APPLICATION OF IEC 61853 MATRIX TO BIFACIAL PV

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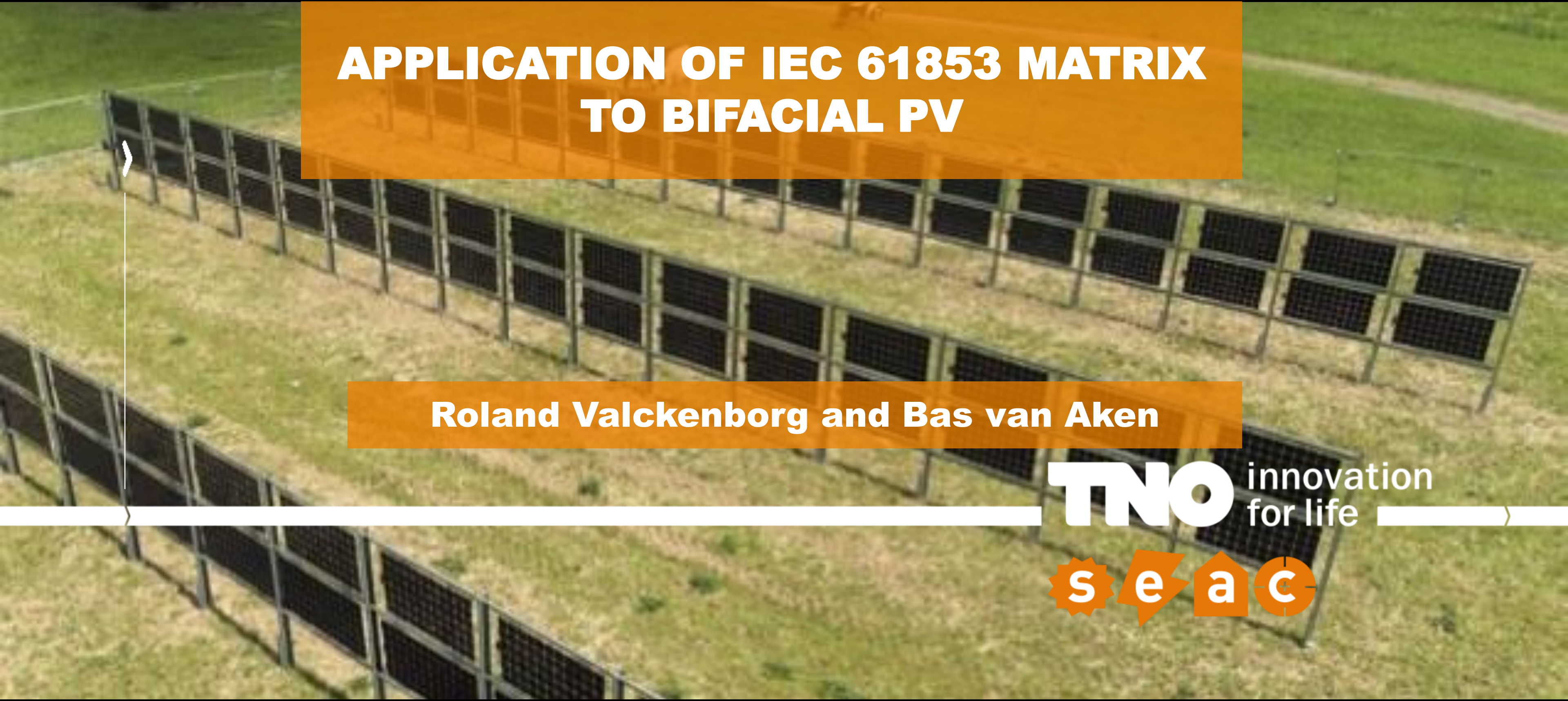

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MOTIVATION

- History:
  - STC most important, and longest history in PV world.
  - Additional parameters (e.g. NOCT) introduced in last couple of decades.

Is it possible to calculate the full year yield based on these datasheet value ?

- **New** 61853 defines 7 G_{POA} x 4 T_{mod} matrix, leaving out the non-existing points:

Irradiance	Spectrum		Module temperature		
$W{\cdot}m^{-2}$		15 °C	25 °C	50 °C	75 °C
1 100	AM1,5	NA			
1 000	AM1,5		STC		
800	AM1,5				
600	AM1,5				
400	AM1,5				NA
200	AM1,5			NA	NA
100	AM1,5			NA	NA

INTRODUCTION 'THE IEC-61853 MATRIX'

- Objective of 61853: **<u>Testing and rating</u>** of a PV-module (under well-defined climatic conditions)
  - Part 1: Irradiance and Temperature performance measurements and power rating
  - Part 2: Spectral responsivity, incidence angle, and module operating temperature
  - Part 3: Calculation of Energy Rating of PV modules
  - Part 4: Standard Reference Climatic Profiles

- Spectral-effects are described also in 61853:2, but less important than the matrix → Future work

OUTLINE PRESENTATION

- Our contribution:
  - additional visualization and statistics
  - for the **Research Purpose** of understanding outdoor performance of various PV technologies
- Demonstrated on a monofacial BIPV façade module (part of PVPS Task15E round robin)
- Use case comparison of monofacial with bifacial
- Use case comparison of bifacial full-cells with bifacial half-cells

INDOOR VS. OUTDOOR DATA COLLECTION

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indoor

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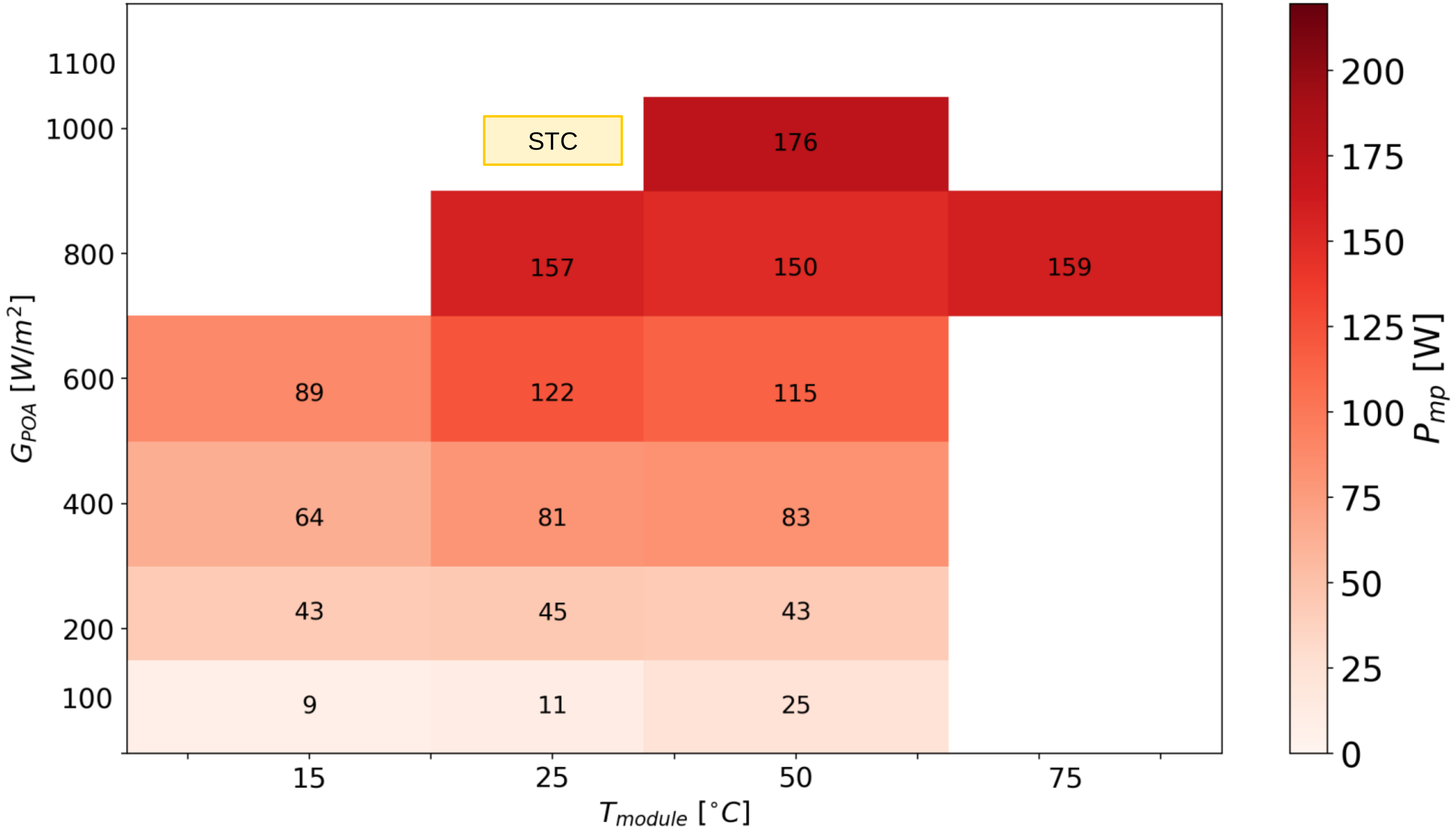
- Matrix according to 61853-1 chapter 8.2 (**indoor**)
- G_{POA} and T_{mod} are set as close as possible to the values in the matrix
- IV-flash from above: AOI = 90° → IAM = 1.0
- *Indoor results presented in 6BV.4.7 'BIPV Round Robin Action of IEA PVPS Task15', P.Illich et.al*

outdoor

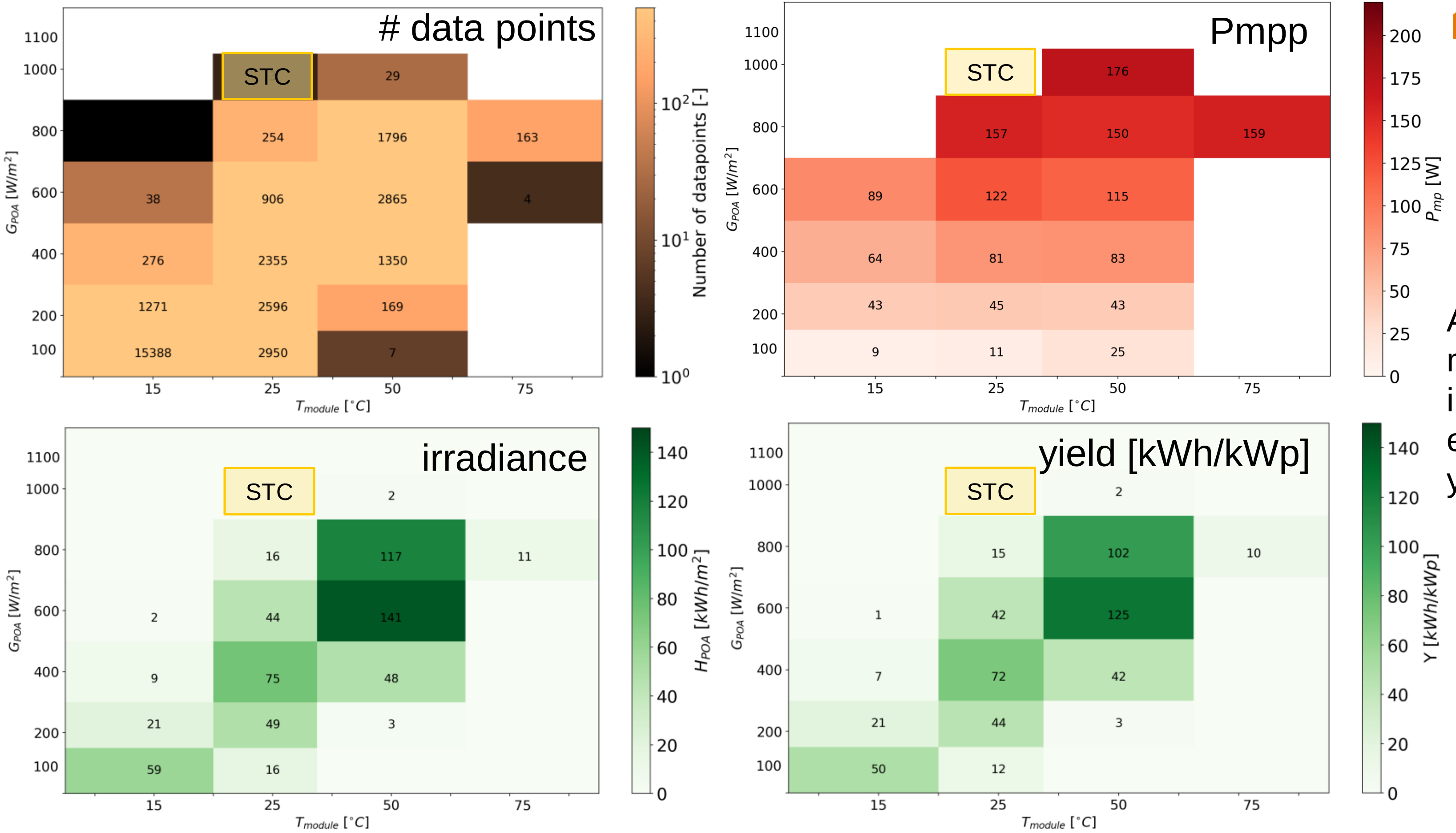
- Matrix according to 61853-1 chapter 8.4 (**natural sunlight without tracker**) taking all points without restriction of 8.3.2
- Example of Taks15E round-robin sample (M17-02288)
- Measurement period = full year (2018-07-01 till 2019-06-29)
- Recording interval = 1 minute & sampling interval = 5 minutes
- AOI varying → IAM varying

- *Comparison between Indoor and Outdoor results are part of 2nd phase of IEA PVPS Task15', to be published in 2020*

1. VISUALIZATION

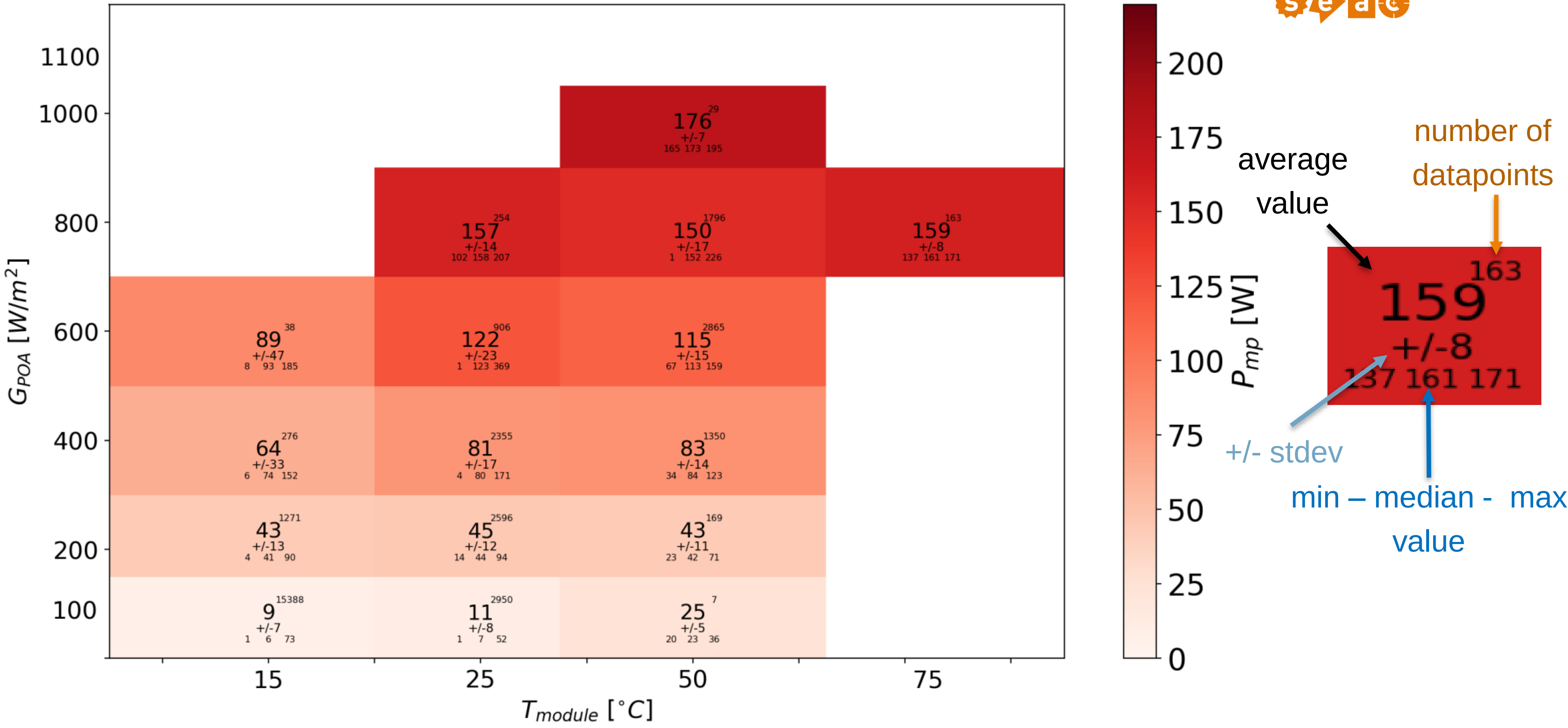


2. SIGNIFICANCE OF EACH BIN-POINT

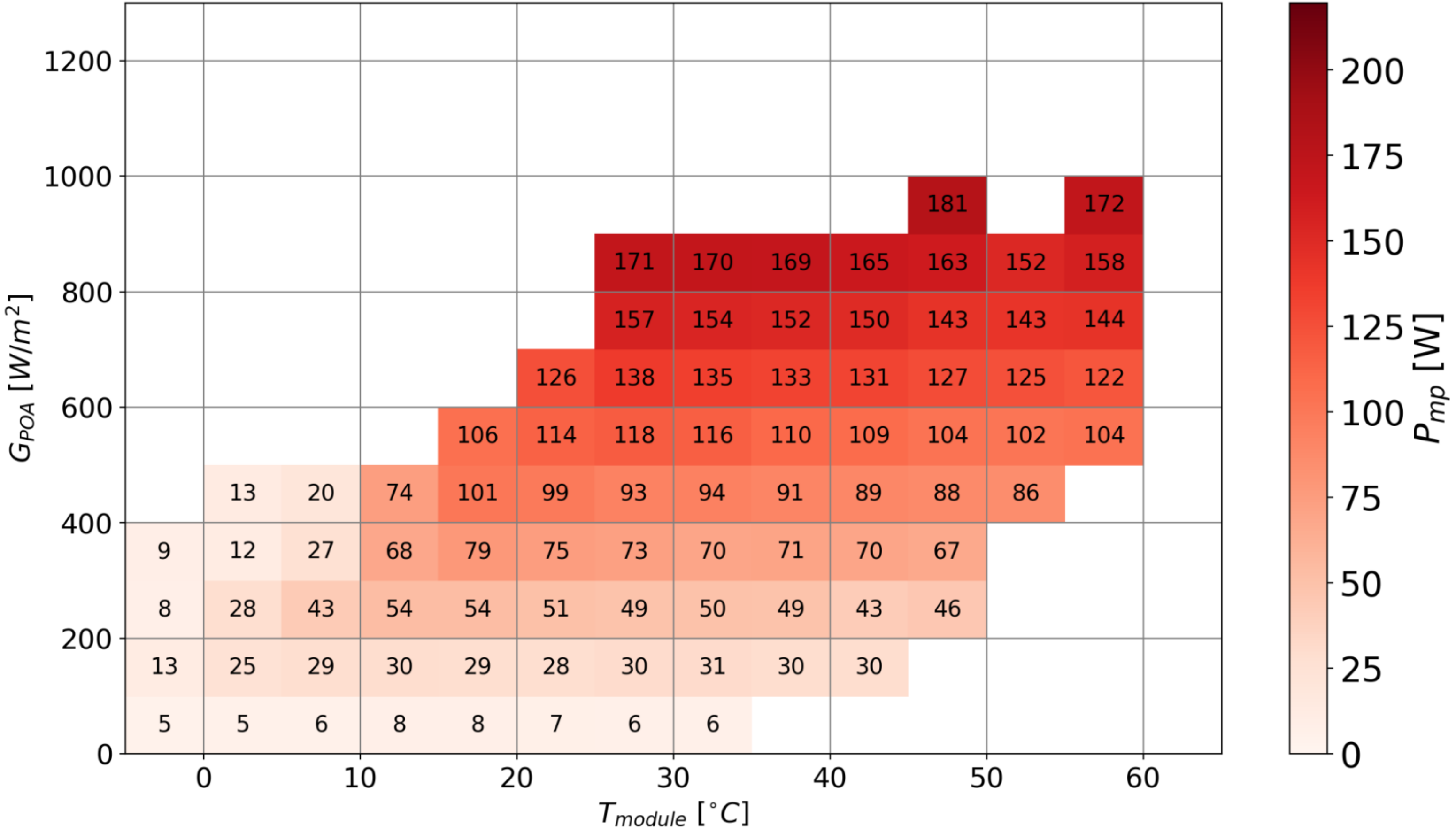


Additional matrices show importance of each bin to total yearly yield

3. STATISTICS PER BIN

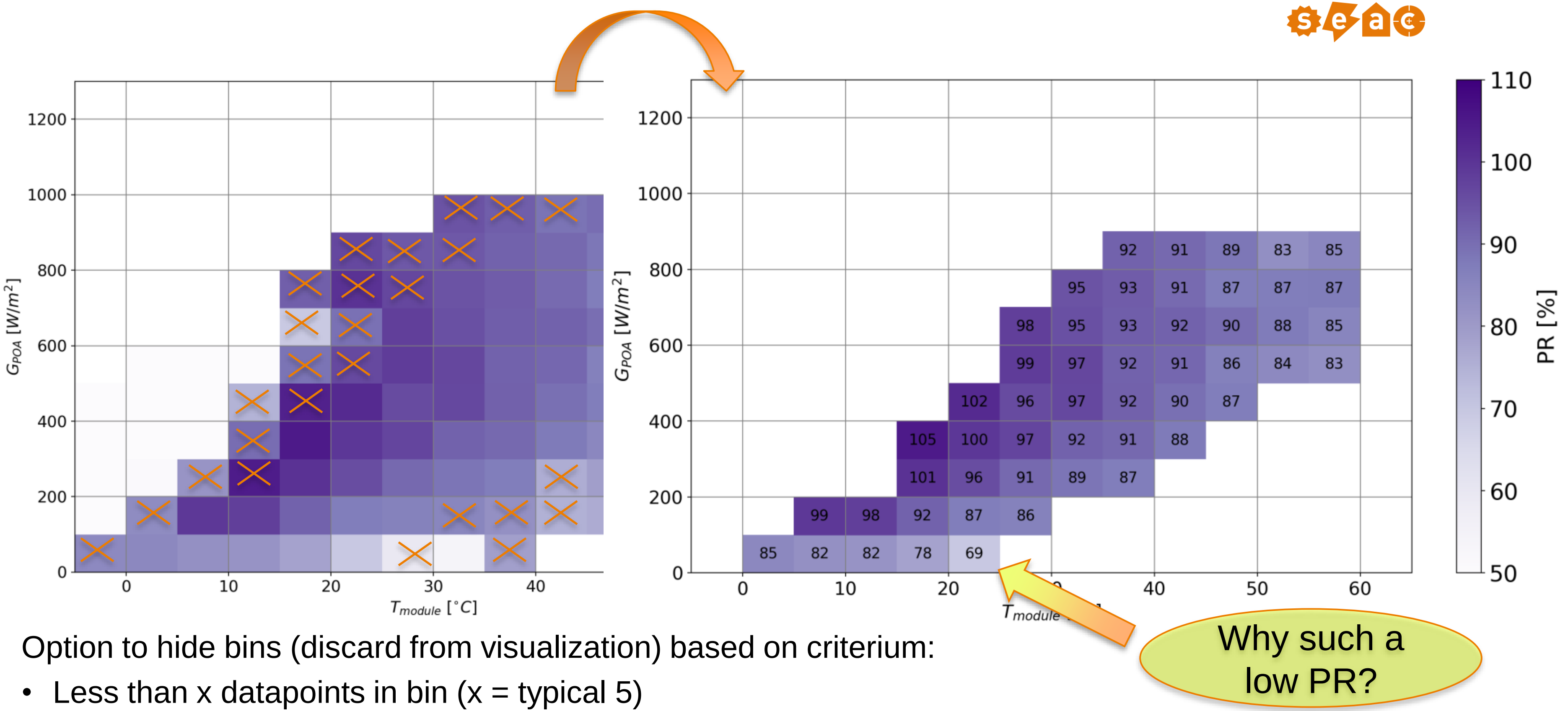


4. MORE BINS



1200
1000
800
600
400
200
0
0
10
20
30
40
50
60
G_{POA} [W/m^2]
T_{module} [°C]
181
172
171
170
169
165
163
152
158
157
154
152
150
143
143
144
126
138
135
133
131
127
125
122
106
114
118
116
110
109
104
102
104
13
20
74
101
99
93
94
91
89
88
86
9
12
27
68
79
75
73
70
71
70
67
8
28
43
54
54
51
49
50
49
43
46
13
25
29
30
29
28
30
31
30
30
5
5
6
8
8
7
6
6
200
175
150
125
100
75
50
25
0
P_{mp} [W]

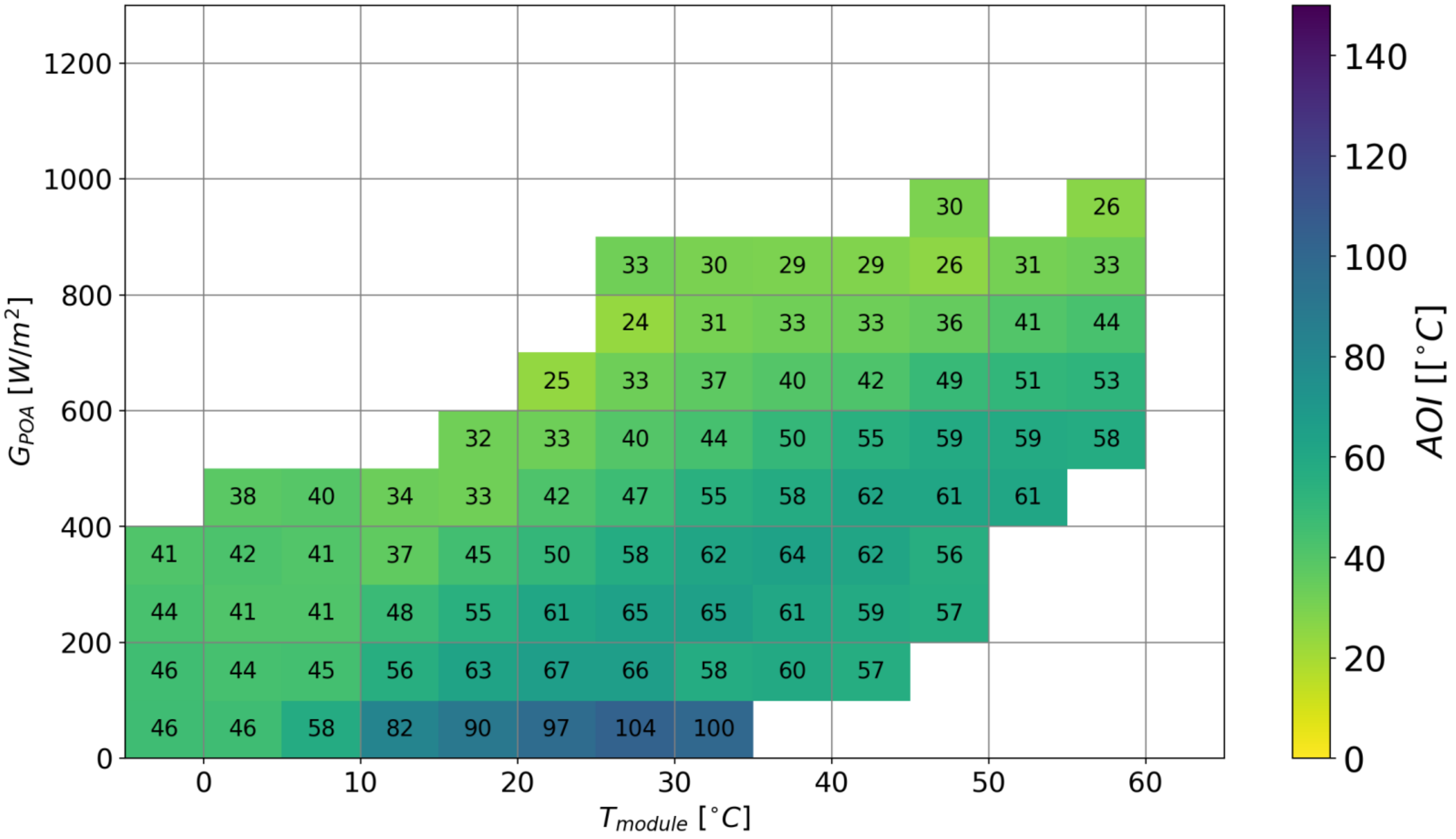
5. HIDING BINS WITH LOW-SIGNIFICANCE



Option to hide bins (discard from visualization) based on criterium:

- Less than x datapoints in bin (x = typical 5)
- Less than y% contribution of yield in bin to total yield (y% = typical 0.5%)

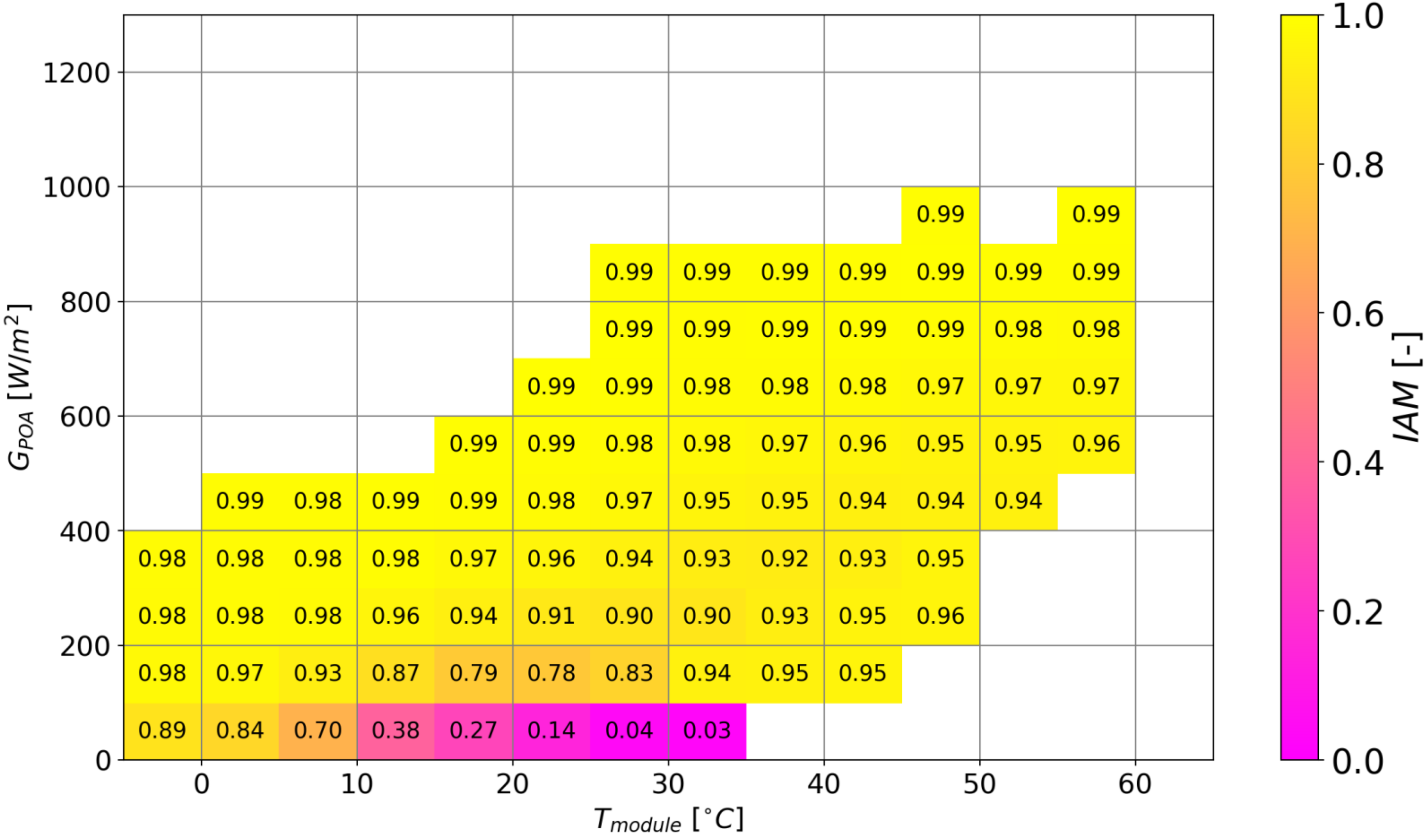
AOI-EFFECT IN OUTDOOR DATA



outdoor

As expected the higher AOI can be found in the lower irradiance bins.

IAM-EFFECT IN OUTDOOR



outdoor

The lowest bin (G_{POA}<100 W/m^2) is nearly completely 'destroyed' by the IAM-effect !

EXPERIMENTAL SETUP

- Rooftop IV-tracing system at ECN.TNO in Petten, the Netherlands

- Every 10 minutes, simultaneuos measurement of all module IV-curves and G_{POA} and T_{mod}
- South-facing, 30° tilt
- Irradiance sensors:
  - G_{POA} : Plane-Of-Array pyranometer and ref cells
  - G_{BOA} : Back of plane reference cells
  - GHI
  - Sun trackers for DNI and DHI

USE CASE 1: MONOFACIAL VS. BIFACIAL

- Two n-PERT modules, left white back sheet, right glass-glass
- March-Dec 2018, 10 minute IV-tracing, ≈ 20.000 data points after removing sensor failures etc.
- DC PR based on G_{POA}

monofacial n-PERT

	-10 -5	-5 0	0 5	5 10	10 15	15 20	20 25	25 30	30 35	35 40	40 45	45 50	50 55
1300-1400							81%	90%					
1200-1300						95%	91%	88%	84%	91%			
1100-1200						90%	95%	96%	92%	93%	91%	89%	86%
1000-1100						102%	99%	97%	93%	92%	90%	90%	88%
900-1000					105%	101%	100%	97%	94%	93%	91%	89%	88%
800-900				110%	107%	103%	100%	97%	95%	93%	92%	90%	89%
700-800				109%	106%	103%	100%	98%	96%	94%	92%	91%	88%
600-700			113%	109%	107%	104%	100%	98%	96%	95%	93%	90%	91%
500-600			110%	111%	107%	105%	101%	99%	97%	96%	94%	90%	
400-500			111%	109%	106%	104%	100%	98%	97%	96%	94%	93%	
300-400			110%	107%	105%	101%	99%	98%	97%	96%	95%		
200-300		110%	109%	106%	104%	100%	99%	98%	97%	95%			
100-200		109%	106%	105%	102%	98%	96%	91%	88%	92%			
0-100	104%	107%	104%	101%	97%	94%	94%	89%	91%				

bifacial n-PERT

	-10 -5	-5 0	0 5	5 10	10 15	15 20	20 25	25 30	30 35	35 40	40 45	45 50	50 55
1300-1400							96%	105%					
1200-1300						109%	108%	99%	107%	94%			
1100-1200						96%	110%	108%	104%	103%	102%	99%	100%
1000-1100						113%	110%	108%	104%	104%	102%	100%	98%
900-1000					116%	113%	110%	107%	106%	104%	102%	100%	97%
800-900				123%	119%	114%	110%	108%	107%	105%	103%	100%	99%
700-800				120%	118%	114%	111%	109%	108%	106%	103%	102%	99%
600-700				121%	118%	115%	112%	111%	109%	107%	104%	103%	102%
500-600				123%	118%	116%	114%	111%	111%	109%	106%	101%	
400-500			121%	120%	118%	117%	114%	113%	112%	112%	109%	109%	
300-400			122%	120%	120%	117%	115%	115%	114%	111%	114%		
200-300		121%	122%	120%	119%	117%	116%	117%	118%	119%			
100-200		124%	121%	121%	120%	117%	119%	128%	117%	120%			
0-100	122%	132%	122%	120%	120%	124%	140%	132%	129%				

ΔPR = DIFFERENCE IN DC PR

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	-10 -5	-5 0	0 5	5 10	10 15	15 20	20 25	25 30	30 35	35 40	40 45	45 50	50 55
1300-1400							15%	15%					
1200-1300						13%	17%	11%	23%	2%			
1100-1200						5%	15%	12%	12%	11%	11%	10%	14%
1000-1100						11%	11%	11%	11%	12%	11%	10%	10%
900-1000					11%	12%	10%	11%	12%	11%	11%	10%	10%
800-900				13%	11%	11%	10%	11%	11%	11%	11%	10%	10%
700-800				12%	12%	12%	11%	11%	12%	12%	11%	11%	11%
600-700				12%	11%	11%	12%	13%	12%	13%	11%	12%	12%
500-600				12%	11%	12%	13%	13%	14%	13%	13%	11%	
400-500			11%	11%	12%	14%	14%	14%	14%	16%	15%	16%	
300-400			13%	12%	14%	16%	16%	17%	17%	15%	19%		
200-300		12%	13%	14%	15%	17%	18%	19%	21%	24%			
100-200		15%	15%	16%	18%	19%	22%	37%	29%	28%			
0-100	18%	25%	19%	19%	23%	29%	46%	43%	38%				

- Gain of ΔPR=11% at high irradiance (700-1100 G_{POA})
- Increasing to ΔPR > 20% gain at low G_{POA}
- Increasing to even higher ΔPR≈40% at high T_{mod} and low G_{POA} : summer evenings

PR BASED ON G_POA (L) AND G_BIF (R)

- $G_{total} := G_{POA} + G_{BOA}$
- However, well-known that G_{BOA} cannot be fully exploited.
- Assume bifaciality factor = 85%. Then $G_{BIF} := G_{POA} + 0.85 * G_{BOA}$

monofacial n-PERT	-10 -5	-5 0	0 5	5 10	10 15	15 20	20 25	25 30	30 35	35 40	40 45	45 50	50 55
1300-1400							81%	90%					
1200-1300						95%	91%	88%	84%	91%			
1100-1200						90%	95%	96%	92%	93%	91%	89%	86%
1000-1100						102%	99%	97%	93%	92%	90%	90%	88%
900-1000					105%	101%	100%	97%	94%	93%	91%	89%	88%
800-900				110%	107%	103%	100%	97%	95%	93%	92%	90%	89%
700-800				109%	106%	103%	100%	98%	96%	94%	92%	91%	88%
600-700			113%	109%	107%	104%	100%	98%	96%	95%	93%	90%	91%
500-600			110%	111%	107%	105%	101%	99%	97%	96%	94%	90%	
400-500			111%	109%	106%	104%	100%	98%	97%	96%	94%	93%	
300-400			110%	107%	105%	101%	99%	98%	97%	96%	95%		
200-300		110%	109%	106%	104%	100%	99%	98%	97%	95%			
100-200		109%	106%	105%	102%	98%	96%	91%	88%	92%			
0-100	104%	107%	104%	101%	97%	94%	94%	89%	91%				

bifacial n-PERT	-10 -5	-5 0	0 5	5 10	10 15	15 20	20 25	25 30	30 35	35 40	40 45	45 50	50 55
1300-1400						96%	96%	94%	95%	90%			
1200-1300						89%	99%	96%	92%	91%	91%	89%	90%
1100-1200						101%	98%	97%	93%	94%	92%	90%	88%
1000-1100					102%	100%	98%	96%	95%	93%	92%	90%	88%
900-1000				108%	105%	101%	98%	96%	95%	93%	92%	90%	88%
800-900				105%	104%	100%	98%	96%	95%	94%	92%	91%	88%
700-800				105%	104%	101%	98%	97%	95%	94%	91%	90%	89%
600-700				106%	103%	101%	98%	96%	95%	94%	91%	88%	
500-600			107%	105%	102%	100%	97%	95%	95%	95%	92%	91%	
400-500			105%	104%	101%	98%	96%	95%	93%	89%	93%	92%	
300-400		106%	103%	102%	99%	96%	94%	94%	93%	92%	92%		
200-300		102%	102%	99%	96%	94%	92%	90%	88%	85%			
100-200		103%	100%	97%	94%	88%	84%	81%	77%				
0-100	98%	99%	98%	94%	89%	84%	77%	75%	76%				

- Bifacial DC PR's more/less aligned with normal behaviour (Temperature loss and R series loss)

USE CASE 2: FULL CELLS VS. HALF CELLS

- Two bifacial n-PERT modules, left full cell, right half cell
- Booth glass-glass modules and BoM identical

- March-Dec 2018, 10 minute IV-tracing, ≈ 20.000 data points after removing sensor failures etc.

Full Cells
R=295 Wp

	-5 0	0 5	5 10	10 15	15 20	20 25	25 30	30 35	35 40	40 45	45 50	50 55	55 60
1300-1400							97%	105%					
1200-1300						100%	109%	96%	107%	93%			
1100-1200							107%	108%	105%	103%	101%	101%	98%
1000-1100					118%	114%	111%	109%	104%	104%	102%	100%	
900-1000					116%	113%	112%	108%	106%	104%	103%	100%	98%
800-900				122%	118%	113%	112%	109%	107%	106%	104%	100%	99%
700-800				121%	117%	114%	112%	110%	108%	107%	104%	101%	99%
600-700			127%	121%	117%	115%	113%	112%	110%	107%	104%	101%	
500-600			124%	122%	117%	118%	114%	113%	111%	111%	106%	101%	
400-500			126%	120%	119%	119%	116%	114%	112%	111%	105%	105%	
300-400			126%	118%	120%	119%	117%	116%	114%	112%	108%		
200-300		127%	122%	121%	120%	119%	118%	116%	114%	113%			
100-200		129%	122%	122%	121%	118%	118%	120%	117%	114%			
0-100	128%	136%	123%	122%	123%	127%	143%	146%	132%				

Half Cells
R=306 Wp

	-5 0	0 5	5 10	10 15	15 20	20 25	25 30	30 35	35 40	40 45	45 50	50 55	55 60
1300-1400							97%	106%					
1200-1300						108%	107%	96%	107%	96%	103%		
1100-1200							106%	108%	106%	103%	102%	101%	98%
1000-1100						115%	110%	109%	105%	104%	102%	100%	100%
900-1000					115%	113%	111%	108%	106%	104%	102%	100%	97%
800-900				123%	118%	112%	111%	108%	106%	104%	102%	99%	97%
700-800				120%	117%	113%	110%	108%	106%	104%	103%	100%	98%
600-700				120%	116%	113%	112%	109%	107%	105%	103%	99%	
500-600			122%	120%	114%	116%	111%	110%	108%	109%	104%	100%	
400-500			121%	118%	116%	116%	112%	110%	109%	106%	101%	103%	
300-400			121%	115%	116%	114%	112%	111%	110%	108%	105%	103%	
200-300			118%	116%	115%	114%	112%	111%	110%	109%			
100-200			116%	115%	115%	112%	113%	117%	112%	109%			
0-100	99%	124%	112%	112%	113%	117%	134%	130%	125%				

∆PR (= HALF CELLS – FULL CELLS)

1300-1400							0%	1%					
1200-1300						9%	-1%	1%	1%	4%			
1100-1200							0%	1%	1%	1%	1%	0%	1%
1000-1100						2%	1%	0%	1%	0%	1%	1%	
900-1000					1%	0%	0%	0%	0%	0%	0%	0%	0%
800-900				2%	1%	0%	0%	0%	0%	0%	-1%	0%	0%
700-800				0%	1%	0%	-1%	-1%	-1%	-1%	0%	0%	-1%
600-700				0%	0%	-1%	-1%	-2%	-2%	-1%	-1%	-1%	
500-600			-1%	-1%	-2%	-1%	-2%	-2%	-2%	-2%	-1%	0%	
400-500			-3%	-2%	-2%	-3%	-3%	-3%	-3%	-3%	-2%	-1%	
300-400			-4%	-2%	-3%	-4%	-4%	-4%	-3%	-3%	-2%		
200-300			-4%	-4%	-4%	-4%	-4%	-4%	-4%	-3%			
100-200			-6%	-6%	-5%	-6%	-4%	-2%	-3%	-4%			
0-100	-28%	-11%	-10%	-10%	-10%	-9%	-7%	-15%	-6%				
	-5	0	5	10	15	20	25	30	35	40	45	50	55
	0	5	10	15	20	25	30	35	40	45	50	55	60

Why such a low PR?

FF FOR FULL CELLS (L) AND HALF CELLS (R)

- Normal behaviour: at high G_{POA} => high I_{sc} => high R losses => low FF
- And also normal behaviour: at high T_{mod} => low V => low FF

Full Cells

1300-1400							72%	74%					
1200-1300						80%	75%	72%	74%	73%			
1100-1200							75%	76%	75%	74%	74%	74%	73%
1000-1100					78%	77%	77%	77%	76%	75%	75%	74%	
900-1000					79%	78%	78%	77%	76%	76%	75%	75%	74%
800-900				81%	80%	79%	78%	78%	77%	77%	76%	75%	75%
700-800				81%	80%	79%	79%	78%	78%	77%	77%	76%	76%
600-700			82%	81%	81%	80%	79%	79%	78%	78%	77%	77%	
500-600			82%	82%	81%	81%	80%	80%	79%	79%	78%	77%	
400-500			83%	82%	82%	81%	81%	80%	80%	80%	78%	78%	
300-400			83%	82%	82%	82%	81%	81%	81%	80%	78%		
200-300		84%	83%	83%	82%	82%	81%	81%	81%	79%			
100-200		84%	83%	83%	83%	82%	81%	79%	80%	81%			
0-100	84%	84%	83%	83%	82%	82%	82%	81%	82%				
	-5		5	10	15	20	25	30	35	40	45	50	
		5	10	15	20	25	30	35	40	45	50	55	

Half Cells

1300-1400							75%	78%					
1200-1300						80%	78%	75%	78%	75%	76%		
1100-1200							77%	78%	78%	76%	77%	76%	75%
1000-1100						79%	79%	78%	78%	78%	77%	76%	76%
900-1000					79%	79%	79%	78%	78%	78%	77%	77%	76%
800-900				81%	80%	79%	79%	79%	79%	78%	78%	77%	77%
700-800				81%	81%	80%	80%	79%	79%	79%	79%	78%	78%
600-700				81%	81%	81%	80%	80%	80%	79%	79%	78%	
500-600			82%	82%	81%	81%	81%	81%	80%	80%	79%	78%	
400-500			82%	82%	82%	82%	81%	81%	81%	80%	80%	80%	
300-400			82%	81%	82%	82%	82%	82%	81%	81%	80%	79%	
200-300		82%	82%	82%	82%	82%	82%	81%	81%	80%			
100-200		83%	83%	83%	83%	82%	82%	81%	81%	81%			
0-100	72%	83%	82%	82%	82%	82%	83%	82%	83%				
	-5		5	10	15	20	25	30	35	40	45	50	
		5	10	15	20	25	30	35	40	45	50	55	

DIFFERENCE IN FF (HALF CELLS – FULL CELLS)

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	-5 0	 5	5 10	10 15	15 20	20 25	25 30	30 35	35 40	40 45	45 50	50 55	
1300-1400							3%	4%					
1200-1300						0%	3%	3%	3%	2%			
1100-1200							2%	2%	2%	2%	3%	3%	2%
1000-1100						2%	2%	2%	2%	2%	2%	2%	
900-1000					0%	1%	2%	1%	2%	2%	2%	2%	2%
800-900				0%	0%	1%	1%	1%	2%	2%	2%	2%	2%
700-800				0%	0%	1%	1%	1%	2%	2%	2%	2%	2%
600-700				0%	0%	1%	1%	1%	1%	2%	2%	1%	
500-600			0%	0%	0%	1%	1%	1%	1%	2%	1%	2%	
400-500			0%	0%	0%	0%	1%	1%	1%	1%	1%	2%	
300-400			-1%	-1%	0%	0%	1%	0%	1%	0%	2%		
200-300		-1%	-1%	-1%	0%	0%	0%	0%	0%	1%			
100-200		-1%	-1%	-1%	0%	0%	1%	2%	2%	0%			
0-100		-1%	-1%	0%	-1%	0%	0%	1%	0%				

Nothing really significant in this ΔFF.

What is happening at low G_{POA}?

I_SC DIVIDED BY G_POA

Full Cells

	-5 0	0 5	5 10	10 15	15 20	20 25	25 30	30 35	35 40	40 45	45 50	50 55	55 60
1300-1400							9.8	10.4					
1200-1300						9.1	10.5	9.8	10.8	9.7			
1100-1200							10.5	10.5	10.5	10.6	10.6	10.8	10.7
1000-1100					10.8	10.7	10.5	10.6	10.4	10.6	10.6	10.6	
900-1000					10.6	10.5	10.6	10.5	10.6	10.6	10.6	10.6	10.6
800-900				10.8	10.6	10.5	10.6	10.5	10.5	10.6	10.7	10.5	10.6
700-800				10.7	10.6	10.5	10.5	10.6	10.6	10.7	10.7	10.6	10.6
600-700			11.0	10.7	10.6	10.6	10.6	10.7	10.7	10.7	10.7	10.6	
500-600			10.8	10.8	10.5	10.8	10.7	10.9	10.9	11.0	10.8	10.7	
400-500			10.9	10.7	10.7	10.9	10.8	10.9	11.0	11.0	10.7	11.0	
300-400			10.9	10.6	10.9	10.9	11.1	11.0	11.1	11.2	11.2		
200-300		11.0	10.9	10.9	11.0	11.1	11.2	11.3	11.2	11.5			
100-200		11.3	11.1	11.2	11.3	11.3	11.5	12.2	12.0	11.6			
0-100	12.0	12.6	11.9	11.9	12.2	12.7	14.2	15.0	13.6				

Half Cells

	-5 0	0 5	5 10	10 15	15 20	20 25	25 30	30 35	35 40	40 45	45 50	50 55	55 60
1300-1400							9.8	10.4					
1200-1300						10.3	10.4	9.9	10.7	10.1	10.7		
1100-1200							10.5	10.6	10.7	10.7	10.6	10.8	10.8
1000-1100						10.9	10.7	10.8	10.6	10.6	10.7	10.8	10.9
900-1000					10.9	10.7	10.7	10.7	10.7	10.6	10.7	10.7	10.7
800-900				11.2	11.0	10.7	10.8	10.7	10.6	10.6	10.7	10.6	10.6
700-800				11.0	10.9	10.7	10.7	10.7	10.6	10.6	10.7	10.7	10.6
600-700				11.0	10.8	10.7	10.8	10.7	10.7	10.7	10.7	10.6	
500-600			11.0	11.0	10.7	10.9	10.8	10.8	10.8	11.0	10.8	10.7	
400-500			11.0	10.9	10.8	11.0	10.8	10.8	10.9	10.9	10.7	10.9	
300-400			11.0	10.8	11.0	10.9	11.0	11.0	11.1	11.1	11.1	11.0	
200-300		11.1	11.0	10.9	11.0	11.0	11.1	11.2	11.2	11.5			
100-200		11.2	11.0	11.1	11.2	11.1	11.4	12.0	11.8	11.6			
0-100	11.2	12.1	11.4	11.4	11.7	12.3	13.9	13.8	13.4				

- Equal or Different ? See next slide.

DIFFERENCE IN (BIFACIAL) I_SC/G_POA

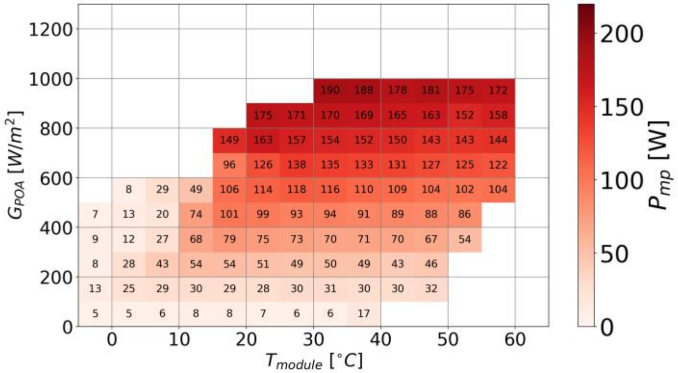
1300-1400							-0.1	0.0					
1200-1300						1.2	-0.1	0.1	-0.1	0.3			
1100-1200							0.1	0.1	0.1	0.1	0.1	0.0	0.2
1000-1100						0.3	0.1	0.2	0.1	0.0	0.1	0.2	
900-1000					0.3	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1
800-900				0.4	0.3	0.2	0.2	0.2	0.1	0.0	0.0	0.1	0.1
700-800				0.3	0.3	0.2	0.2	0.1	0.0	0.0	0.0	0.1	0.1
600-700				0.3	0.3	0.2	0.2	0.0	0.0	0.0	0.0	0.0	
500-600			0.2	0.2	0.2	0.2	0.1	-0.1	-0.1	0.0	0.0	0.1	
400-500			0.1	0.2	0.1	0.1	0.0	-0.1	-0.1	-0.1	-0.1	0.0	
300-400			0.1	0.2	0.1	0.0	-0.1	-0.1	-0.1	0.0	-0.1		
200-300		0.0	0.1	0.1	-0.1	-0.1	-0.1	-0.1	0.0	-0.1			
100-200		-0.1	-0.1	-0.1	-0.1	-0.2	-0.2	-0.2	-0.2	-0.1			
0-100		-0.6	-0.6	-0.5	-0.5	-0.5	-0.3	-1.2	-0.2				
	-5	0	5	10	15	20	25	30	35	40	45	50	55
	0	5	10	15	20	25	30	35	40	45	50	55	60

- Found root cause ! Clearly drop in I_{sc}/G_{POA} for half-cells at lower irradiance.
- Damages due to cutting increase recombination. At low irradiance (low injection) most sensitive.

CONCLUSION

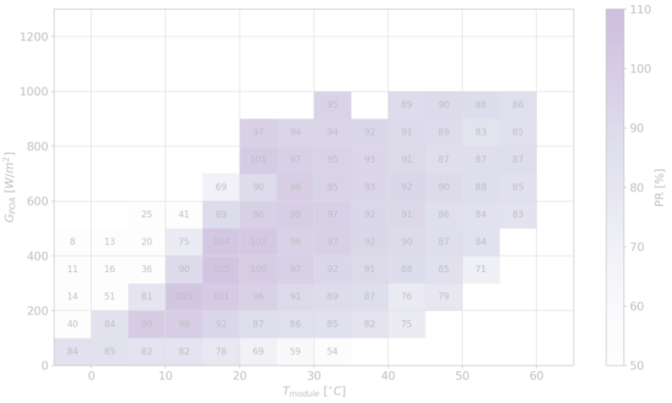
61853-MATRIX STYLE IS PERFECT TOOL FOR RESEARCH ON PV TECHNOLOGIES

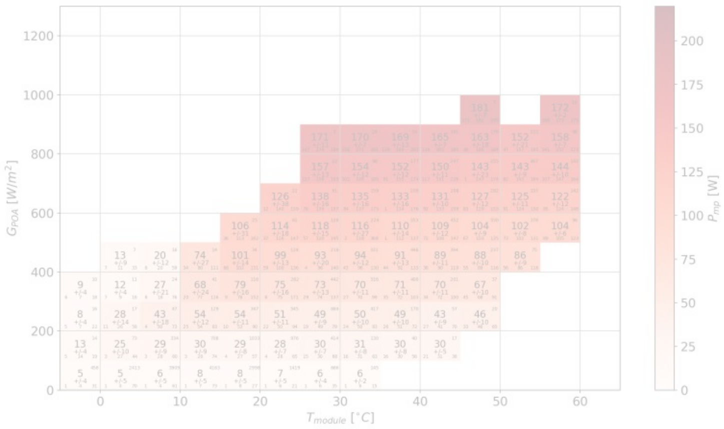
- Making the 7x4 matrix more fine with 100 W/m² and 5°C bins.
- Plotting not only P_{MPP}, but any PV-panel parameter (e.g. V_{OC}, V_{MPP}, PR).
- Analyzing statistics per bin is a tool for cleaning outdoor data.



- Presented use cases:
  1. Comparison of monofacial with bifacial:
     - ΔPR gain highest for low G_{POA}
     - For bifi: PR-matrix based on G_{BIF} looks similar to mono PR-matrix.
     - Hence irradiance boost at low G_{POA}
  2. Comparison of bifacial full-cells with bifacial half-cells:
     - ΔPR drop for low G_{POA} for half-cells not caused by FF (?)
     - Root cause found in Δ (I_{sc}/G_{POA})-matrix! Effect attributed to cutting losses

THE REFINED 61853-MATRIX IS THE TOOL FOR ENERGY RATING AND ANALYSIS OF PV TECHNOLOGIES, LIKE BIFACIAL





THANK YOU FOR YOUR ATTENTION