SOLAR HYBRID PHOTOVOLTAIC/THERMAL (PV/T) TECHNOLOGY

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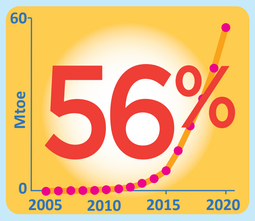
Demand for renewable energy sources, including solar, is growing rapidly due to market forces of pricing and availability. Renewables reduce CO2 emissions, create jobs, and increase security of the energy supply. Can solar hybrid PV/T technology take a larger share of this growing market?

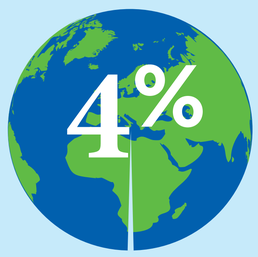
Solar is growing, but is far from reaching its potential

Solar has grown steadily for over fifteen years...

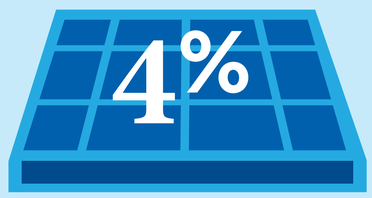


Average annual growth (CAGR), solar energy consumption, 2006-2020

but still represents less than 4% of global electrical energy production.



U.S. solar installations have reached about 4% of available rooftop capacity.



SEIA, 2021 Analysis

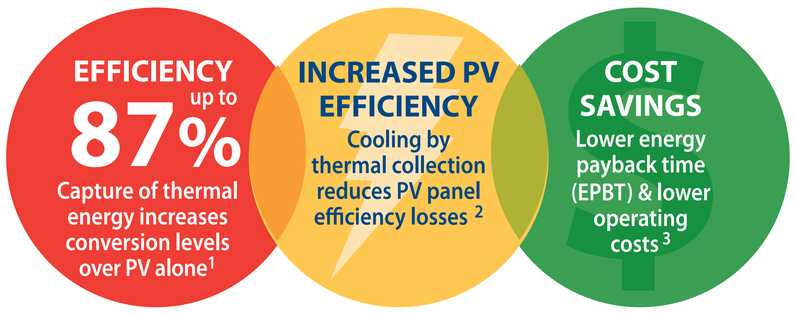
Increasing efficiency may increase market share: Photovoltaic vs. Thermal

Photovoltaic (PV) generation is cheaper than ever, but PV collects a small fraction—less than 20%—of available energy, while thermal (T) systems collect 70% or more. In combination, hybrid PV/T systems offer much higher efficiencies in the same collection unit.

We asked, "Can hybrid PV/T systems deliver higher efficiencies at a reasonable cost?"

Research and analysis demonstrates Hybrid PV/T's viability

Peer-reviewed research dating back to the 1970s identifies the following benefits of hybrid PV/T technology:



[1] Dupeyrata et al., 2010; Tiwari and Sodha, 2005. [2] Dubey, Sarvaiya and Seshadri, 2013. [3] Kern & Russel, 1978; Tripanagnostopoulos et al, 2003–2004.

Despite these findings, commercially available solar hybrid systems remain scarce.

Hybrid PV/T: an economic analysis

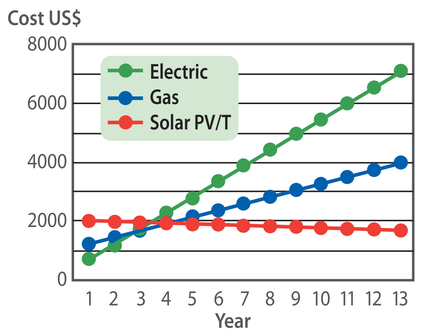
We conducted an economic analysis of the overall costs for heating water, comparing 1kW PV/T, gas, and electric heating systems, using two methods to estimate the thermal energy produced by PV/T systems. We also calculated the value of the thermal versus electrical energy collected by a PV/T system.

We then used typical U.S. installations and their capital and energy costs to calculate annual operating costs and cumulative lifecycle costs for each system.

Results: Clear advantages of Hybrid PV/T systems

- **Negative annual operating cost of -$20** (due to zero fuel costs) quickly offsets higher capital cost.
- **PV/T nets positive in Years 3 & 4 against electric and gas water heating** systems, respectively—without benefit of subsidy or other incentives.
- **Lifecycle savings by Year 12 of $5,324 over electric and $2,200 over gas.**
- Thermal energy collected by PV/T valued at roughly equal to or greater than the electrical energy, with the thermal energy extracted at a lower capital cost.
- Provision of most or all interior space heating in 5 kW or larger PV/T residential systems.

Cumulative Cost Comparison of Water Heating Systems



Value of Energy Collected Daily/Annually from PV/T Systems

PV panel rating	Size (m^2)	Avg. daily thermal energy (Total Btu)	Thermal value 1.01/Therm daily/yr. US$	Avg. daily electrical energy (Tot. kWh)	Electrical value 0.15/kW daily/yr. US$
1 kW	8	59,846	0.61/222.7	3.2	0.48/175.2
5 kW	40	297,013	3.00/1,095.0	16.0	2.40/876.0
10 kW	80	594,026	6.00/2,193.7	32.0	4.80/1,752.0
20 kW	160	1,188,052	12.01/4,383.7	64.0	9.60/3,504.0

Conclusion: Unlike PV only, hybrid PV/T systems offer better ROI

- Early-to-market advantage in global solar energy market (US$ 197B in 2021).
- Much higher energy output and faster customer payback compared to PV.
- Displacement of increasing costs of fossil-fuel systems for heat and electricity.
- Thermal energy is more valuable than PV in colder climates.
- Comprehensive energy plant solution for on- or off-grid applications.
- Adaptable to residential, commercial and retrofit markets.
- Roof substitute/replacement providing *both* electricity and heat.
- Applications include water purification, pumping and heating systems.

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