



Performance study of 10 MW_p grid connected photovoltaic systems installed at Arizona State University campus

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ARIZONA STATE UNIVERSITY



**Fossil fuel
dependence
and
emissions**

**ASU
campus
solarization
status**

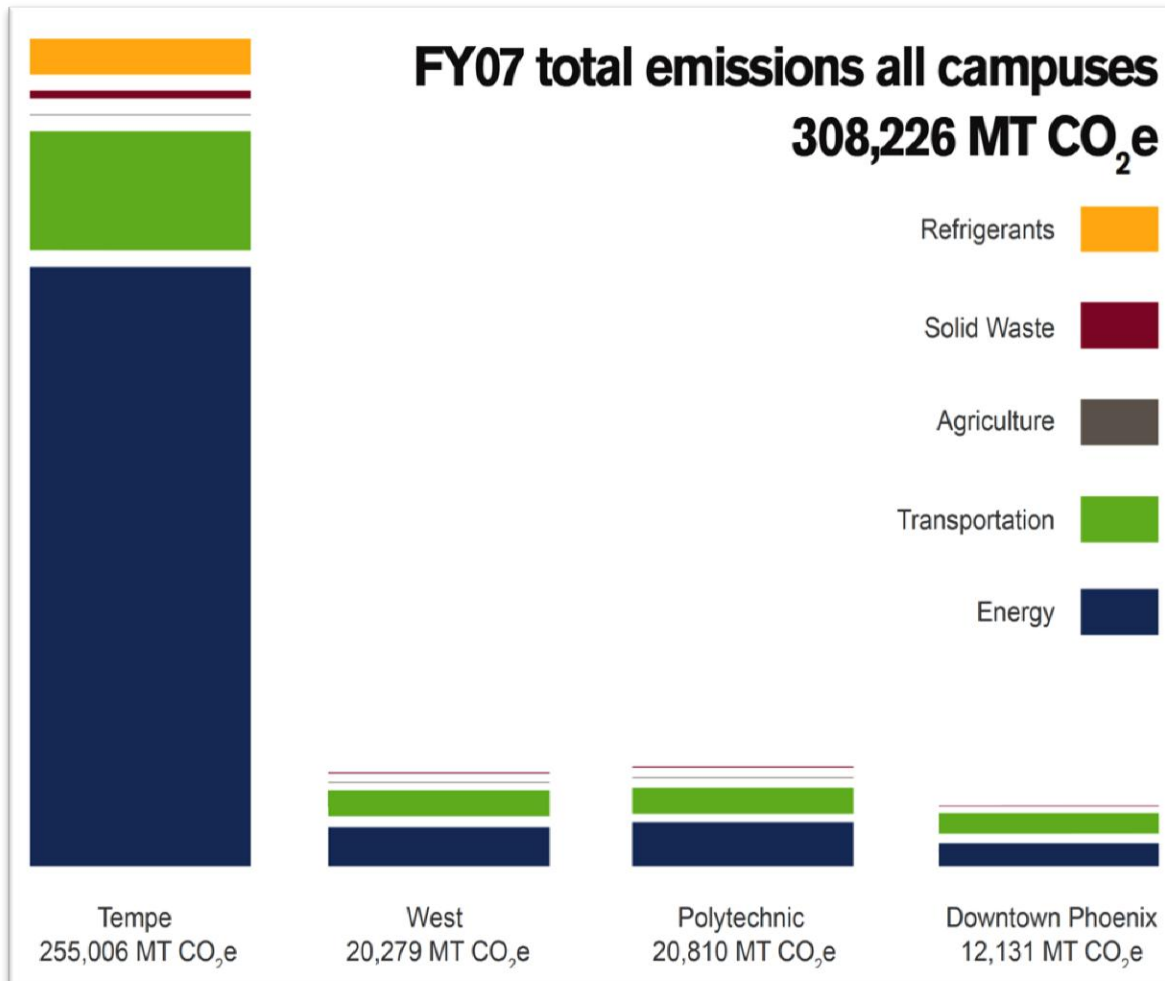
**Campus
Metabolism**

**Peak
electricity
load offset**

**Dust
storms**

**Capacity
factor of PV
systems**

CAMPUS ENERGY USAGE ACCOUNTED FOR 75% OF TOTAL CO₂ EMISSIONS



Electricity
purchased from
local utility
companies was
generated from
fuel sources such as
**coal, natural
gas & nuclear**

campus solarization

campus wide
PV system
installations to
reduce CO₂
emissions &
achieve carbon
neutrality

more than **14**
MW dc installed
capacity on 38
structures
(rooftops,
parking lots,
open spaces)

PV systems
vary in **type**
(fixed tilt vs.
tracking), size
(**13 kW – 2.6**
MW)



data collection

Campus Metabolism is an interactive web tool that displays real-time energy use on campus.



Total currently being tracked on Campus Metabolism:

New: Barrett's College is online.

New: Renewable Energy Data.

Electricity
6689.3
kW

Heating
22.72
mmBtu / hr

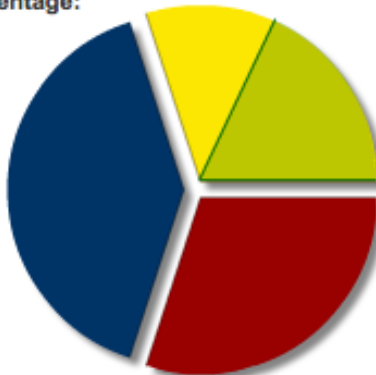
Cooling
2521.8
tons

Renewables
3948.2
kW

Total Usage by Percentage:

Renewables not included in total, they reduce usage.

■ Electricity 30%
■ Heating 30%
■ Cooling 40%
■ Renewables 59% of Electricity



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Units: Default kW mmBTU/hr ton

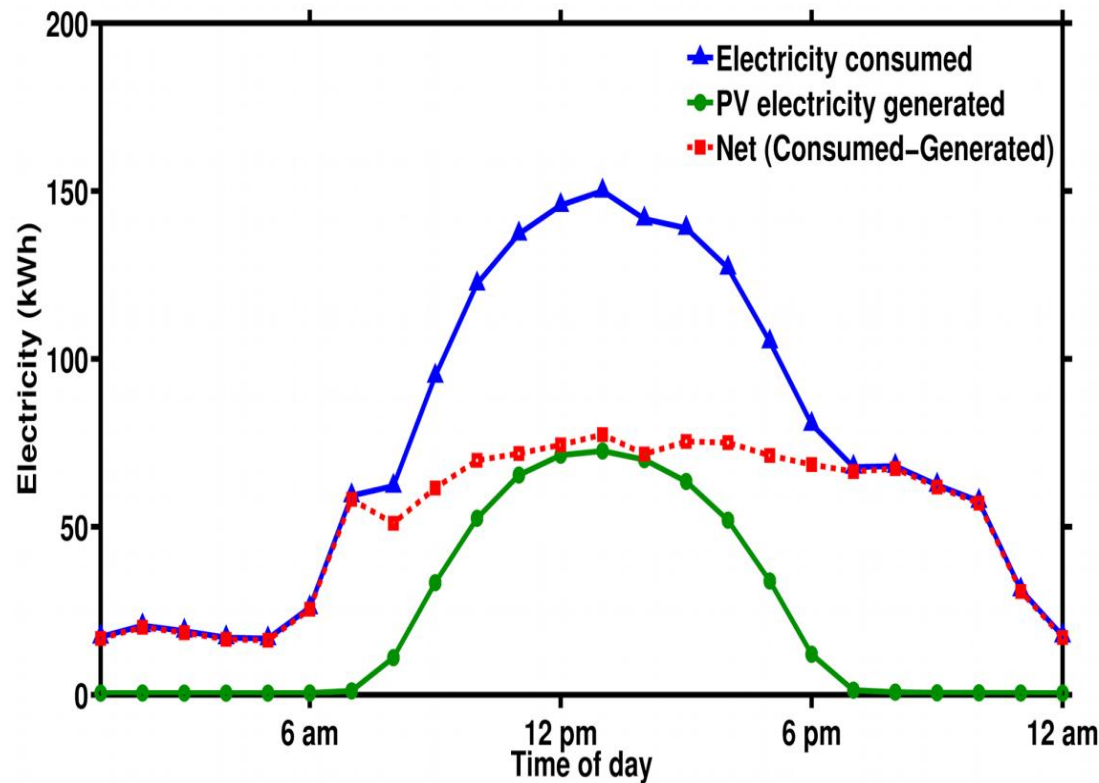
Availability of **weather data, building energy usage & PV generated electricity data**

Real time (1 hour interval) energy data collection for Tempe campus for 1 year

Actual measured PV data & electricity usage data instead of simulated data

Campus Metabolism

peak electricity load offset - I



electricity consumed
does not include cooling
load – chilled water
circulation from central
plant



resembles a typical office weekday electricity demand curve -
different from general buildings (residential halls, libraries,
parking structures)

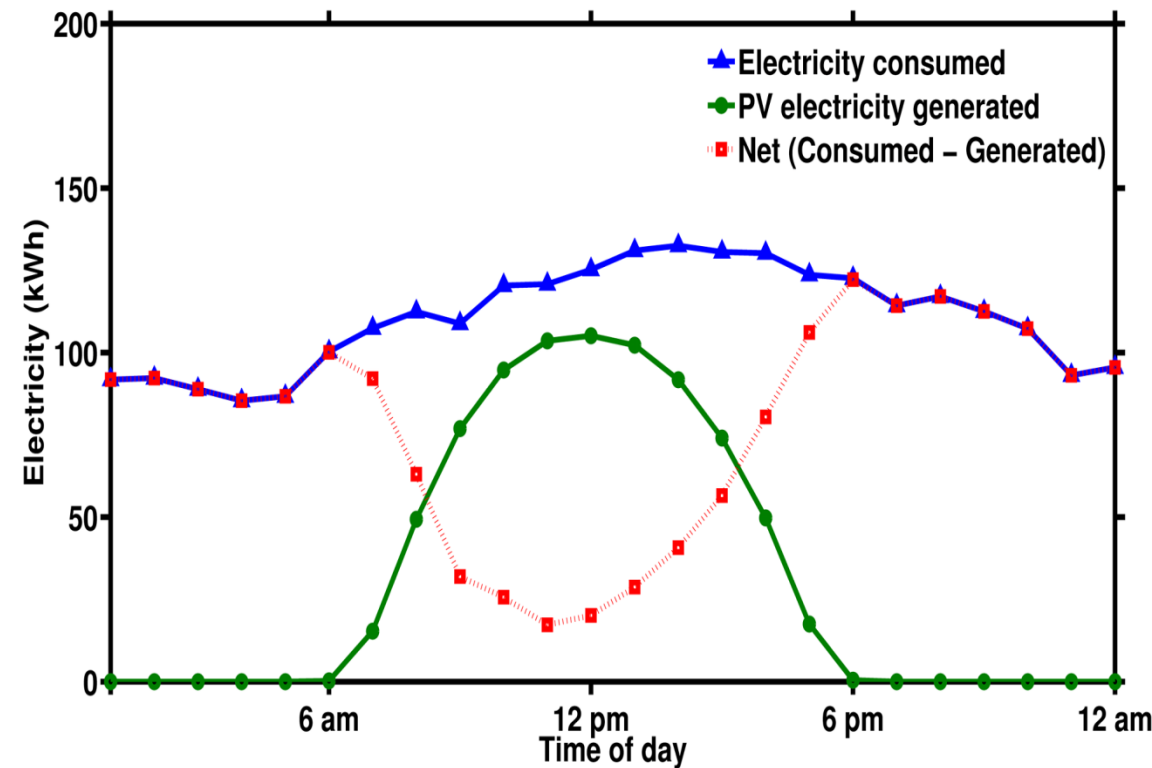


50% peak demand offset by closely matched PV
generation

peak electricity load offset - II



Bldg. B: Standalone structure with heating and cooling load factored into the electricity load

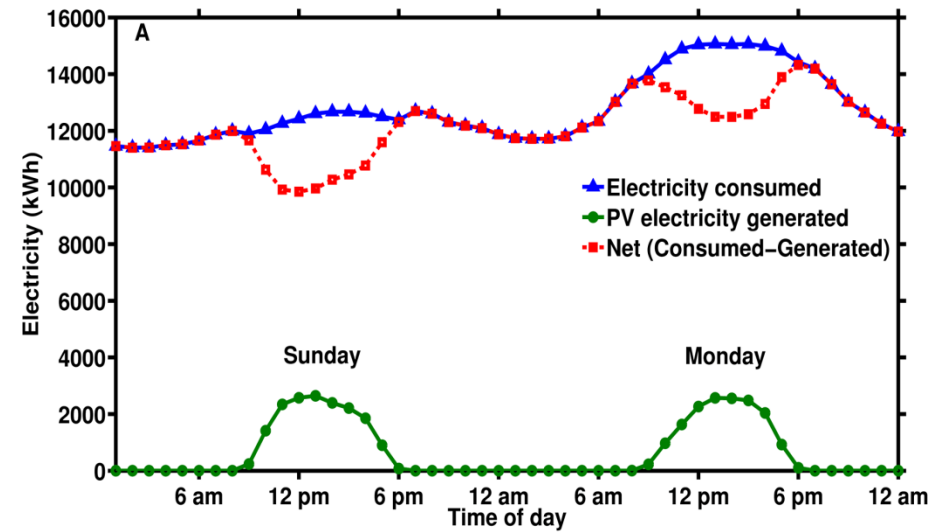


Gymnasium building – **higher demand during night hours**

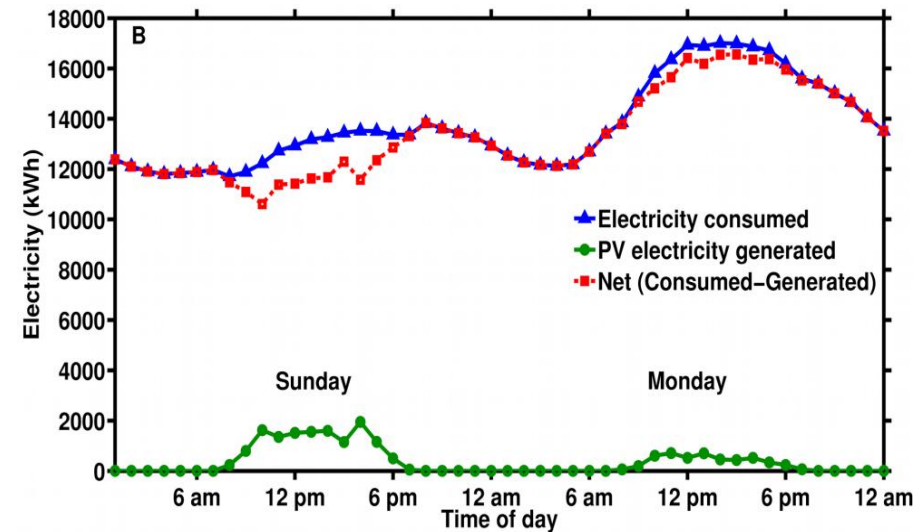


PV system easily offsets approx. **85% of the electricity demand**

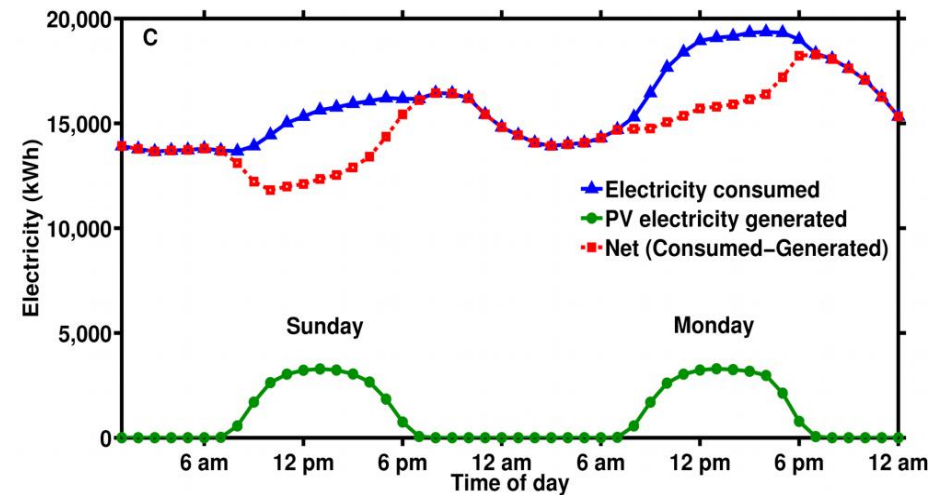
peak load offset – Tempe campus total



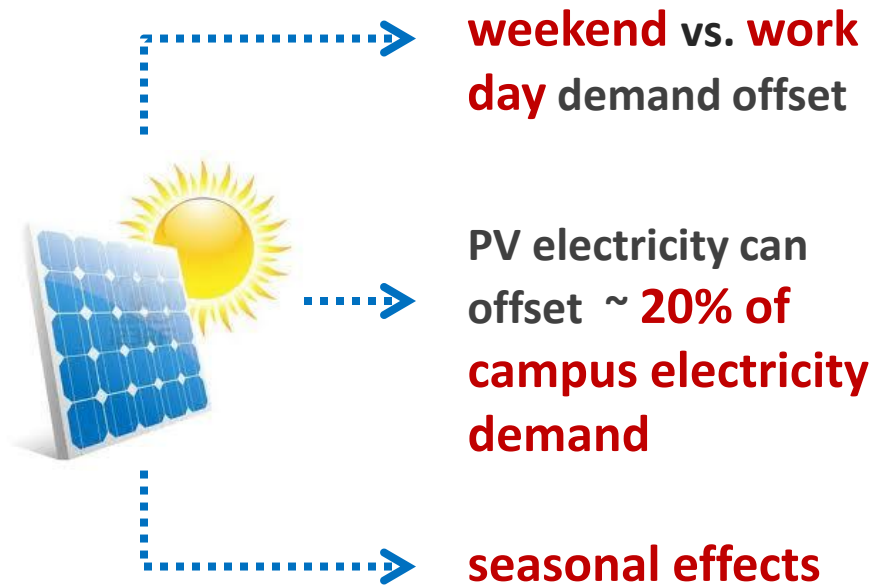
Winter



Rain



Summer



CO₂ emission reductions



PV electricity offsets **20%** of university's electricity demand



Total PV electricity generated :
8887000 kWh
(Oct. 1st 2010 – Sept. 31st 2011)



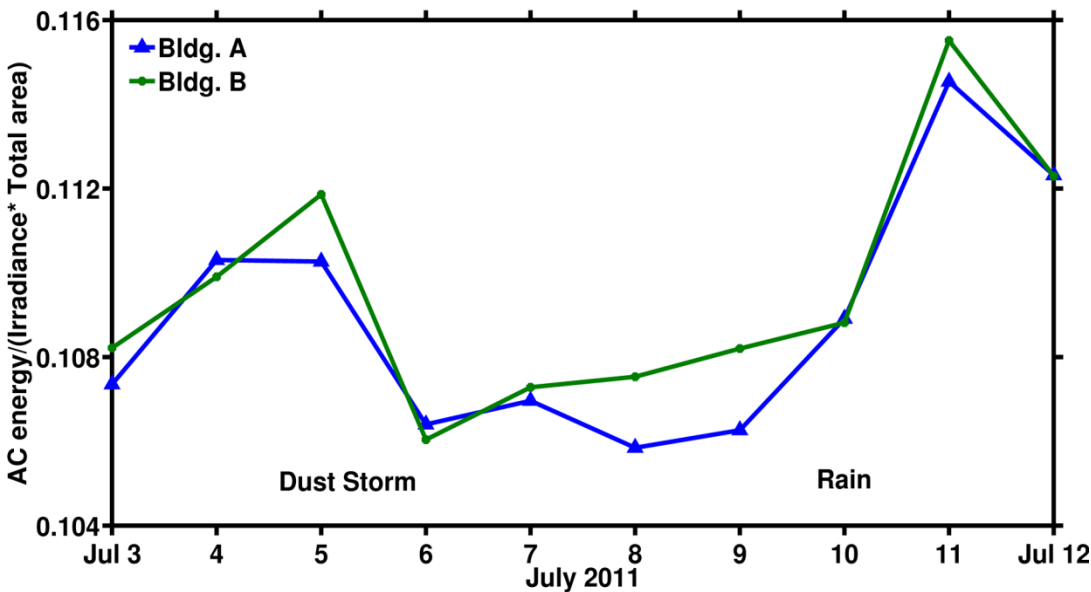
US annual non-baseload emission rate:
 6.895×10^{-4} metric ton CO₂/kWh

total annual CO₂ offset : 6128 metric tons

dust storm – July 5th 2011



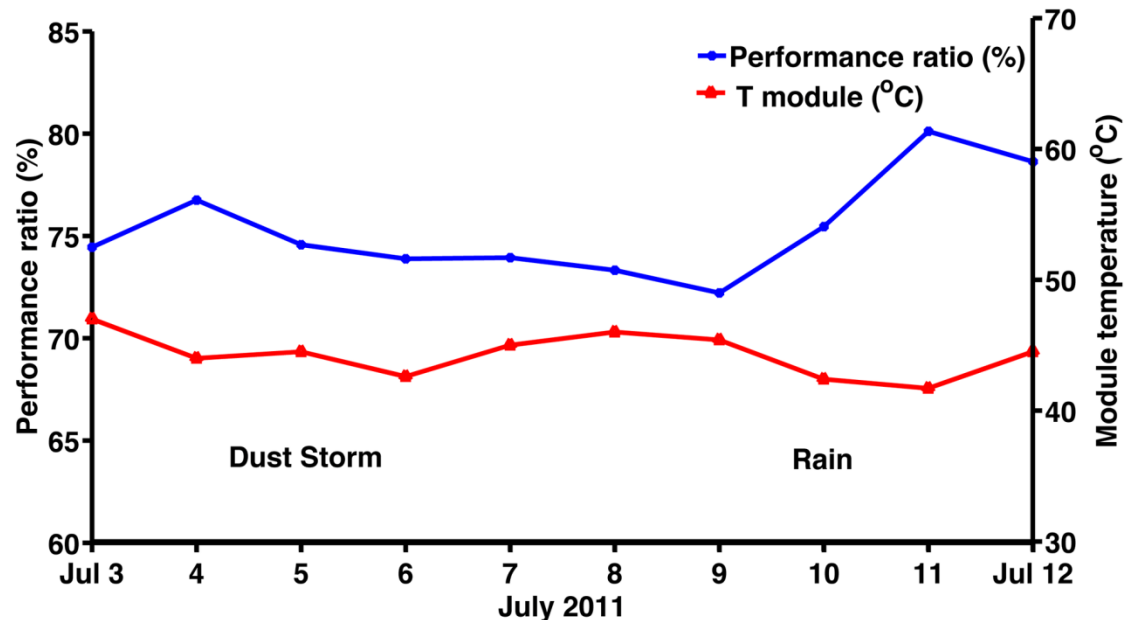
effect of dust storm



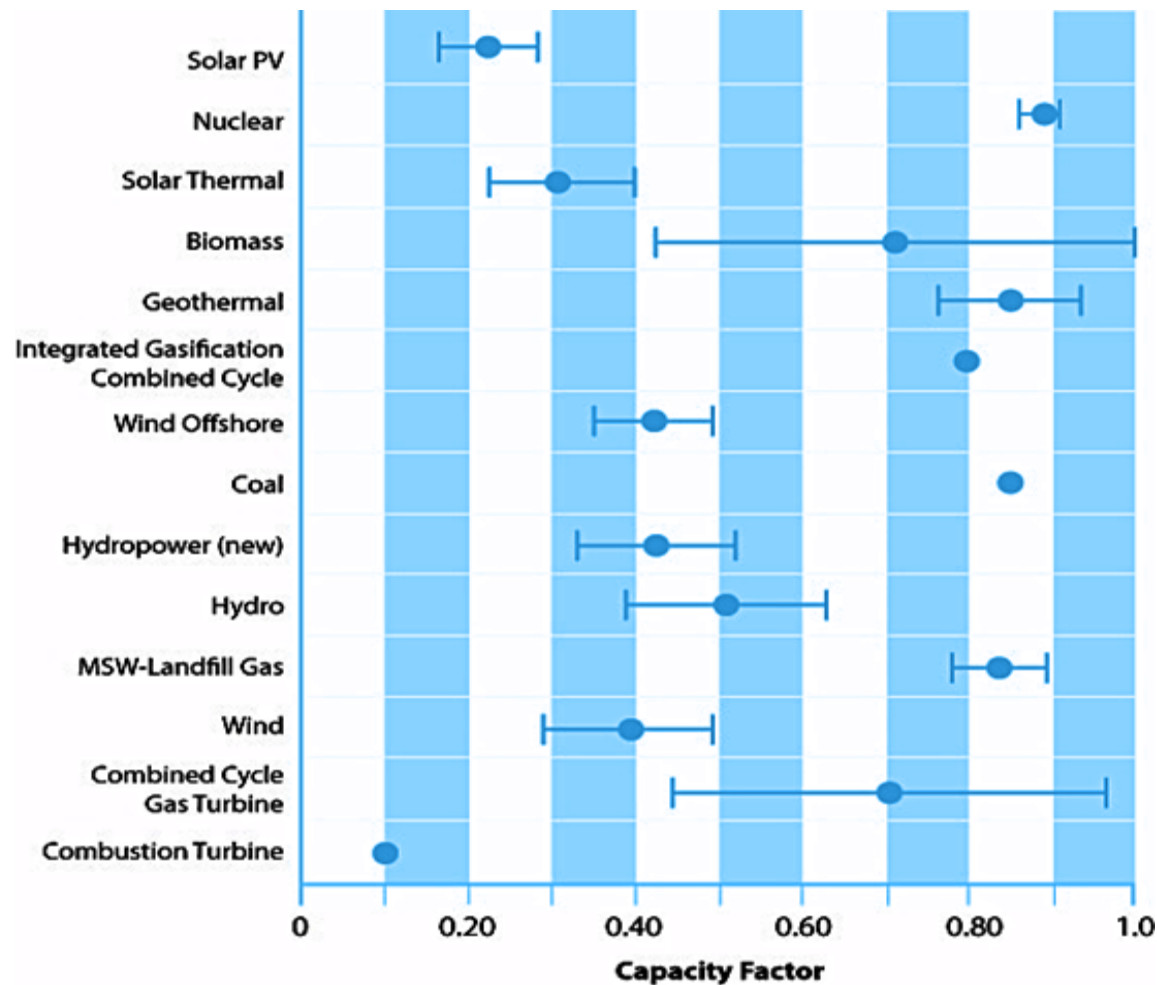
Minimal (~ 5%) drop in system performance (July 6th)

Performance was **recovered** after little (0.2") precipitation (July 11th)

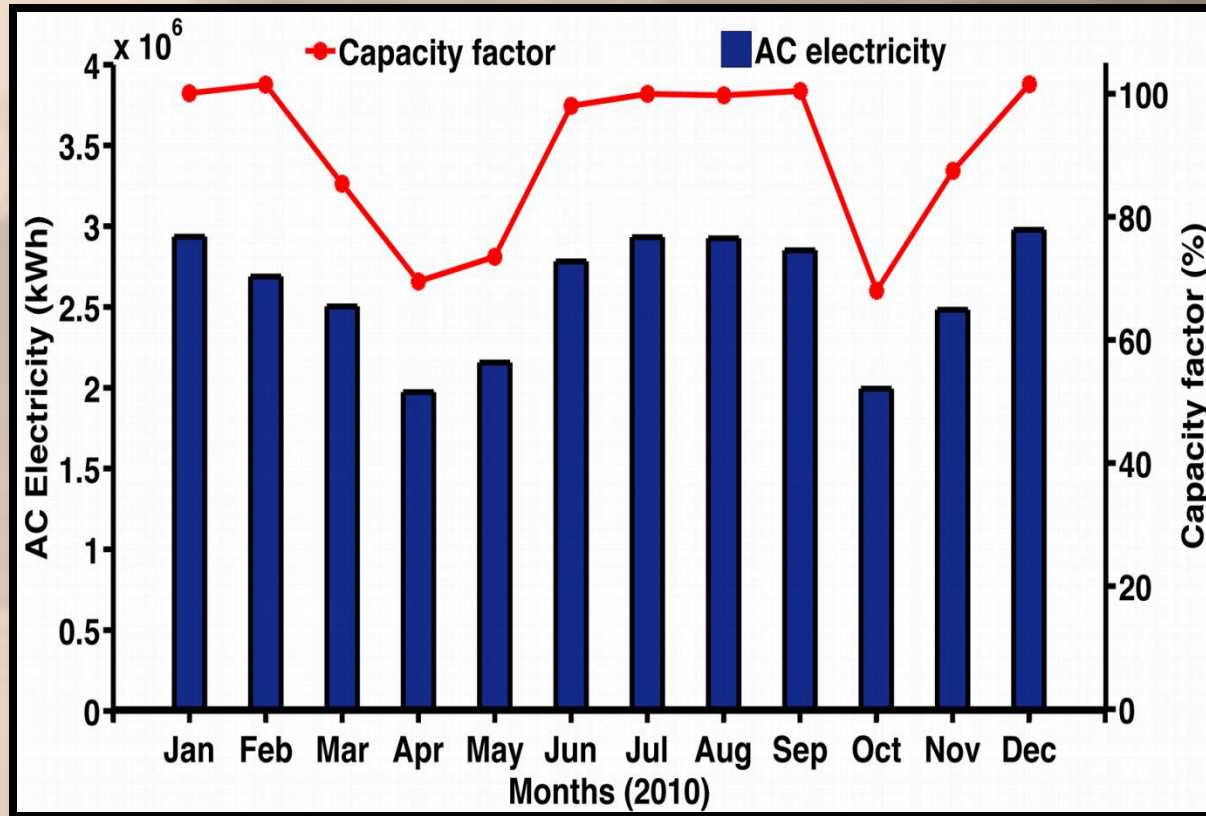
Changes in system performance were **independent of module temperature**



$$\text{Capacity factor} = \frac{\text{Energy Output (kWh)}}{\text{System size (kW)} * \text{Time (h)}}$$



capacity factor – nuclear plant

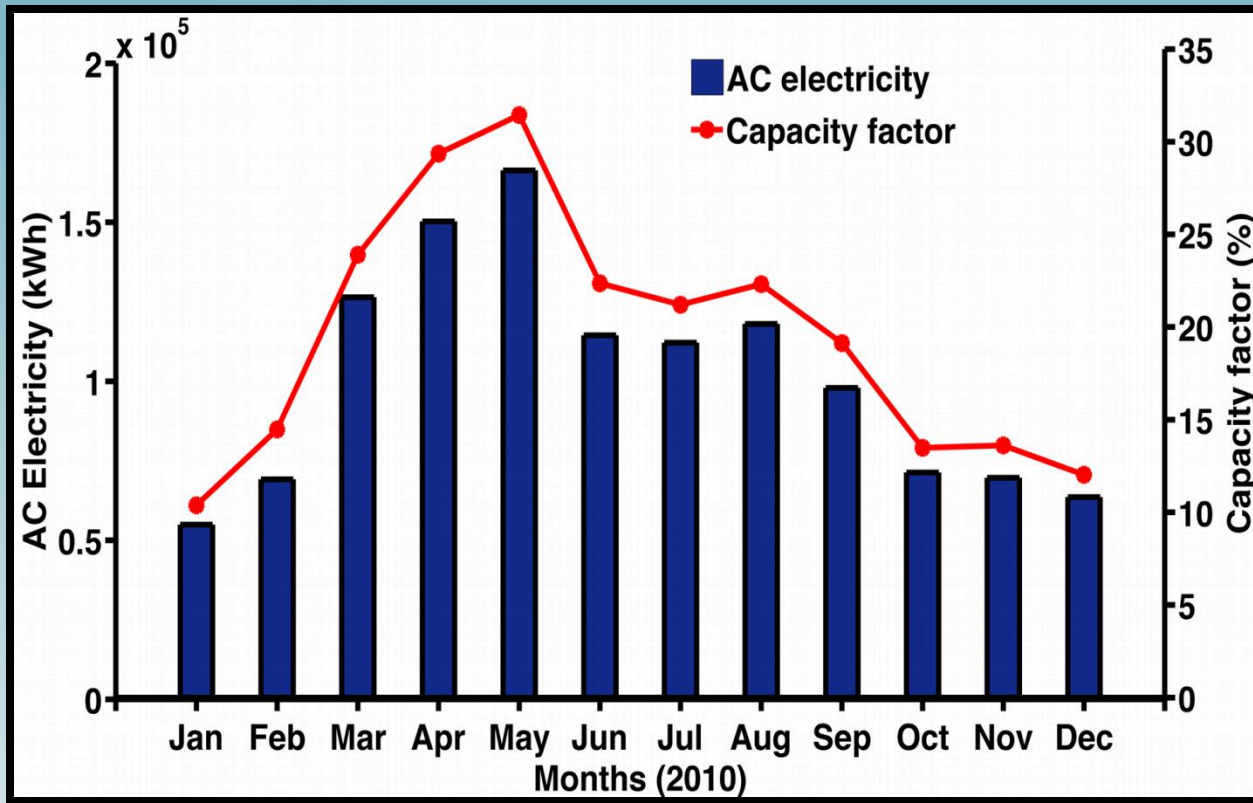


3.9 GW Palo Verde nuclear power plant, Arizona

Avg. annual capacity factor =
90.4%



capacity factor – PV system at ASU



effect of seasonal variations in solar radiation, ambient and cell temperature on capacity factors

710 kW_p single axis tracking PV system at ASU

Avg. annual capacity factor: **22.4%**

annual capacity factors – PV systems at ASU

BUILDING	SYSTEM SIZE (KW)	SYSTEM TYPE	MODULE TYPE	AVG. CAPACITY FACTOR (%)
A	161	FIXED	POLY-SILICON	20.3
B	80	FIXED	POLY-SILICON	20.3
C	70	FIXED	POLY-SILICON	20.1
D	108	FIXED	CdTe THIN FILM	19.4
E	76	FIXED	POLY-SILICON	21.0
F	42	FIXED	POLY-SILICON	18.5
G	880	1-AXIS TRACKER	POLY-SILICON	23.0
H	711	1-AXIS TRACKER	POLY-SILICON	22.4
I	23	FIXED	POLY-SILICON	20.4

acknowledgments

Robert Vandling – ASU campus metabolism

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Image source: Getty Images

