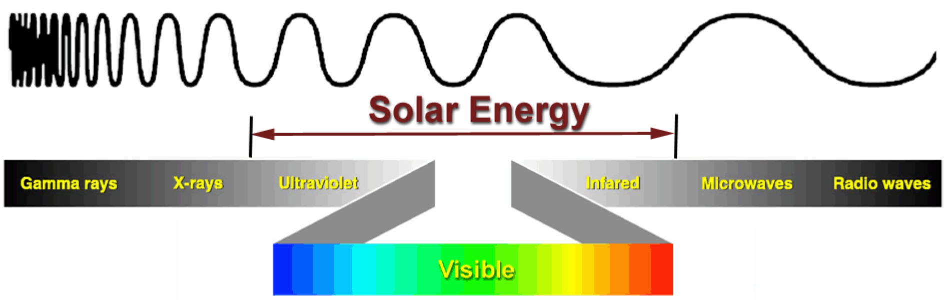
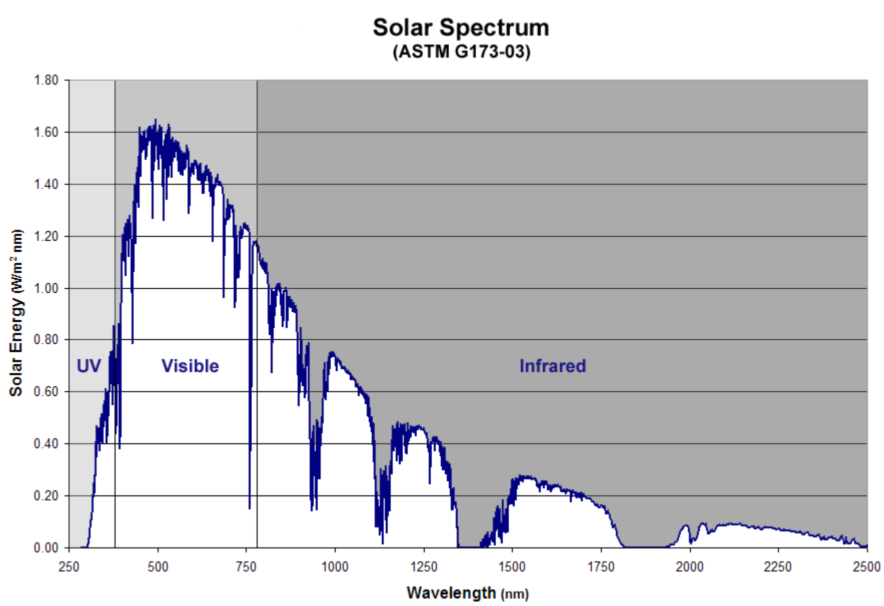
Love Understanding Solar Performance Numbers: Part 1

Have you ever been put on the spot by a customer asking a follow-up question on solar performance numbers? Did you feel uncomfortable or unsure about your answer? Do you think it may have been the reason you lost a particular sale? As a skilled window film professional, you understand that customers rely on a combination of intellectual and emotional responses when making a purchase. Although there are literally thousands of consultants and self-help books that will make you more effective with the emotional trigger points to close the sale, you will not even get to step up to the plate without being able to describe how the product performs. This article is written to better prepare you with the technical knowledge to handle all types of potential customers, even the dreaded retired engineer who has the lethal combination of technical training and spare time!

Q1) How does the sun's energy make it through the window? The same way that it travels those millions of miles to get to the earth. *Radiation*. Simply put, this is energy movement by electromagnetic waves. Just like the waves from a tossed pebble ripple out in a pond, the sun's energy moves via waves to get from one place to the other. Now this solar energy does not travel in just one big wave, but instead in many waves that differ from each other by *wavelength*. Here wavelength means the spacing, or length, between the waves. Back to our pond analogy, ripples that are close to each other have a short wavelength while those that are spread further apart have a longer wavelength. Why is this important? Because different solar wavelengths give us different challenges to address with window film. The shortest wavelengths from the sun are called *ultraviolet* radiation/ energy, or UV, the middle wavelengths from the sun are called *visible light*, and the longest wavelengths are called *infrared* heat/energy, or IR. Please see the diagram below for a descriptive summary:

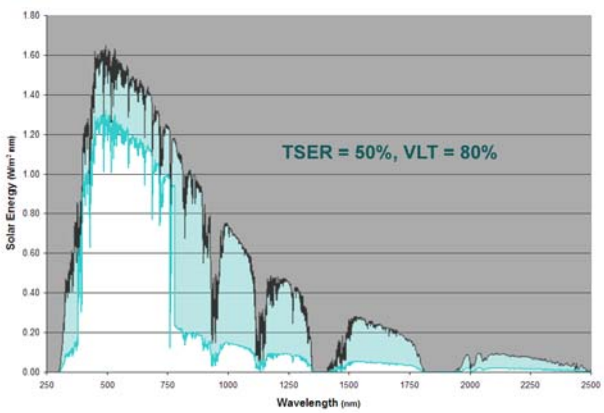


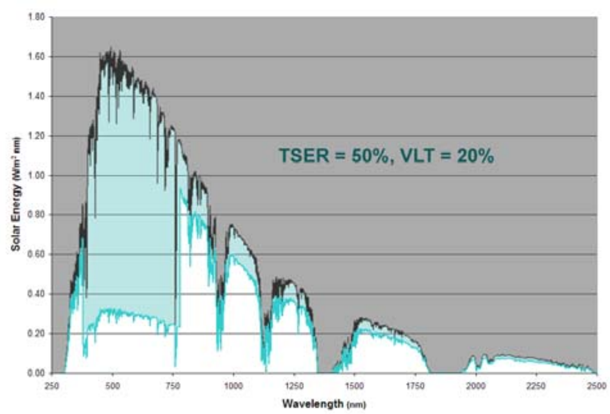
Q2) Is the solar energy the same for all of these wavelengths? No, the amount of energy changes across the solar spectrum. Think about it in terms of your radio. When you turn the dial, you are moving from one wavelength to the other in the radio portion of the electromagnetic spectrum. Some stations come in very clearly, i.e. have a lot of energy behind the broadcast, while others are very faint. The same thing applies with the solar spectrum. Some wavelengths are not produced with as much energy from the sun or are absorbed in the atmosphere, like portions of the UV, while other wavelengths come through quite strong. Here is a plot that shows the amount of energy versus wavelength for the sun. The wavelength is given in dimensions *nanometers* (nm), which is one billionth of a meter. Pretty small indeed!



Q3) Okay, now I understand the solar spectrum better, but how does this relate to window film performance? Let's start out with one of the most important performance numbers, *Total Solar Energy Rejected* (TSER). This metric describes the total amount of solar energy (UV + visible + IR) that is blocked, or rejected, from passing through the window. Let's look again at the solar spectra chart shown above. Since the solar energy sort of looks like piles of white sand in this plot, a TSER of 50% would mean that you shoveled away, or eliminated, half of the sand. This doesn't tell you which pile of sand you shoveled, but simply the total amount of sand that is now gone. Same with TSER. It doesn't tell you which wavelengths are being rejected, but it does tell you the total solar energy performance. Another way to describe the total solar energy performance is with the *Solar Heat Gain Coefficient* (SHGC), defined in the NFRC 200 - 2004 standard. This is a term common in the glass business and will be used more and more with window film in the future. The connection between SHGC and TSER is very simple: TSER = (1 - SHGC) * 100%. So if you have a TSER = 40%, the SHGC = 0.6. The TSER can be thought of as the percentage of solar energy rejected (higher the better) while the SHGC is the fractional amount of solar energy that passes through (lower the better).

Q4) So are you saying that a film with a higher TSER is always the better performing film? No, definitely not, because you can always increase the TSER number by simply making a film darker or more reflective. Remember that TSER looks at UV, visible and IR. Very important point! To make an apples-to-apples comparison, you need to look at films with the same visible light performance. As a quick example, here are two charts that show glazing systems with TSER = 50%, However one of these systems has a *visible light transmittance* (VLT) of 80% while the other has a VLT of 20%. These look identical from TSER, but the 80% film is a much higher performing film because it is *spectrally selective*, i.e. blocks out more IR than visible. If we took the 80% VLT system and tinted it down to the same 20% level, without rejecting any additional UV or IR energy, then the TSER number would increase to approximately 80%! *Luminous Efficacy* was created to help people make this sort of comparison because it is defined as the VLT divided by the Solar Heat Gain Coefficient. Luminous Efficacy is sometimes incorrectly defined as VLT divided by Shading Coefficient (more on shading coefficient below) so make sure to double check how it is being used. The higher the Luminous Efficacy, the better you are doing at rejecting the IR heat and letting the visible light through. Important since studies show that up to 30-40% of the total electricity bill for commercial buildings is interior lighting. I am sure we will start to hear more and more about daylighting in the future.





Q5) You mentioned visible light transmission/transmittance -- is that just the level of tint? Yes, you can get a pretty good idea of the VLT simply by looking at how dark the film makes the window. Visible light transmittance is defined within NFRC 200 - 2004. Simply put, VLT is the total amount of the visible energy, i.e. sunlight (380 - 780 nm), that makes it through your filmed window.

Q6) Can you make a window film with high VLT and good glare reduction? Not without a breakthrough invention since these two performance metrics are exactly opposite each other. Improving one always lowers the other with today's technology. Glare reduction is defined as the percentage of VLT reduced when film is added to the window, i.e. 100% * [VLT(glass) - VLT(filmed glass)] / VLT(glass). It simply tells you the percentage of tint your film adds to the window.

Q7) Sometimes customers ask me how much of a difference window film makes in improving the solar performance of their window? Is shading coefficient the best way to measure this? It is true that simply looking at TSER or SHGC can be a little bit misleading because an average performing film on a great window can get a better number than a great performing film on a poor window. They really don't tell you how much of an improvement the window film made. Shading coefficient helps out a little bit because it compares the SHGC for your filmed window to the case of the SHGC for 1/8" clear glass (= 0.87). But what if your window isn't 1/8" clear glass? This is why I like to use *Heat Gain Reduction* to answer the question because, analogous to glare reduction, it tells you the percent improvement of solar energy rejection when window film is added. It is defined as 100%*[SHGC(glass) - SHGC(filmed glass)] / SHGC(glass). A Heat Gain Reduction of 20% means you are reducing 20% more of the solar energy when film is added. It's that simple.

Q8) I see other companies publish numbers for Total Solar Energy Absorbed, Total Solar Energy Reflected and Total Solar Energy Transmitted. Why don't you do this? The reason I don't care for these numbers is because they only tell a part of the story and can be misleading. Let's take Total Solar Energy Transmitted -- this must mean the total solar energy transmitted through the glass, right? Wrong. It is actually defined as the total solar energy that is *directly* transmitted through the glass, but energy can also indirectly pass through when it is absorbed within the film and then re-radiated into the room. Total Solar Energy Reflected plus Total Solar Energy Absorbed doesn't equal the TSER, even though you would think so since energy can only be reflected or absorbed, because again some of the energy that is absorbed re-radiates into the room. The only number out of here that tells you something more about the film is Total Solar Energy Absorbed because it helps you understand how much the glass may be heating up from the film absorbing energy. This gives you an indication of potential glass breakage. But we calculate the exact center of glass temperature increase with film added to the glass and use this number as a part of our *Glass Checklist* program when issuing warranties. Therefore we don't publish any of these numbers.

Q9) How can I tell whether adding window film will make the glass look more like a mirror? Clear glass by itself has a reflection of visible light around 8%. Whether or not this means you can see a reflection off the window depends on if the light is brighter outside or inside. Traditionally, adding a window film increased the visible reflectivity of the glass. The way this is defined is straightforward -- a visible light reflection of 10% from the interior (Rint) means the glass is slightly more reflective inside and therefore you will see a little bit more of a reflection at night. A visible light reflection of 50% from the exterior (Rext) means the glass will really have a commercial mirror-like appearance during the day. Notice at night, however, that this goes away. Again, it all depends on whether it is brighter inside or out.

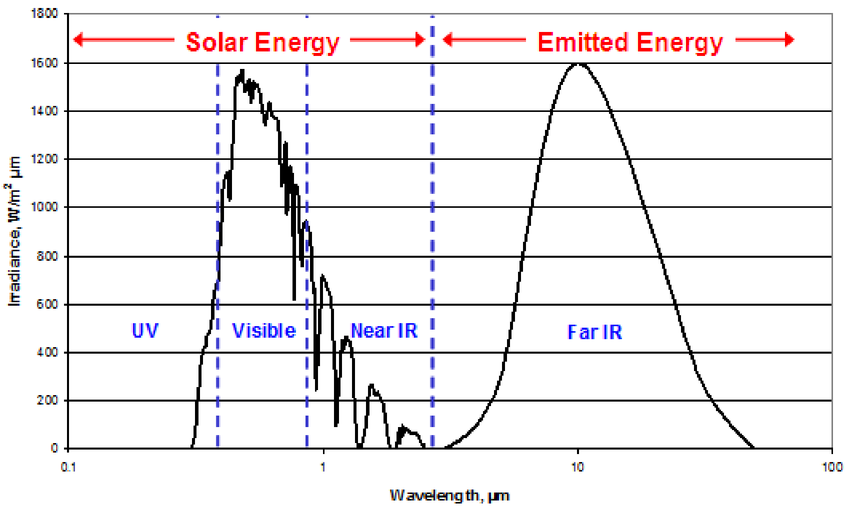
Q10) Is UV Rejection just the amount of UV energy blocked? Yes, it is that simple. Add up all the energy from 300 - 380 nm, see how much of this gets through the film, and therefore you know how much is blocked.

<u>Understanding Solar Performance Numbers: Part 2</u>

In Part 1 of this technical review, we spent some time on a question and answer session for solar performance numbers. Although this discussion was fairly thorough, there were a couple of key areas that were set aside for this article.

Q1) I know you talked about heat rejection in the previous posting, but isn't this the same as infrared (IR) rejection since infrared and heat are the same thing? No. This is a very important point to remember. Although it is true that human skin senses IR wavelengths as heat, these IR wavelengths do not all come directly from the sun. Infrared energy comes in two forms: (1) near infrared, or the solar infrared wavelengths, and (2) far infrared, or the wavelengths emitted inside a building or car as energy is absorbed within. The key point here is that energy cannot just disappear. So if the sun's visible or ultraviolet (UV) energy makes it through the glass, then it will eventually get absorbed and converted to far IR heat. Bottom line: near infrared rejection is an indicator of solar comfort, but you must look at the total solar energy (UV + visible + IR) when making claims about heat rejection. The most direct way to do so is with Total Solar Energy Rejected for overall glazing performance or Heat Gain Reduction to capture the added benefit of the window film.

Q2) What do you mean by far infrared heat? As mentioned above, the far infrared wavelengths carry the emitted energy from a heated building or car. Since we spent a good deal of time discussing the solar wavelengths last article, I will simply mention that the solar wavelengths include UV, visible and near infrared and span the range from about 300 nm to 2500 nm. The far infrared wavelengths are out beyond that point and from a practical standpoint go from about 5000 nm, or the equivalent 5 microns, to around 50 microns. See the graph below. When one refers to a Low-E window or window film, this simply means that the far infrared wavelengths are partially blocked from passing through the glazing. This is most important in cold weather climates where you want to prevent heat from escaping through the windows by radiation. Emissivity is the parameter used to describe this performance. The lower the emissivity, the better the glazing system is at blocking the far infrared wavelengths



Q3) You mention heat escaping by radiation. Are there other ways for heat to pass through a window? Yes. There are three ways for heat to be transported: (1) radiation, (2) convection and (3) conduction. Radiation is the movement of heat by waves, such as the sun's energy. Window film is very effective at blocking this solar radiation -- this is why we emphasized this area in Part 1 of this review. Convection is the transport of heat by fluid (e.g. air) movement. This tends to be a minor effect through the window due to the tight seals in most windows today, but it is important for areas like HVAC design. Conduction is the movement of heat through a material due to the temperature difference between a hot and cold region. This is an important element in the thermal performance of a window and is measured by the U Value. Here U Value represents the flow of heat so the lower the number, the better the glazing system is at insulating against heat loss (or gain) due to conduction. It is important to note that the U Value is primarily determined by the design of the window. The best window films for improving cold weather insulation, such as 3M's LE35AMARL, reduce the U Value by about 20%. Most window films change this value by only a few percent, but going from a single glass unit to an IGU reduces the U Value by over 50%. Another term that you hear more frequently for describing insulation performance is the R value. The big pink fiberglass batts that you see at home improvement stores are rated in R values. Although not commonly used for window films, one can compute the equivalent R Value with the equation $R_{Value} = 1 / U_{Value}$.

Q4) Is there a way to show the added benefit of window film for reducing heat loss by conduction? You are correct that the U Value measures the overall performance of the glazing system, so it may not be clear if the performance is coming from the window film or the glass. Just like the benefit of window film on blocking heat is clearly identified with Heat Gain Reduction, Heat Loss Reduction measures the percent improvement in reducing heat loss when window film is added. It is defined as 100%*[U Value(glass) - U Value(filmed glass)] / U Value(glass)]. A Heat Loss Reduction of 20% means you are reducing 20% more of the building's energy from escaping through the glass when film is added.

Q5) Do you have any product ideas for increasing my sales during the colder months? If you haven't done so previously, make sure you look into the 3M Fasara(TM) film line. These products move year round because they primarily address privacy, daylighting or design issues with glass. There is no seasonality to this market and the films offer very strong benefits over the alternative, etched glass. Architects and interior designers absolutely love this product when they become aware of it so make sure to build your network in this area and you will see definite results.

Decorative Glazing Comparison

3M Fasara	Etched Glass
Strengthens Glass	Weakens Glass
Less Expensive	More Expensive
Design Flexibility	Difficult to Change Design
99% UV Protection	Less UV Protection
Standard Cleaning	Very Difficult to Clean Oil Spots

Understanding Solar Performance Numbers: Part 3

In Parts 1 and 2 of this technical review, we learned about solar performance numbers using a question and answer format. Although this discussion was fairly thorough, we addressed the topic of Low-E coatings only at a cursory level. Because of its prevalence as an OEM glass technology, we will now spend additional time reviewing this important area.

Q1) Tell me again about Low-E coatings -- what does it mean? Low-emittance coatings, or Low-E for short, are microscopically thin metal or metallic oxide coatings deposited on glass to reduce the transport of heat through the window from regions of hot to cold. In climates that require heating, this means you can save energy by partially reflecting the room heat back into the building vs. losing it to the cold exterior. In climates that require cooling, this means that you can save energy by partially reflecting the outdoor heat back outside vs. having it enter the air conditioned interior of the building.

Q2) How do Low-E coatings work? Low-E coatings are designed to reflect far infrared energy. Remember that infrared energy comes in two forms: (1) near infrared, or the solar infrared wavelengths, and (2) far infrared, or the wavelengths emitted inside a building or car as energy is absorbed within. The solar wavelengths include UV, visible and near infrared and span the range from about 300 nm to 2500 nm. The far infrared wavelengths are out beyond that point and from a practical standpoint go from about 5000 nm, or the equivalent 5 microns, to around 50 microns. So if you reflect emitted energy, you reduce the amount of heat transfer and increase the energy efficiency.

Q3) So does a Low-E window mean that you are getting the best energy-performing window, i.e. adding window film gives no benefit? No. Low-E is simply referring to a window that has a coating designed to partially block the far infrared wavelengths. Emissivity is the parameter used to describe this performance -- the lower the emissivity, the better the glazing system is at blocking the far infrared wavelengths. However emissivity says nothing about the ability of the window to block the sun's heat, i.e. total solar energy rejected, and does not even fully describe the insulating performance of the window, i.e. the U-value. Remember that the U-value represents the flow of heat due to the temperature difference between a hot and cold region, so this insulating performance is also affected by other factors such as the design of the window (e.g. single vs. double pane) and the type of gas contained within the insulated glass unit (e.g. air vs. krypton).

Q4) Does a Low-E window block solar energy? Yes. There is some rejection of solar energy with Low-E windows, the actual amount depending on the types of materials and the number of coating layers. One needs to refer to the published solar heat rejection number (SHGC or TSER) to determine the actual performance. The two major categories of Low-E technologies are (1) pyrolytic, or hard coatings, and (2) sputtered, or soft coatings. In general, pyrolitic coatings are more durable whereas sputtered coatings are more fragile but block more solar energy. Please refer to the chart at the end that demonstrates the performance increase for some different combinations of Low-E coatings and 3M Window Films.

Q5) How can I tell if a window has a Low E coating? The simplest way is to place a lit match or small flashlight near the window, with the room darkened, and look at the multiple reflected images. The color of the image will change on the surface that has the Low-E coating. The type of color change will indicate the type of coating for an experienced viewer. A more professional and error proof way to make this assessment is to utilize a handheld Low-E detector and perform the measurement on the window directly.

Q6) What's the bottom line when it comes to Low-E windows and the application of window film? Window films will do little to nothing to change the insulative performance of Low-E windows (U-value) but can make a noticeable difference on the solar heat gain (SHGC). This solar heat gain benefit is most prevalent with pyrolytic coatings and decreases based on the number of silver layers used for sputtered glass. However even in the case of a high performance Low-E window, the application of window film can offer other customer benefits such as glare control or UV blockage even though there is little heat rejection gain.

Pane 1 (on 6 mm clear glass)		Pane 2 (on 6 mm clear glass)	VLT	SHGC		SC		U Value	
Description	Manufact.			NFRC	CEN	NFRC	CEN	NFRC	CEN
LoE^2-256	Cardinal IG	Clear glass	0.54	0.33	0.34	0.38	0.40	1.67	1.58
		PR 70	0.43	0.31	0.32	0.35	0.37	1.64	1.58
		NV 45	0.31	0.31	0.32	0.36	0.37	1.67	1.58
		PR 40	0.24	0.29	0.31	0.34	0.36	1.64	1.58
		NV 15	0.11	0.23	0.25	0.27	0.29	1.67	1.58
		RE35NE	0.27	0.29	0.31	0.34	0.35	1.64	1.58
LoE^2-262	Cardinal IG	Clear glass	0.59	0.35	0.37	0.41	0.42	1.67	1.59
		PR 70	0.47	0.33	0.34	0.38	0.39	1.65	1.59
		NV 45	0.34	0.33	0.35	0.38	0.40	1.67	1.59
		PR 40	0.27	0.31	0.33	0.36	0.38	1.65	1.59
		NV 15	0.12	0.25	0.26	0.28	0.30	1.67	1.59
		RE35NE	0.30	0.31	0.33	0.36	0.38	1.65	1.59
LoE^2-272	Cardinal IG	Clear glass	0.69	0.40	0.42	0.46	0.48	1.67	1.58
		PR 70	0.54	0.37	0.39	0.43	0.44	1.64	1.58
		NV 45	0.39	0.38	0.39	0.43	0.45	1.67	1.58
		PR 40	0.31	0.36	0.37	0.42	0.43	1.64	1.58
		NV 15	0.14	0.28	0.29	0.32	0.33	1.67	1.58
		RE35NE	0.35	0.35	0.37	0.41	0.42	1.64	1.58
Energy Advantage Low-E	Pilkington N.America	Clear glass	0.73	0.62	0.63	0.71	0.73	1.88	1.85
		PR 70	0.57	0.53	0.54	0.61	0.62	1.85	1.85
		NV 45	0.41	0.57	0.58	0.66	0.67	1.88	1.85
		PR 40	0.33	0.50	0.51	0.58	0.59	1.85	1.85
		NV 15	0.15	0.41	0.42	0.47	0.48	1.88	1.85
		RE35NE	0.37	0.53	0.54	0.61	0.62	1.85	1.85
LowE	Viracon	Clear glass	0.70	0.38	0.39	0.44	0.45	1.66	1.58
		PR 70	0.55	0.36	0.37	0.41	0.42	1.64	1.58
		NV 45	0.40	0.35	0.37	0.41	0.42	1.66	1.58
		PR 40	0.31	0.34	0.35	0.39	0.41	1.64	1.58
		NV 15	0.14	0.27	0.26	0.30	0.31	1.66	1.58
		RE35NE	0.35	0.33	0.34	0.38	0.40	1.64	1.58
Low-E 1.1NT	Guardian	Clear glass	0.77	0.55	0.56	0.64	0.64	1.71	1.64
		PR 70	0.61	0.49	0.50	0.56	0.57	1.69	1.64
		NV 45	0.44	0.52	0.52	0.59	0.60	1.71	1.64
		PR 40	0.35	0.47	0.47	0.54	0.55	1.69	1.64
		NV 15	0.16	0.38	0.38	0.44	0.44	1.71	1.64
		RE35NE	0.39	0.48	0.49	0.56	0.56	1.69	1.64

Q7) Why did 3M go out and obtain NFRC certification on our window films?
The NFRC is a non profit organization developed in 1989. The purpose of the organization is to standardize energy performance requirements on a glazing such that consumers can receive accurate and reliable information. Information regarding the NFRC and 3M window films can be found in the certification products directory on the NFRC website at www.nfrc.org.

Q8) Why are the published performance numbers for 3M films different for NFRC vs. printed literature?
The NFRC website lists certified solar performance numbers for 3M window films by type of glass. Table 1 includes an explanation of what is meant by glass "type" on the NFRC label.

Type	Explanation
Residential	68" x 43" Vinyl frame window
Non-Residential	68" x 43" Aluminum frame w/break window

Why is this important? It is important because the NFRC values are not the same as what is published in 3M's sample cards. The reason for this is an apples-to-oranges comparison. NFRC has always certified completely assembled products, such as a window or a door. Thus the specifications that the NFRC prints are “whole window” values that include a specific size of window and frame type. Since light does not transmit through the frame, just the fraction of the window that is glass, the VLT number will be lower for NFRC. The same reasoning applied for SHGC.

Window film companies traditionally publish “center-of-glass” values that are not dependent on the size of the window or frame type. In order to be included in the International Glazing Database (IGDB), these center-of-glass values must go through a rigorous review process upon submission to Lawrence Berkeley National Laboratories. 3M is an active participant in this process. Note that the NFRC and “center-of-glass” numbers are correlated to each other because the IGDB data is used to calculate whole window values.

Q9) Whole window vs. Center-of-Glass, why should I care?
Energy savings is quickly becoming the biggest focus in the world today. With the continued push for energy savings the federal government, state governments, and utility companies have begun to offer more and more energy savings rebates. There are many rebates available for upgrading window performance, of which window film plays a vital role. Typically energy rebates for windows are based on two specifications, the SHGC and Luminous Efficacy. **WHY IS THIS IMPORTANT?** This is important because the specifications for building codes and some energy rebates are given in *whole window values* vs. center-of-glass values. But remember that whole window values will have a lower SHGC, and a lower VLT, than center-of-glass values. Thus it is possible for a window film to qualify for a rebate even though it misses the target at first blush based on sample card data. This same consideration needs to be applied to certification procedures, such as LEED.

In order to help you navigate through this issue more clearly, whole window values have been calculated for six different “standard” (as defined by the NFRC) windows with all of our NFRC certified films. These values can be obtained on the NFRC website under the certified products directory. To get exact whole window values for your specific windows of interest, contact your 3M sales representative or 3M technical service for the necessary calculation. The information needed from you to perform this analysis will be size of window, frame type, and glass type.