Building an Energy Efficient House

As energy prices continue to rise, there is increased interest in building more energy efficient homes. Over the past few years, petroleum based heating fuels have continued to increase in cost. Heating oil, natural gas and propane are the most common of these fuels. It seems that each of these has increased 10 to 15 percent per year lately. As petroleum resources continue to dwindle, this trend will probably continue.

This being the case, it makes sense to improve the energy efficiency of the homes we build. If the homes are more efficient, less energy will be needed to heat and cool them.

There are three basic contributors to an energy efficient house: Efficient windows and doors, an efficient HVAC system and a well insulated building envelope with minimal air leakage. Passive and active solar heating should also be integrated into any design, but this is a subject for another article.

The first two items are relatively easy. As far as windows and doors, there are many good quality windows and doors available on the market. The more efficient windows and doors will be a little more expensive but they will typically have higher insulation values and allow less air infiltration. More efficient windows and doors will reduce your heating and cooling costs compared with less efficient models. You basically get what you pay for. In colder climates, you should look for windows with a lower U value. The U value indicates the overall efficiency of the window. Low-e windows of various types will be more efficient than standard double pane windows. Triple pane windows will be more efficient yet. In hot climates, you need to look for windows with a lower Solar Heat Gain Coefficient (SHGC). These windows are designed to reduce the amount of heat that enters the home through the windows. The most important thing is to not just accept the windows your builder typically uses. Make sure they have the right performance numbers for your area.

In regard to the HVAC system, the same logic applies. The more efficient systems cost more than the less efficient models. A very efficient HVAC system will reduce your energy costs, month after month, year after year. This applies to both heating and cooling. The most efficient type of HVAC system is probably a geothermal system. These systems utilize the ambient temperature of the ground to generate their heating and cooling energy. There are also natural heating and cooling methods that utilize no energy, but these deserve their own discussion.

Another important consideration with the HVAC system is where the ducting is located and how it is insulated. Ideally, you want all of your HVAC ducts within the building envelope (inside the insulation envelope) and not in the attic. Temperatures in the attic can typically reach 130 degrees or more in the summer and be very cold in the winter. It does not make much sense to pump the heated or cooled air through an area of the opposite temperature extreme. This practice simply wastes energy. Also, your ducts should be well sealed with either a special mastic or with an aluminum tape, not with standard duct tape. Duct tape will fail over time and allow leakage from the HVAC ducts. If the HVAC ducts do run through un-conditioned air spaces, they should be well sealed and insulated.

The building envelope is the largest item and by far the most expensive simply because of its size and the amount of materials used to construct it. If the goal is to create a well-insulated building with minimal air leakage, then a stick-framed home using 2x4s and R-13 insulation is the wrong way to accomplish it. The majority of homes built in the US are stick framed with 2x4s. This is a cost effective and fast way to build a house. But, this building method creates a number of problems.

There are multiple issues: lack of insulation space in the walls, thermal bridging, convective heat loss and air infiltration.

The first issue is the lack of space in the wall into which you can place insulation. Since a 2x4 is only 3.5 inches deep, you can only have 3.5 inches of insulation. If you utilize fiberglass or cellulose insulation, you can realistically only attain about an R-13 insulation value. Considering the current and future cost of heating fuels, this is probably inadequate. Most of the typical insulation materials available have an R-value of around R-3.5 per inch. You could add 1 inch of foam sheathing to the exterior of the building. This adds about R-7 to the R-13 for a total of R-20. This is an improvement but it also adds to the cost.

Alternative options would be to use 2x6 construction or other building materials such as ICFs or SIPs. When you build with 2x6s, you can space the studs further apart. This increases the depth and width of the cavity for insulation. Regardless of the insulation material you utilize, this option will increase the energy efficiency of the building. Since a 2x6 is 5.5 inches deep, you can get an R-value of R-19 with fiberglass or cellulose or higher with some expanding foam insulations. Adding 1 inch of foam sheathing to the exterior further increases the R-value of the walls to around R-26.

ICFs or insulated concrete forms use expanded polystyrene (EPS) foam forms, stacked up to create a wall, which is then filled with concrete. The foam provides the insulation for the walls while the concrete provides the strength. This type of wall typically uses between 5 and 6 inches of foam giving you an R-value of about R-24. SIPs are another building product that uses EPS foam sandwiched between two pieces of OSB. These also are typically 6 inches thick for walls but can be made thicker. ICFs create the strongest walls, but SIPs can be erected faster. Both of these systems have the added advantage of very, very little air infiltration, but both systems cost more than framed construction.

The next issue with 2x4 construction is thermal bridging. Wood is not a great insulator. Wood has an R-value of about R-1 per inch while most insulation materials have an R-value of at least R-3.5 per inch. But if we use wood as the structural material for our homes, every 16 inches we have a material that is not a great insulator, the wood stud. Since the stud has a lower insulating capacity, we are creating a bridge across which heat can transfer into or out of the building. When we use 2x6 construction, we space the studs further apart, reducing the number of places for thermal bridging. Adding foam sheathing to the exterior of either a 2x4 or 2x6 wall will reduce thermal bridging by some extent. ICFs and SIPs do not have many structural members that span from the interior to the exterior and thus have much, much less thermal bridging.

With any of these building systems, you need to insulate below the house, either under the slab or below the floor and in the attic. The attic should be insulated to an R-40 value for most areas, more in colder climates. To create an efficient building envelope, insulation needs to be placed on all six sides of the building; top, bottom and the four exterior walls.

Convective heat loss is more specific to fiberglass insulation. Convective heat loss occurs when there are voids in the insulation area of a wall. When there is a void, air will set up a convective, circular cycle. This can be in a very small space or a larger space. This convective cycle moves heat from the warm side of the wall to the cool side and occurs in summer and winter. Since fiberglass insulation installed as batts or in rolls, there is a possibility there will be small voids around electrical boxes, wires or pipes. This can be avoided with careful installation, but most installers are in a hurry and are not all that careful. Cellulose insulation is typically blown in or sprayed on, greatly reducing the propensity for voids. ICFs and SIPs are solid and do not suffer from this problem.

Air infiltration is the last and maybe the biggest cause of energy loss in a house. Air infiltration is when the air is allowed to move freely into or out of the house. Insulation in the walls and house wrap on the exterior of a stick-framed house are designed to reduce air infiltration. If these two items are installed correctly, they can greatly reduce this problem.

A stick-framed house is more likely to have an air infiltration problem than some other building systems. This is because we are building the house using hundreds of parts. The more parts you are joining together, the more chances there are for voids and air leakage. ICFs and SIPs utilize fewer, bigger parts and thus have less chance of air leakage. With any building system, it is also important to carefully seal around any penetrations to the walls, floors and ceilings. These can be from electrical, plumbing, heating or windows and doors. Anywhere there is a small hole or crack, air will leak into or out of the house.

It is possible to build a house that is too tightly sealed. This can potentially cause indoor air quality issues, but this should only be an issue in extreme cases. All houses will have some leakage and we let in fresh air every time we open a door or window. A heat recovery ventilator can also be utilized to bring fresh air into the house. You can have your house tested to see how much air infiltration is occurring.

Building an energy efficient house is basically creating a well-insulated envelope with minimal air leakage, having good quality windows and doors and an efficient HVAC system. It is not rocket science, we just have to be willing to pay for better construction and ensure that our contractors are building the house as requested. Doing so will save you money on every energy bill for the entire life of the house.

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