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Construction and Operational Covers for Photovoltaic Parks

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Table of Contents

Executive Summary

As of today the worldwide installed capacity of photovoltaic power systems has reached around 40 GW. Though this number is still negligible compared to conventional power plants, there has been a dynamic growth in Photovoltaic (PV) system installations over the last years. The rate of growth in different countries varies greatly due to specific regulations and incentive schemes. For example in Germany the installed PV capacity in 2010 already accounts for one tenth of the overall installed power plant capacity due to strong supporting schemes. This leads to a significant new exposure to the insurance industry which this paper endeavours to assess.

From an insurance perspective this fast growing technology bears a lot of new aspects to be assessed. A variety of new hazards arise out of rapidly developing PV technology, often these risks are prototypical in nature. These concerns are not limited to the PV modules, but also include the other sub-systems, requiring the assessment of the system configuration and installation on a case-by-case basis. Furthermore the “usual” risks like fire and natural hazards still needs to be evaluated. With a steadily increasing number of PV systems also accumulation risks need to be taken into account as well.

Photovoltaic is a method of generating electrical power by converting solar radiation directly into electrical energy using semiconductors that exhibit the photovoltaic effect. Unlike solar thermal systems, solar cells have the advantage of functioning in any light, i.e. direct radiation and diffused daylight. Such installations may be ground-mounted or built into the roof or walls of a building, known as Building Integrated Photovoltaics or BIPV for short (approx. 2/3 of the installed capacity). Off-grid PV accounts for an additional 3 to 4 GW. Driven by advances in technology and increases in manufacturing scale and sophistication, the production cost of photovoltaics has declined steadily since the first solar cells were manufactured. Net metering and financial incentives, such as preferential feed-in tariffs for solar-generated electricity, have supported solar PV installations in many countries. PV plants are getting increasingly larger and already reach sizes of 250 MW demanding investments of more than a billion Euros.[1]

Figure 0-1: Projected Share by Source of Annual Global Energy Production

This IMIA WG paper concentrates on aspects relevant to insurance for construction and operation of large scale photovoltaic parks. We have limited our paper to industrial/commercial generation of electricity. In essence these are:

I – Technology
II – PV Market and Trends
III – Insurance Aspects
IV – Operating Experience
V - Insurance Statistics.

For topics such as the principles of functionality, the basics of manufacturing PV cells/modules or panels as well as their domestic applications we recommend the reading of the GDV Renewable Energies publication (2010).

1 Technology

1.1 Photovoltaic Cells and Panels

Solar cells form the smallest units within solar generation systems. Cells are combined into panels, typical ones featuring 36, 54 or 108 solar cells which can generate up to 100 watts by converting light energy into electrical energy. Solar cells will function in any light; however they should have similar electrical characteristics when connected. In Germany about half of the energy is derived from diffused daylight and the other half from direct sunlight. Only concentrating cells will work exclusively by direct sunlight.

The voltage generated in the cells depends on the photon energy (light colour), while the generated electricity depends on the intensity of the light.

Figure 1-1: Photovoltaic Standard Cell [2]

A PV panel usually consists of a covering glass pane, the encapsulating polymer and the backing foil. The encapsulating material consists of PV cells embedded with their soldered conductors. A backing glass pane is also conceivable. PV panels are available in many different designs: Frame or frameless, as a solar roof tile, in reels, as an insulating glass pane for window and roof glazing, etc. The largest serially produced panels and thin-film panels are manufactured by Signet Solar.

In literature panels are distinguished by type of cell

- mono-crystalline (c-Si)
- poly-crystalline / multi-crystalline (mc-Si)
- thin-film panels (a-Si, CdTe-, CIS- or CIGS panel)

Figure 1-2: Photovoltaic panels [3]

Most of the cells produced today are silicon based, however, silicon cells only use a limited band between 400 to 1.100 nm within the light spectrum. Consequently, research is endeavouring to find and use alternative materials with a wider light spectrum that also includes UV light. Below is a list of the customary cell materials and their abbreviated designations:

Designation	Abbrev.
Crystalline silicon	c-Si
Amorphous silicon	a-Si
Micro-morphous silicon	µ-Si
Tandem of amorphous and microcrystalline silicon	a-Si/µc-Si
Copper indium diselenide	CIS
Copper indium gallium selenium (depending on cell type the S can also stand for sulfur)	CIGS
Cadmium telluride	CdTe
Crystalline silicon on glass	CSG
III-V semi-conductor	III-V
II-VI semi-conductor	II-VI

Table 1-1: Customary cell materials and their abbreviated designations

1.2 Types of PV collectors

Laminate panels – Thin-film solar cells are laminated on a base film which, in turn, is welded onto a base, e.g. steel sheet or used as a covering.

Concentrator panels (CPV) - CPV is the generic term for different concepts that use optical systems such as mirrors and lenses to concentrate the light on small solar cells.

Tube collectors - A double tube with CIGS (copper indium gallium diselenide) solar cells mounted in a helical manner on a base cylinder that is housed in a closed glass tube. The space between the two tubes is filled with oil. Each panel consists of 40 tubes mounted within a frame.

Transparent and thin-film panels – Very thin layers of semi-conductor placed on substrates or superstrates (glass, ceramics, metal) produce thin-film panels (opaque or semi-transparent depending on substrate/superstrate). They have lower efficiency (6 to 11%) than crystalline panels. Amorphous cells can be semi-transparent by removing part of the coating by a laser process.

Bifacial PV - Bifacial panels generate 5 to 30% more energy compared to monofacial panels by taking advantage of ambient light on the back face along with direct sunlight at the front face.[4] Minimal price difference between bifacial and monofacial panels makes bifacial modules a realistic alternative. Cell efficiencies in the range of 15% to 24% are reportedly achievable.

1.3 Performance/Yields

The nominal power of photovoltaic systems is usually indicated in kilowatt peak (kW_p). Peak refers to the performance under Standard Test Conditions.

These standard conditions are defined as follows:

- Solar irradiance 1000 Watt/m²
- Module not hotter than 25 °C
- Air mass 1.5 (Air Mass = relative measure for the influence through the thickness of the earth's atmosphere)

These test conditions serve for the standardisation and comparison of solar modules. The electrical values of the component parts, under these conditions, are internationally standardized and are indicated on data sheets.

The energy yield depends strongly on the geographical location of the site of installation. Due to the high irradiation density and the related high energy yield in Locations such as Chile (2400 kWh/kW$_p$/year), California (2150 kWh/kW$_p$/year), Australia (2300 kWh/kW$_p$/year) or India (2200 kWh/kW$_p$/year) very favourable electricity generation costs can be attained.

Figure 1-3: Average solar irradiance, worldwide and in Europe, in watts per square meter. (For a horizontal surface, solar panels are normally mounted at an angle and receive more energy per unit area.)

1.4 Efficiency

Cell efficiency indicates how much of the incoming sun energy is transformed into electricity. The current typical panel efficiency rate is between 14 and 19.6% (sun power SPR-320-WHT-D panel efficiency). A distinction must be made between panel efficiency and cell efficiency. Cell efficiency is significantly higher than the panel efficiency rate.

Organic solar cells currently produce an efficiency of up to 8.13% (as of July 2010), thin-film modules based on amorphous silicon approximately 5 to 13%, solar cells made of polycrystalline silicon 13 to 18%, cells made of monocrystalline silicon between 14 and 24%. Under laboratory conditions concentrator cells – the incoming light is optically concentrated and focused to solar cells – can achieve more than 40% efficiency.

A substantial increase in efficiency can be achieved by reducing the proportion of reflected solar light. Black silicon avoids these reflections almost completely and in the future could increase the efficiency by approx. 30 to 40% compared to conventional silicon modules. Black silicon is a surface modification of the crystalline silicon. Through high-energetic bombardment with ions or ultra-short laser pulses acicular structures emerge on the surface, which reduce the reflection significantly. Currently this technology can only be simulated under laboratory conditions.

Research pursues the following objectives:

- Increase efficiency, i.e. increasing power generation with the same area and light intensity
- Reduce silicon consumption
- Use other materials to substitute silicon
- Change the design of the cells and panels to improve performance (e.g. pyramid structure of the solar cells; concentrator solar cell)
- Reduce the production costs.

1.5 Testing and Safety Standards

Panel certification is desirable, but still not a must. Various international testing labs have testing and certification standards. In Germany corresponding certificates are issued by TÜV Rheinland, VDE Prüf- und Zertifizierungsinstitut and Gütegemeinschaft Solarenergieanlagen e. V.

Basic standards, as well as standards for PV panel testing, include

- IEC 61215:2005 Terrestrial Crystalline Silicon PV Panels
- IEC 61646:2008 Terrestrial Thin-Film PV Panels
- IEC 61730:2004 PV Panels - Safety Qualifications Parts 1 and 2
- IEC 62108:2007 Concentrator PV (CPV) - Panels

Apart from ammonium, these standards take into consideration all influencing magnitudes that are responsible for climatic stresses and aging (degradation). As of 2008, all old TÜV certificates became invalid.
For an index of all certified panels please see the web link of the European Commission:
http://re.jrc.ec.europa.eu/solarec/index.htm

Hail test
Hail impact is included in panel design testing, for example, in Germany ice balls with a diameter of 25 mm are shot at 11 impact points at a speed of 23 m/s in compliance with IEC requirements. In Great Britain the hail test is carried out with steel bullets of 40 mm diameter.

For Enclosure (see chapter 1.7)
A number of standards exist worldwide to define the type and applicability of enclosures. In the U.S. the NEMA-Standards, Publication 250 (National Electrical Manufacturers Association) exist, while in Europe the IEC-International Protection (IP) Standard 60529 (International Electro-technical Commission) is prevalent. IP is sometimes converted into Ingress Protection Code.
The IP code describes the ingress protection against contacts, access to hazardous parts and ingress of solid objects. The IP code has defined ingress protection as a two digit code while NEMA only uses one digit.
IEC and NEMA classifications cannot exactly be equated. NEMA does not test for environmental conditions like corrosion, rust and oil. IEC 60529 does not test for damage of equipment, risk of explosion, moisture condensation and fungus.
The IP test does not include aging. Because of this the classification is not provided for the full lifetime of the enclosure.

1.6 Auxiliary Systems

1.6.1 Panel frames

Panels are available with and without frames. Frames are made of aluminium, stainless steel and plastic. The frames protect the glass edges from damage, provide reinforcement and are used to secure the panel to the substructure.
The panel data sheet or the installation instructions should stipulate how the panel is securely mounted, free of all stresses and in conformity with the manufacturer’s specifications, and list the facilities to be used for this purpose.
The frame must be designed to prevent dirt and water deposits, even when installed at a shallow angle. Penetrated water and condensation must be able to drain out [RAL-GZ 966]. Water that is unable to drain out will eventually burst the frame in freezing temperatures - also known as “frozen frames”.

1.6.2 Panel terminal boxes and cable outlets

A critical source of faults is the cable lead-through. Cables are either conducted through a hole in the back or through the glass edge. A terminal box is bonded over the point where the cable leads out at the back.
In both cases it is very important that no moisture can enter the terminal box or the panel. This requires NEMA 3S / IEC IP54 degree of protection or higher (please refer to chapter 1.5 regarding the rating for Enclosures). The panel terminal boxes must be designed and rated by the manufacturer in such a manner that they withstand all electrical, thermal, mechanical, corrosive and weather-induced conditions when they are used as intended.

1.6.3 Plug connectors

Photovoltaic plug connectors are important components of a PV installation. Their quality is the vital precondition for safe and trouble-free operation of the entire installation. Currents of up to 40 ampere (A) and voltages of up to 1,000 volt (V) flow through PV lines. Extensive quality control and testing criteria are required for plug connectors.

1.6.4 Generator terminal box

Panels are circuited in parallel and in series. Series circuited panels are known as a string.
The strings are brought together in the generator terminal box which also contains the equipotential bonding conductor or the earthing conductor and the overvoltage diverter.
The terminal box can also house monitoring devices that respond in the event of a fault.
The generator terminal box must be suitable for at least the expected service life of the panel.

1.7 Inverter

Photovoltaic panels generate direct current (DC). This has to be transformed into alternating current (AC) compatible with the national voltage/frequency. This transformation is carried out by a power converter/inverter. With inverters a distinction is made between central and string inverters. The string inverter is primarily intended for small installations but also used for large-scale power plants.

Central inverters are usually used in large-scale installations and require a separate transformer that steps up the AC side to 12.4 kV (in Europe 10 kV or 20 kV) or higher and to 50/60 Hz which also provides electrical isolation.

Another purpose of the inverter is to protect the mains and the installation through two independent switching elements (ENS) that monitor the frequency, voltage and impedance of the mains. If limit values are exceeded, then the device will automatically effect a 2-pole disconnection of the inverter from the mains.

For PV installations with an installed capacity exceeding 100 kW_p remote controlled performance reduction for the power inverter is demanded in Germany.

Transformers are not required if the PV panel voltage is clearly above the peak value of the AC (above = 235 V). However, this eliminates the electrical isolation and special circuit protection specific to DC systems are then required.

1.7.1 Additional functions

Inverters fulfill a number of additional functions, depending on the given manufacturer and the type of inverter. These can include:

- Data collecting – e.g. temperature within the inverter, voltages at the inverter input and output, the operating duration, quantity of electricity, device status, faults, etc.
- Installation monitoring. Fault messages can be transmitted via an interface
- Evaluating software. Optional software to evaluate received data
- ON/OFF switching
- Maximum Power Point (MPP*) - Tracking. Solar panels generate maximum power at a defined current-voltage relation. Inverters with MPP tracking search for the given voltage/current at which the power reaches its MPP

1.7.2 Panel inverter

Originally introduced in the 1990's, a high failure rate and low efficiency led to their discontinuance. In 2008 this type of inverter reappeared on the market. Thirteen companies in the USA, but also 3 German companies, are offering panel inverters. These are primarily produced for the U.S. market, but 8 companies are planning to market them in the European Union. Long-term experience is not yet available.

1.7.3 Inverter Installation Rules

Inverters are produced for different ambient conditions. It is therefore imperative that the manufacturer's installation rules are strictly observed.

The following is stipulated by the manufacturer:

Ambient temperature: Inverters will often require active cooling or heating if the ambient temperature goes below/above the permissible temperature. The relative humidity can vary between 0% and 90%, rarely 100%.

Point of installation: Inverters are produced for outdoor and indoor installation.

Falling short of the dew point: Some manufacturers specify that ambient conditions must not fall short of the dew point. Such inverters may require some form of heating.

1.7.4 Inverter reliability

Long-term experience with many inverters revealed an average defect-free period of operation of 5 to 8 years. Extensive repairs or a complete exchange is generally necessary after 10 operating years. Inverter components can reach temperatures in excess of 90° C during operation and research indicates that heat may be a major cause of failures.

Since 2008 high efficiency inverters (as high as 98%) are being marketed that also have lower component temperatures of approx. 65° C. This new type of inverter is expected to reach an operational lifetime of 20 years. Long term experience is still needed to determine the life span.

The loss of cooling fans and dust accumulation also can cause premature fan failure.

1.8 Installation Types

1.8.1 Building Integrated PV (BIPV)

In addition to the generation of electricity BIPV (building integrated PV) systems also fulfill other functions within the building, e.g. cast shadow or insulate against noise; as a "building material" they become an integral part of the building’s cladding (e.g. facade, roof or parapet):

- Sloping roofs: Common on residential buildings. Attention has to be paid to the roof’s tightness against moisture, and adequate back ventilation of the panels has to be ensured.
- Metal Profile System: Secures the standard panels to the roof substructure.
- Flat and vaulted roofs: PV panels can be integrated into all types of flat roofs.
- Solar roof webs: a thin-film laminate without frames, form the top layer on the hard roofing.
- Canopies: Can be mounted at optimal angle of 30° to 45°, back ventilation improves efficiency.
- Facades: Like a standard glass facade, but circuited PV. Requires a proof-of-stability certificate.
- Curtain wall facades: Two-shell structures; the outer shell is an integral part of the architecture.
- Structural sealant glazing (SSG): Glass element bonded to a frame secured to substructure.
- Non-ventilated facades: Takes over all the functions of the surface finish of a building, e.g. statics, heat insulation, weather and noise proofing.
- Double facades: Involve additional glass cladding in front of an existing full-scale facade in order to improve the climate. PV panels provide temperature and noise insulation.

1.8.2 Hybrid Systems

Hybrid renewable systems combine two or more types of renewable energy sources. PV plants are usually combined with wind turbines or diesel generators and often located on islands. The largest European hybrid system incorporating PV is on Pellworm Island, Germany (PV and wind turbines).

A recent trend is constructing PV systems on the same site as solar thermal plants, such as development at Fort Irwin, California, in order to take advantage of weather conditions and inexpensive land.[5] The solar thermal system, which typically incorporates a heat storage system, enables a smoothing out of power production fluctuations. The PV system, conversely, boosts maximum power output while also providing contingency should problems occur in the solar thermal system.

1.9 Assembly Systems and Ground Mounted PV

Ground mounted systems require a base frame with the principal requirement being stability that withstands the strains and stresses of environmental loads and weather conditions. In addition to adequate strength, such a mounting system must be corrosion proof for 20 to 25 years.

1.9.1 Design and stability certification

The design and stability certification of a structural system, or of the unit solar generator and base frame, must at least be based on code requirements of recognized building standards for local conditions for snow loads, wind and seismic activity. Mounting arrays can be subdivided into fixed and tracking systems.

1.9.2 Fixed systems

Fixed systems have stationary panels that are firmly anchored in the ground or feature a raft footing. Fixed, roof mounted system either have ballasted raft footing or are anchored to the roof. Plastic or concrete troughs filled with gravel serve to anchor the systems and they often lack the necessary wind resistance. Systems secured to the building structure may afford better wind resistance.

1.9.3 Tracking systems

Panels achieve their highest generating rates if the sunlight falls always vertically onto the surface. Hence tracking systems follow the sun from East to West during the course of the day to achieve an additional roughly 25% generated yield compared with fixed systems.

The disadvantage compared with fixed systems is their higher production cost and maintenance and repair costs during operation. Tracking systems incorporate moving parts that are subject to increased wear. Another disadvantage is increased power consumption.

Figure 1-2: Tracking System [6]

Single-axle tracker can either rotate around a vertical or horizontal axis to follow the sun in one direction and improve the angle of exposure. Dual-axis tracking aligns the panels in such a manner that the sun's radiation is always vertical in relation to the panel surface by rotating horizontally and vertically. This system is expected to generate the highest amount of electricity. This system is a must in connection with concentrator technology. It requires an accuracy of 0.1 degree.

1.9.4 Foundation of Ground-Mounted Systems

Ground-mounted systems require their own foundation. The type of foundation depends on the level of dynamic and static loads and the soil conditions based on geotechnical surveys and wind speeds at the site. Shallow foundations are normally made of reinforced concrete. It can be of cast-in-place as well as of precast concrete. Ballasted foundations are not suitable for larger installations. Foundations should allow for some soil settings, erosion or heaving.

As the tracking system is vulnerable to storm it should resist the highest wind speed expected on site plus an additional safety factor. Ballasted foundations seldom comply with the standards.

As systems sizes get larger, there are reasons to consider alternate foundation types, such as driven-steel piles, ground screws and drilled piles. Where soil does not contain considerable rocks or subsurface containments the driven-steel pipe is the most commonly used type of foundation. The pile-driving operations have to be carried out by expert companies. All pile-driving actions that do not comply with the guidelines have to be agreed upon with the manufacturer of the mounting system.[7]

Manufacturers of PV modules and mounting systems need to address structural safety seriously and provide design statics for all of their products.

1.9.5 Electrical design Issues

A protective earth (PE) connection ensures that all exposed conductive surfaces are at the same electrical potential as the surface of the earth which is accomplished through a grounding electrode system in accordance with applicable electrical codes.

1.9.6 Wind, snow and seismic zones

Factors such as environmental loads and weather conditions in the project area, including wind and snow, determine the system's structural design. European storm Kyrill demonstrated that many systems were inadequately designed; ballasted raft footing roof-top installations were most affected by the storm. Tracker systems should move the panels to a position with the least wind exposed profile at the wind velocity defined by the manufacturer. However, many systems were unable to do this at the time of the storm. Some of the systems were so severely damaged by gusts of wind that they were then unable to reach the required horizontal position. It appears that single-axle systems are significantly less prone to damage than dual-axis systems.

A market survey indicated that the wind velocities approved by the manufacturers varied between 100 and 300 km/h, however variations in design criteria make it important that extreme caution be exercised in matching design parameters to wind conditions and design codes must be followed. Standardised specifications are definitely lacking, as manufacturer's design specifications are not necessarily comparable. Criteria vary including wind design loads based on limited panel surface exposure (assuming that the installation is moved into a safe position) or regarding an absolute permissible wind velocity.

Snow and ice can lead to shadowing of the panel. In areas with significant amounts of snow, the panel should be installed high enough so that the expected highest snow level does not reach the bottom edge of the lowest module.

1.9.7 Facade installations

PV installations on facades must be in keeping with specific guidelines pertaining to glass structures as there are no special standards for facade installations. Consequently, all corresponding standards and approval conditions of the building industry must be taken into account, and the installer must also regard existing standards as "State of the Art". This applies particularly to public buildings where the area in front of the facade is generally accessible. Vertical and horizontal (canopy structures) both may cause injury to pedestrians by falling glass fragments.

1.9.8 Proof of stability (statics)

For proof of stability a distinction must be made between system statics and "verifiable statics". System statics is concerned with confirming the stability of the securing elements and the panels. In no way should this be equated with the statics for the building.
Many manufacturers of mounting systems, but certainly not all of them, provide system statics in connection with their products.

The building forms the interface. The load-bearing capacity of a building without corresponding capability proof cannot be established by the panel installer or system supplier. Verifiable statics requires information on the manner of construction and state of the building. Such data must be obtained either from the original statics calculation or established by an architect or statistician, and this requires "in-situ" measurements.

1.9.9 Cables

The following are requirements for cables:

Mechanical strength	Pressure, tensile, bending and shearing stress
Weather resistance	UV, ozone, heat, cold, e.g. -55° C to + 125° C
Short circuits and ground leakage protection	Individual conductors with double insulation

Table 1-2: requirements for cables

In 2010 there were no guidelines for solar installations which define the requirements expected of cables. Cables can be subject to UV – A and UV - B degradation as well as ozone.

1.10 Degradation and Common Failure Points

1.10.1 Degradation (Performance loss due to aging)

There are mixed reports regarding age related degradation. Much of the quoted degradation data are based on older technology. Many studies examined older panel types for degradation, but these examinations are not representative. Past production processes assumed a higher degradation rate than is the case with present-day processes. For instance, the Fraunhofer ISE Institute in Freiburg did not measure any degradation during a 10-year period, while the LEE Tiso Institute (CH) measured an annual degradation rate of 0.21% over a period of 21 years.

One of the reasons is due to the fact that measuring procedures were not standardized and the measuring tolerances of laboratory equipment are in the order of +/- 3%. Consequently, measurements conducted in the past are not comparable with present-day examinations. To obtain a statement on long-term degradation, the measured values must always be related to the initial values. To increase the meaningfulness, relative measurements can be carried out where the degradation is compared with non-aged panels of same charge. This procedure resulted in a measuring uncertainty of max. 1%.

The following lists potential degradation causes:

1.10.2 Contamination of the silicon with iron or oxygen atoms

Boron Contamination:
Ethylene vinyl acetate film (EVA) - Studies suggest this most common encapsulation material may cause degradation due to the effects of the decomposition products, especially acetic acid, on the metallic cell connectors, the PV cells and the polymer itself.

Interaction between inverters and thin-film panels may be responsible for accelerating the aging of the transparent layer (TCO layer).

The effects of agricultural emissions such as dust and ammonia on panels and inverters have not yet been fully researched but may be a cause considering the high number of farm installations.

Since experts are still discussing the question of degradation, one should proceed from a crystalline panel degradation rate of 1.1% during the 1st year, followed by 0.25%/a during the subsequent years.

1.10.3 Edge and back sealing

Penetrating moisture corrodes cells and connectors causing failure. The sealing material is critical. In the past, EVA was used to seal off the edges, but the material does not appear to be suitable and is being replaced by polyisobutylene (PIB).

1.10.4 Hot Spots

Hot spots are formed when cells become covered to a lesser or greater extent, for instance by snow, bird droppings or leaves. The cell then becomes a consumer instead of generator, there is a voltage drop due to the resistance and it becomes hot due to current flows. Heat generation can actually result in a fire risk. Defects can also cause this e.g. cell bleaching, bubble formation within the plastic, degradation of the plastic, and cell corrosion. Bypass diodes are circuited parallel to the individual cells to prevent the formation of hot spots by allowing continued generation at lower output.

1.10.5 Delamination

Power losses of up to 43.6% have been measured as a result of delamination. This was a bigger issue on older units and is not common any more.

1.10.6 Physical aging

Physical aging covers primarily such effects as the absorption and release of low-molecular constituents, after-crystallisation, re-orientation of molecular chains and the relief of internal stresses formed during processing.

1.10.7 Chemical aging

Chemical aging is attributable to oxygen or aggressive chemicals and these usually result in molecular chain splitting. Chemical aging is triggered by increased operating temperatures or energy-intense radiation. The most frequent cause of chemical aging is oxidation. Here, a distinction is made between thermo-oxidative (heat + oxygen) and photo-oxidative processes (UV radiation + oxygen).[8]

1.10.8 Arcing due to Contact Failures

While voltage in a PV-circuit is very low, the electrical current may become high. A sudden interruption of such a strong current may create an electric arc, which in contrast to arcs in AC circuits hardly extinguishes itself. Ongoing arcs create extremely high temperatures leading to ignition and finally to a fire incident.

Also slow degradation of electrical contacts (e.g. in connectors, plugs) the electrical resistance may slowly increase and may heat up surrounding materials until ignition temperature is reached.

Since electric arcs generate high frequency noise, detection is possible to a certain degree. Arc detectors for remote detection of dangerous arcs are electronic measuring devices, which bear a considerable complexity. Hence installation of arc detectors into existing PV plants needs professional consulting. In the future it is expected, that these detectors will be an integrated part of new inverters.

1.11 Lightning and Overvoltage

The reasons for lightning currents and overvoltage are:

- Lightning strike
- Overvoltage due to atmospheric electricity (inductive, galvanic and capacitive coupling)
- Switching of inductive and capacitive loads (e.g. electric motors, compensation installations)
- Electrical surges due to switching operations of power supply units and frequency converters

External lightning protection
External lightning protection covers all facilities and measures to collect and conduct off lightning surges. A lightning protection system consists of a collecting device, the actual lightning conductor (at least 16 mm² copper conductor) and the earthing system.

Internal lightning protection
The probability of indirect lightning is much higher than a direct lightning strike. Inductive couplings can arise in the PV panels, the panel lines and the main DC power line. Surge arrestors protect the PV installation against inductive couplings and overvoltage surges in the mains. The surge arrestors

are usually installed in the generator terminal box. External protection against atmospheric overvoltage can be dispensed with if the manufacturer provides the PV components with corresponding overvoltage protection (usually varistors).

A decision has to be made as to whether or not and how each individual PV installation should be earthed. This cannot be generalised in view of the great diversity of requirements.

If a lightning protection system is mandatory for a given building, then the same lightning protection class applies to the PV system on the building. The aim is to ensure that the PV panels cannot be struck directly by lightning. However, this does not mean that the PV installation can be directly connected to the lightning conductor! In fact, it may even be necessary to avoid direct connections with collecting points! They are only permissible if the separating distance between the PV system and the lightning conductor cannot be observed. The separating distance is the spacing that is required to avoid dangerous flashovers. 0.5 m is considered to be the general rule.

A lightning protection system requires regular maintenance. Contacts can become loose or corroded. Inspections should be carried out at three- to five-year intervals.

1.12 Fire Fighting Principles

For a secure fire-fighting operation it is necessary to know all the risks which are generated by the electric current in a PV plant. Voltages at PV plants may exceed physical touch hazard levels of 50 VDC and 120 VAC. Therefore it is necessary to locate the main circuit breaker as close as possible to the power source (PV module). DC circuit breakers (built on or in the inverter) provide this possibility. It must be taken into account that even after disconnecting, the modules and its connections still remain energized as long as they are exposed to any light.
PV plants are often unmanned. An online monitoring system is helpful to control the plant conditions, to identify damage early and to take measures in order to avoid/reduce claims.

In order to avoid fire, the PV plant should
- be equipped with sufficient fire fighting facilities
- be equipped with an online monitoring system
- be equipped with an arc detector
- be protected against unauthorized access (fencing and CCTV monitoring is suitable)
- have a wide gravel pathway around the plant to provide protection from exposures

Following risks are typical for fire fighting of PV plants:
- PV plants can hardly be switched off entirely and even in darkness dangerous voltages can be generated. Any illumination of the scene may generate additional electric voltage
- The PV plant may carry electric voltage up to the DC disconnect
- An active destruction of the modules doesn't prevent de-energizing
- A short circuit can energize the fixing systems
- Fire water introduces electrical hazards
- Consider the stack-effect on facade plants
- Damaging of cable insulation caused by fire

Due to these hazards, the following measures should be taken before and during fire fighting operation:
- Determine the location of the parts of the plant (AC fuses, DC circuit breaker, wiring, inverter ...)
- Adhere to interconnection of big plants (wiring diagram)
- Switch off AC and DC side
- Prevent unintentional restoration of electrical power
- Use nozzles licensed for electric plants only

- The usage of foam is only allowed if the plant is on zero potential (cf. DIN VDE 0132)
- Adhere to distance to electric plant components (cf. DIN VDE 0132)

1.13 R & D activities

The following research and development needs to be undertaken:

- Development of new component structures for solar cells
- Solar cells with highly structured absorbers and nanostructures on the surface
- Production and use of thinner and even ultra-thin silicon wafers (currently 200-300 µm thick) and its lower-cost production
- New kinds of cell structure
- Achieving higher efficiency
- Simplified process technologies
- Research into materials and process for thin-film technologies
- The development of module technologies. PV-cells must be encapsulated to ensure the long-term and safe operation

1.14 Underwriting Recommendations

- Underwriters need to keep themselves informed on developments and technological risks resulting out of the fast development of the technology (penetrating moisture, hot spots, delaminating and other risks mentioned above)
- use a standardized questionnaire to assess the technological risks mentioned above
- check whether inverters, mounting systems and modules are installed as specified by the manufacturer
- If driven piles are used, you should consider the soil condition to its suitability for this establishment. Therefore a site investigations report is requested. [9]
- make sure that there is an adequate fire protection and fire-fighting system in place, already during pre-storage and the construction phase
- check whether there is a maintenance contract in place, and if not who will be responsible for regular check-ups (especially for tracking systems)
- verify whether general rules of technology are recognized [10] (e.g. a frame manufacturer may not overlap the module manufacturer specifications. The installer, who is responsible for its delivery, must consider this [11])

2 PV Market and Trends

2.1 Manufacturers

The production of specialised equipment for the PV manufacturing industry has become a significant business in its own right. Activities and products in this sector of the PV industry value chain include chemical and gas supplies, abrasives and equipment for cutting wafers, pastes and inks for cells, encapsulation materials for modules and specialized measurement equipment for use in production processes.[12] The relevant product and money flows can be seen in figure 2-1.

Figure 2-1: Photovoltaic (PV) industry supply chain [13]

The top ten manufacturers are accounting for 45% of the MW_p output of the overall industry:

Manufacturer	Turnover in Million	Output in MWp
First Solar	2,066 USD	1,228
Sharp	2,214 USD	870
Suntech Power	1,693 USD	704
Canadian Solar	705 USD	620
Yingli	1,048 USD	600
Q-Cells	802 EUR	586
JA Solar	503 USD	520
Kyocera	1,073,805 YEN	400
Trina Solar	845 USD	399
Solarfun	553 USD	313

Table 2-1: Top ten manufacturers [14]

Graph 2-1: Yearly PV module production and production capacity in the IEA PVPS reporting countries [15]

Based on 2008 figures, China is the world's leading producer of PV cells. Rounding out the top 5 producers are Germany, Japan, Taiwan and the USA. Regional manufacturing levels for 2007 and 2008 are as follows:

Region	2007		2008	
	MW	%	MW	%
China	1,200.6	28.1	2,589.0	32.7
Germany	875.6	20.5	1,460.6	18.5
Japan	932.0	21.8	1,269.0	16.0
Taiwan	461.6	10.8	919.5	11.6
North America	273.1	6.4	431.5	5.5
India	64.2	1.5	87.2	1.1
Australia	35.4	0.8	40.0	0.5
Africa & Middle East	1.0	0.0	14,0	0.2
Rest of Europe	295.1	6.9	560.0	7.1
Rest of Asia	140.1	3.3	539.0	6.8

Table 2-2: Regional manufacturing levels for 2007 and 2008 are as follows[16]

One notable announcement in early 2009, reflecting future market expectations and the continuing globalization of PV production, was the reported intention of China's largest cell manufacturer to establish a major manufacturing facility in the USA. Upstream in the PV industry supply chain, China's capacity of solar photovoltaic grade silicon feedstock production was estimated to have seen a fivefold increase in 2008 to 5,000 tons/year, compared to 2007 (1,000 tons/year). Industry analysts expect that this will expand to 20,000 tons/year by 2012.[17]

Country	**cumulative installed capacity** [MW]		
	2008	**2009**	**2010**
Australia	105	184	504
Austria	32	53	103
Canada	33	95	200
Czech Republic	65	463	1,953
China	150	373	893
France	180	430	1,025
Germany	6,000	9,845	17,193
Great Britain	23	30	66
Greece	20	56	206
India			102
Italy	458	1,181	3,494
Japan	2,144	2,627	3,622
Portugal	68	102	130
Spain	3,463	3,523	3,784
South Korea	358	442	655
USA	1,169	1,642	2,528
Total of above	**14,268**	**21,046**	**36,458**

Table 2-3: Estimated installed capacity[18]

2.2 Owners & Operators

Owners and Operators of PV plants can be

- Privately financed Independent Power Producers
- Commercial enterprises
- State owned or parastatal electricity providers

2.2.1 Owners

Owner of plants usually are

- large electricity suppliers, some of which have launched special subsidiaries
- specially created consortia consisting of construction/manufacturing & supply contractors, operators, financiers et. al.
- investment funds taking over or stepping into completed plants and employing own operating contractors

Projects are generally highly leveraged due to well predictable revenues based on various benefitting systems (refer to chapter 2.3). As a direct consequence financiers and lenders often insist on either stringent conditions for insurance by means of lenders agreements and/or other types of guarantees / warranties improving the insured's bankability.

2.2.2 Operators

Owners may directly operate PV power plants or retain specialised operating companies. Most plant owners subscribe to long-term maintenance contracts. Operators should be conversant with the plant technology and stipulations of the maintenance contracts specifying their monitoring & reporting duties.

As of November 2010, the largest PV power plants in the world are:

Location	Description	Power (Maximum)	Constructed
Canada, **Sarnia**	Sarnia PV power plant	97 MW	2009-2010
Italy, **Montalto di Castro**	Montalto di Castro PV power plant	84.2 MW	2009-2010
Germany, **Finsterwalde**	Solarpark Finsterwalde I,II,III	80.7 MW	2009-2010
Italy, **Rovigo**	Rovigo PV power plant	70 MW	2010
Spain, **Olmedilla**	Parque Fotovoltaico Olmedilla de Alarcón	60 MW	2008
Germany, **Straßkirchen**	Solarpark Straßkirchen	54 MW	2009
Germany, **Turnow-Preilack**	Solarpark Lieberose	53 MW	2009
Spain, **Puertollano**	Parque Fotovoltaico Puertollano	50 MW	2008
USA, **Boulder City**, NV	Copper Mountain Solar Facility	48 MW	2010
Portugal, **Moura**	Moura photovoltaic power plant	46 MW	2008

Table 2-4: Largest PV Power Plants in the world by 2010[19]

Energy production from Photovoltaic panels has been increasing by almost 50% each year since 2002. Confidence in this technology has been established and more than 36 GW of PV capacity has been connected worldwide, the majority in Germany, Spain, USA and Canada.
There are several very large plants currently under construction or being planned. In the USA, there are currently five PV power plant projects each with a peak capacity of over 200 MW planned to be completed between 2011 and 2015.

Private / Professional, Commercial

The cost of modules and their installation (per MW) will always be higher for individuals than for operators of commercial solar parks. The costs of the latter depend much more on the price of land, costs of mounting and operational costs rather than module costs alone.[20] The cost of panels constitutes some 60% of the total project costs.
Due to a growing number of producers, it is expected that competition will force the price of solar panels even lower. Continued automation and optimisation of processes will lead to further savings and there is a significant potential for cost savings with regard to materials (semiconductors, process supplies and metals), glass and balance of system (BOS) components.[21]

2.3 Financial Incentive and Benefitting Systems

Most countries are endeavouring to increase the percentage of their electricity supply from renewable sources. But because capital costs for renewable energy plants still are, in most cases, higher per kWh than for fossil-fuelled power plants, governments are looking at all options of encouraging development of greater renewable capacity. Feed-in tariffs (FITs) are one policy tool that has been used, most notably in Europe and Asia. Now North America is testing FITs as well.[22] In the US and Canada at least 29 states and 9 Provinces have Renewable Portfolio Standards (RPS) or Renewable Energy Targets (RET's) in place that mandate specific renewable energy generation ratios within certain time frames. Tax credits for renewable power also vary by state and type of renewable energy source, including PV. National and state incentives vary for commercial vs. residential use.

Government subsidies have been among the key drivers of investor interest in the RE market. Predictable regulatory environment, investment incentives, quota systems and tariffs guaranteed over a longer period of time have been instrumental for both project developers and investors, as they significantly reduce the main market entry barrier – high costs.[23]

The choice of policy instruments depends on a number of factors, including resource endowment and economic structures. An outline of the range of PV support mechanisms in place in the IEA PVPS countries during 2008 can be found in Table 2-5. Additional details about some of these measures can be found in the following section of this report.

(Enhanced) Feed-In Tariff	an explicit monetary reward is provided for producing PV electricity; paid (usually by the electricity utility) at a somewhat higher than retail market rate
Capital subsidies	financial subsidies that directly offset up-front, specific equipment or total installed PV system cost
Green electricity schemes	allows customers to purchase green electricity based on renewable energy from the electricity utility, usually at a premium price
PV-specific green electricity schemes	allows customers to purchase green electricity based on PV electricity from the electricity utility, usually at a premium price
Renewable portfolio standards (RPS)	a mandated renewable generation ratios that the electricity utility (often the electricity retailer) must meet (usually characterized by a broad, least-cost approach favouring hydro, wind and biomass)

PV requirement in RPS	a mandated requirement that a portion of the RPS be met by PV electricity supplies (often called a set-aside)
Investment funds for PV	share offerings in private PV investment funds that focus on wealth creation and business success using PV as a vehicle to achieve these ends
Income tax credits	allows some or all expenses associated with PV installation to be deducted from taxable income streams
Net metering	in effect the system owner receives retail value for any excess electricity fed into the grid, as recorded by a bi-directional electricity meter and netted over the billing period
Net billing	the electricity taken from the grid and the electricity fed into the grid are tracked separately, the electricity fed into the grid is valued at a given price
Commercial bank activities	includes preferential home mortgage terms for houses including PV systems and preferential green loans for the installation of PV systems
Electricity utility activities	includes ‘green power’ schemes allowing customers to purchase green electricity, large-scale utility PV plants, various PV ownership and financing options with select customers and PV electricity power purchase models
Sustainable building requirements	includes requirements for reducing energy usage on new residential/ commercial buildings (and at times, properties for sale). PV may be one option for meeting these mandates or it may be directly mandated

Table 2-5: PV support mechanisms in IEA PVPS countries 2008 [24]

2.3.1 Feed-in tariff FIT

Feed-in tariffs (FIT) represent a policy that
(a) guarantees grid access to renewable energy producers and
(b) sets a fixed guaranteed price at which power producers can sell renewable power into the power network.

FIT’s can be implemented in a variety of ways: payment for all PV electricity generated or only the portion exported to the grid, how to manage take-up rates without using a counter-productive ‘cap’ approach, how to best reward different types of PV plants and how to manage a transition to grid parity. While it is unclear what the total effect has been it is clear that the FIT approach is a prime mechanism for promoting strong growth in grid-connected PV applications. During 2008, under feed-in tariff schemes in the IEA PVPS countries, payments of over 7 billion USD were made for PV electricity (over 30 times the total budget for PV market stimulation in the IEA PVPS countries about a decade ago).

As can be seen in table 2-6 below, the countries not currently employing some form of FIT are in the minority (and, in some cases, have a form of FIT under consideration).[25]

2.3.2 Direct Capital subsidies

One-time payments by the government or utility to cover a percentage of the capital cost of an investment, such as a solar hot water system or rooftop solar PV system [26]

2.3.3 Green Electricity Schemes / Renewable Portfolio Standards (RPS)

RPS regulations place requirements on electricity suppliers to incorporate a specific ratio of their delivered electricity to renewable sources.

	AUS	AUT	CAN	CHE	DNK	DEU	ESP	FRA	GBR	ISR	ITA	JPN	KOR	MEX	MYS	NLD	NOR	PRT	SWE	USA
Enhanced feed-in tariffs	●	●	●	●		●	●	●		●	●		●			●		●		●
Direct capital subsidies	●	●		●		●		●	●		●	●	●		●				●	●
Green electricity schemes	●	●	●	●		●	●		●		●	●								●
PV-specific green electricity schemes	●	●		●																●
Renewable portfolio standards	●								●			●								●
PV requirement in RPS																				●
Investment funds for PV			●			●	●													●
Income tax credits			●	●				●	●			●			●			●		●
Net metering	●	●	●	●	●				●		●			●	●					●
Net billing			●	●		●			●	●		●			●					●
Commercial bank activities	●					●			●			●				●				●
Electricity utility activities	●		●	●	●	●	●		●	●		●								●
Sustainable Bldg. requirements	●		●	●		●	●		●				●					●		●
Indicative household retail electricity price [US cents/kWh]	10.2 –15.6	26.4	6.1	14.7	37.5	31.5			12.5	23.5	19.1-25.8	13.3-19.6	up to 36.5	up to 13.5		11.1-14.3	10.3-19.2	18.3-20.9	18	10.4

Table 2-6: PV support mechanism & indicative retail electricity prices [27]

Electricity retailers are obliged to prove that a certain amount of their traded volume arises out of renewable energies. This can be proven either by green certificates for the electricity produced from their own company or by buying the green certificates at the market.

If the retailer misses the amount of renewable energy in his portfolio he is obliged to pay a penalty which is higher than the price for green certificates. The promotion effect lies in the prices for green certificates for which the producer of electricity from renewable energy sources gets rewarded in addition to the price for the electricity. Certificate models are in place in the following countries: Belgium, Italy, Romania, Sweden, Poland and UK.[28]

2.3.4 Net Metering

Net metering regulations vary widely by jurisdiction. The principle is that electricity that is produced is subtracted (in whole or part) from the electricity consumed resulting in a “net meter” reading. These regulations can be made in such a way that PV and other renewable energies can be remunerated in a way that results in a profit that encourages consumers to become small generation sources as well.

2.3.5 Climate Change Levy (CCL)

CCL is a British tax aimed at fossil fuel generation. Renewable energies are exempt, resulting in an encouragement toward renewable energies.

2.3.6 Tender models

Electricity generated from renewable energies is promoted by way of tendering generation capacities. Therefore generation capacities are tendered by a utility company or a state at contractual agreements for pricing and capacity. Thus tender models are a way to control the price and capacity. A tender model is only used for promotion in Ireland. In Lithuania and France feed-in tariffs are tendered for special technologies. [29]

2.3.7 Tax credits

Investment tax credits allow for investments in renewable energy to be fully or partially deducted from tax obligations or income.
Production tax credits provide the investor or owner of qualifying property with an annual tax credit based on the amount of electricity generated by that facility.

2.4 Future / Trends

Grid-connected applications dominated in the IEA-reporting countries (about 99% of the 2008 market) but the largely unsubsidized off-grid markets continued to grow worldwide, albeit less vigorously than the publicly funded grid-connected PV markets. In 2008 grid-connected centralized applications grew to comprise 35% of the grid connected cumulative installed capacity. This reflects the market for utility-scale PV power systems being developed in a number of countries. While FIT's are the current prime mechanism for promoting strong growth in grid-connected PV applications, across the IEA PVPS countries a number of other key PV support measures also exist and have demonstrated success. Two broader issues are particularly relevant to the future market for grid-connected PV: climate change policy deliberations and the role of electricity utilities.[30]

2.4.1 New Grids

One of the major challenges for solar power to overcome is getting the necessary transmission lines permitted and built.[31] For insurers, transmission and distribution lines need to be considered both during construction and operation. Consideration needs to be given to weather perils and accidental damage. There is also a significant Business Interruption exposure.

2.4.2 Environmental - Cadmium telluride

Expansion of use of solar panel should trigger a surge in demand for raw materials; such as cadmium and tellurium. Limited supply of these metals (132 metric tons in 2006) illustrates the economic necessity of recycling solar cells and could heavily impact the cost and availability of panels.

A further cost consideration is an amendment to European Environmental Directive 2002/95/EC "Restriction of the use of certain hazardous substances" passed in 2010. It precludes the use of heavy metals such as cadmium in electrical devices. Although solar modules are excluded from the directive for now, future developments may place increased demands on the solar industry.[32]

2.5 Underwriting Recommendations

- Verify FIT / benefitting system to be state guaranteed / guaranteed by government
- Check contractual stipulations re FIT benefitting systems corresponding to repair / replacement of PV panels (e.g. with higher efficiency/ output)
- Check on deadlines to be met for being granted FIT / benefits
- Counter party risk
- Political stability and hence guarantee
- For insurance purposes it ought to be considered that the a.m. FIT and incentive elements can form part of the DSU/ALoP sum insured in a time proportional or a non-time proportional manner (analogous to AICoW or Maximum Demand charges they become applicable, if a trigger occurs), depending on the countries' energy politics, incentive scheme and / or Power Purchase Agreements concluded.

3 Insurance Aspects

Fast developing technologies like Photovoltaic Panels certainly bring benefits to society but they also introduce new risks as they are driven by market demands.[33] With fast developing technology there can be less reliance by underwriters on claims history as an indicator of future loss performance since such history may either not exist or be unreliable.[34] Therefore many insurers do not have the “risk appetite” (i.e., do not feel it is economic to assume this risk) for PV products that they consider “prototypes.”[35]

Underwriters who write such fast developing technologies need to keep themselves informed on developments and to judge whether the pace of change is having an influence on the exposure as it is often the level of understanding of the underwriter that determines his/her willingness to accept modifications.[36] An annual review of underwriting assumptions may also prove useful to determine whether there might have been a material change in risk.

However, several risks may occur during some of the phases of a large scale photovoltaic park project (project development phase, construction phase, performance phase) and some may even occur during all phases of the project.

3.1 Generic Risks during all phases of a PV project

Risk	Risk Examples	Possible Mitigation of the Risk
Financial Risk	* fluctuation in interest rate * currency exchange rate * Inflation	* derivative products
Legal Risk	* contract enforcement	* sovereign guarantee of the host government
Regulatory Risk	* lack of long term view * Regulatory uncertainties – changes in approach to determining the feed-in tariff	* some kind of regulatory assurance in the long-term approach to Renewable Energies projects
Political Risk	* currency inconvertibility * expropriation * political violence or war/civil war * breach of contract	* insurance from multilateral agencies, export credit agencies (ECA) and private insurers
Environmental Risk	* penalties * clean-up costs * treatment costs * cost of dismantling	* Liability policies * environmental liability policy * provisions on the owner’s P&L account
Force Majeure Risk	* natural catastrophes * man-made interruptions * (war being treated as political risks)	* insurance for construction phase * insurance for operational phase
Technological Risks	* technical failures and defects * low performance of modules * obsolescence	* Faulty part cover * Supplier warranty * Special covers for defects and Performance

Table 3-1: Risks associated with photovoltaic parks during all phases[37]

3.2 Natural Catastrophes

Photovoltaic parks can be affected by flooding, earthquake, windstorm, landslide and even lightning during construction and operational phase. Natural catastrophes occur at random. The possibility for predicting impacts, time, location and track or footprint of an occurrence is very limited and the time for forecasting an event varies between minutes and several days or is nearly impossible as for earthquakes.

Climate change is probably playing an increasingly decisive role. It is leading to a rise in extreme weather events and its effect on natural catastrophe losses will increase.[38] The clear upward trends observed towards more frequent and more expensive events, will also continue, due to the socio-economic, demographic and climatic changes.

3.2.1 Earthquake / Tsunami

The earthquake exposure of a photovoltaic park varies on one hand with the location and on the other hand with the type of park.

Underwriters need to consider the fact that in many countries with substantial earthquake exposure (and even in countries with no obvious exposure) earthquake building codes exist which should be considered in the structural analysis of the photovoltaic park and its foundation. One may assume that earthquakes also cause damage to ground solar systems mounted on racks. Furthermore, it is very important that the temporary construction stages as well as temporary structures are fully considered in the earthquake design.[39] At present it is not yet possible to name the exact extent to which an earthquake may damage a photovoltaic system.

3.2.2 Flood

Especially where systems are installed near to open water, the risk of flood and its mitigation measures on site must be checked before insurance cover is granted. International geological information systems like “ZÜRS Geo”, a zoning system for flood risks in Germany, may be consulted for instance.

But one should also observe phenomena such as El Niño and La Niña for instance. These phenomena are extreme phases of a naturally occurring climate cycle referred to as El Niño/Southern Oscillation. Both terms refer to large-scale changes in sea-surface temperature across the eastern tropical Pacific. In many locations La Niña (or cold episodes) produces the opposite climate variations from El Niño. For instance, parts of Australia and Indonesia are prone to drought during El Niño, but are typically wetter than normal during La Niña. In these times risks like flood may occur regularly during La Niña and affect the ground mounted PV park.

3.2.3 Windstorm (hurricane, typhoon, cyclone)

With regard to the risk of windstorm, the underwriter should pay attention to the racks on which the system is mounted. How the system is fixed and fastened can also be decisive for the question of whether to insure it or not. Judging by the experience made so far, mover systems (with solar trackers) in particular, are prone to the risk of windstorm.

Before cover is granted, an expert opinion on the ground and a statics calculation regarding the subsoil and the PV system should be submitted. Furthermore, maps of the world for natural hazards (e.g. that of the Munich Re) may be consulted in order to assess the risk.

Considering the size of certain PV plants, the risk of tornado should not be neglected when it exists.

3.2.4 Landslide

During underwriting, note should be taken of where the photovoltaic system is situated. If the facility itself is situated on a slope or at the bottom of a slope, then it may suffer considerable damage in the wake of a landslide. In such cases, expert reports on soil conditions must always be obtained.

These should also state whether a landslide might be possible, for instance due to heavy rainfall. If so, the system must be installed according to statics which take these conditions into account.

3.2.5 Lightning / over-voltage

Currently there are no clear rules which regulate whether module frames have to be grounded in general in order to protect the park against lightning. But almost all manufacturers of modules and also inverters demand a grounding of the module frames. Therefore grounding the module frames is obligatory for the installer and before granting cover, the underwriter should make sure that an appropriate lightning and over-voltage protection concept exists for the project in hand.
Unfortunately in practice the module frames are often not grounded. This can cause operational malfunctions (especially when inverters without transformers are used) or even damages to people.[40]

3.2.6 Fire / bush fire

Photovoltaic ground mounted systems are especially prone to catch fire if the undergrowth between the facilities is too strong. It should therefore be clarified in advance how the undergrowth between the facilities is to be kept short. Strong undergrowth which dries out in the summer and autumn can constitute a major fire hazard. Likewise, where panels are set up in cleared forest areas, the question must be examined whether a forest fire in the surrounding forest can result in damage to the photovoltaic system.
Special care must also be taken during the construction phase when welding or cutting works for steel reinforcements are carried out. Fire hoses (pressurised) as well as an adequate number of fire extinguishers must be available on site. Moreover, the staff must be trained in the practical use of fire-fighting equipment. It goes without saying that such areas must be declared as non-smoking zones.[41]

3.2.7 Hail

As a rule, the risk of hail requires no particular assessment by the underwriter, as the panels should normally have been tested against hailstones. Extreme hailstone showers which exceed the panels' guaranteed resistance to hailstones can of course result in extensive damage to the photovoltaic system. Such severe weather conditions are not geographically predictable.
However, the relevant insurance cover should be in place for such extraordinarily severe events too and be maintained also in the operational phase.

3.3 Theft / vandalism

A risk, which is quite considerable with regard to the insurance of photovoltaic systems, is the risk of theft. In some locations a large number of panels are taken off their mountings to be stolen. Moreover the price of metals being so high an increased number of theft cases has been noted in many countries for the copper. Usually these thefts are executed by organized gangs, well organized to face the security fences.

Fences with simple posts and wire netting frequently do not prevent thieves from entering the premises of the facility. To prevent losses due to theft the construction site should be monitored with an alarm system already during the construction phase. It is recommended that fences with a minimum height of 2 meters should be built around the construction site and in addition modules have to be under lock after being unloaded and during pre-storage.

The underwriter should therefore check before granting cover what security concepts are in place to protect the facility. These must be adequate for the conditions of the insurance location.

3.4 National (Re-) Insurance Solutions in respect of Terror Risks and Natural Catastrophes

In contrast to other types of insurance risks, catastrophic risk poses unique challenges for primary insurers and reinsurers. To establish their exposures and price insurance and reinsurance premiums, insurance companies need to be able to predict with some reliability the frequency and severity of insured losses. Catastrophes are infrequent events that may affect many households, businesses, and public infrastructure across large areas and thereby result in substantial losses that can impair insurer's capital levels.
Underwriters have to consider that several countries worldwide use a variety of approaches to address catastrophe risks. Some governments require insurers to provide natural catastrophe insurance and provide financial assistance to insurers in the wake of catastrophic events, while others generally rely on the private market. However, some governments have established even national terrorism insurance programs.
For example, natural catastrophe coverage is mandatory in France and Spain and the national governments are explicitly committed to providing financial support to insurers through state-backed entities and state guarantees. Other governments, such as Germany, neither require natural catastrophe insurance nor provide explicit financial commitments.

3.5 Construction & Financial Consequential Losses

3.5.1 Special Risks during the Construction Phase

Risk	Risk Examples	Possible Mitigation of the Risk
Construction / Completion Risk	* time overrun * cost overrun * Project does not meet technical specifications * Changes to project assumptions make the project unviable	* CAR / EAR - coverage * ALoP / DSU - coverage
Counterparty Risk	* risk that the Construction Counterparty does not perform as per contract	* surety bonds * performance guarantees

Table 3-2: Risks associated with photovoltaic parks during construction phase[42]

The nature of risk factors associated with completion of a photovoltaic park project is similar to that in the case of other infrastructure projects with there being a possibility of time overrun, cost overrun or completed project not being up to the required technical specifications. The probability of time and cost overruns is pretty high and the extent of impact on account of these is also relatively high. There are standard insurance covers available to mitigate such risks such as Construction/Erection All Risks (CAR/EAR).

Theft of modules and burglary	Damages caused by **third parties** like sabotage, vandalism	Damages to the **surrounding properties**
Damages caused during careless **transportation** of the materials	Bad Workmanship, Negligence, Malicious acts or Human Error	Damages caused by lack in experience of **subcontractors**
Damages due to **manufacturer's risks**	Damages due to scratches and Cracked cells	Damages caused during inadequate **storage**

Table 3-3: Special risks during construction phase (Perils may vary from location to location)

Construction parties include principals, managing and main contractors, contractors and/or subcontractors, manufacturers and/or suppliers, banks and/or financial institutions.

3.5.2 Coverage during Construction phase

Erection All Risk (EAR) / Contractor's All Risk (CAR) plus Third Party Liability
EAR / CAR Coverage protects the insured parties against loss and damage during the construction phase of the photovoltaic park, as well as against third-party claims in respect of property damage or bodily injury arising in connection with the execution of a construction project.[43]
The coverage also protects the owner against financial loss from theft of system components, especially before the panels are affixed during construction and during pre-storage.
The insured parties are usually project owners, principals and contractors. Manufacturers might be included as an insured party if performing a function on the erection site.
General exclusions are liquidated damages or penalties for delay or detention, or in connection with guarantees of performance and efficiency, wilful acts or omissions or gross negligence of any director, manager or responsible on site, war, nuclear risks and political risks.
Natural Catastrophes Risks like earthquakes and/or flood may be excluded or limited depending on the location of the risk.
Third-Party Liability covers injury or loss caused to third parties by the erection or construction activities on or in the near vicinity, near the site, adjacent to the site, and is intended to be an optional cover in addition to the EAR / CAR coverage.[44] Third-party liability coverage is especially important for installers, as risk is greatest during installation.
Ground-mounted PV systems tend to be far from other structures and in less-populated areas, which may reduce the premiums for the third-party liability insurance or may reduce the requirement for additional insurance.
The faulty part itself is usually excluded and it depends on the knowledge of the technology developed by the Underwriters to revoke this exclusion.

3.5.3 Advanced Loss of Profit (ALOP) / Delay in Start-Up (DSU)

ALOP / DSU-Coverage in conjunction with CAR and/or EAR protects against gross profit sustained from a delay in the completion of the project. Construction projects are inherently dynamic and require periodic monitoring to evaluate progress and potential changes in the risk exposure. Typically, the execution of construction projects is hampered by delays due to a variety of reasons. **[45]**
The insured party is the principal or the owner of the project to be constructed or erected as defined in the underlying CAR and/or EAR cover. General exclusions are the same as for CAR / EAR.
In order to ascertain a basis for any ALOP loss adjustment the project status at the time of the loss must be carefully analyzed. The main objective is to identify project delays incurred before the loss which might already result in a late commencement of the insured business. These delays must be clearly distinguished from delays caused by a loss.[46]
When selecting an indemnity period the possible re-ordering and availability of components (especially panels) and materials and the possible transfer of parts back to manufacturers (probably located in a country far away from the site) for repair have to be considered. For example, special panel dimensions are available, but at a significant surcharge. This aspect is a major factor for the delivery time and it will influence insurance coverage for ALOP as well as the replacement costs relating to the EAR/CAR
coverage.[47]
Having identified the key items that are important to production (and therefore the revenue stream) the underwriter should then assess the lead times required to order and obtain the same items of equipment, materials or component parts for delivery to site. A pessimistic interpretation is advisable as suggested timescales are generally based on the delivery of the original items.[48]

3.6 Operation & Financial Consequential Losses (BI / MLOP)

3.6.1 Special Risks during the Operational Phase

Operating errors, clumsiness, negligence	Faults of construction, material, design or workmanship	Short circuits, over-current or over-voltage
Animal bites, bush fires	**Snow pressure** / frost / ice formation / hail	Theft of modules and burglary

Table 3-4: Special risks during operation phase (Perils may vary from location to location)

Snow pressure / frost / ice formation
The weight of snow can exert considerable pressure on the panels. Prior to acceptance, the underwriter should ensure that the relevant statics have been calculated.
Where the additional problem of frost occurs, damage can be caused by moisture getting into the frames of the panels. Such risks can hardly be identified in advance. However, if panels made by reputable manufacturers with the relevant certifications are used, the potential for loss can be reduced.

Animal bites
As ground solar systems are or may be accessible to many rodents as well as larger animals, the wiring should be laid and insulated in such a way as to protect it against animal bites. The underwriter can clarify in advance whether and how the system is protected against animals approaching it or whether this may actually be desired, for example in order to keep the undergrowth short. If so, the resulting risk of animal bites should be taken into consideration when the system is designed.

3.6.2 Coverage during Operational phase / Machinery insurance

Multi-megawatt photovoltaic ground systems represent very high material assets. Per PV system, an investment sum of several 100 million EUR up to more than a billion EUR must be taken into account. Such facilities are exposed to all kinds of hazards during operation which can damage them - in some cases substantially.
To protect the PV systems, which are frequently financed with outside capital, it is essential to take out an insurance contract on an all-risk basis. Usually photovoltaic systems are covered on the basis of Electronics Equipment insurance (in Germany, the “Allgemeine Elektronik Versicherungsbedingungen”, are applied). Comparable All Risks conditions are also provided in the Munich Re EEI or the Comprehensive Machinery Insurance policy. Brokers also frequently offer comprehensive special concepts especially for the insurance of photovoltaic systems.

The scope of insurance should extend to all the essential parts of the photovoltaic plant, in particular:

- Photovoltaic modules
- Module-bearing racks
- Solar trackers, where applicable
- Charge regulators
- Inverters
- Transformers
- Feed-in regulators
- Protective devices against over-voltage
- Accompanying AC/DC cables
- Electricity meters belonging to the policyholder

3.6.3 Extensions of cover

Within the insurance of a photovoltaic system, certain extensions of cover may often make sense. These may include, e.g., first-risk sums for:

- Clean-up, decontamination and disposal costs
- Decontamination and disposal costs for soil
- Movement and protection costs
- The cost of earth works, plaster works
- Air freight costs
- Salvage costs
- Compensation for technical progress

If the series-produced modules can no longer be obtained for the insured photovoltaic systems if the systems are restored by means of series-produced modules with technically similar features, then compensation shall not be limited to the modules' current value.
Inclusion of technical progress can constitute an important element of insurance protection for the policyholder, especially where the rapidly progressing technology of photovoltaic systems is concerned.
Depending on how old the modules are, it must be anticipated that modules of the same output category or with the same measurements can no longer be obtained. In such cases it is possible that the whole facility or at least a whole string of the facility will have to be replaced.

3.6.4 Machinery Loss of Profits (MLoP) / Business Interruption (BI)

Furthermore, any damage to a PV farm usually goes hand in hand with an interruption of business, so that as a rule a supplementary BI insurance is also taken out in order to safeguard the servicing of the loan in the case of outside capital as well.
When all of the underwriting criteria for the property insurance have been settled, a business interruption insurance may be offered on the same basis.
Here it is important to make sure that the annual BI sum insured is calculated accurately. At the beginning of the insurance this should be calculated as follows:

$$\boxed{P_p\ [kW_p] \times PDI\ [kWh/a/kW_p] \times FIT\ [€/kWh]}$$

Pp := Peak power of the system in kW_p
PDI := peak direct insulation (kilowatt hours per year per kilowatt peak rating)
FIT := Feed-in remuneration rate in Currency / kWh

Most damage that interrupts operation can be remedied within a few days or weeks. However, the past has shown that panel delivery and also inverters bottlenecks can cause considerable delays. This is particularly the case if the panels do not have standard dimensions. The BI then becomes even greater.
Panels within a string must be identical with regard to their origin (manufacturer), type and performance. If this is not possible, then a new string has to be laid for a new panel, and it may even be necessary to connect a separate inverter.

During the continued operation of the system, however, over the years other influencing factors must be taken into account to determine the actual loss of power. Time Element compensation relates only to the output actually generated by the photovoltaic system based on a variety of influences.

3.6.5 Data of Global Irradiation

Irradiation levels need to be considered when determining the actual or theoretical output of a PV power plant over a specific time period. Various data suppliers offer global irradiation data, i.e. data relating to solar radiation falling on a given surface. The irradiation values must take into account both the share of direct solar irradiation as well as diffused irradiation. The total sum of both components forms the global irradiation on a panel surface. Meteorological satellites detect and measure cloud fields and other atmospheric impediments (aerosols, particles, water vapour and trace gases) to measure irradiation levels. Such information is taken by satellites, land based weather stations and atmospheric modelling. If the distance between site and weather station is more than about 20 km satellite data is more accurate than ground measurements. Monthly mean air temperature data and altitude also impact efficiency as well (higher temperature decreases efficiency, higher elevation increases it).

The annual irradiation in exceptional years can deviate from the mean value within a 25 year period. For Germany this deviation can amount to as much as 20%. By comparison this deviation from the mean value for southern Spain can be in the order of 10%.

In the event of a loss, the above-mentioned influences can be taken into account when the amount of compensation is calculated.

3.6.6 Performance Ratio

The “Performance Ratio” (PR) assessment magnitude is an internationally adopted value for the utilization factor of a complete installation. The performance ratio is the share of useable energy within the nominal energy that can be generated, as measured at the inverter output, and that is composed of the panel surface, panel efficiency (from the data sheet) and the irradiation at the panel level. In addition to the establishment of the actual irradiation, an earnings assessment also always indicates the losses that can arise in a given installation such as deviations from manufacturers’ data, dirt/dust, inverter efficiency, AC and DC line loss, annual degradation and other losses.

In consideration of these and other losses (shadow, heat, partial load), computer models produce a performance ratio in the range of > 70%. Only ideal installations with optimal components achieve values in the order of 80%.

However, it is not that easy to determine exactly what output the system would have generated. That is why the usual BI adjustment practice, i.e. settlement on the basis of the evaluation period, is frequently followed. In some cases one tries to take account of the different output within one year by splitting the annual sum insured (e.g. at a ratio of 60% in the summer and 40% in the winter). One can, however, also include special arrangements regarding the determination of payable compensation in the contract in order to determine the loss of output which actually occurred as accurately as possible. The kWh not fed into the grid as the result of a property loss can be determined as follows:

- In the case of partial failures – the failure of individual strings – the power supplied by the intact strings can be used as a basis.
- In the case of a total failure of the system, the values of a similar system installed in the vicinity can be used as a basis.

In the case of a total failure, a solar energy expert opinion relating to the particular location and time of the failure can help determine the amount of compensation due. (Other losses mentioned above are not taken into consideration here, though.)

3.7 Other / Special Covers

In addition to the above mentioned traditional insurance coverage investors of PV parks and manufacturers of PV modules increasingly search for additional insurance solutions in order to mitigate their business risks.

3.7.1 “Lack of Sun” / Lack of irradiation – Coverage for Investors

Investors in solar parks have to make strict business plans for their financiers. Therefore, a significant variation between the forecasted output and the actual output is undesirable. For instance, the global radiation is directly linked to the output of the solar park and due to a shortfall in global radiation the cash flow of the solar park is affected heavily.

The Lack of Sun cover protects the cash flow via a global radiation trigger and therefore reduces the impact of global radiation on the turnover, giving more certainty to investor and financier.

Graph 3-1: By smoothing the output Lack of Sun provides higher certainty

Reducing the cash flow volatility and therefore cash flow certainty for investors	Directly linked to weather parameter only	Protecting the debt and interest payments of solar park investors
Derivative and insurance solution possible	High transparency	Multi-year solution (up to 5 years) possible

Table 3-5: Possible key service offerings at Lack of Sun Coverage products

3.7.2 Cover for availability and performance

If an installation does not perform as well as expected, the profit may well be insufficient to service bank borrowings. Return on investment is extremely important for operators of and investors in renewable energy installations. They are reliant on the installation attaining the annual production targets, which involves producing a minimum average amount of electricity and attaining a certain number of hours of operation.

The guarantees given by the plant manufacturer are often insufficient to cover these minimum requirements in full, and traditional insurance products generally only cover the physical damage resulting from machinery breakdown. So there is a substantial gap in cover.

Availability and performance covers can insure the investor for the technical availability and, where appropriate, the performance of the PV installation, if significantly below plan, thus enabling the investor to avoid a precarious financial situation.

For example, the insurance provides cover for the following risks:

- Restricted technical availability of plant during a year of operation, assessed on the basis of the number of hours of operation
- Failure to attain the minimum annual production, e.g. a minimum number of MWh of electric energy to be supplied to the grid

3.7.3 Cover for claims arising outside statutory warranty

The manufacturers of photovoltaic modules are generally obliged under accounting standards and conventions to establish reserves for the volume of complaints they expect to receive in connection with their performance guarantees*.* Under these performance guarantees, module manufacturers assume 20 years of liability for each and every year of production, the potential claims under the guarantees thus can accumulate into huge sums.

The provisions actually established, however, make up only a fraction of the liabilities and could potentially be exhausted by a single major loss or serial loss. If further losses occur in subsequent years, these provisions are no longer available, and the manufacturer is faced with a liquidity shortage that threatens its very existence.

A high number of complaints and low reserves can result in financial imbalances at the manufacturers of photovoltaic modules. Some insurance products claims therefore arise outside the statutory warranty period and in excess of the relevant manufacturer's deductible.

For the operators of solar farms and their investors, for the related funds, and also for all other customers of the solar module manufacturers it is therefore particularly important that the modules operate faultlessly at all times. If modules fail, they not only have to be replaced, but also result in loss of earnings.

Main risk for manufacturers: defective modules and an unexpected number of complaints.

Most manufacturers guarantee the minimum performance of their modules in relation to the condition on delivery for at least 20 years. In almost all cases, the manufacturers guarantee a minimum performance of 90% in the first ten years and 80% in the next ten. Precisely these performance guarantees are reflected in the amortisation calculations of solar farm operators.

Transferring entrepreneurial risk to an insurer stabilises the solar module manufacturers' sales and yield planning. This is essential if more advantageous refinancing terms are to be obtained and gives equity investors a further incentive to maintain or even increase their holdings in solar firms.

Another advantage is that while even relatively small losses may deplete a manufacturer's own reserves entirely, an insurance policy can cover claims time and again.

3.7.4 Cover for Carbon Risks

Coverage of carbon credits and carbon allowances can partially be provided by existing DSU and BI covers, but many policies, perhaps most, remain silent; as a result the financial obligations of the insured are ignored and the extent of coverage is arguable.

Some insurers have developed policies under the generic heading "Carbon Risks Insurance" to cover owners of projects which generate carbon credits, as well as companies whose greenhouse gas emissions are capped under the EU Emissions Trading Scheme. These policies carve out the carbon assets and provide a multi-line basis of coverage to cater for the special exposures created by the carbon markets; policies also tie in the timing of claims payments to the financial needs of the insured (as mandated by delivery contracts or by compliance requirements). In addition to being multi-line, coverage can also be multi-year.

Policies can be structured to cover physical assets and carbon assets combined, or for the carbon assets on a stand-alone basis. If insuring the physical assets, the standard range of project-related risks can be insured (marine cargo, CAR/EAR/DSU, operational "All Risks" machinery breakdown and B.I., TPL) as well as the non-generation of carbon credits caused by these risks and others chosen by the insured party, such as non-registration of the project with the CDM, insolvency, weather risks and technical performance. The value of carbon credits and the timing of the loss payment (both critical to the financial viability of the project) are pre-agreed.

3.7.5 Errors and Omission liability

Coverage for professional services may play an important part in these PV projects as in many instances the owner is not necessarily a professional of this industry. By employing specialist engineers to advise him on the location for example, the installation parameters of the panels (the tilt angles either during summer or winter, their alignment on a complex topography, etc.) or on the choice of the panels, the owner would have the benefit of the Error and Omission cover.

These E&O coverages are fairly often sub-limited by underwriters and in some PV projects, especially the small scale ones, neglected by even the owners.

3.7.6 Accumulation control

The insurer must keep a constant watch on regional accumulation with regard to an accumulation of insured risks in the same region. Particularly as far as natural hazards are concerned, substantial accumulated values can arise in the coverage of various photovoltaic systems within one region. Here, the overall risk may need to be limited by allocating an appropriate maximum sum insured to each photovoltaic system.

3.8 Underwriting Recommendations

- It is the underwriter’s responsibility to check whether any or which of these numerous risks mentioned above are relevant and how they are to be assessed before granting cover for a photovoltaic system
- As photovoltaic risks are strongly exposed to nearly all kinds of natural hazards the site location specifics have to be thoroughly assessed
- It is possible that several of the risks mentioned above can only be insured with limits, i.e. with a maximum sum insured, or – in isolated cases - must even be excluded from cover altogether due to their highly exposed risk situation
- As the number of PV power plants will steadily grow in the future, local accumulation of risks has to be controlled
- Particularly in poor weather conditions damage may be done during construction to a variety of individual modules by improper handling. Contractually, it can lead to disputes, as every single damage could be assigned to a single deductible
- Study and interpretation of the Gantt chart (assessment of critical path) has to be delivered in case of a DSU-coverage
- Check whether there is adequate protection against theft / vandalism

4 Operating Experience

4.1 Costs

The price for a ready-to-operate medium-size ground installation (no tracking) is approx. 2,700 to 3,500 €/kW$_p$ (as from 2010). In contrast to 2009 and 2008 this signifies an average reduction of approx. 10% to15%. It is estimated that this trend will continue in the future.

Country		AUS	AUT	CAN	CHE	DEU	DNK	ESP	FRA	GBR	ITA	JPN	KOR	MEX	MYS	PRT	SWE	TUR	USA
Installed system prices, grid-connected >10 kW [EUR/W]	min	3.9	4.8	3.8	5.2	3.7	6.7	5.7	5.1	5.0	4.2	3.5	5.7	5.8	4.9	4.2	6.9	4.0	4.4
	max	5.6	5.5	5.1	5.4		13	6	6	9.9	5.5								

Table 4-1: Indicative PV installed system prices IEA PVPS countries as of the end of 2008 and in selected countries in 2008 [49]

4.1.1 Comparison of the installation costs/primary energy costs of different power plant types

The following table shows the comparison of the average investment costs and the costs of the primary energy of different power plant types. PV-plants have high investment costs per kW. These costs will be reducing in coming years. A PV advantage (like most renewable) - have no primary energy costs.

Type	Performance	Investment costs	Primary energy costs
Coal	1,000 MW$_{el}$	1,300 €/kW$_{el}$	medium
Gas	300 MW$_{el}$	400 €/kW$_{el}$	high
Wind	3 MW$_{el}$	onshore 1,000 €/kW$_{el}$ offshore 2,000 €/kW$_{el}$	none
PV	1 MW$_p$	static 3,000 €/kW$_p$	none
Nuclear	1,500 MW$_{el}$	2,500 €/kW$_{el}$	low
Hydro	200 MW$_{el}$	1,500 €/kW$_{el}$	none

Table 4-2: Comparison of average investment costs and primary energy costs[50]

4.2 Operation Experience Example

The following section describes the operation experience in 2009 on 143 MW$_p$ of ground mounted PV-Systems of T-Solar Global the biggest PV electricity producer in Spain. The module technology of these 28 plants is mono- and polycrystalline silicon from different suppliers. Only one system is equipped with 2-axis trackers, all others are static devices. All systems are permanently remote monitored (performance, real time failure control, atmospheric conditions, etc) in a centralized control centre.

The main results are the following:

- The total energy produced during 2009 is 218 GWh
- Average value of performance ratio is 78.1%
- Average value of availability is 99.3%. The high availability is mainly due to real time monitoring, which provides early failure detection.

The increase in energy production that can be reached by using trackers is a very important parameter to take into account when evaluating the viability of a PV project. Figure 5-1 shows the monthly production of energy of the plant La Poza (3 MWp with 2-axis trackers) in comparison with the "static" plants Veguilla (7.5 MWp), Buenavista (3.5 MWp) and Morita (8.5 MWp).

All these sites are located in the same province so the weather and radiation conditions are very similar. The production of energy in La Poza was 30% higher than in the other three locations.

Figure 4-1: Monthly yield. Tracking system vs. fixed [51]

In this case, the 30% higher energy production is not enough to compensate for the disadvantages of plant with trackers (increase in costs, increased operation and maintenance costs, risk of durability of the tracker system, high risk of incident related to strong winds).
Further details see www.tsolar.com

4.3 Claims Examples

As discussed in Section 4, PV plants are exposed to different range of dangers. Following pictures show several claim examples.

4.3.1 Storm/snow load

The respective standards especially for storm and snow load are to be taken into account and are to be matched with the local conditions/requirements.

Figure 4-2: Storm damaged modules - demonstrate that many plants were not capable of withstanding the occurring exposure. [52]

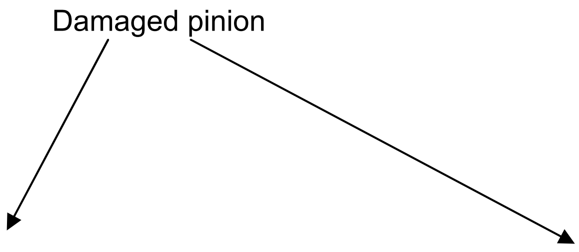

Figure 4-3: Tracking system pinion damage relating to storm-damages of a dual-axis plant. [53]

4.3.2 Theft

Product should be securely installed against theft (also roof mounted PV plants). Theft proof screw connection should always be used. An adequate fencing and CCTV shall be provided for ground mounted PV plants.

Figure 4-4: Theft damage [54]

4.3.3 Rodent bites

Bites of rodents are not completely avoidable. In order to prevent marten bites necessary protection must be taken.

Figure4-5: Damage caused by a marten bite [55]

4.3.4 Faulty production

Insufficient controlling during the production can cause damages of faulty workmanship, faulty material and faulty manufacturing.

Figure 4-6: Damage caused by humidity entry [56]

4.3.5 Overvoltage

Overvoltage and short circuits are frequent causes of losses. Adequate overvoltage protection must be installed.

Figure 4-7: Short circuit and overvoltage converter [57]

4.3.6 Construction and Installation faults

Faults in construction and installation are causes of large and serial losses.
Installation companies should have adequate experience in erection of PV plants.
Approved fixing technique should be used by all means.

Figure 4-8: Crack damage – fixing system [58]

Figure 4-9: PV plant with magnet fixing [59]

Figure 4-10: Damaged fixing system [60]

Figure 4-11: adenoid vegetation

5 Insurance Statistics

Derived from the installed capacity as per table 2-3 the worldwide premium for PV is estimated to have grown from in the range of EUR 100 Mio in 2008 to EUR 160 Mio in 2009 and more than 230 Mio in 2010.

The following table indicates the total losses of the GdV Members in regard of the insured PV plants in Germany for the year 2009:

		Photovoltaic
		2009
Number of Insurance Policies		252,312
Premium	Thsd. EUR	55,140
Number of Losses		6,963
Loss expenditure		21,909
Loss frequency		2.8 %
Loss ratio		39.7 %
Loss average	EUR	3,147

Table 5-1: Extract from the Annual Statistics Renewable Energies Insurance for the 2008 Financial Year [61]

The portion of losses due to various reasons is shown in the table below. The large volume due to fire losses arises due to the fact that roof-mounted systems are also taken into account. This portion will be lower in an insured portfolio of solar parks.

Figure 5-1: Number and Volume of Losses 2004 – 2007 Germany [62]

Further non NatCat related causes for losses can be:
- Cracked cell (the thinner the worse)
- Glass edge damage for frameless modules
- Fatigue of ribbon due to thermal cycling
- Reduced adhesion leading to corrosion/delamination
- Electrochemical corrosion
- Delamination of layers
- Moisture ingress
- Diode failure
- Busbar failure (mechanical and electrical)

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