .01 ACH. With such a tight home, it will be critical to make sure that the fresh air intake settings are generous enough to provide the occupants with enough oxygen-rich air.

CONCLUSION

Being a part of the LEED for Homes pilot program has been very exciting. It clearly distinguishes our firm's commitment and willingness to step out from the normal home builder and to "raise the bar" on our projects' performance. The U.S. Green Building Council brings considerable credibility to green performance standards that many builders are quick to claim, but few are delivering. I have attended several meetings and training sessions for this program, and I appreciate the fact that the USGBC leadership is open and willing to listen to builders' comments and criticism. The rating system is already undergoing some revisions, and I believe the pilot will come to a successful conclusion as long as the leadership remains open to ideas from the industry.

There are several challenges that LEED program leaders need to focus on to keep the program viable. First, the program leadership needs to find ways to keep the cost of certification low. One of the greatest strengths of the certification process is the third-party testing concept, but this testing has costs associated with it that fall either to the homeowner or to the builder. Over time, the certification cost per unit should come down if there are many local providers.

Second, program leaders need to find ways to keep the rating system simple to understand and implement. LEED's "two page checklist" is a summary representation of a rather complex rating system that is over 100 pages long. Only those who are truly committed will have the patience to work through the first home or two and learn the real "guts" of the program. The negative effect of a 100+ page program is that it may be too complicated for many to learn and to adopt.

For a builder who is seriously considering embarking on the LEED certification process, he or she will be successful if three basic concepts are followed:

1. ***Become a student again.*** Really take the time to understand how the envelope of your building works. Start with the low-tech concepts first, such as site orientation and external shading. Learn about different wall systems, window performance, and air infiltration. Above all, do not believe that you know it all. Be open-minded.
2. ***Align your company with the very best HVAC subcontractors.*** This does not necessarily mean that you are hiring the most expensive, but the best will likely cost a little more. The "very best" will be those who are knowledgeable enough to understand and implement the HVAC portions of the ENERGY STAR® program. Ultimately, the builder is responsible for the performance of the whole building, but the builder will rely heavily on the HVAC contractor to design and implement the HVAC system. If your house fails the ENERGY STAR® tests, the failure will likely be in the envelope or in the HVAC system. Since testing occurs near the end of the project, there is no inexpensive fix. Passing ENERGY STAR® is not possible without great HVAC subs.
3. ***Be willing to change some management practices.*** This is not that complicated for those who are committed to doing a good job with green building practices. Management personnel will need to understand and be committed to the rating system to exercise more control over your site work, waste management, recycling efforts, some accounting practices (for verification purposes), and other concepts.

Green building is not some kind of fad sales program. It is too complicated to adopt and implement for a short-term profit cycle; it is long-term fare. Green building is absolutely the wave of the future and consumers are already demanding it of the building industry. Our firm is constantly in demand for our green building services, and we have found it viable and profitable for our business. Builders who take the time to internalize the concepts will truly be building very high-performance homes while minimizing environmental impact. This is a win-win for builders, designers, and consumers. I believe that the LEED for Homes program has the most credibility of any green building program available at this time owing to its association with the rapidly growing USGBC and the other LEED programs. Environmentally conscious builders should be leading the way—it is our responsibility to our industry and our world.

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