There is increasing concern among the public about indoor air quality, moisture, and mold. There is a lot of confusion and misunderstanding: the media often portrays moisture and mold problems as a result of “tight” construction and energy-efficient design. In reality, most of the mold and moisture problems in buildings result from poor exterior water management, followed by thermal and air barrier defects. We are now using more and more building materials that are subject to damage and decay from moisture, and provide better nutrient sources to mold than we did even 10-15 years ago. In fact, the recent emphasis in codes and building practice on using highly vapor permeable exterior sheathings and highly impermeable interior vapor barriers has led to some dramatic building failures resulting from inward-driven moisture in air-conditioned buildings in the North.

Besides the obvious issues of liability and insurance, any builder or designer who wishes to set him- or herself apart can learn the basics about healthy construction, indoor air quality, and especially mold and water management. While you must be careful not to promise a “mold free” environment, you can certainly create an edge for yourself as a designer or builder of homes with “reduced risk” for mold and other air quality concerns. In fact, these concerns may attract a lot more attention among buyers than energy efficiency! In truth, if you design and build a building to be mold resistant, comfortable, and healthy it will be an energy-efficient building as well.

Overview

There are many issues relating to health and safety in residential buildings. Structural integrity and loading of beams, seismic, wind and snow loads, fire protection and egress, basic sanitation, and electrical safety are all covered in building codes and associated mechanical, fire, plumbing and electrical codes. The majority of requirements in most codes are related to life safety issues: prevent the building from falling on people, help get
them out quickly in case of a fire, prevent electrocution and fire hazards from wiring, and provide for clean, reliable potable water and waste removal. These are the immediate, obvious health and safety issues which codes quite properly govern to ensure a basic level of security for homebuyers, and a level playing field for builders. Codes that address other health related concerns such as fresh air ventilation standards are often not clearly understood. And there are some less obvious, but perhaps equally important issues that arise in residential building construction. The purpose of this section is to provide a brief overview of the health and safety aspects of the “house system.” This summary is only a brief introduction to “healthy construction” concepts; more resources are provided in Appendix B.

Are Cars Safer Than Homes?
Not really, but you can think about these health and safety issues in the context of shopping for an automobile. Whether you buy a luxury model, a compact economy car, a gas-guzzling sport-utility, or a race car, you expect a certain level of safety. Even though these cars may perform very differently and fill different needs, they all have seat belts, headlights, and air bags. Similarly, even though houses are designed differently to meet many different needs, they should all have a basic set of protections for health and safety beyond those that are found in building codes. Air sealing and water vapor control is just as critical as a seat belt in a car. A mechanical ventilation system is as essential as an airbag. Sealed combustion equipment and a carbon monoxide detector can be compared to headlights and taillights, and a good exterior water management system is the equivalent of windshield wipers. You wouldn’t buy a car without these safety features, and every home should have health and safety as a priority as well.

Priorities
People are becoming more and more aware of the health hazards associated with indoor mold exposure, dust mites, volatile organic compounds, and other airborne contaminants. The incidence of asthma has nearly doubled in the last 20 years, and scientists believe that changes in the indoor environment are the primary cause. Researchers have found that indoor air quality is more polluted—sometimes as much as 100 times more—than outdoor air, and this pollution contributes to allergies, nausea, sinusitis, fatigue, and even extreme chemical sensitivities. In addition, some building scientists suspect that many cases of low-level carbon monoxide poisoning go undiagnosed. Because some people have special health conditions or environmental sensitivities it is difficult to choose a
standard that can be applied universally. However, a basic approach to creating a safe, healthy home can be summarized by five principles, all of which involve control of the indoor environment: control of air flows, water vapor flows, energy flows, particulate flows, and pollution sources and flows. The following paragraphs outline the basic approaches to accomplish this level of control:

- **Air flows**—unintended air flows can be unhealthy for many reasons. These air flows can result from the stack effect (uncontrolled infiltration), duct leaks in basements and attics, unbalanced supply and return duct flows, exhaust fans, or combustion appliance makeup air, all of which create air pressures. Low pressures in basements can increase concentrations of radon, sub-soil pesticide treatments, or other soil gases in the home, as well as increased energy loads. High pressures can result in warm, moisture laden air being pushed into exterior walls or into attics and roof systems, where water vapor can condense and cause mold, mildew and decay. Air flows caused by induced pressures or by the stack effect can conduct deadly car exhaust or fumes from stored chemicals from a garage right into the house, or can backdraft combustion appliances. For all these reasons, it is important to reduce or eliminate unintended air flows from homes. The most important methods to control air flows are as follows:
  - Create a very tight building envelope by sealing air leaks
  - Design ducts properly for balanced air flows
  - Seal ducts tightly
  - Install only sealed combustion appliances
  - Design and install makeup air for large exhaust appliances if necessary

- **Moisture flows**—Either too much or too little moisture can be unhealthy. High humidity can lead to increased concentrations of biological contaminants such as mold and mold spores, dust mites, mildew, bacteria and viruses. Low humidity can result in increased incidence of respiratory infections, rhinitis (chronic runny nose), and discomfort. It is generally recommended to keep indoor moisture levels between 30 and 60 percent relative humidity (some experts say 35 to 50 percent, which is very close—also see page 71). To do this reliably year-round you must:
  - Build a very tight envelope to reduce the air exchange that dries air in the heating season and brings in humid air in the summer. This includes tightly sealing any ducts that may be outside the insulated envelope.
• Provide controlled ventilation air to reduce moisture loads in winter.
• Provide spot ventilation for bathrooms and kitchens, and any other special sources of moisture loading (pool, hot tub, fish tanks, etc.).
• Provide dehumidification or air conditioning in the summer. Note that oversized air conditioning will not provide the level of dehumidification needed to keep humidity levels under control; it is actually better to have a slightly undersized air conditioning system for optimum health throughout the summer. With a slightly undersized air conditioner, the indoor air temperature may drift up by a degree or two for a few hours during the hottest days of the year. Indoor air quality, by contrast, will be improved for the vast majority of the humid cooling season.

• Bulk water leaking into a home (or from plumbing) can also be a source of high humidity or wet building materials, resulting in many of the same biological contaminants. The following steps are also critical to controlling moisture in buildings:
  - Foundation water management systems, such as capillary breaks, footing drainage, rainwater drainage and grading.
  - Exterior water management systems such as flashing, siding and roofing details, and a properly installed secondary drainage plane (building paper or housewrap) behind siding. Even better is a vented rain screen, with an air space between the siding and the drainage plane. Be especially careful of flashing details where roofs and decks meet vertical walls. (See EEBA’s Builder and Water Management Guides.)

• Energy flows—Limiting energy use in a building is related to health, although less directly than the other approaches in this list. In addition to the increased energy loads that result from large air flows through the building envelope, cold, poorly insulated surfaces may lead to condensation, mold and mildew. It is also possible that when people living in a home are more comfortable, they will tend to be healthier.
  - Select windows that have, at a minimum, low-e glazing and argon gas fills. Higher performance glazings, heat mirror films, “warm-edge” spacers, and insulated frames will all raise surface temperatures and reduce the chance of condensation and fungal growth on the glass and sash.
  - Higher levels of insulation, and framing details that avoid thermal “bridging” of framing from inside to outside surfaces, will also reduce condensation problems and increase comfort.
  - Insulate basement walls and slab floors to prevent condensation in
the summer, even if they are not in the finished living space.

- Duct insulation and vapor jackets on the exterior of insulated ductwork is critical. Anywhere heating, air conditioning, or exhaust air ducts travel through unconditioned spaces, they should be well insulated, and the vapor jacket on the outside of the insulation should be uninterrupted. Ducts that carry cold air in winter, located in conditioned space or unconditioned basements, should also be insulated carefully with an exterior vapor jacket installed. (Examples include ventilation supply ducts, or the outdoor exhaust duct from a heat recovery ventilator.)

- **Particulate flows**—Most homes have no real provisions for filtering the indoor air. Filters that are provided with furnaces, central air conditioners or heat pumps are only designed to protect the equipment from damage. Better air filters can reduce many of the particles that can cause health problems. High Efficiency Particulate Attenuation (HEPA) filters are the best grade of filter, which may be indicated for people with existing respiratory ailments. It’s a good idea to design a whole-house ventilation system or air distribution system with the capability of adding a HEPA filter later, if needed. Avoid electrostatic filters, ionizers, and any air treatment devices that produce ozone. Also note that any filter must be carefully designed into the air handling system, to account for any pressure resistance created by the filter.

- One advantage of balanced, supply and exhaust ventilation (such as an Energy Recovery Ventilator) is that the fresh air supply can be filtered, unlike exhaust-only systems.

- Whole house air circulation with filtration can be provided by the air handler fan of a furnace or air conditioner. Use a low speed setting on the blower with constant or intermittent circulation. Controls are available that keep track of blower run time to ensure minimum ventilation rates.

- **Contaminant sources and flows**—This category is last on the list, because it has the least to do with energy; however, reduction of contaminant sources is perhaps the most important priority. Sources are many: volatile organic compounds (VOCs) are found in paints, paint strippers, solvents, wood preservatives, and carpeting, as well as stored fuels and automotive products; formaldehydes are found in manufactured wood products such as interior grade plywood, medium density fiberboard (MDF), carpets, and furniture; stored household chemicals such as cleaning products, aerosol sprays, and moth repellents are often toxic; and pesticide and herbicide treatments may be present immediately around or stored in the home. Radon gas can be drawn into the house from below the ground, if it is present. Some
of these products are not under the control of the builder or designer of the home, but many of them are. Reduction, separation and dilution are the main strategies to reduce contaminant exposures.

- **Source reduction** is the most effective way to reduce exposure. If you reduce the source, you need less separation and dilution. Use of low VOC paints, glues and finishes, hard surface flooring (wood or tile) instead of carpeting, wood cabinets or sealed MDF, and non-toxic wood preservative treatments all have the potential to improve the health of the occupants. Most of these options are within the scope of the builder to influence.

- **Separation from the living space** of those contaminants that can not be eliminated is the next best strategy to reduce exposure. One aspect of this that is often overlooked is the elimination of unwanted air flows; be sure to keep air that has a high likelihood of contamination away from the people in the house. These areas especially include garages, combustion appliances, and the earth around the foundation. These air flows are under direct control of the builder, although builders rarely pay attention to them.

- **Dilution** is the last strategy, and by no means least important. Fresh air ventilation is important to help ensure that contaminants that are present (or may be introduced after the house is finished) can be reduced to safe levels. At a minimum every home should have a simple exhaust only ventilation system; balanced supply and exhaust systems with or without heat recovery allow filtration and control the source of the supply air.

- **Radon pre-mitigation** is a form of controlling contaminant flows. Every basement or on-grade slab should have at least 4" of uniform, washed stone underneath, 1/2" to 1-1/2" diameter, with no fine particles. Put it under the insulation if you are insulating the slab. Radon levels should be tested after occupancy by an EPA-certified lab. If high levels are found the stone will allow for effective sub-slab depressurization with a fan to be added later. At a minimum, install a short stub of 4" PVC pipe vertically through the slab, left 4-6" above and capped off. The bottom end should be in the stone layer. Even better, run the pipe right up through the roof, and if a fan needs to be added later it can be easily installed in the attic with a minimum of disruption.