BIG MODULES - BIGGER BALLAST?

New safety considerations for the rooftop sector

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AGENDA

#1 ABOUT PMT

#2 ABOUT IFI

#3 MODULE DEVELOPMENT

#4 RESULTING PROBLEMS

#5 WIND TUNNEL TESTING

#6 BASICS OF AERODYNAMICS

#7 CONSEQUENCES

#8 SOLUTION WITH PMT EVO 2.0

N E X T

L E V E L

M O U N T I N G

#1 ABOUT PMT

- Founded in 2012
- PMT is leading the market with innovative and practical solar mounting solutions: flat and pitched roofs as well as solar carports, Agri PV and trapezoidal sheet roofs
- Products are extensively tested with a focus on constant improvement
- PMT was amongst the first companies to receive a general building approval for an aerodynamic flat roof mounting system from the German Institute for Building Technology

#2 ABOUT I.F.I.

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#2 ABOUT I.F.I.

- Founded in 1990
- Goal: to bring science and industry together
- studies of PV mounting systems since approx. 2008
- I.F.I. is active in research and regularly publishes new insights in the aerodynamics of PV structures
- involved in several standardization committees (SEAOC PV-2 2017, Wind Engineering Society for Germany/Austria/Switzerland) and relevant industry guidelines

#3 MODULE DEVELOPMENT

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1983
First modules
48 watts
36 cells (100 x 100 mm)
module ~ 600 x 600 mm

M2 wafer
156,75 x 156,75 mm
Module ~ 1.650 x 990 mm
2012

2016
M3 wafer
158,75 x 158,75 mm
module ~ 1.700 x 1.020 mm

M4 wafer
161,7 x 161,7 mm
module 1 ~ 1.725 x 1.035 mm
(60 / 120 HC)
module 2 ~ 2.080 x 1.035 mm
(72 / 144 HC)
2018

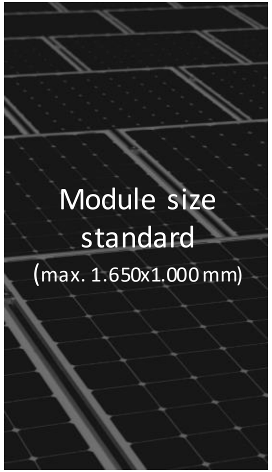
2019
M6 wafer
166 x 166 mm
module 1 ~ 1.775 x 1.050 mm
(60 / 120 HC)
module 2 ~ 2.130 x 1.050 mm
(72 / 144 HC)

M12 wafer
210 x 210 mm
module 1 ~ 2.150 x 1.300 mm
(60 / 120 HC)
module 2 ~ 2.550 x 1.300 mm
(72 / 144 HC)
2020 and future

#3 MODULE DEVELOPMENT

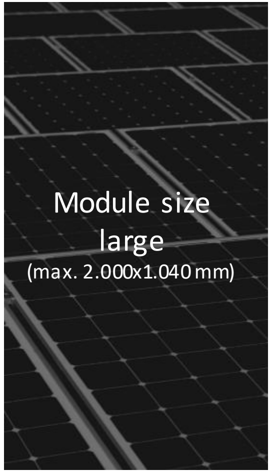
TOP 10
module manufacturer

- Jinko
- LONGi
- JA Solar
- Canadian Solar
- Risen
- Q CELLS
- Trina
- GCL
- First Solar
- Talesun



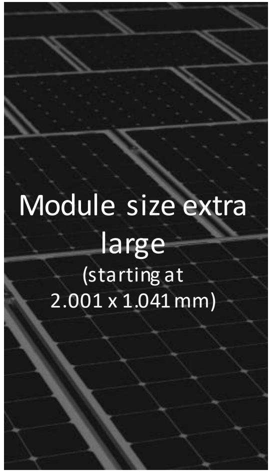
current market capitalisation:
28%

estimated for the future:
15 %



current market capitalisation:
42%

estimated for the future:
45 %



current market capitalisation:
30%

estimated for the future:
40%

#4 RESULTING PROBLEMS

#4 RESULTING PROBLEMS

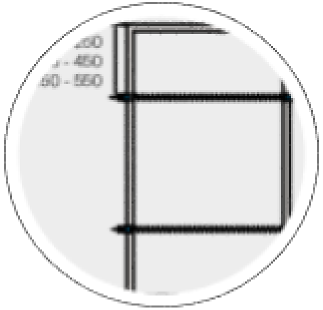
mechanical strength
of the system

S: more or reinforced components
C: higher cost

national technical
approval (2m² rule)

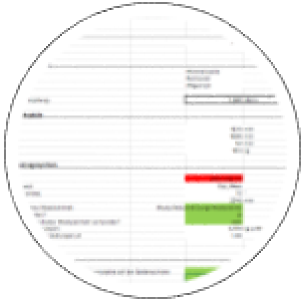
S: change in the norm
C: cannot currently be used in GER (!)

approval
manufacturer



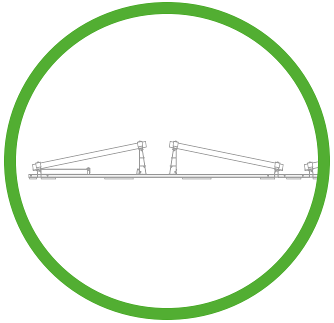
S: additional clamping points
C: new substructure and/or higher cost

increased loads on secondary
components – insulation foil!



S: more contact area
C: higher cost

aerodynamics



S: more space or more ballast
C: not buildable (statics) or less power

#5 WIND TUNNEL TESTING

#5 WIND LOADS ON BUILDINGS

- wind loads on buildings in Germany according to DIN EN 1991-1-4
- PV structures not mentioned
- some guidance e.g. in ASCE 7-16 and SEAOC PV-2 2017 (US) or NEN 7250:2014 (NL)
- as always with codes: broad applicability, unspecific, safety margins, limitations
- codes don‘t keep up with recent trends

⇨ Wind Tunnel Testing!

#5 WIND TUNNEL TESTING - IDEAS

- get specific data for your system
- quickly adapt to new developments (module size etc.)
- broad and general applicability

- accurately scaled models of solar panels *(venting characteristics)*
- sample array configuration
- place models on roofs of generic buildings

#5 WIND LOADS ON PV STRUCTURES

- scientific research and progress over the past 10 years
- evolution of test methods, data analysis, data reduction and application of results
- special requirements for wind tunnel testing:
  - boundary layer wind tunnel
  - adjustments if model scale is not equal to the scale of the flow simulation
  - high-frequency pressure measurements
  - pressure coefficients are a function of tributary area and scale with building size
- made its way into several guidelines, codes and standards: ASCE 7-16, SEAOC PV-2 2017, ASCE 49-12; in Germany: wind tunnel testing guideline of the WTG

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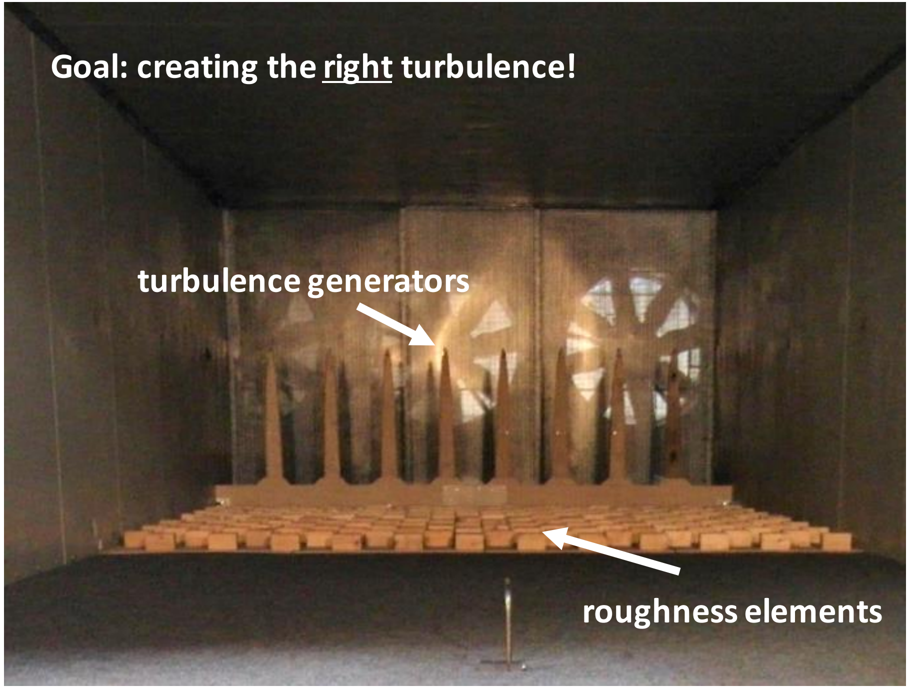
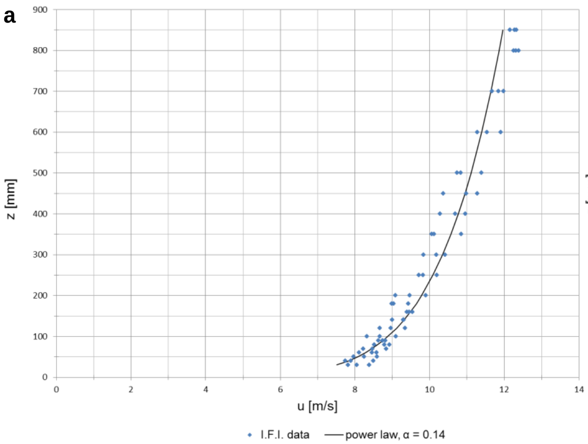
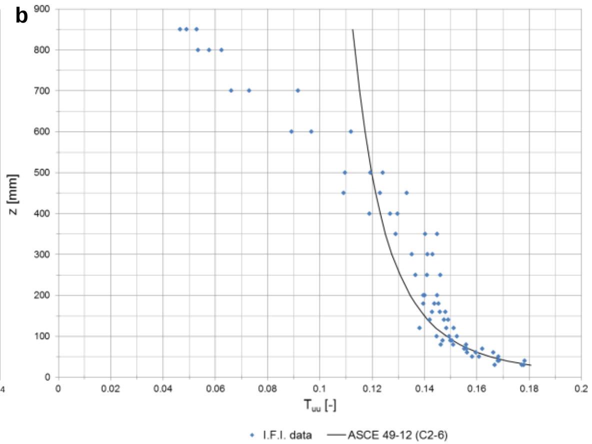
#5 BOUNDARY LAYER WIND TUNNELS



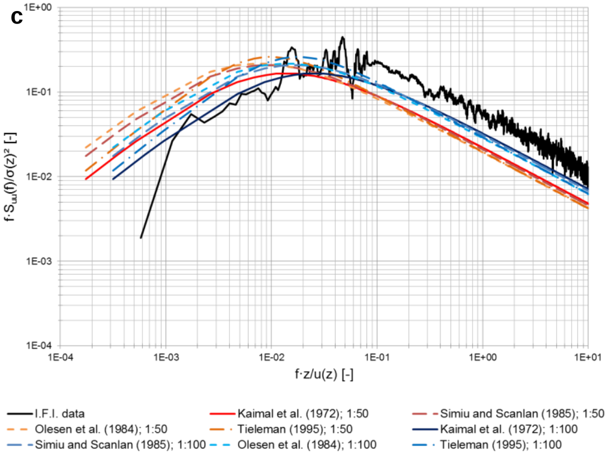
#5 MATCHING THE CURVES



velocity

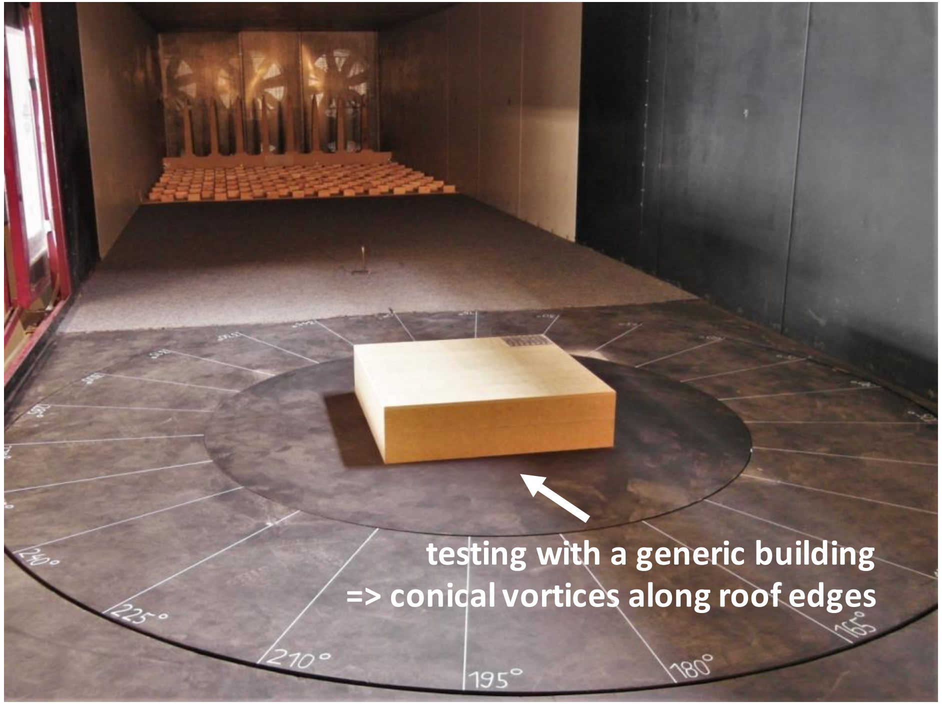


turbulence
intensity



spectral density of turbulence

#5 TESTING FOR PV FLAT-ROOF SYSTEMS



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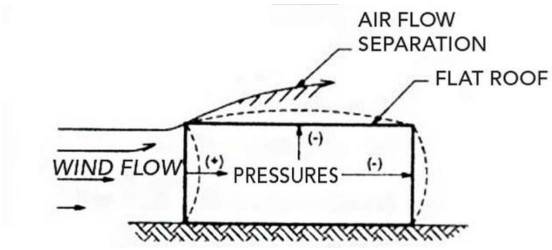
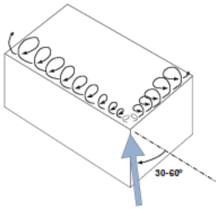
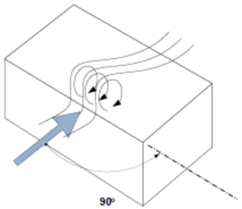
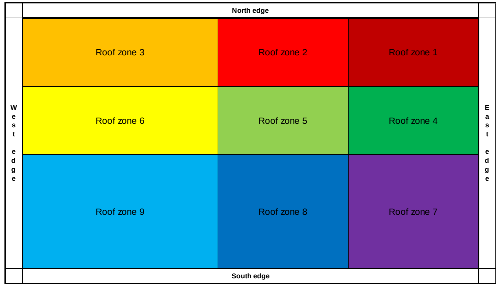
#5 PARAMETERS THAT INFLUENCE PV WIND LOADS

PARAMETER	PHYSICAL REASON	HOW TO DEAL WITH IT
Building size	Flow displacement	Test with multiple building geometries
Roof egde: parapets	Point of flow detachment	Test with sharp edges and parapets of different heights
Wind direction	Corner vortices at oblique winds	Test for different wind directions
Roof size	Reattachment etc.	Test at different positions on the roof

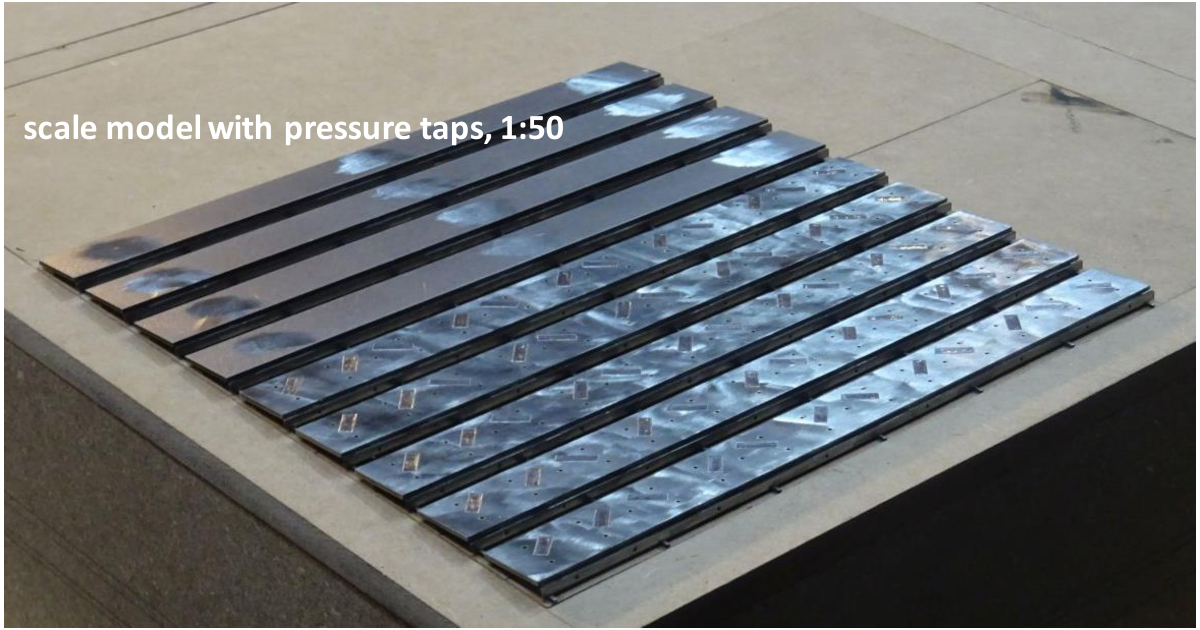




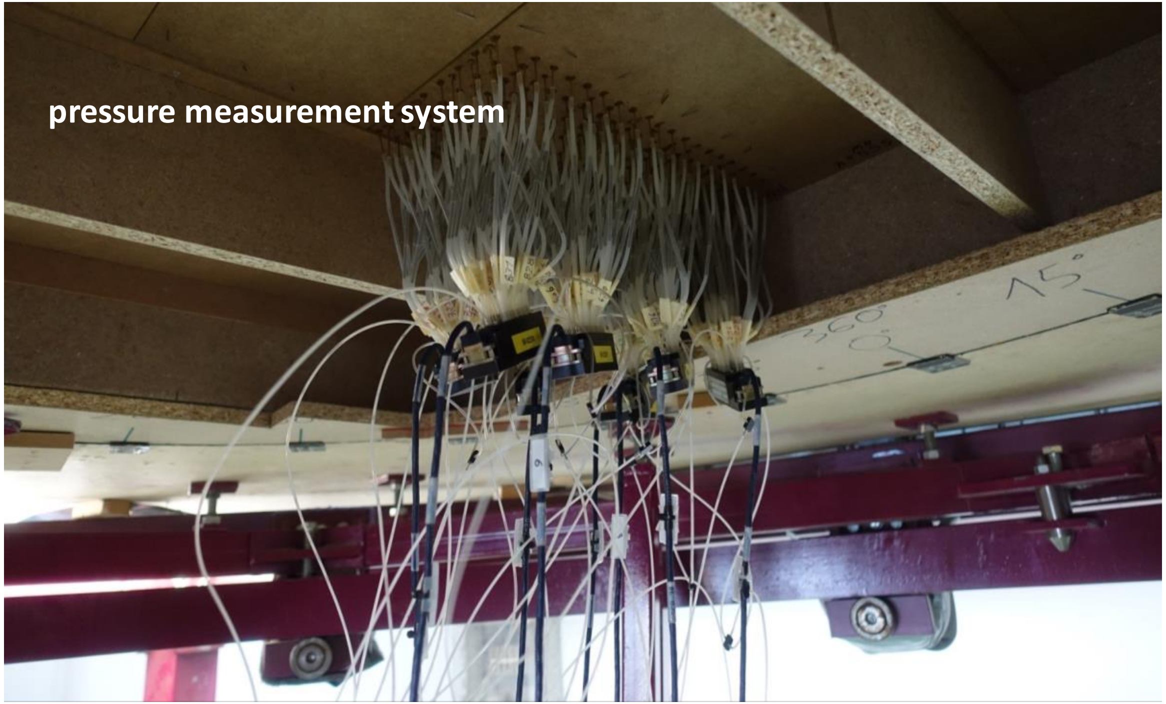




#5 SCALE MODELS



#5 MEASUREMENT TECHNIQUES



#6 LOAD EFFECTS AND LOAD CASES

- load cases uplift and sliding govern the design (rarely others i.e. overturning moment)
- uplift usually critical for EW systems, sliding for S systems

- loads depend on several parameters
  - tilt angle
  - row spacing
  - venting characteristics
  - module size / chord length
  - tributary area

#6 SUMMARY

- Why conduct wind tunnel testing?
  - lack of code-based approaches
  - system specific data => economic and efficient design
  - keep up with current market trends

- at the moment: larger modules
  - implies changes in system geometry (venting)
  - will heavily affect loads
  - only way to find out: wind tunnel testing!

#5 BASICS OF AERODYNAMICS

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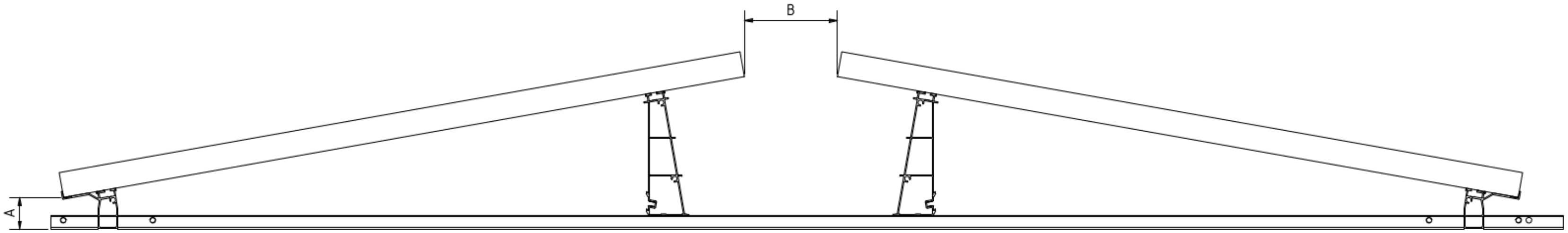


Load derivation:

- load case 1: lifting (Bk=- $\frac{1,5}{0,9} * V_{sog,k} - G_k$)
- load case 2: shifting (Bk= $\frac{1,5}{0,9} * \left(\frac{H_{sog,k}}{\mu} - V_{sog,k}\right) - G_k$)
- load case 3: tilt

In simple terms:

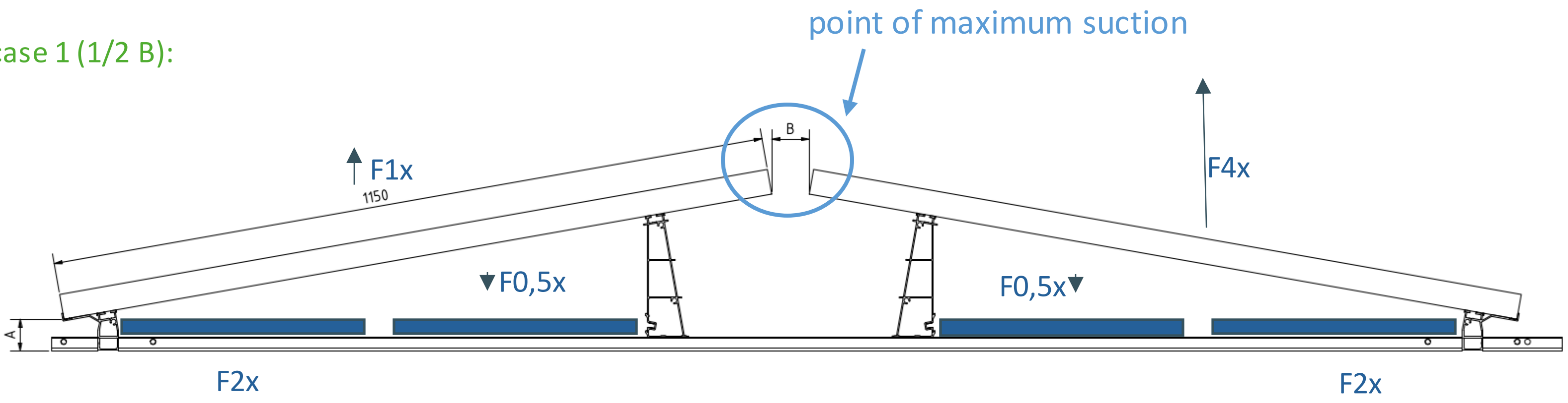
relation B to relation A

→ the bigger the better

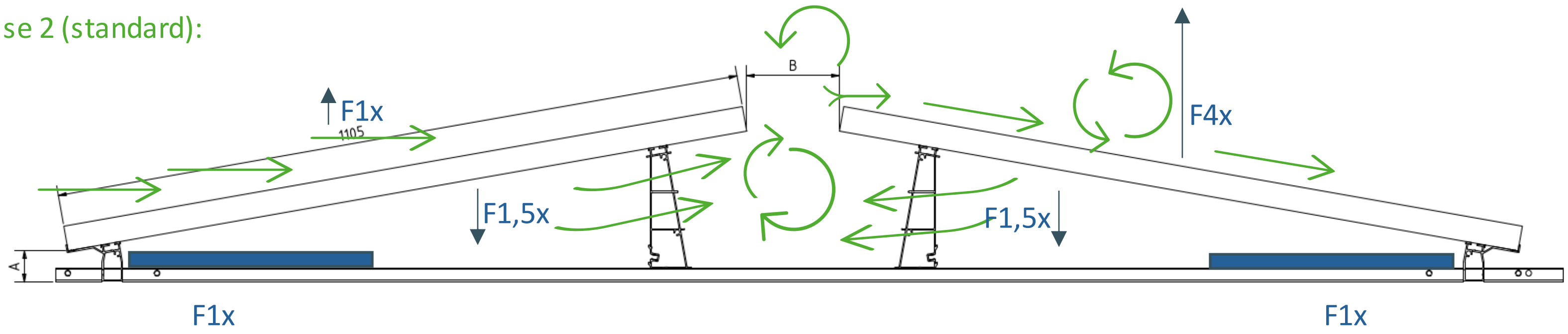
→ the smaller the worse

#5 BASICS OF AERODYNAMICS

case 1 (1/2 B):



case 2 (standard):



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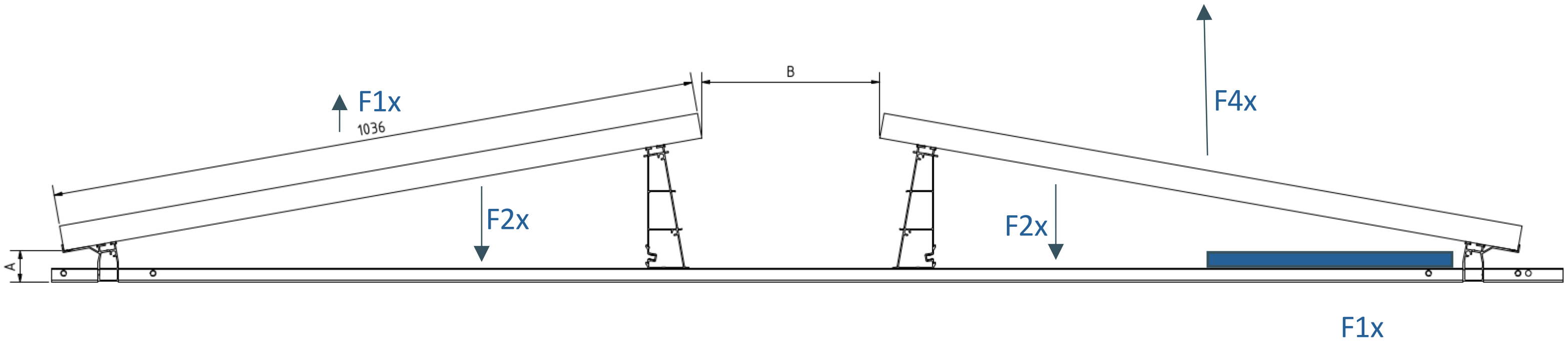
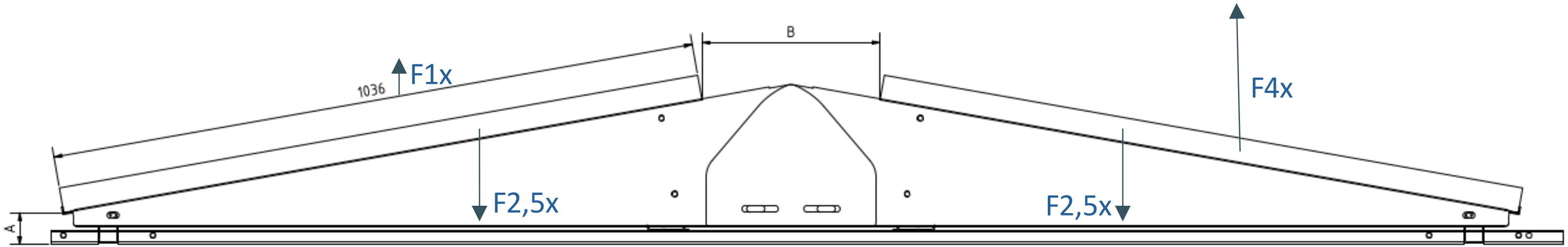
#5 BASICS OF AERODYNAMICS

case 3.1 (2 B):



case 3.2 (2 B + side cover):



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#7 CONSEQUENCES

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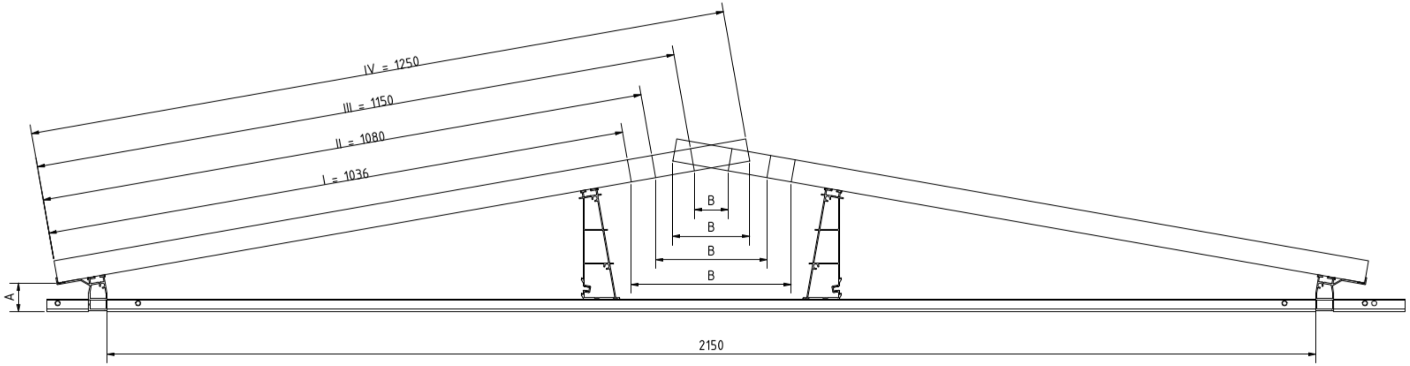

case	dimensions	cp values (1 double module)	ridge- eaves gap ratio
I	1.036 mm	cp = -0,677 / -0,237	B = 5,5 x A = 330 mm
II	1.080 mm	cp = -0,705 / -0,221	B = 4,0 x A = 240 mm
III	1.150 mm	cp = -0,802 / -0,175	B = 2,5 x A = 150 mm
IV	1.250 mm	mechanically not detachable	

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#7 CONSEQUENCES

general project information

Stadtsteinach (Germany)

15 m building height

0° roof pitch

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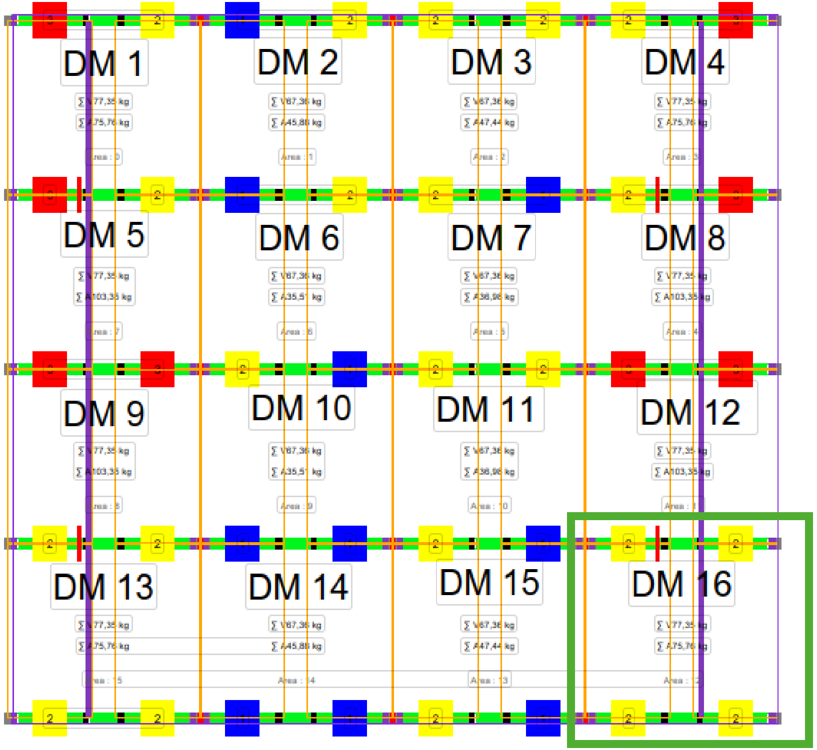


#7 EVALUATION

	Case I (DM 16)
cp value	-0,385 / -0,002
composite	16
ballast lifting	77,35 kg
ballast shifting	75,76 kg
ballast total	1.170 kg
system basis weight	25,38 kg/m²

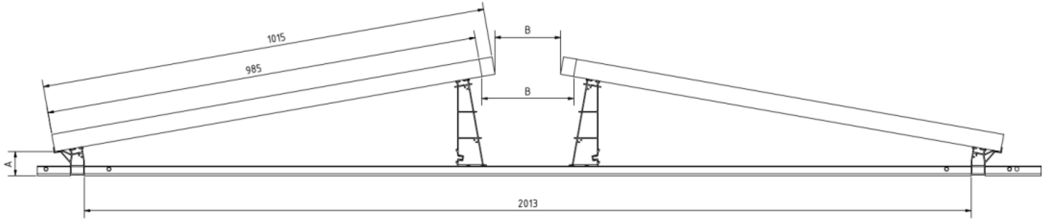
	Case II (DM 16)
cp value	-0,363 / -0,039
composite	16
ballast lifting	85,48 kg
ballast shifting	101,82 kg
ballast total	1.530 kg
system basis weight	30,21 kg/m²

	Case III (DM 16)
cp value	-0,353 / -0,036
composite	16
ballast lifting	89,74 kg
ballast shifting	108,40 kg
ballast total	1.635 kg
system basis weight	31,62 kg/m²

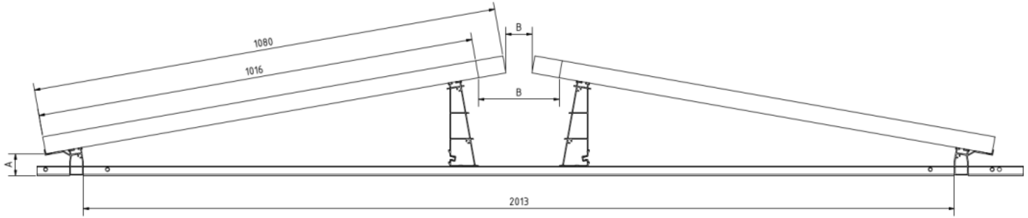
#8 SOLUTION WITH PMT EVO 2.0

#8 SOLUTION WITH PMT EVO 2.0 EW 10°

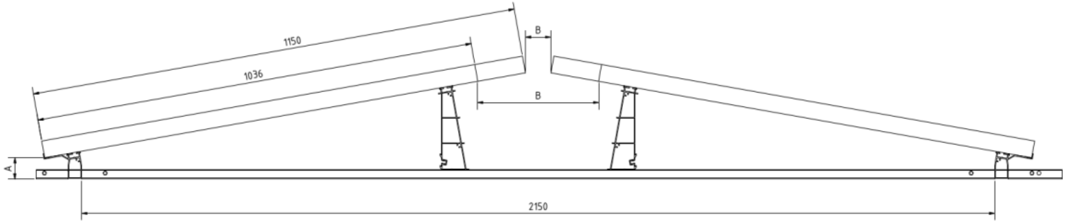
main ground rail TYP 2013
module min. 985 mm
module max. 1.015 mm



main ground rail TYP 2013; M6 Base
module min. 1.016 mm
module max. 1.035 mm
module extreme 1.080 mm

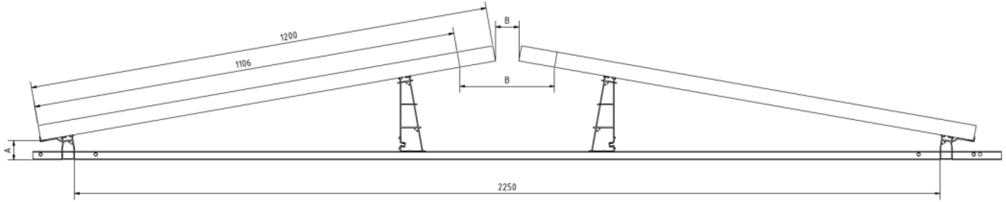


main ground rail TYP 2150; M6 Base
module min. 1.036 mm
module max. 1.105 mm
module extreme 1.150 mm

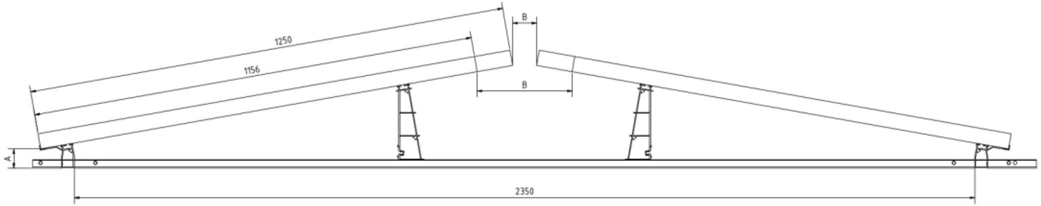


#8 SOLUTION WITH PMT EVO 2.0 EW 10°

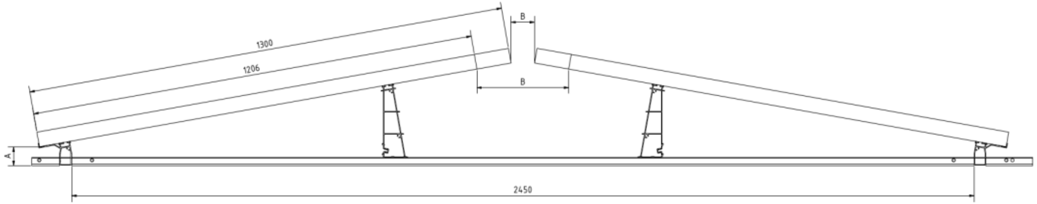
main ground rail TYP 2250; M6 Base
module min. 1.106 mm
module max. 1.155 mm
module extreme 1.200 mm



main ground rail TYP 2350; M6 Base
module min. 1.156 mm
module max. 1.205 mm
module extreme 1.250 mm

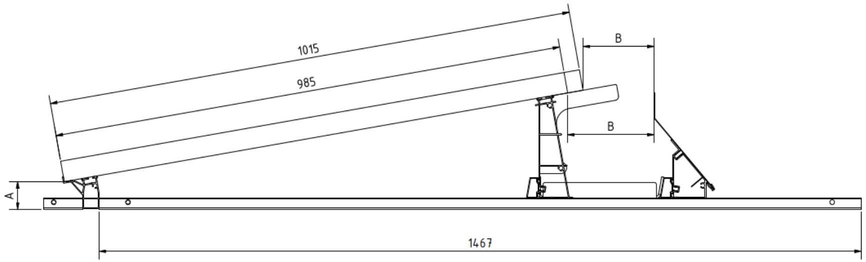


main ground rail TYP 2450; M6 Base
module min. 1.206 mm
module max. 1.255 mm
module extreme 1.300 mm

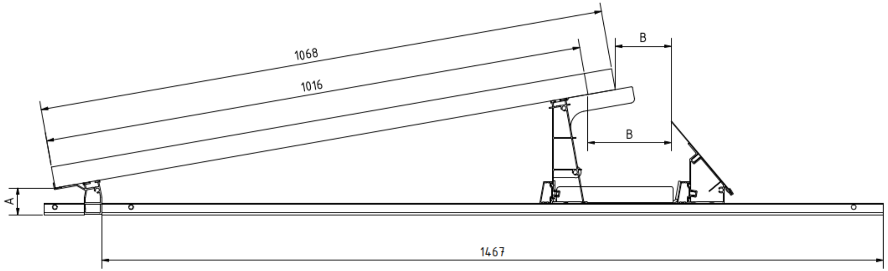


#8 SOLUTION WITH PMT EVO 2.0 S10°

main ground rail TYP 1467
module min. 985 mm
module max. 1.015 mm
„higher shadow“

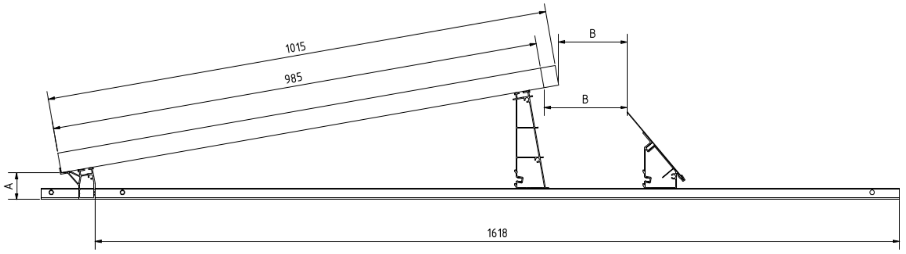


main ground rail TYP 1467; M6 Base
module min. 1.016 mm
module max. 1.035 mm
module extreme 1.068 mm
„higher shadow“

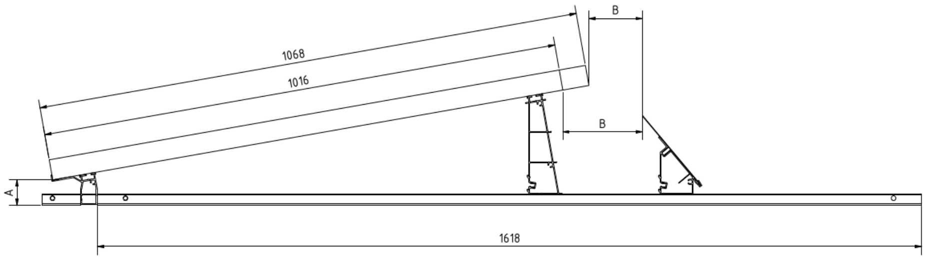


#8 SOLUTION WITH PMT EVO 2.0 S 10°

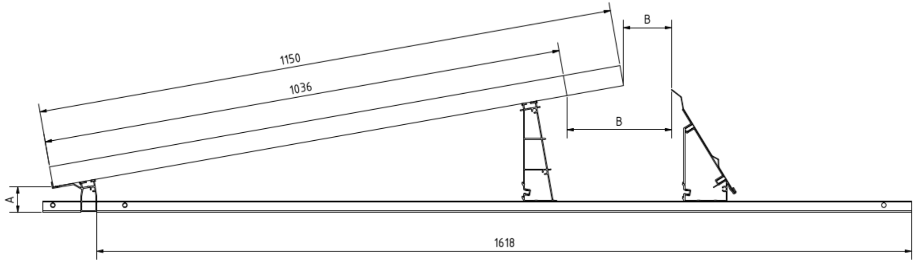
main ground rail TYP 1618
module min. 985 mm
module max. 1.015 mm
„lower shadow“



main ground rail TYP 1618; M6 Base
module min. 1.016 mm
module max. 1.035 mm
module extreme 1.068 mm
„lower shadow“

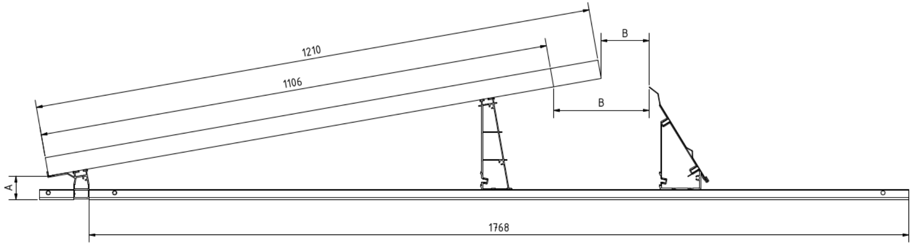


main ground rail TYP 1618; M6 Base Pos. 2
module min. 1.036 mm
module max. 1.105 mm
module extreme 1.150 mm

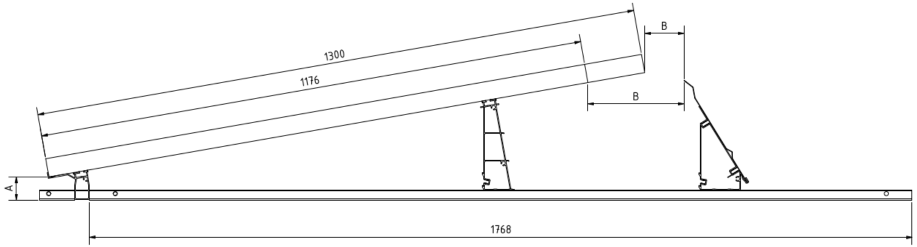


#8 SOLUTION WITH PMT EVO 2.0 S 10°

main ground rail TYP 1768; M6 Pos. 1
module min. 1.106 mm
module max. 1.175 mm
Module extreme 1.210 mm



main ground rail TYP 1768; M6 Base Pos. 2
module min. 1.176 mm
module max. 1.245 mm
module extreme 1.300 mm



#8 SUMMARY

- latest wind load reports
- national technical approval
- lightning protection capacity
- low resistance connection
- fall protection
- extensive accessories
- european technical approval applied for
- guarantee up to 20 years
- project acceptance PMT PROOF

→ PMT can respond to all of the customer´s requirements!

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