PV Systems: Low Levels of Glare and Reflectance vs. Surrounding Environment

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EXECUTIVE SUMMARY

The glare and reflectance levels from a given PV system are decisively lower than the glare and reflectance generated by the standard glass and other common reflective surfaces in the environments surrounding the given PV system. Possibilities of random glare and reflectance observed from the air: the PV industry has multiple large projects installed near airports or on air force bases. Each of these large projects has passed FAA or Air Force standards and all projects have been determined as "No Hazard to Air Navigation". Although the possible glare and reflectance from PV systems are at safe levels and are decisively lower than other standard residential and commercial reflective surfaces, it is suggested that customers and installers discuss any possible concerns with the neighbors/cohabitants near the planned PV system installation.

EXPLANATION OF REFLECTANCE AND PV GLASS

SECTION 1

In general, since the whole concept of efficient solar power is to absorb as much light as possible while reflecting as little light as possible, standard solar panels produce less glare and reflectance than standard window glass. This is pointed out very well in US patent # 6359212 (Method for testing solar cell assemblies and second surface mirrors by ultraviolet reflectometry for susceptibility to ultraviolet degradation), which explains the differences in the refraction and reflection of solar panel glass versus standard window glass. Specifically, on a more technical level, solar panels use “high-transmission, low-iron” glass, which absorbs more light, producing smaller amounts of glare and reflectance than normal glass. In order to further explain these differences, we will need to explain some basic scientific terms that are used when discussing beams of light impacting the surfaces of other mediums, as the light beams leave air to enter the other mediums.

Reflection, Refraction and Angles-of-incidence

The imaginary line at 90° to a given reflective surface is called the Normal. The original beam of light is called the incident beam, and the angle at which it strikes the surface is called the incident angle. The quantity of reflected light is called the reflectance, and the angle at which it leaves the surface is the angle of reflectance. With transparent surfaces, the amount of light which bends slightly as it goes through the surface is called the refracted beam OR transmittance. These basic concepts of reflection (return of light from a surface) and refraction (bending and transmission of light through a surface) are pointed out in the first two figures on the next page. Both have a normal, an incident beam and an incident angle;

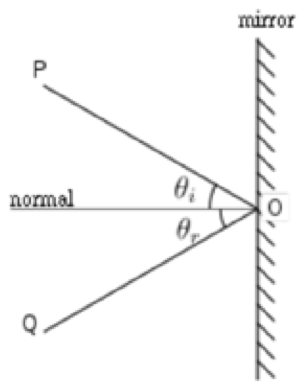

Figure 1.1; Reflection

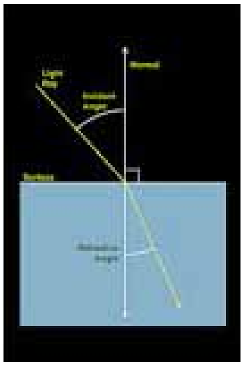

Figure 1.2: Refraction

Since our main discussion concerns types of glass and sunlight, we will further our explanation using glass as the example and speaking in terms of reflected energy percentages:

Incident light and Reflected Energy percentages. When a beam of light falls on a piece of glass, some of the light is reflected from the glass surface, some of the light passes through the glass (transmitted), and some (very little) is absorbed by the glass.

- The measure of the proportion of light reflected from the surface is called reflectance (reflection).
- The measure of the proportion transmitted is the transmittance (This is where the term high light-transmission glass comes from because the glass is formulated to allow more light to pass through its surface than would pass through a standard glass surface).
- The measure of the proportion absorbed is the absorptance (absorption (this amount is very small for clear glass – much, much smaller proportionately, than the other two components).
- Each quantity is expressed as a fraction of the total quantity of light in the beam. If the intensity of the beam is represented by the numerical 1, reflectance by R, absorptance by A and transmittance by T, intensity may be expressed as follows: $R + A + T = 1$, where glass is the glazing material pointed out in figure 2-2 in the next column (Figure 2-1 is a rough depiction of the percentages of light for each component of the equation).

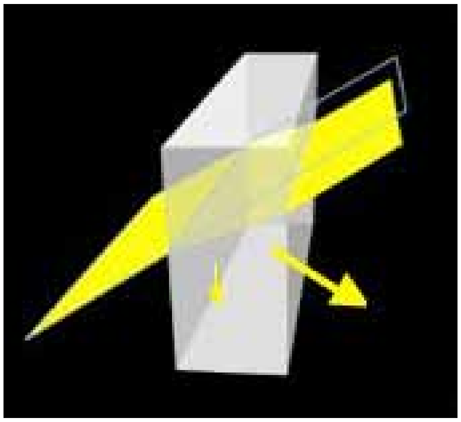

Figure 2.1: Depiction of resultant percentages for incident components

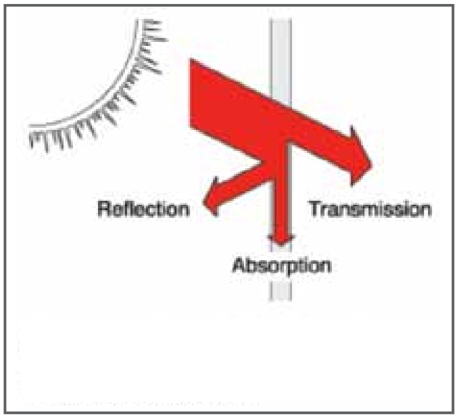

Figure 2.2: Solar radiation through a glazing material is either reflected, transmitted or absorbed

The reflection/refraction behavior of a medium is directly related to its index of refraction. The lower the index of refraction for a medium, the less light it reflects because the medium is allowing more of the incident beam to pass directly through (in our case, directly through the glass to the solar cells). The following list and graphical representation are one-to-one in the order of a materials' representation;

n	Common Reflective Surfaces (in surrounding environments for PV systems)	
2.500	Material Reflectivity (percent of incident light reflected)	Steel
1.980		Snow (fresh, flakey)
1.517		Standard Glass
1.500		Plexiglass
1.460		Plastic
1.333		Smooth Water
1.329		Solar Glass (high light transmission, low iron)
1.250		Solar Glass w/AR coating

Figure 2.3: Common Reflective Surfaces and Index of Refraction, "n" (the value "n" may vary by reference source, but the hierarchy of "n" values from one material to another will remain the same).

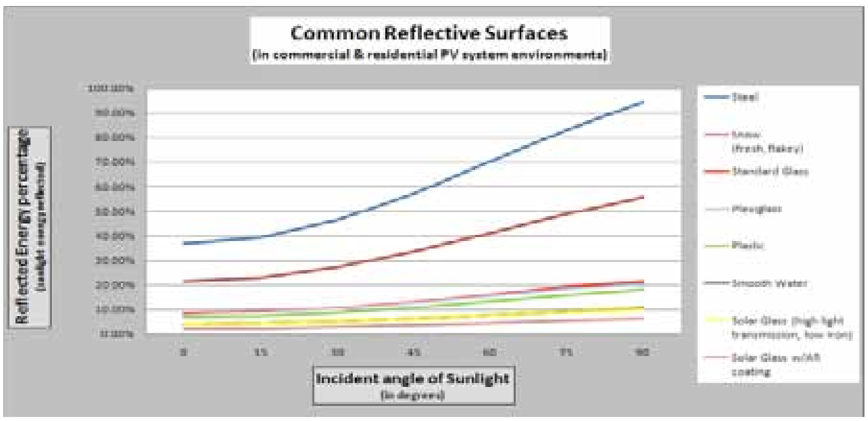

Figure 2.4: Common Reflective Surfaces and reflectance percentages.

In the below we show the reflected energy percentages of sunlight, off of some common residential and commercial surfaces. The legend and the graph lists the items from top to bottom in order of the highest percentage of reflected energy (as does the list of Common Reflective Surfaces); E.g. – 'Steel' reflects more energy than 'Snow'. 'Snow' reflects more energy than 'standard glass', etc. It should be noted from the graph and the table below, that the reflected energy percentage of Solar Glass is far below that of standard glass and more on the level of smooth water.

Common Reflective Surfaces (in surrounding environments for PV systems)		Incident angle in degrees						
		0	15	30	45	60	75	90
Material Reflectivity (percent of incident light reflected)	Steel	36.73%	39.22%	46.34%	57.18%	70.02%	83.15%	94.40%
	Snow (fresh, flakey)	21.69%	23.09%	27.29%	33.63%	41.23%	48.98%	55.59%
	Standard Glass	8.44%	9.01%	10.65%	13.12%	16.09%	19.10%	21.69%
	Plexiglass	8.00%	8.54%	10.09%	12.44%	15.25%	18.11%	20.56%
	Plastic	6.99%	7.46%	8.82%	10.87%	13.33%	15.83%	17.97%
	Smooth Water	4.07%	4.35%	5.14%	6.33%	7.76%	9.22%	10.47%
	Solar Glass (high light transmission, low iron)	3.99%	4.26%	5.03%	6.20%	7.61%	9.03%	10.26%
	Solar Glass w/AR coating	2.47%	2.64%	3.12%	3.84%	4.71%	5.59%	6.35%

Figure 2.5: Common Reflective Surfaces and reflectance percentage values.

Stippled Glass" and "Light Trapping"

In addition to the superior refractive/reflective properties of solar glass versus standard glass, many PV suppliers uses stippled solar glass for their panels. Stippled glass is also used with high powered telescopes and with powerful beacons and flashlights. The basic concept behind stippling is for the surfaces of the glass to be "textured" with small types of indentations. As a result, stippling allows more light energy to be channeled/transmitted through the glass while diffusing (weakening) the reflected light energy. "Light trapping" is also used by more high-quality PV suppliers. "Light Trapping" is the practice of using additional techniques like mirrors and natural surface textures to "trap" light within the layers of the solar cell, allowing even less light to escape by reflection. These concepts are why a reflection of off a high-quality solar panel will look hazy and less-defined than the same reflection from standard glass. This occurs because the stippled and light-trapping PV glass and cell texture are transmitting a larger percentage of light to the solar cell while breaking-up the intensity of the reflected energy.

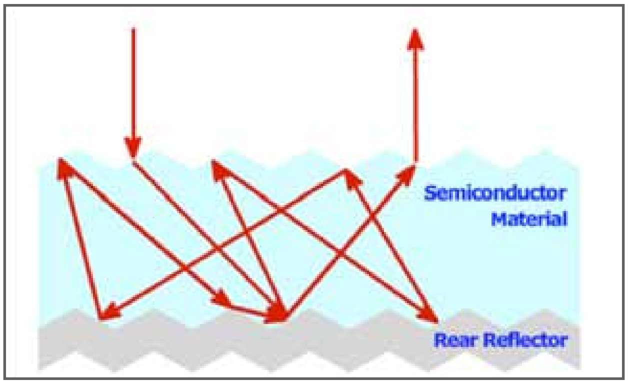

Figure 3.1: Light Trapping. More light energy is absorbed by the cell with each ensuing reflection of the initial light beam.

Try this basic optical experiment where ever a reflection comparison can be safely made between a high-efficiency/high-quality PV panel and a large window or plate of glass.

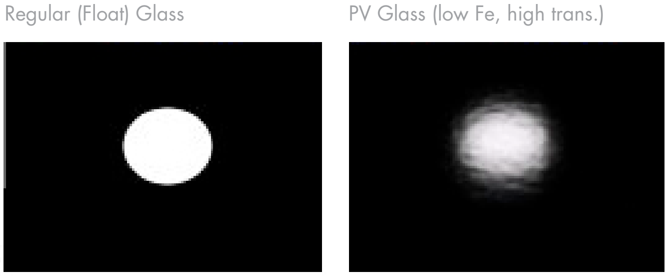

Figure 3.2: Reflection Characteristic example

No Hazard to Air Navigation

A handful of PV suppliers are proud to point out their PV installations at airports and on Air Force bases. The statement "No Hazard to Air Navigation" is the FAA status consistently applied to the large system arrays and power-plants which are continuously being erected on and around airports and Air Force bases. After covering the information prior to this section, it should come as no surprise that PV installations have this status concerning air navigation.

CONCLUSION

SECTION 2

In support of the executive summary, the studies, data and light-beam physics behind the charts and graphs prove beyond a reasonable doubt that solar glass has less glare and reflectance than standard glass. The figures also make it clear that the difference is very decisive between solar glass and other common residential and commercial glasses. In addition, not to be lost in the standard light/glass equations and calculations, PV solar-glass is often stippled and has a light-trapping, very photon-absorbent solar cell attached to its' back side, contributing additional factors which result in even less light energy being reflected.

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SECTION 3

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