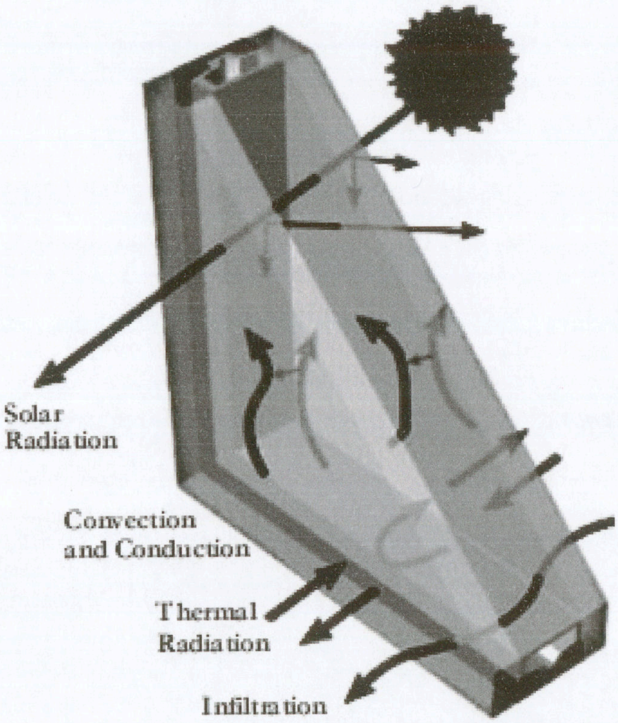
The Missing Link in Energy Efficiency in Buildings

In our world, we face common problems which directly affect the energy efficiency of most buildings. In buildings unwanted heat and the loss of heat are the two largest issues that directly affect the energy efficiency and therefore our enjoyment of them. The unfortunate reality is that the strategies that we have been taught to control the temperature heat/loss issue do not completely address the problem. In fact, most current strategies only address two out of the three modes of heat transfer: conduction and convection. Conductive heat transfer is the passing of energy in the form of heat through matter acting to balance the energy from an area of high heat to an area of low heat. What this actually means is that heat passes through the walls, floors, windows and ceilings and that insulating attics, roofs, walls, and foundations restricts the flow of conductive heat transfer. Convection is the transfer of energy through a fluid or gas; more accurately the transfer through the fluid or gas to the surface where the fluid or gas touches. Again insulation addresses this by restricting the amount of energy transferred into the surface where the fluid or gas (air) touches. Double glazed windows attempt to restrict both conductive and convective modes of heat transfer by insulating against heat conduction and by reflecting energy for heat convection.



So we have talked about two of the three modes of heat transfer. We have briefly discussed:

1: Conduction Heat Transfer: a molecule to molecule (molecular motion) direct heat flow through matter. An example is the heating of one end of a metal rod. The heat travels through the metal by conduction to the other end resulting from actual physical contact.

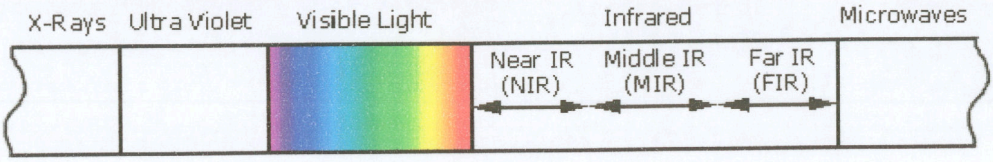
We also discussed Convection Heat Transfer. A good example of convection is a flame which heats the air around it.

What we haven't discussed is Radiant Heat Transfer. Radiation is the transfer of heat through space via electromagnetic waves or light energy. It can be transferred across a perfect vacuum in a straight line.

If you think of our previous example of the flame heating the air around it, the light from the flame and the colors of it are examples of radiation. Another example that is taken for granted is the operation of a common television set. A transmitter sends out electromagnetic waves (they are not always in the visible spectrum) that travel through space. The television uses a tuner to interpret the waves into a video image. Radiation is a band of electromagnetic waves that extend from the visible to the invisible regions of the spectrum – a wide range of frequencies. For our purposes it is important to remember that radiation is a form of transfer of energy.

Understanding Radiant Energy (Heat)

The solar spectrum is the total distribution of electromagnetic radiation emanating from the sun. The different regions of the solar spectrum are described by their wavelength. Less than half of the sun's energy is visible. Solar radiation is short wave (0.3 to 4.5 microns), and made up of visible light (0.4 to 0.7 microns), accounting for 43 percent of the total energy. Shorter wavelengths of energy beyond purple are called ultra violet (below0.4 microns) and contribute 3 percent of the energy, and longer wavelengths beyond the red part of the visible spectrum are infrared (over 0.7 microns) which account for 54 percent of the remaining energies. Radiation emitted by ground and building surfaces is entirely infrared (heat) (5 to 50 microns).



When the sun's energy strikes a window, the radiation is either, partially reflected, absorbed or transmitted into the building. It should be noted that absorption of radiation causes the brick, siding, roofing, and glass temperatures to rise, and transmitted radiation causes a heat gain in the building by passing through the walls and other building materials and transferring energy to the gas and fluids inside. All radiant energy, both visible and invisible, produces heat when absorbed. Windows are the largest, least insulated areas of any building so understanding the transmission characteristics of glass to radiation striking it should be discussed as it is the missing link in addressing energy conservation in a building.

Understanding Windows and Radiant Heat Flow

Windows are thermal holes. Single pane clear windows are 20 times less energy efficient than the wall area they replace and double pane Low-E windows are 10 times less energy efficient than the wall area they replace. What that means is that an average home can lose more than 30% of its heat or air conditioning energy through its windows. And while the amount heat loss or heat gain through windows depends on whether the windows are single pane glass, clear double pane, low e coated or gas filled; the amount of heat loss or gain can be reduced dramatically with the addition of insulating radiant barriers.

Window manufactures use the term shading coefficient (SC) to describe how much solar heat is transmitted by each glazing system. A totally opaque unit scores 0 and a single pane of clear glass scores 1 on this comparative scale. **A clear double pane window scores 0.84 because it allows 84% as much heat to pass through the window as a single pane of glass.** Many buildings still have clear double pane and single pane windows.

The new more accurate way to describe solar heat gain is solar heat gain coefficient (SGHC). SHGC is the fraction of available incident solar heat that successfully passes through a window. It too uses a scale of 0 for none to 1 (for 100% of available). The key difference is that SHGC looks at a percentage of available solar heat rather than looking at a percentage of what comes through a single pane of glass. It considers various sun angles and the shading effect of the window. As a result it is about 15% lower than SC values. So the SHGC for a clear double pane window is 0.714. These are both descriptive terms that attempt to attribute a measureable value to the radiant heat transmission of glass structures.

Window manufactures have added low-e (emissivity) coatings which are formulated to block specific wavelengths of energy in order to better address the transfer of radiant heat flow through glass. However, emissivity is a surface characteristic of a material and it is defined as the relative ability of a surface to absorb and reflect energy in the form of radiation. Low emissivity (Low-E) coatings reduce the surface emissivity of the glass. The coatings are mainly transparent over the visible wave. A SHGC of 0.40 is recommended for warmer climates and a SHGC of 0.55 for colder as a higher solar gain means that you will have a warmer house from radiant energy gain. It is possible to have a glass coating that blocks long-wave heat energy (low SHGC) while allowing shorter wave light energy to enter a building, however one needs to keep in mind all radiant energy, both visible and invisible, produces heat when absorbed, that absorption of radiation causes the glass temperature to rise, and transmitted radiation causes a heat gain in the building.

Other radiant barriers are available that can further prevent heat gain and loss. A common example of these barriers are the blinds, curtains and sheers that are used to "dress" up most windows. These are only minimally effective but do contribute to the reduction of some radiant heat transfer.

Summary

A materials response to far infrared radiation can be quite different from its response to sunlight. Since a large percentage of sunlight is in the visible range, we characterize materials by color and clarity. For example common window glass transmits more than 85% of incident sunlight but absorbs more than 85% of the far infrared energy that strikes it. The "solar greenhouse effect" results in part from this phenomenon. Absorbed infrared energy readily passes through the glass and is absorbed by the opaque surfaces within a space, becoming trapped inside the space as heat and increasing the interior temperature. Radiation emitted by ground and building surfaces is entirely infrared (heat) (5 to 50 microns).

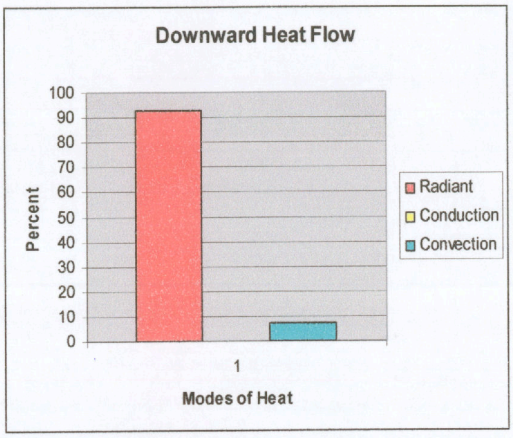
The sideways flow of radiant heat (electromagnetic waves) accounts for 65% to80% of heat movement and the largest percentage of windows are installed vertically, directly inline with the sideways flow of radiant heat . This is also why we say that windows are thermal holes; heat sink holes that majorly contribute to the heat gain and loss of a building. Recall that single pane clear windows are 20 times less energy efficient than the wall area they replace and double pane Low-E windows are 10 times less energy efficient than the wall area they replace. What this means in practice is that an average home can loose 35% plus of its heat or air conditioning energy through its windows. Glass and Low-E coatings only minimally reduce the unwanted transfer of heat in and out of a building. While the SHGC describes the fraction of available incident solar heat that successfully passes through a window unit.

If the SHGC for a clear double pane window is 0.714 which means that 71.4% of the available incident solar heat that successfully passes through a window; literally then 48% to 59% of the radiant heat is still entering the building through the windows.

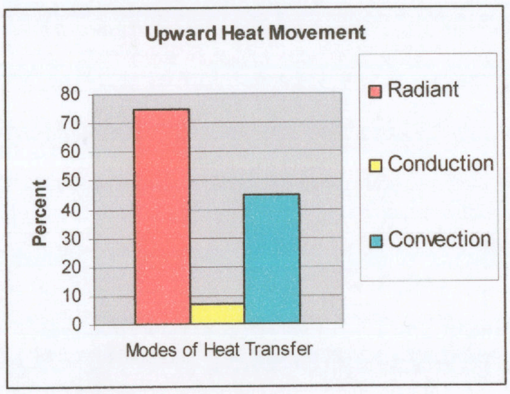
If the SHGC for a double pane Low-E window for colder climate is 0.55 which means that 55% of the available incident solar heat that successfully passes through a window; then 35% to 44% of the radiant heat is still entering the building through the windows. By the same token, if the SHGC for a double pane Low-E window for warmer climate is 0.40 it means that 40% of the available incident solar heat that successfully passes through a window; 35% to 44% of the radiant heat is still entering the building through the windows.

RADIANT HEAT ACCOUNTS FOR 50% TO 80% OF HEAT MOVEMENT IN AND OUT OF BUILDINGS.

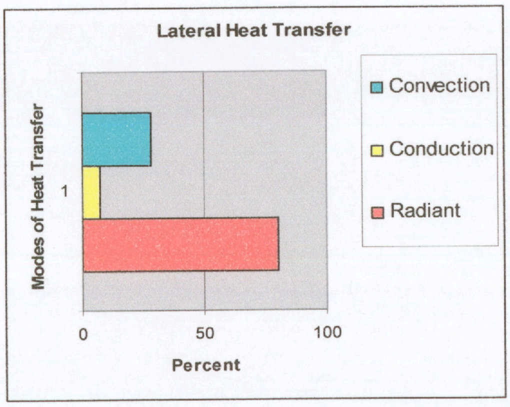
Directional Heat Flow



Radiant mode of heat transfer accounts for 93% of the downward flow of heat while the conduction mode of heat transfer accounts for 5%-7% and the convection mode of heat transfer is zero.



The radiant mode of heat transfer accounts for 50%-75% of the upward flow of heat while the conduction mode of heat transfer accounts for 5%-7% and the convection mode of heat transfer accounts for up to 45%.



The radiant mode of heat transfer accounts for 65%-80% of the lateral (sideways) flow of heat while the conduction mode of heat transfer accounts for 5%-7% and the convection mode of heat transfer accounts for up to 15%-28%.

Please understand, that radiant heat gain in warmer climates and radiant heat loss in colder climates is more than a perception. In warmer climates heat is not required as much and just the light is desired. In contrast, colder climates welcome both light and heat and once captured we don't want it to escape out the window.

Insulating radiant heat barrier systems are a method of stopping infrared radiation from getting into building interiors and increasing air-conditioning loads (required to cool the space). Radiant barriers are materials that restrict the transfer of far infrared radiation across an air space. They do this by reflecting the radiation that strikes them and at the same time by not radiating energy. A material that has this capability is said to have a low emissivity, consequently the lower the emissivity of a material, the better the radiant barrier.

Aluminum is an excellent radiant barrier, it has a low emissivity (0.050), and therefore, it eliminates 95% of the radiant transfer potential. Aluminum is a good thermal conductor which means that it has a very low R value. However if it is placed between materials that are attempting to transfer thermal energy by radiation (rather than by conduction) and if it is separated from these materials by an air layer, the aluminum effectively eliminates the normal radiant energy exchange across the air space. This is one of the operating principles of radiant barrier systems and can be used reduce the flow of heat through building components.

The insulation values for buildings are typically R-20 for walls and R-40 for roofs and attics, however if you were to look at the comparable R value of a window it is R-1 to R4.5. The R factor or resistance to heat flow is the reciprocal of U; in other words, 1/U. The lower the U factor fraction the larger the R factor, the better the insulation's ability to restrict conductive heat flow. We utilize radiant heat barriers for roof, attics, and walls, to make buildings more energy efficient. Up to this point we have ignored the largest heat sink holes "the windows".

The ideal solution to the weakest area of the building enveloping system (the windows) and the missing link to energy efficiency with windows is a see through insulating radiant heat barrier designed for windows which keeps unwanted radiant heat out in the summer (lowering cooling bills) and is reversible, reducing heat loss through windows in the winter while having the characteristics that once reversed it becomes a one way heat transfer absorbing electromagnetic waves; collecting the heat and re-radiating it into the building and thereby lowering heating costs.

About the author:

Michael P. Levesque is the President & CTO of the Engineered Systems Networked Group of Companies, a dedicated consortium of companies that create, design, prototype and manufacture renewable and green technology systems on a global scale. The Engineered Systems Networked Group of Companies consists of: Engineered Systems Incorporated, Engineered Systems Wind Power Division, Engineered Systems Consumer Products Group, Engineered Systems LED Lighting Systems, Engineered Systems Military Operations, Green Source Electronics, HK and EOA Solar Systems Ltd., PRC. He can be reached at mike@engsysinc.com .

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