Bifacial Solar System On Flat Roofs: Wind loads and Heat Transfer Coefficients

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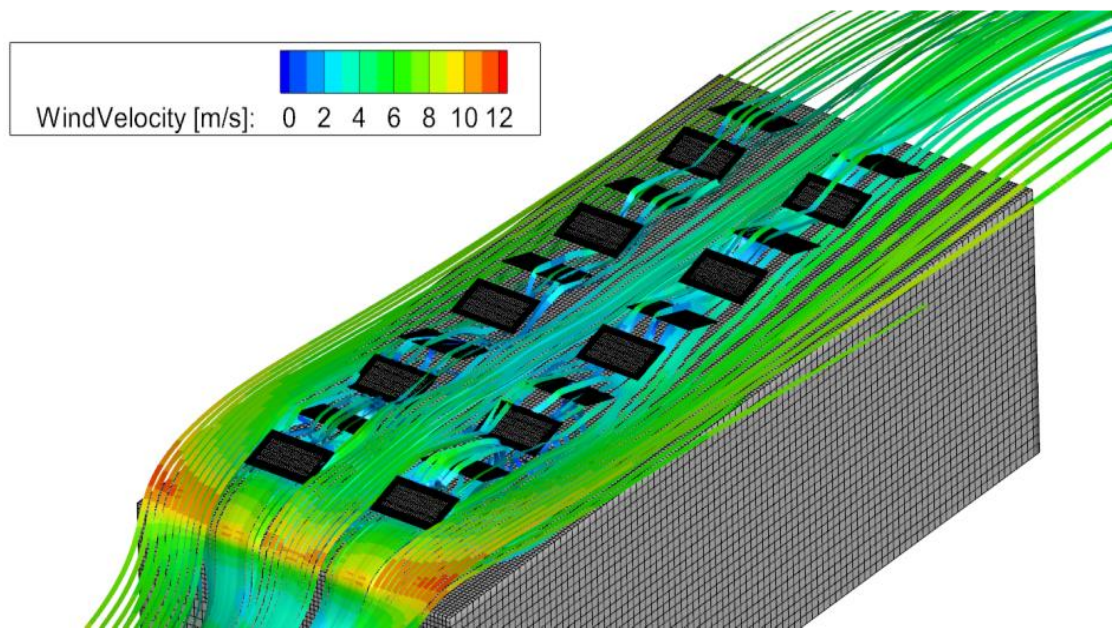
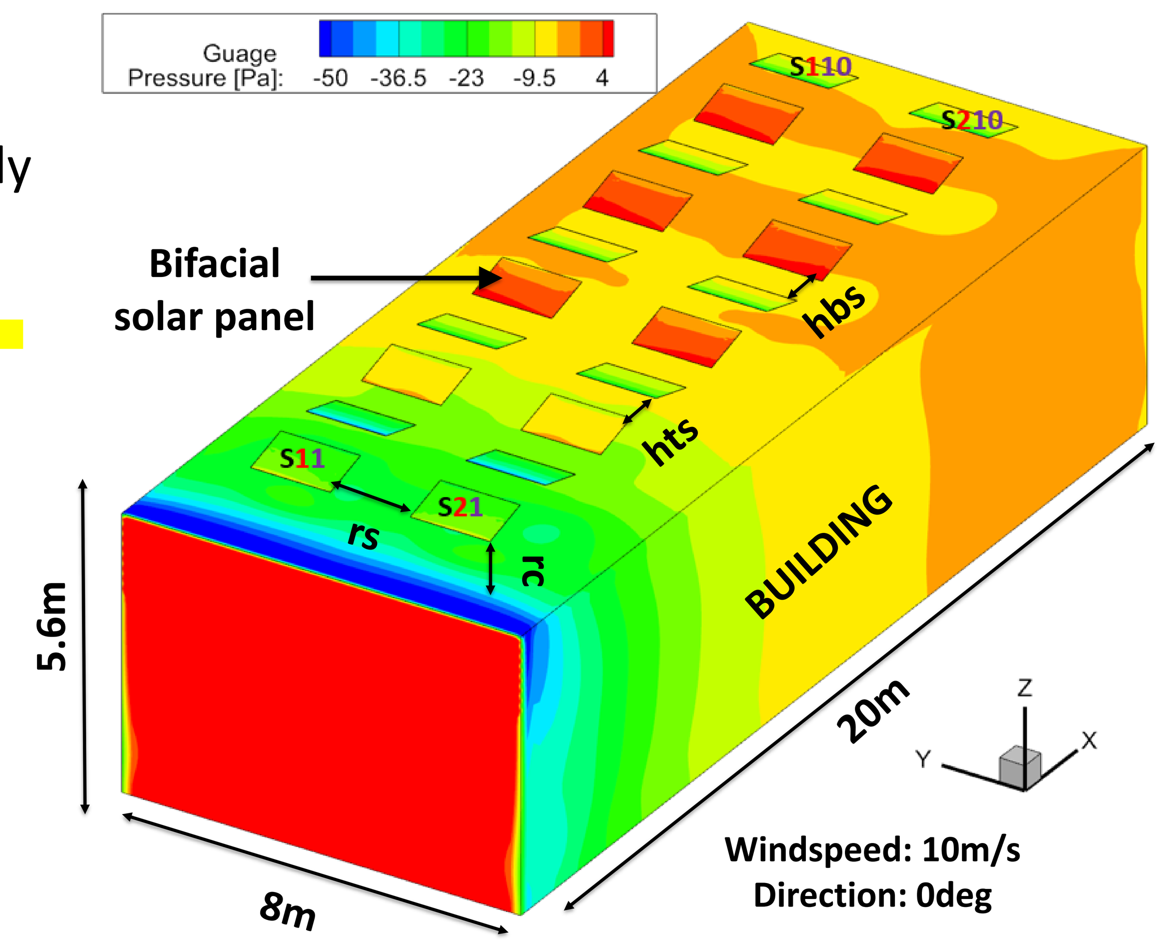
Solar systems with bifacial panels can give 10-20% higher energy yield

- **Higher energy yield can be reached with:**
    1. High ground albedo (e.g. white roof)
    2. Higher distance from ground (ground clearance)
    3. More space around modules
- **PV systems on roof with elevated mounting structure, face challenge of high wind loads**

Wind impact on flat-roof PV systems

- A system should not exceed high downward force (20 kg/m^2) to maintain structural integrity of roof construction
- High lift forces demands heavier ballast, thus the lift forces are also required to be maintained below 20 kg/m^2.
- On the positive side: wind brings convective cooling (HTC), that beneficially affects on energy yield. (0.5%^{rel}/^{o}C)





Approach (parametric study):

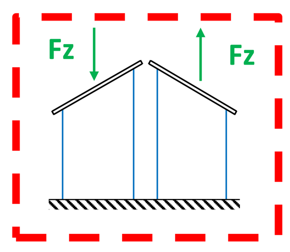
- Fixed building (20x8x5.6m) with 20 modules with East-West 'hat' configuration
- Geometry parameters:

Row spacing (rs)	0.3, 0.9 m
Roof clearance (rc)	0.3, 0.6 m
Hat top- and bottom spacing (hts/hbs)	0.1, 0.3, 0.5 m
Module inclination	15 deg

- Wind conditions:

speed (roof height)	10, 20 and 30 m/s
Direction	0, 22.5, 45, 67.5, 90 deg

- Compute wind impact using validated CFD model (validation case[1,2])
    - Output: Forces and heat transfer coefficients (HTC)
- Compute energy yield using Bigeye model[3]
- **Input: Geometry and HTC values from wind CFD model**



Fz [N]

S	1	2	3	4	5	6	7	8	9	10
1	-13	10	-15	9	-20	16	-21	19	-22	22
2	-13	10	-15	9	-20	16	-21	19	-22	22

Fx [N]

S	1	2	3	4	5	6	7	8	9	10
1	5	3	4	3	6	4	6	5	6	6
2	5	3	4	3	6	4	6	5	6	6

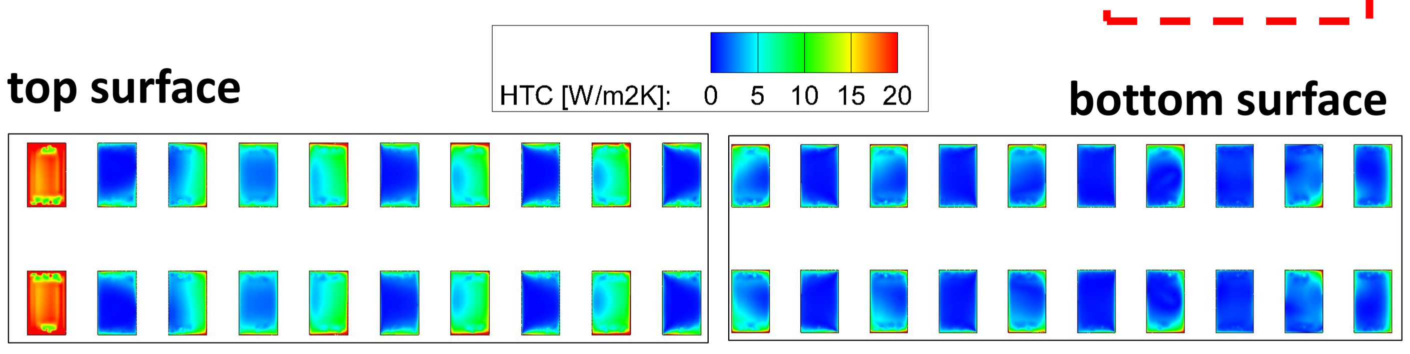
Module top convective HTC [W/m2/K]

S	1	2	3	4	5	6	7	8	9	10
1	19	2	6	4	8	3	8	3	8	3
2	19	2	6	4	8	3	8	3	8	3

Module bottom convective HTC [W/m2/K]

S	1	2	3	4	5	6	7	8	9	10
1	3	3	1	3	1	4	2	4	2	5
2	3	3	1	3	1	4	2	4	2	5

top surface



bottom surface

Parametric results

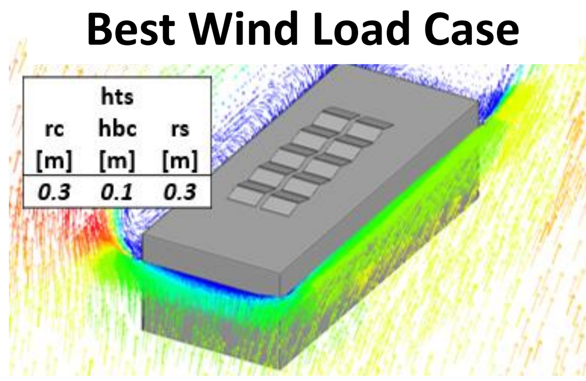
General trends:

- Increase roof clearance **(rc)** or module hat spacing **(hts, hbc)**
    - Increased forces
    - Increased heat transfer
- Increased module row spacing **(rs)**
    - Reduced Fz (lift/weight) forces
    - Increased heat transfer
- Maximum force are found at the wind direction of 22.5deg

hts			Max Forces [N]			HTC [W/m2/K]			Yield
rc [m]	hbc [m]	rs [m]	Lift (+Fz)	Weight (-Fz)	Side (Fx, Fy)	Top sur. (max)	Bottom sur. (max)	(Avg)	(kWh) using Avg HTC
0.3	0.1	0.3	48	63	18	37	20	13.1	5513
0.3	0.1	0.9	45	67	19	38	21	13.7	5593
0.3	0.3	0.3	49	73	20	37	21	14.2	5763
0.3	0.3	0.9	47	70	20	37	23	15.8	5862
0.3	0.5	0.3	53	80	22	36	25	15.5	5930
0.3	0.5	0.9	52	76	21	36	25	16.3	6012
0.6	0.1	0.3	58	71	21	41	23	17.4	5879
0.6	0.1	0.9	56	74	21	42	24	18.4	6023
0.6	0.3	0.3	58	75	22	41	25	18.1	6110
0.6	0.3	0.9	40	78	22	42	25	18.6	6228
0.6	***0.5***	***0.3***	***60***	***86***	***24***	***41***	***32***	20.6	6306
0.6	0.5	0.9	58	82	23	41	32	23.0	6443

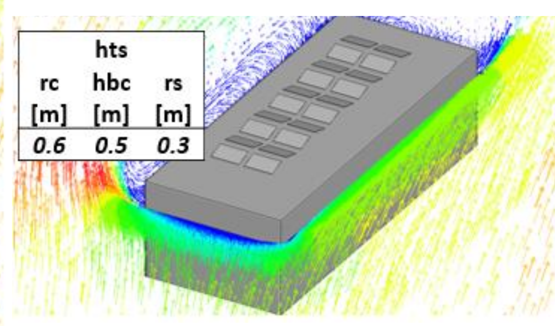
Chance** of max(|Fz|) > 20kg/m2

Best Wind Load Case

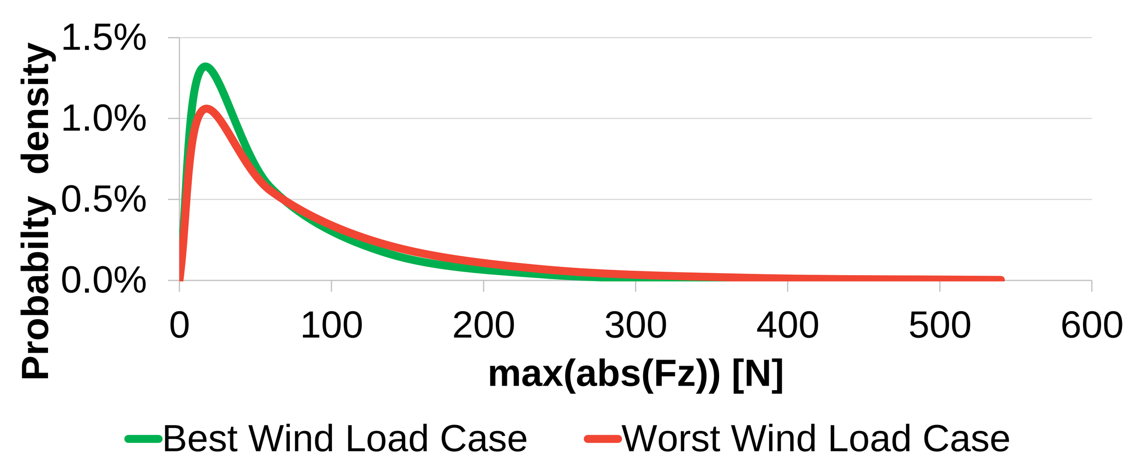


0.9%/year

Worst Wind Load Case



2.9%/year



Conclusions

- Lift and weight forces higher than side forces.
- Hat system: Odd panels downward force, Even panels upward force
- 1-3% chance that F-down is higher than 20 kg/m2.
- Highest force: wind direction 22.5 degrees
- Highest energy yield for open systems at the expense of higher wind forces i.e. HTC improves with ground clearance/spacing and it is synergetic with light access.
- Tailored system design required to equilibrate up and down forces.

Acknowledgements

- Project biface: Netherlands Enterprise Agency (www.rvo.nl), SOLAR-ERA.NET, Austrian institute of Technology (AIT)

1. Richards, P. J., and R. P. Hoxey. "Pressures on a cubic building—Part 1: Full-scale results." Journal of Wind Engineering and Industrial Aerodynamics 102 (2012): 72-86.
2. Hölscher N, Niemann H-J. Towards quality assurance for wind tunnel tests: a comparative testing program of the Windtechnologische Gesellschaft. Journal of Wind Engineering and Industrial Aerodynamics 1998;74e76:599e608.
3. Poster A.R. Burgers at this workshop & G.J.M. Janssen et al., Energy Procedia 77 (2015) 364

** Considering 1.5 safety factor (on computed forces) with wind probability density for Petten, Netherlands, 2007 at 32m height.