CHAPTER 2

What Is a Green Home?

We've explored why people are building and buying green homes. But what exactly do we mean by the term "green home?" Reading the first chapter, you might surmise that there are many possible definitions, depending on what features a builder includes in a home and what rating or certification system a builder uses. There are no "Consumer Reports" or "J. D. Power" ratings for green homes, as there are for cars, home appliances and so many other consumer products, so to some degree you're on your own in looking for a green home.

Sam Rashkin, head of the ENERGY STAR for Homes program of the US Environmental Protection Agency, says his simple rule for homebuyers is: "First blue, then green."[1] Blue is the ENERGY STAR logo's color, so what he means is that your home should first of all be at least 15 percent more energy-efficient than a standard home. Then you should add the other green features described in this chapter, such as water conservation, better ventilation and healthy finishes. So, as a homebuyer, your first question for the builder should be: "How energy-efficient is this home and who vouches for that?"

I wholeheartedly agree. Not only does Rashkin's rule save you money in the long run, but it also helps reduce your carbon footprint by reducing the amount of coal, oil or gas that needs to be burned to provide your home's energy needs. (Remember the electricity production and distribution

Figure 2.1. Six elements of a green home.

system is less than 30 percent efficient from start to finish, so for every unit of electricity you don't use at the home, you're saving three-plus units at the source.) Moreover, once the home is built, it's very hard, and often expensive, to change its basic energy demand for heating, cooling and hot water, since most of these features are built into the home's structure and core energy-conversion systems. Your new home will probably last 50 years or more and its "embedded" energy use will remain for most of that period, with all the impacts on the environment that come with energy production.

Key Features of a Green Home

Figure 2.1 shows the elements that most people consider when they talk about buying a green home.

Sustainable Site Development/Location and Linkages

- Avoiding development on inappropriate sites such as prime farmland, flood plains and near wetlands
- Orienting the lots so that you can get warm sunlight in the home in the winter and keep it out during the summer (good lot orientation can save you 10 percent or more of your home's energy use)
- Locating sites near transit and neighborhood amenities, so that you don't have to get in a car to get a quart of milk or travel to work
- Treating stormwater on or near the development, so that less contaminated runoff goes in local streams or, eventually, the ocean or nearby lakes
- Designing roads and other hard surfaces to absorb less sunlight, reducing the temperature of the local microclimate, so there's less need for air conditioning.

Water Conservation

- Using native and locally adapted plants that require less water to thrive
- Using efficient drip irrigation or high-efficiency irrigation for public spaces (remember more than half the water used by a single-family home is typically for irrigation)
- Installing more efficient water-using features in the home, such as dual-flush toilets, low-flow faucet aerators and "home runs" or recirculation loops for hot water distribution (this means you won't run the water so long before you get hot water at the faucet)
- Installing water-efficient appliances such as dishwashers and clothes washers with an EPA WaterSense™ certification.

Energy Conservation

- Passive design measures, including overhangs over south and west-facing windows and deciduous vegetation on the south and west sides, that will shade the home in summer while still allowing light — and heat — in during the winter
- An ENERGY STAR home rating, assuring you that your home will use at least 15 percent less energy than a typical home in the area, operated in a similar fashion
- To achieve the ENERGY STAR home rating, expect increased insulation and better insulated windows, along with a host of smaller measures grounded in "building science" (more about this later in this chapter)
- ENERGY STAR home appliances (as you saw in chapter 1, a minority of your energy use comes from heating and cooling)
- A well-insulated, efficient water heater or tankless water heater (water heating can account for 25 percent of your total home energy use)
- Easily programmable thermostat, so that you can set back temperatures at night and let the home cool off or heat up (depending on the season) when you're away at work
- Efficient lighting fixtures, including compact fluorescent bulbs (CFLs) throughout the home, especially in those areas you're likely to be using a lot, such as living room, kitchen, study and bedrooms. Outdoor lighting should also rely on CFLs (there are special types that can take the cold)
- In colder climates, look for a "heat (or energy) recovery ventilation" system that will use the heat in the exhaust air to preheat the colder incoming air, saving you energy

- Solar power systems to provide 10 percent to 20 percent (or more) of your annual electricity needs
- Solar water heaters to provide 50 percent or more of annual hot water needs.

Materials and Resource Conservation

- Your homebuilder should be recycling 50 percent or more of construction waste
- Your home should contain recycled content materials wherever possi-

Energy Conservation at DR Horton, Sacramento (CA) Division

We interviewed Rich Coyle of DR Horton in Sacramento about the company's program. He says:

> Green building has been an evolution. Here in Sacramento, we have embraced energy-efficient homes since 2001. We looked at energy-efficient, sustainable houses as our niche in our marketplace. We started offering homes that offer guarantees on heating and cooling [costs]. At that same time we started a Building America project designed to reach Environments for Living (EFL) Platinum levels. Now for every new project, we offer the guarantee. We do at least the Gold Plus level for Environments for Living which is about 15 percent better than [California's Title 24 Energy] code. All of our projects are ENERGY STAR rated.
>
> A few years ago we started to offer solar as an option, and now we're starting a project where solar is standard — we're working to rate that project as LEED for Homes Silver.
>
> We've tried to do things that make sense for a production builder. That's been our progression. We've probably built over 5,000 homes that have energy [usage] guaranteed with them. Last year [2006] we built 1,100 alone. This year [2007] it will also be about 1,100 homes. All of our homes are guaranteed by Environments for Living (EFL). There are different levels of energy efficiency in the EFL program, with the minimum being "Gold Plus" level. We guarantee the maximum amount of heating therms and cooling kilowatt-hours that will be used by the homes for a three-year period. We also have a guarantee that the center of the room will not vary by more than three degrees from the thermostat temperature.

ble, but these must have the same quality, durability and aesthetic appeal as the rest of the home

- You might consider upgrading to cabinets using wood from sustainably harvested forests
- Similarly, you might want to look at flooring made from rapidly renewable materials such as cork, bamboo and linoleum, again with full consideration of aesthetics, durability and quality (materials from the local region may be more sustainable because of reduced transportation energy use).

We were finding it's hard to get the word out to buyers about our green offerings. It's important to educate the buyers because they are comparing builder A and builder C to DR Horton. Even though a green home may cost a little more, we need to let them know that in the long run, buyers are going to come out ahead because they are going to save money on their energy bills.[2]

Keith Sutter, courtesy of DR Horton, Sacramento Division

Figure 2.2. Equipped with solar electric systems and other energy-efficient features, each home in DR Horton's Provence community in Sacramento will reduce CO_2 emissions by 4,700 pounds a year, the equivalent of not consuming 244 gallons of gasoline.

Indoor Environmental Quality

- Look for a home with the ENERGY STAR indoor-air-quality package that will assure you of a healthier home with superior ventilation (the trick of course is to have good ventilation without increasing energy use for heating and cooling incoming air)
- Your home should be made with low-toxicity finishes, especially paints and carpets, so that there is no "new home" smell when you move in, which consists of the off-gassing of potentially harmful contaminants
- Look for cabinets and other finishing touches made without urea-formaldehyde resins (go into any furniture store and smell the furniture: you can tell if it is off-gassing formaldehyde)
- Look for a quiet, efficient bathroom fan, to keep mold out of the bathroom; this will ventilate adjacent spaces as well

Indoor Air Quality in North Texas Homes

We interviewed Steve Hayes, division president for McGuyer Homebuilders, Inc., Dallas. He says:

> We have a fresh-air intake on all of our air conditioners. It's mechanically controlled and computer-operated to make sure that a certain amount of fresh air comes in throughout the entire year. It's not a hand-controlled damper system [that might not allow enough fresh air into the home]. Indoor air quality, according to the [federal] EPA, is one of the top five health concerns in the nation right now. The air inside of the home a lot of the time is worse than the air outside the home, because of the furnace, cooking oils burning and different things that go on when someone lives in a home. That air becomes very stale, and there's a lot of moisture in the air. The fresh-air intake at the air conditioning unit allows for the circulation of new fresh air into that home and circulates the old, stale air back out of the home. Having fresh air for the family living inside the home is very important. We also do a four-inch media filter on all our air conditioning units. Our air conditioning company gave us an interesting analogy: the normal one-inch air filter, which you see at the return air grill [in most homes], is designed to catch the softballs, baseballs and golf balls. The four-inch media filters are designed to catch grains of sand. It's made to filter fine particles out of the air coming into the house, compared to the one-inch typical filter which is simply designed to keep large dust particles out of the A/C unit.[3]

- Good daylighting without glare is the hallmark of a green home; this can come from large windows (with overhangs), clerestory windows in a cathedral ceiling, north-facing skylights, light tubes and other means. Good daylighting allows you to do many of your daily tasks without turning on the lights.

Most good green-home rating systems incorporate each of these five features, even though they might give them different emphasis. Some green-home rating and certification systems, such as the US Green Building Council's (USGBC) Leadership in Energy and Environmental Design (LEED), have prerequisites in each category, while others, such as the National Association of Homebuilders (NAHB) Model Green Home Guidelines, require builders to achieve a minimum score in each category. Most good green-home rating systems require onsite inspection and testing of at least leaks in the home (this is done by pressurizing the home with a "blower door" and seeing how much air leaks out) and in the ventilation ductwork (in this case, the home rater pressurizes the ducts and measures leakage). We'll talk more about the requirements and merits of various rating and certification systems in chapter 5.

Sometimes homebuilders and homebuyers have different views about what's important in a green home beyond energy conservation measures. For example, Richard Barna of Pepper Viner Homes, a builder at the Civano green community in Tucson, Arizona, says:

> Civano is a unique community. A lot of people that are looking here are looking for something that's green and energy-efficient. ENERGY STAR is a good starting point. If the home isn't meeting that level then you should ask, why not? It can be done.
>
> When we started this project we asked "What is quality?" We wanted to build a higher-quality house than the average builder. Everybody uses the same subcontractors; they all use the same sheetrock, etc. So we thought that if we could design a house that works better than the average house and you can document it and prove it by third-party testing, then there's no more debate about quality.
>
> We're also working with Building America, which is the US Department of Energy's program to make production housing more energy-efficient. They help us and suggest things that we can be doing to improve our methods. There are labels now for greenbuilding programs, and if somebody is just saying "ours is green" but they don't have anything to back it up, it probably isn't green.

> We thought that if we built a house that was super-energy-efficient, it should have just a tiny increase in cost. You wouldn't even notice the price difference from what we sold before to now. It really didn't cost us that much to do it. It took a lot of effort and a lot of time, but some things that you do [to meet that standard] actually save you money. Plus there are government tax credits for the builder. Our goal is to build an energy-efficient house so people don't have that decision to make: Would I pay a whole bunch more? The goal would be to get it for the exact same price that they were paying anyway and get a house that's worth a lot more. Some of our houses are saving 50 to 54 percent on heating and cooling costs — that's pretty major savings. That meets the federal EPACT 2005 standard, and it doesn't cost all that much to get there.
>
> We've been a design-oriented company, but now we're positioning ourselves both as a high-performance and a high-design company. This has taken a change in the mindset of our company. We decided that our whole company culture had to reflect a green approach. We decided that it wasn't mandatory to build simple little boxes. There's a stereotype about that with super-energy-efficient homes, because people think that you probably don't have a lot of design features in it.[4]

Jeff Baxter bought a home at the Noisette Company's Oak Terrace Preserve subdivision in North Charleston, South Carolina. He says:

> There are about 20 houses built or being built in this neighborhood [this year]. Ultimately there will be 300 single-family homes and about 60 or 70 townhomes. The community itself has a New Urbanism premise, so there are alley-fed houses [garages at the back of the property]. From a community standpoint, they are encouraging activity on the street-front as opposed to having a garage for your front door. It's also very dense housing. The average lot is 4,000 to 5,000 square feet which is small — it equates to eight to 10 homes per net acre.
>
> Community-wide, you have to use native plants or plants that don't require special irrigation needs for landscaping. So sod and turf grass are discouraged; you can only have a certain percentage of turf grass. The stormwater system is a low-impact design. Ideally 95 percent of the rainfall is dealt with onsite through a system of bioswales and rain gardens, as opposed to having it run off the site as quickly as possible into pipes and channeling it out to the river.

Photo courtesy of Oak Terrace Preserve

Figure 2.3. Each home in the Oak Terrace Preserve community is built and certified according to stringent green building standards in healthy, efficient, durable and comfortable residential design. The entire community was developed according to traditional neighborhood design; homes have front porches and are within easy walking or bicycling distance to schools, retail establishments and recreational areas.

> This builder specializes in "back-to-the-basics," proven methods to build a good house that's more energy-efficient. They don't push things like photovoltaics and real unusual features or things that add cost. It's great to have an efficient air conditioning system, but if the envelope of your house isn't up to par, then it's still inefficient. They look at it as a whole-house concept. They're using a smaller air conditioning system because they have a really tight envelope with high R-value insulation. Their goal is to compete at the same price point as a normal house but deliver one that is more durable and saves you money on your energy bill.
>
> I would have been willing to pay more for the house because of the green features. I would associate a premium to it, and I'm willing to pay a premium for something that is well designed, is going to hold up and that I have confidence in. The price point was competitive with a regular house that does not include those features.[5]

Building Science Basics

"Building science," a term that's coming into vogue as home energy efficiency becomes more important, means using sound scientific and engineering principles in home design to achieve lower energy use, more comfort, healthier indoor air quality and fewer moisture-related problems such as mold. Building science has also developed "advanced framing techniques" that reduce the use of building materials, especially wood, while still achieving a strong, energy-efficient home. Over the past 20 years, through the federal government's Building America program, scientists and engineers have built up an impressive array of tools and techniques that many progressive builders have begun to adopt. This collection of homebuilding "best practices," known as "building science," is all about the control of temperature, air movement, moisture and radiation (in areas with radon gas in the ground).

A house is an interactive system of many different parts. Change any part, and you impact the whole — favorably or unfavorably. That's a key premise behind building science. A growing number of residential builders are looking to the answers of building science to assist them in constructing better homes.

Building science is based on seven key phenomena, easily recognizable to anyone who's taken high-school science:

1. Heat flows from hot to cold. (A warm house wants to lose heat in winter and a cool house wants to gain heat in summer.)
2. It takes energy to maintain a constant temperature in the home and to move air around, because heat is always being lost or gained. (Even a "net-zero-energy" home requires input from solar power or other renewable sources.)
3. Warmer air rises and cooler air falls. (This leads to convection currents — drafts — caused by cold windows and warm rooms.)
4. Air moves from higher to lower pressure. (Air ducts not well sealed will leak conditioned air into unconditioned spaces; if the leak is large, air may not get to all the rooms of the house. Also, if the wind is blowing, the outside air can be higher or lower pressure than the home, depending on wind direction, so both infiltration and exfiltration may occur — unwanted air coming in on the high-pressure side and conditioned air leaking out on the low-pressure side.)
5. Moisture flows from higher to lower concentrations. (If it's moist outside and dry inside, moisture wants to enter the house.)
6. Moisture condenses on a cool or cold surface, when there's enough humidity in the air. (If outside humid air gets through a vapor barrier to an air conditioned wall, it will condense and stay there, potentially causing mold.)

7. Gravity pulls everything down, so water that gets through the cladding of the home has to be taken out at the bottom of the wall. (Anyone over 50 will see this principle at work daily in the bathroom mirror!)

One of North America's leading experts in building science, Dr. Joe Lstiburek of Building Science Corporation, says:

> Controlling rain intrusion is the single most important factor in the design and construction of durable buildings and in the control of mold. Drainage planes (water-resistant barriers such as DuPont's Tyvek®) located inside the exterior cladding of a home (stucco, brick, etc.) are used in the design and construction of building enclosures to control rain and direct it down and away from the house.[6]

Building science calls for home designs that are regionally specific. The US Department of Energy has identified eight main climatic regions in the US and Canada.[7] Each one calls for different approaches to heating, cooling, moisture control and human comfort:

1. **Hot-humid** (East Texas through the lower Southeast) — more than 20 inches of rain and more than 3,000 hours with a wet-bulb temperature above 67°F. (This means that the air is warmer than that temperature.)
2. **Mixed-humid** (the upper Southeast, plus Oklahoma, Kansas, Missouri, the Ohio Valley, parts of Illinois and Indiana, plus southern New Jersey and southeastern Pennsylvania) — more than 20 inches of rain, less than 5,400 heating degree-days and average monthly winter temperature below 45°F. (See Glossary, after chapter 11, for definition of degree-day.)
3. **Hot-dry** (West Texas, southern Arizona and the California Central Valley) — less than 20 inches of rain and average monthly outdoor temperatures (even in winter) above 45°F.
4. **Mixed-dry** (Las Vegas, southern New Mexico and the Texas Panhandle) — less than 20 inches of rain, less than 5,400 heating degree-days and average winter monthly outdoor temperature below 45°F for one or more months.
5. **Marine** (West coast from San Diego to Vancouver and Victoria, BC) — a summer dry season, at least four months with average temperatures above 50°F, plus a warmest month average below 72°F, and with an average temperature of the coldest month between 27°F and 65°F.

6. **Cold** (as you might guess, everything else in the US up through western BC and southeastern Alaska, including southern Ontario and the Canadian Maritimes) — 5,400 to 9,000 heating degree-days.
7. **Very cold** (Most of the rest of populated Canada and Alaska, plus pieces of northern Minnesota, Wisconsin and North Dakota) — 9,000 to 12,600 heating degree-days
8. **Subarctic/Arctic** (interior and northern Alaska, Nunavut and caribou country) — more than 12,600 heating degree-days.

Heating degree-days are measured from a 65°F base and determine the amount of heating energy you'll need for the home. For example, a day with an average temperature of 45°F will represent a 20 heating degree-day. Add that up for a 30-day month and you get 600 heating degree-days. If the monthly average were 30 degrees Fahrenheit instead, there would 1,050 heating degree days. The key point here is that sizing of heating and cooling equipment and approaches to moisture management are going to vary greatly depending on where you live, so that there are no "one size fits all" design approaches. This means that if you're moving from one region to another, don't be surprised if some of the building practices are markedly different; there's usually a good reason.

The essence of building science can be summed up in ten core principles. Some of these elements are shown in Figure 2.4, for a home in the hot-humid region.

1. Design a comfortable home that uses as little energy as possible. (Sounds easy, but it's not!)
2. Build a tight building envelope (something we heard about from Richard Barna), so that all ventilation air goes through the air filtration system (except when you purposefully open the windows or doors).
3. Ventilate adequately and purposefully, so that the home is always getting fresh air and is not losing conditioned air inadvertently.
4. Use more insulation than standard practice to make sure that the home is more like a thermos bottle than a glass carafe, as shown in Figure 2.5.
5. Control moisture, so that it doesn't hide in the walls, foundations and other places of the home, where it will eventually wear away the building materials. In this way, the home is more sustainable because it's more durable.
6. Make sure that all homes are oriented so that there is a south-facing roof slope that can accommodate solar panels, without being shaded, either now or in the future. (This could also be a garage roof.)

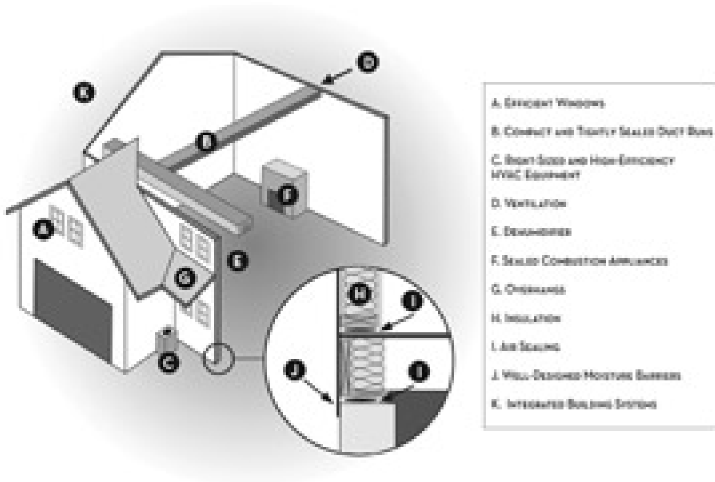

Figure 2.4. Elements of building science. *Adapted from US Department of Energy's Building America Best Practice Series, Volume 1*

7. Use the most efficient heating, cooling and hot water systems properly sized for the job. In most cases, the HVAC system is 20 percent to 40 percent oversized, which adds cost and results in less efficient operation. (See Figure 2.6)
8. Use efficient lighting and appliances matched to actual needs. Since such equipment can use more than 25 percent of a home's total energy, this is very important. For example, more task lighting and less ambient (overhead) lighting would be a better match to actual needs in most homes and would reduce energy use.
9. Reduce home energy use 40 percent to 70 percent (compared with conventional homes) before adding solar power systems for electricity and hot water.
10. Make sure all systems are working properly according to design intent (a process called "building commissioning" using a

Figure 2.5. The well-insulated thermos bottle will keep liquids hot for a long time, while the uninsulated carafe always needs supplemental heat to stay warm.

third-party — independent — inspector) before the eventual owners move into the home.[8]

Figure 2.6 shows how these principles might be applied by a builder to get a home that could save almost 10,000 kilowatt-hours yearly in North Carolina.

From this example, you can see that following simple building science principles allows a homeowner to save almost $900 per year on energy costs (assuming electricity costs $0.09 per kWh) AND a homebuilder to save considerable money by installing an electric heat pump that's just half the conventional size! Since the only extra costs are for higher-efficiency insulation and windows, the builder's *net* extra costs are about zero, but the

Figure 2.6. Reducing HVAC size with energy-efficiency upgrades (2,000 square foot home in Raleigh, North Carolina)

	Conventional Construction	**With Energy-efficiency Upgrades**
Wall insulation level	R-11	R-19
Ceiling insulation level	R-19	R-38
Window glass	Single-pane	Double-pane with low-e coating
Window overhangs	One foot	Two feet
Duct leakage	Average, with ducts in unconditioned space	None, with ducts inside conditioned space
House air leakage[1]	8 air changes per day	6 air changes per day
Manual J design heating load	46,100 BTU/hour	21,300 BTU/hour
Manual J design cooling load	52,100 BTU/hour	23,300 BTU/hour
Electric heat pump size	4.0 to 5.0 ton	2.0 ton
Annual heating energy usage	12,641 kWh	4,677 kWh
Heating savings[2]	—	$717
Annual cooling energy usage	3,808 kWh	1,790 kWh
Cooling savings	—	$182
Total annual energy savings	—	$899

1. Measured by blower door test, at 50 Pascal pressure.
2. At $0.09 per kWh.
US Department of Energy, "Right Sizing Heating and Cooling Equipment," eere.energy.gov/buildings/info/documents/pdfs/31318.pdf, accessed January 5, 2008

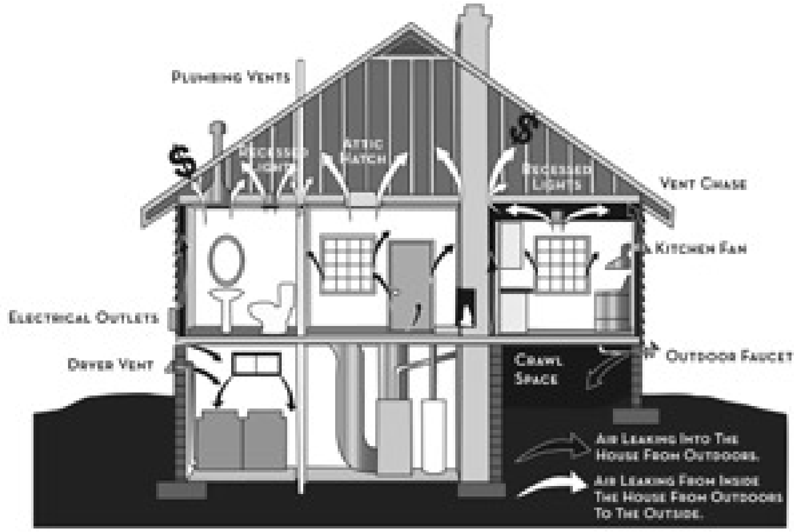

Figure 2.7. In typical homes, energy loss can occur because of holes and penetrations for plumbing, wiring, lighting and ductwork. *Adapted from ENERGY STAR*

sales benefit should be considerable. You can estimate the value of your potential savings from similar measures by consulting Figure 2.8.

What's Wrong with Typical New Homes?

The first five building science principles are the most important, according to building science experts we interviewed for this book. The first problem in single-family housing design is locating the mechanical (heating, cooling and ventilation) equipment in a vented space that is unconditioned. It's just a bad idea to put equipment and ducts in a vented crawlspace — things like furnaces and boilers and air handlers.

The same is true with attics; there are many houses built today — the majority of production homes — that have their air handlers and ductwork in vented attics. Even in a cold climate, in a larger house with a basement, you might find two systems — one in the basement and one in the attic, where the basement isn't vented but the attic is.

According to the experts, all crawl spaces and attics should be conditioned spaces, meaning they should be properly insulated. Why is this one issue so important? A building could lose up to 30 percent of its energy due to air leakage associated with having vented attics and vented crawl spaces. That includes energy loss from duct leakage, air-handler leakage and openings between the ceiling and the attic, as well as those between the floor and the crawl space. Because of plumbing, wiring and vents, we have openings in floors and ceilings to connect everything and those make the entire house leaky.

The second big problem results from the fact that a house is a six-sided cube, and there are often big holes somewhere because of the way that it was built or designed. For example, there can be bathtubs on outside walls where the bathtub was put in place before the sheetrock was put in, and as a result, the connection of the tub lip to the interior drywall isn't tight. Air will leak out of the house because the closure wasn't finished behind the wall of the tub or shower enclosure. In another situation, there might be kitchen cabinets on an outside wall, and the builder installed the soffit above the cabinets before the drywall, creating a place that's open to the outside forever. In another case, there might be a porch roof where, for whatever reason, the sheathing didn't go continuously. There could be a lot of big holes that result in air leakage that you can't see when you're ready to buy your house.

How can you know if you have any of those problems? Make sure you buy a home that's had a blower door test, so you can determine the air tightness of the home. There are hundreds of RESNET (home energy raters) around the country who do these tests. The homebuyer should ask the builder for the blower door test results and look at the numbers to see that they meet a standard of air tightness, such as no more than 0.35 air changes per hour.

Another common situation results from ineffective (read "cheap") exhaust fans in the bathrooms. There are good, quiet fans today that are energy efficient and pull out air very well. When you're looking at buying a home, go in and switch on the fan in the bathroom. If it makes a lot of noise, it's probably not working very well. You can also do a simple "tissue test": Take a piece of tissue and see if it will actually stick to the fan grill; if it doesn't, there is a problem, because the purpose of the fan is to take the moisture out of the bathroom. If it can't hold up a tissue, it's not going to get rid of moisture very well.

Believe it or not, some bathroom fans may not exhaust directly outdoors. Buyers should see if they can follow the duct from the fan up through the roof. Otherwise, the fan will be depositing moist air into the attic where it could lead to mold or mildew problems. To avoid building up moisture, you have to have air changes in the house. Without getting moisture out of the attic, especially if it is a sealed (conditioned) attic, you could be creating indoor air quality problems. What's the point of having an energy-efficient house with poor indoor air quality?

Make sure that you or your home inspector gets up into the attic and see where the ducts go. You or the inspector should be able to figure out where the space above each bathroom would be. You can always look on the outside to see if there are any exhaust vents anywhere. If there aren't or you can't figure out where things vent, you need to ask the builder where the bathroom vent exhaust goes until you're satisfied there is a clear path for moisture out of the home.

If a home is leak-free, it won't cause excessive air changes by mistake. Your goal should be to have only purposeful air changes. Obviously, you'll be opening your windows and screen doors during mild weather, which you can think of as intentional holes, which is fine. What you don't want are unintentional holes, and most homes have lots of them!

Having intentional air changes (or leakage) improves indoor air quality, but it does affect the energy efficiency. If you had a home that was hermetically sealed and well insulated, you wouldn't have to add any heat to maintain a certain temperature for a long time. The minute you exchange indoor air with outside air at a different temperature, you have to use energy to keep indoor temperatures stable.

But we need fresh air to live. We need oxygen, and we need to change the air in our homes. We can't live in a hermetically sealed house. So it's how you cause that air change that really matters. If you don't cause air changes in a controlled way, you'll be using more energy than necessary for comfort and health. Your objective should be: when you're using energy to heat, cool, humidify, dehumidify or filter the air, you do it in a way that results in as few air changes as possible and only what you really need for your health. This is where you have to rely first on the builder to provide a high-quality design and secondly on the HERS raters to test the design as built.

There's a lot more you can learn about building science, if you're interested. From my own reading, I can tell you that the details of the actual science are fairly complex (it's easier if you have an undergraduate degree in science or engineering), but the basic principles are pretty straightforward. In the end, however, as a homebuyer, you have to rely on the builder to be familiar with these principles and to incorporate these best practices into the construction of each home. Make sure to get a home that has had a certified "HERS rater" (see chapter 5) do at least a blower door test and duct pressurization test, so that the actual construction has been tested. Make that part of your home inspection requirements. Then, make sure that the builder participates in a formal home-rating and evaluation system, such as those I profile in chapter 5, preferably with independent third-party certification.

Make sure the home has an ENERGY STAR rating as well. One other thing: try to talk with other homeowners who've bought from the same builder, if you can, to see what their experience has been. All of these tools will give you more assurance that your new home will be healthy, comfortable and less expensive to operate.

Finally, you might like to look "under the hood" at the economics of energy efficiency upgrades from both your perspective and that of the homebuilder. In my research for this book, I found one builder willing to share his costs and your estimated benefits.

Tom Hoyt of McStain Neighborhoods (Denver, Colorado) prepared an analysis of the economics of green homes, from a homebuilder's perspective. His independent surveys showed that McStain's homes' resale value is 4 percent to 11 percent higher than homes of comparable age and size in the same market. His surveys also show that McStain's new homes command a $10 per square foot premium ($20,000 on a 2,000 square foot home) against direct competitors in the seven-county Denver Metro area. Such premiums are one way to convince a builder to offer the high-performing green home you are looking for. Customer referrals in 2006 ran at 33 percent; in other words, one buyer out of three bought from a personal referral.[9] Think of what this does to reduce the builder's advertising and marketing expenses!

Figure 2.8 shows what McStain pays for energy-efficiency upgrades and the expected savings they deliver to occupants, from a homebuilder's perspective, for a 1,733 square foot townhome in the Denver area. You can see from Figure 2.8 that a builder could invest less than $5,000 to save you $555 on your annual heating, cooling and hot water bills, a tax-free return on investment (for you) of 11 percent or more.

Would you be willing to pay $5,000 extra for a home that was certified to have all of these features? From the builder's perspective, that's where the rubber meets the road. If builders can't command a cost premium for these measures, they'll do just the minimum possible to get an ENERGY STAR certification or some other (less difficult) local certification, but you'll be the one paying the bills as long as you live in the home.

Figure 2.8. Economics of energy-efficiency upgrades, Denver townhome

Features	Estimated Annual Savings ($)	Extra Cost ($)
Advanced framing 2" × 6"	36	545
Low-e, argon-filled windows	55	210
92.1% efficient direct vent furnace	88	900
Water heater — sealed combustion	22	400
Advanced insulation system	89	975
Infiltration/advanced air sealing	81	410
Sealed conditioned crawl space	19	110
Engineering duct distribution system • all ducted system inside conditioned space • set-back digital thermostat	60	920
Fireplace with added electronic ignition	72	0
Downsize furnace/air conditioning (reduces builder's cost)	43	−750
Mechanical (forced) ventilation	−10	300
Third-party verification/energy commissioning	0	580
Total	$555	$4,600
Payback period (Years)	—	8.3
Annual return on Investment (%)	—	12.0