A state-of-the-art review of fire safety of photovoltaic systems in buildings : key conclusions and actions needed

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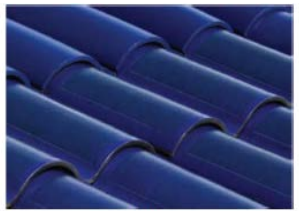
EUROPEAN FIRE SAFETY WEEK 2021

Fire Resistance in Plastics

Building Integrated Photovoltaic Systems (BIPV)

- With the advancement in PV technologies, PV modules are integrated into building skins
- Turn them into electricity-generating building elements
  - Solar exterior claddings
  - Solar glass curtain walls
  - Solar balcony
  - Solar skylight
  - Solar roofing



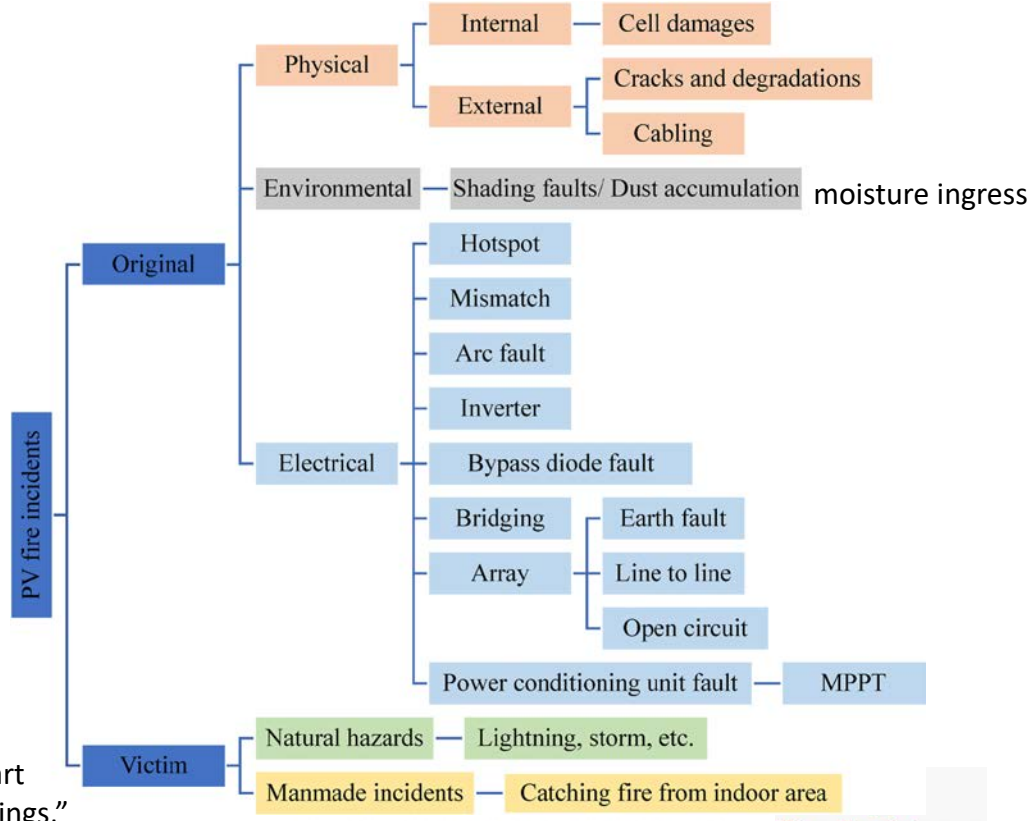
Glass facade with integrated photovoltaics towards the busy street

photoes:
Photovoltaics in architecture - lessons learned in PV Nord, 2004
Guidelines on building integration of photovoltaic in the Mediterranean area

BIPV Fire Risks

- What makes the BIPV products more vulnerable than other regular building materials → fire can be originated from the BIPV
- Fire risks of BIPV should be addressed
- for electrical safety of PV modules/systems
  → to prevent a fire originating on PV modules
  → Electrical standards/regulations (IEC standards)
- for fire resistance of PV products as building components
  → to limit the fire spread to the building and neighboring buildings; and to allow safe egress.
  → BIPV standards do not provide PV specific fire resistance requirements in detail, yet refer to local building codes (EN 50583 refers to EN 13501 for normal construction products and building elements).

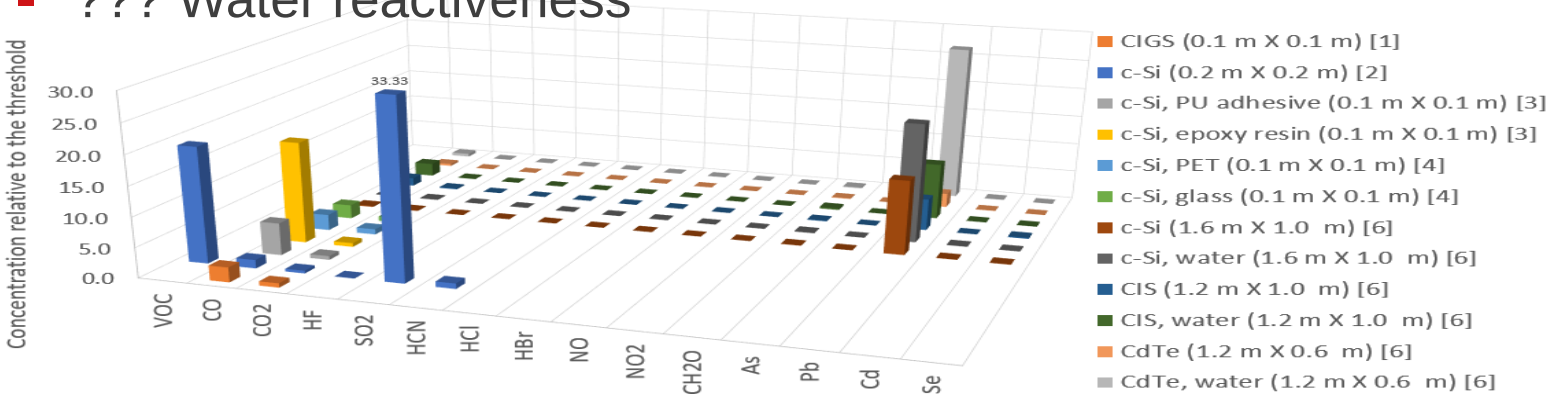

Dietz & Watson in Delanco, NJ (Source: FOX)

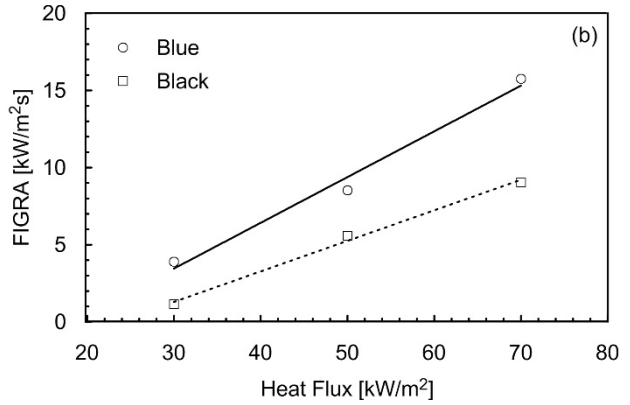


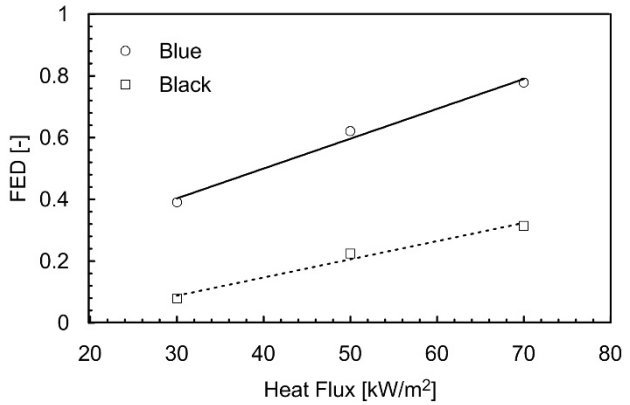
M. Aram, X. Zhang, D. Qi, and Y. Ko, "A state-of-the-art review of fire safety of photovoltaic systems in buildings," *J. Clean. Prod.*, Jul. 2021

Evaluations for material reaction to fire

- The encapsulant of PV modules (e.g., EVA) → combustible, the back-sheet → flammable
- Construction materials are required to be evaluated for their fire behaviour, combustibility, ignitability, heat and smoke generation, and flame spread.
- ??? PV specific test methods or enhanced performance requirements
- ??? Fire behavior/flame spread when electrically active
- ??? Smoke Toxicity
- ??? Water reactiveness







toxic gases of sulfur dioxide, hydrogen fluoride, hydrogen cyanide and VOCs from PET laminated PV fires.

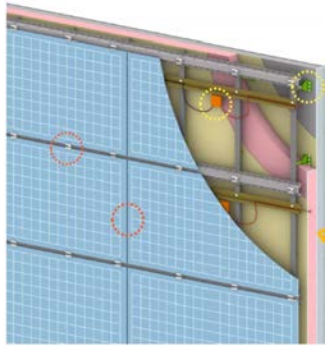
Resistance to fire originating from the BIPV

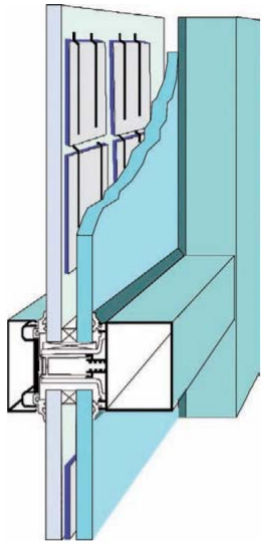
- Solar wall claddings can self-ignite due to electrical defects, physical impacts, module damages and environmental issues such as moisture ingress

→ a requirement for a barrier might be needed particularly for BIPV cladding/curtain systems

→ to resist the spread of fire originating from the PV exterior claddings.

→ Currently, the thermal barrier is required in the IBC in the US when a cladding system contains an insulation layer, to separate the cladding from the interior of the building.





http://pvtrin.eu/assets/media/PDF/Publications/Other%20Publications/39.BIPV%20BEST%20PRACTICES.pdf

Resistance to fire exposure from within a building

- Solar claddings → any system mounted shall not affect the fire resistance of the primary exterior walls.
- Solar glass curtain walls when a fire rating is required → BIPV curtain wall to be tested by the standard fire resistance wall tests.
- ??? The current failure/temperature criteria are applicable to BIPV
- ??? Testing during the operation, BIPV could be heated up to 100°C in even normal operation

Mitrex.com
Front tempered glass, solar cells (Monocrystalline or thin-film technology), Back tempered glass, Air space, and interior glass

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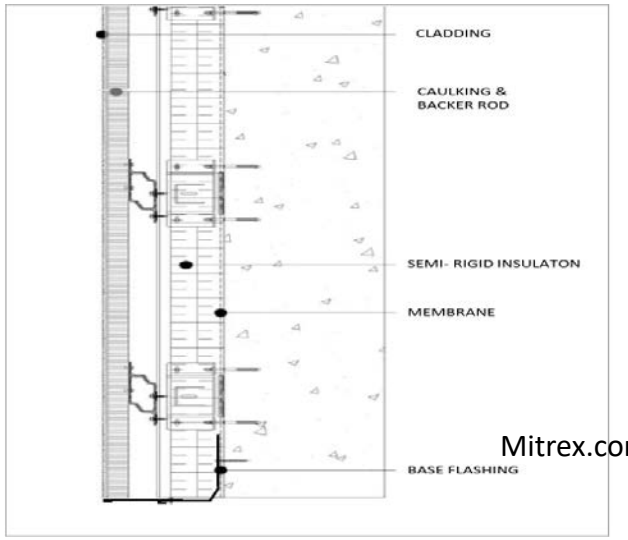
Resistance to fire spread on exterior BIPV facade

- Smoke and flame tend to propagate rapidly via the cavity space behind the combustible claddings.
- Fire spread could be attributed to the PV operation temperature; combustibility of PV and substrate layers; and designs of mounting systems (cavity space for cooling).
- For the vertical fire spread testing, the current local building codes require combustible claddings and curtain walls pass large-scale façade fire spread tests (NFPA 285, ISO 13785 etc.) exposing the BIPV to the window flame.



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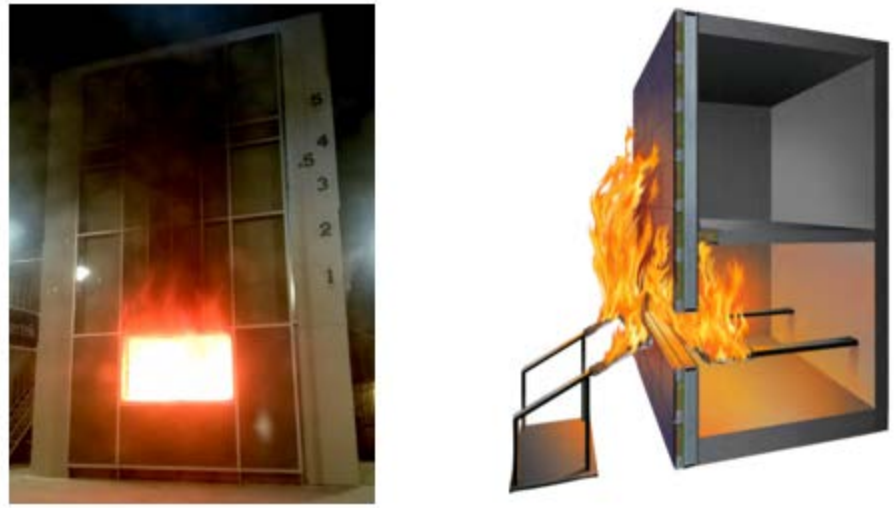


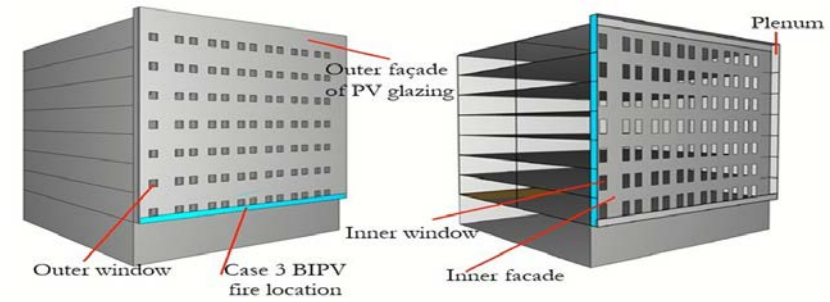
(a) CAN/ULC S134 test (source: glascurtain.ca) (b) NFPA 285 test (source: thermafiber.com)

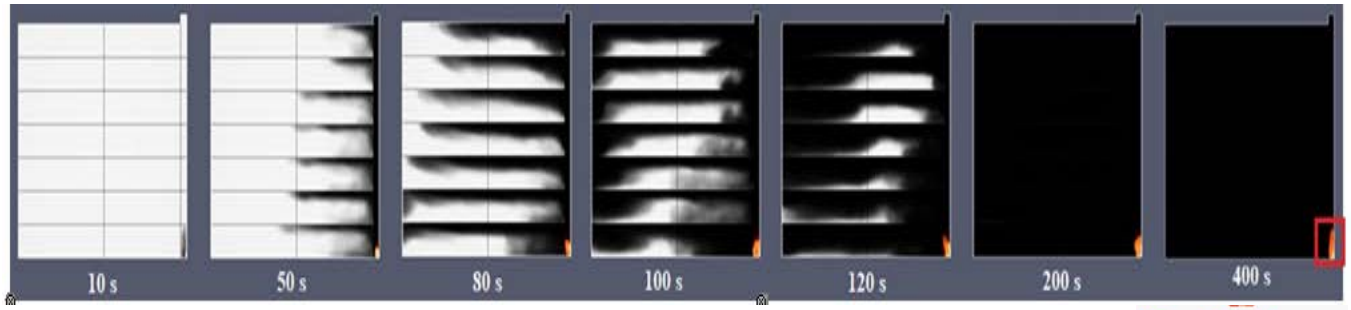
Fire safety requirements for BIPV DSF

- The BIPV Double Skin Facade (DSF) is novel façade technology used in new buildings as well as retrofit projects, two skins (PV exterior glazing + normal glazing)
- Between the two, plenum space
- ??? The detailed design requirements/codes for the PV DSF are not yet available, and the fire risks of the PV DSF are also not fully understood.
- Concerning a fire starting from the PV skin, the PV DSF should be designed for smoke and fire protection
- Smoke could propagate through the plenum space endangering the occupants inside the building

PV double skin façade (source: tboake.com)

M. Aram, D. Qi, and Y. Ko, “Fire Smoke Control for Building Integrated Photovoltaic (BIPV)”, ASHRAE Conference 2021.





Key conclusions and actions needed

- The fire safety requirements/testing methods for BIPV are relayed back to the local building codes/standards, which are developed for ordinary construction systems.
- Meeting the requirements in the current building codes and standard test methods does not verify the fire safety of BIPV systems.
- The current fire safety test and performance requirements should be re-evaluated in application to BIPV
- to address the unique challenges posed by them and reflect the actual burning behaviour of PV modules (when electrically active in operation).
- New standards/test methods/guides for
  - Evaluating potential toxic smoke hazards from BIPV and their impact on occupant evacuation
  - Evaluating any additional fire protection system requirements for effective fire detection, fire suppression and safe occupant evacuation.
  - Fire fighting considerations including tactics, potential electrical shocks and so on.

Thank you so much

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