

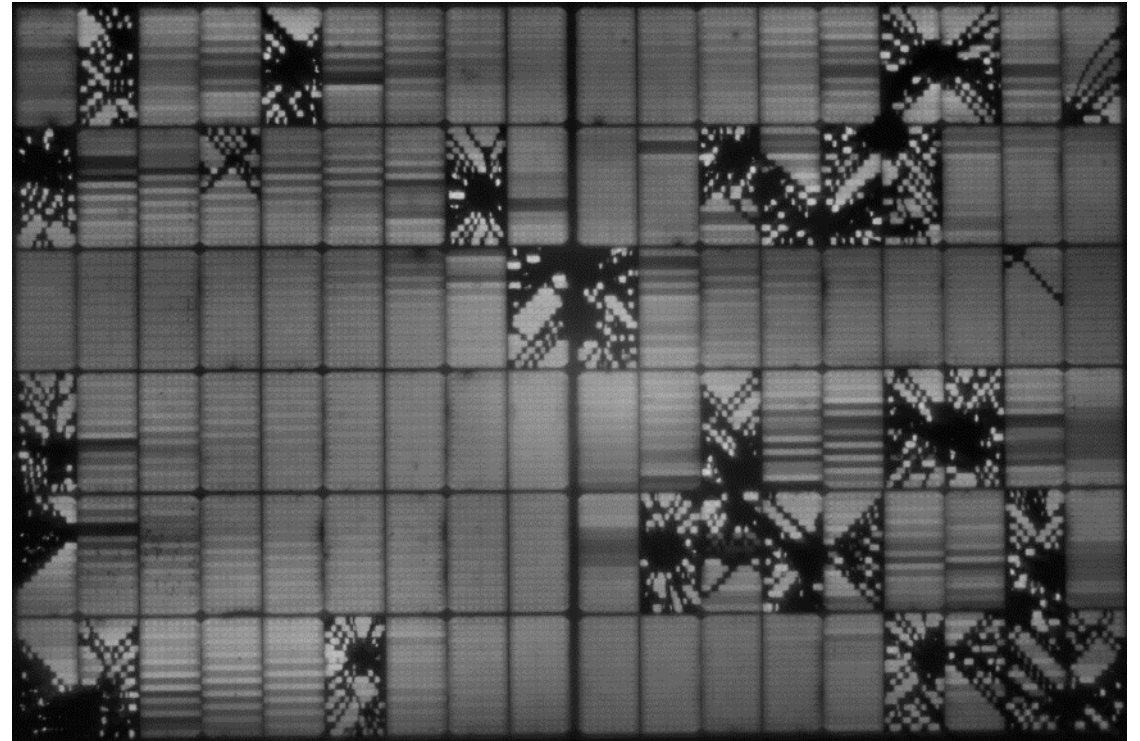
SUPSI

Fotovoltaico e grandine: prime esperienze riguardo a gestione degli impianti, comportamento dei moduli, analisi, ecc.

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Solar update Bellinzona, 06.06.2024

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Requisiti per la protezione degli edifici dalla grandine

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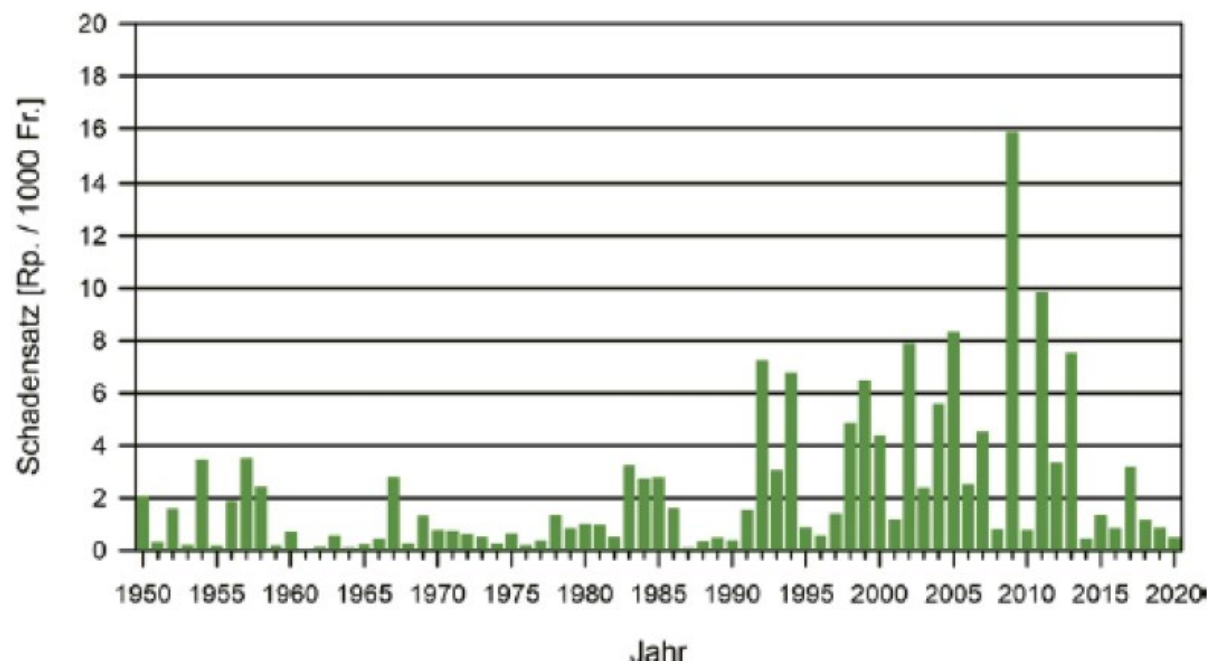
SIA 261/1:2020 Costruzione



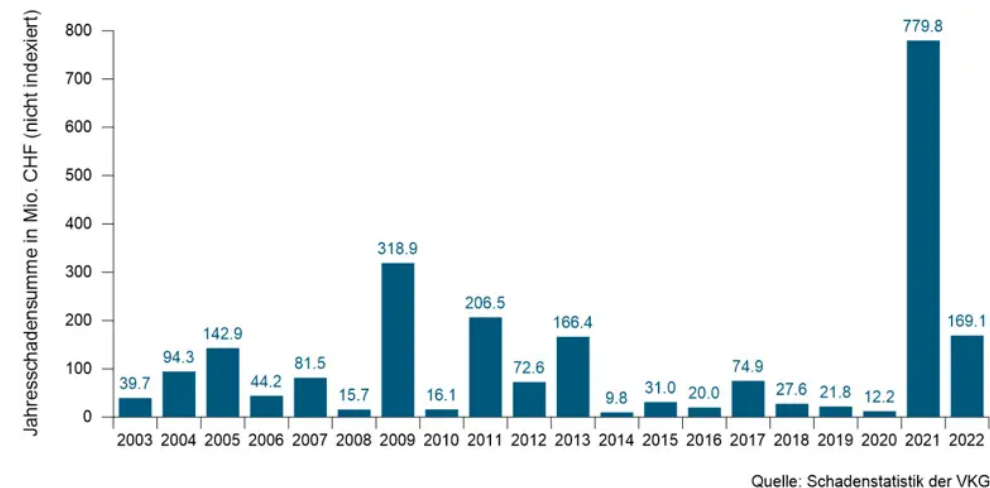
505 261/1

- I requisiti specifici per la protezione degli edifici dalla grandine sono stabiliti dalla norma SIA 261/1:2020 che definisce le specifiche supplementari alle azioni sulle strutture.
- La norma è in fase di revisione, dopo appena 4 anni, per includere i risultati del progetto "Hail Climate Switzerland". Una nuova generazione di dati radar e di riferimento e la loro valutazione con metodi statistici moderni hanno permesso di migliorare significativamente la precedente base per la valutazione dei rischi e dei pericoli: **Il rischio grandine è molto più elevato** rispetto all'Allegato G attualmente in vigore.

Requisiti per la protezione degli edifici dalla grandine



Hagel



- Tasso di danni da grandine 1950-2020 (danni totali assicurati in centesimi di CHF divisi per la somma assicurata totale dei diciannove assicuratori edili cantonali in CHF 1.000).

Fonte grafici: VKG

- Zoom su 2003-2022, con i danni del 2022 più che raddoppiati rispetto al 2009

Danni da grandine a Locarno, agosto 2023: 300 Mio CHF

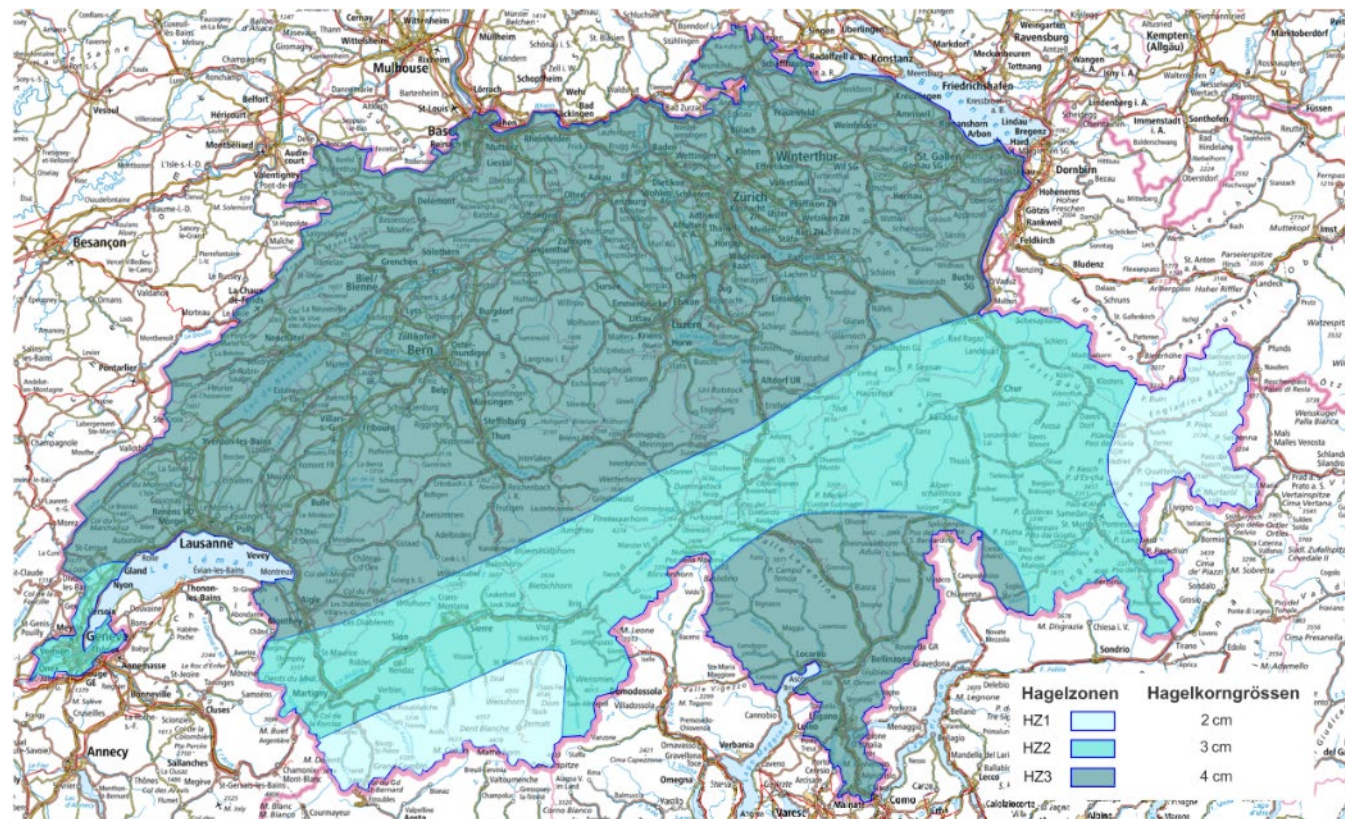


Fonte immagine: Alsolis

«Il settore assicurativo stima che il numero totale di sinistri sia superiore a 20.000, per un totale di 300 mio CHF», Eduard Held, Responsabile del settore Danni e Riassicurazione dell'Associazione Svizzera delle Assicurazioni SVV,.

«Abbiamo 70 sfollati a Locarno. Una stima, molto grossolana dei costi: per l'Expo Fevi si stimano 4 milioni e mezzo, per il Palacinema quasi 2 milioni di franchi», Alain Scherrer, sindaco di Locarno

Requisiti per la protezione degli edifici dalla grandine: nuova mappa del rischio

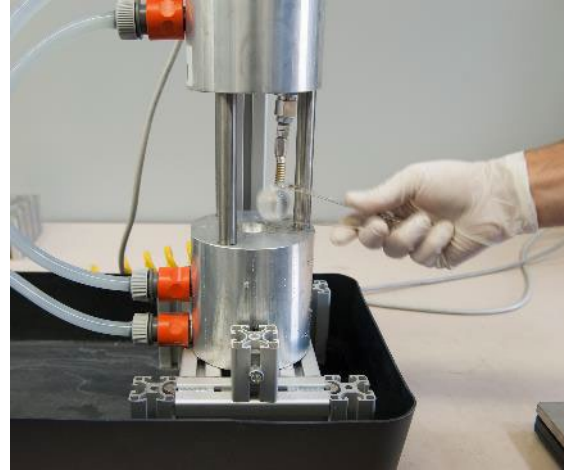
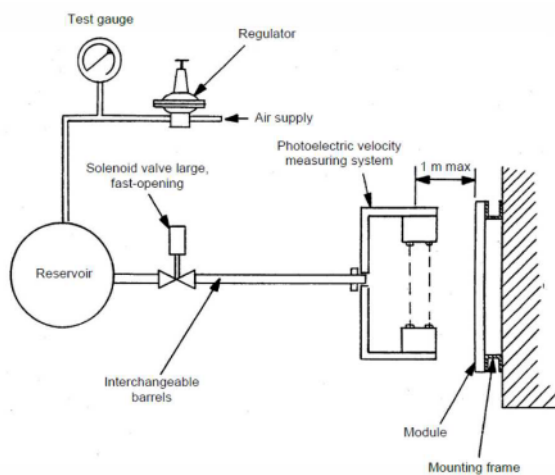


Fonte immagine: SIA 261/1 / Meteosuisse

Per quanto possibile e ragionevole, i componenti dell'edificio devono durare per l'intera vita utile dell'edificio. La vita utile non deve essere ridotta dalla grandine. Il risparmio di materiali e di energia, il riutilizzo e il riciclaggio sono pietre miliari sulla strada verso un'edilizia sostenibile.

Ticino e altopiano passano a grado 4 (mappa di rischio a 50 anni)

Come simulare? Standard di prova per test sulla grandine: VKF Pr.25 v IEC 61215-2



- Conservazione delle sfere di ghiaccio a -20°C almeno 48 ore dopo la produzione (IEC: -4°C per 1h)
- Colpo valido se l'energia d'impatto rientra nei limiti minimi e massimi. (IEC: massa, diametro, velocità $\pm 5\%$)
- 5 colpi aggiuntivi nel punto debole della struttura del modulo fotovoltaico

Hail resistance CLASS	Hailstone diameter [mm]	G_{\min} - min. mass \geq [g]	G_{\max} - MAX mass \leq [g]	V_R - Velocity on impact [m/s]	Impact energy - min. limit E_{\min} \geq [J]	Impact energy - MAX limit E_{\max} \leq [J]
HW1	10	0.43	0.51	13.77	0.04	0.09
	15	1.46	1.71	16.87	0.22	0.37
HW2	20	3.46	4.04	19.48	0.69	1.0
	25	6.76	7.90	21.77	1.69	2.3
HW3	30	11.68	13.65	23.85	3.50	4.4
	35	18.55	21.67	25.76	6.5	7.9
HW4	40	27.70	32.35	27.54	11.1	13.2
	45	39.43	46.06	29.21	17.7	20.9
HW5	50	54.09	63.18	30.79	27.0	31.5
	55	72.00	84.10	32.30	39.5	45.9
	60	93.47	109.18	33.73	56.0	64.7
	65	118.85	138.81	35.11	77.1	89.0
	70	148.43	173.38	36.44	104	120
	75	182.57	213.25	37.72	137	157
	80	221.57	258.80	38.95	177	204

Il progetto ACHILLES: domande di ricerca su grandine e fotovoltaico

- Quando si verifica un danno con quali moduli e tipi di cellule?
- Effetto delle micro-fessure su diverse tecnologie di celle (ad esempio celle con contatti smartwire o celle IBC)?
- Come invecchiano le micro-fessure nelle celle e qual è il comportamento a lungo termine in termini di sicurezza e prestazioni?
- La precedente categorizzazione dei moduli deve essere adattata?
- Quali moduli possono continuare a funzionare e quali devono essere sostituiti?

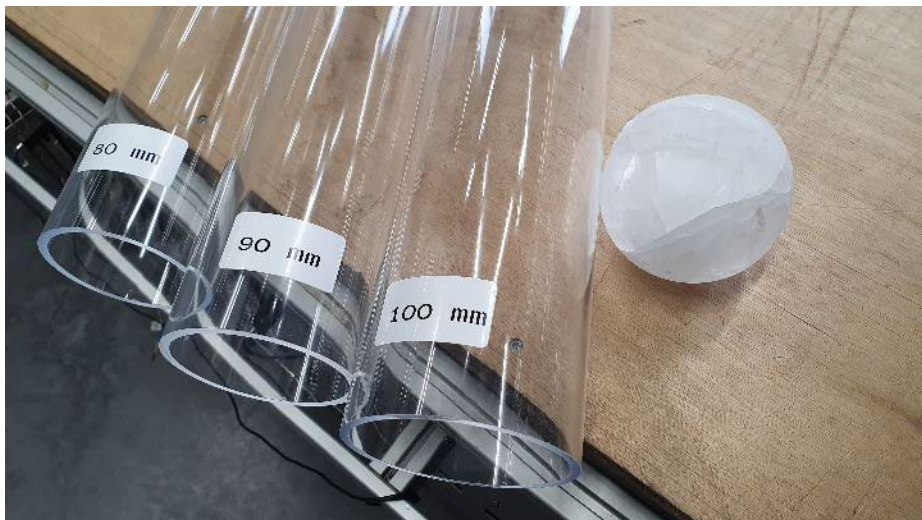


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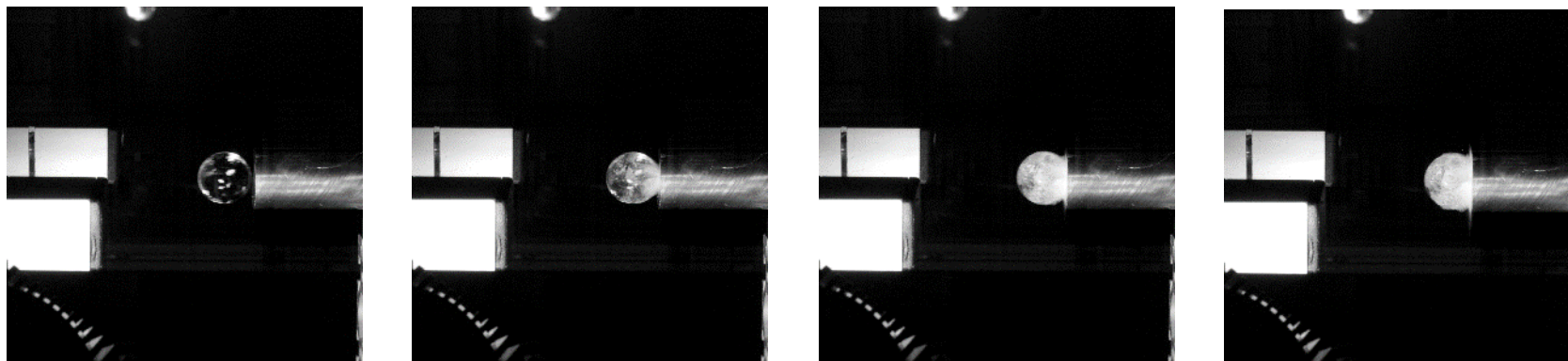


Dimensioni crescenti: fino a 100mm

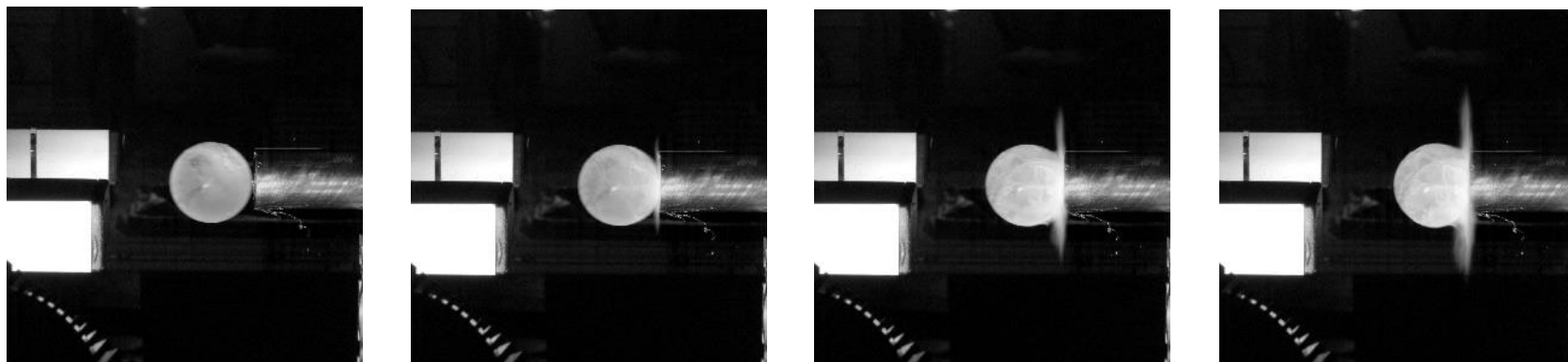


Fragmentation process

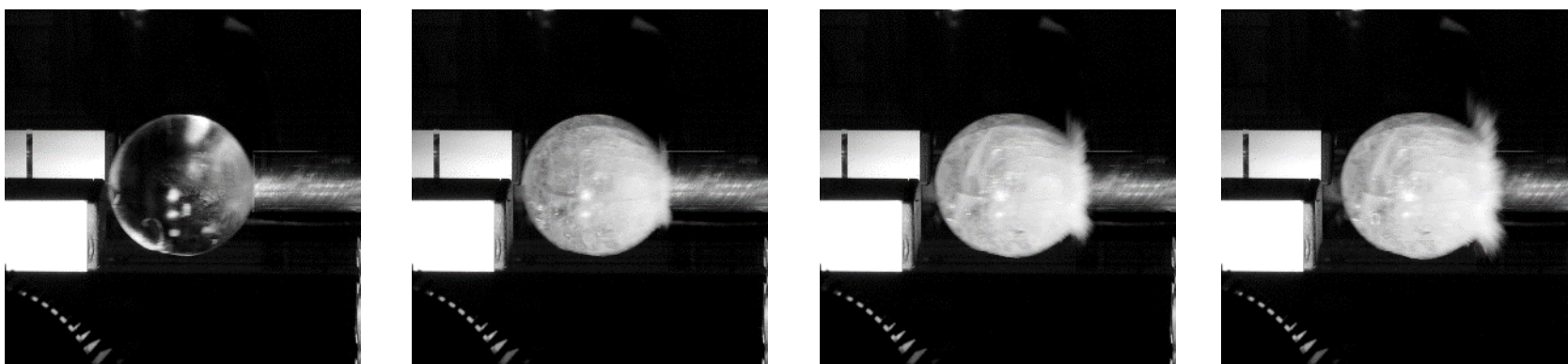
$r = 25$ mm



$r = 40$ mm



$r = 70$ mm



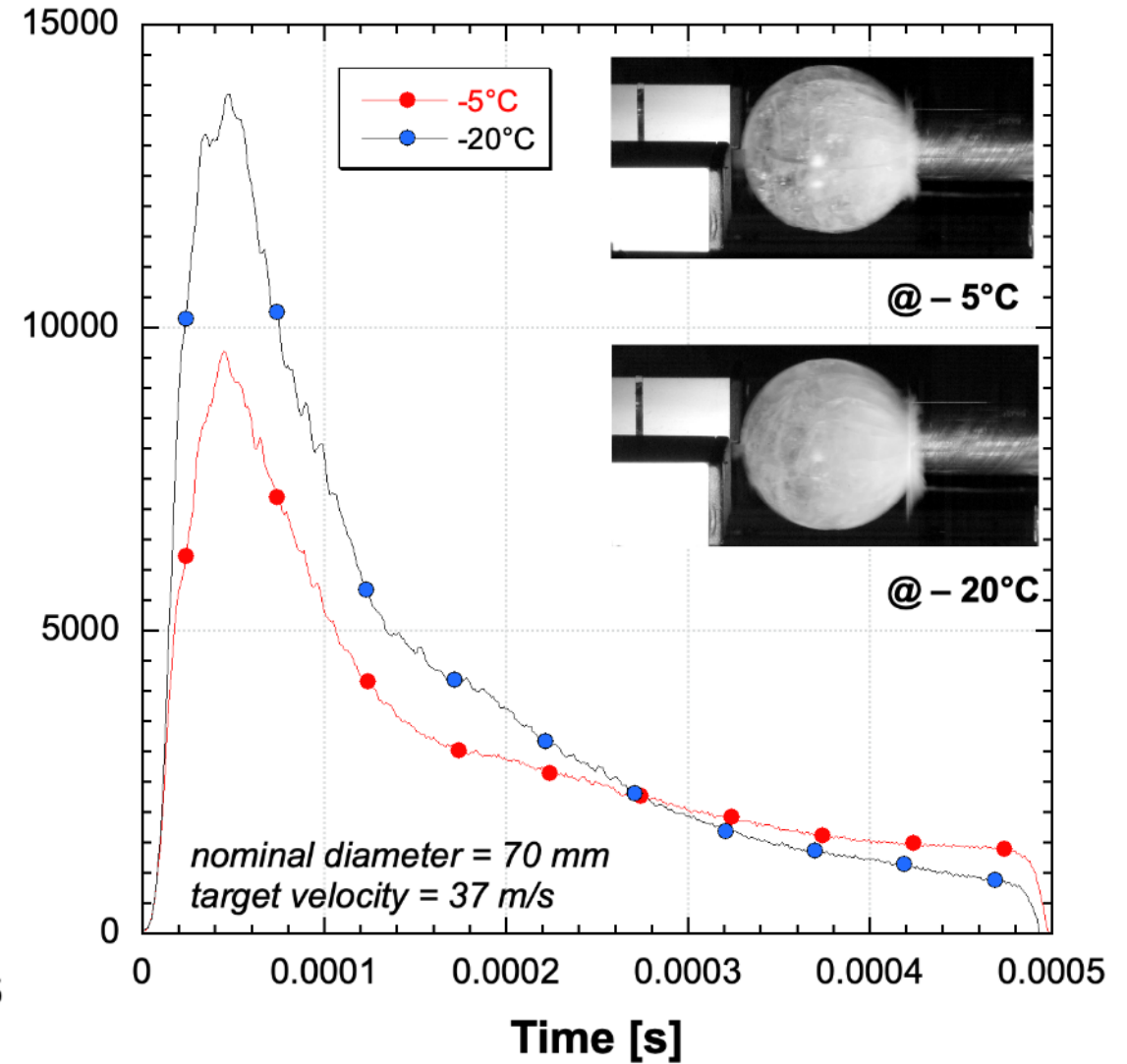
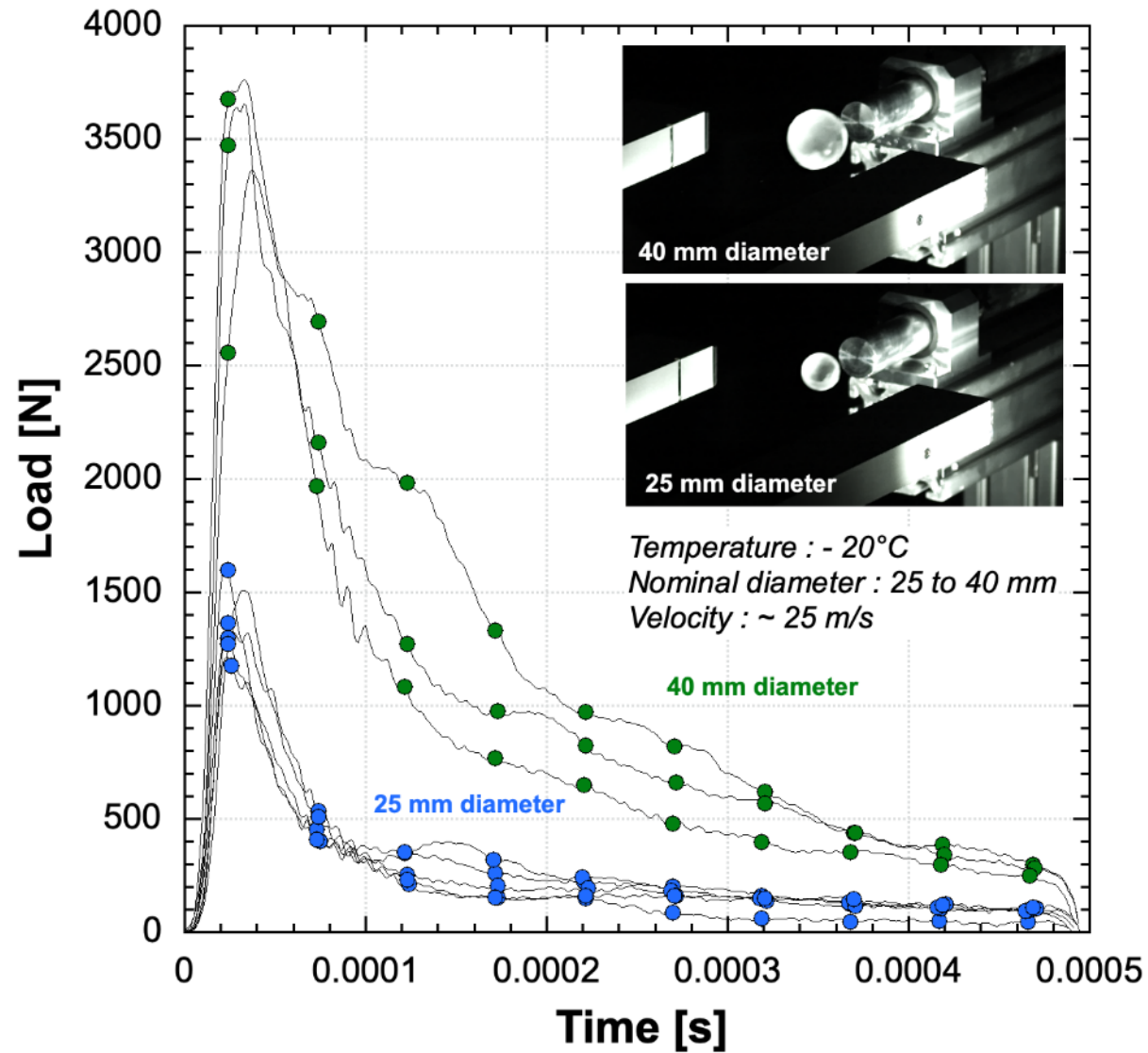


Table 1

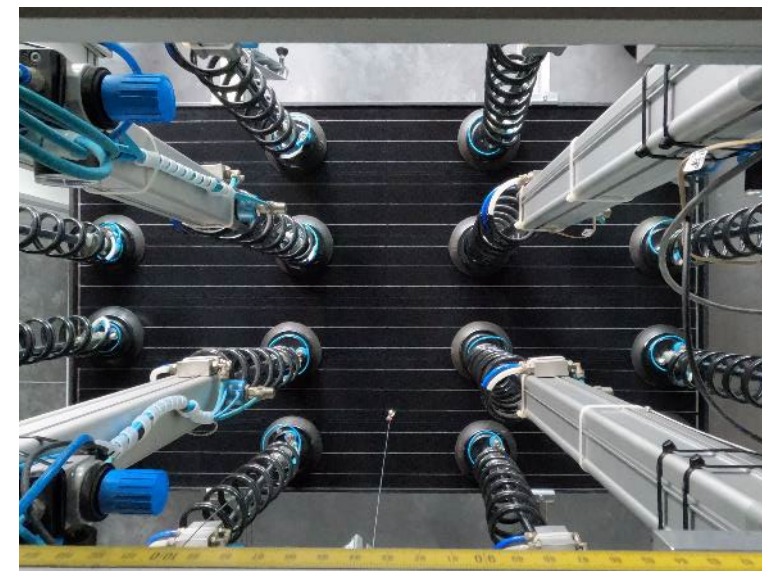
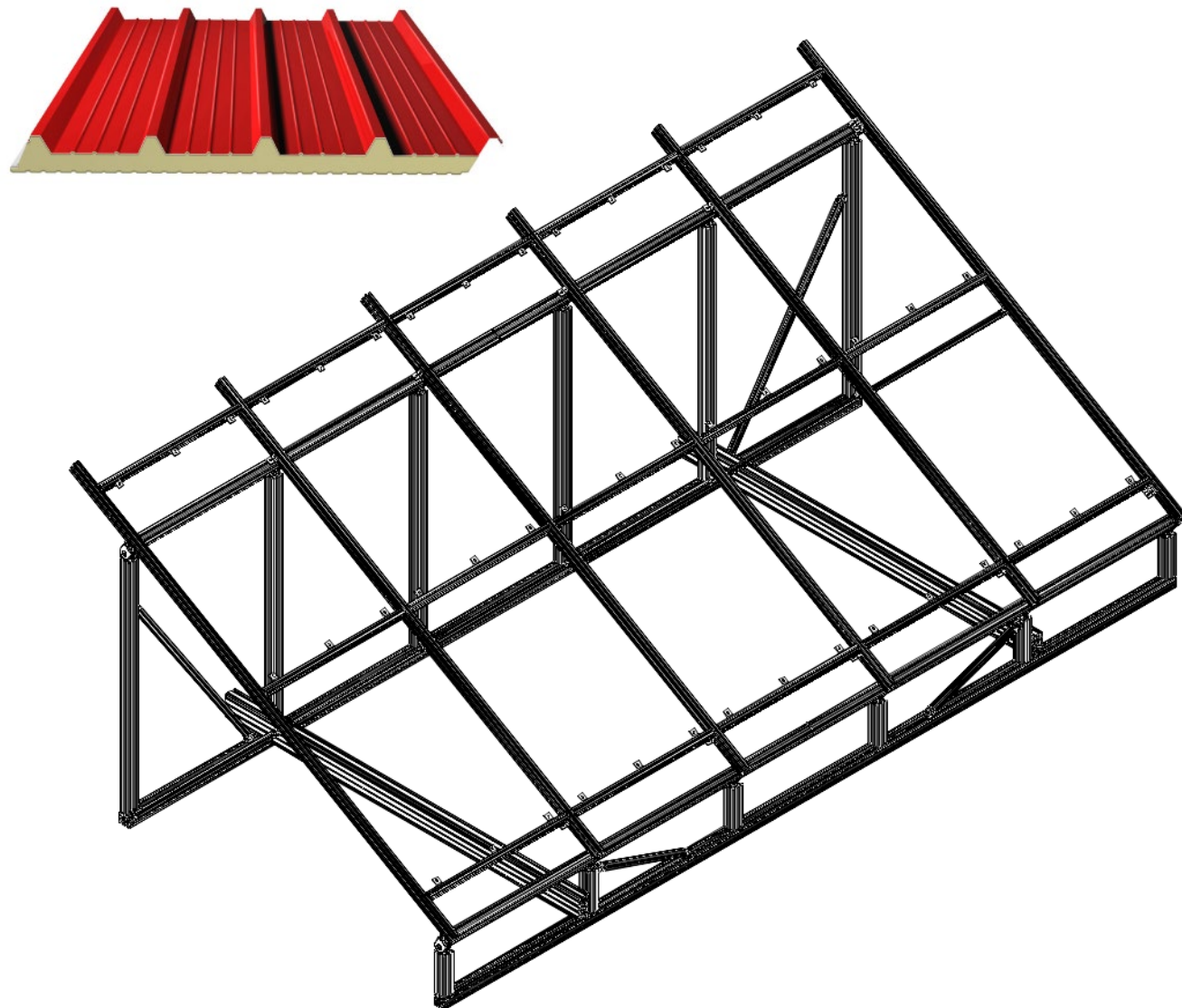
Experimental results with hail stones of different diameter.

Diameter (mm)	Temperature (°C)	Mass (g)	Velocity (m/s)	Max. load (N)	Fracture time (μs)	
25.1 ± 0.1	−5°C	7.9 ± 0.1	21.8 ± 0.8	851 ± 112	37 ± 7	Increase 70 %
25.3 ± 0.1	−20 °C	8.0 ± 0.1	23.6 ± 0.5	1447 ± 144	26 ± 4	
39.4 ± 0.1	−5°C	29.7 ± 0.1	27.7 ± 0.3	2257 ± 72	43 ± 10	Increase 59 %
39.5 ± 0.0	−20 °C	29.8 ± 0.2	27.8 ± 0.6	3594 ± 205	34 ± 2	
69.0 ± 0.1	−5°C	159.7 ± 0.2	36.7 ± 0.5	10042 ± 417	48 ± 1	Increase 44 %
69.1 ± 0.1	−20 °C	160.0 ± 0.1	38.5 ± 0.1	14463 ± 586	47 ± 4	

ACHILLES: Situazione

- È difficile rompere le celle senza rompere i moduli: 4 moduli su 8 colpiti dalla grandine indoor sono stati distrutti.
- I moduli sul campo sembrano presentare importanti danni alle cellule, senza rotture del vetro.
- Differenze tra condizioni interne ed esterne:
 - Strutture di montaggio, incurvamento del vetro
 - Invecchiamento dei moduli (materiali, rottura delle celle, ecc.)
 - Qualità del vetro/approccio statistico (solo 1 modulo testato per la prova della grandine)
 - Impatti multipli
 - Forma dei chicchi di grandine

Outdoor mock-up stand vs test accelerati indoor (IEC TS 63397)



Criteri di giudizio: IEA Task 13

- Due criteri:
 - sicurezza (rischio fuoco, shock elettrico o fisico)
 - Perdita di potenza (6 diversi livelli)

4.3 Definition of safety failure and safety categories

A safety failure is a failure that may endanger somebody who is applying or working with PV modules or simply passing the PV modules. The safety categories categorise the failure type for the safety of the PV system. In Tab. 4.3.1 three classes are defined. These classes are useful to assess the action needed to be taken if the failure occurs.

Tab. 4.3.1: List of safety categories.

Safety category	Description
A	Failure has no effect on safety.
B(f,e,m)	Failure may cause fire (f), failure may cause electrical shock (e), failure may cause physical danger (m), if a follow-up failure and/or a second failure occurs.
C(f,e,m)	Failure causes direct safety problem (definition of f,e,m see B).

4.4 Definition of power loss failure and power loss categories

If the module power P_m measured in accordance with IEC 60904 [IEC 60904] plus the total uncertainty of the measurement ΔP_m is lower than the power printed on the module label P_l minus the tolerance stated on the label ΔP_l a power loss failure occurs:

$$P_m + \Delta P_m < P_l - \Delta P_l \quad (4.4.1)$$

The reverse definition is given in the standard IEC 61853-1 [IEC 61853-1] for the case of no power loss. The power loss categories describe how the power loss evolves from the initial power value to a time in the service life of a PV module. In most cases this discrepancy between the reference values may lead to inconsistent results, because the power printed on the PV module label may substantially deviate from the initial PV module power.

However, each definition is useful for its application area.

1. Legal application: power loss failure uses the power printed on the PV module label as reference value.

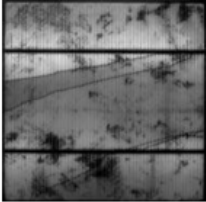
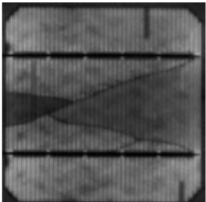
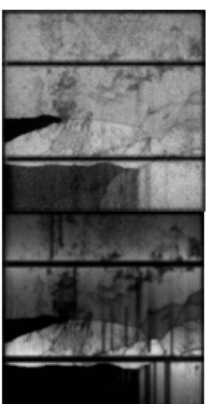
2. Technical application: the power loss category uses the initial power as a reference value.

The power loss categories given in Tab. 4.4.1 allow the assessment of the impact of the failure over time.

Tab. 4.4.1: Definition of power loss categories.

Power loss category	Description
<u>A</u>	Power loss below detection limit <3%
<u>B</u>	Exponential-shaped power loss degradation over time
<u>C</u>	Linear-shaped power loss degradation over time
<u>D</u>	Power loss degradation saturates over time
<u>E</u>	Degradation in steps over time
<u>F</u>	Miscellaneous degradation types over time

Criteri di giudizio: IEA Task 13

	Cell failures			
6.2.2	Cracks in solar cell modus A. The cell has a crack but the crack does not influence the current flow over the crack (no crack resistance)	B	<u>C</u>	
6.2.2	Cracks in solar cell modus B+(A). The cell has a crack and the crack influences the current flow to the cell interconnect ribbon of the cell. However the cell is still connected.	B(f)	<u>C</u>	
6.2.2	Cracks in solar cell modus C+(B+A). The cell has a crack and the crack completely isolates cell part(s) from the cell interconnect ribbon. An EL image taken at about 1/10 of the rated current (upper image) of the PV module is more capable to reveal isolated cell parts as one taken at the rated current (lower image), compare lower left parts of the two images.	B(f)	<u>C</u>	

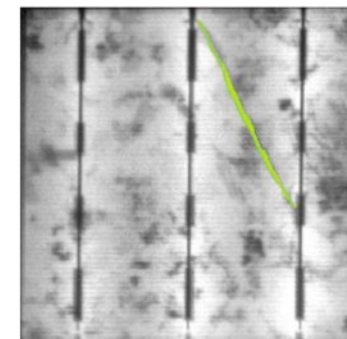
Criteri di giudizio: MBJ

- Unico Criterio:
 - Perdita di potenza (4 classi), area della cella interessata e tipologia della micro-fessura

Classe Modulo	Categoria delle celle			Totale Celle segnate
	verde	giallo	rosso	
A	<10%	0%	0%	<10%
B	<20%	<10%	0%	<20%
C	≥20%	≥10%	<10%	<30%
D	-	-	≥10%	≥30%

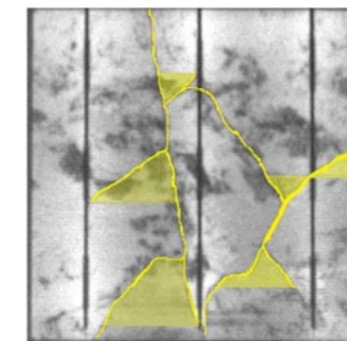
Tabella 4: Classi dei moduli in base alle categorie delle celle

Fonte: MBJ



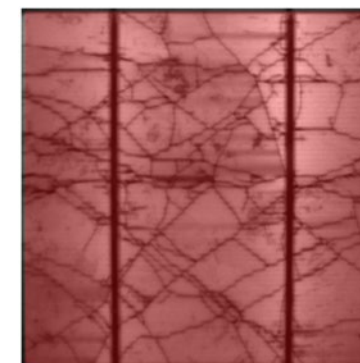
Judgment

A further expansion of the cell break is not expected. Possible cell area disconnection 0%.



Judgment

Breaks can potentially reduce the active area of the cell approx. 10%.

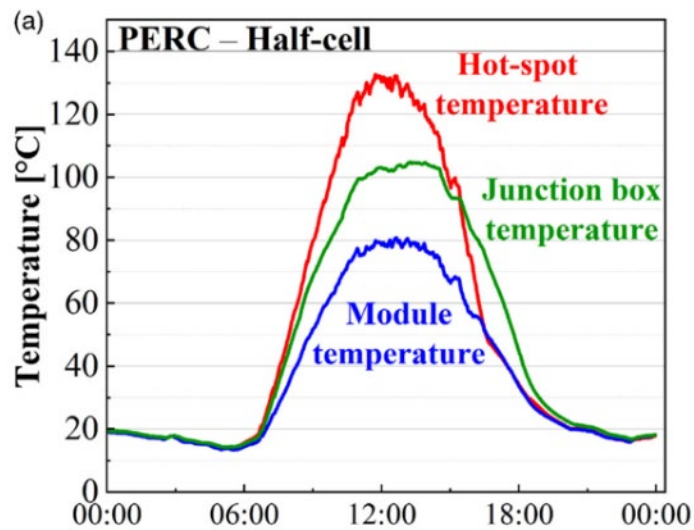


Judgment

These cracks can potentially reduce the active area of the cell far more than 20%.

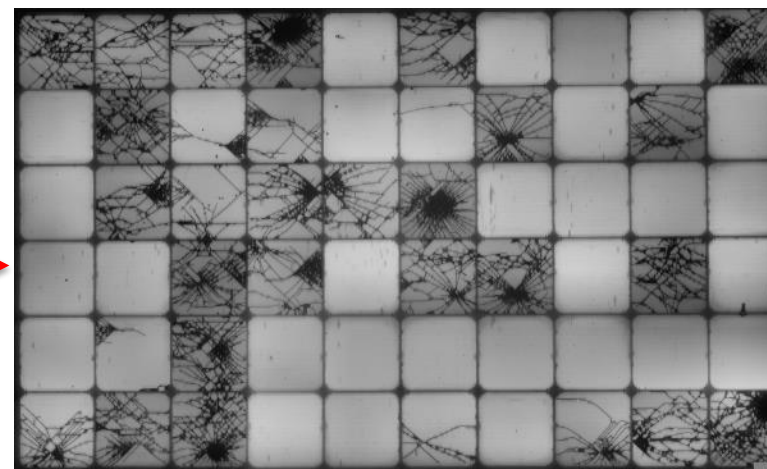
Criteri di giudizio: Hot spot

Component Defect	Module Hot-spot (thermal patterns)	PVFS 1-19vs.01
Appearance	A hot-spot is a thermal abnormality such as a local overheating or a thermal pattern which deviates from the normal behaviour of a module. It can be detected only by imaging techniques such as e.g. infrared thermography. Hot spots are not visible by the naked eye until they lead to irreversible hot-spot damages like e.g. local yellowing , burn marks , glass or cell break-age . The position, size, intensity and pattern of the hot-spot/s depends on the origin and progress of the failure, but also under which conditions the module is operating (shading, load and irradiance level). A temperature gradient of smaller than 10 K is considered as normal and is not a hot spot or thermal abnormality.	
Detection	IRT, (VI)	

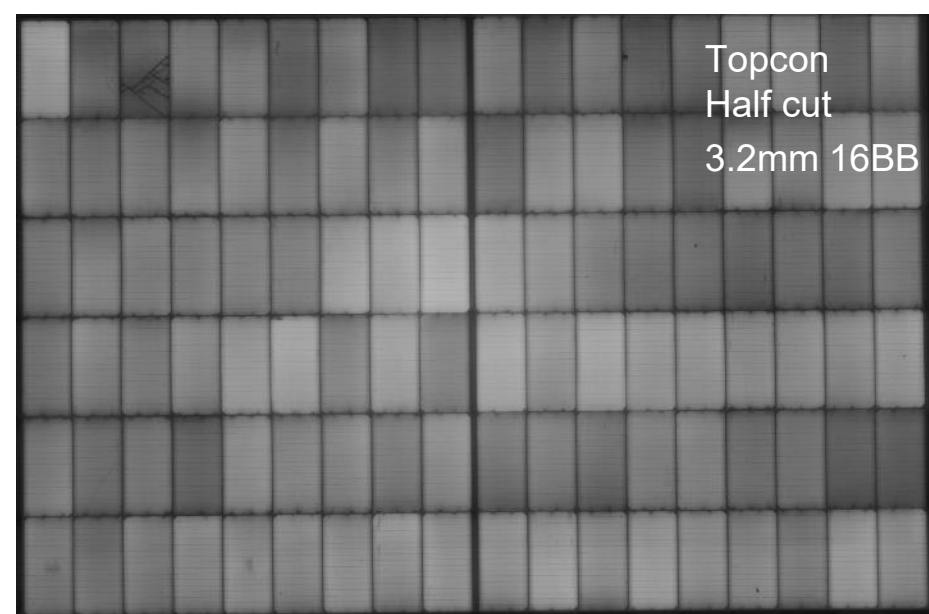
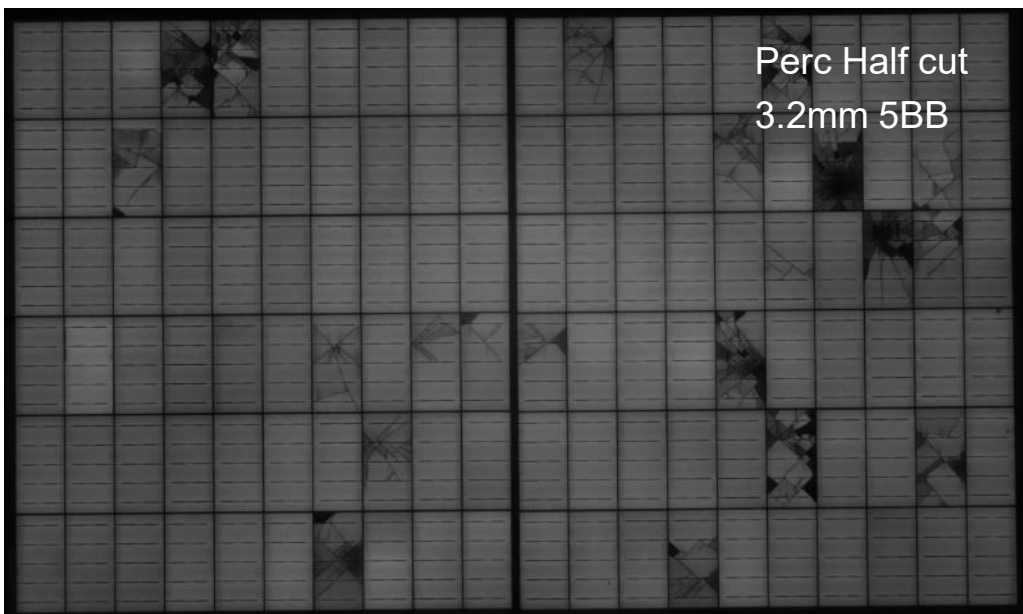
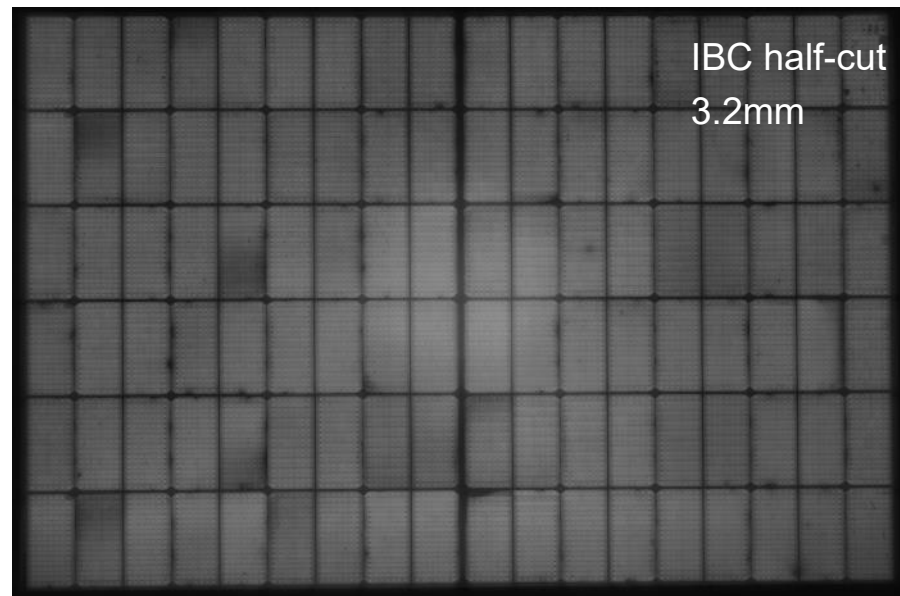
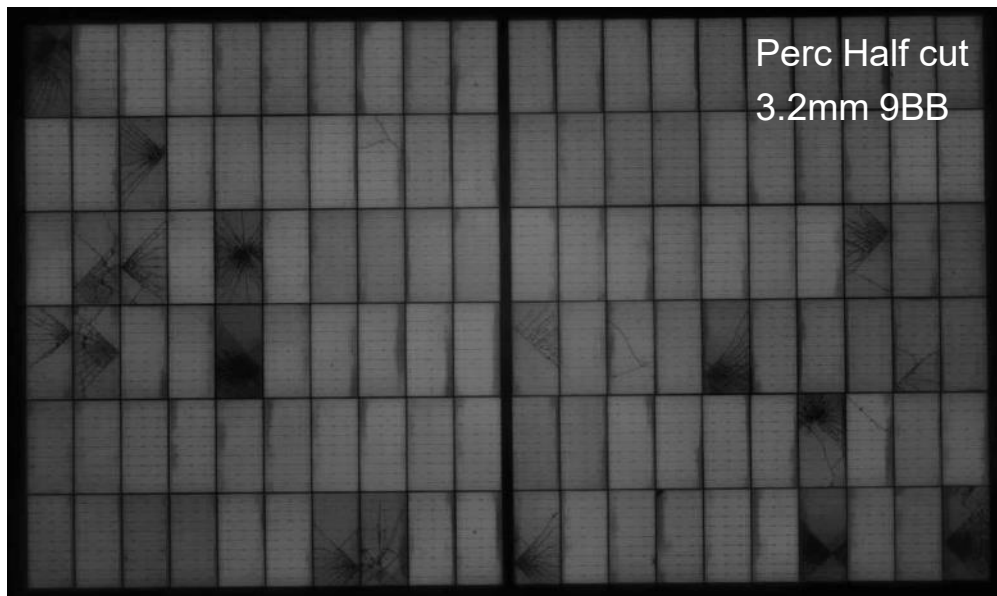


Fonte: PV Failure Sheets IEA task 13, " The effect of partial shading on the reliability of photovoltaic modules in the built-environment", E.Özkalay et al.

Outdoor: la grandinata di Locarno del 25 agosto 2023



La grandinata di Locarno: verifiche in laboratorio.





Grazie dell'attenzione!