SolarPower Europe
Rooftop PV Fire Safety Factsheet

Rooftop solar PV installations are growing quicker than anticipated by EU member states. They are the preferred energy source for Europeans.[1] This public support requires high safety levels for solar installations on businesses and homes. Like all electrical equipment, its possible for rooftop PV equipment to catch fire. Furthermore, rooftop PV systems can alter the fire dynamics of buildings.

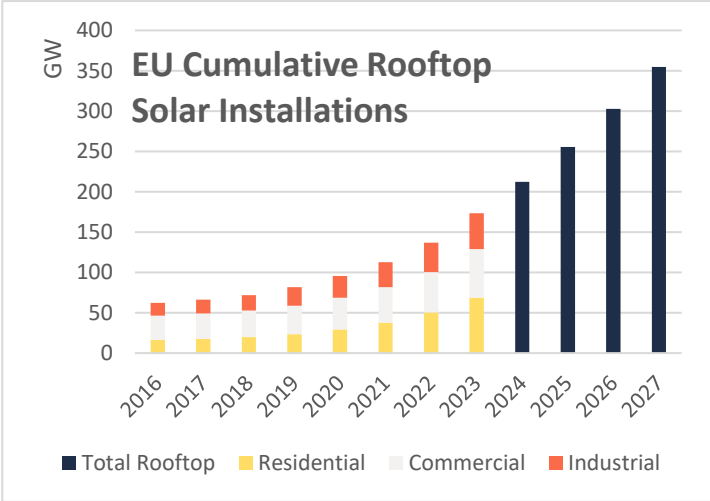


Figure 1: EU cumulative solar installation capacity, historic and forecast for residential, commercial, and industrial buildings. Source: SolarPower Europe. 2023. European Market Outlook for Solar Power

The latest statistics about fires involving PV systems in Europe are from 2018. Significantly more data is needed to better understand the correlation between fires and rooftop solar. [2] The necessary data should be reported by firefighters and insurance companies.

0.006% - 0.014%

Frequency of fires caused by solar PV in Germany (1993-2013) and the Netherlands (2018)

Fires of solar PV systems are marginal. The Dutch research institute TNO reported, that for the Netherlands, between 2015 and 2018, 27 fires on buildings with PV occurred in the Netherlands. 23 of these fires happened on residential buildings and 4 on commercially used buildings. It concludes that PV systems on residential buildings cause fires in 0.014% of the cases because 170,000 new PV systems were installed on residential buildings in 2018 (23/170,000).[3] The second statistical assessment is from Fraunhofer ISE, which reported that 0.006% of PV installations have caused a fire with major damage between 1993 and 2013.[4] Of Germany's total 1.3 million solar PV installations in 2013, 350 were involved in fires and 120 caused a fire.[5]

According to current research, the causes vary and are linked to the quality of the installation service or faulty equipment. In the rare instances, where the PV system caused a fire, it was due to a DC arc fault

[1] Solar energy shines in global survey with 68% support | Reuters
[2] There are –data missing– solar power fires per year – pv magazine USA (pv-magazine-usa.com)
[3] We note that this calculation seems inconsistent. Instead of just installations for 2018, numbers from 2015 to 2018 should be considered both for the fire instances and the annual installations, instead of just for the fire instances. Adjusting this calculation would further reduce the fire percentage by a factor of 2-3.
[4] Recent Facts about Photovoltaics in Germany (fraunhofer.de)
[5] The Italian National Fire Rescue and Service (CNVVF) published additional data reporting an incident rate of 0.45% on 550.000 PV systems from 2002 to 2015. This is roughly 1/200 PV installations. As a response to these high numbers, the Italian government has updated regulations. Accordingly, the report notes a peak of fire cases in 2013 with declining rates from that date on.

or localised overheating.[6] Arc faults on AC cables are also possible but much less frequent - the alternating current usually extinguishes the arc. There are several possible sources for DC arc faults or localised overheating:

- Poor installation, including earthing issues[7], poor wire management, such as wires running over sharp edges, inadequate weather protection of components, using incorrect crimping tools during installation, or DC connectors of different brands or insufficiently inserted. Some of these shortcomings can damage wires and equipment, which can cause arcs, short circuits and overheating.
- Faulty components: as with all electronic devices, inverters can malfunction, modules can contain production flaws, and electronic components can have quality issues. Additional potential causes are interconnections between or inside system components, such as DC connectors and cables, wire terminals of switches, junction boxes, etc. These can have defects and wear and tear over time. The failure of these connection points can create electrical arcs. An increase in connection time / DC connectors increases the likelihood of failure.

Further data from Germany (2015) and the UK (2017) suggests the following distribution of root causes: installation errors - 39% (DE) and 48% (UK), product defects - 36% (DE) and 16% (UK), design errors - 18% (DE) and 7% (UK), and external causes - 10% (DE) and 29% (UK).[8] Therefore there is a higher fire risk due to poor installation practices, and not of faulty components. 35% of fires happened in the first year after installation, and 90% of fires happened in the first 6 years of the installation.[9] The solar industry uses such knowledge to constantly improve installation practices, training of installers, products, and standards.

Existing measures to ensure safe PV installations

Several measures are already in place to address risks. Member states use different approaches to ensure high-quality installations and avoid electrical failures. Some require installers to undergo appropriate training, others have quality requirements before grid connection, and others require a final inspection of installations above a certain capacity. Product, installation, and documentation standards are available and are constantly updated as solar deployment evolves. To maintain high safety levels, compliance with the existing rules ensures high levels of safety.[10] Below are listed key requirements to ensure the safety of PV installations.

- **Before having a PV system installed, customers should check their insurance policy and inform the insurer.**
- **For preventing electrical hazards and fire spread, proper planning and installation according to the installation standards are key and ensure high safety levels.** They must be executed according to national requirements. Products must comply with national standards and product certification. Installers are expected to design installations to minimize flame spread in the case

[6] An arc fault is the flow of electrical energy through an air gap by way of ionized gas molecules. Whilst air is normally regarded as a non-conducting medium, a high potential difference (voltage) between two conductors in close proximity can cause the air molecules to break down into their ionized constituents (called a 'plasma'), which can then carry a charge from one electrode to the other, i.e. cause an arch.
[7] Earthing in solar PV systems is a safety step that involves connecting specific parts of the solar equipment to the ground. It provides a designated path to stray currents and prevents damage to electrical equipment and human injuries.
[8] BRE. 2017. Fire and Solar PV Systems – Investigations and Evidence
[9] Fraunhofer ISE. 2013. Schadens- und Brandfallanalyse an PV-Anlagen
[10] Recent Facts about Photovoltaics in Germany (fraunhofer.de)

of an incident. Where flammable insulating materials are used in a roofing assembly, it may be advisable to use non-flammable materials between PV modules and roofing materials ('cover-boards') or arc fault protection equipment. Installers are required to place the equipment distant from flammable materials and prevent the accumulation of flammable materials, such as dry leaves. They ensure ventilation or good airflow at components to reduce the risk of overheating. Installers are expected to ensure that cables are correctly attached, protected, not hanging loose, and that they are not pinched or under compression (for instance, between roof tiles).

- **All systems should be maintained regularly** to ensure safe operation over the lifetime of the PV system. The installer should communicate a maintenance plan to the system owner.
- **All inverters today are equipped with insulation monitoring** to find and avoid earth faults, which is an arcing risk. The function monitors DC circuits to detect an unintended current path to the earth. It is required by the International Electrotechnical Commission in their relevant standards: IEC 62109 and more recently specified in IEC 63112. When a fault is detected, the system will respond by sending an error message or by shutting down the system depending on the system typology. PV system owners must require an inspection by an installer in case of an issue.
- **The Arc Fault Protection function detects and mitigates arcing faults** on DC conductors which can occur in the intended path of current flow.[11] IEC 63027 (also a European Norm standard) defines **requirements for equipment** which provide arc fault detection and interruptionThis reduces the risk of fire to an even lower level.
- **Member states have implemented measures to support firefighters operating on buildings with PV systems**. Regarding reported cases, according to data and web research, out of all solar PV rooftop installations in the EU and the US, until October 2023, one firefighter was seriously injured while extinguishing a fire involving a PV system but the cause of the injury is unknown, including if it was linked to the PV installation. The incident happened in the US.[12] Possible safety measures are defined in the IEC TR 63226 technical report.

Standards

Planning, installation, connection and documentation of the PV system must be executed according to national requirements. These existing rules build upon Europe's PV module and rooftop fire requirements and classification. Roofs and BIPV systems are classified according to EN 13501-5 (10) based on test protocols with specific fire scenarios. The European standard on modules, EN IEC 61730-2: 2018, requires testing the module's reaction to external fires, according to EN ISO 11925-2 (11). Following the European approach, both are tested and classified separately. Where the combination of a PV system with a roof is tested, it commonly happens using the American test ANSI/UL 790.

[11] IEC TR 63226: Arc-fault detection (5.3)
[12] Referring to web research and data:

- Fraunhofer. 2023. Recent Facts about Photovoltaics in Germany
- BRE. 2017. Assessing Fire Risks in Photovoltaic Systems and Developing Safety Concepts for Risk Minimization
- BRE. 2018. Fire and Solar PV Systems – Investigations and Evidence
- Firehouse. 2019. Roof Solar Panel Fire Injures Springfield MA Firefighter

Solar roofs are classified according to EN 13501-5 (10) based on test protocols with specific fire scenarios under CEN/TS 1187. Germany, the Netherlands and Belgium require testing according to Broof (t1), Sweden, Norway, Finland and Switzerland according to Broof (t2), and France according to Broof (t3).

An overview of recommendations about applicable standards is available with IEC 62446-1, an international standard for commissioning tests, documentation and inspections of grid-connected PV systems. For example, on planning and installation, IEC 62548 covers PV system design standards, and IEC 60364-7-712 covers PV installation standards. IEC 62446-2 covers the maintenance of PV systems. The international technical report IEC TR 63226 illustrates further measures to manage fire risks related to PV systems.