Sandia National Laboratories

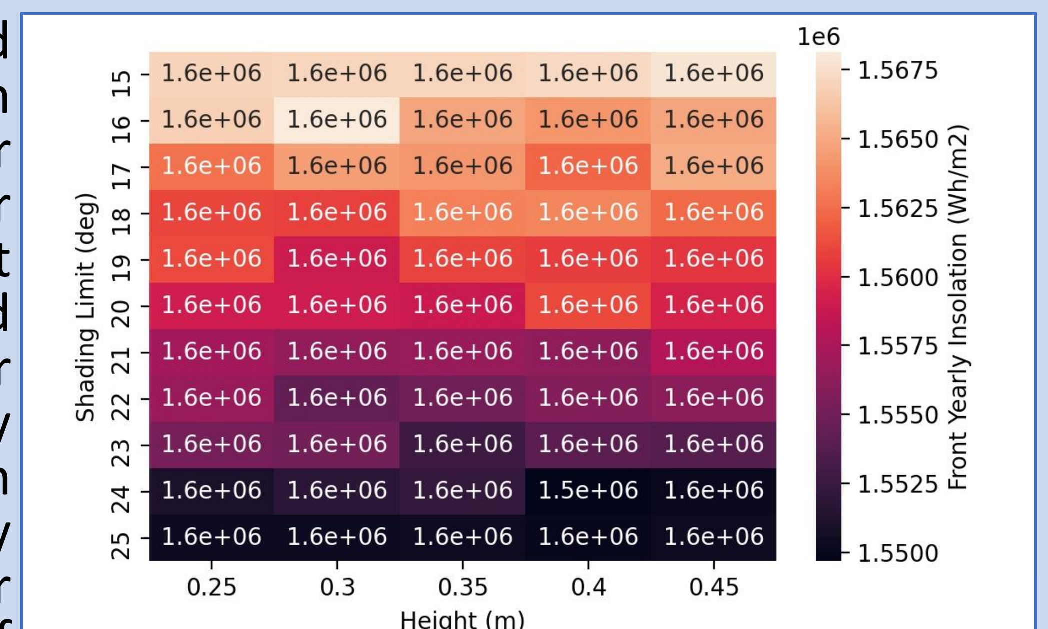
Jennifer L. Braid[1], Joshua S. Stein[1], Pierre Lacert[2], Francois Gilles-Gagnon[2]
[1]Sandia National Laboratories, Albuquerque, New Mexico, USA
[2]Opsun, Quebec, Quebec, Canada

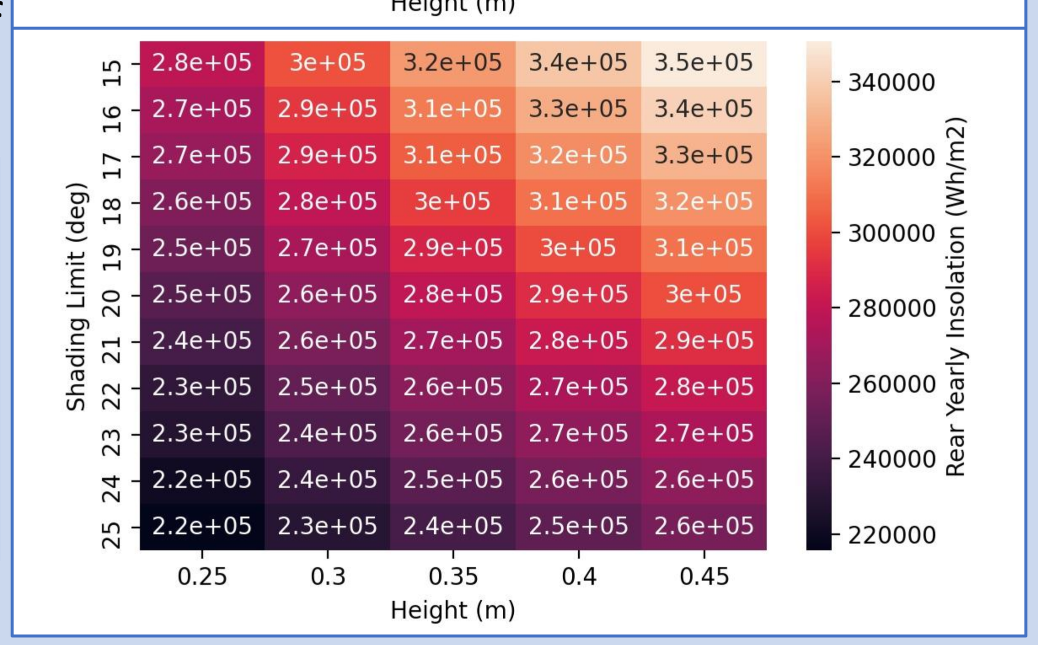
Financial Optimization of Commercial-Scale Photovoltaic Systems

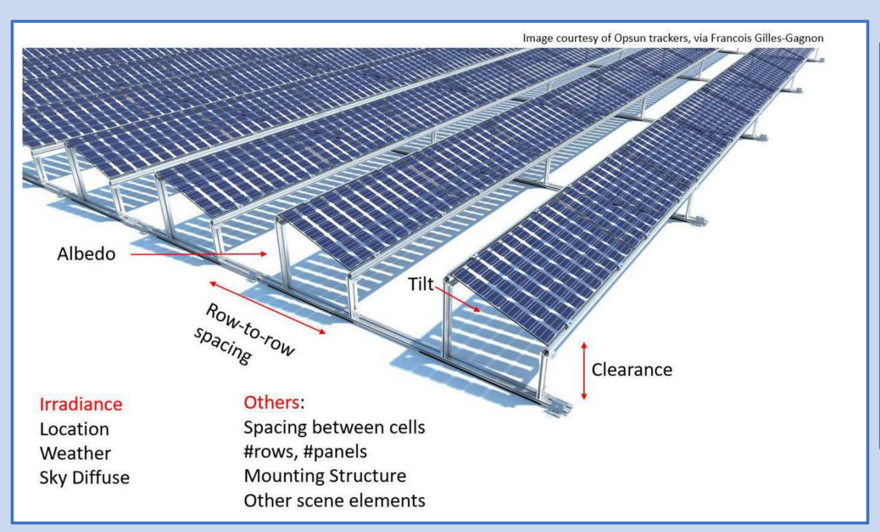
Fixed-Tilt Commercial Rooftop PV Systems require major design choices including module type, total installed capacity, tilt angle, row spacing, and mounting type, which **affect both system cost and energy yield**. Choices are typically made by EPCs and presented to the customer, who may not know how these design parameters affect their financial interests. The goal of this research is to provide **resources for Commercial Rooftop PV Customers to quantify financial impacts of system design specifications.**

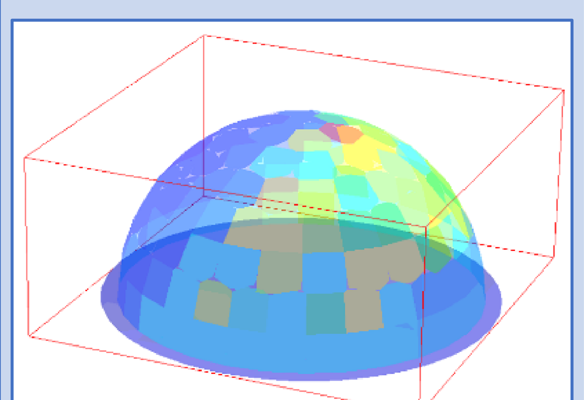
Performance Modeling of Fixed Tilt Commercial Systems

Energy yield for each system configuration was estimated with ray-tracing simulations using *bifacial_radiance* [3], in which we used the *cumulative_sky* approach. Input weather data is from EnergyPlus Weather [4] files that are 1-year timeseries of irradiance and weather conditions reported at hourly intervals for each site. The *cumulative_sky* method bins the irradiance over a year into 145 spatially equiangular sections of a hemispherical dome [5]. This cumulative sky dome is then used to perform ray-tracing simulations for each geometric configuration of PV modules to estimate yearly energy yield. At right are examples of the yearly insolation for the module front (top) and rear (bottom) for combinations of different shading limits (row spacing) and heights.





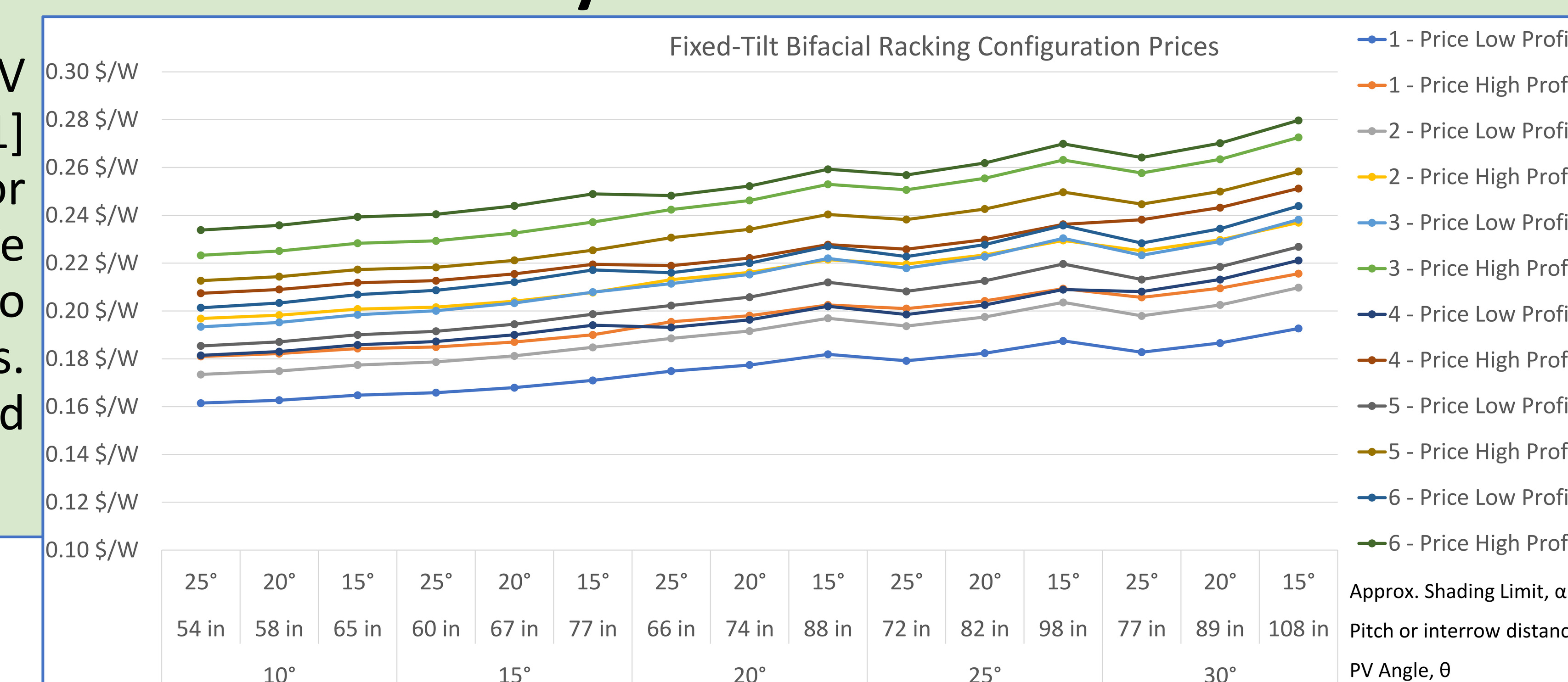


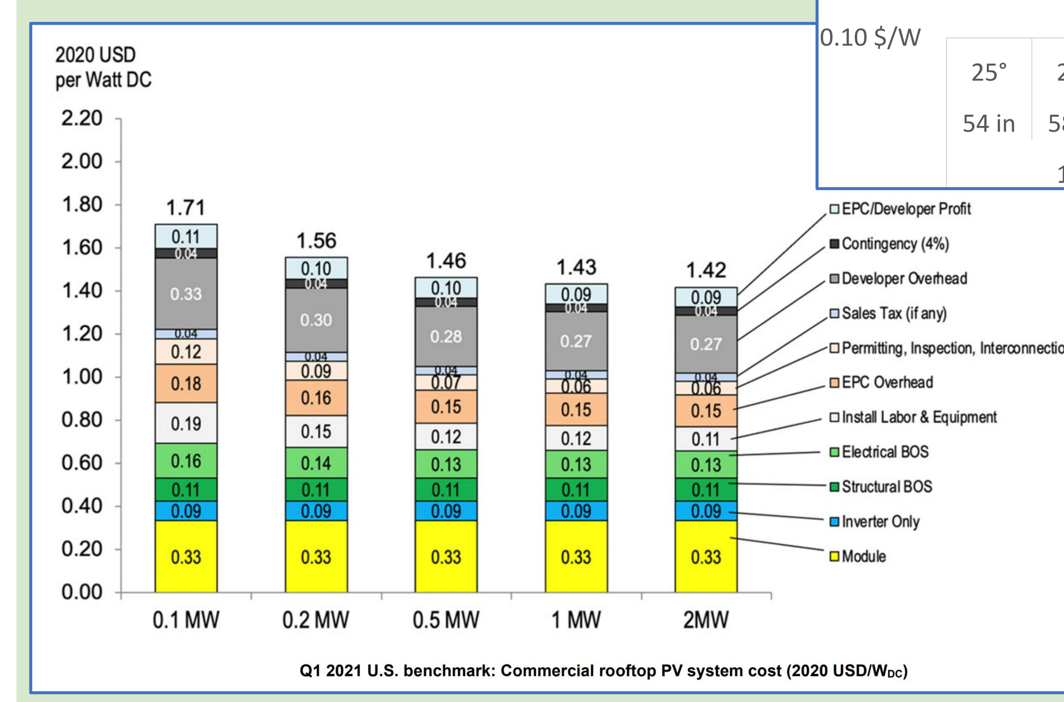


cumulative_sky method for ray-tracing in *bifacial_radiance*

Cost Modeling of Fixed Tilt Commercial Systems

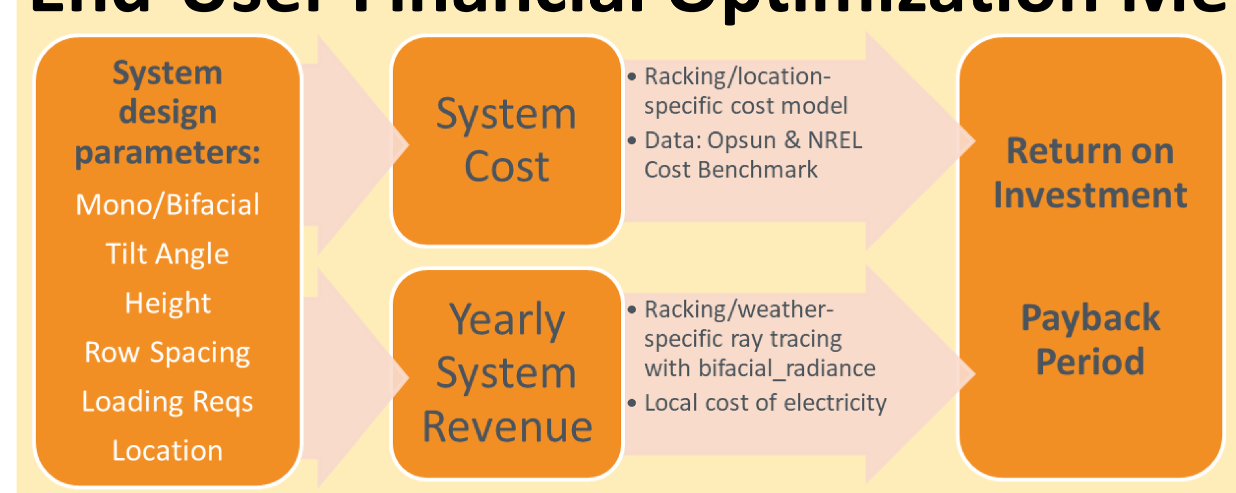
2021 US commercial rooftop PV cost estimates from NREL [1] (below) use fixed values for module and racking costs. We have improved this model to include module type (bifacial vs. monofacial) and racking type and configuration in system cost.





Using cost data from Opsun for bifacial (above) and monofacial racking configurations for commercial rooftop PV (with different tilt angles, clearance heights, row spacings, module orientation, and wind/snow loading requirements [2]) we built multilinear models for structural BOS costs. Together with estimates for other costs from the 2021 US benchmark, we modeled total system cost as a function of module type and racking design specifications.

End-User Financial Optimization Methods

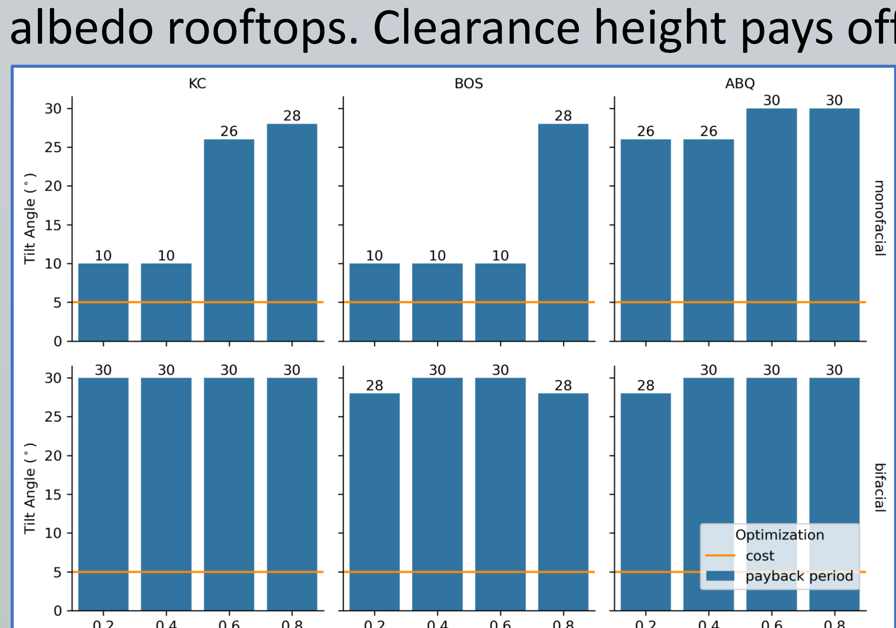


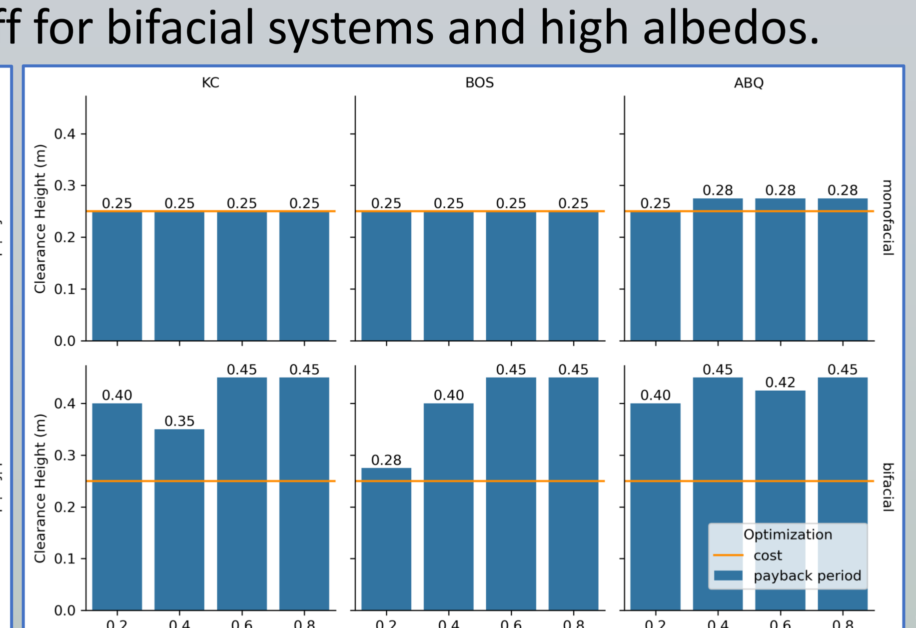
Workflow for end-user financial optimization

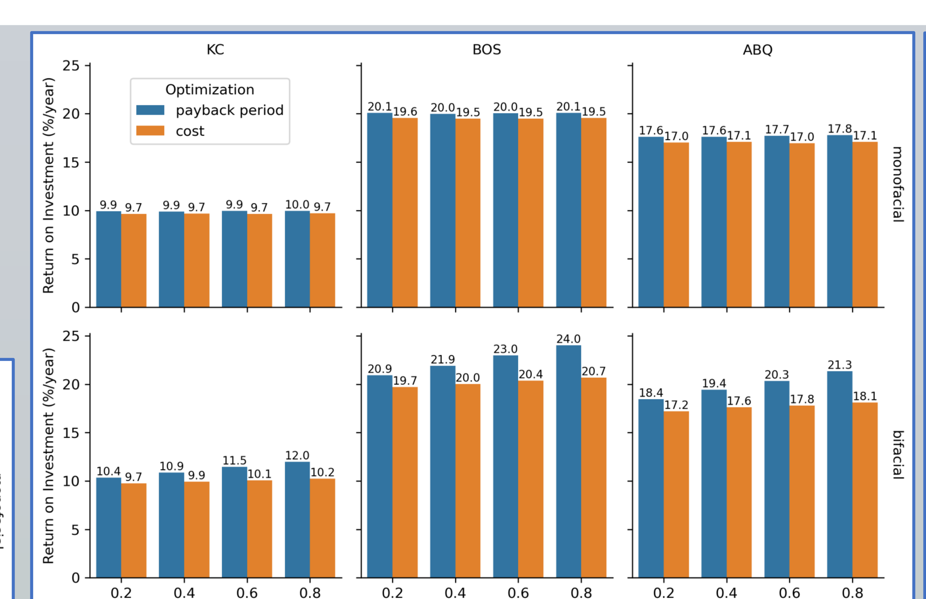
Ray-tracing estimates of system energy yield are scaled by the local cost of commercial electricity to produce a yearly system revenue. System cost is divided by yearly revenue to yield the payback period in years. Inversely the yearly return on investment (% of system cost) can be analyzed. Optimal system configurations can be determined by payback period/ROI, or cost, or revenue by location.

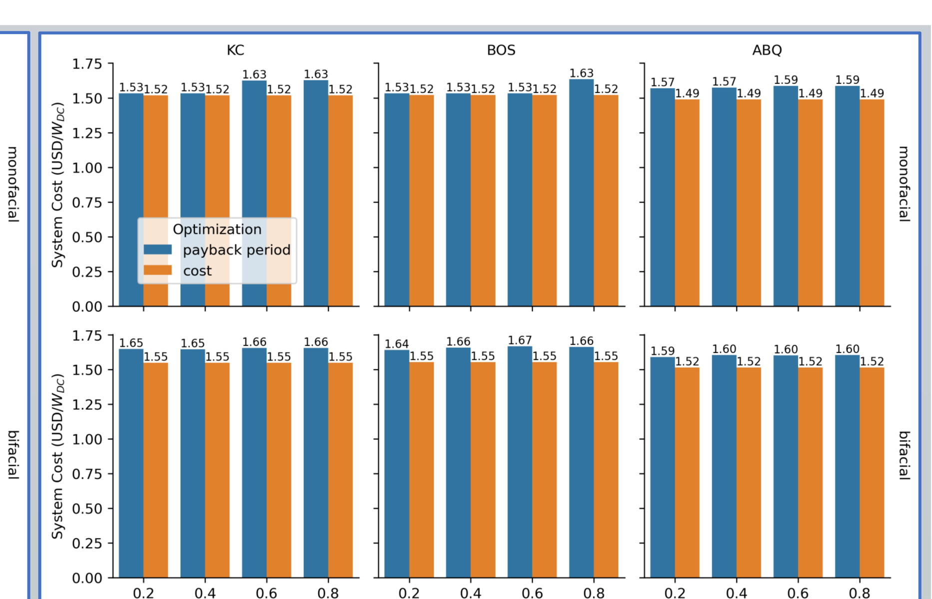
Financial Optimization Results

Optimized system tilt angle (left) and clearance height (right) are shown below for each location/module type/surface albedo. Increasing tilt angle pays off for all bifacial systems, and greater tilt angles also pay off for monofacial systems on high albedo rooftops. Clearance height pays off for bifacial systems and high albedos.









Return on investment (left) and system cost (right) are shown above for systems optimized for cost or payback period. While energy yield is lower in Boston vs. Albuquerque or Kansas City, the return on investment is higher due to the local cost of commercial electricity. Despite higher system costs of payback-period optimized systems, **bifacial systems at high tilt and spacing offer the greatest long-term financial advantage for customers across all locations and rooftop albedos.**

Conclusions

Commercial rooftop PV systems with high tilt angles, greater row spacing, and bifacial modules offer financial advantages to system owners to end-users, despite the greater system cost versus typical low-tilt, close-spaced installations. **Financially optimized PV systems not only pay for themselves more quickly, but also provide greater equivalent revenues for the system owners in the future**, demonstrated here across a range of US locations and rooftop albedo values.

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology &Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.
SAND No. 2022-7833 C

References

1. Ramasamy, V. & Feldman, D. *U.S. Solar Photovoltaic System and Energy Storage Cost Benchmarks: Q1 2021*. https://www.osti.gov/dataexplorer/biblio/dataset/1829310 (2021) doi:10.7799/1829310.
2. ATC Hazards by Location. https://hazards.atcouncil.org/.
3. Ayala Pelaez, S. & Deline, C. bifacial_radiance: a python package for modeling bifacial solar photovoltaic systems. *J. Open Source Softw.* **5**, 1865 (2020).
4. EnergyPlus. https://energyplus.net/weather.
5. Robinson, D. & Stone, A. Irradiation modelling made simple: the cumulative sky approach and its applications. in (2004).