Mitigating PV fire risk

Experts from the Fire-safe Sustainable Built Environment project, FRISSBE, report on their research on PV fire risk reduction on flat roofs

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Grunde is an experienced researcher, lecturer, consultant, leader, and mentor. He is currently leading the FRISSBE project, which has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 952395.

A SHIFT from carbon-based energy sources is seen as a major component of the drive towards reducing carbon emissions and a sustainable future, with solar energy proving to be one of the main options for moving towards this solution.

To that end, a great portion of buildings, from small residential houses to large industrial production facilities and storage warehouses, are going to have photovoltaic (PV) systems installed on their roofs in the coming years. These provide power for the building itself, as well as returning any surplus back to the national power grid.

However, several recent PV-related fires on roofs have caught significant attention in the media - the latest being the fire on the roof of the Lidl distribution centre in Peterborough. It once again raised the question of how these PV systems alter the fire dynamics of roof fires and the potential risk profile of these buildings. To help raise awareness of how installing a PV system affects the fire risks of buildings and to point out some key aspects concerning PV-related fires, researchers from the Slovenian National Building and Civil Engineering Institute (known by its Slovenian acronym, ZAG) recently carried out a demonstration.

The design of the test

The simple experimental matrix is presented in Table 1 and it shows the variations among the four different tests performed.

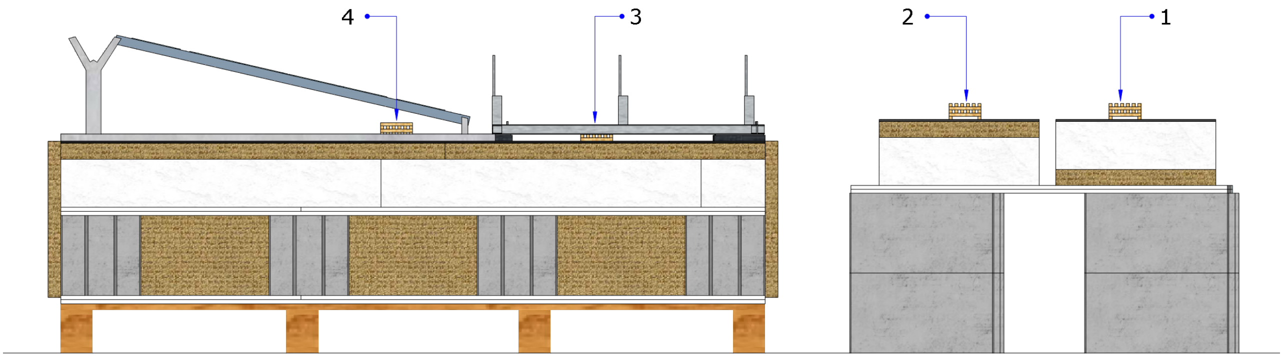
Table 1: Experimental matrix

	Mitigation layer	PV geometry
Test 1	No	No panel
Test 2	Yes	No panel
Test 3	Yes	Vertical
Test 4	Yes	Inclined

Test 1 represented a case of the buildup where the expanded polystyrene (EPS) insulation was directly covered by the membrane (bitumen). The mineral wool below the EPS was there for the protection of the parts below and to have both samples at a similar height. Mineral wool is not considered a part of the roofing segment in this case. Test 2 represents a case of a buildup where an additional mitigation layer of mineral wool was positioned between the insulation and the top cover. The same roof structure (bitumen, mineral wool, EPS) was also used for the larger setup supporting Tests 3 and 4. Test 3 represents a case of a vertical PV installation, while Test 4 represents a case of an inclined PV panel. The sketch of the entire setup is shown in Figure 1.

The larger part of the demo was utilised to show how two distinct PV configurations affect the development of fire on a flat roof. One was a typical configuration of inclined PV panels, and the other was a vertical PV panel >>>

***Figure 1:** Sketch of the experimental setup. 1 – no mitigation layer, 2 – mitigation layer between the top cover and insulation, 3 – vertical PV installation, 4 – inclined PV installation*

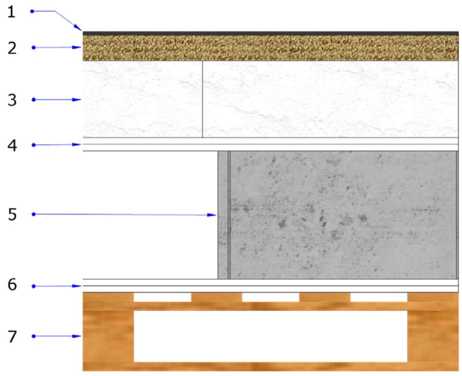


Kirils Simakovs, Research Assistant in the FRISSBE project team at ZAG

Kirils has an educational background in chemistry and experience in pharmacy, business management, and construction. He helps design, prepare, manage, and carry out experiments, as well as providing the technical documentation.

Nik Rus, PhD candidate in the FRISSBE project team at ZAG

Nik is enrolled as a PhD student in the Renewable Materials for Healthy Built Environments programme at the University of Primorska. His research focus is on the fire risk of PV systems.



1. Bitumen - consisting of a base layer (2.8mm) and top layer with aggregate aggregate (4.2 mm)
2. Mineral wool (50 mm) – Euroclass A1
3. EPS (150 mm) – Euroclass E
4. Plasterboards
5. Aerated concrete blocks
6. Plasterboards
7. Wooden pallet – for handling

Figure 2: *Structure of the roof with a mitigation layer and material details*

configuration. Two smaller standalone samples were placed at an angle next to the larger roof segment.

The detailed structure of the experimental roof setup is shown in Figure 2, along with details about the materials used. Layers 1-3 are representative of the realistic roofing structure, while the parts below just provided easier handling of the sample and protection of the floor in the laboratory.

The panel used for the traditional configuration in the test was a pre-used panel with glass on top and a polymer backside mounted on an aluminium mounting system. The dimensions were approximately 1.6 m x 1.0 m. The vertical panels were also pre-used bifacial panels (glass on both sides) mounted on an aluminium mounting system. The dimensions of the panels are 1.6 m x 0.25 m, and three vertical panels were mounted with a distance of 0.4 m between them. The standard and the vertical panels were kindly provided by the Istituto Giordano (Italy) and by Over Easy Solar AS (Norway), respectively.

Figure 3 shows the top view of the ignition locations, the close-up of the ignition source, and the moment of ignition. A wood crib (and its design) was picked as the ignition source since some of the standards use a similar version of it (e.g. EN 1187) and also because the heat transfer of a burning wood crib goes in all directions, includes all forms of heat transfer (conduction, convection, and radiation) and creates a fire that is in direct contact with the roofing membrane – all of which is deemed more challenging than a gas burner or other potential sources of ignition, while also being more realistic.

The locations of the cribs were chosen to reflect the worst-case scenario for both configurations with panels. For the inclined configuration, the crib was located close to the bottom edge of the panel where the height between the membrane and the backside of the panel was 11 cm to reflect findings about fire spread below PV panels by Kristensen et al. (2018, 2021, 2022). For the vertical configuration, the crib was located close to the junction box. For the smaller buildups, the crib was positioned in the centre of the samples.

The moment of ignition of the cribs is also shown in Figure 3. Moments before the ignition the cribs were soaked with 5-6 mL of isopropyl alcohol to ensure fast and uniform ignition of all parts of the cribs. After soaking the cribs, all four of them were ignited within less than five seconds by a lighter.

Figure 3: *Locations of the ignition sources (top right); schematic of the wood crib (bottom right); and the simultaneous ignition by FRISSBE members, Kirils Simakovs (left) and Nik Rus (right).*

To watch the video of the experiment, scan this QR code:

***Figure 4**: The fires at different locations before the extinguishment. Note that the rightmost buildup was put out earlier.*

Size of the fires

The fire on the unmitigated sample (Test 1) was extinguished around 12.5 minutes after the ignition due to the deformation of the EPS insulation and to prevent all of the EPS from burning.

The rest of the tests were extinguished around 15 minutes after the ignition. The extinguishment was carried out when the fire in Test 4 (the setup with the inclined geometry of the PV panel) spread across the whole roofing area under the panel and engulfed it. It should be noted that very limited damage to the underlying EPS was observed even for the bigger fire. In a fire with a duration as in the demonstration, the mineral wool provided a very good mitigation layer for this setup, which could represent a typical buildup for an existing roof where the EPS needed a mitigation layer (to avoid the complete involvement of the EPS, as seen in Test 1.)

The sizes of the fires before the extinguishment are shown in Figure 4 – the snapshot from the video shown in Figure 4 was taken somewhere around 14+ minutes after ignition.

Taking into account the same time frame and comparing the fires that developed in Tests 2, 3, and 4 (all with the same underlying roof setup) shows that the growth and spread of the fire were very comparable between Tests 2 and 3. There was no considerable fire spread beyond the crib area in any of them, but in Test 4 the fire managed to spread to a significantly larger area – it covered the whole surface below the inclined PV panel.

Two key findings can be taken from the demonstration. Firstly, the comparison of the vertical and the inclined PV panels demonstrates vividly that the inclined panels create conditions that enable rapid fire spread on the roof membrane, which is the same material that in other tests does not allow the flame to propagate (as shown in this demonstration). Secondly, having no mitigation layer between the roof membrane and insulation that is prone to damage from heat is strongly advised against, independent of the type and geometry of the PV panels installed on top. Note that similar results are found for other typical roofing membranes.

Conclusions

The demonstration tests provides two valuable insights to consider when deciding on a PV installation for the roof:

1. Configuration of the PV panels – panels installed in an inclined configuration can facilitate fire spread on the roofing membrane that would not promote any fire spread in scenarios without the PV installation or with PV panels in a vertical configuration.
2. Importance of the mitigation layer – in cases where the insulation materials of the existing roof are less resilient to the effects of heat, a mitigation layer of non-combustible material should be considered to prevent extensive damage.

All of this points out that when planning to install and maintain the PV system on a roof, consultation with fire experts should not be omitted. For more information regarding the fire dynamics and risks related to PV installations, feel free to reach out to us at ZAG or FRISSBE via the official channels, or directly via email (available on the ZAG website) or LinkedIn.

References

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