FACULTY OF ENGINEERING AND ARCHITECTURE

A STUDY OF THE REQUIRED SPACING FOR PREVENTING FIRE SPREAD BETWEEN PHOTOVOLTAIC ARRAYS ON FLAT ROOFS

Mingcian HONG

SFPE Benelux General Assembly meeting 2021/06/23

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SFPE IMFSE STUDENT CHAPTER

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MINGCIAN HONG

IMFSE graduate in 2018
PhD student in Ghent University

RESEARCH PROJECT

Modelling of liquid pool fires in a confined and mechanically ventilated compartment

- Improving the numerical model of liquid pool fires in FDS

THE RESEARCH TEAM

Prof Grunde Jomaas

- Prof at the University of Edinburgh in Fire Safety Engineering
- BRE Chair of Fire Safety Engineering

Jens Steemann Kristensen

- PhD student at the University of Edinburgh
- Project: Fire safety related to the installation of photovoltaic (PV) systems on commercial buildings

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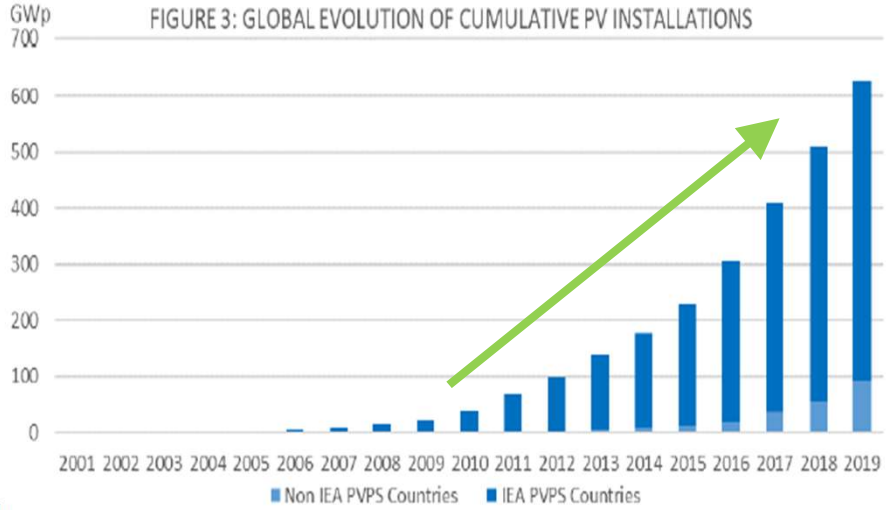
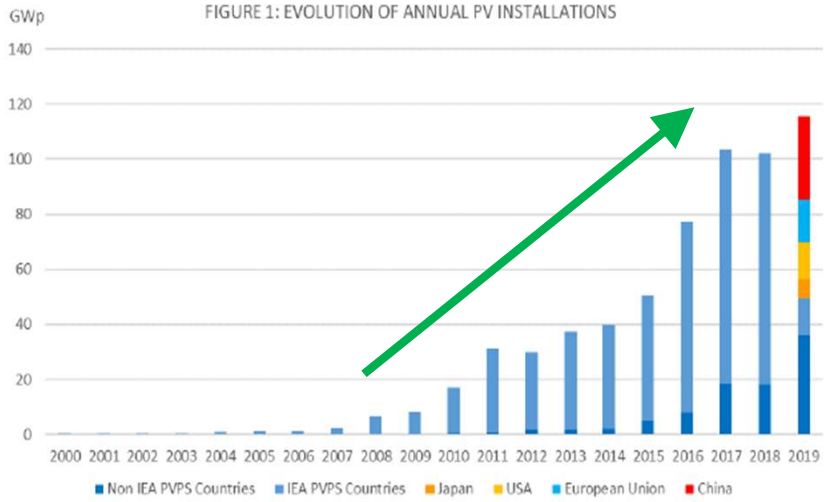
WHY IS IT IMPORTANT?

- Rapid increase of installations of solar energy system in the last decade
  - ➢ 2 million solar systems installed in US (2019)[1]
  - ➢ 2.4 million homes with rooftop solar in Japan (2018) [1]
  - ➢ 1.4 million solar power installations in Germany (2021) [1]
  - ➢ Around 4% of the electricity demand can be provided by solar energy in Belgium[2]

[1] https://pv-magazine-usa.com/2019/08/22/there-are-solar-power-fires-per-year/
[2] https://en.wikipedia.org/wiki/Solar_power_in_Belgium#cite_note-:0-2



Source: IEA PVPS annual report; Snapshot of Global Photovoltaic Markets 2020



Source: IEA PVPS annual report; Snapshot of Global Photovoltaic Markets 2020

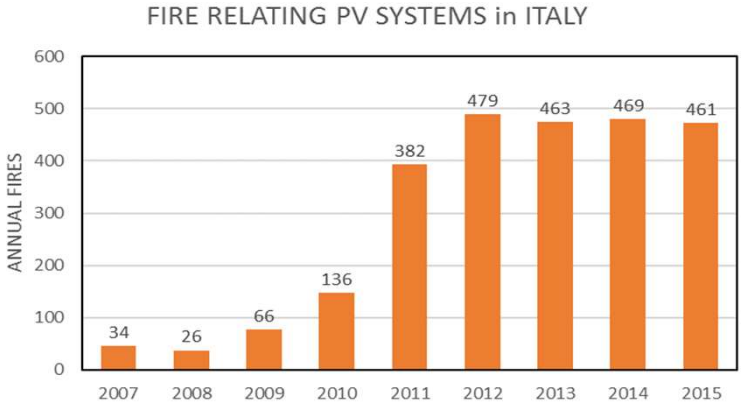
WHY IS IT IMPORTANT?

- More fires are reported related to PV systems

A warehouse installed with 7000 solar panels burned down in New Jersey In 2013
Source:https://www.nj.com/burlington/2013/09/dietz_and_watson_warehouse_fire_solar_panels_make_battling_blaze_much_harder_officials_say.html

A 1000 m2 warehouse housing a PV plant keep on fire
Source:Fire Risk Assessment of Photovoltaic Plants. A Case Study Moving from two Large Fires: from Accident Investigation and Forensic Engineering to Fire Risk Assessment for Reconstruction and Permitting Purposes, Fiorentinia et. Al (2016)

Walmart filed suit against Tesla over fires for installation and maintenance of PV systems.
Source: https://pv-magazine-usa.com/2019/08/21/walmart-accuses-tesla-of-gross-negligence-in-fire-lawsuit/



Source: A review of the photovoltaic module and panel fire tests, Cancelliere P. et al., 2nd International Fire Safety Symposium 2017

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WHY IS IT IMPORTANT?

- New fire risks are introduced after PV installations
  - ➢ Fire dynamics change under PV modules
  - ➢ Extra fire load
  - ➢ New sources of ignition
  - ➢ Influence for smoke and venting systems
  - ➢ Intervening rescue actions and electrocution hazard for firefighting

- The fire risks of PV installations are **NOT** yet well studied

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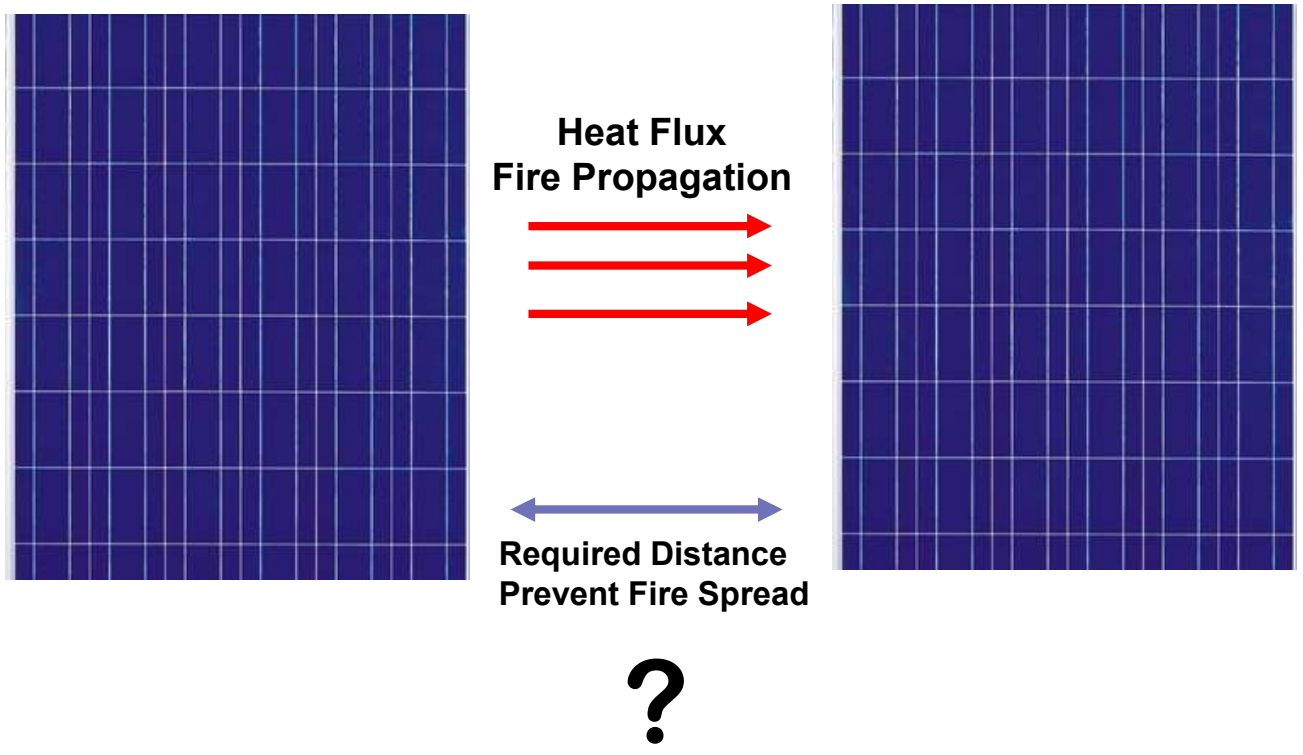
WHAT ARE MY RESEARCH QUESTIONS?



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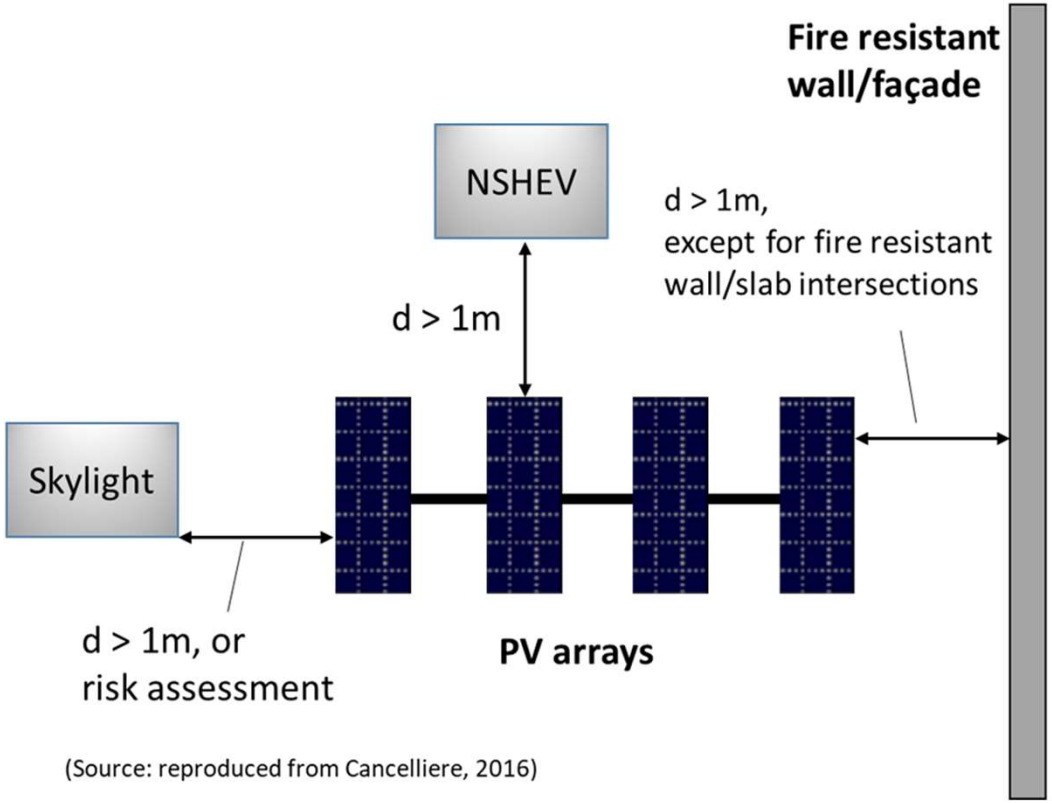
WHAT ARE MY RESEARCH QUESTIONS?

- Regulations?
- Italian fire safety guidelines: **one-meter clearance** between PV panels and roof elements



(Source: reproduced from Cancelliere, 2016)

NSHEV: Natural smoke and heat exhaust ventilators

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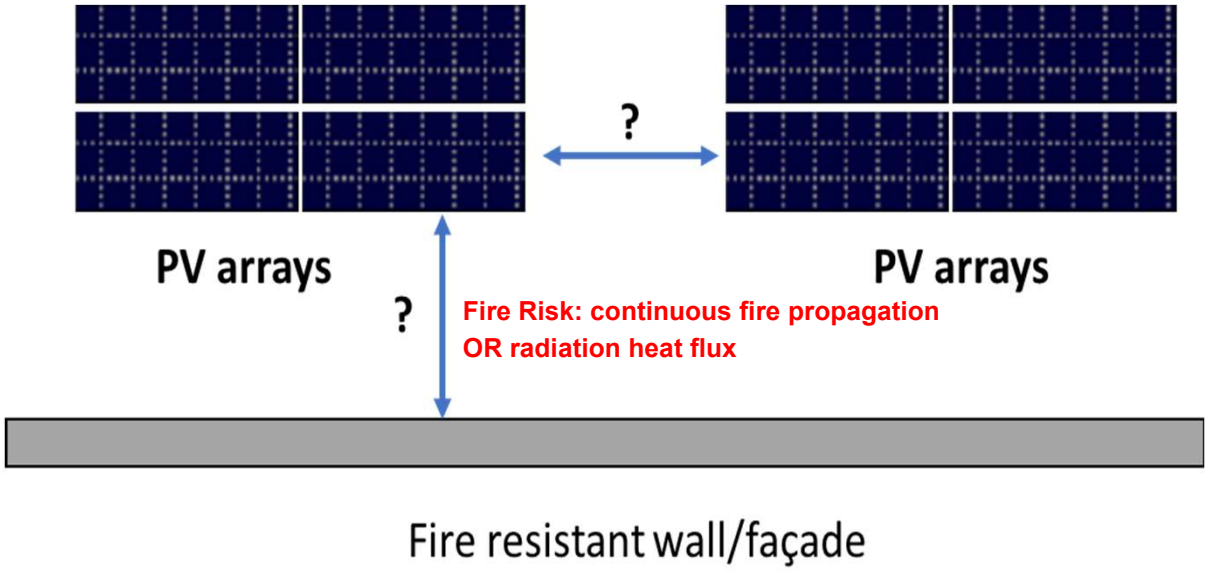
WHAT ARE MY RESEARCH QUESTIONS?

The Research Questions:

- Is there a **required spacing** for preventing the fire spread between PV arrays?
- Is the **one-meter** clearance suggested by Italian fire safety guideline **enough?**



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EXPERIMENTAL SETUP (1/3)

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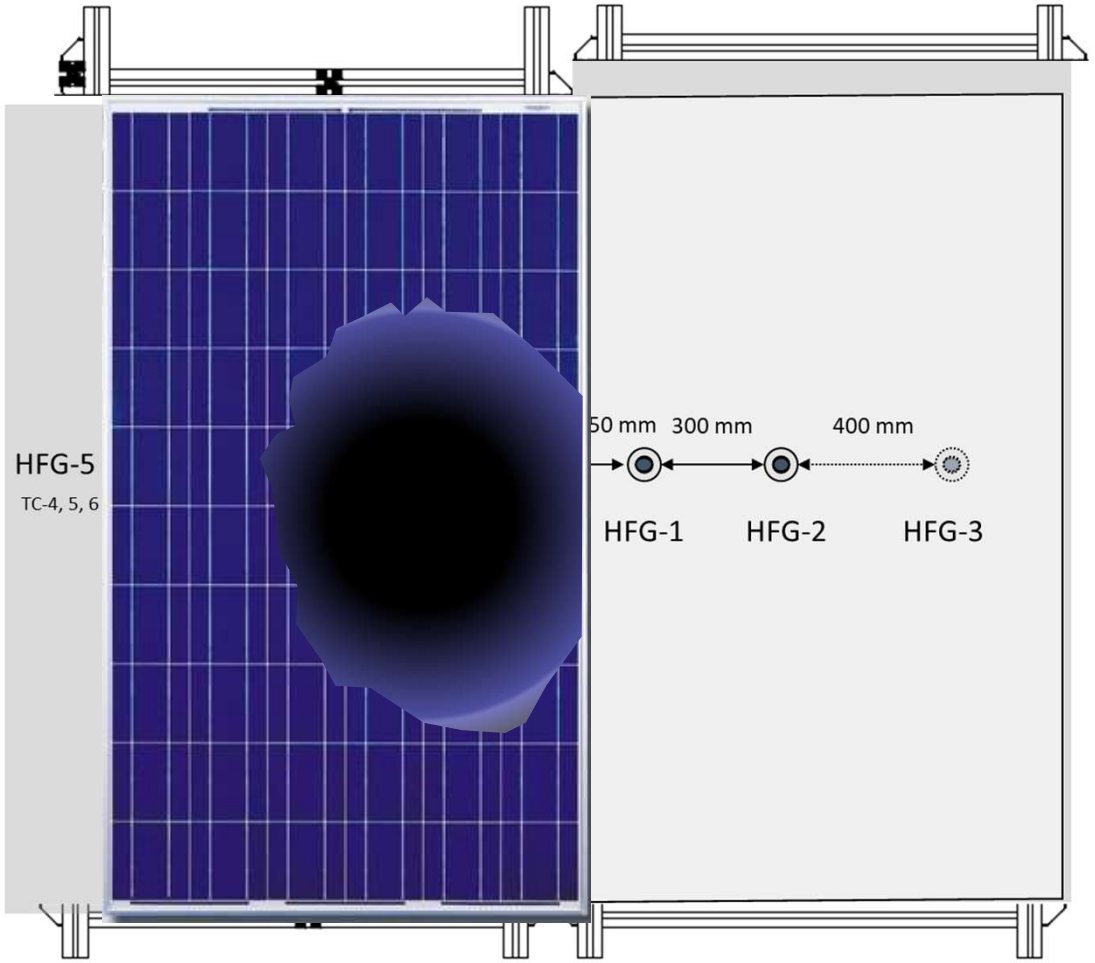
EXPERIMENTAL SETUP (2/3)



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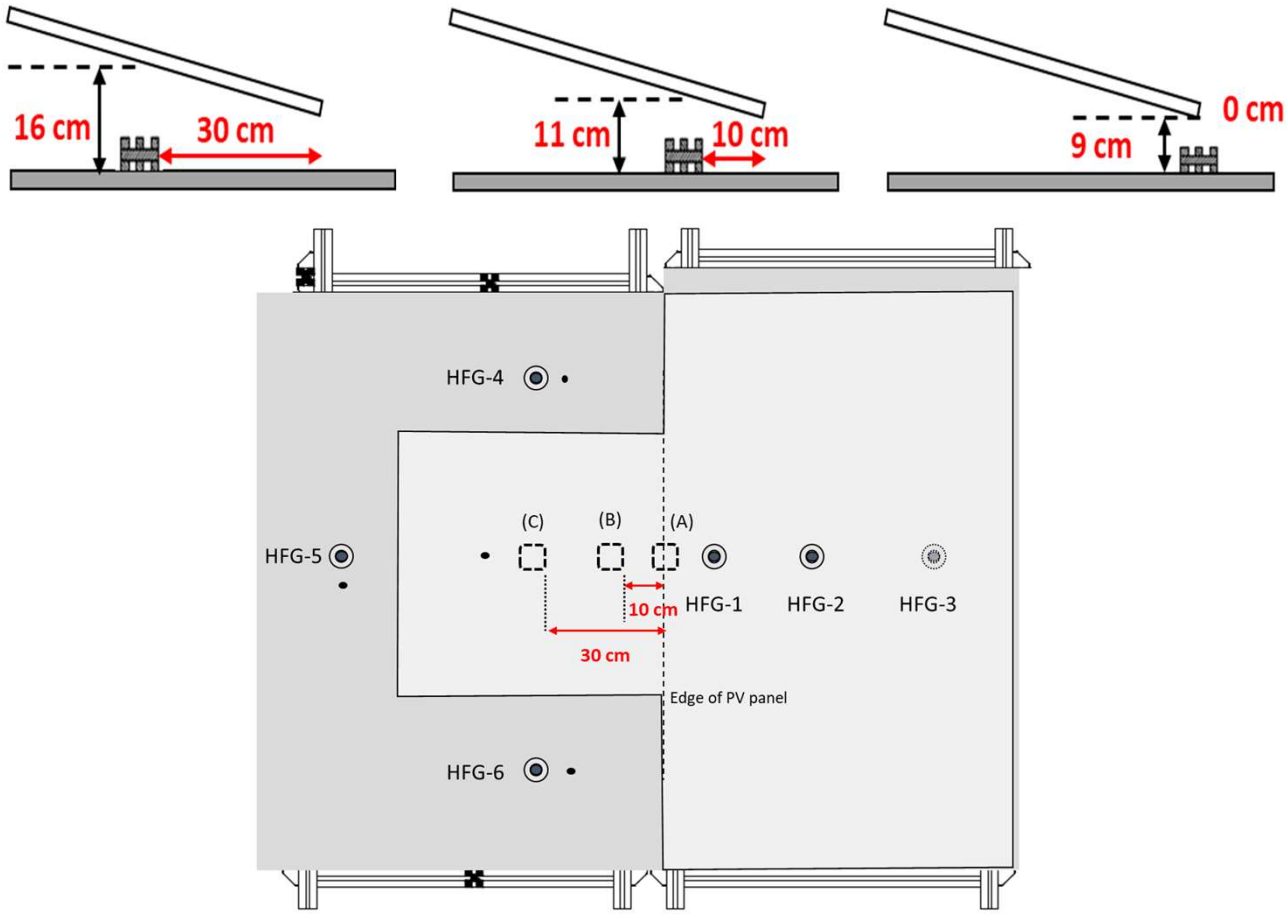
EXPERIMENTAL SETUP (3/3)



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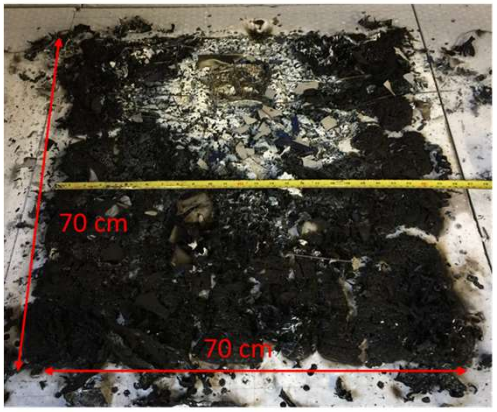
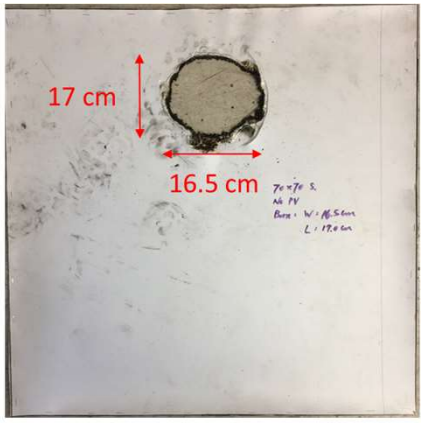
THE FIRE BURNS STRONGER AND FASTER UNDER PV



Test 10 (under PV)

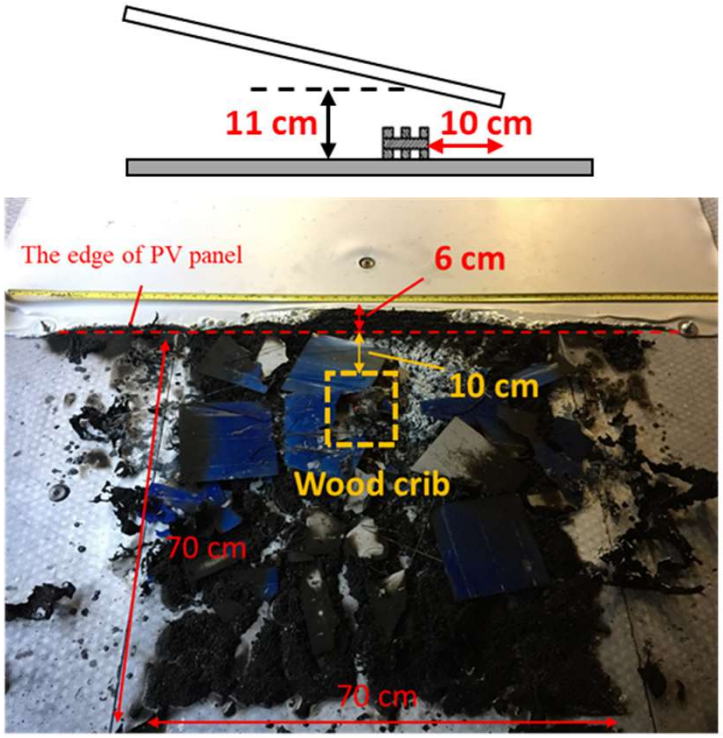


Test 11 (without PV)

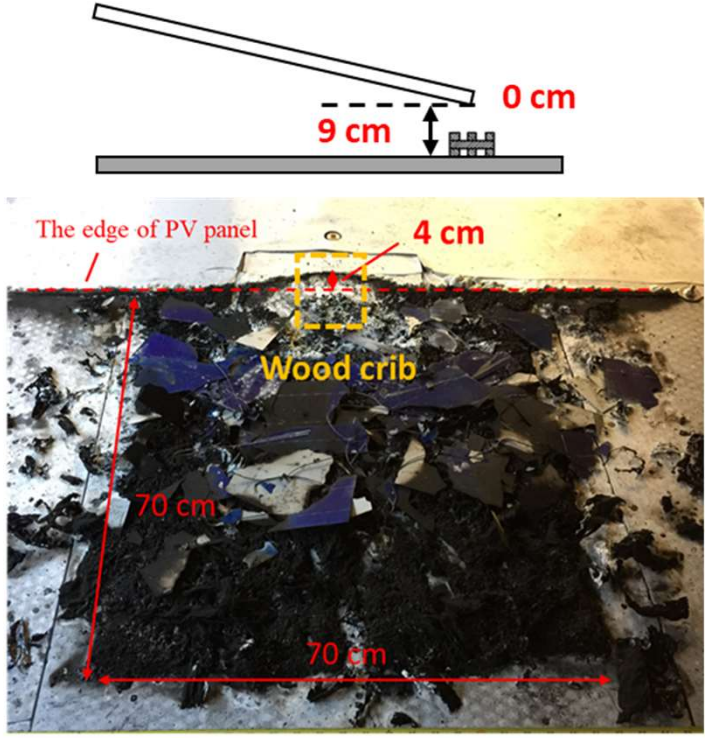
	Under PV Installation (Test 10)	Without PV Installation (Test 11)
Fire spread	Whole membrane burned	The flame only spread a few centimeters
Peak HRR	**141 kW**	**5 kW**
Fire growth	**Faster** (400 seconds to reach 141 kW)	Slower (540 seconds to reach 5 kW)

- The PV installation is changing the fire dynamics underneath
  - ➢Feedback of radiation heat
  - ➢More heat is accumulated
  - ➢Adding a “roof” on the top of fire
- The fire was more violent under **NEW** PV modules
  - ➢The PV module is adding more fuel
  - ➢The added heat source is inferred to be more dominant than the re-radiation heat
  - ➢93 kW (new PV) vs. 16 kW (burned PV)

THE RISK OF FIRE PROPAGATION IS LOW IN THE ABSENCE OF WIND



Test 26, peak HRR = 93 kW
Position of ignition: **10 cm** from panel



Test 29, peak HRR = 81 kW
Position of ignition: **0 cm** from panel

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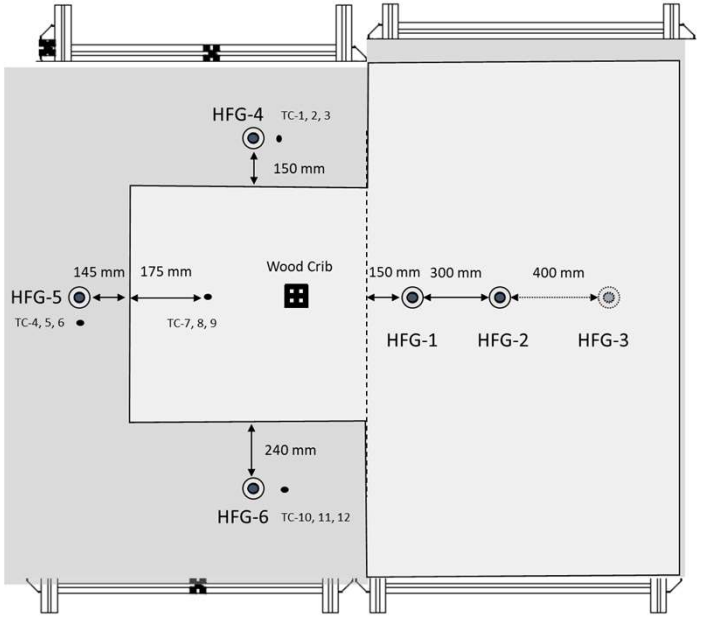
THE RISK OF DISTANT IGNITION OUTSIDE THE PV INSTALLATION IS LOW

- The **heat flux outside the PV was very low**
  - ➢ 1.4 kW/m^2 for a 93 kW fire
  - ➢ ~8 kW/m^2 is required to ignite the roof membrane placed
- < 1.7 kW/m^2 to human skin: no pain is experienced no matter how long the duration of the exposure of thermal radiation (SFPE handbook, 5th ed.)

Number of Test	Max. HRR (CDG) [kw]	HFG1 [kW/m2]
Test 10	141	**1.0**
Test 26	93	**1.4**
Test 29	81	**1.1**



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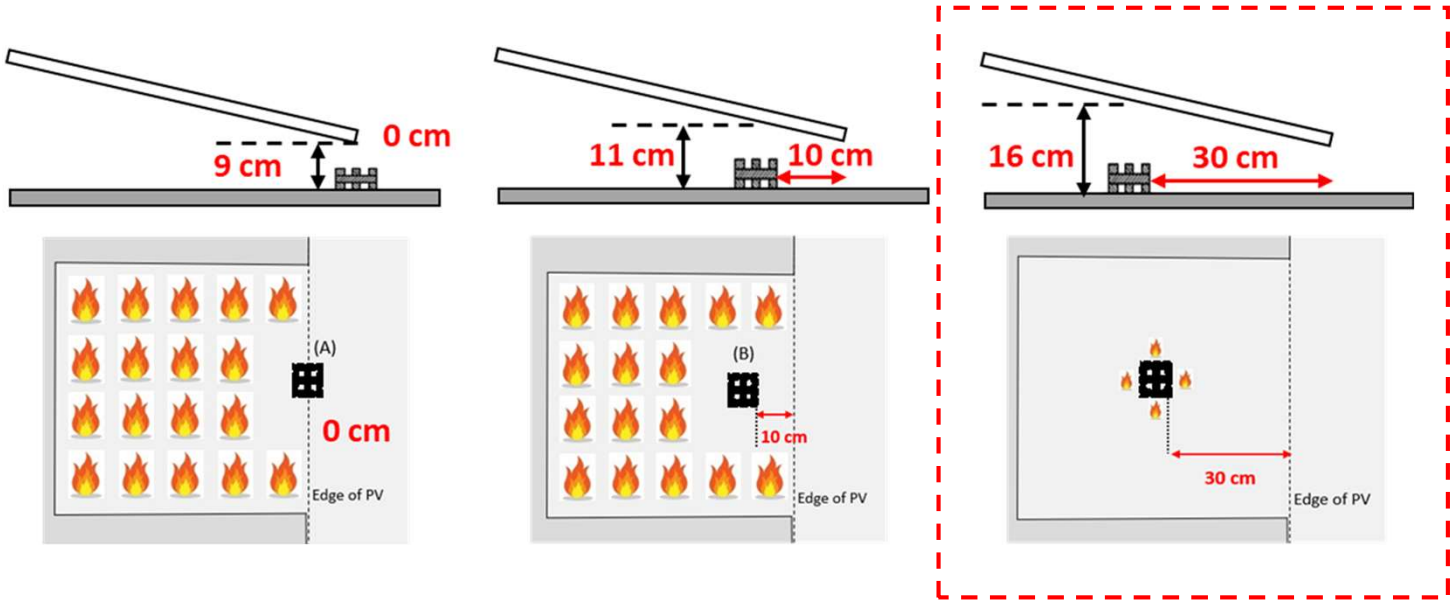
EFFECTS OF IGNITION POSITION AND GAP DISTANCE

- The **gap distance can influence the fire spread under PV**
- As the gap distance increased to 16 cm, the fire propagation was very limited in the test
- More difficult to ignite the PV module
- Re-radiation heat flux decreased as gap distance increased

➢ **can be a way for mitigating the fire risk under PV installations**



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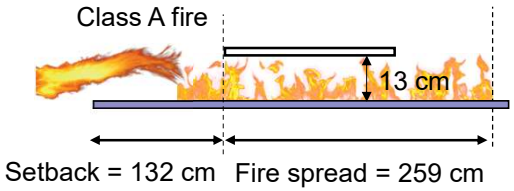
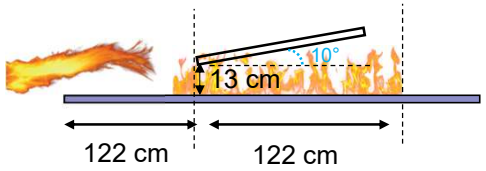
UL PV FIRE TESTS (FIRE SPREAD)



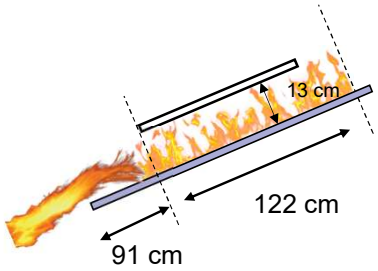
Low Slope Roof
PV: Inclination = 0°
Gap = 13 cm
Setback = 132 cm

(X) FAIL



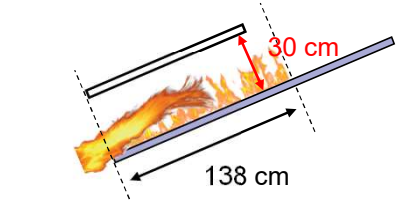
Low Slope Roof
PV: Inclination = 10°
Gap= 13 cm
Setback = 122 cm

(O) PASS



Steep Slope Roof
PV: Inclination = 0°
Gap= 13 cm
Setback = 91 cm

(O) PASS



Steep Slope Roof
PV: Inclination = 0°
Gap = 30 cm
Setback = 0 cm

(O) PASS

Roof Slope[1]	PV Module			Fire Rating (Class A)
	Setback [cm]	Angle [°]	Gap [cm]	
Low	132	0	13	Fail
Low	122	10	13	Pass
Steep	91	0	13	Pass
Steep	0	0	30	Pass

[1] steep slope roofs: constructed by 3-tab shingles over plywood, the slope is around 23° inclination
low slope roofs : constructed by roof membrane and insulation boards
[2]Source: UL tests (Backstrom, 2012)

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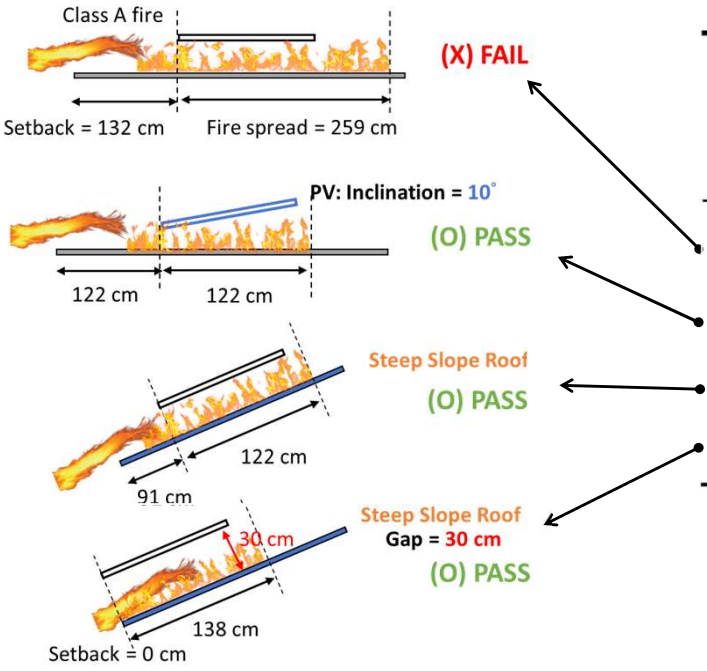
Discussion of Italian regulations and UL tests

- **Details of PV installation and roof construction** are important for determining the required distance for PV arrays
- The **one-meter clearance suggested by Italian fire safety guidelines might be not enough**

➢ the fire can spread more than 1.2 m for a large fire



Roof Slope[1]	PV Module			Fire Rating (Class A)
	Setback [cm]	Angle [°]	Gap [cm]	
Low	132	0	13	Fail
Low	122	10	13	Pass
Steep	91	0	13	Pass
Steep	0	0	30	Pass

PV inclination

Gap distance

Roof slope and building materials

[1] steep slope roofs: constructed by 3-tab shingles over plywood , the slope is around 23° inclination
low slope roofs : constructed by roof membrane and insulation boards
[2]Source: UL tests (Backstrom, 2012)

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CONCLUSIONS OF THIS STUDY

- The fire can grow faster and stronger under PV installations.
- It is safe to assume the probability of fire spread between PV arrays on flat roof is low
  - when some distance between the clusters &
  - when wind effects are neglected
- Two major causes for the increased fire risks under PV installation
  - The heat release from the burning film on the backside of PV
  - Re-radiation by PV modules
  - The heat contribution from the burning film was inferred to be more dominant.
- The fire risks under PV can be reduced by
  - changing the gap distance: increase (or eliminate)
- By analyzing the results of UL tests,
  - Details of PV installation and roof construction are important to determine the fire risks under PV arrays.
  - The 1 m separation distance suggested by Italian regulations might not be enough during larger fires.

MORE ATTENTIONS REQUIRED FOR PV FIRE RISKS

- **LACK OF PV FIRE STATISTICS**
  - The fire statistics of solar energy systems are rare in Europe
  - PV fires are categories as “others” in the U.S. Fire Administration (USFA) and no information available on PV fires in U.S. National Fire Data Center[1]
- **LACK OF PV FIRE SAFETY REGULATIONS**
  - Few countries have PV fire safety regulations (more focus on electrical safety, or even on maintenance and energy efficiency)
  - The study showed that the installation method and roof construction can influence a lot for the fire risks. → very few regulations found for this part
- **LACK OF AWARENESS OF PV FIRE SAFETY**
- MORE **ATTENTIONS** REQUIRED!

[1] https://pv-magazine-usa.com/2019/08/22/there-are-solar-power-fires-per-year/

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THANK YOU FOR YOUR ATTENTION

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