Efectis Nederland
P.O. Box 554 | 2665 ZN Bleiswijk
Brandpuntlaan Zuid 16 | 2665 NZ Bleiswijk
The Netherlands
+31 88 3473 723
nederland@efectis.com

REPORT

Research on fire safety of industrial flat roofs with PV installations

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Sponsor	Stybenex Kerkstraat 14 4191 AB GELDERMALSEN
Prepared by	Efectis Nederland BV
Author(s)	M.P. de Feijter, B.Sc. T.G. van der Waart van Gulik, M.Sc.
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1. INTRODUCTION

By order of Stybenex, Efectis has carried out a study into the fire safety of industrial flat roofs with solar panels. With some regularity, publications report fires that took place on industrial roofs with solar panels. Insurers make additional demands on the building materials to be used on a roof in combination with solar panels.

1.1 PURPOSE OF THE STUDY

The aim of the study is to draw up a recommendation for the optimization of the fire safety of flat roofs with solar panels based on an inventory of several fires and (scientific) investigations into the fire behaviour in comparable constructions.

1.2 RESEARCH METHOD

Efectis requested information from the Fire Service about a number of fires on flat roofs where solar panels were present. Some scientific studies on fire development on flat roofs with solar panels have been studied. Based on the information obtained, an analysis has been carried out in order to list the factors that influence the course and spread of the fire. Subsequently, an advice was drawn up to optimize the fire safety of flat roofs with solar panels

2. AVAILABLE INFORMATION

2.1 FIRES ON FLAT ROOFS WITH PV SYSTEMS

The fires known to the client were provided for investigation and additional fires were provided by Efectis. Information about the fires was requested from the Fire Service. Not all requests were responded to. Where no information was available, use was made of publicly available information.

A study of fires involving solar panels was carried out by TNO on behalf of the Netherlands Government Agency for the Environment[1]. This investigation into fires in the period 2016-2018 revealed 3 fires on flat roofs, 1 of which occurred on a flat roof of an industrial function.

This report includes 8 fires in solar panels on flat roofs in the period 2016-2021. In August 2020, a fire occurred on the roof of Heineken in Den Bosch. No information was obtained about this fire and it could therefore not be included in the study.

2.1.1 5 July 2016, Nordhornsestraat 101 Denekamp, Nijhuis Interior Construction

2.1.1.1 Roof structure

The roof construction consists of steel girders with perforated steel roofing sheets. The cannelures in the roofing sheets are filled with rock wool (for acoustic purposes). It is not known whether the rock wool was packed in a PE foil and whether there was a vapour retarding foil. On the roof, a layer of EPS insulation of unknown thickness was applied, with a PVC roof covering on top.

Figure 1 Fire on the roof (source: www.rtvoost.nl)

Whether there was an intermediate layer between insulation and roofing is not known. The photograph does not show any glass fibre interlayer. The fire class of the roof and whether the roof was flammable according to NEN 6063 is not known.

[1] Fire incidents with photovoltaic (PV) systems in the Netherlands, E.E. Bende, N.J.J. Dekker, TNO, 2019

Figure 2 Overview of damage on the roof (source: unknown)

Figure 3 Damage to the roof (source: Fire brigade Twente)

Figure 4 The fire has been stopped before the fire separation (at the location of the tarpaulin on the roof) (source: Fire brigade Twente)

2.1.1.2 Solar panels

The photos show that the distance between the rows of solar panels is approximately 20-40 cm. The support structure of the solar panels seems to be made of aluminium profiles with some plastic parts.

2.1.1.3 Fire behaviour

The fire service determined that the fire originated on the roof. There were no ignition sources on the roof other than the solar panels and associated equipment.
Based on the images of the damage, the fire does not appear to have spread beyond an area about 4 metres from the solar panels.
A secondary fire started in the building as a result of falling burning material (the Fire Service states that the fire spread was caused by burning, dripping EPS). If the rockwool cannelure filling is wrapped in HDPE foil, it cannot be ruled out that this foil could have caused the fire to spread through the holes in the roof by burning droplets.


Figure 5 The roof is interrupted at the fire-resistant partitions with rock wool, but not covered with a layer of concrete tiles (source: Fire Department Twente)


Figure 6 Secondary fire in the building caused by burning falling material (source: Fire brigade Twente)

2.1.2 19 June 2018, Opmeer, Town Hall

2.1.2.1 Roof structure

The roof construction is made of concrete with 100 mm EPS insulation and a bituminous roof covering. There is a layer of gravel on the roofing. There is no information about the fire compartmentation of the building.

2.1.2.2 Solar panels

The solar panels (Shell Solar Energy RSM 110) are installed in two rows on the roof. There is no gravel directly under the solar panels.

2.1.2.3 Fire behaviour

The fire was limited to two solar panels. The bituminous roof covering also started to burn and the photos show that the EPS insulation had melted, evaporated or burned away over an area of roughly 40x40 cm (estimate based on photo). Where there is gravel ballast on the roof, the fire did not spread.


Figure 7 Fire on roof of Opmeer town hall (source: www.noordhollandsdagblad.nl)

The fire started in a solar panel. Traces of overheating were found in several places in the solar panels. Based on the photos, part of the supporting structure of the solar panels appears to be made of plastic and these parts participated in the combustion.

Figure 8 Damage to solar panels and roof. Melted EPS is visible in the red arrow. Characteristic "caramelised drops" (source: Municipality of Opmeer)

2.1.3 17 September 2019, Amsterdam, Storage Hall

2.1.3.1 Roof structure

The roof construction consists of steel roofing sheets, PIR insulation and PVC roofing. It is not known whether the roof is compartmentalised.

2.1.3.2 Solar panels

The roof is almost completely covered with solar panels. There is about 30 cm space between the panels (estimate on based on photos).

2.1.3.3 Fire behaviour

The fire started in a switch box that had fallen over prior to the fire.
The fire damage is limited to an area next to the switch box, along the cable duct and at the location of the solar panels involved in the fire. The fire did not spread further across the roof or inwards.

Figure 9 Damage on the roof of the storage hall (source: Amsterdam-Amstelland Fire Service)

The fire spread from the switch cabinet via the cable duct to the solar panels. This corresponds to the normal fire behaviour in an electrical installation. The fire is running in the direction of the power source (in this case, the solar panels) as a result of the repeated occurrence of electrical connections.

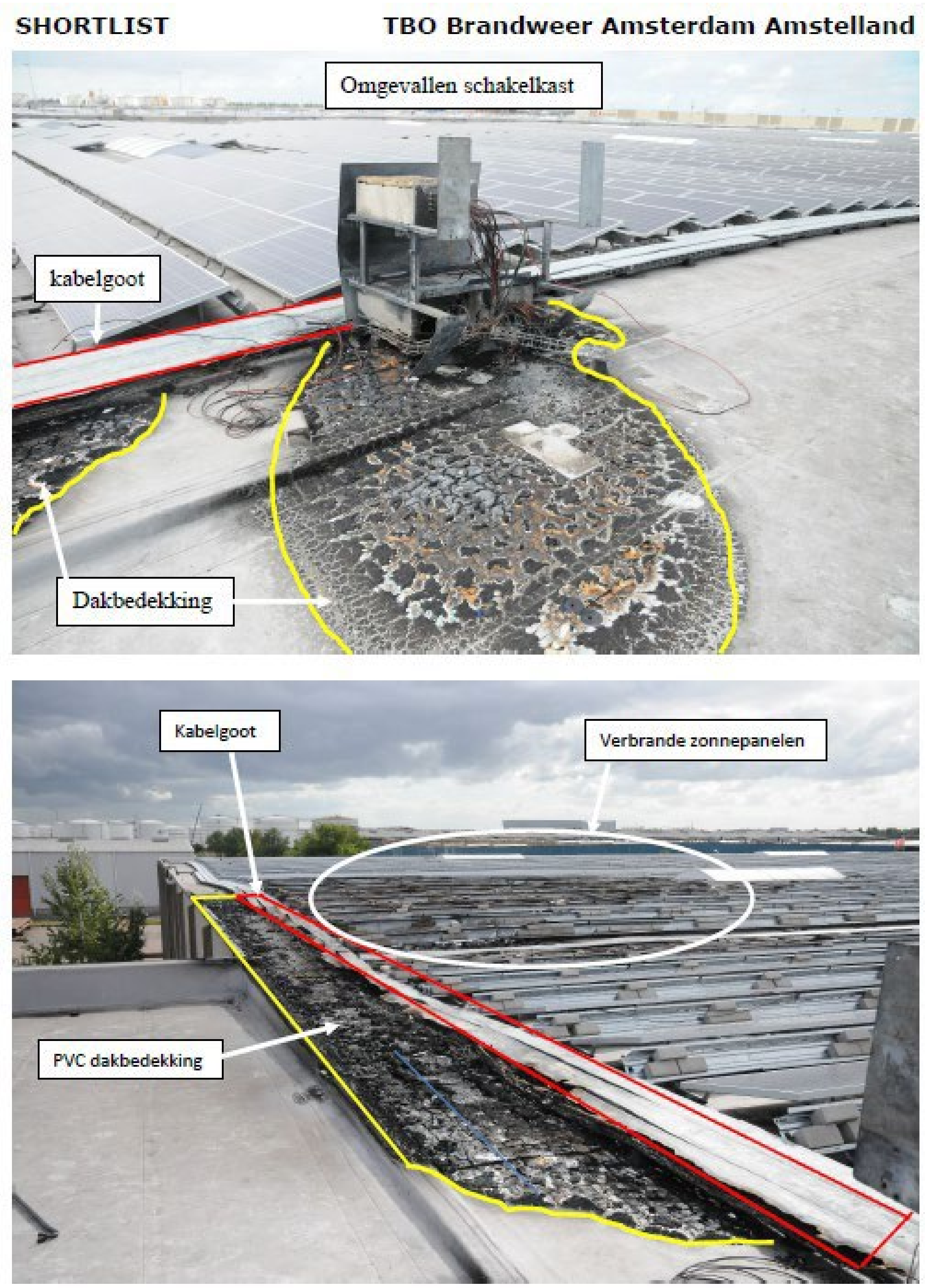

Figure 10 Damage next to the switch box and the cable duct (source: Amsterdam-Amstelland Fire Service)

2.1.4 5 June 2019, Animals, Gazelle bicycle factory

The only information about this fire received from the fire service was that rock wool insulation had been used in the roof. News reports on the internet only mention a fire on the roof without any internal spread. One of the photos available shows that a skylight melted as a result of the fire, but the fire had not yet penetrated the building.

Figure 11 Damage on the roof of Gazelle (source: www.omroepgelderland.nl)

Figure 12 Damage on roof of Gazelle, where the fire reached a skylight (source: unknown).

2.1.5 23 May 2020, Veenland Wateringen

2.1.5.1 Roof structure

The roof construction consists of a bitumen layer with 15 cm EPS insulation resting on a steel sheet piling. The building has a surface area of 1610 m2. There is no division into fire compartments.

2.1.5.2 Solar panels

There were 108 solar panels on the warehouse where the fire started. There were 42 solar panels (type AC 260p / 156-60 S) on the office. The inverters were located under the roof. Concrete tiles measuring 30x30 cm were placed between the rows of solar panels.

2.1.5.3 Fire behaviour

The fire started in a junction box under a solar panel (source: TBO Fire Brigade Haaglanden). The solar panels were placed on a plastic support structure (with concrete ballast tiles) that contributed to the fire development. Leaves and cabling were underneath the solar panels, which contributed to the initial fire development. Subsequently, the bituminous roofing started to burn along with the EPS insulation.
Through cracks in the roof construction, it was observed that the fire moved between the roof plate and the bitumen.

The fire did not spread further across the roof or into the interior.

Figure 13 Damage on the roof (source: TBO Fire Department Haaglanden)

Figure 14 Plastic support structure

2.1.6 21 June 2019, Sporthal Buitenpost

No information about this fire has been received from the Fire Service. Based on the photograph known at Efectis and news articles on the internet, the following can be established: The fire was limited to two rows of solar panels. There was no further spread across the roof or into the building.
Based on the photograph, it appears that a PVC roofing material was used on the roof. The applied insulation is not known.

2.1.7 27 September 2017, Wellensiekstraat 4, Ede

Information about this fire has already been received from the Fire Brigade for an earlier investigation by Efectis.

2.1.7.1 Roof structure

The roof construction consists of a steel roof plate with 65 mm PIR insulation (Kingspan TR26 FM) and an Alkorplan F 35176 (PVC) roof covering.

2.1.7.2 Solar panels

The solar panels were installed on sloping roof sections with a clearance of 8 cm between the roof and the solar panel.

2.1.7.3 Fire behaviour

The fire was noticed by a passer-by, after which a successful extinguishing attempt was made with a hand-held fire extinguisher. The fire was limited to one solar panel.
The fire was able to spread along an upstanding roof edge, but did not reach the inside.


Figure 15 Fire damage limited to a few panels and a small part of the roof.

2.1.8 30-12-2021, Sporthal Elst.

2.1.8.1 Roof structure

The roof construction consisted of a steel roof plate with stone wool insulation (thickness unknown) and a bituminous roof covering. Ventilators in plastic housing were present at various places on the roof.

2.1.8.2 Solar panels

Approximately 80% of the roof was covered with solar panels. The panels were laid in an east-west orientation on an aluminium support structure. The installation was not yet connected to the mains. Based on the photos, the distance to the fans is estimated at max. 1 meter.

2.1.8.3 Fire behaviour

The fire service determined that the fire originated in one of the fans. The plastic casing of the fan then caught fire, causing the fire to spread to the roof surface and the solar panels.
Just over a quarter of the area of solar panels was involved in the fire. The fire did not spread inside. However, there is considerable water damage in the sports hall. The sports hall consisted of one fire compartment, so the fire could not spread to another compartment.

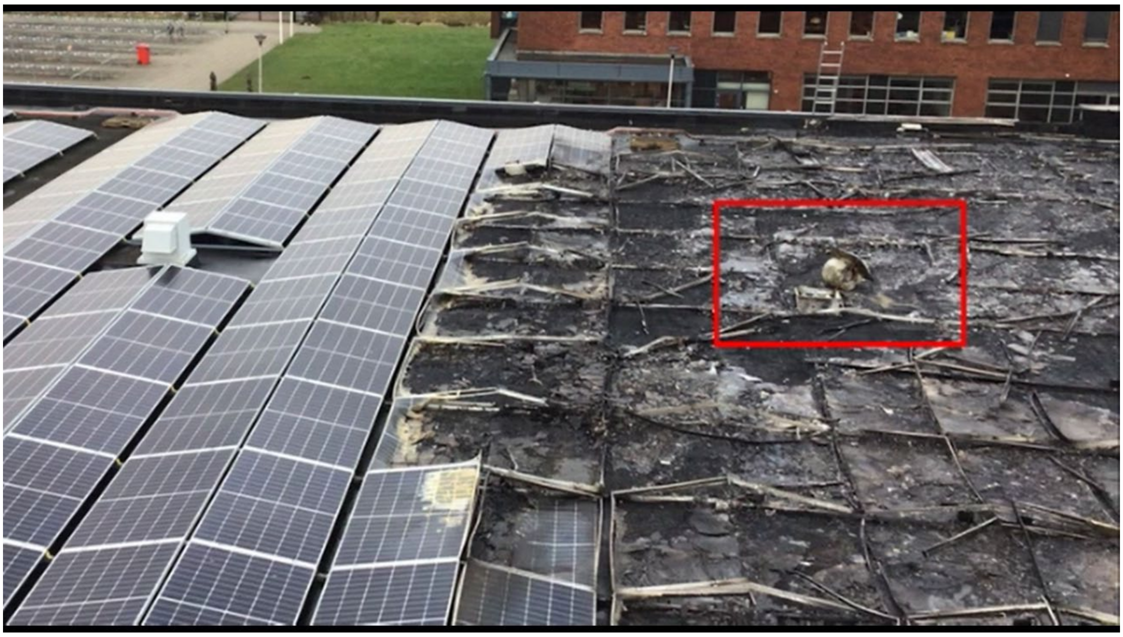

Figure 16 The place where the fire started, marked in red, with a similar fan on the left. (Source: Gelderland-Midden Fire Service)

Figure 17 Damage to the PV plant and roof (Source: Gelderland-Midden Fire Brigade)

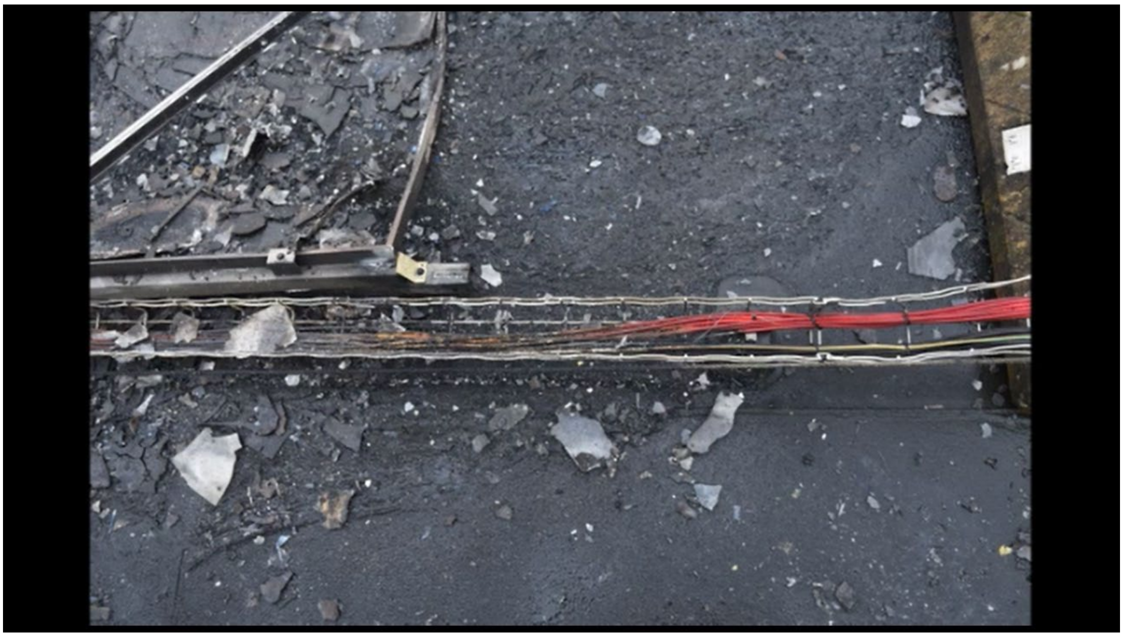

Figure 18 Damage to the cables (Source: Gelderland-Midden Fire Brigade)

2.2 STUDIES ON FIRE BEHAVIOUR ON FLAT ROOFS WITH PV SYSTEMS

The investigations that have been carried out generally focus on the cause of fire in the panel or the associated installation parts. Addressing the cause of fire in solar panels is beyond the scope of this study.
The number of studies into fire development under solar panels is limited. Three relevant studies were found by Efectis. The findings of these studies are summarized below.

Experimental Study of the Fire Behaviour on Flat Roof Constructions with Multiple Photovoltaic (PV) Panels, J. Steemann Kristensen and G. Jomaas.
The study was carried out on flat roof pieces measuring 2.4 x 6 meters and 4.8 x 6 meters with 6 solar panels on top. The roof construction consisted of steel sheet piling, 150 mm EPS insulation and on top of that a layer of 40 mm PIR or a layer of 30 mm rock wool. The insulation was covered with PVC roofing.
A wooden crib with a capacity of 30kW was fired under the solar panels. The test was performed outside, so the wind had an influence on the course of the test.

Fire spread from the crib to the roof occurred after approximately 7 minutes. The fire spread across the field of solar panels and extended to about 1 metre beyond the surface of the solar panels in all tests, with size and direction varying under the influence of the wind.

In all tests, it was observed that the plastic parts of the support structure started to burn and continued to burn throughout the test.

At the location where the wood scribe was placed, the PIR insulation burned through (after one hour and three minutes) and from that location the EPS insulation started to melt and burn. Under a large part of the rock wool insulation, the EPS insulation had melted away, but had not ignited. The EPS insulation used did not meet fire class E in accordance with NEN 13501-1.

Effect of Rack Mounted Photovoltaic Modules on the Fire Classification Rating of Roofing Assemblies, Bob Backstrom, Mahmood Tabaddor, PhD, UL.
This study examined the effects of the presence of solar panels in a standard test for determining the fire behaviour of a roof in accordance with UL790.

The study shows that the distance between the solar panels and the roof affects fire development and the temperature between the solar panels and the roof.

At a distance of less than 5 cm, flame spread and temperature are limited. At a distance of 25 cm and 10 cm, flames travel in approximately the same way along the bottom of the panels between the panels and the roof, but at a distance of 10 cm, the temperature becomes higher because less cooling can take place due to a limited air supply. Fire development depends in part on the fire behaviour of the solar panels. The test was carried out with the solar panels in an arrangement on a sloping roof, with the solar panels fitted parallel to the roof surface.

Flame Propagation Between Flat Roofing and Photovoltaic Installations, Farah Binte Mohd Faudzi, University of Edinburgh.
This study examined the influence of the distance between the solar panel and the roof on the flame spread in the space between the solar panel and the roof.
In the study, a strip of PMMA with a width of 300 mm was chosen to represent combustible materials in the roof and a steel sheet to represent the solar panel. In the tests with an opening of more than 20 cm between the solar panels and the roof, the fire spread occurred at a rate of 0.15-0.2 mm/s, which is comparable to the fire spread over a surface without solar panels above it.
At a distance of less than 17 cm, flame spread is up to 10 times faster than without a solar panel above the roof.

3. ANALYSIS

3.1 FIRE CAUSE

The fires considered in chapter two show that the cause of the fires often lies in the solar panel installation. The fire can start as a result of a defect in the panels themselves, in the equipment under the solar panels or the installation parts under the roof, or in a switch box or inverter to which the solar panels are connected. One of the fires started in a fan with a plastic casing, after which the fire was able to spread to the solar panels .

3.2 FIRE RUN

When analysing the behaviour of a fire, it is important to distinguish between the different components involved.
In the roof construction, the following parts are involved:

- The underside of the roof structure and any gaps in it;
- The type of roof insulation;
- The type of roofing;
- The presence of a ballast, such as gravel or tiles;
- The support structure of the solar panels (material);
- The solar panels (material, orientation);
- Inverters/switchgearboxes;
- Cabling.

In addition, external factors such as detection time, extinguishing possibilities and weather conditions obviously play an important role in the course of a fire. These factors fall outside the scope of this investigation.

3.2.1 Fire development in the solar panels

The fires investigated show that when solar panels (irrespective of make and type) are spaced less than about 0.5 metres apart, it can be expected that fire development (irrespective of the type of roofing and insulation) will continue over and under the panels. Many solar panels contain a flammable film that causes the fire to develop in the solar panel itself.

3.2.2 Fire spread across the roof

In most fires, the fire development remained limited to the area where the solar panels were present. In the fire in Opmeer, the fire remained limited to the part of the roof where there was no ballast in the form of gravel. In the fire in Denekamp, the fire spread to approximately 4 metres from the edge of the solar panels. On this roof, EPS insulation with a PVC roof covering had been applied to a perforated steel sheet.
The fire in Wateringen involved EPS insulation with bituminous roofing. In this fire, there was no fire spread across the roof outside the solar panel field. For none of the roofs is it known which fire class was satisfied and what the effect of this was on the spread of fire across the roof. The spread of fire across the roof was similar in the fires investigated regardless of the type of insulation used. The fire remained limited to the field of solar panels.

3.2.3 Fire spread to inside

The fire in Denekamp is the only fire where fire spread to the inside of the building took place as a result of burning dripping materials through the perforated roof sheet. The fire service states that the fire spread is the result of burning, dripping EPS.
The question is whether there are any other components in the roof structure or the solar panels that could drip on fire, such as a possible PE foil around the cannelure filling and a vapour retardant foil. It may be expected that the PVC roof covering will not drip on fire.

There are plastic parts on the support structure of the solar panels. It is not known what plastic these parts are made of, but in general, these parts are made of plastics that can drip on fire. It cannot therefore be completely ruled out that some of these parts ended up in the building on fire. However, this would require the roofing and insulation to have burnt/melted away first.

3.2.4 Fire development in other system parts

In the fire in Amsterdam, the fire originated in a switch cabinet and then spread through the cable duct to the solar panels. This fire demonstrates that in an electrical system, fire development is in the direction of the power source. The fire started in the switch box, causing a short circuit in the cables leading to the solar panels. As the solar panels are always live, the fuse moves along the cable to the panel and the heat released by the fuse will set fire to surrounding materials. The ignition source is only gone when the solar panel no longer functions. This means that regardless of the roof covering or roof insulation used, a fire will always spread (during the day, when the panels are generating power) via the cables to the solar panels and over the solar panel field. Whether or not a fire spreads further across the roof depends on the materials used in the roof and the fire behaviour requirements.

3.2.5 Fire development in the support structure of the solar panels

Many support structures have some plastic components which may contribute to the development of the fire. In the case of the fire in Wateringen, the support structure was made entirely of plastic. It is not known what type of plastic was used and whether this construction was tested for its fire behaviour. The images show that the plastic support structure did contribute to the development of the fire.

3.2.6 Conclusions on the course of the fire

Where the solar panels are located at a distance of less than 0.5 metres from each other, it can be expected that the fire will continue to develop over and under the panels, regardless of the type of roof covering and insulation.

Where the solar panels burn and there is no ballast on the roof in the form of gravel, the roof covering will participate in the combustion and (irrespective of the type of roof covering and insulation) the insulation will be damaged or participate in the combustion. Outside the area where the solar panels are situated, the fire development over the roof is the same as a normal fire development on a flat roof and depends on the materials used.

When there are openings in the roof plate, but also penetrations and roof lights (as in the fire in Dieren), in combination with an EPS insulation and/or a bituminous roofing in combination with another type of insulation, fire spread to the inside can occur.

In the event of a fire in the system belonging to the solar panels, the fire can spread along the cables to the solar panels and other parts of the building, regardless of the type of roof covering and insulation.

In none of the fires did the fire spread beyond a fire-resisting barrier.

3.3 SEARCH

The number of studies dealing with fire development between solar panels and roof is very limited. The research carried out on a field of 6 solar panels with an EPS insulation with PIR and rock wool layer on top of it gives a picture of the fire development under the panels, but has some limitations.
The combination of insulation materials used in the test is rarely, if ever, used in practice in the Netherlands.
The ignition source for the fire is a wooden crib with a capacity of 30 kW. A wooden crib radiates heat to the bottom, which affects the roof. During the test, it can be seen that the

heaviest damage occurred at the location of the crib. It should also be noted that the burn-through of the PIR insulation occurred only after an hour.
A fire in solar panels mainly involves plastics, which (due to melting) behave more like a liquid fire and therefore emit less radiation to the surface below.

The presence of solar panels above the roof deflects flames and exposes the roof to more heat radiation than without solar panels. Research by the University of Edinburgh shows that the speed of fire spread can increase by a factor of 10. Incidentally, this research was carried out on a very limited scale and cannot be translated on a one-to-one basis to an actual fire under solar panels.

The studies show that the presence of solar panels has an effect on the rate of fire spread in the space between the solar panels and the roof. The distance between the solar panels and the roof has a major influence on the temperature and speed of flame spread.

3.4 REQUIREMENTS FOR THE ROOF STRUCTURE AND THE SOLAR PANELS

The Buildings Decree 2012 sets the following requirements for a roof construction of an industrial function at new building level:
Article 2.71. Roof area

1. *The upper side of a roof of a building is not fire-hazardous, determined in accordance with NEN 6063. This does not apply if the building has no floor intended for people that is higher than 5 m above the measurement level and the fire-hazardous parts of the roof are at least 15 m from the plot boundary. If the plot on which the building is situated borders on a public road, public water, public greenery or a plot that is not designated for construction or for a playground, camping area or storage of flammable substances or of flammable substances that are not hazardous to the environment, this distance is maintained to the centre of the road, the water, the greenery or the plot.*

For existing buildings, this requirement does not apply, and for renovations, the legally obtained level is important.

The explanatory notes to the Building Act state that the purpose of this article is to prevent the roof of a building from catching fire due to flying fires from the surroundings. Flying fires (or showers of sparks) can be caused by, for example, an open fire or a fire in a nearby building.

The following requirements are imposed on electrical cables at new construction level:
Article 2.69a. Electrical cables and pipe insulation

1. *By way of derogation from Article 2.67, the following applies to electrical cables that are adjacent to indoor air:*
   a. *smoke class s1(ca) in extra protected escape routes and smoke class s2(ca) in other rooms, both determined in accordance with NEN-EN 13501-6; and*
   b. *the fire class indicated in table 2.66, determined in accordance with NEN-EN 13501-6.*
2. *By way of derogation from Article 2.67, the following applies to pipe insulation adjacent to the indoor air:*
   a. *sin extra protected escape routes smoke class s1(L) and in other rooms smoke class s2(L), both determined in accordance with NEN-EN 13501-1; and*
   b. *the fire class indicated in table 2.66, determined in accordance with NEN-EN 13501-1.*
3. ***Contrary to Article 2.68, the fire class specified in table 2.66, determined in accordance with NEN-EN 13501-6, applies to an electric cable which is adjacent to the open air. (class B, C or D)***
4. *Contrary to article 2.68, the fire class specified in table 2.66, determined in accordance with NEN-EN 13501-1, applies to pipe insulation that borders on the open air.*

This requirement does not apply to existing buildings and, with regard to subsections 3 and 4, it is the legally obtained level that is important. In the case of a conversion, however, subsections 1 and 2 do apply on a one-to-one basis.

Furthermore, the NEN 1010 gives various requirements for electrical systems and the fire safety of the components used.

The Buildings Decree does not provide any performance requirements for the fire behaviour of solar panels and their supporting structure. The requirements of the Building Regulations for a roof are based on the scenario of a shower of sparks from a chimney or a neighbouring burning building. The fire basket test method used for this purpose is inadequate for a fire scenario where the solar panels or associated plant catch fire and the fire can spread between the solar panels and the roof.

4. SOLUTIONS FOR IMPROVING FIRE SAFETY

Despite the requirements for the installation of solar panels and the associated equipment, it is not entirely possible to prevent fires. The following section looks at how to prevent the escalation of a fire once it has started. It looks at the initial development and further spread of the fire.

4.1 FIRE DEVELOPMENT

4.1.1 Cause of fire in switchgear/ inverter

When fire starts in a switch cabinet, a fire can develop from there over the surface of the roof. The first development can be stopped by placing the cupboard on a non-combustible surface such as concrete tiles. Around the cupboard, for example, two 30x30cm concrete tile strips can be used to screen off the roof surface and limit the initial fire spread.

From the switch box, the fire will almost always develop in the direction of the solar panels as a result of a closure in the cables. It is therefore important to ensure that the cables are kept clear of the roof surface, and preferably a fireproof covering is fitted between the cable tray and the roof surface. This can be done at by placing the cable tray on a strip of concrete tiles, for example.

4.1.2 Fire cause in the solar panels and the equipment under the solar panels

If the fire originates in the solar panels or the equipment under the panels, it must be assumed that the fire will spread unhindered over the field of solar panels and damage the roof covering and insulation (regardless of the type of insulation).
In order to limit the development of fire, especially under the panels, the use of plastics in the supporting structure of the solar panels could be limited. If metal support structures are used, the development of the fire is limited. In line with the philosophy behind the exceptions in the Building Decree, a maximum of 5% plastic should be used in the support structure, although it is unknown whether a support structure without plastic would be practical.

Another possibility is to assess the solar panels and supporting structure in combination with the roof covering by means of a test method yet to be developed. Based on the test methods available at the time of writing, Efectis recommends, in addition to the above suggestions, that the roof structure should at least comply with class Broof t1 in accordance with EN 13501-5 or with the classification non-flammable according to NEN 6063.
Where a roof is fitted with ballast gravel, Efectis recommends that the gravel, or alternatively concrete tiles, should also be laid under the solar panels in order to prevent the roofing material from catching fire and thus to limit further fire development.
Another possibility is to fit a plate between the solar panels and the roof, which prevents direct heat radiation to and flame contact with the roof covering.

In addition, reference is made to the NEN 7250, which formulates performance requirements for the solar energy system as a whole in its constructional application and is currently being revised. Although this standard has not been designated in the Dutch Building Decree, the standard itself states that it meets the principles and requirements with regard to the safety and usability of constructions. And, that with application of this standard, in principle, the Buildings Decree 2012 is complied with. Insofar as the cases considered in this report have not already given rise to a particular recommendation, it is recommended (in addition to this) that the performance requirements from NEN 7250 be used.

4.2 FIRE SPREAD

4.2.1 Fire spread to inside

Irrespective of the type of insulation used, inward expansion can occur through penetrations, openings in the roof sheet and through roof lights and skylights. If a perforated roof sheet is used in combination with melting materials, an open connection between the solar panels and the interior can occur and there is a risk of fire spreading inwards.

If a perforated roof sheet is used, Efectis recommends that a barrier be provided to create a fire-resistant roof and to prevent the spread of fire to the interior. This could be a flameproof plate between the solar panels and the roof or a fireproof covering on the underside of the insulation or on the underside of the roofing sheet.

The study shows that with a closed steel roof plate, regardless of the insulation used, no inward expansion takes place.

4.2.2 Around roof lights and lead-throughs, Efectis recommends placing the solar panels at a sufficiently safe distance and preferably equipping lead-throughs with a fire-resistant device. Fire spread to other fire compartments

None of the fires involved fire spread to another fire compartment. Fire spread to another compartment can be prevented by the usual fire resistant separations in a roof construction (Interruption of combustible insulation by means of rock wool and a strip of concrete tiles above the fire resistant separation). For new building situations, the width of the tile strip can be determined on the basis of a NEN 6068 consideration.

4.2.3 Follow-up study

In order to gain more insight into the course of a fire on an industrial flat roof with solar panels, the following follow-up studies can be considered:

- Through the fire investigation teams of the Fire Service, collect information on fires on industrial flat roofs with solar panels;
- Practical tests with different solar panel systems on different roof types to determine the fire behaviour;
- Practical tests in combination with heat radiation calculations to determine the safe distance between solar panels and roof openings.

M.P. de Feijter, B.Sc.
Project leader fire investigation

T.G. van der Waart van Gulik, M.Sc.
Project leader fire engineering