Photovoltaic Solar Power Systems

A Comparative Analysis

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ES 386(Mager)

A solar future, but what type?

As solar power expands, questions remain as to which type of solar generation is most cost effective. This analysis compares four major types of photovoltaic solar systems: fixed roof mount, fixed tilt open rack, single axis tracking, and dual axis tracking.

Data Sources from National Renewable Energy Laboratory:

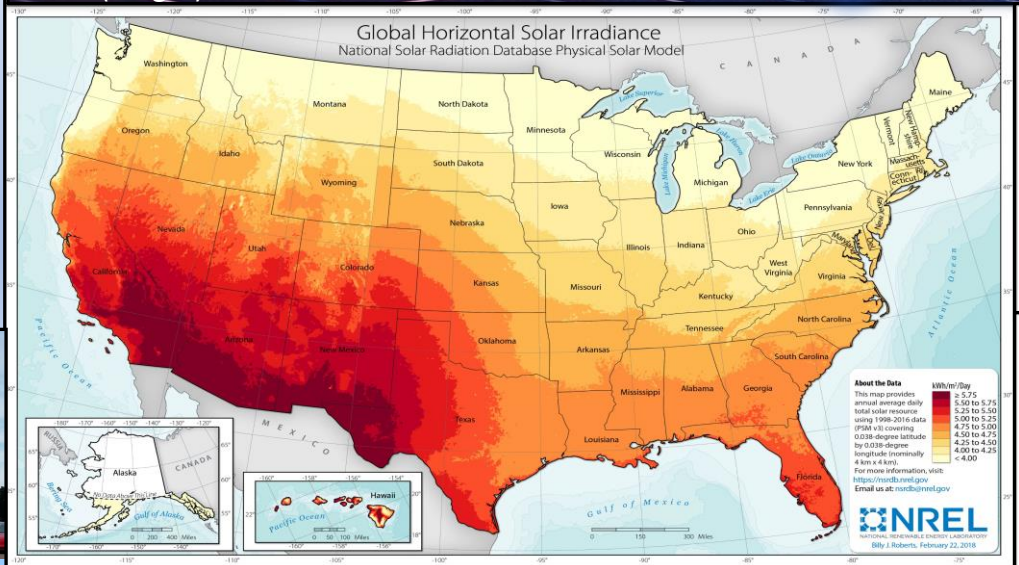
- PV Watts online calculator: Estimates solar production and energy value for any location in the US[5]
- National Solar Radiation Database: Illustrates Direct Normal Irradiance (DNI), a measure of solar radiation received by a surface perpendicular to the sun's rays[4]

Dataset factors:

- 1MW solar array at local commercial electric rates
- 35 total cities
- Locations in seven regions of DNI

Results:

- Individual roof mounted systems are least cost effective
- Fixed tilt open rack systems remain most common
- Single axis tracking is the fastest-growing system type due to declining initial costs[6]
- Dual axis tracking exceeds all system types in productivity and energy value but remains limited due to high initial costs[1]

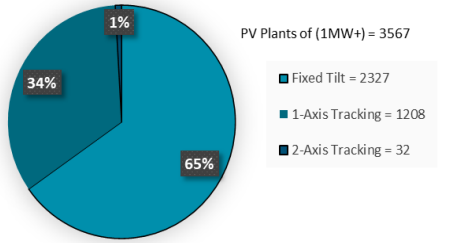


ANOVA Results: A two-way analysis of variance test indicated that both location and system type are statistically significant indicators of energy value (defined as the product of kWh generated times the value of energy produced in $kWh) above a 99% level of confidence in all DNI regions analyzed. The analysis determined further that specific location is of greater significance than system type due to wide variations in local costs of electricity. Photovoltaic solar remains a good investment in locations with lower DNI and high electricity rates.

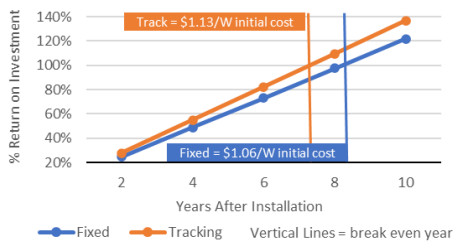
Cities Selected for Analysis[4]

4-4.5 DNI	4.5-5.0 DNI	5.0-5.5 DNI	5.5-6.0 DNI	6.0-6.5 DNI
Albany, NY	Brooklyn, NY	Ashland, OR	Bend, OR	Abilene, TX
Charleston, WV	Daly City, CA	Baton Rouge, LA	Boise, ID	Chico, CA
Chicago, IL	Hot Springs, AR	Buffalo, WY	Casper, WY	Denver, CO
Coeur D'Alene, ID	Houston, TX	Lincoln, NE	Ft. Worth, TX	Dodge City, KS
Columbus, OH	Kansas City, MO	Oakland, CA	Huntchinson, KS	Elko, NV
Eugene, OR	Memphis, TN	San Antonio, TX	Santa Cruz, CA	Grand Junction, CO
Crescent City, CA	Spokane, WA	Springfield MO	Sarasota, FL	Klamath Falls, OR

PV Utility Generators in the US (2019)

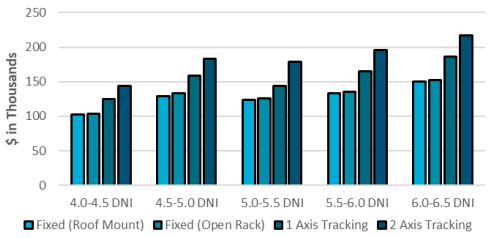


Return on Investment
Fixed v. Tracking, by % of Initial Costs and Year



Tracking provides a greater return on investment than fixed tilt systems. At a starting point of $1.13/W for single axis tracking and $1.06 for fixed tilt (at 0.82% degradation per year). Initial research indicates that dual axis systems will provide greater long-term ROI despite higher initial costs.[1,3,5]

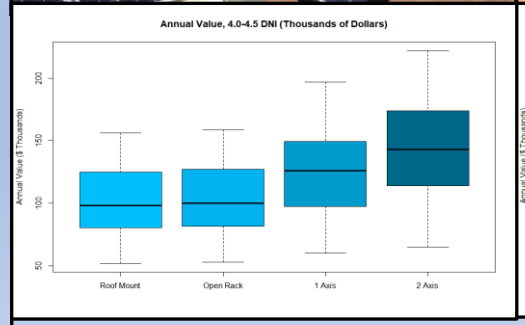
Mean Annual Value by System Type and DNI
($ in thousands for 1MW DC array)

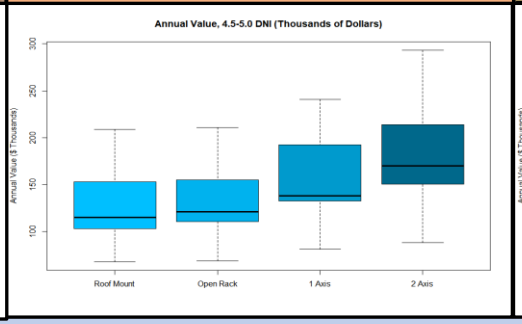


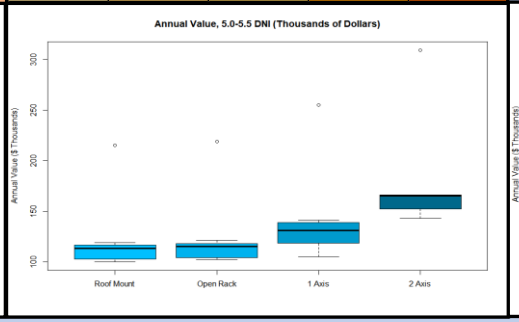
Fixed tilt photovoltaic generators remain the most common type of solar generation that public utility systems employ, but single axis tracking is on the rise due to decreased costs. Roof mounted systems provide the least energy value across all system types. Dual axis tracking provides the highest energy value but remains in a nascent stage due to higher installation costs.[1,2,6]

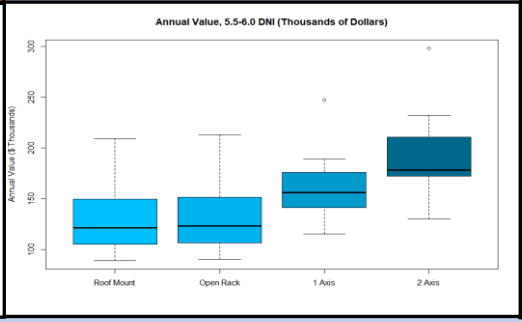
References

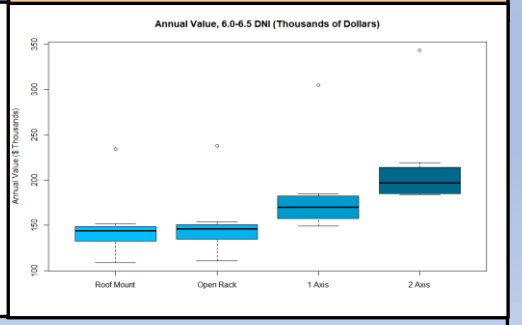
1. Asiabanpour, Bahram, et. al (2017). "Fixed versus sun tracking solar panels: an economic analysis." *Clean Technologies and Environmental Policy* 19, 1195-1203.
2. Energy Information Administration (2020). *Electricity: Form EIA-860 detailed data with previous form data (EIA-860A/860B).* Final 2019 Data. https://www.eia.gov/electricity/data/eia860.
3. Fu, Ran, David Feldman, and Robert Margolis (2018). *U.S. Solar Photovoltaic System Cost Benchmark: Q1 2018.* Golden, Colorado: National Renewable Energy Laboratory. https://www.nrel.gov/docs/fy19osti/72399.pdf
4. National Renewable Energy Laboratory (n.d.). *National Solar Radiation Database Viewer. maps.nrel.gov/nsrdb-viewer.*
5. _____ (n.d.). *PVWatts Calculator.* pvwatts.nrel.gov.
6. Stein, Adam (2018). *Utility-Scale Fixed-Tilt PV Vs. Single-Axis Tracker PV: NEMS Projections to 2050* [unpublished Master's Thesis]. Johns Hopkins University.











Annual Value Based on DNI Region and System Type: The range of energy values for each type of photovoltaic generator (1MW DC) across five DNI regions illustrate the significance of DNI and specific location for energy value for solar. In some cases, local electricity rates are a greater determinant of energy value for solar than DNI. Electricity rates in Charleston, West Virginia and Columbus, Ohio, for example, increase mean energy value in the 4.0-4.5 DNI region because electricity costs in these locations are about 20% higher than the average. The outliers in regions with higher DNI are due to locations in California with substantially higher demand and costs for electricity.[4]