P5 Presentation

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Fire Safety of Building Integrated PhotoVoltaics (BIPV):

A risk-based design support tool for designing façades with BIPV

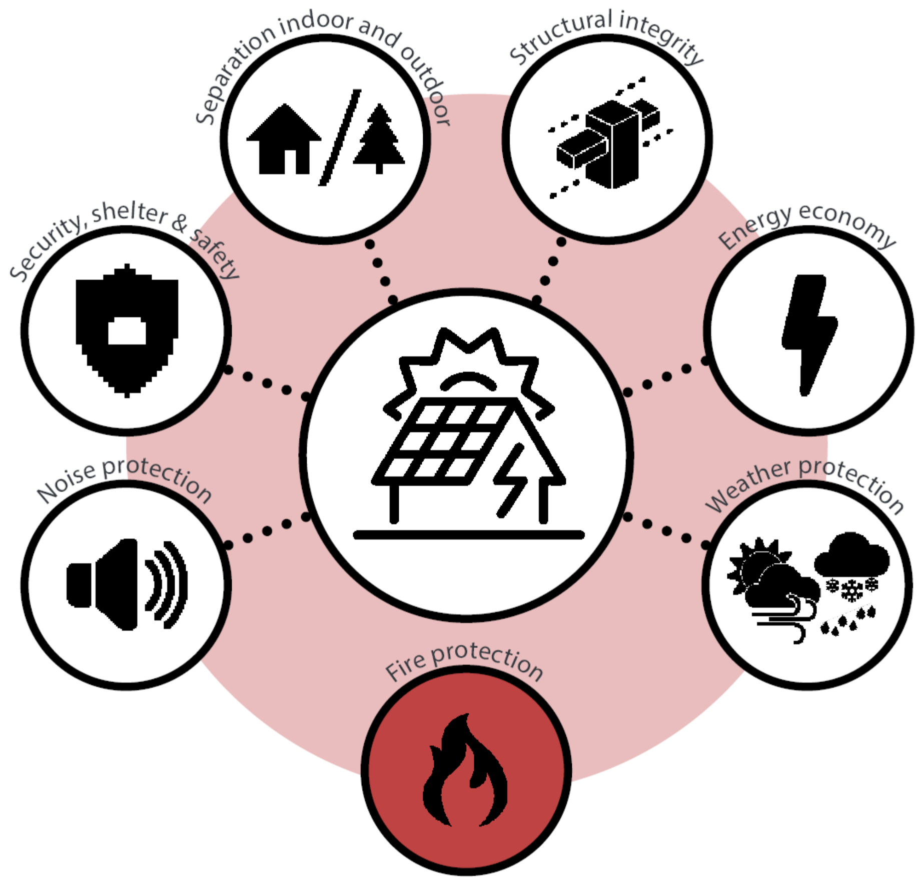
BIPV definition

"A BIPV module is a PV module and a construction product together, providing functional requirements for the building envelope

…

If the BIPV module is dismounted, it would have to be replaced by an appropriate construction product.

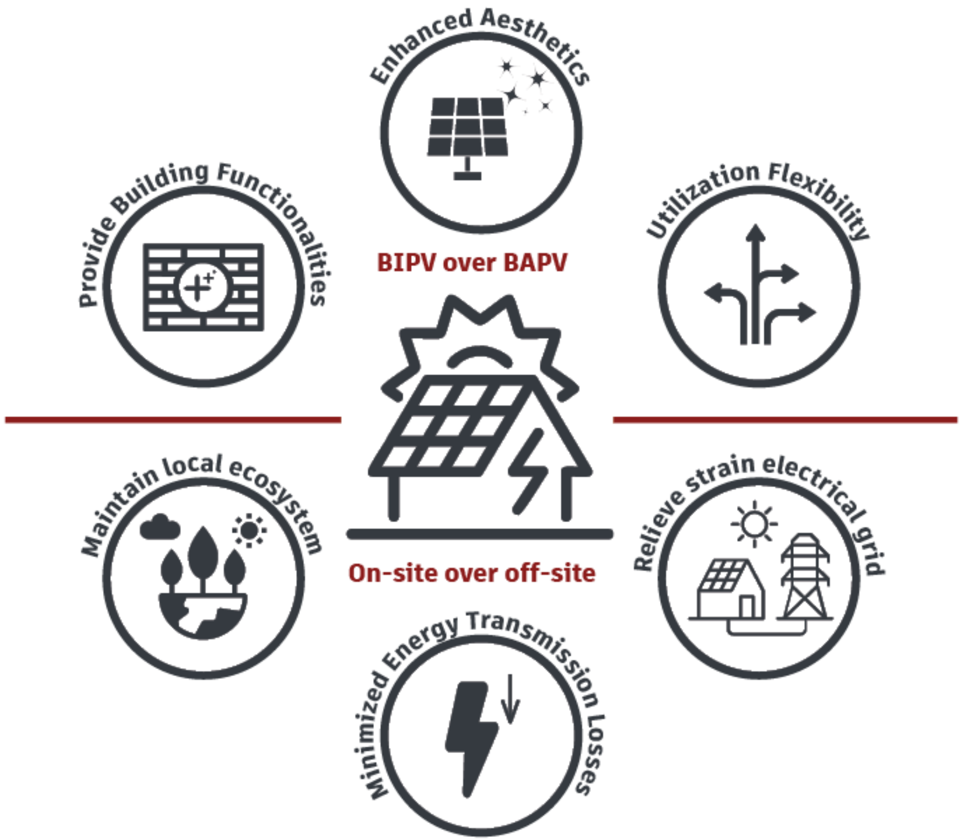
- IEA PVPS Task 15 (2018) -



BIPV & BAPV

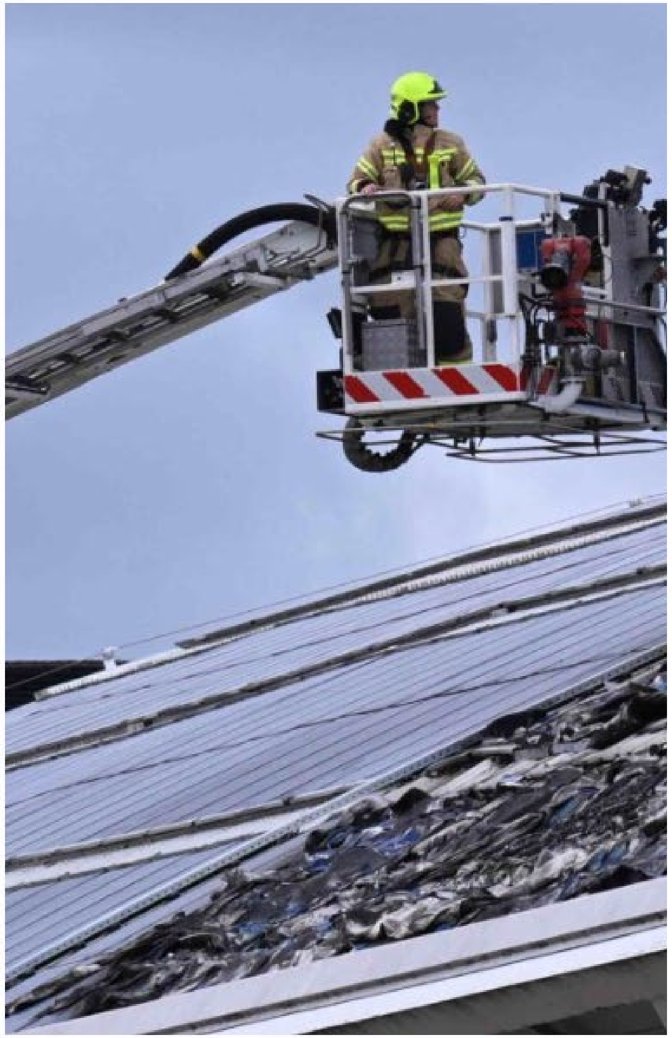
Building Integrated PhotoVoltaics (BIPV)

Building Applied PhotoVoltaics (BAPV)



NOS

Fire at huge aquatic
evacuations at majo



NOS Nieuws • Maandag 19 juni 2023, 21:29

Brandweer pleit na brand in woonblok voor strengere bouwregels zonnepanelen

Regulatory reaction

- On-roof PV (=BAPV)
- In-roof PV (=BIPV)
- *Façade   (BAPV & BIPV)*

I
Research Proposal

II
Research Findings

III
Design Support Tool

IV
Discussion & Conclusion

V
Future Research

Problem statement

BIPV façade systems introduce high-voltage ignition sources, carrying DC currents up to 1000 V, directly into façade structures, a hazard unprecedented in conventional façades. Despite this…

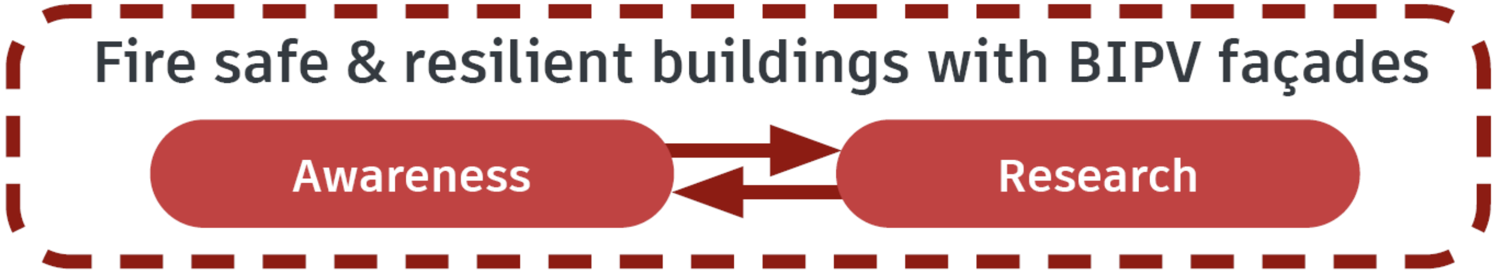
Regulatory gap

- (Yang et al., 2023) No fire safety building codes and performance criteria are tailored for BIPV facades
- (Aram et al., 2021) Fire test for BIPV façades fail to account for the unique fire scenarios
- (IEA PVPS Task 15, 2023) No statutory quality systems for BIPV installations

→ pre-normative state

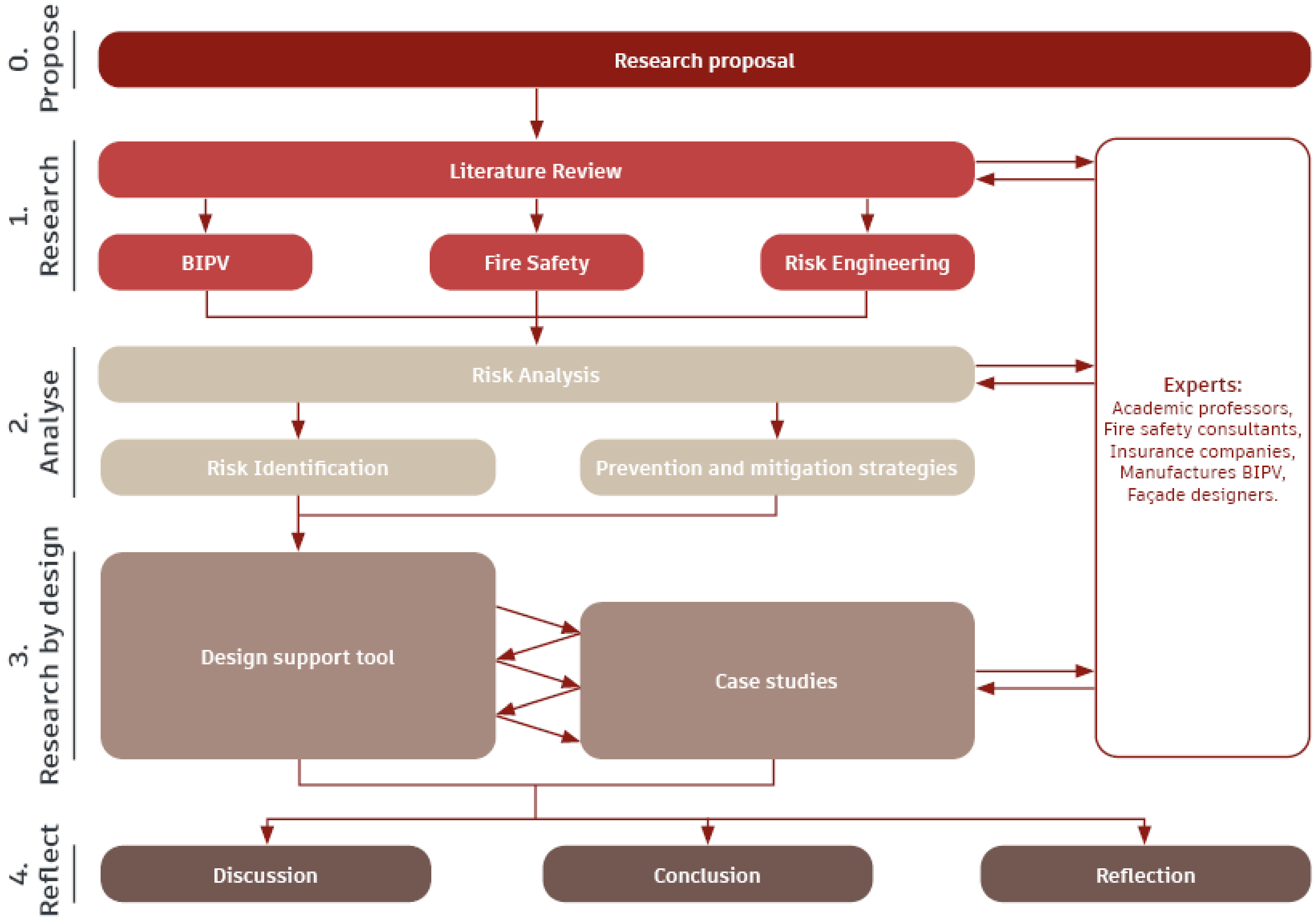
Main objective

"To achieve fire safe and fire resilient buildings with BIPV systems in façades"



Research question

RQ1 | Can a risk-based design support tool aid designers of façades in the design process to achieve fire safe and fire resilient designs when integrating building-integrated photovoltaic systems?


0. Propose
Research proposal
1. Research
Literature Review
BIPV
Fire Safety
Risk Engineering
2. Analyse
Risk Analysis
Risk Identification
Prevention and mitigation strategies
3. Research by design
Design support tool
Case studies
4. Reflect
Discussion
Conclusion
Reflection
Experts:
Academic professors,
Fire safety consultants,
Insurance companies,
Manufactures BIPV,
Façade designers.

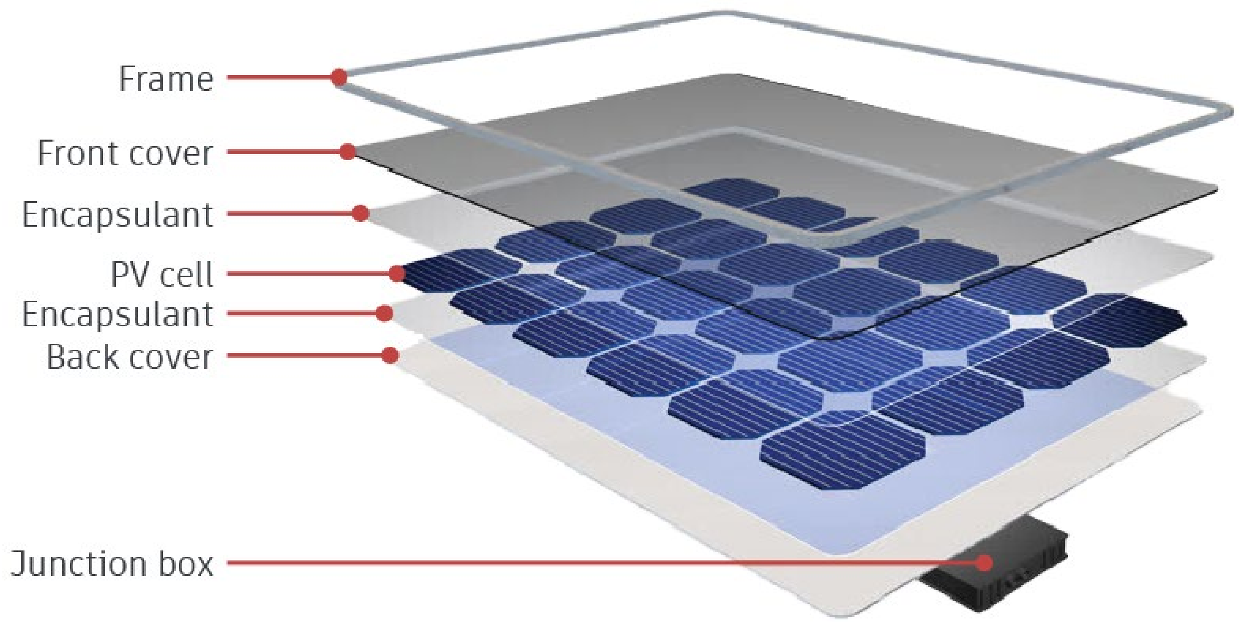
I

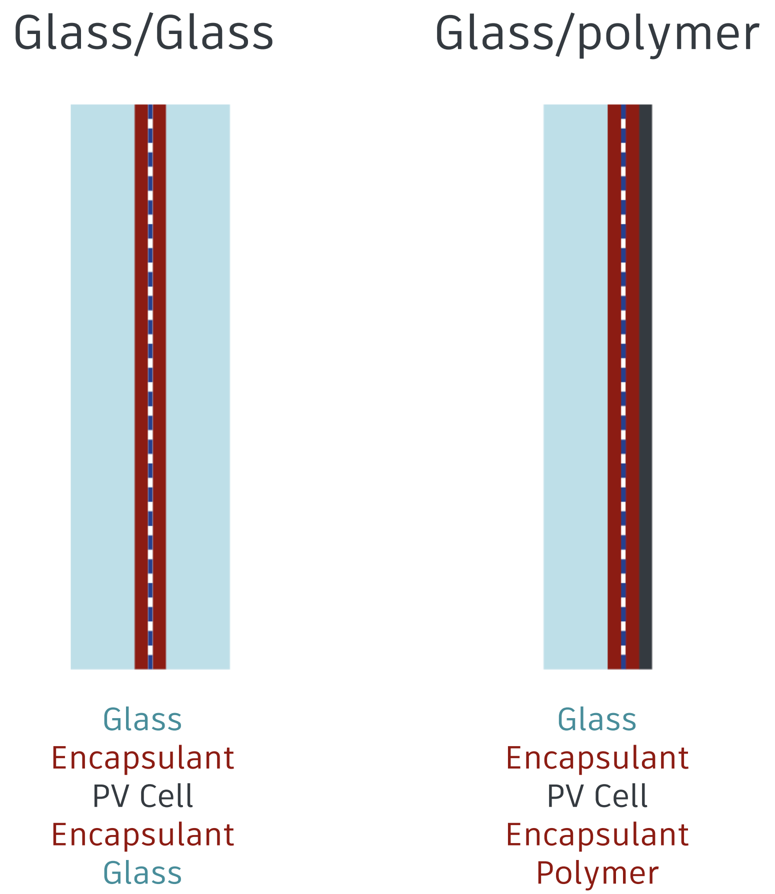
Research Proposal

II

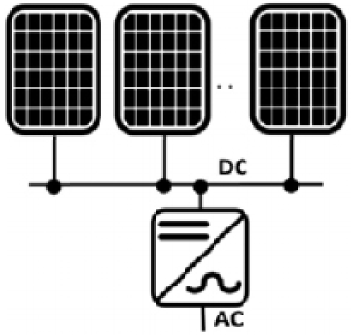
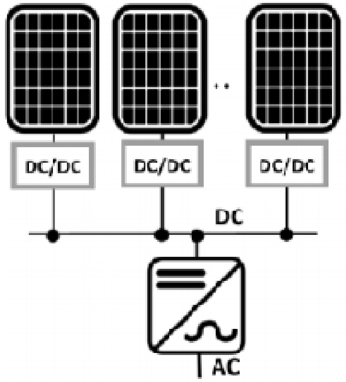
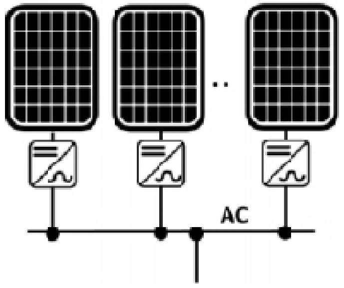
Research Findings

BIPV façade: module types





BIPV façade system: electrical configurations

			
Electrical config.	**String inverter**	**String inverter + optimiser**	**Micro-inverter**
Typical components	1 inverter per 10-20 modules	1 inverter per 10-20 modules 1 optimiser per 1 module	1 inverter per 1-2 modules
Typical placement components	String inverter: indoors	String inverter: indoors Optimiser: in façade cavity	Micro-inverter: indoors (or façade cavity)
Voltage in façade	High voltage DC (<1000 V)	High voltage DC (<1000 V)	Low voltage AC (<80 V)
Fire risk	High	Medium	Low
Costs	Low	Medium	High
Efficiency	Medium	High (due to individual module optimization)	High (due to individual module optimization)
Shading Performance	Poor (whole string affected)	Good (only shaded module affected)	Excellent (each module independent)
Flexibility	Low (dependent on string design)	High (independent module control)	Very high (independent module control)
Monitoring	Basic (string level)	Advanced (module level)	Advanced (module level)

Fire safety regulations

Electrotechnical norms (IEC)

- Aimed at preventing ignition
  - E.g. NEN-EN-IEC-61730

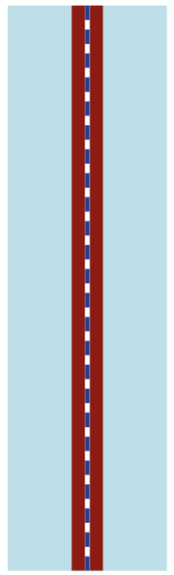
Building decree & norms

- Treated equally as conventional façade materials

Fire class requirements

New building	
Artikel 2.68	
Façade height < 2.5 m	B (if highest floor > 5m)
Façade height > 13 m	B
*1 Façade height > 30 m	A2 (sleeping function with reduced self-reliance), B (other functions)
*1 Façade height > 50 m	A2 (sleeping function), B (other functions)
Façade adjacent to extra protected escape route	B (cell function), C (other functions)
Façade adjacent to protected escape route	B (cell function), C (sleeping function), D (other functions)
Façade part (other)	D
Exception: doors, windows, window frames	D
Artikel 2.84 and 2.94	
Façade between two fire compartments	B (condition WBDBO / NEN 6068)
Façade between protected sub fire compartments and fire compartments	B (condition WBDBO / NEN 6068)
*1 Expected to be implemented in Bbl	
• Classes A2/B/C/D according NEN-EN 13501-1	

Glass/Glass



Glass
Encapsulant
PV Cell
Encapsulant
Glass

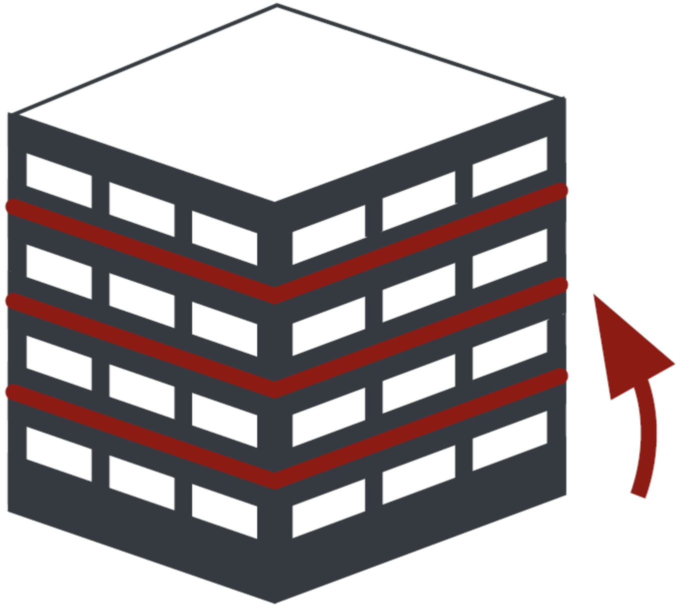
Euro classification	Fire behaviour of the material	
A1	No contribution	Non-combustible
A2	Almost no contribution	Almost non-combustible
B	Limited contribution	Limited combustibility
C	Big contribution	Combustible
D	High contribution	Easily combustible
E	Very high contribution	Highly combustible
F	Dangerous contribution	Very highly combustible

Risk analysis

Techniques	Procedure	Advantages	Disadvantages
FMECA	Examine whether components or process can have some failures	Good for equipment, mechanic systems	Little attention given to human factors Does not estimate cost of failure
HAZOP	Use the nodes of industrial plants to search for deviations from designed intent	Improve chemical process and operability	Time-consuming Experienced team leader required
ETA	Structuring cause back to the consequences	Quantitative with graphic tool Good for technology performing	Cannot analyze multiples failures
FTA	Structuring consequence back to the causes	Reveals the main causes of failure Give graphical view	Problem of reliability when data are minimized
RADM	Combining probability and severity of hazard. Determining a risk priority number	Graphical tool. Good relation between probability and severity ranking risks	Inadequate if there are many risks Cannot be used to deduce causes and consequences
PHA	Ask questions about potential failure, fault	Prioritize recommendations	Cannot be used to find details concerning a hazard
What-if	Checks for potential hazards by posing "What-if" questions	Very fast in searching for consequences	Cannot determine causes Very basic
Checklist	Use a list of hazards to record consequences and safety actions	Useful to have an overview of the hazards list	Much time required to find a hazards list
HRA	Evaluates human–machine interface, carry out task analysis.	Can help reducing human errors by improving performance shaping factors	Much time required if there are a lot of personnel

Fault tree analysis

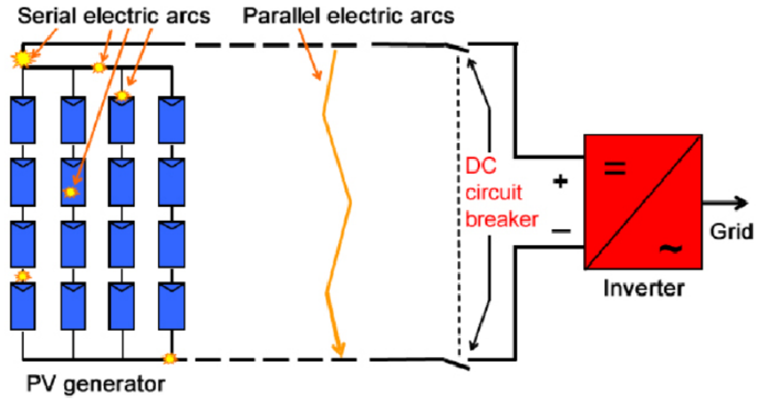
Top event: vertical fire spread over multiple fire compartments

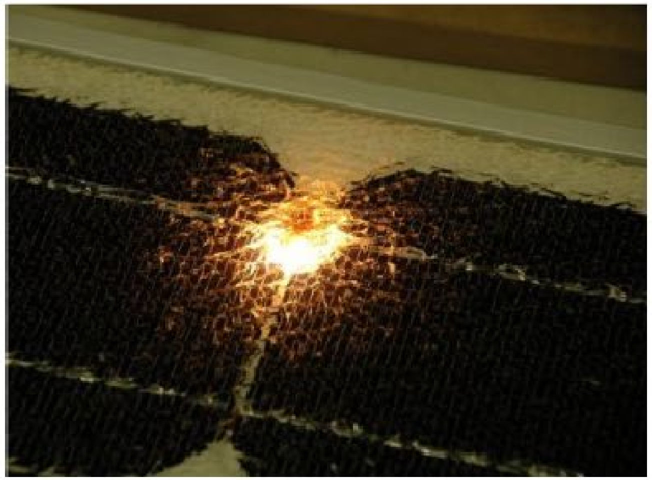


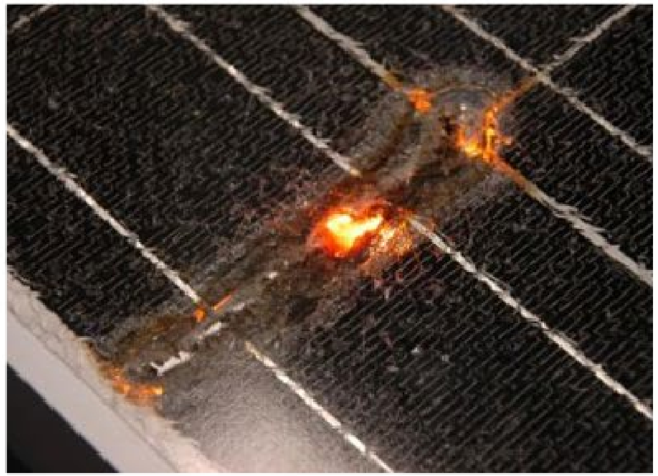
FTA: Vertical fire spread over multiple fire compartments

Critical failure modes:

- Electric arc (AC and DC) All electrical components





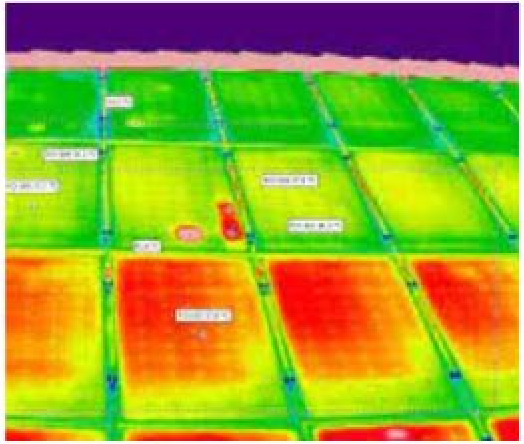


FTA: Vertical fire spread over multiple fire compartments

Critical failure modes:

• Electric arc (AC and DC)	All electrical components
• Hot-spot	BIPV module

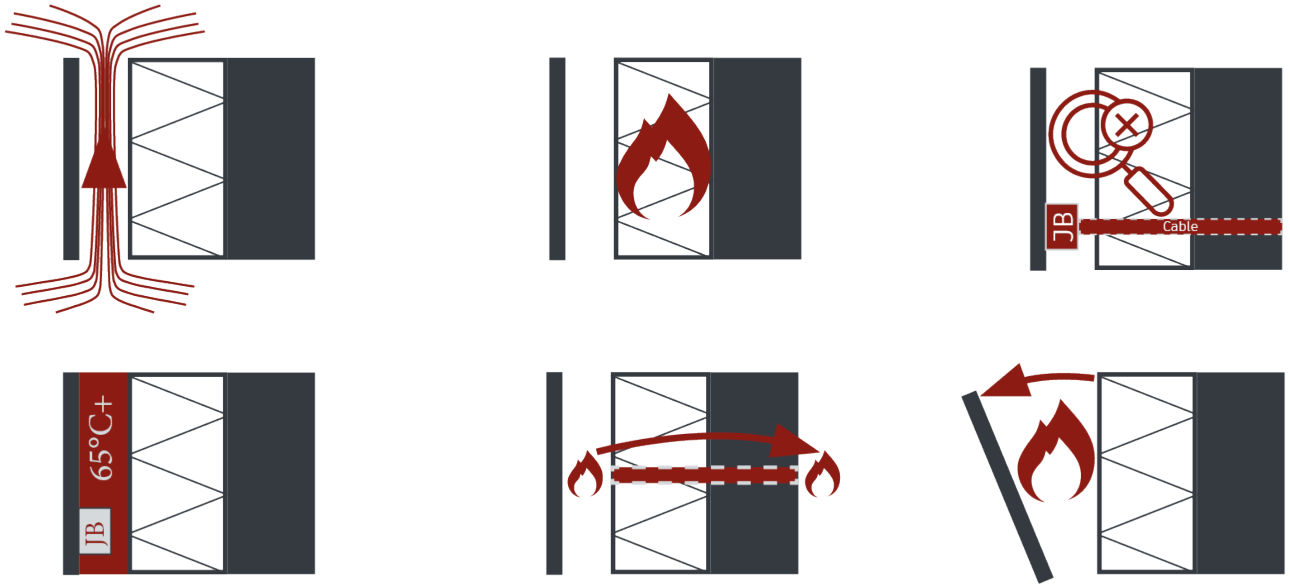


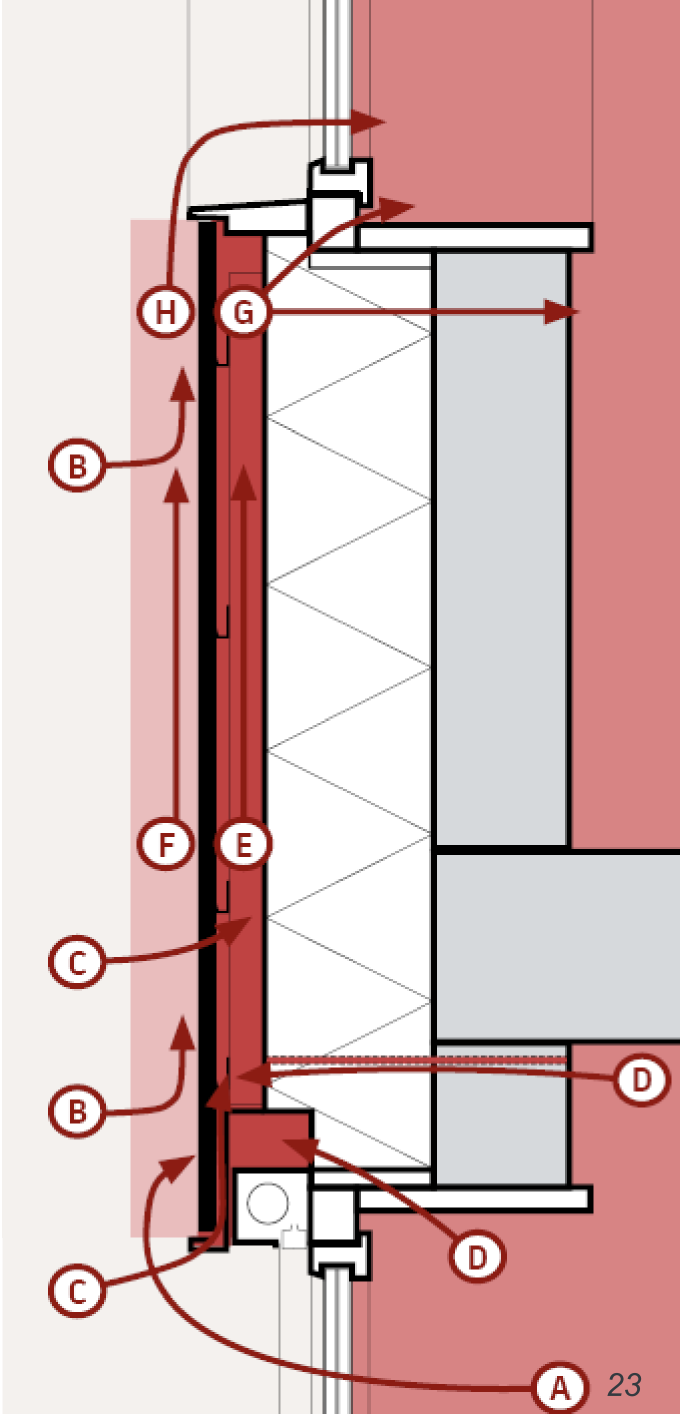



FTA: Vertical fire spread over multiple fire compartments

Why are BIPV façades of high risk?

- Ventilated façade → chimney effect
- Combustible materials in façade
- Inability to inspect components in facade
- Elevated cavity temperatures
- Cable penetrations
- Falling BIPV modules





Potential area of ignition scenario occurring:

Ignition scenario 1
Ignition scenario 2
Ignition scenario 3 &4
Ignition scenario 5

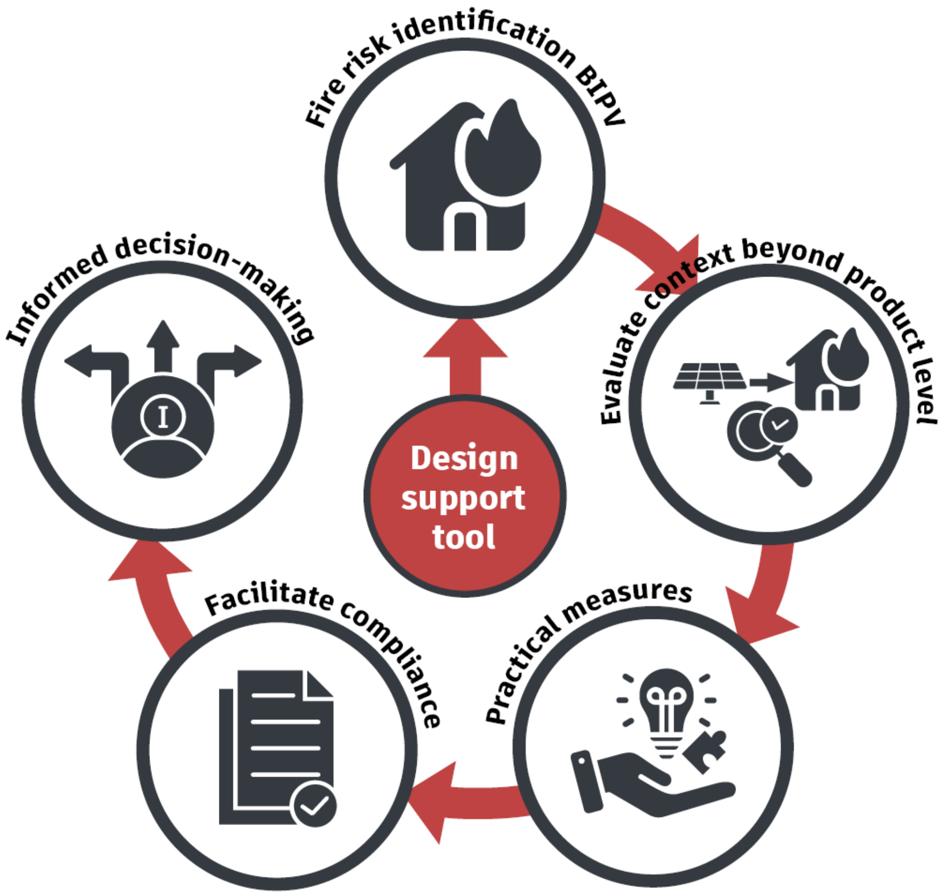
II

Research Findings

III

Design Support Tool

Design support tool: goal



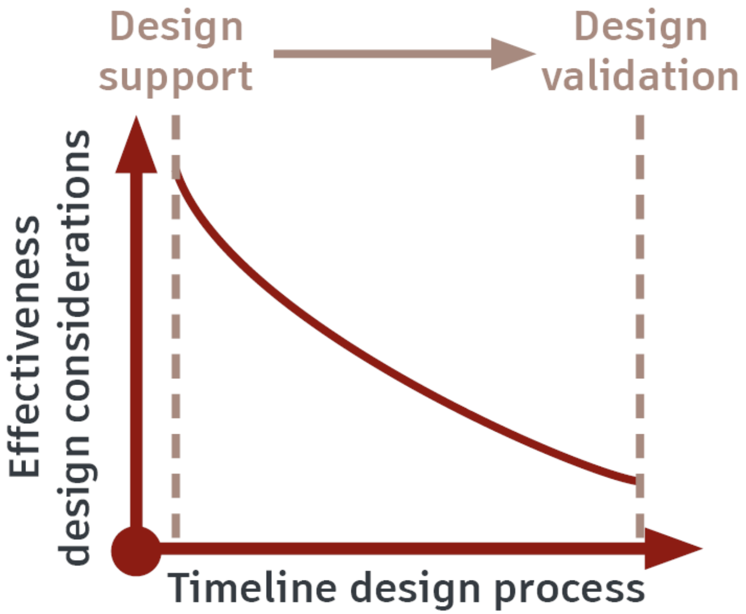
Design support tool: who/when/how

Intended user

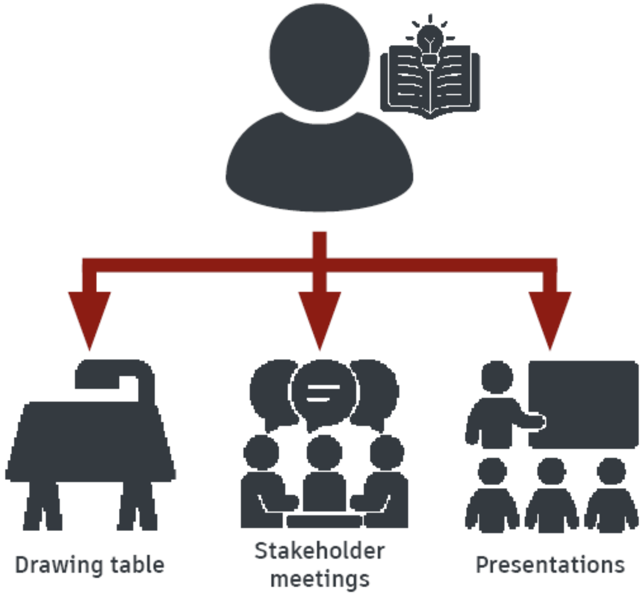
Designed for:
Architects
Façade engineers

Can also be used by:
Manufactures
Fire safety consultants
Clients
Developers

When to use



How to use optimally



Design support tool: reference tools

DGMR: handreiking brandveiligheid gevels

Globale risico-schatting voor brandbare gevels	Factor	Gebouw 1	Gebouw 2	Gebouw 3	Gebouw 4
Gevelkenmerken					
1a. Brandvoortplanting buitenblad		1	1	1	1
Toplaag <3 vol.% brandbaar	1				
Toplaag 3-30 vol.% of kopse zijde >30 vol.% brandbaar	4				
Toplaag >30 vol.% brandbaar	16				
Onbekend	16	Toelichting	Toelichting	Toelichting	Toelichting
1b. Brandvoortplanting buitenblad *1		1	1	1	1
Geen risico-reducerende factor	1				
Effectieve gevelonderbreking op elke verdieping *2	0,25	Toelichting	Toelichting	Toelichting	Toelichting
2a. Brandvoortplanting geventileerde gevelspouw		1	1	1	1
Geen geventileerde spouw	1				
Toplagen samen <3 vol.% brandbaar	1				
Toplagen samen 3-30 vol.% brandbaar	2				
Toplagen samen >30 vol.% brandbaar	4				
Onbekend	4	Toelichting	Toelichting	Toelichting	Toelichting
2b. Brandvoortplanting geventileerde gevelspouw *1		1	1	1	1
Geen risico-reducerende factor	1				
Effectieve spouwonderbrekingen op elke verdieping *3	0,5	Toelichting	Toelichting	Toelichting	Toelichting
Gebouw(gebruik)-kenmerken					
3. Gebruiksfunctie		1	1	1	1
Gezondheidszorg-bedgebied, wonen voor zorg of celfunctie	8				
Kinderopvang met bedgebied	4				
Woonfunctie in woongebouwen, logiesfunctie in logiesgebouwen	4				
Overige gebruiksfuncties	1	Toelichting	Toelichting	Toelichting	Toelichting
4. Hoogte gebouw		1	1	1	1
Gebouwhoogte <15m	1				
Gebouwhoogte 15m-40m	2				
Gebouwhoogte 40m-100m	4				
Gebouwhoogte >100m	6	Toelichting	Toelichting	Toelichting	Toelichting
5a. Ligging vluchtroutes		1	1	1	1
Twee trappehuizen op afstand >H/2	1				
Twee trappehuizen op afstand <H/2 in twee kernen	2				
Twee trappehuizen op afstand <H/2 in één kern	4				
Eén trappenhuis	8	Toelichting	Toelichting	Toelichting	Toelichting
5b. Ligging vluchtroutes *1		1	1	1	1
Geen risico-reducerende factor	1				
Eén trappenhuis zonder gevelopeningen	0,5				
Twee trappenhuizen zonder gevelopeningen	0,25	Toelichting	Toelichting	Toelichting	Toelichting
6. Extra voorzieningen		1	1	1	1
Standaard Bouwbesluit / geen extra voorzieningen	1				
BMI met volledige bewaking waar dit niet vereist is	0,25				
Blusinstallatie	0,25				
Brandwerende gevel	0,25	Toelichting	Toelichting	Toelichting	Toelichting
		1	1	1	1

Risico-categorieën				
Weging	< 50	50 - 200	200 - 800	> 800
Code	Groen	Geel	Oranje	Rood

*1: Een factor 1 staat voor een zeer laag risico en kan daarom niet verder worden verlaagd met een risico-reducerende maatregel, dus wordt de eindscore berekend met: 1a x 1b ≥ 1, 2a x 2b ≥ 1 en 5a x 5b ≥ 1

*2: Effectieve gevelonderbrekingen: balkon/uitkraging op elke verdieping, breed >0,5m en 'brandvast', of horizontale raamstrook, hoog >1m, op elke verdieping. Brandvast: <3 vol.% brandbaar en niet-smeltend.

*3: Effectieve spouwonderbrekingen: spouwonderbreking op elke verdieping, met buitenblad en ophanging daarvan 'brandvast' (<3 vol.% brandbaar en niet-smeltend).

DGMR & Nieman: borgingsprotocol

Stap 5: Vermenigvuldig gevel- en gebouwrisico's

Nr.	Omschrijving gevels door toetser:	Risicoscore uit stap 2 (gebouw gerelateerd risico):	Risicoscore uit stap 3 (geveltype gerelateerd risico):	Risicoscore uit stap 4 (risico bijzondere gevel)	Gecombineerde risicoscore (gebouw- x gevelrisico x bijzonder risico)	Risiconiveau (laag - middel - hoog) volgend uit de gecombineerde risicoscore:
		Zie pagina 2	Zie pagina 4 t/m 12	Zie pagina 14	-	-
0	Voorbeeld: Studentenwoning gevel type A	16	128	1	2048	Middel
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						

16 | Borgingsprotocol brandveiligheid gevels | B.2020.1346.00.R001

Design support tool

Home | Info BIPV | Risk overview | F1 | F2 | F3 | F4 | Measures

DESIGN SUPPORT TOOL: FIRE SAFETY FACADE BIPV SYSTEMS

Are you an architect or facade engineer, tasked with designing a new building that incorporates Building Integrated Photovoltaic (BIPV) systems into its façade? You're excited about the possibilities these systems offer in terms of sustainability and energy efficiency. However, there's a problem... You're not entirely sure about the fire risks associated with BIPV installations. You've heard some concerns, but you're not sure how to navigate them effectively?

That's where this design support tool comes in. It's designed to bridge the gap of the pre-normative regulatory framework surrounding BIPV systems, making it easier for architects like you to understand and address fire safety concerns.

How to use the tool

Step 1

Assess your case of study in the "Risk Overview" by filling in the design considerations for your facade(s)

Step 2

Consult sheets "Risk parameters (1-22)" or "Info BIPV" for information regarding the fire risk of each risk parameter

Step 3

Assess each facade in detail in the sheet "Facade Overview" (F1-F4)

Step 4

Consult sheet "Measures" for tailored measures and strategies

Risk overview

What is the amount of facades that you want to assess?		Grosspeter tower	The Pulse of Amsterdam	Concept proposal: PCT Cartuja	Villa Lichtenberg
Four façades		North	North	North	North
What do the colours and (..) values mean?		More info on façade 1	More info on façade 2	More info on façade 3	More info on façade 4
Building characteristics risk level					
1 What is the building function of use?	More info	(8) Healthcare with sleeping area, healthcare residential, detention function			
2 What is the building height?	More info	(8) Building height >100m			
3 What is the location of the escape routes?	More info	(1) One staircase in residential or accomodation not in residential building or accomodation building			
4 How would you estimate the value of the building?	More info	(1) Low value			
Façade characteristics risk level					
5 Does the BIPV facade continuously span over multiple fire compartments?	More info	(8) Yes, over more than two fire compartments	(1) No, each BIPV segment is limited to a single fire	(8) Yes, over more than two fire compartments	(1) No, each BIPV segment is limited to a single fire
6 Does the BIPV facade cavity continuously span over multiple fire compartments?	More info	(1) No, each BIPV cavity is limited to a single fire	(1) No, each BIPV cavity is limited to a single fire	(8) Yes, over more than two fire compartments	(1) No, each BIPV cavity is limited to a single fire
7 Will there be openings in the BIPV facade?	More info	(2) Yes, distributed openings	(2) Yes, distributed openings	(2) Yes, distributed openings	(2) Yes, distributed openings
8 Will there be protrusions along the BIPV façade?	More info	(1) No	(0,75) Horizontal protrusion < 0,5m	(1) No	(1) No
9 Will the BIPV façade be entirely accessible by the fire brigade?	More info	(4) No	(4) No	(1) Yes	(1) Yes
10 Do BIPV modules endanger an escape route?	More info	(2) Yes, BIPV modules are situated above multiple	(2) Yes, BIPV modules are situated above multiple	(1,5) Yes, BIPV modules are situated above an escape	(1,5) Yes, BIPV modules are situated above an escape
11 Will the façade be load-bearing?	More info	(1) No	(1) No	(1) No	(2) Yes
12 Will the orientation of the facade be in the prevailing wind direction of the location?	More info	(1) The facade is subjected to the prevailing wind or	(1) The facade is subjected to the prevailing wind or	(1) The facade is subjected to the prevailing wind or	(1) No
BIPV & façade product characteristics risk level					
13 What type of BIPV module will be employed?	More info	(1) Glass/glass	(1) Glass/glass	(1) Glass/glass	(1) Glass/glass
14 What will be the fire class of the BIPV module according NEN-EN 13501-1?	More info	(1) B	(1) B	(1) B	(1) B
15 What will be the fire class of the BIPV module according ANSI/UL 1703 (via UL 790)?	More info	(1) Not applicable	(1) Not applicable	(1) Not applicable	(1) Not applicable
16 Will the BIPV modules be easily removable?	More info	(2) No	(1) Yes	(1) Yes	(2) No
17 What is the main electrical configuration that will be employed?	More info	(2) String inverter	(0,5) Micro-inverter	(0,5) Micro-inverter	(2) String inverter
18 Will an active AFCI be employed in the BIPV system?	More info	(0,5) Yes	(0,5) Yes	(0,5) Yes	(0,5) Yes
19 Will the BIPV cavity exceed the maximum temperature specified for the BIPV system's	More info	(8) Yes, 20+ °C higher	(4) Yes, 0-20 °C higher	(8) Yes, 20+ °C higher	(1) No
20 What material will be situated in the cavity opposite to the BIPV module?	More info	(2) Sheet layer or insulation layer (fire class B)	(2) Sheet layer or insulation layer (fire class B)	(2) Sheet layer or insulation layer (fire class B)	(2) Sheet layer or insulation layer (fire class B)
21 What material will be used for the mounting system of the BIPV modules?	More info	(2) Aluminium	(2) Aluminium	(2) Aluminium	(2) Aluminium
22 Will BIPV system cables penetrate through the facade?	More info	(2) Yes	(2) Yes	(2) Yes	(2) Yes
23 Will quality control measures for the BIPV system be employed?	More info	(1) Yes, InstallQ	(0,25) Yes, InstallQ and SCOPE12	(16) No quality control will be employed	(1) Yes, InstallQ
		More info on façade 1	More info on façade 2	More info on façade 3	More info on façade 4

Overview risk score per façade	*Façade 1*	*Façade 2*	*Façade 3*	*Façade 4*
Building characteristics				
Façade characteristics				
BIPV & facade product characteristics				

Risk overview

Risk parameter

Design consideration

13 What type of BIPV module will be employed? More info (1) Glass/glass

Risk factor

13 What type of BIPV module will be employed? More info (8) Glass/polymer

Risk overview

	Low risk	Although less critical, care should still be given to ensure basic safety measures are in place.
	Moderate risk	Care should be taken to implement appropriate safety measures to manage the identified risks.
	High risk	Extra care and higher levels of measures should be implemented to mitigate the risk effectively.

Building characteristics risk level

1	What is the building function of use?	More info	8) Healthcare with sleeping area, healthcare residential, detention function
2	What is the building height?	More info	8) Building height >100m
3	What is the location of the escape routes?	More info	1) One staircase in residential or accomodation not in residential building or accomodation building
4	How would you estimate the value of the building?	More info	1) Low value

Façade characteristics risk level

			Façade 1	Façade 2	Façade 3	Façade 4
5	Does the BIPV facade continuously span over multiple fire compartments?	More info	8) Yes, over more than two fire compartments	(1) No, each BIPV segment is limited to a single fire	(8) Yes, over more than two fire compartments	(1) No, each BIPV segment is limited to a single fire
6	Does the BIPV facade cavity continuously span over multiple fire compartments?	More info	1) No, each BIPV cavity is limited to a single fire	(1) No, each BIPV cavity is limited to a single fire	(8) Yes, over more than two fire compartments	(1) No, each BIPV cavity is limited to a single fire
7	Will there be openings in the BIPV facade?	More info	2) Yes, distributed openings	(2) Yes, distributed openings	(2) Yes, distributed openings	(2) Yes, distributed openings
8	Will there be protrusions along the BIPV façade?	More info	1) No	(0,75) Horizontal protrusion < 0,5m	(1) No	(1) No
9	Will the BIPV façade be entirely accessible by the fire brigade?	More info	4) No	(4) No	(1) Yes	(1) Yes
10	Do BIPV modules endanger an escape route?	More info	2) Yes, BIPV modules are situated above multiple	(2) Yes, BIPV modules are situated above multiple	(1,5) Yes, BIPV modules are situated above an escape	(1,5) Yes, BIPV modules are situated above an escape
11	Will the façade be load-bearing?	More info	1) No	(1) No	(1) No	(2) Yes
12	Will the orientation of the facade be in the prevailing wind direction of the location?	More info	1) The facade is subjected to the prevailing wind or	(1) The facade is subjected to the prevailing wind or	(1) The facade is subjected to the prevailing wind or	(1) No

BIPV & façade product characteristics risk level

			Façade 1	Façade 2	Façade 3	Façade 4
13	What type of BIPV module will be employed?	More info	1) Glass/glass	(1) Glass/glass	(1) Glass/glass	(1) Glass/glass
14	What will be the fire class of the BIPV module according NEN-EN 13501-1?	More info	1) B	(1) B	(1) B	(1) B
15	What will be the fire class of the BIPV module according ANSI/UL 1703 (via UL 790)?	More info	1) Not applicable	(1) Not applicable	(1) Not applicable	(1) Not applicable
16	Will the BIPV modules be easily removable?	More info	2) No	(1) Yes	(1) Yes	(2) No
17	What is the main electrical configuration that will be employed?	More info	2) String inverter	(0,5) Micro-inverter	(0,5) Micro-inverter	(2) String inverter
18	Will an active AFCI be employed in the BIPV system?	More info	0,5) Yes	(0,5) Yes	(0,5) Yes	(0,5) Yes
19	Will the BIPV cavity exceed the maximum temperature specified for the BIPV system's	More info	8) Yes, 20+ °C higher	(4) Yes, 0-20 °C higher	(8) Yes, 20+ °C higher	(1) No
20	What material will be situated in the cavity opposite to the BIPV module?	More info	2) Sheet layer or insulation layer (fire class B)	(2) Sheet layer or insulation layer (fire class B)	(2) Sheet layer or insulation layer (fire class B)	(2) Sheet layer or insulation layer (fire class B)
21	What material will be used for the mounting system of the BIPV modules?	More info	2) Aluminium	(2) Aluminium	(2) Aluminium	(2) Aluminium
22	Will BIPV system cables penetrate through the facade?	More info	2) Yes	(2) Yes	(2) Yes	(2) Yes
23	Will quality control measures for the BIPV system be employed?	More info	1) Yes, InstallQ	(0,25) Yes, InstallQ and SCOPE12	(16) No quality control will be employed	(1) Yes, InstallQ

More info on façade 1 | More info on façade 2 | More info on façade 3 | More info on façade 4

Overview risk score per façade

	Façade 1	Façade 2	Façade 3	Façade 4
Building characteristics				
Façade characteristics				
BIPV & facade product characteristics				

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Risk overview

What is the amount of facades that you want to assess?	Grosspeter tower	The Pulse of Amsterdam	Concept proposal: PCT Cartuja	Villa Lichtenberg
Four façades	North	North	North	North
What do the colours and (..) values mean?	More info on façade 1	More info on façade 2	More info on façade 3	More info on façade 4

Building characteristics risk level

1	What is the building function of use?	More info	(8) Healthcare with sleeping area, healthcare residential, detention function
2	What is the building height?	More info	(8) Building height >100m
3	What is the location of the escape routes?	More info	(1) One staircase in residential or accomodation not in residential building or accomodation building
4	How would you estimate the value of the building?	More info	(1) Low value

Façade characteristics risk level

			Façade 1	Façade 2	Façade 3	Façade 4
5	Does the BIPV facade continuously span over multiple fire compartments?	More info	(8) Yes, over more than two fire compartments	(1) No, each BIPV segment is limited to a single fire	(8) Yes, over more than two fire compartments	(1) No, each BIPV segment is limited to a single fire
6	Does the BIPV facade cavity continuously span over multiple fire compartments?	More info	(1) No, each BIPV cavity is limited to a single fire	(1) No, each BIPV cavity is limited to a single fire	(8) Yes, over more than two fire compartments	(1) No, each BIPV cavity is limited to a single fire
7	Will there be openings in the BIPV facade?	More info	(2) Yes, distributed openings	(2) Yes, distributed openings	(2) Yes, distributed openings	(2) Yes, distributed openings
8	Will there be protrusions along the BIPV façade?	More info	(1) No	(0,75) Horizontal protrusion < 0,5m	(1) No	(1) No
9	Will the BIPV façade be entirely accessible by the fire brigade?	More info	(4) No	(4) No	(1) Yes	(1) Yes
10	Do BIPV modules endanger an escape route?	More info	(2) Yes, BIPV modules are situated above multiple	(2) Yes, BIPV modules are situated above multiple	(1,5) Yes, BIPV modules are situated above an escape	(1,5) Yes, BIPV modules are situated above an escape
11	Will the façade be load-bearing?	More info	(1) No	(1) No	(1) No	(2) Yes
12	Will the orientation of the facade be in the prevailing wind direction of the location?	More info	(1) The facade is subjected to the prevailing wind or	(1) The facade is subjected to the prevailing wind or	(1) The facade is subjected to the prevailing wind or	(1) No

Façade 2	Façade 3	Façade 4
lass/glass	(1) Glass/glass	(1) Glass/glass
	(1) B	(1) B
ot applicable	(1) Not applicable	(1) Not applicable
es	(1) Yes	(2) No
) Micro-inverter	(0,5) Micro-inverter	(2) String inverter
) Yes	(0,5) Yes	(0,5) Yes
es, 0-20 °C higher	(8) Yes, 20+ °C higher	(1) No
heet layer or insulation layer (fire class B)	(2) Sheet layer or insulation layer (fire class B)	(2) Sheet layer or insulation layer (fire class B)
luminium	(2) Aluminium	(2) Aluminium
es	(2) Yes	(2) Yes
5) Yes, InstallQ and SCOPE12	(16) No quality control will be employed	(1) Yes, InstallQ
More info on façade 2	More info on façade 3	More info on façade 4

Façade 2	*Façade 3*	*Façade 4*

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DESIGN SUPPORT TOOL: FIRE SAFETY FACADE BIPV SYSTEMS

Are you an architect or facade engineer, tasked with designing a new building that incorporates Building Integrated Photovoltaic (BIPV) systems into its façade? You're excited about the possibilities these systems offer in terms of sustainability and energy efficiency. However, there's a problem... You're not entirely sure about the fire risks associated with BIPV installations. You've heard some concerns, but you're not sure how to navigate them effectively?

That's where this design support tool comes in. It's designed to bridge the gap of the pre-normative regulatory framework surrounding BIPV systems, making it easier for architects like you to understand and address fire safety concerns.

How to use the tool

Step 1

Assess your case of study in the "Risk Overview" by filling in the design considerations for your facade(s)

Step 2

Consult sheets "Risk parameters (1-22)" or "Info BIPV" for information regarding the fire risk of each risk parameter

Step 3

Assess each facade in detail in the sheet "Facade Overview" (F1-F4)

Step 4

Consult sheet "Measures" for tailored measures and strategies

Home | Info BIPV | Risk overview | F1 | F2 | F3 | F4 | Measures

Risk overview

What is the amount of facades that you want to assess?	Grosspeter tower	The Pulse of Amsterdam	Concept proposal: PCT Cartuja	Villa Lichtenberg
Four façades	North	North	North	North
What do the colours and (..) values mean?	More info on façade 1	More info on façade 2	More info on façade 3	More info on façade 4

Building characteristics risk level		
1 What is the building function of use?	More info	(8) Healthcare with sleeping area, healthcare residential, detention function
2 What is the building height?	More info	(8) Building height >100m
3 What is the location of the escape routes?	More info	(1) One staircase in residential or accomodation not in residential building or accomodation building
4 How would you estimate the value of the building?	More info	(1) Low value

Façade characteristics risk level					
5 Does the BIPV facade continuously span over multiple fire compartments?	More info	(8) Yes, over more than two fire compartments	(1) No, each BIPV segment is limited to a single fire	(8) Yes, over more than two fire compartments	(1) No, each BIPV segment is limited to a single fire
6 Does the BIPV facade cavity continuously span over multiple fire compartments?	More info	(1) No, each BIPV cavity is limited to a single fire	(1) No, each BIPV cavity is limited to a single fire	(8) Yes, over more than two fire compartments	(1) No, each BIPV cavity is limited to a single fire
7 Will there be openings in the BIPV facade?	More info	(2) Yes, distributed openings	(2) Yes, distributed openings	(2) Yes, distributed openings	(2) Yes, distributed openings
8 Will there be protrusions along the BIPV façade?	More info	(1) No	(0,75) Horizontal protrusion < 0,5m	(1) No	(1) No
9 Will the BIPV façade be entirely accessible by the fire brigade?	More info	(4) No	(4) No	(1) Yes	(1) Yes
10 Do BIPV modules endanger an escape route?	More info	(2) Yes, BIPV modules are situated above multiple	(2) Yes, BIPV modules are situated above multiple	(1,5) Yes, BIPV modules are situated above an escape	(1,5) Yes, BIPV modules are situated above an escape
11 Will the façade be load-bearing?	More info	(1) No	(1) No	(1) No	(2) Yes
12 Will the orientation of the facade be in the prevailing wind direction of the location?	More info	(1) The facade is subjected to the prevailing wind or	(1) The facade is subjected to the prevailing wind or	(1) The facade is subjected to the prevailing wind or	(1) No

BIPV & façade product characteristics risk level					
13 What type of BIPV module will be employed?	More info	(1) Glass/glass	(1) Glass/glass	(1) Glass/glass	(1) Glass/glass
14 What will be the fire class of the BIPV module according NEN-EN 13501-1?	More info	(1) B	(1) B	(1) B	(1) B
15 What will be the fire class of the BIPV module according ANSI/UL 1703 (via UL 790)?	More info	(1) Not applicable	(1) Not applicable	(1) Not applicable	(1) Not applicable
16 Will the BIPV modules be easily removable?	More info	(2) No	(1) Yes	(1) Yes	(2) No
17 What is the main electrical configuration that will be employed?	More info	(2) String inverter	(0,5) Micro-inverter	(0,5) Micro-inverter	(2) String inverter
18 Will an active AFCI be employed in the BIPV system?	More info	(0,5) Yes	(0,5) Yes	(0,5) Yes	(0,5) Yes
19 Will the BIPV cavity exceed the maximum temperature specified for the BIPV system's	More info	(8) Yes, 20+ °C higher	(4) Yes, 0-20 °C higher	(8) Yes, 20+ °C higher	(1) No
20 What material will be situated in the cavity opposite to the BIPV module?	More info	(2) Sheet layer or insulation layer (fire class B)	(2) Sheet layer or insulation layer (fire class B)	(2) Sheet layer or insulation layer (fire class B)	(2) Sheet layer or insulation layer (fire class B)
21 What material will be used for the mounting system of the BIPV modules?	More info	(2) Aluminium	(2) Aluminium	(2) Aluminium	(2) Aluminium
22 Will BIPV system cables penetrate through the facade?	More info	(2) Yes	(2) Yes	(2) Yes	(2) Yes
23 Will quality control measures for the BIPV system be employed?	More info	(1) Yes, InstallQ	(0,25) Yes, InstallQ and SCOPE12	(16) No quality control will be employed	(1) Yes, InstallQ
		More info on façade 1	More info on façade 2	More info on façade 3	More info on façade 4

Overview risk score per façade	*Façade 1*	*Façade 2*	*Façade 3*	*Façade 4*
Building characteristics				
Façade characteristics				
BIPV & facade product characteristics				

Option	What type of BIPV module will be employed?	Risk factor	Elaboration per option
13.A	(1) Glass/glass	1	A BIPV module with a glass front and backsheet
13.B	(8) Glass/polymer	8	A BIPV module with a glass frontsheet and a polymer backsheet

What to fill in?

Select the type of BIPV module to be used in the project. The options include glass/glass and glass/polymer modules. A glass/polymer module has a glass frontsheet and a polymer backsheet. A glass/glass module features both a glass frontsheet and backsheet, providing enhanced properties over a glass/polymer module like structural rigidity, sound insulation, and thermal insulation, etc. This type is predominantly utilized in BIPV façade applications due to these additional functional requirements.

Fire risk

A glass/glass provides enhanced properties over a glass/polymer module like structural rigidity, sound insulation, thermal insulation, but also in fire safety. This type is predominantly used in BIPV façade applications due to the additional functional requirements of facades over roofs. For roofing applications, where the requirements are lower, glass/polymer modules are more commonly used.

Glass/glass BIPV modules offer enhanced fire safety compared to glass/polymer modules. In glass/glass modules, both the front and back covers are made of non-combustible glass, which serves as an effective barrier to protect the combustible encapsulants, typically PVB or EVA. These encapsulants, despite their thinness (0.7 mm to 1.0 mm) and high calorific values (30 MJ/kg for PVB and 40 MJ/kg for EVA), are less likely to contribute to a fire due to the protective glass layers.

Conversely, glass/polymer BIPV modules feature a non-combustible glass front cover but a combustible polymer back cover. Polymeric materials have lower ignition points than glass, making these modules more susceptible to fire risks. In the event of a localized hot spot or arcing incident, the polymer backsheet can quickly ignite and exacerbate the fire, potentially affecting adjacent materials and structures. The polymer backsheet's vulnerability to fire increases the overall risk, as it can provide additional fuel, accelerating the spread of the fire.

Additionally, when employing incombustible insulation materials in the facade cavity with fire classes A2/A1 and reflective layers, the heat of a facade cavity would not be absorbed by the insulation but rather be reflected back across the cavity, intensifying the thermal load on the opposing panel. This phenomenon highlights the highcriticality of using BIPV modules with polymeric backsheets in façades, as they especially vulnaroble to cavity fires.

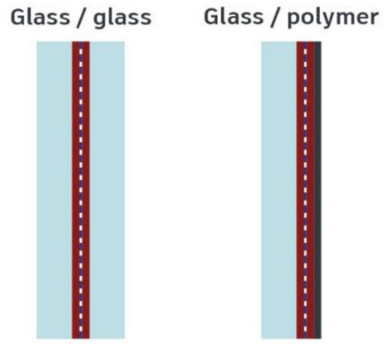


Figure 1: (BI)PV Module components . Source: Sauer (2021). Own edit

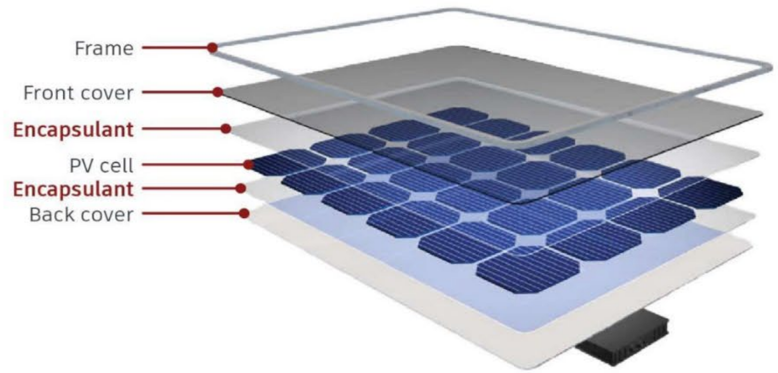


Figure 2: Typical (BI)PV module configurations.

BIPV module config.	Glass / glass	Glass / polymer
Front cover	Glass (non-combustible)	Glass
Encapsulants	PVB or EVA **(combustible)**	PVB or EVA **(combustible)**
Back cover	Glass (non-combustible)	Polymer **(combustible)**
Fire risk	Low	High
Quality	Higher-end	Lower-end
Structural Rigidity	High	Low
Durability	High	Moderate
Main application	Facade	Roof

Figure 2: Glass/glass & glass/polymer module characteristics. Own work

Option	What will be the fire class of the BIPV module according NEN-EN 13501-1?	Risk factor
14.A	(?) A2/A1	?
14.B	(1) B	1
14.C	(8) C or lower	8

What to fill in?

Enter the fire class of the BIPV module as classified under NEN-EN 13501-1. Note that this classification corresponds to the fire class requirements as referenced in the Bbl (Building decree). Ensure that the fire class selected matches the requirements set in thes regulations (figure 1).

Fire risk

In the Netherlands, fire safety standards and codes for BIPV systems in façades align with the regulations for façades, as these modules are treated as conventional building materials. As such, BIPV modules must meet the fire classification requirements outlined in NEN-EN 13501-1, adhering to the minimum classes specified in Figure 2 . These modules are evaluated using the same testing methods detailed in Figure 4, with the SBI test being most commonly used (Figure 1).

The current market standard for BIPV facade modules is fire class B. No modules have been identified as fire class A2 or A1 during the course of this studie. This is a result of the modules containing combustible encapsulants, EVA or PVB, which limit the potential to achieve fire class A2 or A1.

By current market standards for fire tests for facade products and configurations, BIPV facade systems are tested using the SBI-test (NEN-EN 13823). However, this test has several limitations in the context of BIPV facades:

Ventilation | The SBI-test does not account for the impact of a naturally ventilated cavity on fire development, as it only positions the fire source against the exterior pane and overlooks the unique fire behavior within these cavities.

Fire load | The SBI-test does not reflect real-world fire conditions adequately because it uses a 30 kW burner, which fails to simulate the critical temperatures for material ignition, thus not capturing the full potential of fire propagation.

Set-up scale | The SBI test fails to fully account for the importance of setup scale because it does not replicate end-use conditions accurately, particularly regarding factors such as ventilation, surface airflow, and thermal deformation of the construction elements.

Connections | The limited dimensions of the SBI test prevent the examination of critical façade connections such as window/door frames and transitions, which are essential pathways for fire spread in building façades

To address the above-mentioned limitations, the introduction of NPR 6999 in the Netherlands will enhance the testing possibilities (Figure 5). For instance, ISO 13785-1 offers a practical intermediary solution as it bridges the gap between the limited SBI test and the more extensive, costly alternatives such as DIN 4102-20 or BS 8414, thus allowing for a balanced and effective evaluation of fire safety. However, it should be noted that these methods do not represent the unique ignition source of BIPV systems.

Additionally, upcoming regulations from the Bbl, influenced by the new NPR 6999, will impose stricter requirements and will require to adhere to one of these options:

1. | Ensure that the façade meets fire class A2.

2. | A portion of the façade construction must comply with option 1 and shield more combustible materials with fire-resistant cladding that meets EI15 standards.

3. | Test the façade construction on a larger scale than is currently customary and ensure compliance with a specific class according to NPR 6999.

As the BIPV market currently does not provide modules that meet fire class A2 or A1, these upcoming requirements could pose challenges

Figure 1: SBI-test with PIZ BIPV cladding system. Source: IEA PVPS Task 15 (2023)

New building	
Artikel 2.68	
Façade height < 2.5 m	B (if highest floor > 5m)
Façade height > 13 m	B
*1 Façade height > 30 m	A2 (sleeping function with reduced self-reliance), B (other functions)
*1 Façade height > 50 m	A2 (sleeping function), B (other functions)
Façade adjacent to extra protected escape route	B (cell function), C (other functions)
Façade adjacent to protected escape route	B (cell function), C (sleeping function), D (other functions)
Façade part (other)	D
Exception: doors, windows, window frames	D
Artikel 2.84 and 2.94	
Façade between two fire compartments	B (condition WBDBO / NEN 6068)
Façade between protected sub fire compartments and fire compartments	B (condition WBDBO / NEN 6068)
*1 Expected to be implemented in Bbl	
· Classes A2/B/C/D according NEN-EN 13501-1	

Figure 2: Summary of minimal fire classes from "Besluit bouwwerken leefomgeving (Bbl)

Test name	Applicable fire classes
Non-Combustibility test (NEN-EN ISO 1182)	A1, A2
Heat of Combustion test (NEN-EN ISO 1716)	A1, A2
Single Burning Item (SBI) test (NEN-EN 13823)	A2, B, C, D
Small Flame test (NEN-EN ISO 11925-2)	B, C, D, E, F

Figure 3: Current fire test used in the Netherlands for determining fire classes of building products

Euro classification	Fire behaviour of the material		Smoke production		Droplet forming	
A1	No contribution	Non-combustible	S1	Barely	D0	None
A2	Almost no contribution	Almost non-combustible	S2	Average	D1	Some
B	Limited contribution	Limited combustibility	S3	Big	D2	Quite a lot
C	Big contribution	Combustible				
D	High contribution	Easily combustible				
E	Very high contribution	Highly combustible				
F	Dangerous contribution	Very highly combustible				

Option	What is the main electrical configuration that will be employed?	Risk factor
17.A	(0,5) Micro-inverter	0,5
17.B	(1) String inverter + Optimiser	1
17.C	(2) String inverter	2

What to fill in?

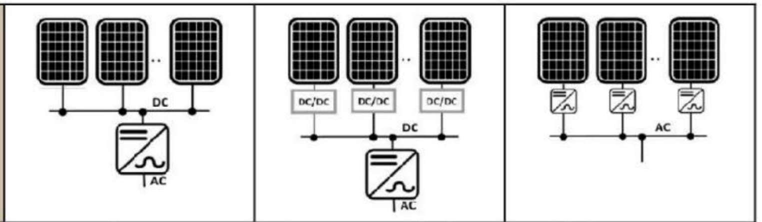
Fill in what the main electrical configuration is that will be employed, which relates back to the type of inverter.

Fire risk

Micro-inverter | The micro-inverter configuration involves placing an inverter for every one to two modules, typically within the facade cavity. This setup operates at low voltage AC (<80 V) on the facade, significantly reducing the fire risk compared to high voltage systems. At lower voltages around 80 volts, electric arcs are much less likely or even impossible and not capable of causing damage.This low voltage characteristic makes micro-inverters the safest option in terms of fire risk. However, the complexity of maintenance and higher costs are notable downsides, balanced by improved efficiency and shading performance. The advanced module-level monitoring allows for precise performance tracking and early detection of potential issues, enhancing overall safety and reliability.

String Inverter + Optimiser | In the string inverter + optimiser configuration, one inverter manages 10-20 modules, while each module has its own optimiser, typically placed in the facade. The system operates at high voltage DC (<1000 V) in the facade, presenting a high fire risk due to the potential for arcing and overheating in the high voltage DC environment. The use of optimisers enhances safety by allowing individual module control, reducing the likelihood of overheating and potential fires compared to traditional string inverters. This setup strikes a balance between cost, efficiency, and safety, offering high efficiency and good shading performance. Maintenance is more complex due to optimiser placed in the cavity being hard to reach, and monitoring capabilities are advanced, providing detailed insights at the module level.

String Inverter | A traditional string inverter configuration uses a single inverter for every 10-20 modules, with the inverter usually placed indoors. The system operates at high voltage DC (<1000 V) in the facade, presenting a high fire risk due to the potential for arcing and overheating in the high voltage DC environment. This setup is simpler and less expensive but sacrifices safety and performance. The entire string is affected if one module is shaded, leading to poor shading performance and medium efficiency. Maintenance is more straightforward, but monitoring is basic, limited to the string level, offering minimal insights into individual module performance or potential issues.



Electrical config.	**String inverter**	**String inverter + optimiser**	**Micro-inverter**
Typical components	1 inverter per 10-20 modules	1 inverter per 10-20 modules 1 optimiser per 1 module	1 inverter per 1-2 modules
Typical placement components	String inverter: indoors	String inverter: indoors Optimiser: in facade	Micro-inverter: facade cavity
Voltage in facade	High voltage DC (<1000 V)	High voltage DC (<1000 V)	Low voltage AC (<80 V)
Fire risk	High	Medium	Low
Costs	Low	Medium	High
Efficiency	Medium	High (due to individual module optimization)	High (due to individual module optimization)
Shading Performance	Poor (whole string affected)	Good (only shaded module affected)	Excellent (each module independent)
Flexibility	Low (dependent on string design)	High (independent module control)	Very high (independent module control)
Maintenance	Simple	Moderate	Complex
Monitoring	Basic (string level)	Advanced (module level)	Advanced (module level)

Figure 1: Characteristics of main electrical configurations BIPV systems

Option	What material will be used for the mounting system of the BIPV modules?	Risk factor
21.A	(1) Steel	1
21.B	(2) Aluminium	2

What to fill in?

Fill in what material will be used for the mounting system of the BIPV modules.

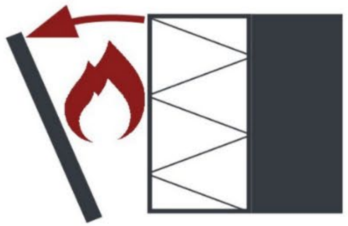
Fire risk

In the event of a fire, it is probable that the structural integrity of the mounting frame will be compromised, leading to the BIPV modules falling. While falling debris is a common occurrence in façade fires, the size and weight of BIPV modules pose an enhanced risk, potentially falling on people, blocking escape routes or causing additional structural damage. Aluminum mounting frames are the market standard for mounting BIPV facade modules, but steel mounting frames also exist.

Aluminium | Aluminum loses 50% of its structural strength at temperatures around 200°C and melts at approximately 600°C. Thus, in the event of a fire, it is highly probable that the structural integrity of the aluminum will be compromised, resulting in BIPV modules falling down.

Steel | Although heavier, steel offers significantly better fire resistance than aluminum. Steel retains its structural integrity at higher temperatures as the melting point is around 1400 °C . Consequently, steel mounting frames provide additional time during a fire, potentially preventing or delaying the collapse of BIPV modules

Special attention should also be given to the impact of falling BIPV modules on the effectiveness of fire breaks. When these modules fall, they can expose potential pathways for fire to bypass the fire breaks, undermining their function.



(a) 15 minutes (b) 25 minutes (c) 30 minutes (d) 36 minutes

Figure 2: Large scale test BIPV facade. Impact falling BIPV modules. Source: Stølen et al. (2024)

Option	Will quality control measures for the BIPV system be employed?	Risk factor
23.A	(0,25) Yes, InstallQ and SCOPE12	0,25
23.B	(0,5) Yes, SCOPE12	0,5
23.C	(1) Yes, InstallQ	1
23.D	(16) No quality control will be employed	16

What to fill in?

Indicate whether quality control measures for the BIPV system will be employed.

Fire risk

The Netherlands has quality schemes like SCIOS Scope 12 and InstallQ to ensure the safety and reliability of (BI)PV installations. The main difference between quality of installation scheme InstallQ and quality inspection scheme SCIOS Scope 12 lies in their focus (Figure1). InstallQ adresses the competence and processes of installers from the (e-)design phase through to installation, ensuring high-quality workmanship and adherence to safety standards. SCIOS Scope 12 focuses on the post-installation phase, providing retrospective inspections to verify the safety and performance of the completed systems

InstallQ | Ensures that certified installation companies and advisors are well-known in relevant regulations and guidelines, applying them safely and effectively in practice. These professionals can provide legally valid documents such as energy labels and tailored advice and can guarantee the quality of installation, replacement, or maintenance of systems. InstallQ regularly evaluates and monitors these companies through inspections by InstallQ inspectors or certifying institutions.

Scope12 | A detailed inspection of PV installations to verify safety and compliance with manufacturer guidelines and applicable standards. This includes for example ensuring proper insulation, adequate fuses and protective equipment to prevent overloads, and regular maintenance to uphold safety throughout the installation's lifespan. Additionally, Scope 12 inspections address points such as reviewing drawings and documents, verifying electrical equipment compliance, conducting visual inspections, measuring current and voltage, and performing thermographic analysis (including drone inspections and data analysis).

While quality installation by accredited installers minimizes installation errors, it does not fully eliminate them, as mistakes can always occur. Therefore, independent quality inspection is of high value, ensuring an additional layer of safety and reliability.

	installQ aantoonbaar beter	SCIOS GECERTIFICEERD SCIOS INSPECTIES SCOPE 8,10 & 12
Scope	Professional competence of installers	Retrospective inspection of existing installations
Systems	BIPV & BAPV	BIPV & BAPV
When relevant	During and before installation	After installation
Initiated By	Techniek Nederland, Holland Solar and Verbond van Verzekeraars	Verbond van Verzekeraars, Holland Solar and various inspection companies, represented by trade organizations such as iKeur and Techniek Nederland.
Regulatory status	Non-statuary	Non-statuary
Accredited companies	*https://www.echteinstallateur.nl/*	*https://www.scios.nl/relatie/*

Figure 1: InstallQ and SCOPE12 comparison

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DESIGN SUPPORT TOOL: FIRE SAFETY FACADE BIPV SYSTEMS

Are you an architect or facade engineer, tasked with designing a new building that incorporates Building Integrated Photovoltaic (BIPV) systems into its façade? You're excited about the possibilities these systems offer in terms of sustainability and energy efficiency. However, there's a problem... You're not entirely sure about the fire risks associated with BIPV installations. You've heard some concerns, but you're not sure how to navigate them effectively?

That's where this design support tool comes in. It's designed to bridge the gap of the pre-normative regulatory framework surrounding BIPV systems, making it easier for architects like you to understand and address fire safety concerns.

How to use the tool

Step 1

Assess your case of study in the "Risk Overview" by filling in the design considerations for your facade(s)

Step 2

Consult sheets "Risk parameters (1-22)" or "Info BIPV" for information regarding the fire risk of each risk parameter

Step 3

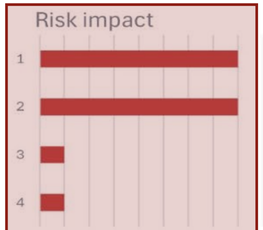
Assess each facade in detail in the sheet "Facade Overview" (F1-F4)

Step 4

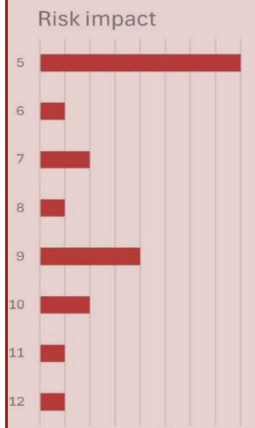
Consult sheet "Measures" for tailored measures and strategies

Facade 1 Overview

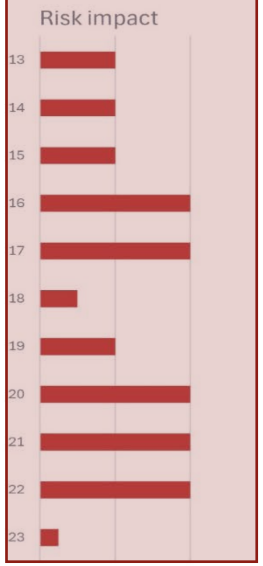
Building characteristics			
1	What is the building function of use?	More info	(8) Healthcare with sleeping area, healthcare residential, detention function
2	What is the building height?	More info	(8) Building height >100m
3	What is the location of the escape routes?	More info	(1) One staircase in residential or accomodation not in residential building or accomodation building
4	How would you estimate the value of the building?	More info	(1) Low value



Facade characteristics				Influence on fire safety
5	Does the BIPV facade continuously span over multiple fire compartments?	More info	(8) Yes, over more than two fire compartments vertically	Vertical continuation of BIPV modules presents a high risk as this can facilitate vertical fire spread across all these fire compartments
6	Does the BIPV facade cavity continuously span over multiple fire compartments?	More info	(1) No, each BIPV cavity is limited to a single fire compartment	Limiting BIPV cavities to a single compartment enhances fire safety by preventing fire spread within the cavity.
7	Will there be openings in the BIPV facade?	More info	(2) Yes, distributed openings	Can facilitate fire spread through multiple points, enabling fire propagation across several fire compartments both horizontally and vertically
8	Will there be protrusions along the BIPV façade?	More info	(1) No	No interruptions allow fire to spread across the BIPV facade
9	Will the BIPV façade be entirely accessible by the fire brigade?	More info	(4) No	Lack of accessibility impedes firefighting efforts, requiring stricter WBDO standards and increasing fire spread risk.
10	Do BIPV modules endanger an escape route?	More info	(2) Yes, BIPV modules are situated above multiple escape routes	BIPV modules above multiple escape routes increase the risk of (multiple) escape route obstructions, obstructing/endangering evacuation paths
11	Will the façade be load-bearing?	More info	(1) No	The collapse of a non load-facade does not directly compromise the building's structural integrity.
12	Will the orientation of the facade be in the prevailing wind direction of the location?	More info	(1) The facade is subjected to the prevailing wind or runs parallel to it.	Depending on the wind direction and speed, fire can spread rapidly or in various directions, including sideways or even downwards in extreme case



BIPV & facade product characteristics				Influence on fire safety and possible advice
13	What type of BIPV module will be employed?	More info	(1) Glass/glass	Glass/glass modules offer better fire performance with non-combustible glass layers protecting combustible encapsulants.
14	What will be the fire class of the BIPV module according NEN-EN 13501-1?	More info	(1) B	This module meets the minimal requirement according the building decree (Bbl)
15	What will be the fire class of the BIPV module according ANSI/UL 1703 (via UL 790)?	More info	(1) Not applicable	Don't take into account this fire classification. Refer to NEN-EN 13501-1 for correct fire classification
16	Will the BIPV modules be easily removable?	More info	(2) No	Non-removable modules complicate maintenance, increasing the risk of undetected issues and potential fire hazards.
17	What is the main electrical configuration that will be employed?	More info	(2) String inverter	String inverters present the highest fire risk due to high voltage DC operation, with simple maintenance but basic monitoring and lower shading performance.
18	Will an active AFCI be employed in the BIPV system?	More info	(0,5) Yes	Employing an AFCI reduces the risk of fire from electric arcs, enhancing system safety
19	Will the BIPV cavity exceed the maximum temperature specified for the BIPV system's components?	More info	(1) No	Staying within temperature limits ensures component safety and optimal efficiency, reducing the risk of failure and fire
20	What material will be situated in the cavity opposite to the BIPV module?	More info	(2) Sheet layer or insulation layer (fire class B)	Fire class D or lower materials increase fire risk by potentially facilitating ignition from electric arcs and contributing to cavity fire propagation
21	What material will be used for the mounting system of the BIPV modules?	More info	(2) Aluminium	Aluminum loses strength at lower temperatures, increasing the likelihood of BIPV modules falling during a fire
22	Will BIPV system cables penetrate through the facade?	More info	(2) Yes	Cable penetrations create vulnerabilities, potentially allowing fire spread if not properly designed and fireproofed.
23	Will quality control measures for the BIPV system be employed?	More info	(0,25) Yes, InstallQ and SCOPE12	InstallQ and SCOPE12 together ensure comprehensive quality control from installation to post-installation inspections.

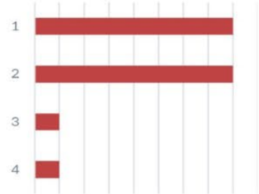


Facade 2 Overview

Building characteristics

	Question		Answer
1	What is the building function of use?	More info	(8) Healthcare with sleeping area, healthcare residential, detention function
2	What is the building height?	More info	(8) Building height >100m
3	What is the location of the escape routes?	More info	(1) One staircase in residential or accomodation not in residential building or accomodation building
4	How would you estimate the value of the building?	More info	(1) Low value

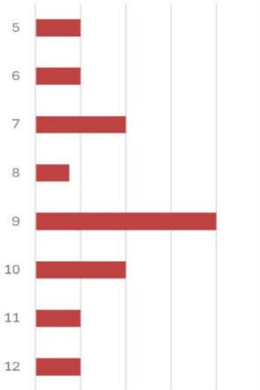
Risk impact



Facade characteristics

	Question		Answer	Influence on fire safety
5	Does the BIPV facade continuously span over multiple fire compartments?	More info	(1) No, each BIPV segment is limited to a single fire compartment	Limiting BIPV segments to a single fire compartment reduces the risk of fire spreading between compartments, enhancing overall fire safety.
6	Does the BIPV facade cavity continuously span over multiple fire compartments?	More info	(1) No, each BIPV cavity is limited to a single fire compartment	Limiting BIPV cavities to a single compartment enhances fire safety by preventing fire spread within the cavity.
7	Will there be openings in the BIPV facade?	More info	(2) Yes, distributed openings	Can facilitate fire spread through multiple points, enabling fire propagation across several fire compartments both horizontally and vertically
8	Will there be protrusions along the BIPV façade?	More info	(0,75) Horizontal protrusion < 0,5m	#N/B
9	Will the BIPV façade be entirely accessible by the fire brigade?	More info	(4) No	Lack of accessibility impedes firefighting efforts, requiring stricter WBDO standards and increasing fire spread risk.
10	Do BIPV modules endanger an escape route?	More info	(2) Yes, BIPV modules are situated above multiple escape routes	BIPV modules above multiple escape routes increase the risk of (multiple) escape route obstructions, obstructing/endangering evacuation paths
11	Will the façade be load-bearing?	More info	(1) No	The collapse of a non load-facade does not directly compromise the building's structural integrity.
12	Will the orientation of the facade be in the prevailing wind direction of the location?	More info	(1) The facade is subjected to the prevailing wind or runs parallel to it.	Depending on the wind direction and speed, fire can spread rapidly or in various directions, including sideways or even downwards in extreme case

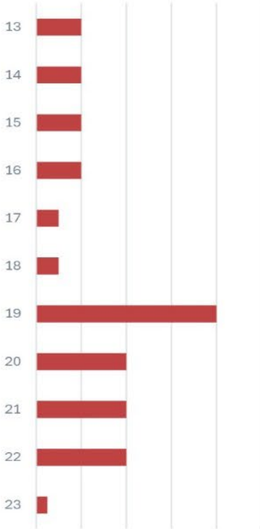
Risk impact



BIPV & facade product characteristics

	Question		Answer	Influence on fire safety and possible advice
13	What type of BIPV module will be employed?	More info	(1) Glass/glass	Glass/glass modules offer better fire performance with non-combustible glass layers protecting combustible encapsulants.
14	What will be the fire class of the BIPV module according NEN-EN 13501-1?	More info	(1) B	This module meets the minimal requirement according the building decree (Bbl)
15	What will be the fire class of the BIPV module according ANSI/UL 1703 (via UL 790)?	More info	(1) Not applicable	Don't take into account this fire classification. Refer to NEN-EN 13501-1 for correct fire classification
16	Will the BIPV modules be easily removable?	More info	(1) Yes	Easy removability allows for efficient maintenance and replacement, reducing fire risk from undetected issues.
17	What is the main electrical configuration that will be employed?	More info	(0,5) Micro-inverter	Micro-inverters operate at low voltage AC, reducing fire risk and allowing precise performance monitoring but are costlier and complex to maintain.
18	Will an active AFCI be employed in the BIPV system?	More info	(0,5) Yes	Employing an AFCI reduces the risk of fire from electric arcs, enhancing system safety
19	Will the BIPV cavity exceed the maximum temperature specified for the BIPV system's components?	More info	(4) Yes, 0-20 °C higher	Exceeding temperature by 0-20°C stresses components, increasing the risk of wear, electrical failures, and efficiency loss.
20	What material will be situated in the cavity opposite to the BIPV module?	More info	(2) Sheet layer or insulation layer (fire class B)	Fire class D or lower materials increase fire risk by potentially facilitating ignition from electric arcs and contributing to cavity fire propagation
21	What material will be used for the mounting system of the BIPV modules?	More info	(2) Aluminium	Aluminum loses strength at lower temperatures, increasing the likelihood of BIPV modules falling during a fire
22	Will BIPV system cables penetrate through the facade?	More info	(2) Yes	Cable penetrations create vulnerabilities, potentially allowing fire spread if not properly designed and fireproofed.
23	Will quality control measures for the BIPV system be employed?	More info	(0,25) Yes, InstallQ and SCOPE12	InstallQ and SCOPE12 together ensure comprehensive quality control from installation to post-installation inspections.

Risk impact

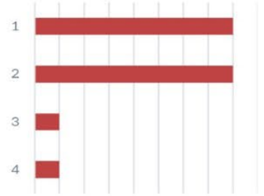


Facade 3 Overview

Building characteristics

#	Question		Answer
1	What is the building function of use?	More info	(8) Healthcare with sleeping area, healthcare residential, detention function
2	What is the building height?	More info	(8) Building height >100m
3	What is the location of the escape routes?	More info	(1) One staircase in residential or accomodation not in residential building or accomodation building
4	How would you estimate the value of the building?	More info	(1) Low value

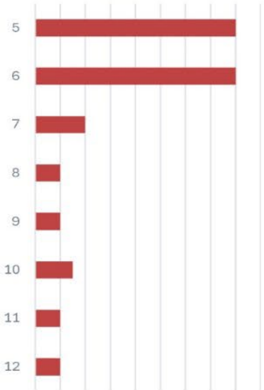
Risk impact



Facade characteristics

#	Question		Answer	Influence on fire safety
5	Does the BIPV facade continuously span over multiple fire compartments?	More info	(8) Yes, over more than two fire compartments vertically	Vertical continuation of BIPV modules presents a high risk as this can facilitate vertical fire spread across all these fire compartments
6	Does the BIPV facade cavity continuously span over multiple fire compartments?	More info	(8) Yes, over more than two fire compartments vertically	Vertical BIPV cavities can spread fire between floors, increasing critical vertical fire risk.
7	Will there be openings in the BIPV facade?	More info	(2) Yes, distributed openings	Can facilitate fire spread through multiple points, enabling fire propagation across several fire compartments both horizontally and vertically
8	Will there be protrusions along the BIPV façade?	More info	(1) No	No interruptions allow fire to spread across the BIPV facade
9	Will the BIPV façade be entirely accessible by the fire brigade?	More info	(1) Yes	Full accessibility allows effective firefighting, improving safety and emergency response
10	Do BIPV modules endanger an escape route?	More info	(1,5) Yes, BIPV modules are situated above an escape route	BIPV modules above an escape route pose a high risk of falling debris obstructing/endangering evacuation paths.
11	Will the façade be load-bearing?	More info	(1) No	The collapse of a non load-facade does not directly compromise the building's structural integrity.
12	Will the orientation of the facade be in the prevailing wind direction of the location?	More info	(1) The facade is subjected to the prevailing wind or runs parallel to it.	Depending on the wind direction and speed, fire can spread rapidly or in various directions, including sideways or even downwards in extreme case

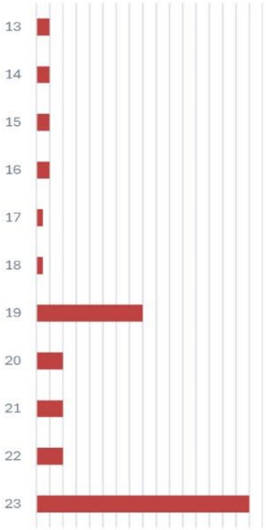
Risk impact



BIPV & facade product characteristics

#	Question		Answer	Influence on fire safety and possible advice
13	What type of BIPV module will be employed?	More info	(1) Glass/glass	Glass/glass modules offer better fire performance with non-combustible glass layers protecting combustible encapsulants.
14	What will be the fire class of the BIPV module according NEN-EN 13501-1?	More info	(1) B	This module meets the minimal requirement according the building decree (Bbl)
15	What will be the fire class of the BIPV module according ANSI/UL 1703 (via UL 790)?	More info	(1) Not applicable	Don't take into account this fire classification. Refer to NEN-EN 13501-1 for correct fire classification
16	Will the BIPV modules be easily removable?	More info	(1) Yes	Easy removability allows for efficient maintenance and replacement, reducing fire risk from undetected issues.
17	What is the main electrical configuration that will be employed?	More info	(0,5) Micro-inverter	Micro-inverters operate at low voltage AC, reducing fire risk and allowing precise performance monitoring but are costlier and complex to maintain.
18	Will an active AFCI be employed in the BIPV system?	More info	(0,5) Yes	Employing an AFCI reduces the risk of fire from electric arcs, enhancing system safety
19	Will the BIPV cavity exceed the maximum temperature specified for the BIPV system's components?	More info	(8) Yes, 20+ °C higher	Exceeding temperature by 20+°C significantly heightens the risk of component failure, electric arcs, and substantial efficiency loss.
20	What material will be situated in the cavity opposite to the BIPV module?	More info	(2) Sheet layer or insulation layer (fire class B)	Fire class D or lower materials increase fire risk by potentially facilitating ignition from electric arcs and contributing to cavity fire propagation
21	What material will be used for the mounting system of the BIPV modules?	More info	(2) Aluminium	Aluminum loses strength at lower temperatures, increasing the likelihood of BIPV modules falling during a fire
22	Will BIPV system cables penetrate through the facade?	More info	(2) Yes	Cable penetrations create vulnerabilities, potentially allowing fire spread if not properly designed and fireproofed.
23	Will quality control measures for the BIPV system be employed?	More info	(16) No quality control will be employed	No quality control heavily decreases safety and reliability of (BI)PV installations due to lack of safety verification.

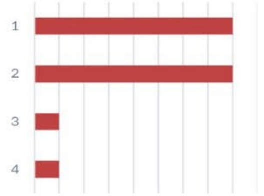
Risk impact



Facade 4 Overview

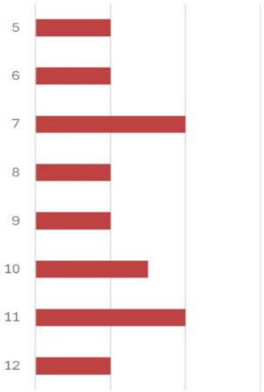
Building characteristics		
1 What is the building function of use?	More info	(8) Healthcare with sleeping area, healthcare residential, detention function
2 What is the building height?	More info	(8) Building height >100m
3 What is the location of the escape routes?	More info	(1) One staircase in residential or accomodation not in residential building or accomodation building
4 How would you estimate the value of the building?	More info	(1) Low value

Risk impact



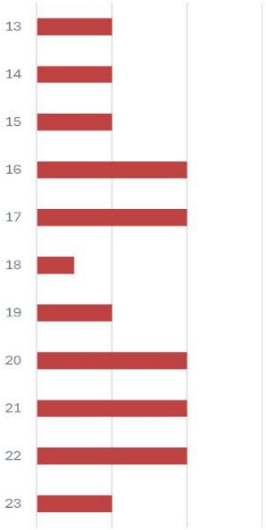
Facade characteristics			Influence on fire safety
5 Does the BIPV facade continuously span over multiple fire compartments?	More info	(1) No, each BIPV segment is limited to a single fire compartment	Limiting BIPV segments to a single fire compartment reduces the risk of fire spreading between compartments, enhancing overall fire safety.
6 Does the BIPV facade cavity continuously span over multiple fire compartments?	More info	(1) No, each BIPV cavity is limited to a single fire compartment	Limiting BIPV cavities to a single compartment enhances fire safety by preventing fire spread within the cavity.
7 Will there be openings in the BIPV facade?	More info	(2) Yes, distributed openings	Can facilitate fire spread through multiple points, enabling fire propagation across several fire compartments both horizontally and vertically
8 Will there be protrusions along the BIPV façade?	More info	(1) No	No interruptions allow fire to spread across the BIPV facade
9 Will the BIPV façade be entirely accessible by the fire brigade?	More info	(1) Yes	Full accessibility allows effective firefighting, improving safety and emergency response
10 Do BIPV modules endanger an escape route?	More info	(1,5) Yes, BIPV modules are situated above an escape route	BIPV modules above an escape route pose a high risk of falling debris obstructing/endangering evacuation paths.
11 Will the façade be load-bearing?	More info	(2) Yes	The collapse of a load-facade does directly compromises the building's structural integrity.
12 Will the orientation of the facade be in the prevailing wind direction of the location?	More info	(1) No	Depending on the wind direction and speed, fire can spread rapidly or in various directions, including sideways or even downwards in extreme case

Risk impact



BIPV & facade product characteristics			Influence on fire safety and possible advice
13 What type of BIPV module will be employed?	More info	(1) Glass/glass	Glass/glass modules offer better fire performance with non-combustible glass layers protecting combustible encapsulants.
14 What will be the fire class of the BIPV module according NEN-EN 13501-1?	More info	(1) B	This module meets the minimal requirement according the building decree (Bbl)
15 What will be the fire class of the BIPV module according ANSI/UL 1703 (via UL 790)?	More info	(1) Not applicable	Don't take into account this fire classification. Refer to NEN-EN 13501-1 for correct fire classification
16 Will the BIPV modules be easily removable?	More info	(2) No	Non-removable modules complicate maintenance, increasing the risk of undetected issues and potential fire hazards.
17 What is the main electrical configuration that will be employed?	More info	(2) String inverter	String inverters present the highest fire risk due to high voltage DC operation, with simple maintenance but basic monitoring and lower shading performance.
18 Will an active AFCI be employed in the BIPV system?	More info	(0,5) Yes	Employing an AFCI reduces the risk of fire from electric arcs, enhancing system safety
19 Will the BIPV cavity exceed the maximum temperature specified for the BIPV system's components?	More info	(1) No	Staying within temperature limits ensures component safety and optimal efficiency, reducing the risk of failure and fire
20 What material will be situated in the cavity opposite to the BIPV module?	More info	(2) Sheet layer or insulation layer (fire class B)	Fire class D or lower materials increase fire risk by potentially facilitating ignition from electric arcs and contributing to cavity fire propagation
21 What material will be used for the mounting system of the BIPV modules?	More info	(2) Aluminium	Aluminum loses strength at lower temperatures, increasing the likelihood of BIPV modules falling during a fire
22 Will BIPV system cables penetrate through the facade?	More info	(2) Yes	Cable penetrations create vulnerabilities, potentially allowing fire spread if not properly designed and fireproofed.
23 Will quality control measures for the BIPV system be employed?	More info	(1) Yes, InstallQ	InstallQ ensures high-quality installation, minimizing initial installation errors.

Risk impact



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DESIGN SUPPORT TOOL: FIRE SAFETY FACADE BIPV SYSTEMS

Are you an architect or facade engineer, tasked with designing a new building that incorporates Building Integrated Photovoltaic (BIPV) systems into its façade? You're excited about the possibilities these systems offer in terms of sustainability and energy efficiency. However, there's a problem... You're not entirely sure about the fire risks associated with BIPV installations. You've heard some concerns, but you're not sure how to navigate them effectively?

That's where this design support tool comes in. It's designed to bridge the gap of the pre-normative regulatory framework surrounding BIPV systems, making it easier for architects like you to understand and address fire safety concerns.

How to use the tool

Step 1

Assess your case of study in the "Risk Overview" by filling in the design considerations for your facade(s)

Step 2

Consult sheets "Risk parameters (1-22)" or "Info BIPV" for information regarding the fire risk of each risk parameter

Step 3

Assess each facade in detail in the sheet "Facade Overview" (F1-F4)

Step 4

Consult sheet "Measures" for tailored measures and strategies

Measures

Compliance

- Ensure compliance with NEN 6068 and NEN 6069.
- Align facade construction with fire class requirements of the Bbl (according NEN-EN 13501-1). Refer to risk parameter 14 for more information about fire class requirements
- Conduct representative fire tests that closely represent end-use scenarios. Refer to risk parameter 14 for more information about testing BIPV systems

Generic advice that should always be considered

- The architect / façade designer, BIPV manufacturer and electrical installer should closely collaborate to design the electrical configuration of the BIPV system and adequately implement the effects of the system on the detailing, particularly in the façade (e.g. component placement in façade, cable penetrations, etc.).
- Ensure a maintenance schedule is developed and executed, tailored to the risk of the building to preserve the BIPV system.
- Ensure the BIPV module & system components are designed and installed according the product specifications of the manufacturer.
- Employ high quality electrical components with CE marking (be aware of fake certifications).
- Ensure the use of high-quality, heat-resistant and compatible connectors to minimise the possibility of electric arcs.
- Ensure AC and DC cables are extra protected (e.g. double isolated or fire-resistant).
- Prevent moisture penetration of electrical components, especially in the cavity, by avoiding the possibility of still standing water in the cavity and by employing components with a sufficient IP class.
- Employ bypass diodes with lower maximum currents than the junction box specifications to decrease the likelihood of overheating of junction boxes.
- Employ measures (e.g. bee beaks) to limit the impact of animals like birds, rodents or other animals nesting in the cavity.-
- Minimize the seams between BIPV modules and adjacent exterior façade materials to ensure that joints are tight and well-sealed, thereby restricting pathways for fire to penetrate into the cavity
- Think about design considerations to limit damage to the BIPV modules, potentially caused by a BMU or other external factors
- Implement lightning strike provisions (e.g. lightning conductors with overvoltage protection.

Tailored advice per facade based on input from sheet "Risk Overview"

More info on façade

Façade 1

- Ensure the materials in the BIPV cavity opposite the BIPV module are fire class A2 or A1 to act as a fire barrier (e.g. CEM board 10 mm), minimizing cavity fire and preventing enhanced fire propagation

- Consider adding optimizers to improve remote monitoring and control, enhance system performance, or use micro-inverters instead of string inverters to lower the operating voltage and reduce the risk of electric arcs

- Consider segmentizing the BIPV facades that span two fire compartments vertically to limit a façade fire to singular fire compartment. How? By creating physical gaps or barriers between BIPV modules at the borders of fire compartments.

- Strategically place façade openings to prevent critical fire propagation routes, and employ smart detailing around openings and BIPV cavities to prevent fire spread between them (e.g. non-combustible flashings).

More info on façade

Façade 2

- Ensure the materials in the BIPV cavity opposite the BIPV module are fire class A2 or A1 to act as a fire barrier (e.g. CEM board 10 mm), minimizing cavity fire and preventing enhanced fire propagation

- Ensure the cavity temperature remains below the maximum operating temperature of the electrical components in the façade. How? Increase airflow in the cavity by enlarging cavity openings or increasing cavity depth

- Strategically place façade openings to prevent critical fire propagation routes, and employ smart detailing around openings and BIPV cavities to prevent fire spread between them (e.g. non-combustible flashings).

- Ensure at least one main escape route has enhanced safety measures and assess the need for extra protection on other routes. How? Implement physical barriers, such as cantilevers, around critical areas like exit doors, or use steel mounting structures for BIPV systems above, or not situating BIPV modules

More info on façade

Façade 3

- Ensure quality control with InstallQ qualified installers or conducting a SCOPE 12 retrospective inspection by a certified company.

- Ensure the materials in the BIPV cavity opposite the BIPV module are fire class A2 or A1 to act as a fire barrier (e.g. CEM board 10 mm), minimizing cavity fire and preventing enhanced fire propagation

- Ensure the cavity temperature remains below the maximum operating temperature of the electrical components in the façade. How? Increase airflow in the cavity by enlarging cavity openings or increasing cavity depth

- Consider segmentizing the BIPV facades that span two fire compartments vertically to limit a façade fire to singular fire compartment. How? By creating physical gaps or barriers between BIPV modules at the borders of fire compartments.

- Split up the BIPV cavity vertically at the fire compartment borders to limit

More info on façade

Façade 4

- Consider conducting a SCOPE 12 retrospective inspection by a certified company.

- Ensure the materials in the BIPV cavity opposite the BIPV module are fire class A2 or A1 to act as a fire barrier (e.g. CEM board 10 mm), minimizing cavity fire and preventing enhanced fire propagation

- Consider adding optimizers to improve remote monitoring and control, enhance system performance, or use micro-inverters instead of string inverters to lower the operating voltage and reduce the risk of electric arcs

- Strategically place façade openings to prevent critical fire propagation routes, and employ smart detailing around openings and BIPV cavities to prevent fire spread between them (e.g. non-combustible flashings).

- Critically consider the ease of removal for BIPV modules to facilitate maintenance and replacement. How? Use mounting systems that allow for

Measures

More info on façade

Façade 1

- Ensure the materials in the BIPV cavity opposite the BIPV module are fire class A2 or A1 to act as a fire barrier (e.g. CEM board 10 mm), minimizing cavity fire and preventing enhanced fire propagation

- Consider adding optimizers to improve remote monitoring and control, enhance system performance, or use micro-inverters instead of string inverters to lower the operating voltage and reduce the risk of electric arcs

- Ensure AFCIs are implemented in the system and ensure they are active to limit the possibilities and effects of electric arcs in the system.

- Ensure the cavity temperature remains below the maximum operating temperature of the electrical components in the façade. How? Increase airflow in the cavity by enlarging cavity openings or increasing cavity depth

- Always employ a glass/glass BIPV module to minimize cavity fires and prevent enhanced fire propagation.

- Consider segmentizing the BIPV facades that span two fire compartments vertically to limit a façade fire to singular fire compartment. How? By creating physical gaps or barriers between BIPV modules at the borders of fire compartments.

- Strategically place façade openings to prevent critical fire propagation routes, and employ smart detailing around openings and BIPV cavities to prevent fire spread between them (e.g. non-combustible flashings).

- Critically consider the ease of removal for BIPV modules to facilitate maintenance and replacement. How? Use mounting systems that allow for this, avoiding glued connections.

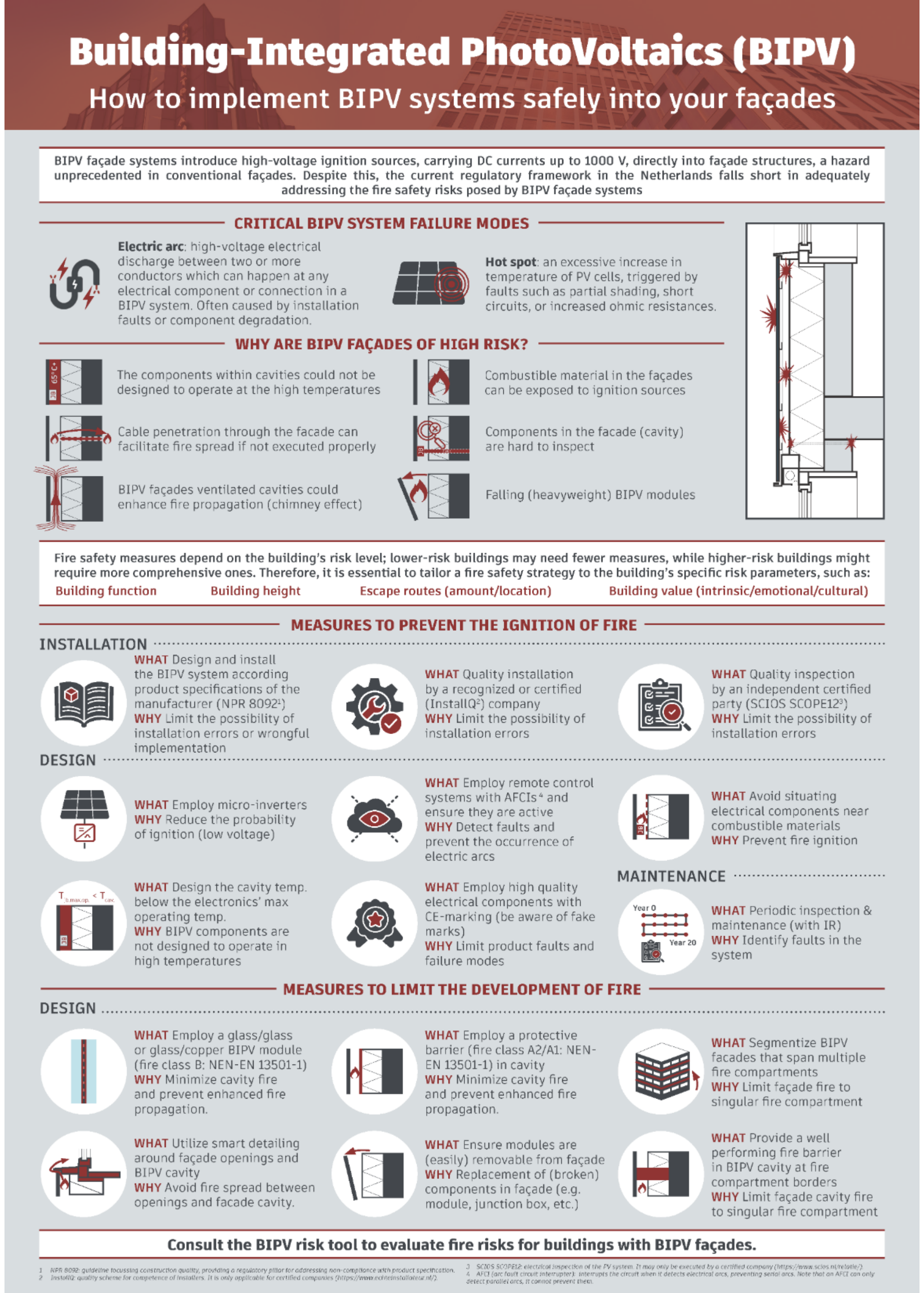
- Ensure at least one main escape route has enhanced safety measures and assess the need for extra protection on other routes. How? Implement physical barriers, such as cantilevers, around critical areas like exit doors, or use steel mounting structures for BIPV systems above, or not situating BIPV modules above escape routes.

- Conduct a wind analysis and consider the effects of wind on fire spread.

- You are employing a BIPV module with a lower fire class (NEN-EN 13501-1) than permitted by the building decree (Bbl). Ensure the BIPV module meets a minimum fire class of B.

One-pager

- Summary of tool
- Quick spread of knowledge
- Wider target group:
  - Developers
  - Clients
  - Fire safety consultants
  - Manufactures



One-pager

MEASURES TO PREVENT THE IGNITION OF FIRE

INSTALLATION

WHAT Design and install the BIPV system according product specifications of the manufacturer (NPR 8092[1])
WHY Limit the possibility of installation errors or wrongful implementation

WHAT Quality installation by a recognized or certified (InstallQ[2]) company
WHY Limit the possibility of installation errors

WHAT Quality inspection by an independent certified party (SCIOS SCOPE12[3])
WHY Limit the possibility of installation errors

DESIGN

WHAT Employ micro-inverters
WHY Reduce the probability of ignition (low voltage)

WHAT Employ remote control systems with AFCIs[4] and ensure they are active
WHY Detect faults and prevent the occurrence of electric arcs

WHAT Avoid situating electrical components near combustible materials
WHY Prevent fire ignition

WHAT Design the cavity temp. below the electronics' max operating temp.
WHY BIPV components are not designed to operate in high temperatures

WHAT Employ high quality electrical components with CE-marking (be aware of fake marks)
WHY Limit product faults and failure modes

MAINTENANCE

WHAT Periodic inspection & maintenance (with IR)
WHY Identify faults in the system

MEASURES TO LIMIT THE DEVELOPMENT OF FIRE

DESIGN

WHAT Employ a glass/glass or glass/copper BIPV module (fire class B: NEN-EN 13501-1)
WHY Minimize cavity fire and prevent enhanced fire propagation.

WHAT Employ a protective barrier (fire class A2/A1: NEN-EN 13501-1) in cavity
WHY Minimize cavity fire and prevent enhanced fire propagation.

WHAT Segmentize BIPV facades that span multiple fire compartments
WHY Limit façade fire to singular fire compartment

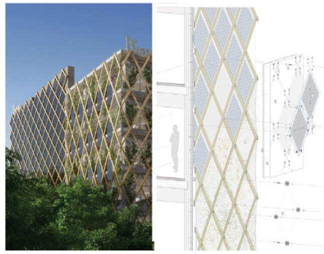
WHAT Utilize smart detailing around façade openings and BIPV cavity
WHY Avoid fire spread between openings and facade cavity.

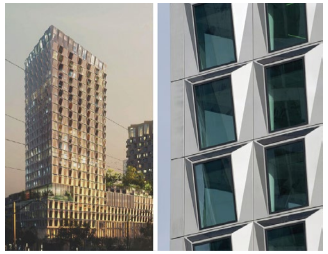
WHAT Ensure modules are (easily) removable from façade
WHY Replacement of (broken) components in façade (e.g. module, junction box, etc.)

WHAT Provide a well performing fire barrier in BIPV cavity at fire compartment borders
WHY Limit façade cavity fire to singular fire compartment

Design support tool development: risk factor evaluation






What is the amount of facades that you want to assess?		Grosspeter tower	The pulse of amsterdam	Concept proposal: PCT Cartuja	Villa Lichtenberg
One façade		North	North	North	North
What do the colours and (..) values mean?		More info on façade 1	More info on façade 1	More info on façade 1	More info on façade 1
Building characteristics risk level					
1 What is the building function of use?	More info	(1) Other building functions	(4) Residential in a residential building, accomodation i	(4) Residential in a residential building, accomodation i	(1) Other building functions
2 What is the building height?	More info	(4) Building height 50m-100m	(8) Building height >100m	(2) Building height 15m-50m	(1) Building height <15m
3 What is the location of the escape routes?	More info	(2) Two staircases on distance <H/2 in two cores	(2) Two staircases on distance <H/2 in two cores	(2) Two staircases on distance <H/2 in two cores	(1) One staircase in residential or accomodation not i
4 How would you estimate the value of the building?	More info	(2) Medium value	(4) High value	(2) Medium value	(1) Low value
Façade characteristics risk level					
5 Does the BIPV facade continuously span over multiple fire compartments?	More info	(8) Yes, over more than two fire compartments	(1) No, each BIPV segment is limited to a single fire	(8) Yes, over more than two fire compartments	(1) No, each BIPV segment is limited to a single fire
6 Does the BIPV facade cavity continuously span over multiple fire compartments?	More info	(1) No, each BIPV cavity is limited to a single fire	(1) No, each BIPV cavity is limited to a single fire	(8) Yes, over more than two fire compartments	(1) No, each BIPV cavity is limited to a single fire
7 Will there be openings in the BIPV facade?	More info	(2) Yes, distributed openings	(2) Yes, distributed openings	(2) Yes, distributed openings	(2) Yes, distributed openings
8 Will there be protrusions along the BIPV façade?	More info	(1) No	(0,75) Horizontal protrusion < 0,5m	(1) No	(1) No
9 Will the BIPV façade be entirely accessible by the fire brigade?	More info	(4) No	(4) No	(1) Yes	(1) Yes
10 Do BIPV modules endanger an escape route?	More info	(2) Yes, BIPV modules are situated above multiple	(2) Yes, BIPV modules are situated above multiple	(1,5) Yes, BIPV modules are situated above an escape	(1,5) Yes, BIPV modules are situated above an escape
11 Will the façade be load-bearing?	More info	(1) No	(1) No	(1) No	(2) Yes
12 Will the orientation of the facade be in the prevailing wind direction of the location?	More info	(1) The facade is subjected to the prevailing wind or	(1) The facade is subjected to the prevailing wind or	(1) The facade is subjected to the prevailing wind or	(1) No
BIPV & façade product characteristics risk level					
13 What type of BIPV module will be employed?	More info	(1) Glass/glass	(1) Glass/glass	(1) Glass/glass	(1) Glass/glass
14 What will be the fire class of the BIPV module according NEN-EN 13501-1?	More info	(1) B	(1) B	(1) B	(1) B
15 What will be the fire class of the BIPV module according ANSI/UL 1703 (via UL 790)?	More info	(1) Not applicable	(1) Not applicable	(1) Not applicable	(1) Not applicable
16 Will the BIPV modules be easily removable?	More info	(2) No	(1) Yes	(1) Yes	(2) No
17 What is the main electrical configuration that will be employed?	More info	(2) String inverter	(0,5) Micro-inverter	(0,5) Micro-inverter	(2) String inverter
18 Will an AFCI be employed in the BIPV system?	More info	(0,5) Yes	(0,5) Yes	(0,5) Yes	(0,5) Yes
19 Will the BIPV cavity exceed the maximum temperature specified for the BIPV system's	More info	(8) Yes, 20+ °C higher	(4) Yes, 0-20 °C higher	(4) Yes, 0-20 °C higher	(1) No
20 What material will be situated in the cavity opposite to the BIPV module?	More info	(2) Sheet layer or insulation layer (fire class B)	(2) Sheet layer or insulation layer (fire class B)	(2) Sheet layer or insulation layer (fire class B)	(2) Sheet layer or insulation layer (fire class B)
21 What material will be used for the mounting system of the BIPV modules?	More info	(2) Aluminium	(2) Aluminium	(2) Aluminium	(2) Aluminium
22 Will BIPV system cables penetrate through the facade?	More info	(2) Yes	(2) Yes	(2) Yes	(2) Yes
23 Will quality control measures for the BIPV system be employed?	More info	(1) Yes, InstallQ	(0,25) Yes, InstallQ and SCOPE12	(16) No quality control will be employed	(1) Yes, InstallQ

What is the amount of facades that you want to assess?		Hotel Breeze	Soltech Factory	Bornholms Hospital	Rott Up
One façade		North	North	North	North
What do the colours and (..) values mean?		More info on façade 1	More info on façade 1	More info on façade 1	More info on façade 1
Building characteristics risk level					
1 What is the building function of use?	More info	(4) Residential in a residential building, accomodation i	(1) Other building functions	(8) Healthcare with sleeping area, healthcare residentia	(4) Residential in a residential building, accomodation i
2 What is the building height?	More info	(2) Building height 15m-50m	(2) Building height 15m-50m	(2) Building height 15m-50m	(8) Building height >100m
3 What is the location of the escape routes?	More info	(2) Two staircases on distance <H/2 in two cores	(2) Two staircases on distance <H/2 in two cores	(2) Two staircases on distance <H/2 in two cores	(4) Two staircases on distance <H/2 in one core
4 How would you estimate the value of the building?	More info	(2) Medium value	(2) Medium value	(2) Medium value	(4) High value
Façade characteristics risk level					
5 Does the BIPV facade continuously span over multiple fire compartments?	More info	(1) No, each BIPV segment is limited to a single fire	(1) No, each BIPV segment is limited to a single fire	(8) Yes, over more than two fire compartments	(1) No, each BIPV segment is limited to a single fire
6 Does the BIPV facade cavity continuously span over multiple fire compartments?	More info	(1) No, each BIPV cavity is limited to a single fire	(1) No, each BIPV cavity is limited to a single fire	(1) No, each BIPV cavity is limited to a single fire	(1) No, each BIPV cavity is limited to a single fire
7 Will there be openings in the BIPV facade?	More info	(2) Yes, distributed openings	(1) No	(2) Yes, distributed openings	(2) Yes, distributed openings
8 Will there be protrusions along the BIPV façade?	More info	(1) No	(1) No	(1) No	(1) No
9 Will the BIPV façade be entirely accessible by the fire brigade?	More info	(1) Yes	(1) Yes	(1) Yes	(1) Yes
10 Do BIPV modules endanger an escape route?	More info	(1) No	(1) No	(1,5) Yes, BIPV modules are situated above an escape	(1) No
11 Will the façade be load-bearing?	More info	(1) No	(1) No	(1) No	(1) No
12 Will the orientation of the facade be in the prevailing wind direction of the location?	More info	(1) The facade is subjected to the prevailing wind or	(1) No	(1) The facade is subjected to the prevailing wind or	(1) No
BIPV & façade product characteristics risk level					
13 What type of BIPV module will be employed?	More info	(1) Glass/glass	(1) Glass/glass	(1) Glass/glass	(1) Glass/glass
14 What will be the fire class of the BIPV module according NEN-EN 13501-1?	More info	(1) B	(1) B	(1) B	(1) B
15 What will be the fire class of the BIPV module according ANSI/UL 1703 (via UL 790)?	More info	(1) Not applicable	(1) Not applicable	(1) Not applicable	(1) Not applicable
16 Will the BIPV modules be easily removable?	More info	(2) No	(1) Yes	(2) No	(2) No
17 What is the main electrical configuration that will be employed?	More info	(1) String inverter + Optimiser	(1) String inverter + Optimiser	(2) String inverter	(1) String inverter + Optimiser
18 Will an AFCI be employed in the BIPV system?	More info	(0,5) Yes	(0,5) Yes	(0,5) Yes	(8) No
19 Will the BIPV cavity exceed the maximum temperature specified for the BIPV system's	More info	(1) No	(4) Yes, 0-20 °C higher	(4) Yes, 0-20 °C higher	(4) Yes, 0-20 °C higher
20 What material will be situated in the cavity opposite to the BIPV module?	More info	(2) Sheet layer or insulation layer (fire class B)	(1) Sheet layer or insulation layer (fire class A2 or A1)	(1) Sheet layer or insulation layer (fire class A2 or A1)	(2) Sheet layer or insulation layer (fire class B)
21 What material will be used for the mounting system of the BIPV modules?	More info	(2) Aluminium	(2) Aluminium	(2) Aluminium	(2) Aluminium
22 Will BIPV system cables penetrate through the facade?	More info	(2) Yes	(2) Yes	(2) Yes	(2) Yes
23 Will quality control measures for the BIPV system be employed?	More info	(16) No quality control will be employed	(1) Yes, InstallQ	(1) Yes, InstallQ	(0,5) Yes, SCOPE12

Design support tool development: user feedback

Feedback group
- 2 façade engineers
- BIPV manufacturer
- Fellow student
- Dummy user

Main feedback points
- Validation of concept
  - Valuable for multiple purposes and stakeholders
- Effective for designers without knowledge BIPV fire safety
- Less effective for designers with knowledge BIPV fire safety
- Improvements for User Interface (UI) and User Experience (UX)

III

Design Support Tool

IV

Discussion & Conclusion

Discussing the method

Risk analysis

- Overview of main fire risks & measures BIPV facades
- Foundational layer of knowledge for other BIPV systems typologies
    - Lack of supportive empirical data

Design support tool

- Spread of knowledge / foster informed decision-making
- Provides baseline understanding of BIPV fire risk in building context
    - Fails to represent risk nuances / interdependencies
    - Does not consider all risk parameters
    - Risk factors (Subjective nature, can be considered as absolute truth)

Answering the research question

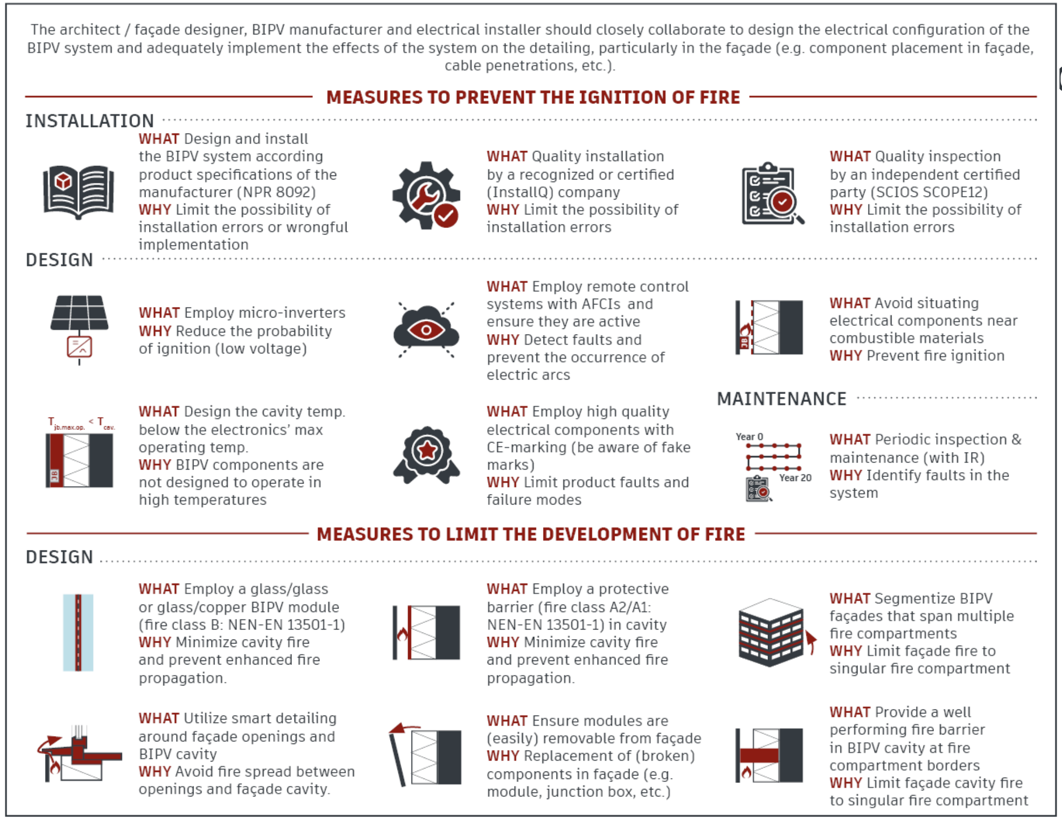
RQ1 | Can a risk-based design support tool aid designers of façades in the design process to achieve fire safe and fire resilient designs when integrating building-integrated photovoltaic systems?

Discussing fire safety BIPV systems in façades

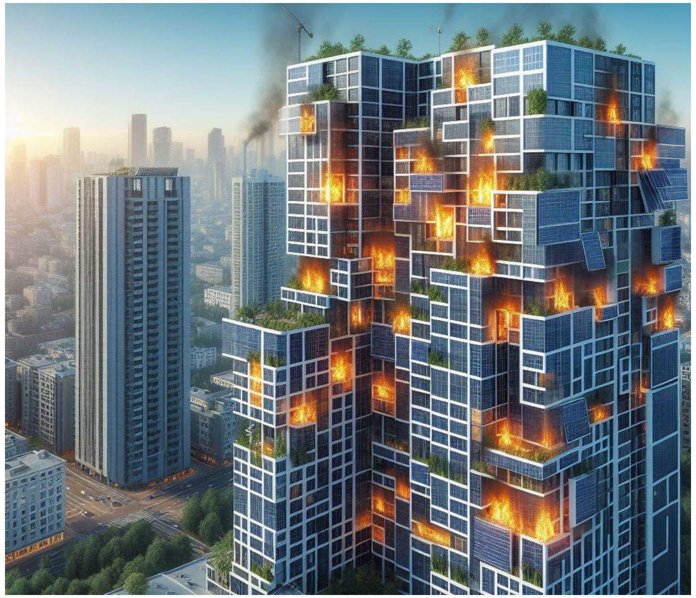
The risks of BIPV façade systems should not be underestimated

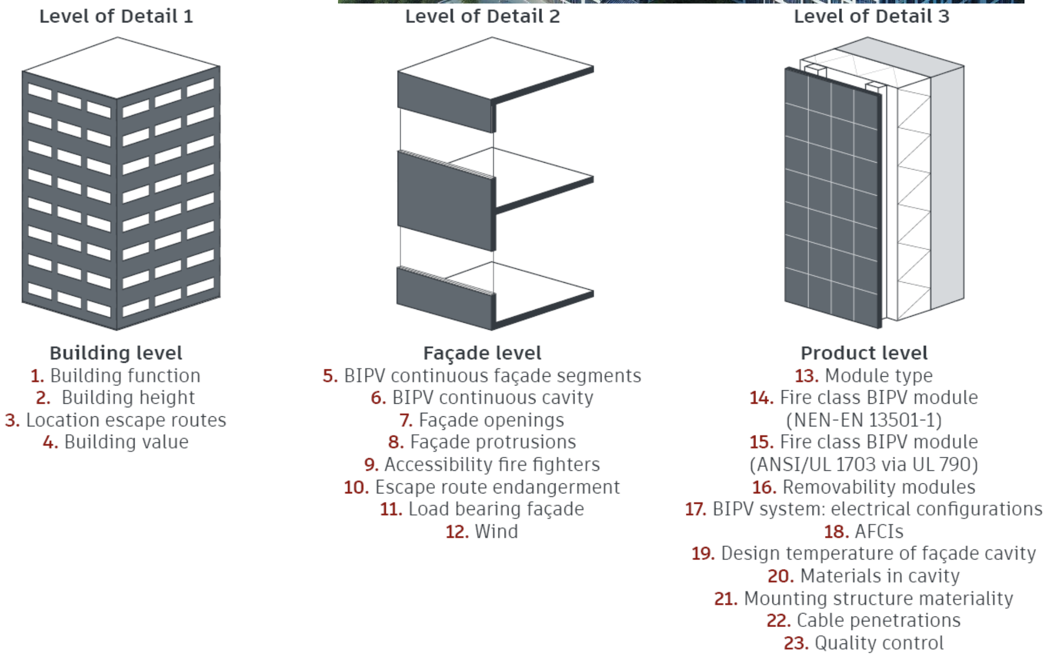
However, …

- Manageable with:



dance….





Thialf moet zonnepanelen uitzetten om verzekerd te blijven

IV

Discussion & Conclusion

V

Future Research

Future recommendations

Design support tool
- Professional tool development
- Tool validation
- Risk factor improvement
- Extend focus
- Cost integration

Research fire safety BIPV facades
- In-depth risk analysis BIPV façade systems

Test proposals
- Fire barrier performance (mounting structure)
- BIPV cavity design considerations

Regulatory framework
- Reporting & documenting fire causes
- BIPV façade fire test method
- Lobbying SCOPE12

P5 Presentation

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External guidance

DMGR	Ir. B.H.G.(Björn) Peters
DGMR	Ir. P.H.E. (Peter) van de Leur

Thank you all for listening