PV Systems and Fire Hazard

Experiences and discussion topics in Germany

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Fraunhofer-Institut für
Solare Energiesysteme ISE

Fire Asia 2018,
May 7, 2018 – May 9, 2018
Hongkong

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PV Systems and Fire Hazard

Agenda

- Role of PV in Germany
- Electricity and fire hazard
- PV physical pecularities
- PV fire incidents analysis
- Fire fighting: procedures and hazard mitigation
- Conclusions + recommendations

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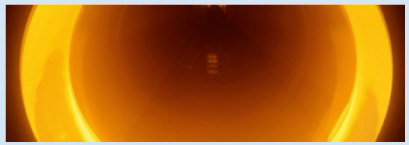
At a Glance

Fraunhofer is a research organisation dedicated to applied research

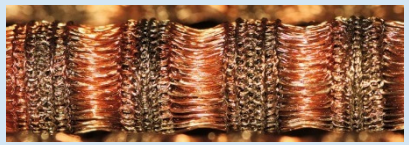
Institute Directors:
Prof. Dr. Hans-Martin Henning
Dr. Andreas Bett

Staff:	ca. 1200
Budget 2016:	€89 million
Established:	1981



Photovoltaics

Solar Thermal Technology



Building Energy Technology

Hydrogen Technologies

Energy System Technology

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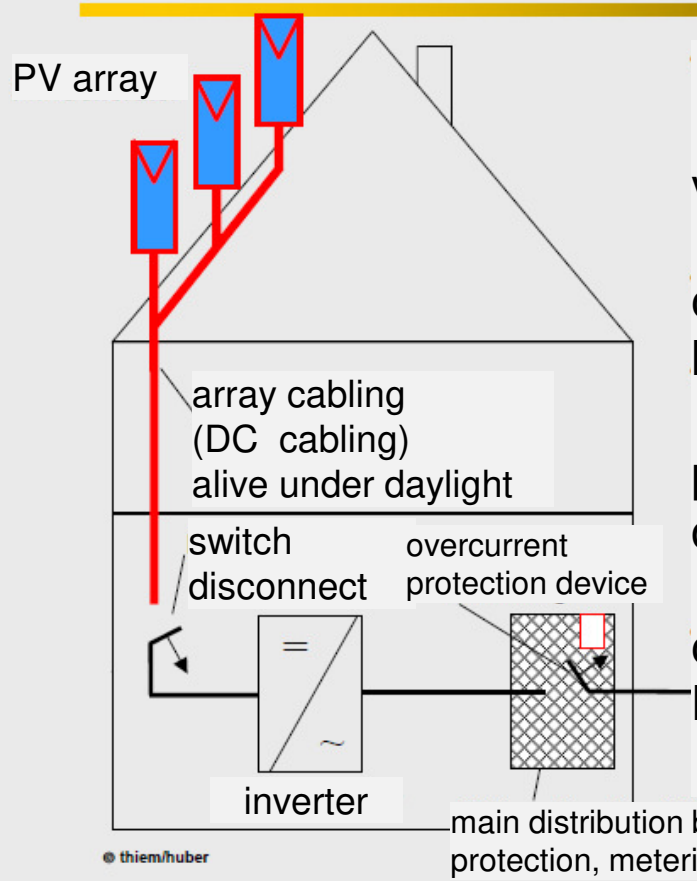
PV Systems and Fire Hazard
Photovoltaics (PV)

Basic structure of a PV System



voltage DC side: up to 1500 V

current: some Amps …. some kiloAmps

power:
domestic some kilowatt

commercial, industrial some Megawatt

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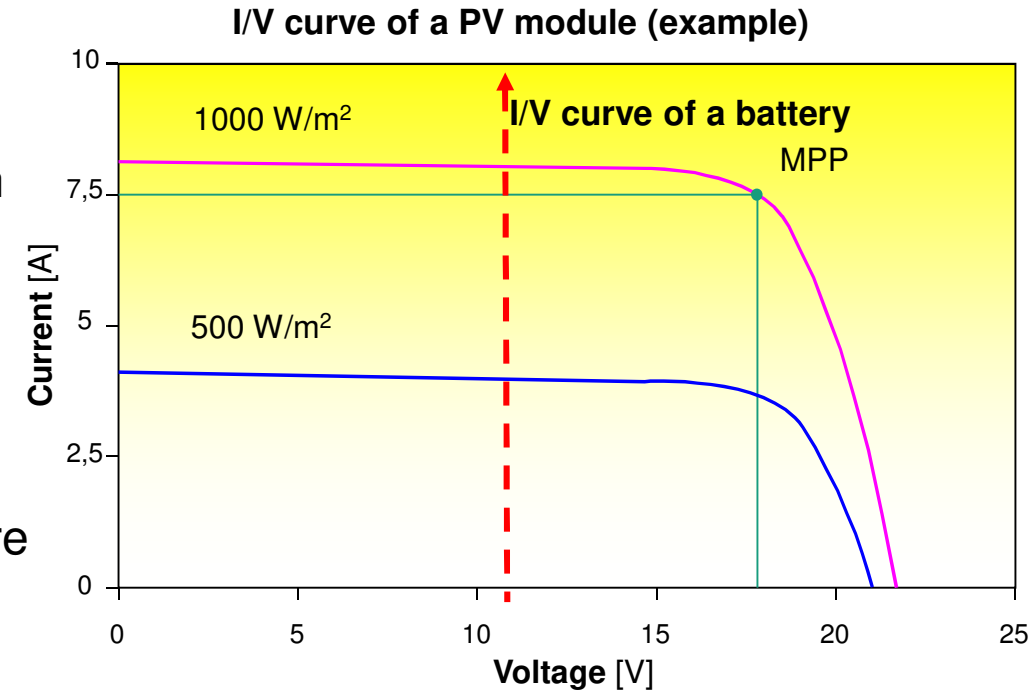
PV Systems and Fire Hazard
Photovoltaics (PV)

PV converts (sun) light directly into DC current

a PV module is different from conventional power outlet

- Current is limited
- Current depends on irradiation
- Cannot trip a circuit breaker or fuse
- voltage reaches nominal value at rather low irradiation
- ➢ Under sunlight: PV systems are always alive



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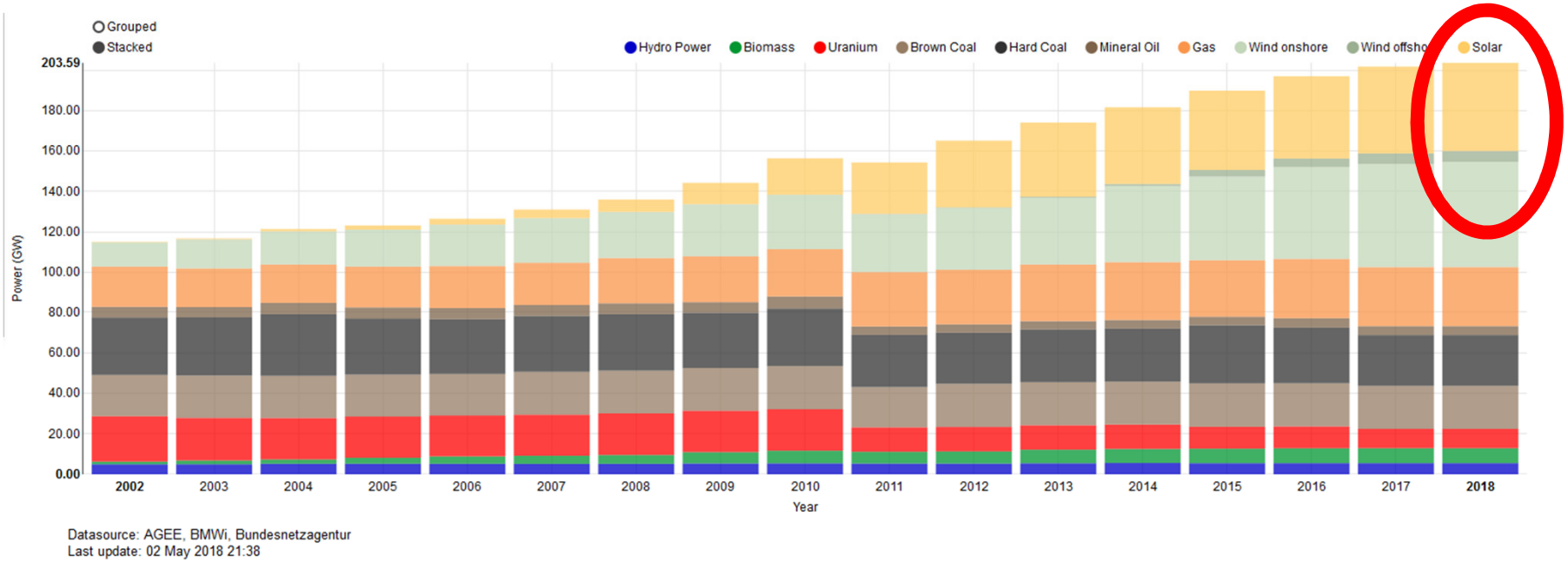
PV Systems and Fire Hazard

Role of PV in Germany

installed nominal power

- some 1.6 million PV systems with some 46 GWp nominal power
- About 200 GW total production power



Source: https://www.energy-charts.de/power_inst_de.htm

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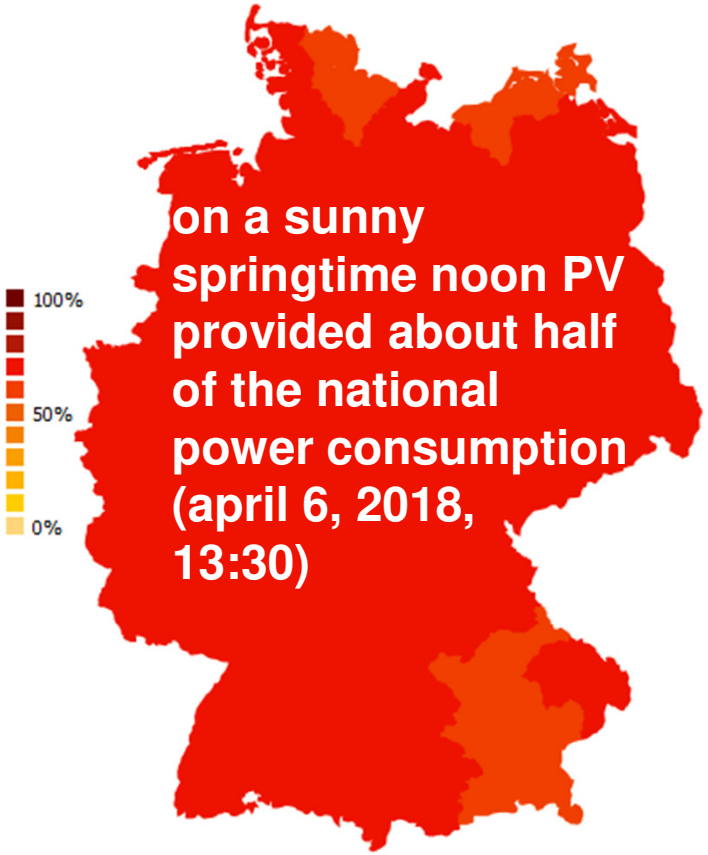
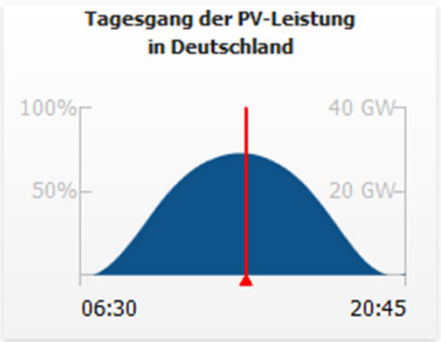
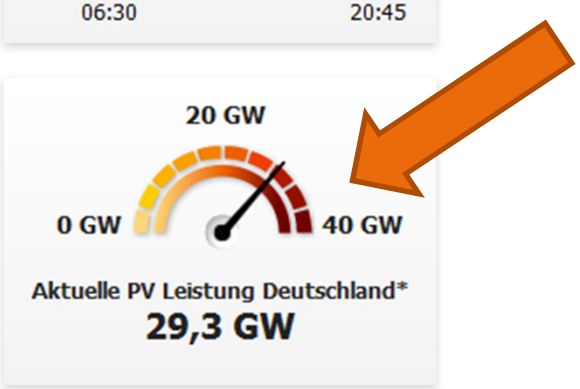
Role of PV in Germany

- PV heavily impacts the German electricity system







https://www.sma.de/unternehmen/pv-leistung-in-deutschland.html

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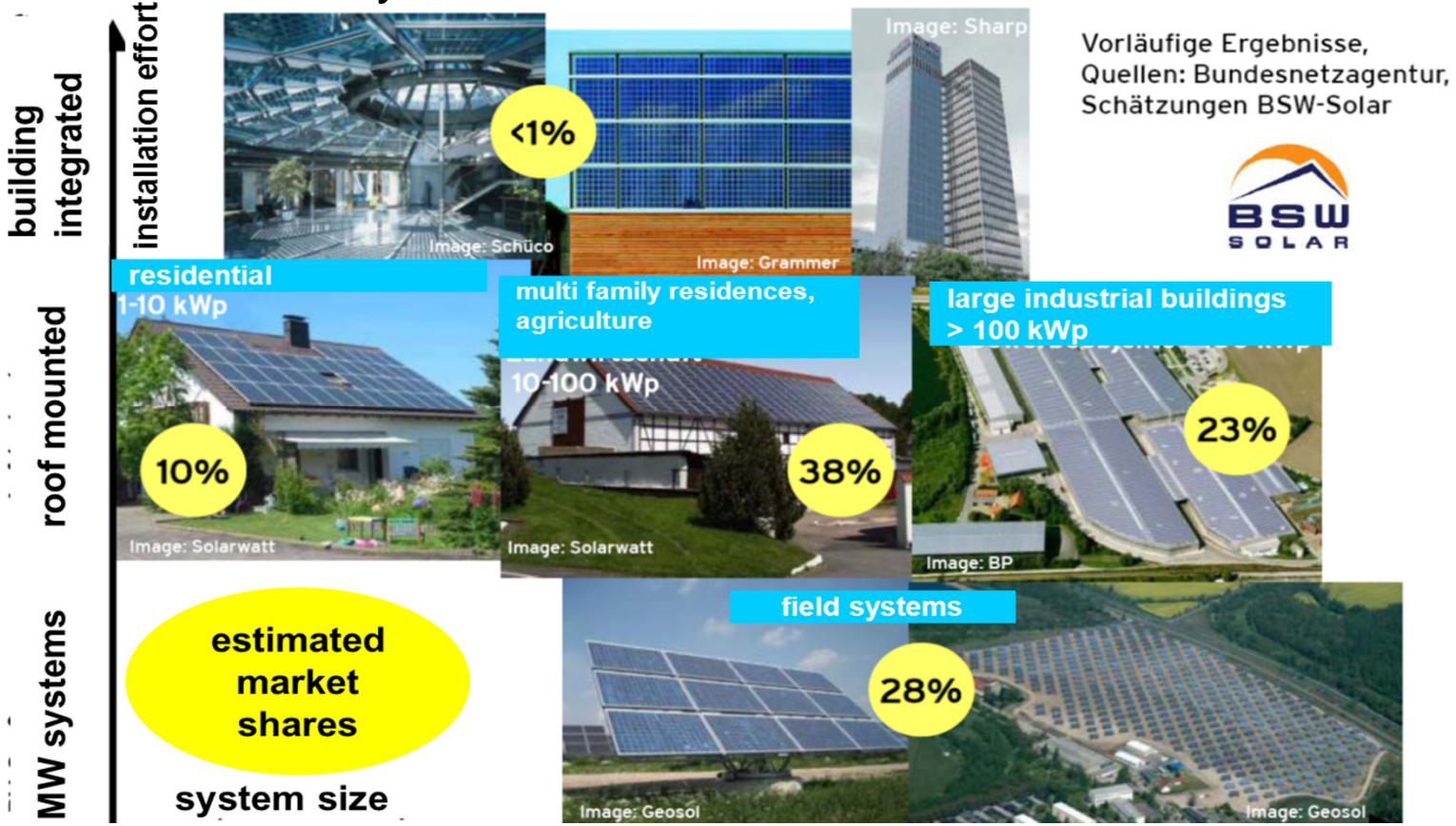
Role of PV in Germany

End 2017 : 1.6 million PV systems with 46 GWp nominal power

Where are this systems located?



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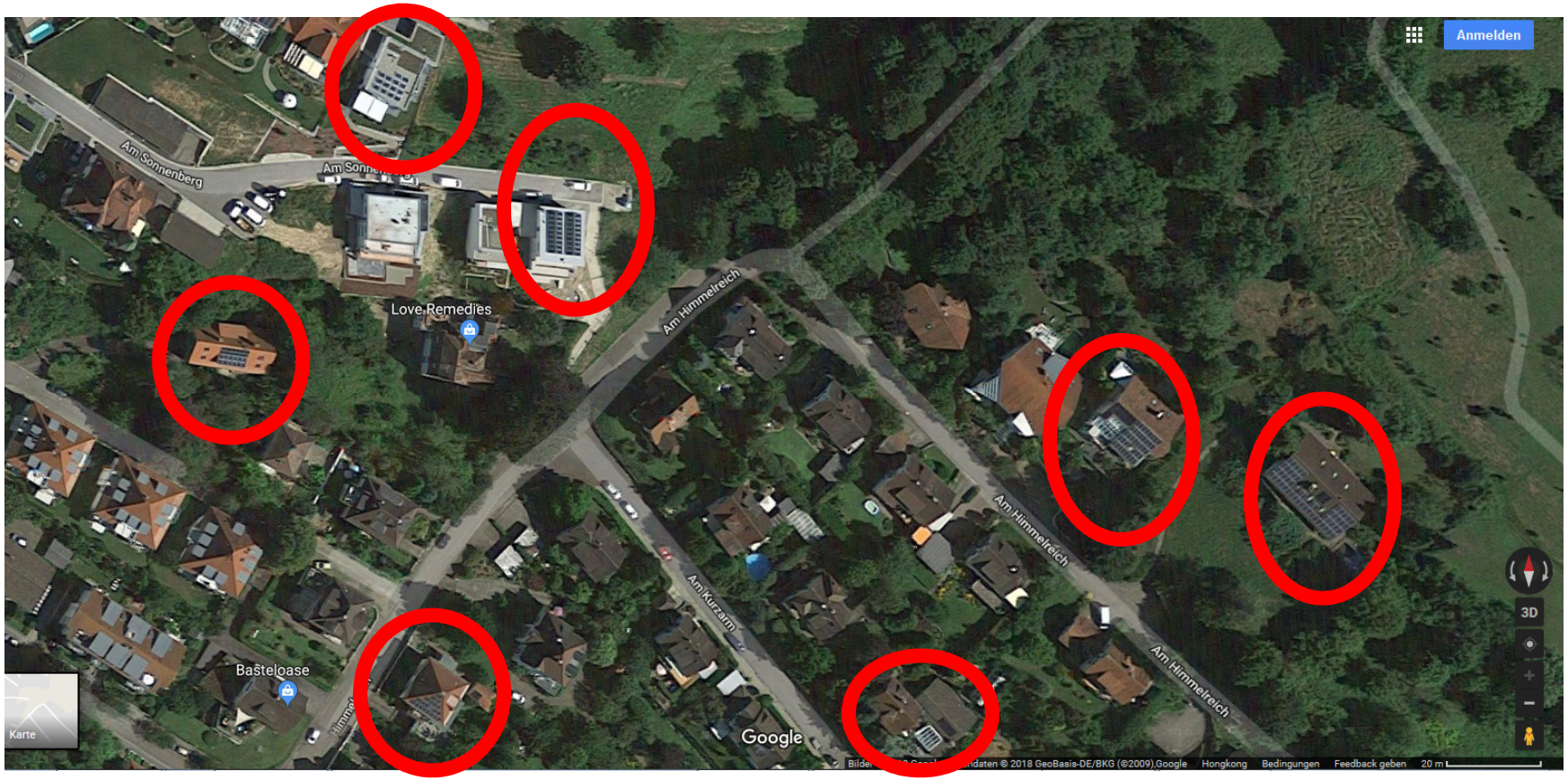
Role of PV in Germany



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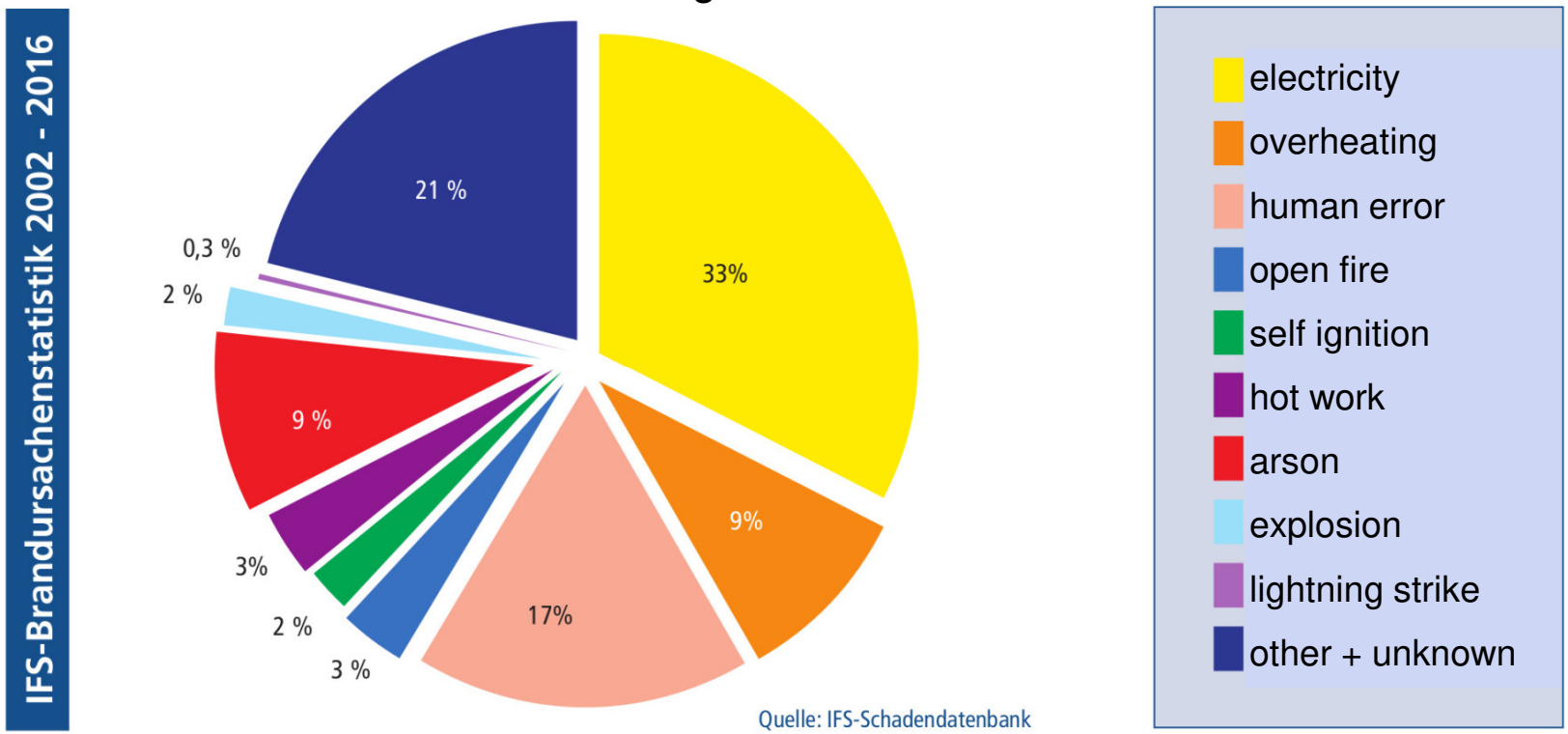
The broader view – Electricity and fire hazard

Statistical evaluation of electricity triggered fires in Germany
(from „institute for loss prevention and loss research“ of an insurance company group)
based on some 15 000 fire investigations



➢ Electricity is predominant cause of fire

https://www.ifs-ev.org/schadenverhuetung/ursachstatistiken/brandursachenstatistik

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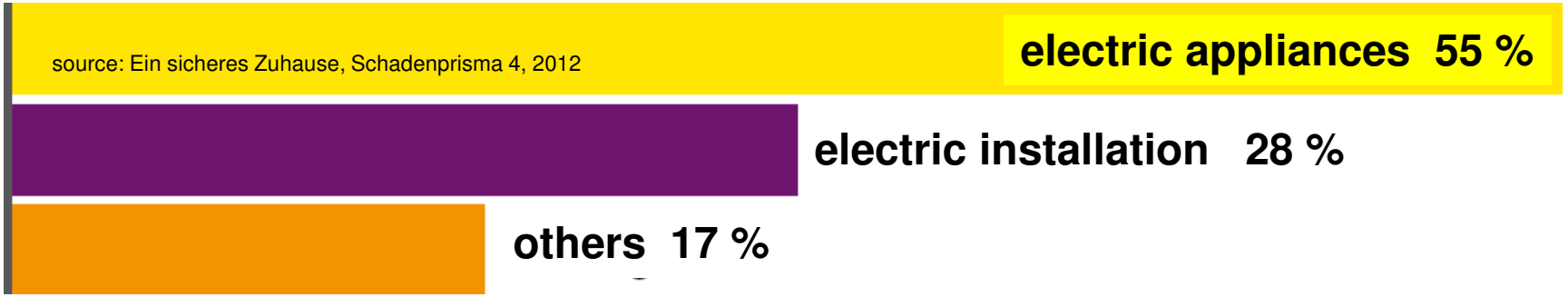
The broader view – Electricity and fire hazard



- root cause:
  „Experience from root cause analysis of fires in electrical systems clearly shows that a very large fraction of electrical defects sparking a fire is to be attributed to **failing electrical connections**.“

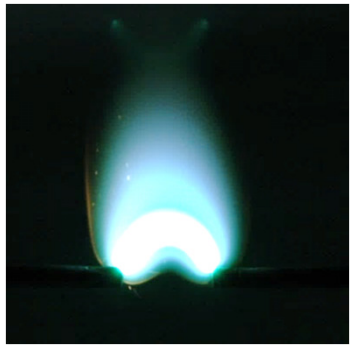
  source: Eine „heimtückische“ Brandgefahr: Die fehlerhafte elektrische Verbindung, Schadenprisma 3 /2015

- **poor contacts** are the predominant cause of fire!

PV Systems and Fire Hazard
investigations and assessment of PV fire incidents

- some 190 000 fire fighting missions each year (Deutscher Feuerwehrverband)

- baseline end of 2012: about 1.3 million PV systems with some 30 GWp installed capacity
- PV fire incidents collection for 10 years
  - some 350 fires reported, where PV systems had been affected
  - in some 130 cases fires are attributed to PV systems
  - in some 220 cases PV systems were damaged by a building fire (some more 50 cases of heat damage to components)
  - a fault on the DC side can evolve into an electric arc and ignite its surrounding.



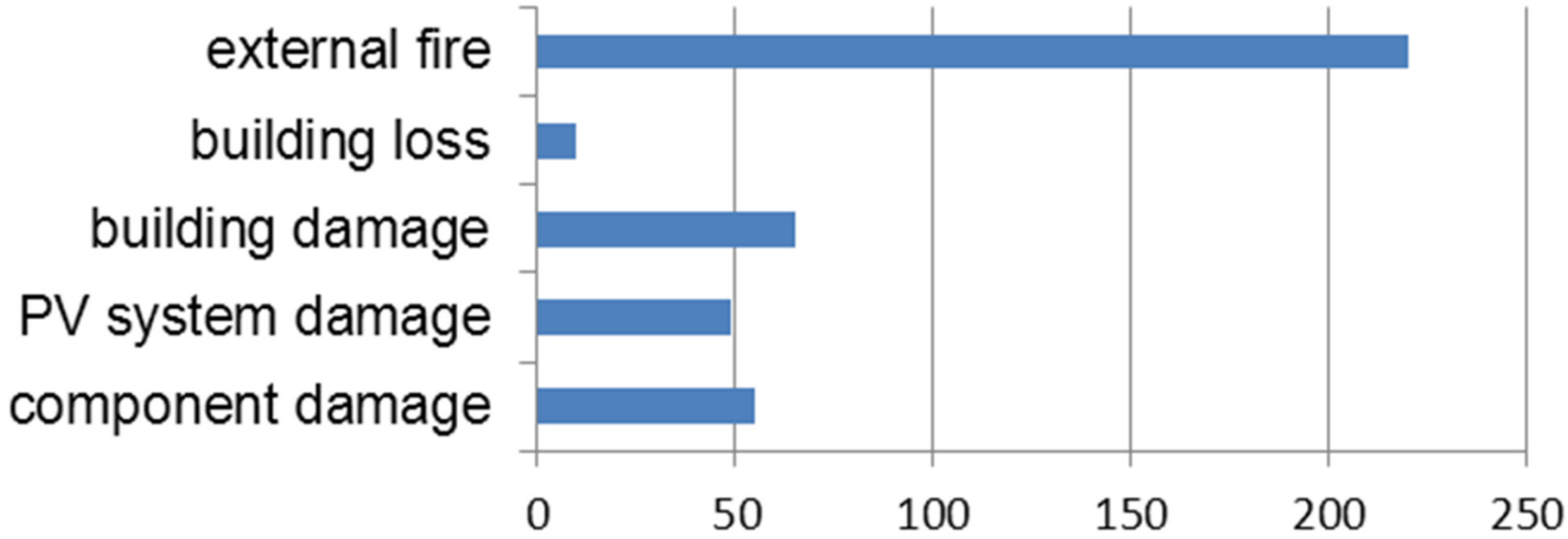
PV Systems and Fire Hazard

investigations and assessment of PV fire incidents

severity of damage - impact on surrounding

data basis: some 180 cases of fire damage and overheating

some 220 cases of PV damaged by external fire



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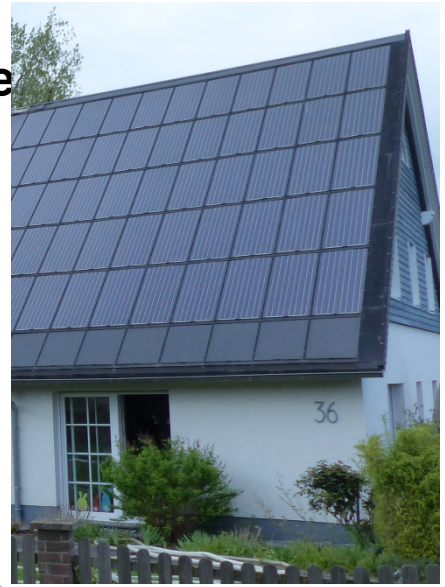
investigations and assessment of PV fire incidents

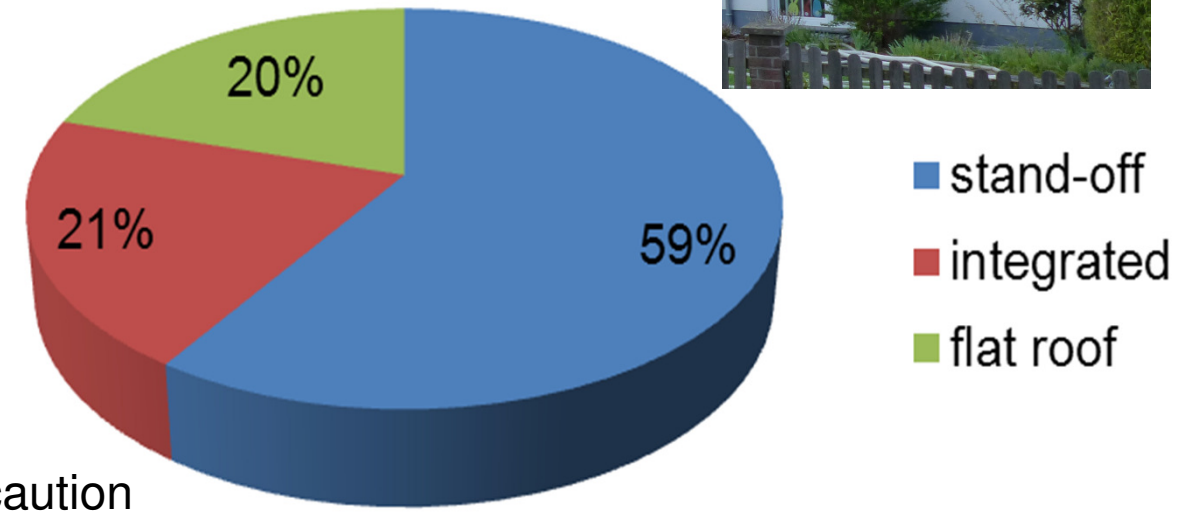
building damage risk strongly depends on mounting type



cases of damaged buildings only (63 cases)

- stand-off systems protected by “hard roofs” (tiles)
- fire hazard of roof integrated systems (BIPV) far above average

  1 % of systems,
  20 % of damages



- BIPV needs special precaution

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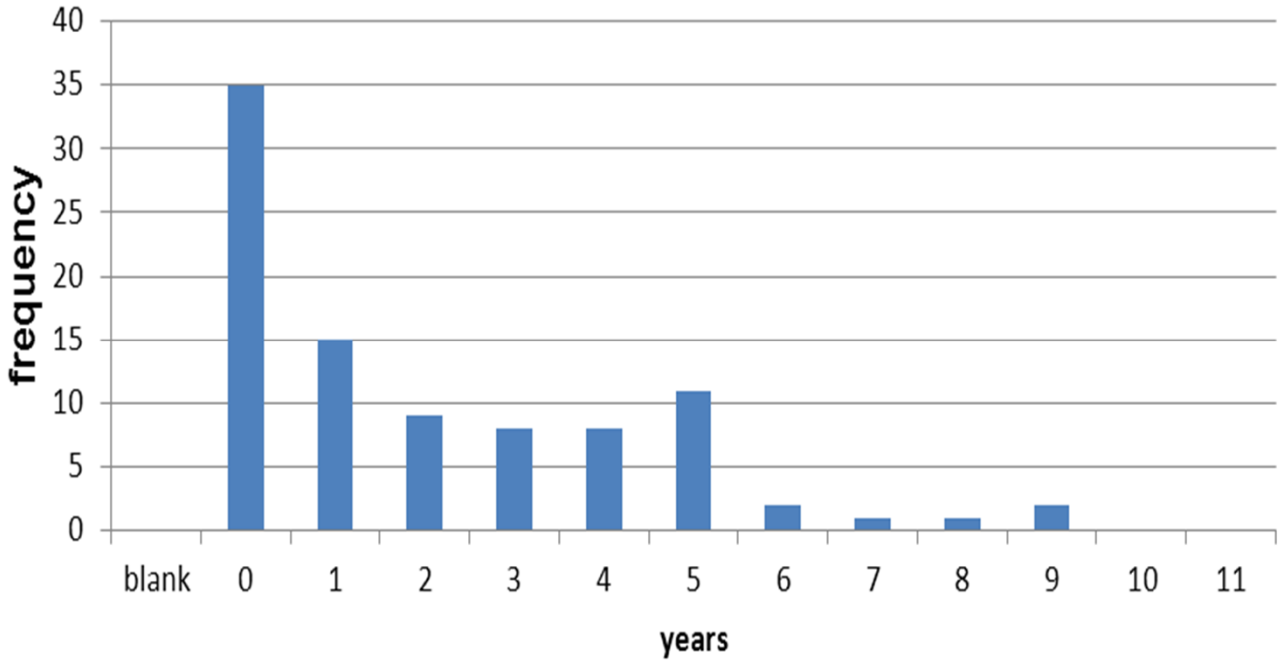
investigations and assessment of PV fire incidents

age of system at damage event

most incidents occured during installation or first year of operation

probably many installation flaws



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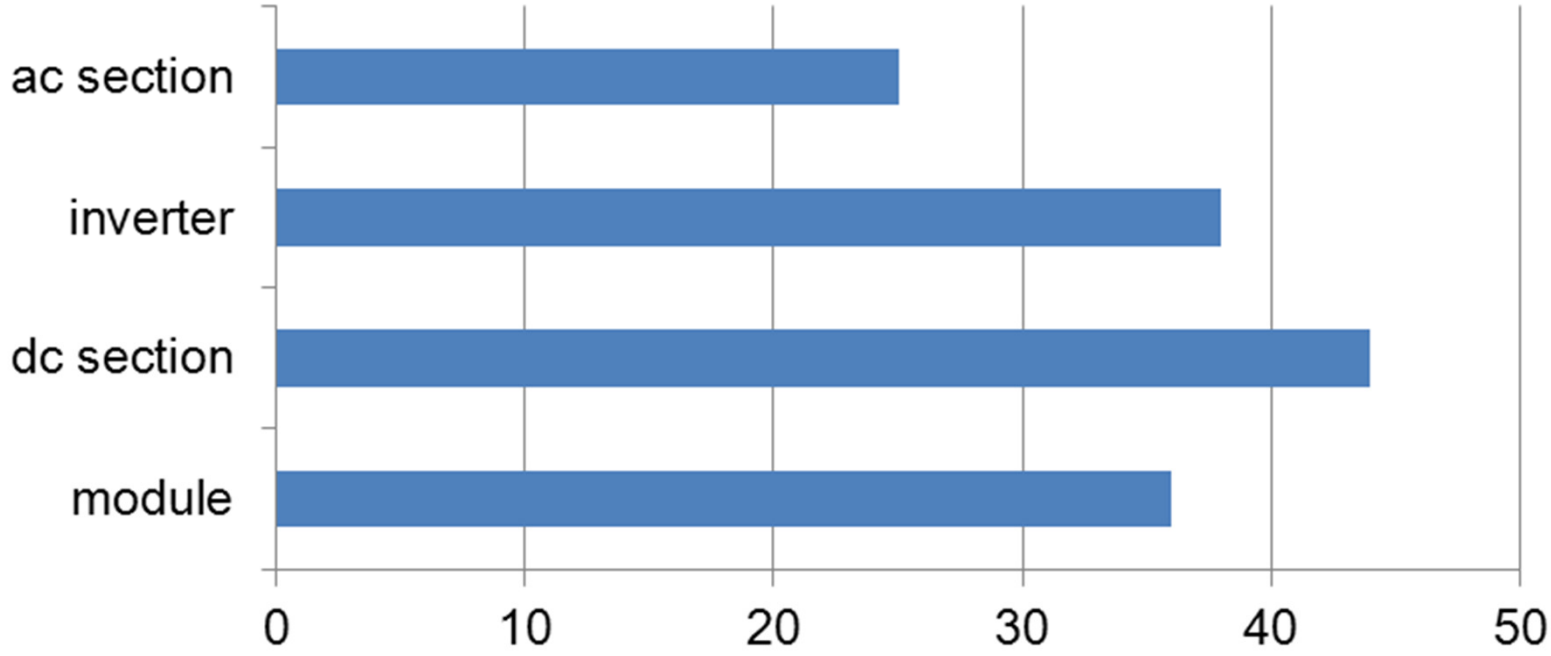
investigations and assessment of PV fire incidents

location of incident – source of damage

ac side nearly as often as dc side



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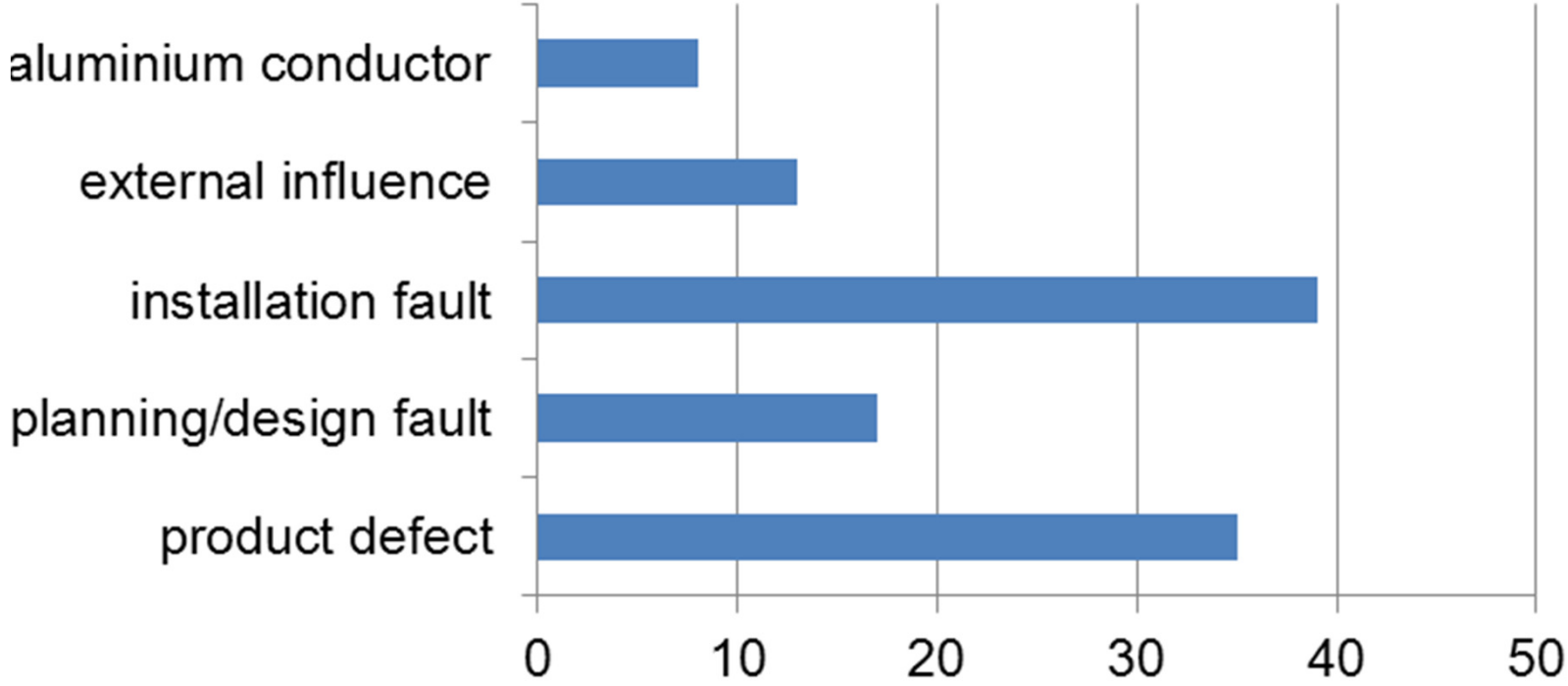
investigations and assessment of PV fire incidents

main root cause of damage

(inappropriate use of aluminium cable is included in installation faults)



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investigations and assessment of PV fire incidents

causes of installation faults

often ignorance and sloppiness

but also tough working conditions

- time pressure
- exposure on roofs
- heat, hot surfaces, “burning” and glazing sun

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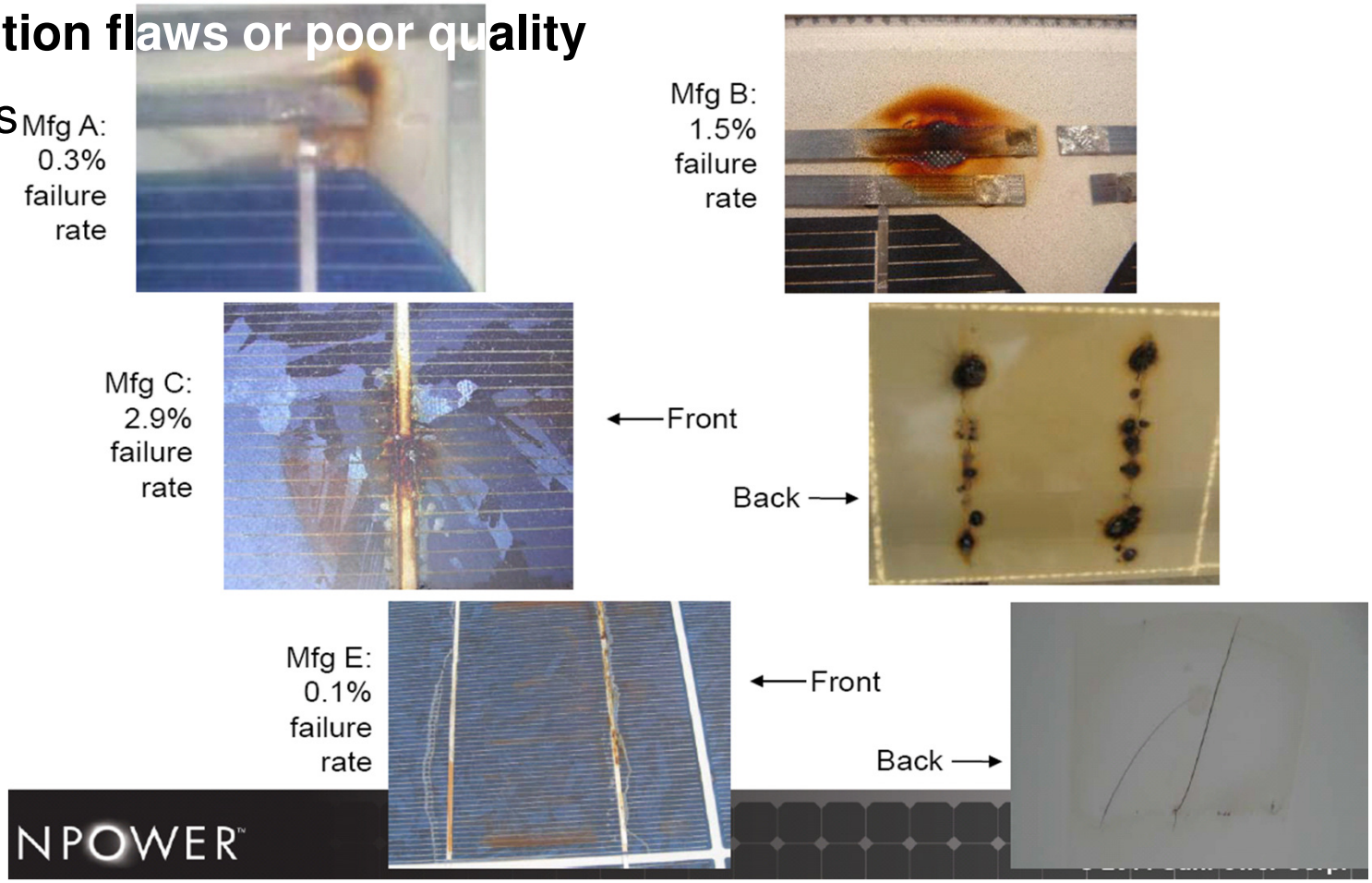
investigation and assessment of PV fire incidents

Production flaws or poor quality modules



(David DeGraaff, Ryan Lacerda, Zach Campeau, Zhigang Xie, How do Qualified Modules Fail –What is the root cause?, SunPower Corp, NREL 2011 International PV Module Quality Assurance Forum San Francisco, 15 July 2011)

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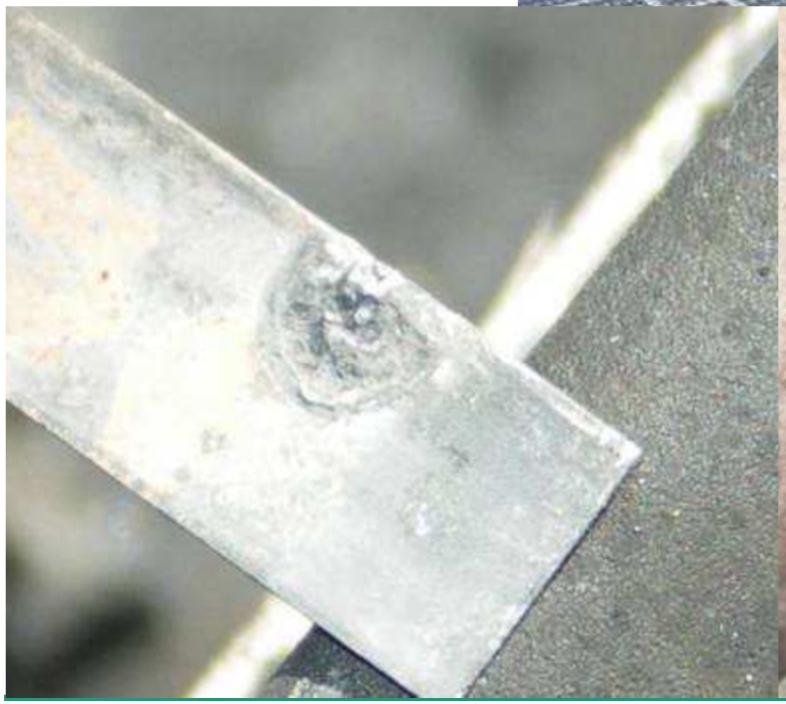
investigations and assessment of PV fire incidents

Production flaws or poor quality
components - modules

- many poor soldering connections within modules



photos: W. Rütz

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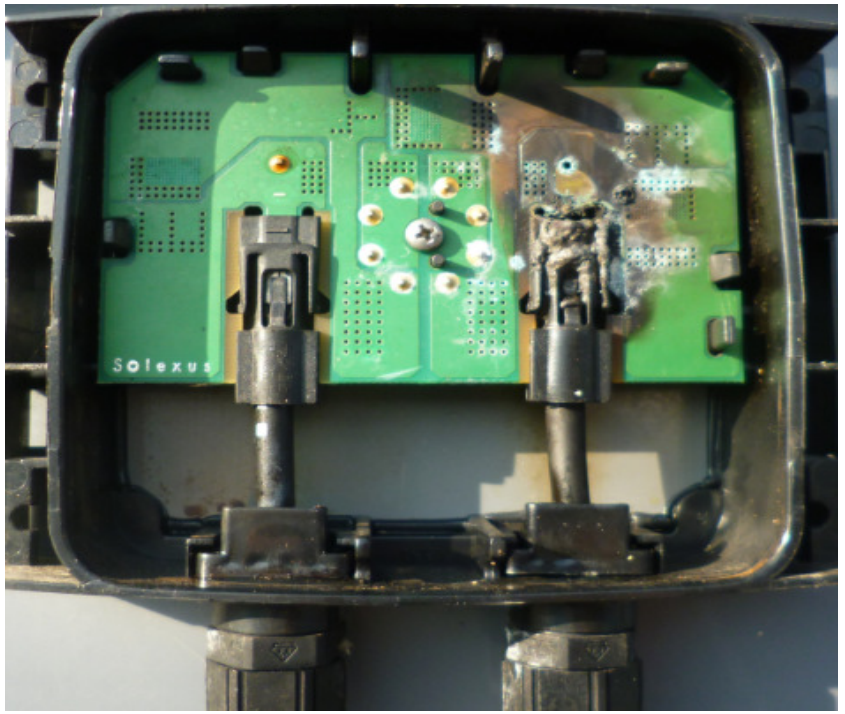
investigations and assessment of PV fire incidents

Production flaws or poor quality

components – modules - module junction box

- systematic fault in junction box caused several fires in France ,
  > 100 000 modules concerned
- rather high property loss due to roof integrated systems due to government incentives



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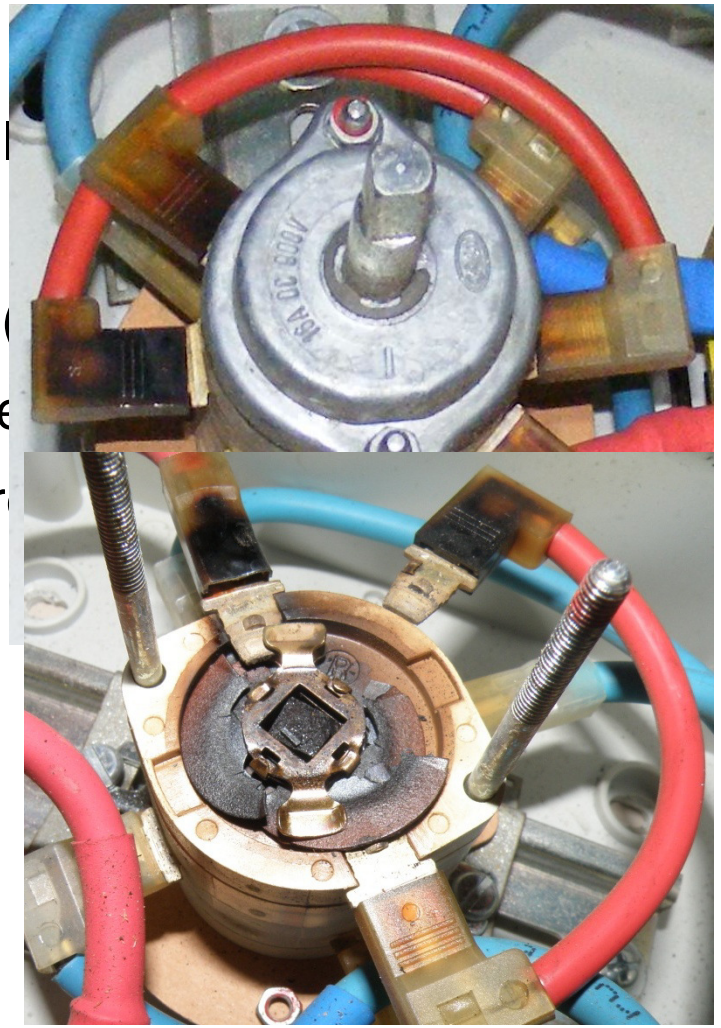
investigations and assessment of PV fire incidents

DC disconnect swithc
combination of stress influences caused fail

- source of fire was a DC switch
- inverter room in the attic – heat from the
- many inverters tightly mounted - more he
- small room – poor ventilation – even mor



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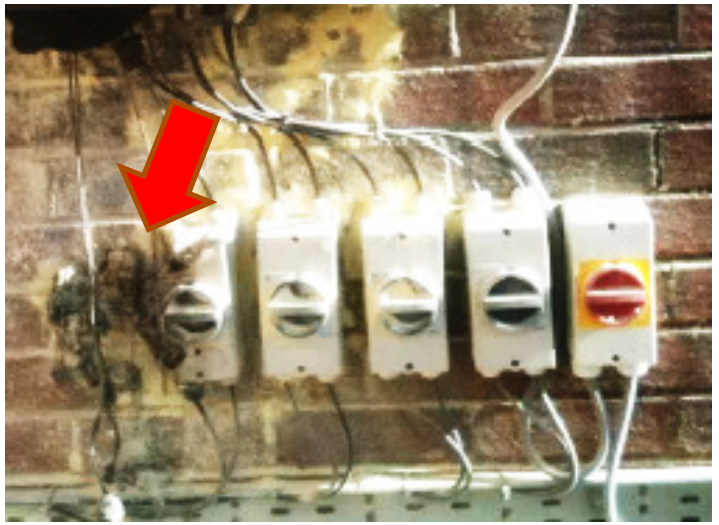
investigations and assessment of PV fire incidents

UK investigation:
main fault location; DC disconnector

- 9 out of 15 cases installation fault
  - 5 x water ingress
  - weak point: cable gland on top of housing exposed to weather (no drainage ?)



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investigations and assessment of PV fire incidents

PV DC connectors

Overheated connectors caused fire

- main root causes
  - poor crimp connection (installer)
  - cross mating
    (combination of male and female parts of different manufacturers
    products are basically NOT compatible)

remains of two connectors found in fire debris
top: connection Verbindung intact
bottom: melting traces from arcing at crimping side

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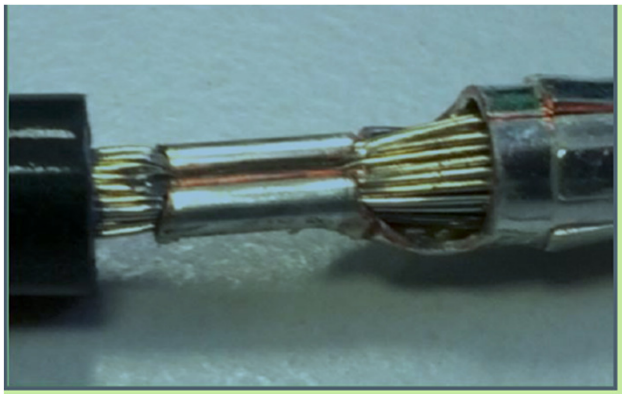
investigations and assessment of PV fire incidents

Crucial: on-site crimping



Pull out force: 454N

Gas tightness

Long-term durability

Pull out force: 94N

No gas tightness

→ corrosion, danger of electrical shock & fire

Berginski, 24.01.2013, PV-Brandsicherheit Freiburg: Paarung Fremdprodukte & Crimpen im Feld

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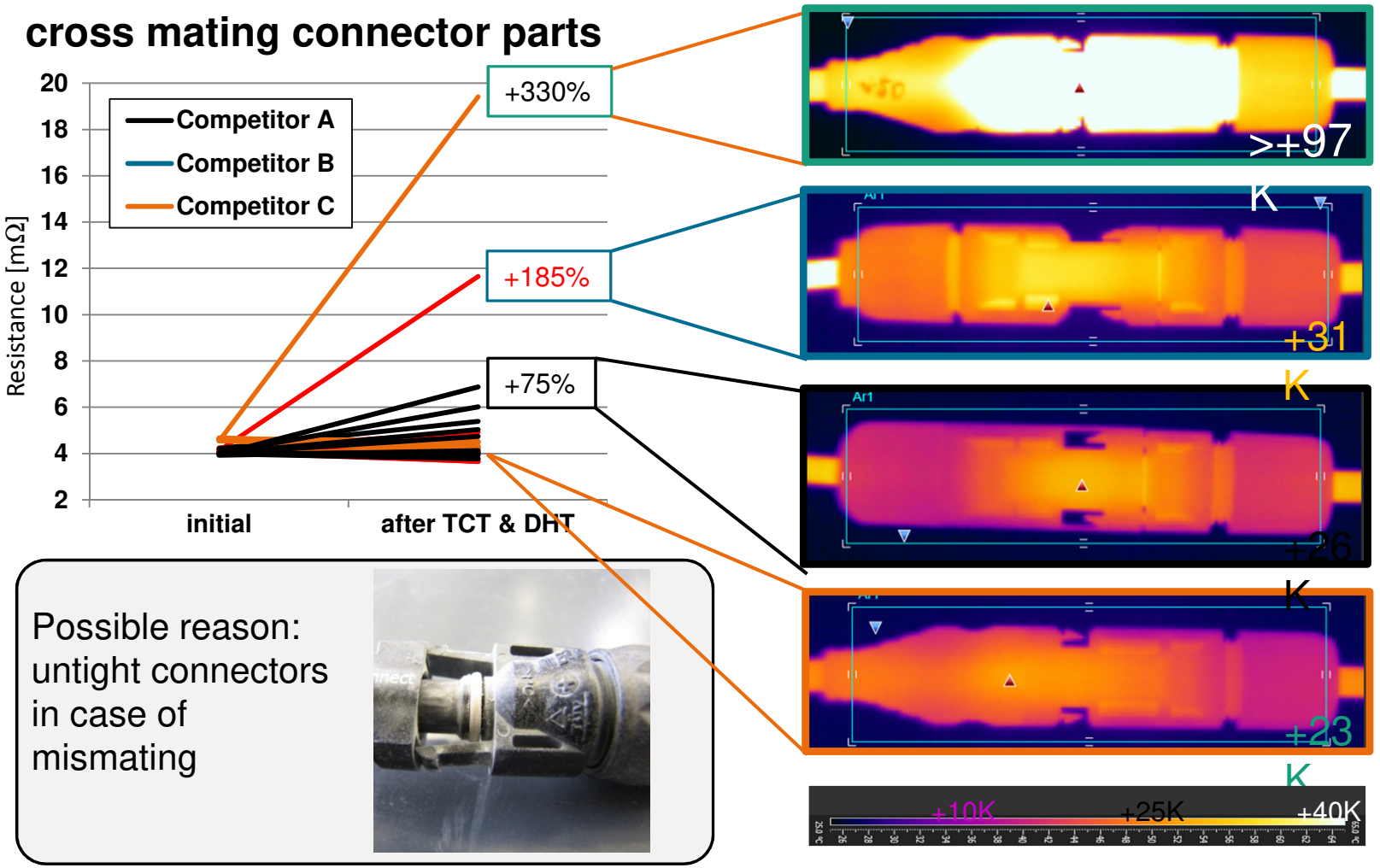
investigations and assessment of PV fire incidents



Possible reason:
untight connectors
in case of
mismating

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investigations and assessment of PV fire incidents

regular AC side components fail unexpectedly often

- fuses
- terminals/cables
- aluminum conductors !

photos: U. Motzer

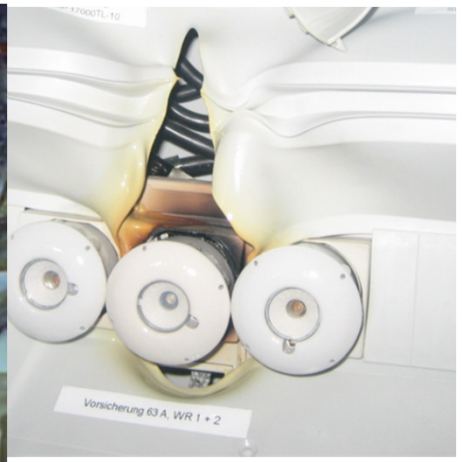

photo: H. Godard

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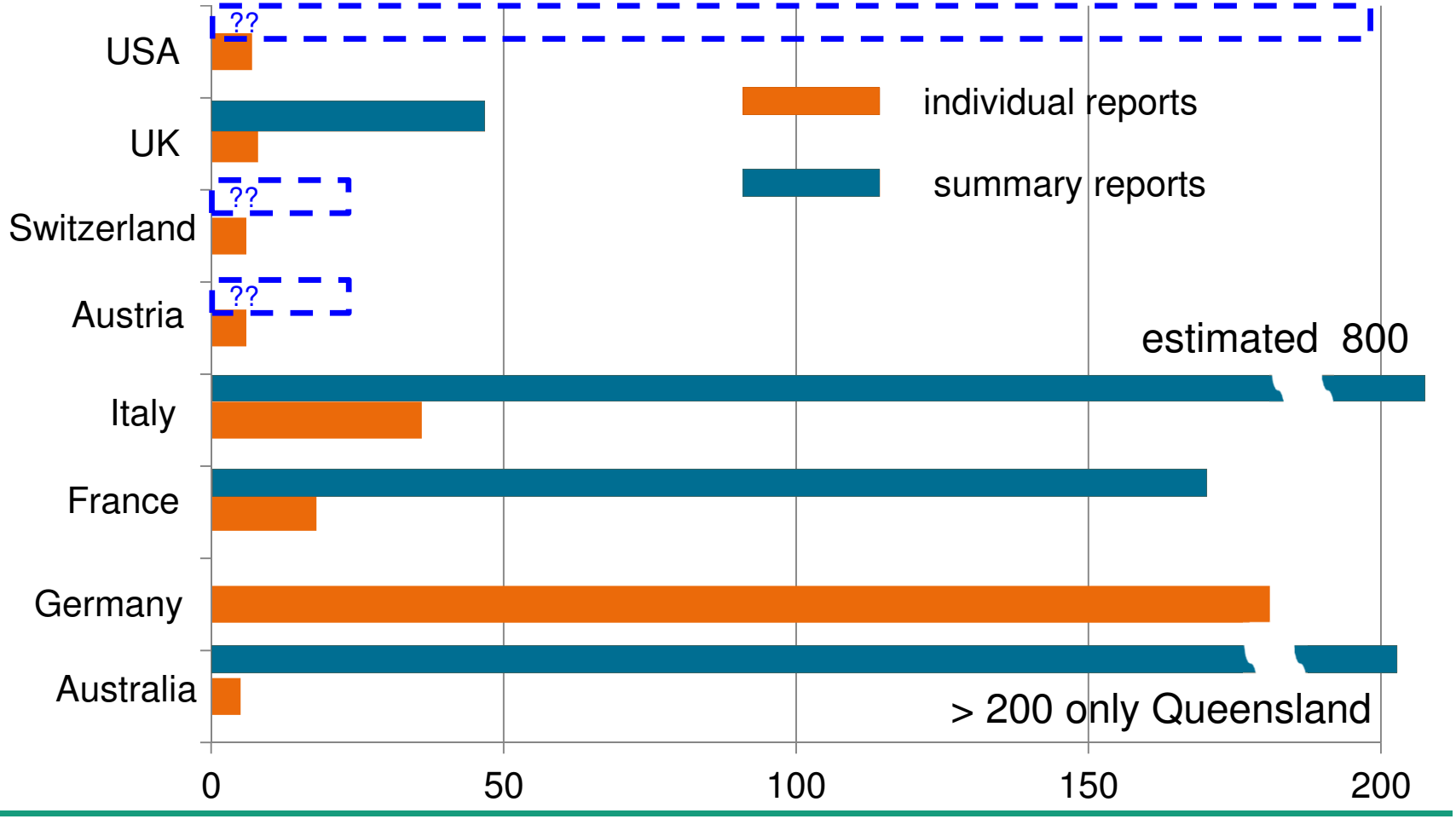
investigations and assessment of PV fire incidents

recent survey found some 285 individual loss reports – and summarising reports



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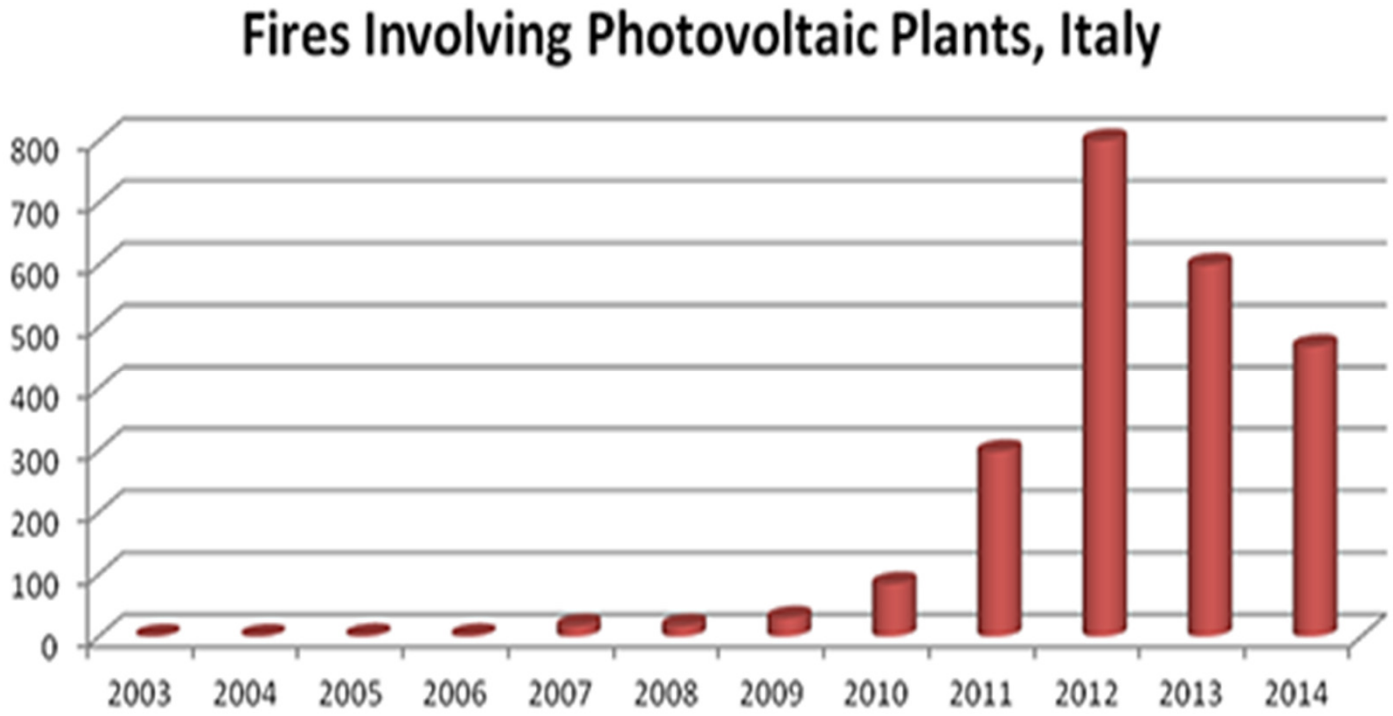
investigations and assessment of PV fire incidents

- sharp rise in fire fighter missions with PV systems involved

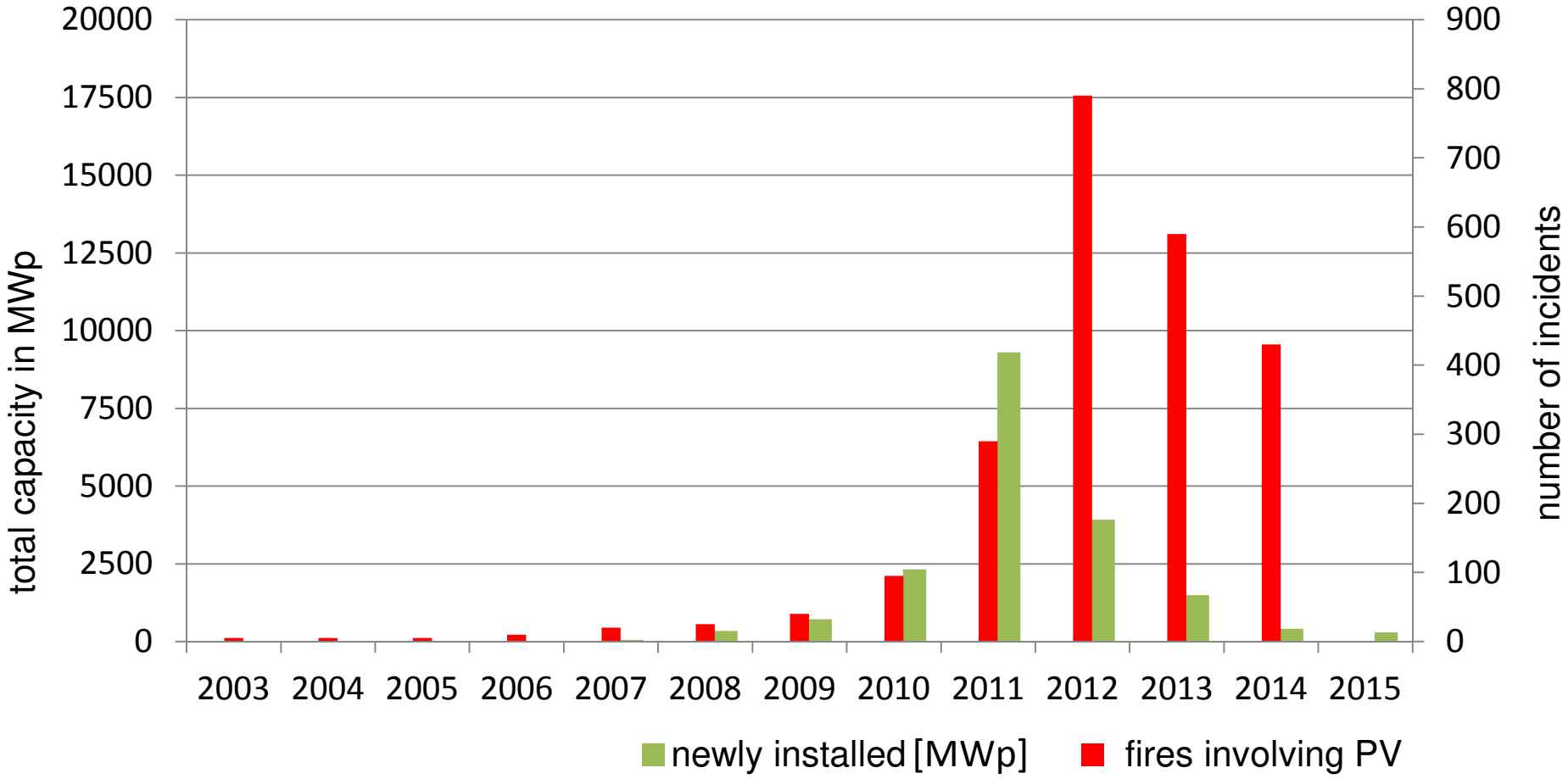


Fires in Photovoltaic Systems: Lessons Learned from Fire Investigations in Italy
By Luca Fiorentini, Luca Marmo, Enrico Danzi and Vincenzo Puccia, SFPE, 2015

- reason: short time changes in support scheme
  - high time pressure for system planning and installation
  - little PV experience among installers /electricians

PV Systems and Fire Hazard

investigations and assessment of PV fire incidents



- the count of fire incidents correlates well with new PV installations

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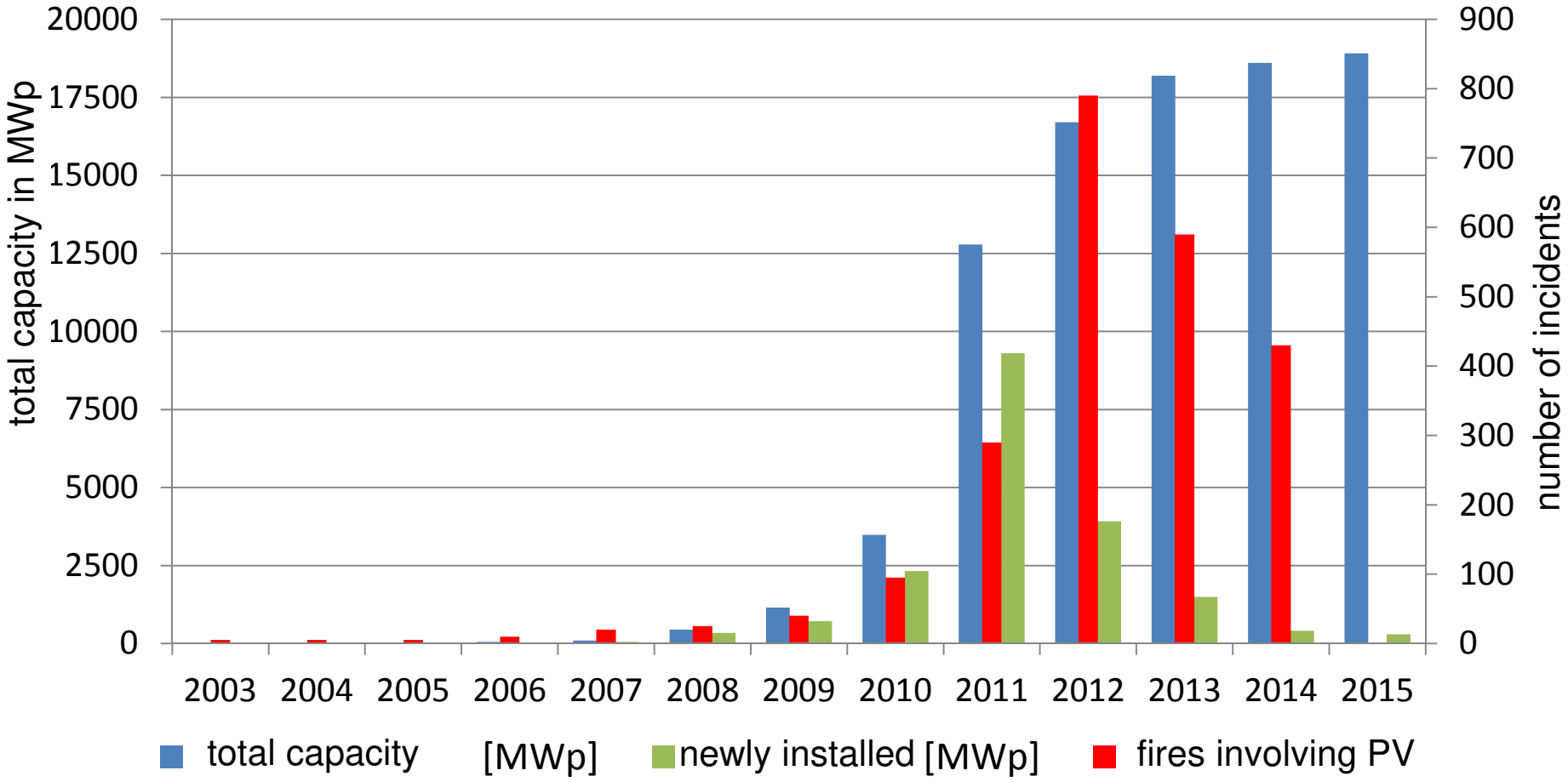
investigations and assessment of PV fire incidents



- … rather with total installed capacity

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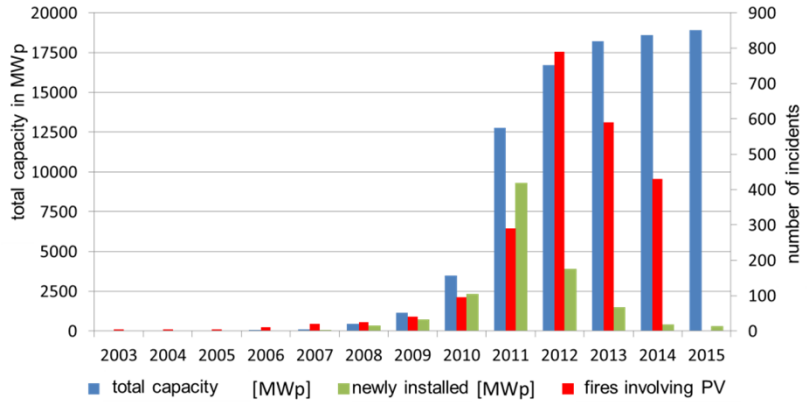
investigations and assessment of PV fire incidents



- several big building damages from arcing which ignited inflammable insulation material as polyurethan foam and styrofoam

➢ … there is a need for a comprehensive review of the fire and building code requirements for PV roof installations.
Specifically, these requirements should address combustible insulating and roof materials located below active PV system components …"

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PV Systems and Fire Hazard
investigations and assessment of PV fire incidents

- Australia, end 2012: normative requirement for a „Rooftop DC Isolator Switch“ to enhance firefighter safety
- until November 2014 → more than 200 fires because of „Rooftop Switch“ only in Queensland state with about 400 000 Systems
  (http://www.theaustralian.com.au/business/business-spectator/the-firefighter-device-putting-solar-systems--and-homes--at-risk/news-story/408992f49b61b3c9cddffe923c4d352d)

- -> immature products without proper specification and type testing

=> avoid hastily introduction of components without proven product standard

PV Systems and Fire Hazard
Risk mitigation for fire fighting

Eduation and information

- education and training of fire fighters on PV (some 20 000 mostly municipal departments in DE)
- checklist and flow diagram for mission

- On site information
  - information sign „PV system“
  - PV system documentation at building entrance including cabling routes

Operational procedures

- general assumption: system is alive with deadly voltage
- safety distance to PV system

PV Systems and Fire Hazard
Risk mitigation for fire fighting

PV systems generally cannot be switched off

-> fire fighters work under “live voltage”

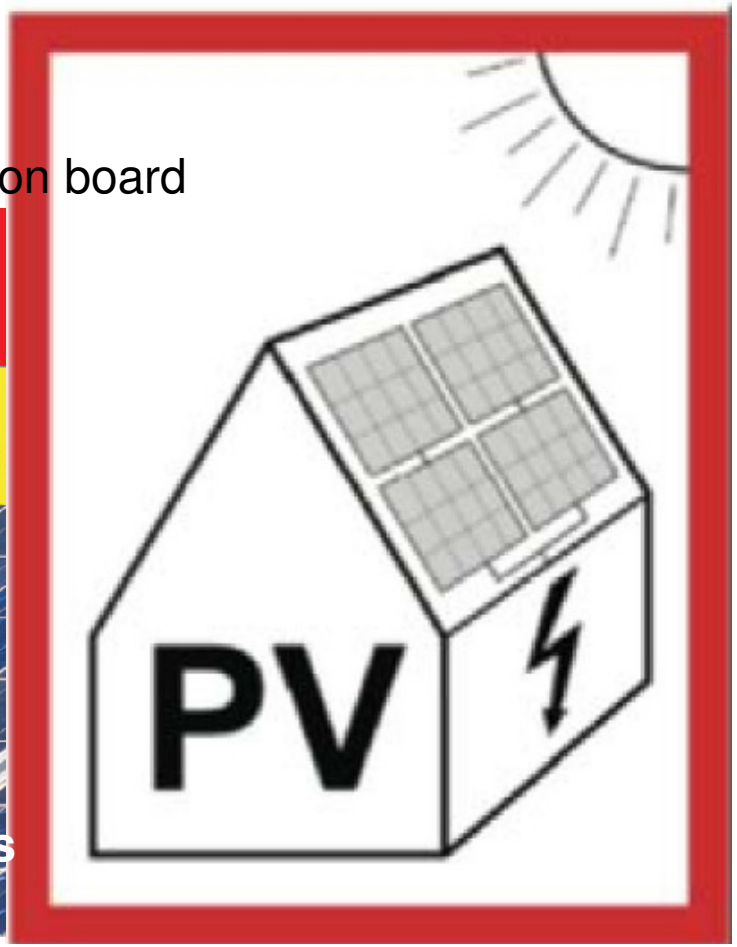
- Main hazard perceived during “interior attack” and dense smoke:
  wires “with” burnt away insulation are “invisible”
  - fire protected installation of DC cables
  - installation of DC cables outside building skin
  - perhaps in future:
    remote controlled DC switch disconnector
    or short-circuit switch
    (fire fighter association is sceptical)

PV Systems and Fire Hazard
Risk mitigation for fire fighting

information of fire brigades

education material

standardised information sign at main distribution board



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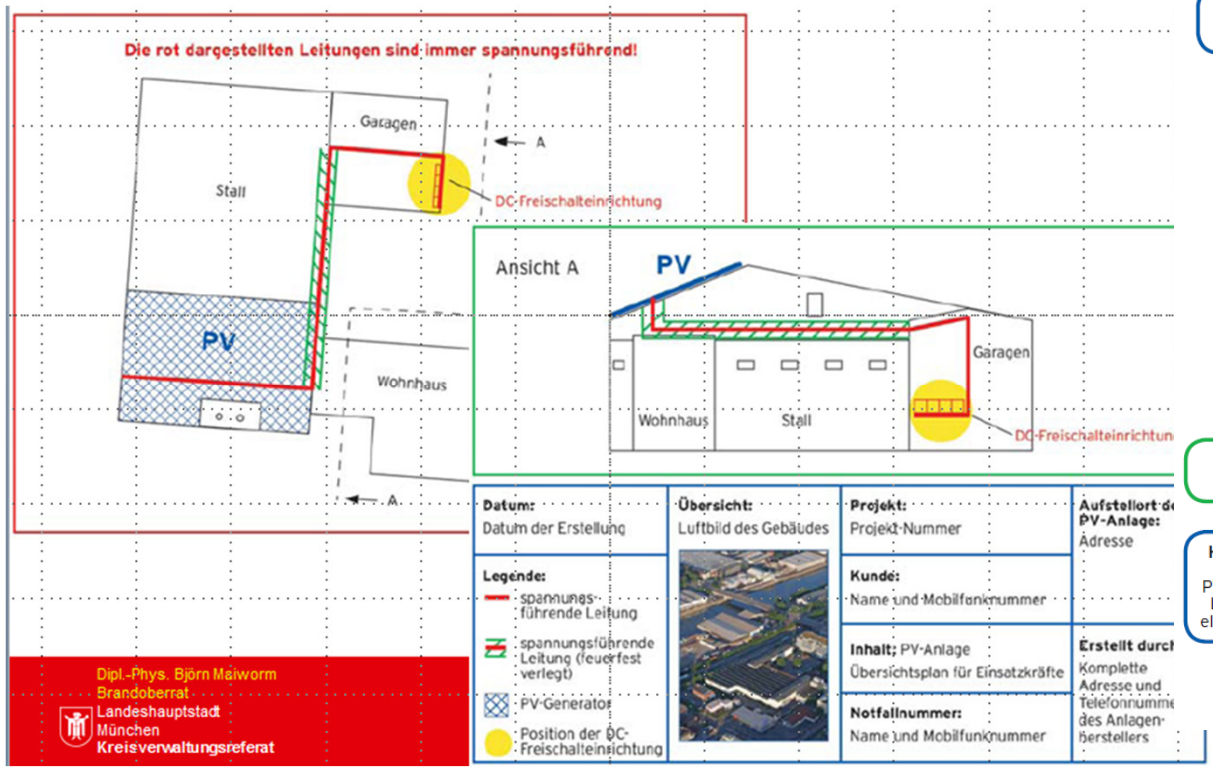
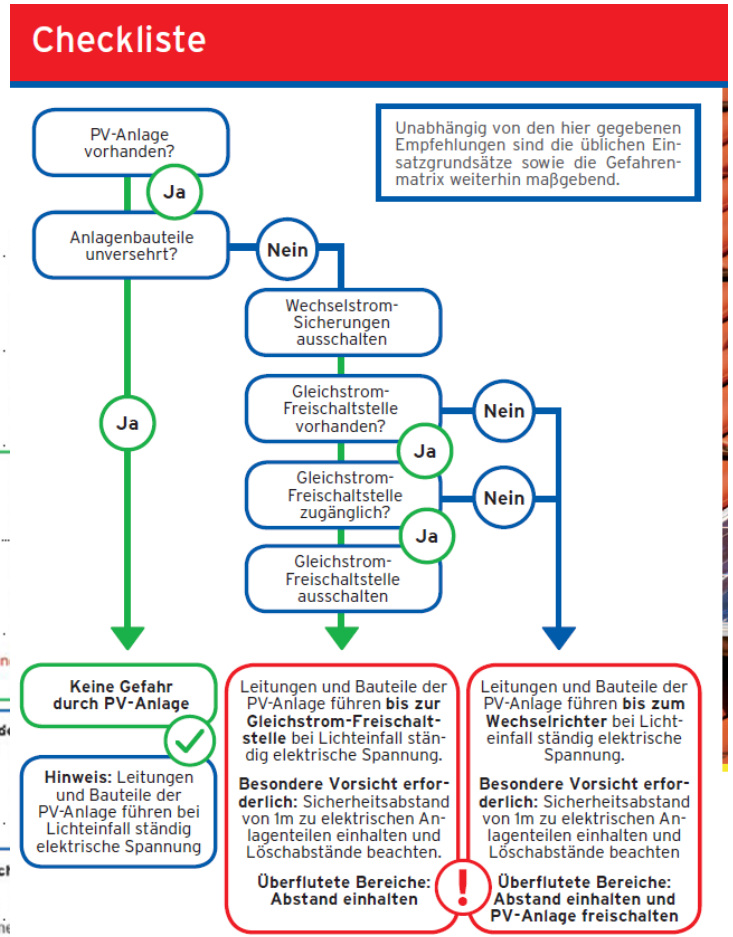
PV Systems and Fire Hazard

Risk mitigation for fire fighting

information

- checklist and flow diagram for mission
- map of components location and cable routing





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PV Systems and Fire Hazard
Risk mitigation for fire fighting

keep clear of presumably live components

minimum distance depending on voltage level (according to standard VDE 0132)

Jet type		**low voltage <= 1000 V AC or 1500 V DC**	**high voltage > 1000 V AC or 1500 V DC**
spray		1 m	5 m
full jet		5 m	10 m

PV Systems and Fire Hazard
Summary and Conclusions

- there is a small risk that fires can be started by PV components
- the risk is significantly higher for roof integrated PV generators
- fire risk can be reduced by
    - careful installation – educate installers
    - initial and periodic verification i.e. inspection and testing
    - regularly inspect connections by infrared camera
- avoid financing/regulation schemes with sudden important changes as well as untested technical requirements
- Education for fire fighters on PV Systems is crucial -- and needs to be established

PV Systems and Fire Hazard
Summary and Conclusions

- there are established procedures to deal with the hazards of electricity
- improved installation methods can reduce these hazards even more

"Your fundamental understanding of photovoltaic systems will improve your confidence in working with and around solar technology safely."

assessment of fire incidents
further reading

- Report: Recent Facts about Photovoltaics in Germany, https://www.ise.fraunhofer.de/en/publications/studies/recent-facts-about-pv-in-germany.html - includes a section on fire risks
- Fire and PV – broad collection of information including documents from Germany, Britisch PV Industry Association; http://bpva.org.uk/media/38257/fire-pv_v4_20130821105943.pdf
- British project on PV fire hazard – final report due in 2018; https://www.bre.co.uk/nsc/page.jsp?id=3676
- PV and fire hazard - a website in German including some reports in English; comprehensive final report in Englisch by end 2018; www.pv-brandsicherheit.de
- summary report on systematic fire exposure tests on PV Modules https://www.irbnet.de/daten/kbf/kbf_e_F_2897.pdf
- PV battery systems for domestic application - safety issues; a website in German with some publications in englisch; www.speichersicherheit.de/
- examples of PV Systems in Hongkong, http://re.emsd.gov.hk/english/solar/solar_ph/solar_ph_ep.html

Thanks!

to You, for Your attention

the German Federal Government for financial support

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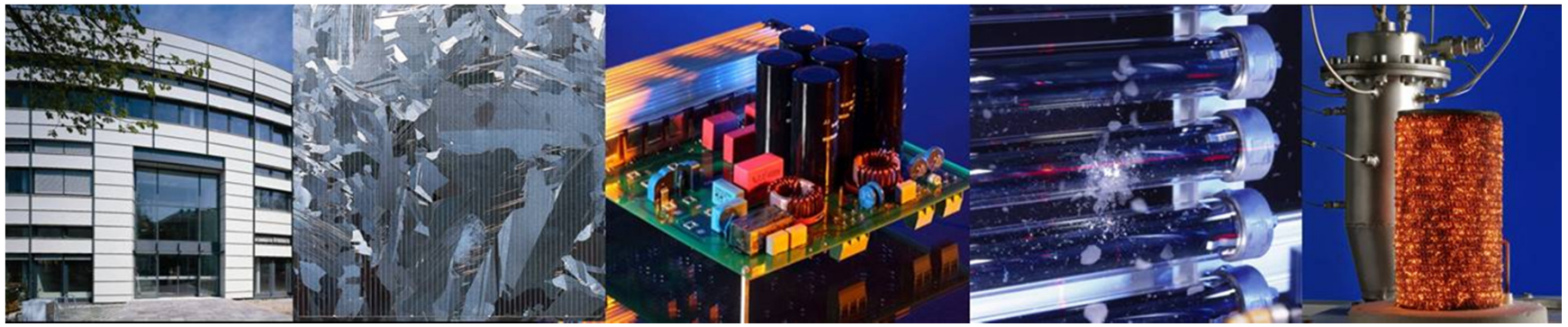

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