Supporting Information

Quantification of the Impact of Fine Particulate Matter on Solar Energy Resources and Energy Performance of Different Photovoltaic Technologies

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Table S1. Key specifications of the PV modules used in the experiments. The details of the model and manufacturer of all PV modules are faded away to avoid conflicts of interest.

PV module		Specification [a]								
		$P_{m,ref}$ (W)	$V_{oc,ref}$ (V)	$I_{sc,ref}$ (A)	$V_{mp,ref}$ (V)	$I_{mp,ref}$ (A)	Dimension (mm×mm)	α (%/°C)	β (%/°C)	γ (%/°C)
mono-Si	#1	305	40.2	9.94	33.0	9.24	1650×991	0.059	–0.30	–0.39
	#2	300	39.76	9.77	32.41	9.26	1670×1000	0.04	–0.28	–0.39
poly-Si	#1	280	38.65	9.37	31.61	8.86	1650×991	0.058	–0.33	–0.40
	#2	275	38.72	9.35	31.36	8.77	1670×1000	0.04	–0.29	–0.40
a-Si	#1	140	42.3	5.28	32.2	4.34	1310×1110	0.01	–0.38	–0.47
	#2	130	73.42	2.76	53.94	2.41	1300×1100	0.07	–0.32	–0.29
CIGS	#1	140	106.7	1.79	86.5	1.62	1190×790	0.01	–0.27	–0.32
	#2	115	37.6	4.52	29.7	3.87	2598×370	0.008	–0.28	–0.38
CdTe	#1	107.5	86.6	1.75	68.6	1.57	1200×600	0.04	–0.29	–0.34
	#2	80	118.9	0.95	94.1	0.85	1200×600	0.06	–0.321	–0.214

[a] $P_{m,ref}$, $V_{oc,ref}$, $I_{sc,ref}$, $V_{mp,ref}$, $I_{mp,ref}$, α, β, and γ refer to maximum power at standard test conditions (STC), the open-circuit voltage at STC, short-circuit current at STC, the voltage at maximum power point (MPP) at STC, current at MPP at STC, temperature coefficient of $I_{sc,ref}$, temperature coefficient of $V_{oc,ref}$, and temperature coefficient of $P_{m,ref}$, respectively.

Table S2. Estimated absolute and relative changes in E_{AC} and Y_f of ten solar PV systems for given conditions of PM2.5 pollution in Hong Kong.

PV module	mono-Si		poly-Si		a-Si		CIGS		CdTe	
	#1	#2	#1	#2	#1	#2	#1	#2	#1	#2
baseline										
E_{AC} (Wh)	1643.00	1513.71	1426.88	1384.42	633.21	660.00	686.63	613.21	648.00	414.79
Y_f (kWh/kWp)	5.39	5.05	5.10	5.03	4.52	5.08	4.90	5.33	6.03	5.18
0–12.0 μg/m³ PM2.5										
E_{AC} (Wh)	1624.75	1510.85	1430.42	1389.15	634.81	659.31	684.48	618.13	651.83	415.27
ΔE_{AC} (Wh)	−18.25	−2.85	3.54	4.73	1.60	−0.69	−2.15	4.92	3.83	0.48
Y_f (kWh/kWp)	5.33	5.04	5.11	5.05	4.53	5.07	4.89	5.38	6.06	5.19
ΔY_f (kWh/kWp)	−0.06	−0.01	0.01	0.02	0.01	−0.01	−0.02	0.04	0.04	0.01
ΔE_{AC}, ΔY_f (%)	−1.11	−0.19	+0.25	+0.34	+0.25	−0.10	−0.31	+0.80	+0.59	+0.12
12.1–35.4 μg/m³ PM2.5										
E_{AC} (Wh)	1580.99	1472.02	1396.03	1376.40	611.28	638.11	667.41	620.49	627.31	393.31
ΔE_{AC} (Wh)	−62.01	−41.69	−30.84	−8.02	−21.93	−21.89	−19.22	7.28	−20.69	−21.48
Y_f (kWh/kWp)	5.18	4.91	4.99	5.01	4.37	4.91	4.77	5.40	5.84	4.92
ΔY_f (kWh/kWp)	−0.20	−0.14	−0.11	−0.03	−0.16	−0.17	−0.14	0.06	−0.19	−0.27
ΔE_{AC}, ΔY_f (%)	−3.77	−2.75	−2.16	−0.58	−3.46	−3.32	−2.80	+1.19	−3.19	−5.18
35.5–55.4 μg/m³ PM2.5										
E_{AC} (Wh)	1517.99	1392.80	1335.41	1301.30	571.71	589.04	629.62	575.12	581.81	369.13
ΔE_{AC} (Wh)	−125.01	−120.90	−91.46	−83.12	−61.50	−70.96	−57.01	−38.09	−66.19	−45.66
Y_f (kWh/kWp)	4.98	4.64	4.77	4.73	4.08	4.53	4.50	5.00	5.41	4.61
ΔY_f (kWh/kWp)	−0.41	−0.40	−0.33	−0.30	−0.44	−0.55	−0.41	−0.33	−0.62	−0.57
ΔE_{AC}, ΔY_f (%)	−7.61	−7.99	−6.41	−6.00	−9.71	−10.75	−8.30	−6.21	−10.21	−11.01

Table S3. Nomenclature.

Abbreviations	
AC	alternating current
AQI	air quality index
a-Si	amorphous silicon
CdTe	cadmium telluride
CIGS	copper indium gallium selenide
c-Si	crystalline silicon
DC	direct current
mono-Si	monocrystalline silicon
MPP	maximum power point
PM2.5	fine particulate matter
POA	point-of-array
poly-Si	polycrystalline silicon
PV	photovoltaic
STC	standard test conditions
Symbols	
AM	air mass
E_{AC}	net AC energy output (Wh)
h	altitude (m)
I_0	extraterrestrial horizontal irradiance (W/m^2)
I_c	clear sky irradiance (W/m^2)
I_d	diffuse horizontal irradiance (W/m^2)
I_g	global horizontal irradiance (W/m^2)
$I_{mp,ref}$	current at MPP at STC (A)
I_{POA}	point-of-array irradiance (W/m^2)
I_{ref}	PV reference irradiance (I_{ref} = 1000 W/m^2)
$I_{sc,ref}$	short-circuit current at STC (A)
K_d	diffuse fraction
K_t	clearness index
P_0	installed nominal power (kWp)
$P_{m,ref}$	maximum power at STC (W)
PR	performance ratio (%)
R	correlation coefficient
T_L	Linke turbidity coefficient
$V_{oc,ref}$	open-circuit voltage at STC (V)
$V_{mp,ref}$	voltage at MPP at STC (V)
Y_f	final yield (kWh/kWp)
Y_{ref}	reference yield (kWh)
α	temperature coefficient of $I_{sc,ref}$ (%/°C)

α_s	solar altitude angle (°)
β	temperature coefficient of $V_{oc,ref}$ (%/°C)
γ	temperature coefficient of $P_{m,ref}$ (%/°C)

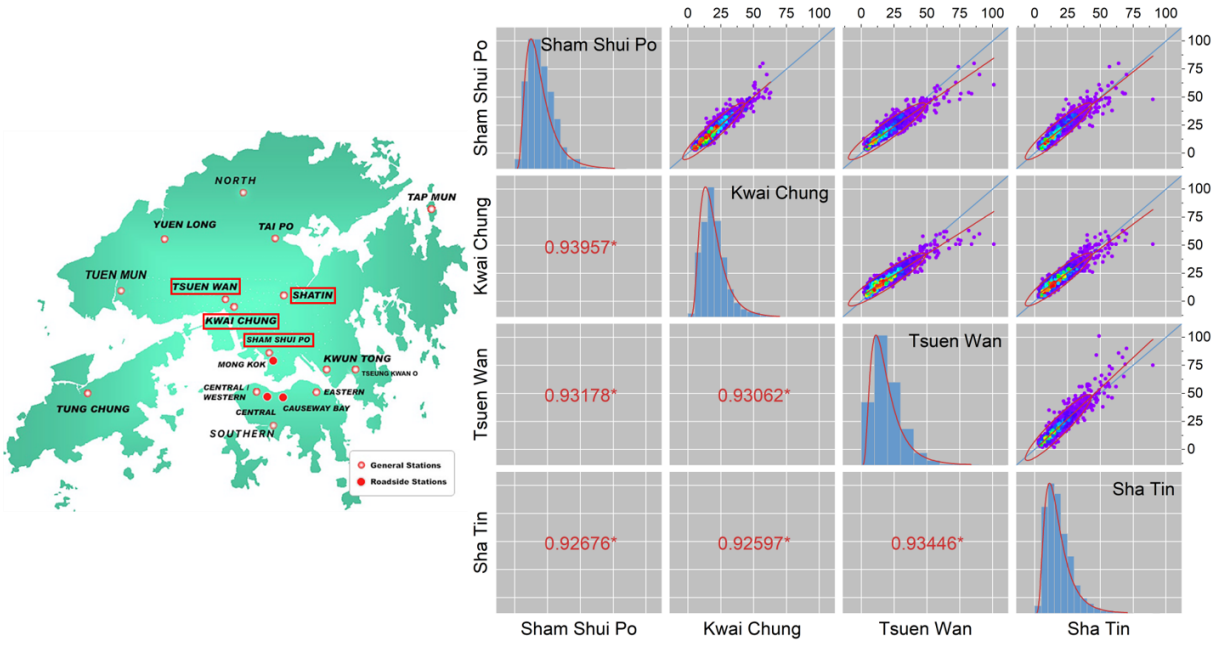

Figure S1. Correlation matrix for Tsuen Wan, Kwai Chung, Sha Tin, and Sham Shui Po air quality monitoring stations. The air-line distances between the four general stations are within 7 kilometers. * denotes significant correlations at the 0.01 level ($p < 0.01$). PM2.5 concentration data were taken from the Environmental Protection Department of Hong Kong (https://cd.epic.epd.gov.hk/). From 2016 to 2020, the point-to-point correlation between the measured time series in those stations was more than 0.92, indicating a statistically significant ($p < 0.01$) relationship. Also, there is an obvious correlation between the statistical distributions of PM2.5 concentration values.

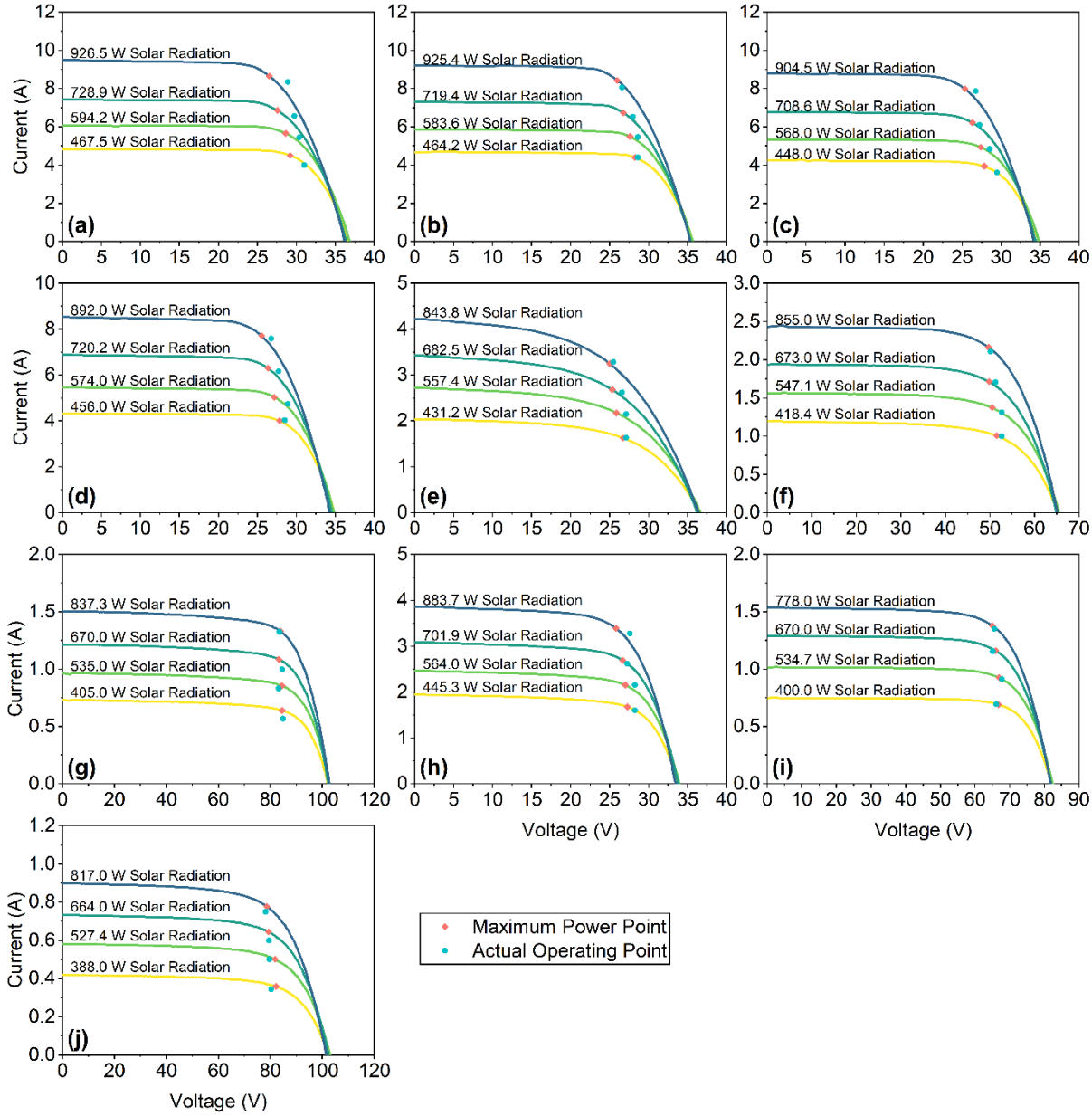

Figure S2. Calibration of the power output from optimizers by I-V curve tests for (a) mono-Si #1, (b) mono-Si #2, (c) poly-Si #1, (d) poly-Si #2, (e) a-Si #1, (f) a-Si #2, (g) CIGS #1, (h) CIGS #2, (i) CdTe #1, and (j) CdTe #2 under different levels of solar radiation from 300 W to 1000 W. The rhombic points are the currents and voltages recorded by the optimizer/inverter of the system, while the circular points and lines indicate the I-V curves measured by the I-V checker. The results show that the maximum power points tracked by the optimizers/inverter are all close to the maximum power points detected by the I-V curve checker, demonstrating that the PV modules did produce their maximum power at any time.

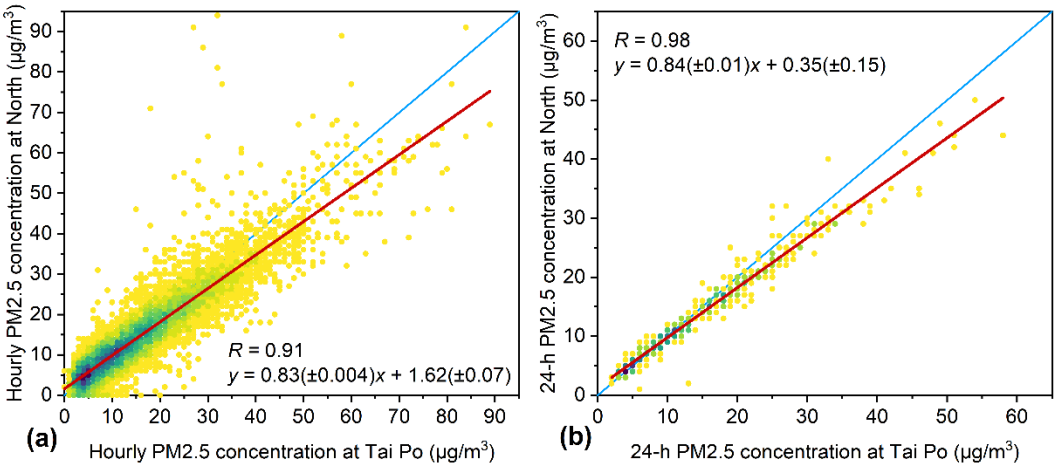

Figure S3. Correlation between PM2.5 concentration recorded at the experimental site (North station) and Tai Po station between 10 July 2020 and 31 October 2021 with (a) hourly, and (b) 24-h frequency. PM2.5 concentration data were taken from the Environmental Protection Department of Hong Kong (https://cd.epic.epd.gov.hk/).