Making solar PV viable at sensitive sites

Aerial view of the PV system. More than 2,000 modules with Phytonics film physically rule out reflections onto the nearby runways

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Sites at airports, along transport corridors and in urban areas are increasingly being developed for solar power generation. The duration and intensity of disruptive reflections can determine whether a project is approved or rejected. A bio-inspired anti-glare film from Karlsruhe-based Phytonics GmbH makes sensitive sites usable for PV. A new car park at a Belgian airport demonstrates how this works on an industrial scale.


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PV deployment in Europe is accelerating rapidly. This is intensifying conflicts over land use and competing interests. More and more PV systems are being installed on rooftops, on open land, near airports and alongside motorways. Most conventional solar modules reflect incoming light so strongly that they can cause glare for nearby residents, pilots and drivers, potentially compromising road and aviation safety.

In Germany, the Federal Highway Authority has therefore, for the first time, issued uniform requirements for glare assessments of PV systems along motorways. At Amsterdam Schiphol Airport, glare from a nearby solar park led to temporary runway closures in 2025; a court later ordered the removal of part of the installation.

When 1% becomes a problem

The physics behind these incidents is straightforward. The sun has a luminance of around 1.6 billion candela per square metre. The human eye can experience glare at luminance levels as low as 100,000 cd/m². Even modern anti-reflective coatings reflect at least 1% of incoming light. That is enough to exceed commonly used thresholds for disruptive glare.

At grazing angles, this effect becomes much stronger. Modules marketed as low glare can still exceed the critical threshold of 100,000 cd/m² under oblique light conditions and in many cases even the one million cd/m² mark.

For project developers, this has serious economic consequences. Approvals may be delayed, investors may become cautious and entire sites can become unviable. Glare can be a decisive hurdle, especially at locations near transport corridors or in densely populated areas. Yet a considerable share of today's available PV potential lies precisely in these locations, as leaving these areas unused slows the pace of the energy transition.

Stricter rules at multiple levels

The recent initiative by the Federal Highway Authority is one element in a growing regulatory landscape. Its published framework paper sets a tolerance threshold of 30,000 cd/m² for PV systems along motorways. Germany's Federal Imission Control Act requires installations to avoid harmful effects on the environment, including significant nuisance to people. Glare caused by reflected light can fall within this scope.

In aviation, glint and glare are assessed as potential safety risks, particularly near approach and departure paths. International Civil Aviation Organization (ICAO) regional working groups and national aviation authorities are increasingly addressing glare from solar panels at or near aerodromes. This must be taken into account when PV modules are planned close to runways.

The market is also receiving a boost from the revised EU Energy Performance of Buildings Directive (EPBD). In future, new non-residential buildings and large existing buildings will have to be made 'solar ready'. The directive also requires the staged installation of suitable solar systems where technically, economically and functionally feasible. This brings PV closer to transport routes, airports and urban environments. Glare protection is therefore moving from an optional feature to a planning requirement.

Bionics as a model for light management

Over millions of years, plants have evolved microscopic surface textures that efficiently guide light into their leaves, even under oblique light conditions. The XRF anti-glare film from Phytonics GmbH, a spin-off of the Karlsruhe Institute of Technology, uses this principle. The film transfers the natural microstructure to a technical polymer layer, creating a microscopic topography with peaks of varying heights.

The anti-glare film consists of a scratch resistant functional coating on a UV and weather resistant polymethyl methacrylate (PMMA) carrier film. Polymethyl methacrylate is a transparent, lightweight thermoplastic. A permanent adhesive layer bonds the film to the solar glass. The functional coating improves the light collection under an oblique angle and scatters reflected light very strongly. As a result, reflected luminance remains below the critical threshold of 100,000 cd/m². The film is produced in a roll-to-roll process and is available as pre-cut sheets for individual module sizes.

These bioinspired structures help to optimise several properties at once. Across a wide angular range, the so-called incidence angle modifier (IAM) remains almost constant. This improves the angular stability of power generation. For example, at an oblique angle of incidence of 80°, it increases the electricity yield by around 40% compared to a standard anti-reflection coated solar module.

PMMA is one of the few polymers that remain stable in the long term in outdoor applications. The transparent roof of the Munich Olympic Stadium from the 1970s is made of the same material. The film withstands temperatures from -40 °C to +85 °C and more than 1,000 hours of salt spray testing without loss of function.

This makes it suitable even for installations near the coast or in climatically demanding regions. An integrated UV blocker also protects the modules against UV-induced degradation, a growing cause of permanent performance loss, particularly with modern cell technologies.

Industrial-scale deployment at Belgian airport

A car park at a Belgian airport shows how well the technology performs in practice. A large-scale PV system stretches across the roof. It delivers around 1,150 MWh of solar power annually. The electricity supplies the charging points and the building, with surplus power fed into the grid. This location posed a particular challenge for the planners. The car park sits directly alongside the runways. Approval was therefore subject to a clear condition: the modules must not cause glare for pilots or tower personnel. Even brief reflections would pose a safety risk.

The PV specialist Eoluz from Belgium took on the engineering, procurement and construction of the steel canopy with PV for the new car rental parking. The team installed more than 2,200 PV modules on the seventh floor of the building, a total of 6,380 square metres in size, with the Phytonics film. The micro-textured functional coating suppresses specular reflection, meaning the direct mirroring of sunlight. This prevents hazardous glare in the assessed scenarios.

The film's superior performance is supported by concrete measurements. At a light incidence of 10°, the reflected luminance is 2,000 cd/m². At 30°, it rises to 4,000 cd/m², and at 50° to 6,000 cd/m². Even at 70°, it remains at 23,000 cd/m², well below the threshold for disruptive glare. UV transmission through the film is 0%. Visible and near-infrared light, by contrast, passes through at over 98%. At normal incidence, the film reduces power output to 95 to 97%. Under oblique light conditions, the effect can be positive overall, because modules fitted with the film may generate more electricity than standard modules.

The project does not stand alone. In parallel, an 8.5 MWp installation was built at Brussels Charleroi Airport. There, the operator fitted around 5,000 of 12,000 modules with the anti-glare film. Both sites show that glare-free PV close to transport corridors can work at an industrial scale. They also provide an economic argument. Instead of requiring expensive redesigns or leaving roof areas unused, the film enables coverage with minimal additional effort.

From retrofit to series production

The film addresses more than project-specific glare problems. It also opens up new paths for the PV industry. Film application can be integrated into existing module production lines with little effort. Existing installations can also be retrofitted. Modules do not have to be replaced, avoiding high follow-up investment.

6,000 m² of PV modules stretch across the roof of the eight-storey car park of a Belgian airport

No smoke and mirrors: a clear view of the key figures for the XRF film

- Effect: The reflected luminance remains below the disruptive glare threshold for the eye of 100,000 cd/m² even at shallow light incidence.
- Optics: UV radiation is blocked; more than 98% of visible and near-infrared light is transmitted.
- Performance: Module performance is 95-97% at perpendicular light incidence; more angle-stable than standard modules at oblique incidence.
- Durability: Service life of more than 25 years, weathering test in accordance with IEC 61215 passed, fire protection class B-s1,d0.
- Structure & processing: PMMA carrier film with bioinspired functional coating; roll-to-roll production, applicable to new as well as installed solar modules.

Compliance with relevant standards is well documented. The film passes weathering tests in accordance with IEC 61215. These include a damp heat test over the course of 2,000 hours and a hail test with 35 mm ice at 28 m/s. The company demonstrated UV resistance in accordance with ISO 16474-3 in a 5,000-hour cycle. For reaction to fire, it achieves class B-s1,d0 in accordance with DIN EN 13501-1 and is therefore classified as flame-retardant.

The market is also moving. In the private rooftop segment, full-black modules have established themselves as the new standard in recent years. Modules with white intercell gaps, which were previously common, have largely disappeared. Market experts expect matt full-black to be the next trend. Such modules are designed to fit harmoniously into architecture and the landscape instead of appearing as foreign objects. Bioinspired anti-glare films provide the optical basis for this.

A learning curve for solar deployment

With each realised project comes a growth in knowledge on the interplay of optics, materials science and system engineering. This makes future planning simpler, lowers risks and increases the willingness to invest in PV projects at sensitive sites. Even a single piece of foil can therefore have a significant impact on the energy transition, especially at a time of volatile global fossil fuel prices.

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