SOLARIF GROUP

WHITE PAPER

A Fireproof Business

Fire safety assurances for rooftop PV installations

SOLARPLAZA

Reading guide

Introduction
- What is the problem?
- What causes fires?
- How is safety currently being approached?
- The impact and the handling of fires

The situation
- Assessing the situation and the building

Application and installation of materials
- The rooftop structure
- Installation approach and materials
- Dealing with safety during the installation
- Applied insulation materials and fireproof coatings
- Conditions for cables and cable management

Inspection and maintenance
- Checking for rules, guidelines, and points of attention
- Additional measures
- Regular maintenance and inspections
- Conclusion

Introduction

The amount of fires in which photovoltaic (PV) installations were involved has steadily increased over recent years. Fires can erupt within a PV installation, as with any other electrical installations in and around a building. For any kind of electrical installation, the same basic principle applies: the more there are of them, the higher the (absolute) risks of fire are. Therefore, with the steady increase of PV installations on roofs, the risks of fires have been increasing for insurers.

Focusing on the topic of fire safety, this document has been compiled to provide insights and directions to project developers, installers, roofers, and (future) owners of PV installations, as they determine their 'Plan of Approach' (Dutch: 'Plan van Aanpak'). This Plan of Approach has to demonstrate and address the risks of the building, and the PV installation it hosts, throughout the entire lifecycle of the PV installation in question. In other words: how can the defined risks be mitigated in the best way, so a PV installation can function safely on a roof.

The composed Plan of Approach needs to be discussed with the insurer (home insurer) of the building and should be fine-tuned to prevent disappointment or disagreement at a later stage. The goal of such a conversation is to keep the insurer on board as the insurer of the building, after a PV installation has been added to it. Ideally, without the addition of the PV system leading to an increase in the insurance premium.

Additionally, it is considered prudent to set up a dialogue with the local fire brigade, so they will also be aware of the ins and outs of the PV installation, the building, and the location. With this knowledge, they can advise on a better approach to dealing with possible fire risks and measures. Their advice is free, without obligation, and always useful. Use it! Should something still go wrong, at least the firefighters will have been informed properly in advance.

It's also good to know that the fire brigade has a so-called 'duty of effort', not a duty of results. Their advice and/or efforts can make the difference between a few burnt-down solar panels, coupled with a few thousand euros' worth of damage, or a completely burnt-down building with millions of euros' worth of damage.

Anything can catch fire

In and around a PV installation various elements could cause a fire. Below we'll identify a few of the most common causes of fire.

The use of two different types of connectors that are not fully compatible or exchangeable. As a result, the connection might be faulty, which can lead to a higher transition resistance. This can cause excessive heat, which can overheat the connectors and eventually cause them to burn out. That might lead to an electric arc, which can cause a fire if there are any flammable materials around. In the case of a DC system, the electric arc might be sustained prolonged.

Problems with connectors, caused by not fully inserting the vein, improperly clasping the ferrule, insufficiently tightening union nuts, and/or bending cables directly behind the nut can all lead to an increased risk of fire.

Improperly applying plastic insulation materials, such as polystyrene (EPS, also known as styrofoam), polyurethane (PUR), or polyisocyanurate (PIR). These insulation materials are labeled as flammable. It's estimated that more than half of Dutch roofs contain EPS[1] or a similar material. Therefore, chances are high that your roof will contain EPS or something similar to it.

Through a technical malfunction, fire erupts in a solar panel or in the cabling/connectors of the solar panels. Solar panels are installed in sections against each other. A fire that erupts in a solar panel can jump to directly-adjacent panels within the same row. Additionally, the burning junction box of a solar panel could detach and fall on the roof, causing surrounding materials to catch fire.

Fire might also erupt when, for example, the plastic junction box starts to melt. The melting material might drip unto a flammable subsurface, which can also catch fire. Think of, for example, flammable roofing. In case of flammable roofing, the chances of a fire expanding towards the building are high. Depending on the insulation material used, this either leads to a roof fire or fire penetration into the building.

Cables that are too thin, fuses that are too light and cable bundles that are too big are other points of attention that could lead to increased fire risks.

Furthermore, an electric arc may occur between different conductive parts that haven't been mutually equalized or have been poorly equalized. If a bad connection was created between metal parts (like a cable duct), an electric arc could occur due to lightning strikes, for example.

Lighting and other extreme weather conditions like storms, rain and heat can all lead to fires.

The type of roof also matters. If the roof is made of concrete or has roof tiles, other principles apply with regard to safety. The roof might also contain metal plating, be flat or be sloped: all of this does make a difference at the bottom line. When the combination of different types of roofs, as mentioned above, the technical installations and architectural aspects - such as installed channels and cable entries, building division into compartments, etc. - are not taken into account, the chances of fire can increase considerably.

[1] *TNO Rapport 2019 P10287 "Brandincidenten met fotovoltaïsche (PV) systemen in Nederland 13 maart 2019*

Also not unimportant is the drainage of the rooftop. If the roof can not drain excessive water fast enough or well enough, risks of short circuits and electrocution occur. Therefore it's important to take these things into account, by checking if the cabling is positioned higher than the emergency overflow level, for example. If water is not sufficiently drained from the roof, this also impacts the weight pressing unto the roof. It often happens that the extra load that a PV installation adds to the roof can cause it to slightly bend or sag. This might cause the emergency overflows to not function properly anymore, meaning that a heavy rain shower can create a water pocket on the roof. The weight of the installation, equipment of third parties, the water present and potential people on the roof can then soon amount to an excessive load. That might result in danger of roof collapse. Therefore, it's essential that sufficient emergency overflows are implemented, which also take the extra load of the PV installation into account.

Apart from internal factors in the PV installation itself, and external factors like the weather, poor craftsmanship also plays an important role in increased fire risks. Examples of that are: damaging of the roof skin by improper installation of the PV system, insulation with insufficient compressive strength, connectors that have not correctly been fixated, or improper use of tools that lead to sparks which increase the risk of fire.

"To err is to be human." However, we always need to be wary of the dangerous situations which might occur as a result of mistakes. Think of flammable materials, like boxes that might be stored inside the fire compartment of inverters, which increases the risk of fire.

Installing inverters on flammable materials, like wood, can also have dire consequences.

The presence of cable trays also increases the risks of tripping and falling. It's also possible that the roof skin incurs damage. The roof skin might also receive damage when people tread on it under high temperatures. A flat roof can heat up to 80 degrees[2] Celsius, meaning that - under high temperatures - the absorption of heat can cause the roof skin to melt in certain places or become more sensitive to damage. Any kind of damage to the roof skin can result in an increase of the fire risk.

Safety first

We are firm believers of "safety first!", whether that's before, during or after the installation of a PV system. What strikes us is that there's a clear lack of uniformity when it comes to safety. Currently, safety regulations are primarily focused on personal safety resources (Dutch: 'PBM's' -> 'persoonlijke beschermingsmiddelen') and the use of tools during construction. Prior to installing a PV system many things can go wrong, if the risks are not properly being taken into account. Also after construction the safety needs to be safeguarded. Think of safety during maintenance, for example. How can a maintenance worker reach the installation on the roof if the entire roof has been covered with solar panels? In those areas, the current safety regulations are insufficient. Safety needs to be ensured in every phase, so the risk of mistakes can be minimized. Therefore, it's important that for every phase there's a reflection on safety guidelines that relate to that specific phase.

[2] *http://aludakrenovatie.nl/meer-info*

The roof is on fire

Even though everything should be done to prevent it, a fire might erupt, even with careful measures in place. If this happens, it's important to master the fire as quickly as possible. Here, awareness of common fire risks comes into play. Both owners of PV systems and owners of buildings should be aware of the risks and the necessary precautions that should be taken to minimize those risks.

The Gelderland-Midden fire brigade indicates that risk awareness, more than anything, contributes to a faster handling of a fire outbreak. For example, a fire hose, on a standard model fire truck, has a standard reel with a length of maximum 60 meters. This means that there's a deployment potential with a maximum reach of 50 meters from the fire truck to the roof. It's important that this is taken into account when installing a PV system, so the firefighters can effectively reach and extinguish a potential fire.

Furthermore, it's prudent to subdivide the PV installation into compartments of maximum 1.600 m^2 each, with wide strips of at least 1 meter in between them and, perpendicular to those, strips of at least 2 meters. This subdivision aids in minimizing the spreading of fire. These strips also ensure suitable access to the PV system for maintenance, inspection and firefighters, in case of a calamity.

A small risk with grave potential consequences is the situation in which objects, that are still under power, pose an electrocution hazard when extinguished by the fire brigade. Solar panels and junction boxes might also detach, potentially causing serious harm.

To master a fire even faster, the presence of fire extinguishers on location can be a great preventative measure. The extinguishers need to be placed in easily-accessible spots, preferably as close to the PV system as possible, so a minimum amount of time is lost to retrieving the extinguisher. Foam extinguishers are preferred, as parts of the installation might still be under power. To extinguish inverters and other electrical appliances, spray extinguishers are most suitable. The spray extinguishers must be stored outside of the technical area. Take into account that the extinguishers should, however, be within easy reach. For all kinds of extinguishers the same applies: they need to be inspected every year, taking the inspection protocol into account. All other extinguishing equipment also needs to be inspected periodically.

During a fire, the fire brigade will make their best efforts to minimize the impact and the size of the fire. To do this to the best of their abilities, it's important that the right information about the PV system is available. There include things like: the system layout, disconnection options, safety measures, and up-to-date contact information of the right point of contact. With this information at hand, the fire brigade can make a well-informed and logical plan of approach to fighting the fire. Of course, during a fire, the safety of the firefighters is the first priority; absence of electrocution hazard and/or risk of collapsing are main considerations.

Helping each other out: steps to take to reach an ideal situation

A PV system can easily function safely, if the right steps have been taken by the right people in the right manner. Guidelines and procedures play a crucial role in this process. All of these factors need to come together in a streamlined process, of which we shall now describe the core elements.

I: Inventory of the situation

Inspection of the building kicks off this process.

During this type of inspection, we crawl under the roof skin to see if there is any flammable insulation material, how it's been applied and if the type of material doesn't pose any risks in combination with the type of roof. It's a simple fact that the fire hazard increases when potentially flammable insulation material is present. Based on this inspection, choices need to be made with regard to the safety, and necessary actions will be plotted.

Apart from checking the presence of flammable insulation materials, the same inspection also looks into the roof and its state. It will go into the technical installation and architectural aspects, such as installed channels and cable ducts, building division into compartments, etc. There is a link between the state of the roof and the risks of fires. The fire hazard significantly increases when the state of the roof deteriorates.

During the roof inspection, special note needs to be taken of the presence of skylights. To prevent skylights from jumping or burning materials falling through them, it's recommended to take sufficient distance - say 1.5 meters - into account between PV system elements and skylights.

If a roof is older than 25 years and contains flammable insulation material, the most important question to ask is whether it wouldn't be best, safest and most economical to replace the roof entirely and apply non-flammable insulation material. The answer to that question is always a solid 'yes'.

If the roof is between 10 and 25 years old and contains flammable insulation material, but is still in good condition, replacing the roof won't be a direct necessity. It could also be that the cons of replacing the roof don't (yet) outweigh the pros of other measures. In that case, the choice might be made to leave the flammable insulation material and take other measures to minimize the fire hazard.

If the roof is younger than 5 years, it's clear that replacing the roof would not warrant the costs. In those cases, a fitting solution should be sought in consultation.

Of course, there's also a scenario possible under which there's no flammable insulation material present in the roof. That, however, doesn't mean that there aren't any risks involved. Different types of roofs and insulation materials can implicate different risks. The type of insulation material that was used in combination with the type of roof can increase the risk. In every situation, proper guidelines are necessary to minimize the risks.

II: Installation

When the building inspection has been completed, a Plan of Approach has been composed - and has been agreed upon with the insurer, and possibly the fire brigade - it's time to install the PV system.

In this phase we also go into the first aspect of safety: safely installing the system and thoroughly instructing the workers. It's advisable to already think about the installation safety during the design phase. That can be achieved with a Risk Inventory and Evaluation (Dutch: 'Risico Inventarisatie en Evaluatie' -> 'RI&E'); a process during which it's estimated which risks have the highest chance of occurring. Prior to installation, toolbox sessions might be scheduled to pre-discuss the construction and installation work and safeguard the safety.

Before installing the PV system, it's important to - prior to the installation - perform a proper carrying capacity calculation to determine whether the roof has enough carrying capacity to deal with the additional load of the PV system. The roof (including solar panels, ballast, cabling and appliances) should not be too heavy, otherwise there might be risk of roof collapse. During the calculation of the carrying capacity, the extra weight of construction and/or maintenance workers, their materials, snow load or rainwater that hasn't been drained yet should also be considered. Anything else that was already attached to the roof, like sprinklers, air treatment appliances etc., should also be taken into account. Furthermore, one should consider the effects of wind and internal loads.

During the installation it's of paramount importance that the right means and materials are being used. The tools need to be in a good state and must be resistant to the right voltages. Measurements should only be made using inspected and calibrated measuring tools. The installer needs to work with the right kinds of tools and measuring equipment. The installers themselves of course need to be professional.

Not unimportant, but often forgotten: the safety of the installers and inspectors themselves.

To ensure the safety of the people that go on the roof, enough distance between solar panels needs to be maintained, so no one has to step on or crawl over any panels. This is not only important for the installation, inspections, and repairs, but also for potential fire extinguishing. Additionally, enough space needs to be maintained between the system and the roof edge (2 to 4 meters) so there's no risk of falling, but also to reduce wind load. This is the so-called 'no-go zone'. Working with fall protection is of course crucial.

A risk that's often forgotten during installation arises when materials are incorrectly stored or left on the roof. Connectors, for example, can not lie on the roof unprotected and should be capped as well.

During the installation of the solar panels, several matters are of great relevance. The type of roof is of course an important factor. If you're dealing with a PVC roof, for example, then the roof might expand under high temperatures,

which needs to be taken into account during installation. Apart from the type of roof, the construction materials are also important to consider. Plastic constructions should be made of fire-retardant material, so they are resistant to flyfire. But also during construction thermal expansion plays a role. When the construction expands, this might lead to caterpillar action of the roof skin, which definitely won't contribute to its integrity. With plastics, there is no thermal expansion, making it the material of choice to keep the rooftop as solid as possible.

The Gelderland-Midden fire brigade indicates that heat reflection during sub-panel fires is another aspect that needs to be taken into account. It's advisable to keep as much distance between the solar panels and the roof, for which the minimal distance indicated by suppliers should be the main reference point. Also enough distance between the solar panels themselves should be maintained. Additionally, sufficient ventilation should be ensured below the solar panels.

When the inverters are mounted on a non-flammable back wall in a separate space, that same space also needs to include smoke detectors. The technical area in which the inverters are installed should, in an ideal situation, be able to contain an erupted fire for at least 60 minutes. Of course that space needs to be kept clean, and should not lack proper ventilation. An alternative solution is to install the inverters on the roof itself, guarded from weather influences. Of course, inverters should not be placed against a fireproof separation.

When choosing an inverter, it's important to consider what role the inverter can play in the context of fire safety. Think of features like surge protection and electric arc detection.

A few last points of attention:

- cable ducts from and to the roof need to be fire retardant;
- make sure the PV installation is properly grounded. Grounding is a specialistic discipline, so let a specialist execute or at least inspect it. Take any existing lighting rods into account, if present;
- maintain a distance of at least 50 centimeters between the lightning rod and solar panels, the racking and/or cable ducts. If this distance can not be kept, then the metal parts of the PV installation need to be connected to the lightning rod. In these cases, it's necessary to protect the inverter and the maint distribution board of the indoor electrical installation against damage caused by overvoltage with a type 1 surge arrester. Despite these surge arresters, lightning partial currents will flow through the cabling from the solar panels to the main distributor. Therefore, these cables must be laid separately at some distance from the other cabling in the building. Here too, lightning protection is specialist work. Have this carried out by a specialist;
- to prevent a substantial number of the mentioned problems with connectors, it is strongly advised to use connectors of the same type and from the same manufacturer, and to secure them with the compatible crimping tool and mounting key, so a closing connection is ensured.

III: Insulation materials

It may be that a choice is made to leave flammable insulation material inside the roof (from a cost perspective, for example). It is of course recommended to replace flammable insulation material with a non-flammable insulation material before mounting the solar panels and other equipment. When replacement is not an option, a suitable alternative must be chosen: reduce the general risks where possible, and apply a fire-resistant layer under the junction boxes and inverters on the roof.

There are several options for that, such as: gravel, tiles or a fire-resistant foil. A layer of gravel should be at least three centimeters thick. A fire-resistant foil must be applied in strips of about 30 to 60 centimeters wide under the solar panels and connectors. In any case, the chosen solution must prevent burning material from the solar panels from penetrating the roof and reaching the flammable insulation materials, with all the associated consequences.

If the inverters are on the roof, the same fire-resistant layer is applied under the inverters and with the string cabling.

In all cases, the load-bearing capacity of the roof must also be taken into account when opting for a fire-resistant layer.

Various parties are currently working on other solutions to the aforementioned problem. Not only tiles, gravel and fire-resistant foil, but also fire-resistant coating and the use of special roof clicks are reviewed as potential new solutions. It is important here that the correct functioning of the products is confirmed by an independent certification company, that thorough testing takes place, and that the projects in which this is used are periodically assessed, especially with highly insured interests.

IV: Cables and cable management

After the structures have been installed and measures have been taken against any flammable insulation material, it is time to pay special attention to the cables and their management.

First of all, a number of points of attention: run cable harnesses safely through the roof; pay particular attention to shielding from flammable insulation material; mainly place cable routes on the outside of the building; avoid placing cable routes over, or through, fire-resistant partitions as much as possible - if there is no other option, these lead-throughs must be sealed fire-resistantly over or through fire-resistant partitions.

Furthermore, when installing cable ducts or laying cables, more attention must be paid to potential tripping hazards. If someone stumbles over a cable duct or over cables, this creates extra danger for the people themselves and can also lead to damage to the roof or the system. Safety lines or pictograms could make a positive contribution to safety when entering the roof. This also ensures that any damage to the roof can be reduced.

We've also noticed that there are different degrees of poor cable management. This ranges from loose cables on the roof to cables in cable ducts where there is poor equalization (or none at all). For cable management, it is recommended to lay the positive and negative

cables separately, bundled by means of UV-resistant binding strips, in a ventilated cable tray with a maximum of 10 to 20 cm in between. This way, parallel electric arcs cannot occur. For the pluses, we like to see red cabling, for the minuses, black cabling. This sounds very logical, but unfortunately this does not always happen. And of course the cables should not be under tension. We also recommend opting for cables that are free of constituents that can attract rodents.

Liquidation also plays an important role. Ideally, the balancing wire will run taut through the center of a cable tray. All conductive parts must be smoothed. Between the parts, the cables must be of the correct diameter and must be properly assembled. This is to prevent possible electric arcs as a result of high currents, like in the case of a lightning strike. If there is a lightning conductor on the roof, it must first be discussed - with the supplier of the PV system - whether adjustments might be required. After completion of the PV installation, everything must be reassessed by an authorized lightning protection expert.

As already mentioned, it is also important that the connectors are not left loose or unprotected on the surface. It is advisable to attach these at a higher point, preferably to the racking, to prevent the cables and connectors from being submerged in water.

V: Inspection

The second-to-last phase is that of inspection. During the inspections, the finishing touches are put in place, so that the risk of fire due to, for example, flammable insulation material or human errors can be minimized. During the inspections, it is checked whether the installation complies with the set standards and guidelines.

In the future, this will go in accordance with Scope 12, but - for the time being - we will at least assume the NEN-EN-IEC 62446 and NEN 1010: 2015 norms for current inspections. These are, respectively, the current requirements for the inspection of photovoltaic (PV) systems and the safety provisions for low-voltage installations in the Netherlands.

Does the inspected PV system at the very least meet the requirements specified in these standards? Do the inspectors not see or measure any other strange matters? Then the installation can be approved. Please note that an independent party is always included for the inspection. The installer cannot perform this inspection themselves, because then you will get a situation in which “the butcher inspects their own meat”.

You may be surprised to learn that this has to be said, but more than half of the current PV installations do not meet these safety requirements.

Something that will yield more benefits in the long run, but is currently still being done far too little, is to involve the external inspector in the entire process of the system installation. Upon delivery, it is often no longer possible to look under the panels, for example. If the inspector is involved in the PV installation from the outset, and carries out an interim check, then delivery is a lot easier and more complete. This means that the PV systems are in the best possible condition and that the delivery inspection only confirms this.

Consequently, during the inspection phase, we must pay attention to all the risks that we previously considered. The inspector checks

and measures all matters carefully. However, checking and measuring the PV system can only go so far. For example, certain defects in the solar panels cannot be detected with the naked eye and cannot be measured. Inspection largely remains human labor, and therefore prone to mistakes.

Here, the use of drones can be considered as a second pair of eyes. Drones can help us detect defects and impurities at the cell level, per solar panel, by means of thermographic images. The information obtained by the drones provides a very detailed picture of the situation. Based on this information, it can be decided, for example, to replace panels or perform other measurements to identify a problem in the string. With large PV installations, it may be advisable to also perform an IV curve measurement at an irradiance level of at least 200 W / m2 (and preferably higher).

As always, prevention is of course better than curing. By checking key products before the installation, problems can be discovered before the panels are placed. A so-called 'batch inspection' offers a solution here. In that case, the solar panels and inverters are already checked in the factory. If problems or other matters, which can lead to reduced quality, are already noticed in the factory, action can be taken on-site to immediately replace non-conforming products.

VI: Maintenance

An annual inspection is recommended to ensure the quality and fire safety of the PV installation. There are two types of inspections:
- First Special Inspection (Dutch: 'Eerste Bijzondere Inspectie' -> 'EBI')
- Periodic (continued) Inspections (Dutch: 'Periodieke Inspecties' -> 'PI')

The EBI is mainly focused on the quality of the installation of the PV system. In other words: does the installation comply with the applicable standards and the manufacturer's instructions? In addition to the check of the technical condition of the PV installation, this inspection also includes a risk component with the check of sufficient load-bearing capacity of the building construction, the ventilation of in-roof systems, the flammability of roof materials, the connectors, etc.

The PI mainly focuses on the state of the PV system.

Periodic maintenance reduces the risk of major long-term problems. Certainly in view of the new Scope 12 inspections - under which at least one EBI inspection every three years or every five years becomes the standard. Major benefits can be achieved through the smart use of periodic maintenance. An example of periodic inspections could look like this: When a PV installation is delivered, the first delivery inspection, an EBI, must be carried out by a recognized inspection company. The following year, a thermographic drone inspection could be performed in which the panels are inspected for possible damage. In the third year, a PI can take place, carried out by the installer or the O&M company. The following year, another drone inspection followed by an extensive EBI in the fifth year.

In addition to significant cost savings, drones give system owners another major advantage when it comes to the maintenance of the installations, namely data. Data is knowledge and knowledge is money. By gaining insight into what is defective (and where) and also how efficiently the PV installation works, preventive maintenance can be effectively scheduled.

The above inspections ensure the quality of the PV installation and ensure that the system remains in good condition and can be properly maintained throughout its life cycle. Ultimately, the above also reduces the total fire risk.

In summary, the diagram below shows the process of achieving a fire-safe PV installation.

Conclusion: focused on fire safety

Fire risk can significantly be reduced when design, product selection, appropriate measures, professional installation work and targeted inspections come together to ensure a safe PV installation.

It is absolutely possible to install a PV system without significantly increasing the fire risk and thus the insurance premiums for all parties. A combination of great care, expertise, craftsmanship and the right material will minimize the risk of fire - and other damage - as much as possible. Therefore, in our opinion, keeping a PV rooftop system insurable is a fireproof business.

For questions, remarks and further contact:

Solarif Group B.V
Meester B.M Teldersstraat 11 | 6842 CT Arnhem | PO Box 4192 | 6803 ED Arnhem
The Netherlands | T. +31 (0)26 711 5050 | E: support@solarif.com | www.solarif.com
IBAN NL93 RABO 0302 0737 44 | COC 09193608

This piece was written by Solarif Group. We would also like to thank Tim Spijkers and Nick Put of the VGGM Risk Management team, Reinier van Brakel of PVX solutions and Dennis van Eerten of ESDEC for their contribution and expertise.