The hidden costs of dirt on solar panels

Stephen Byers, Ritec International Limited
Innova House, 4 Kinetic Crescent, Innova Science Park, Enfield EN3 7XH, England

Keywords

Solar panels / durable glass surface protection / light transmission / energy output

Abstract

Mechanisms for producing or converting energy require some type of fuel and solar panels, both thermal and photovoltaic (PV), are no exception. However, solar panels have a major advantage because their fuel – sunlight – is free.

Other components of solar panels have price tags – from mechanical and electrical components to glass which is commonly used as a protective cover. Glass is normally used as a cover for solar panels because it not only helps to protect internal components from the elements, but also allows sunlight to pass through for conversion of solar radiant energy into heat or electricity.

Much time, effort and money is invested in making glass that meets specific requirements of solar panels, especially PV panels, for converting solar radiant energy into electricity. PV panels require special optical properties such as high transparency and light transmission.

To achieve these optical properties, dedicated float lines produce low iron glass and often an anti-reflective (AR) coating is added for improved light transmission. These added features and benefits require significant manpower, energy and other resources – and should mean real Added Value for solar panels over extended periods of time.

Unfortunately, shading gets in the way and reduces light transmission. Normally the term 'shading' is used to describe shadows from buildings, chimneys, antennae or other objects blocking sunlight, but one of the biggest causes of shading is DIRT.

A relatively small surface area of glass shaded by dirt can reduce energy output by significant amounts. For example, the effects of dirt on glass in solar panels is so great that it can quickly and easily negate the typical eight (8) percentage point increase in light transmission produced by a combination of low iron glass and an anti-reflective (AR) coating. As a result, resources invested in these two added value features easily become wasted.

Scientific studies and publications show that airborne contaminants reduce light transmission of glass with or without an AR coating by at least 6%, but this can easily increase to 20% or more depending on location and environmental conditions.

A relatively small surface area shaded by dirt can reduce energy output by significant amounts. For example, because of the ways that some PV solar panels work, their power output can be reduced up to 50% when only 1.4% of its surface area is shaded. Shading can be caused by leaves of a tree or dirt on the glass.

There is a common misconception that glass in solar panels is "self-cleaning" when installed at an angle of 15 degrees or more, i.e. that rain and wind will take away any dirt that blocks light transmission. This may be true under laboratory conditions or on a mountaintop, but not in urban, industrial or seaside locations.

Residues of airborne contaminants such as traffic film, industrial pollution and sea spray bond chemically to glass and are difficult, sometimes impossible, to remove from ordinary glass using conventional cleaning methods. Bonded contaminants reduce light transmission, causing a solar panel to fail in meeting its original performance specifications – causing higher operating costs and longer periods for payback of investments.

The effects of dirt on glass explains why the original performance of glass in solar panels, i.e. high transparency and light transmission, is often short-lived. The effects of dirt may also explain why glass in solar panels is normally marketed like a commodity instead of a speciality product based on higher performance over many years.

This paper discusses proven ways of protecting the Added Value of glass for the life of a solar panel by maintaining its original light transmission and power output.

The Importance of Clean Glass in Solar Panels

Glass is used in solar panels – photovoltaic (PV) and thermal – primarily because it is the material of construction that transmits the broadest spectrum of sunlight. Optimum light transmission is paramount because the objective of a solar panel is to convert radiant solar energy into a different form of energy – electricity or heat.

The need for optimum light transmission creates a need for clean glass. When new, glass promises transparency, clarity and cleanliness. Of these three promises, cleanliness is the most important because it affects the other two. Cleanliness of the glass depends on its cleanability, i.e. its resistance to surface corrosion and the adhesion of all types of dirt described below.

Above all, solar glass promises light transmission. There is a direct relationship between transmission of sunlight through glass in a solar panel and its output of electricity or heat. When light transmission drops, power

Figure 1 Solar glass promises high levels of light transmission

output often goes down more than the drop in light transmission.

In general, anything that interferes with light transmission is negative and anything that helps to maintain light transmission is positive. Therefore, it is important to consider ways of keeping the original light transmission, otherwise costs can easily rise and output drop to a point where investments in the options for glass will be lost or wasted.

The greatest negative effects on light transmission of solar glass are:

- glass surface corrosion caused by moisture and alkalinity;
- shading by objects such as trees, chimneys and snow;
- shading by dirt.

The greatest positive effect is durable, "non-stick" glass surface protection because of its resistance to surface corrosion and adhesion of dirt – helping to maintain the original light transmission and power output.

Figure 2. Snow acts as a serious source of shading.

The "Self-Cleaning" Solar Panel Myth

It is often believed that rainfall and wind will clean glass in solar panels installed at an angle of 15 degrees or more. This is easily proven to be a fallacy by simply pointing out that solar panels require cleaning. However, this misconception costs the solar power industry lots of time, effort and money - a situation that can be avoided by learning from the experiences of other markets such as architectural and marine glass.

In the past, glass in buildings and marine vessels was known to be highly susceptible to dirt and high in maintenance because it required frequent and sometimes intensive washing. However, this situation was accepted or tolerated because there was no practical solution at that time.

At that time it was often believed that dirt on exterior glass could easily be washed away by rain and wind, or by spraying the glass with tap water. This may have worked when the glass was new, but not after months or years of glass surface corrosion. It may have worked for "non-bonded" or "loose" dirt, but not for dirt firmly bonded to the glass surface as shown below.

Now, with the ever-increasing demand for solar panels, it is important to learn from the experiences of glass in other market sectors. Rain and wind will not keep the glass in a solar panel clean, regardless of its angle of installation, but there is now a solution to the problems caused by dirty glass. Durable, "non-stick" glass surface protection makes glass much easier to clean and keep clean, helping to maintain the original light transmission and power output.

Risks of the 'Numbers Game'

The solar panel industry relies on numbers for comparisons of output and other features, but these numbers are based on laboratory conditions and theoretical calculations instead of actual conditions. These numbers may not be achieved when solar panels are exposed to real life field conditions.

This situation risks solar panels losing their original added value. It also risks damage to the reputations of companies and the industry in general.

PV solar panels are normally advertised and compared by a number called 'peak power' or 'rated capacity' - a calculated figure that represents the potential power that a module can generate under certain Standard Test Conditions (STC) set by the industry. Other measures for solar panels include rated power, peak power, cell efficiency, module efficiency and capacity factor.

The peak conversion output of PV solar panels is typically about 15%, meaning that 85% of sunlight reaching the panel is not converted into electricity. The output is reduced even further by 'shading' as described below.

STC testing is generally based on conditions of 1,000 watts per square metre solar irradiance at 25 degC cell temperature, air mass equal to 1.5 and a certain standard spectrum. This is basically the level of sunlight at the equator at noon, but testing is under ideal conditions in a laboratory and does not reflect real world exposure.

This situation is similar to advertising a car with top speed of 300 miles per hour knowing this is not practical or possible in real life, or advertising 60 miles per gallon (mpg) knowing this mileage is only achieved on a test track under controlled conditions, and that 40 mpg is all you can achieve under actual driving conditions. Failing to meet users' expectations risks damage to the reputations of companies and the industry in general.

Shading: the Greatest Risk to Power Output

Shading is a major enemy of energy output simply because it restricts or blocks the transmission of sunlight through solar glass. This can be anything that restricts or potentially limits light transmission, including shadows of trees or features of buildings such as roofing, chimneys or antennae. Snow is another serious cause of shading as shown in the photograph.

Thermal solar panels are able to tolerate some shading, but PV panels are very sensitive to a small reduction in sunlight. For example, shading only one of 36 cells in a typical PV panel (2.8% of the surface area), causes a drop in electricity output of up to 50%.

Shading from the shadow of a distant tree or building reduces light transmission because the sunlight is diffuse or dispersed. Shading from directly above or on a PV panel, such as a tree branch or bird droppings, stops light from reaching PV cells in the panel and this can cause output of the panel to drop to 50% of its un-shaded value.

Glass surface corrosion can cause shading when it reaches a stage of etching the surface and making it appear white. The root causes of glass surface corrosion are:

- Moisture, both liquid and vapour – from seawater and tap water;
- alkalinity – including residues of seawater and hard tap water.

Moisture attack is one of the most common causes of glass surface corrosion and glass that remains wet, or even damp, is highly vulnerable. Alkalinity alone can attack the surface of glass and in concentrated form causes dissolution of the surface.

At even higher risk is unprotected glass exposed to a combination of moisture, especially in the vapour phase, and alkalinity – when surface corrosion can be quick and irreversible. This aggressive combination makes unprotected glass high in maintenance by creating an even rougher substrate and making it easier for contaminants to bond chemically, which further increases the rate of surface corrosion. As a result, over time glass loses its transparency and may become cloudy in appearance.

If glass does not have resistance to the causes of surface corrosion, it becomes increasingly difficult to clean and keep clean – making it high in maintenance. Cleanability becomes a real issue for glass without resistance to surface corrosion because cleanliness cannot be achieved easily without ever-increasing resources such as manpower, energy and cleaning materials.

Dirty Glass = Reduced Light Transmission = Lower Power Output

Another serious, but often unseen, cause of shading is dirt. The negative effects of dirt can be measured within a relatively short period of time. For example, a two-month study in central Athens (August-September 2009) using PV solar panels installed at an angle of 30 degrees and no cleaning of the glass showed significant losses in light transmission and energy output.

There are two general categories of dirt on solar glass:

- bonded dirt – cannot easily be washed away using conventional methods because it chemically reacts with glass to form a strong attachment

Scientific studies show that bonded dirt accounts for a minimum of 3% loss in light transmission and power output of PV solar panels.

- non-bonded dirt, commonly known as "loose dirt", such as dust, pollen and other particles – can be washed away using conventional methods because it is not chemically bonded.

Scientific studies show that non-bonded dirt causes a PV solar panel to lose light transmission and power output at least 6% and many times up to 20% or more.

Dirt, both non-bonded and bonded, are major causes of shading. A relatively small surface area of glass shaded by dirt can reduce energy output by significant amounts. For example, the effects of dirt on solar glass is so great that it can quickly and easily negate the typical eight (8) percentage point increase in light transmission produced by a combination of low iron glass and an anti-reflective (AR) coating. As a result, resources invested in these two added value features easily become lost or wasted.

Realities of Real Life Conditions

When new, glass in PV panels typically shows light transmission as follows:

- standard float glass, 3mm = 87%
- low iron glass typically adds four percentage points = 91%
- AR coating typically adds four percentage points = 95%.

With exposure to real life conditions, dirt can quickly and easily negate the above numbers:

- bonded dirt – typically a minimum reduction in light transmission of three percentage points, negating benefits of the AR coating;
- non-bonded or loose dirt – typically a minimum reduction in light transmission of six percentage points minimum, negating benefits of the low iron glass.

Therefore, dirt can easily negate the increases in light transmission initially gained by adding a combination of low iron glass and AR coating. Keeping in mind that these figures are considered as minimums, the actual reductions can easily be much greater.

Figure 3 shows the typical effects of dirt on light transmission and PV output.

Added Value Glass Options for Solar Energy Panels

Standard float glass adds value to solar energy panels because it protects internal components and is the material of construction that transmits the broadest spectrum of sunlight. More value is added through glass processing, depending on the type of solar panel and its purpose. The glass may be flat, curved or formed into cylinders. It can be toughened or laminated for reasons of safety.

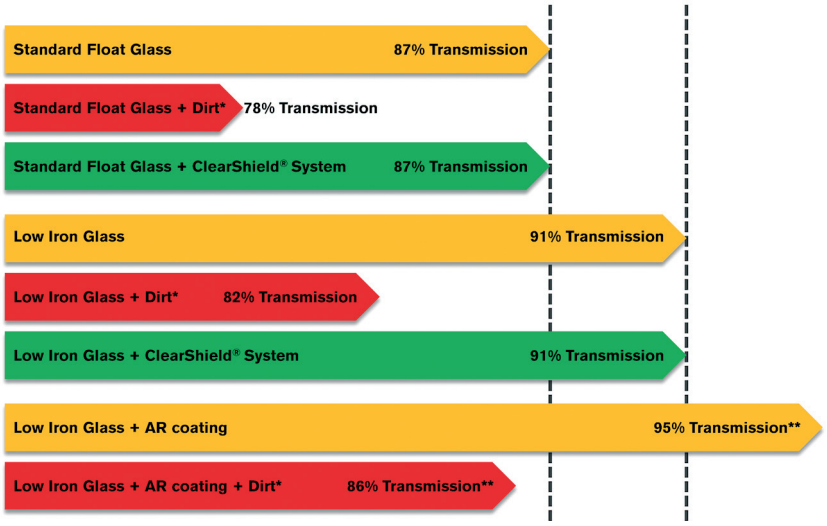
Options adding the highest values to solar glass are those proven to improve or maintain the all-important transmission of sunlight:

- low iron glass – specially produced to minimise the iron oxide that gives standard float glass a green tint and restricts light transmission.

Low iron glass, when new, typically has 91% light transmission (3mm thickness) compared with standard float glass at 87%, for an increase of four (4) percentage points. However, this initial improvement can quickly and easily be negated by dirt.

- anti-reflective (AR) coating – mainly based on silicon dioxide (SiO_2), the primary component of glass, has:
  - a microscopically rough surface with many places for dirt to bond
  - an affinity for moisture, a major cause of glass surface corrosion
  - low resistance to alkalinity, another major cause of glass surface corrosion.

AR coatings typically increase light transmission of 3mm glass by four (4) percentage points, so if applied to low iron glass the result is typically 95%.



Note: typical values for 3mm glass.
*Losses due to dirt are typical minimums of 3% bonded and 6% non-bonded for a total of 9%.
**AR coatings do not have a proven surface protection technology.

Figure 3. Typical effects of dirt on the light transmission and PV output of glass.

However, as described above, this initial improvement can quickly and easily be negated by dirt.

- ClearShield® durable glass surface protection with "non-stick" performance – based on a special polymeric resin with strong resistance to moisture, alkalinity and other causes of glass surface corrosion. The only glass surface protection proven in performance and durability for 30 years under actual field conditions.

ClearShield® works on any type of solar glass, including standard float and low iron, to help maintain the original light transmission and power output. To date ClearShield® has not been found to work on AR coatings, therefore optimum results for light transmission are achieved by applying ClearShield® to low iron glass.

Summary and Conclusions

Generally speaking, anything that helps to maintain the original light transmission of glass in solar panels – photovoltaic (PV) or thermal - is positive and anything that interferes with light transmission is negative. The importance of light transmission emphasises the need for glass that is clean, since energy output depends on the transmission of natural sunlight. Dirty glass means reduced light transmission and power output.

Maintaining the original light transmission and power output also maintains original added value. This is for the benefit of everyone in the supply chain – glass manufacturer, solar panel fabricator, distributor, installer and end user.

To achieve these valuable benefits, solar panel glass needs surface protection like most other materials. Long-lasting glass surface protection is not a cost, it is an investment that enhances both man-made and natural environments by helping to keep glass clean. Glass without durable surface protection meets industry performance standards at the time of supply but may not meet the standards afterwards, creating risks to the markets for solar energy panels.

The simplest and most cost-effective way of maintaining the original light transmission and power output of solar panels is durable, glass surface protection with "non-stick", easy-clean performance.

Ritec International Limited is the developer and manufacturer of ClearShield®. For more details see www.ritec.co.uk.