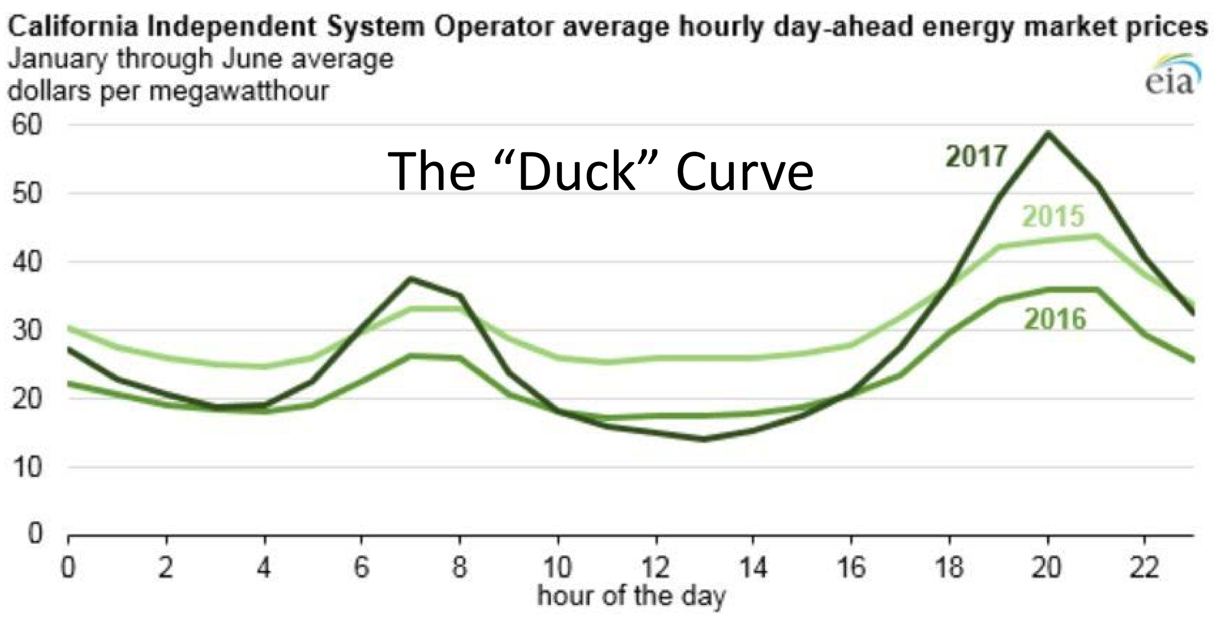
Two-Stage High Concentration Hybrid SBS CPV/CSP Collector

Widyolar, B., Jiang, L., Ferry, J., Winston, R., Kirk, A., Osowski, M., Cygan, D. and Abbasi, H., 2018, September. Two-stage 50X hybrid spectrum splitting CSP/CPV collector with InGaP/GaAs solar cells. In *Nonimaging Optics: Efficient Design for Illumination and Solar Concentration XV* (Vol. 10758, p. 1075806). International Society for Optics and Photonics.

1. Motivation

Increased penetration of variable renewables (PV, wind) without an economic means of storage has a destabilizing effect on the grid (curtailment of power, the "Duck" curve) and reduces the value of additional future variable generation.

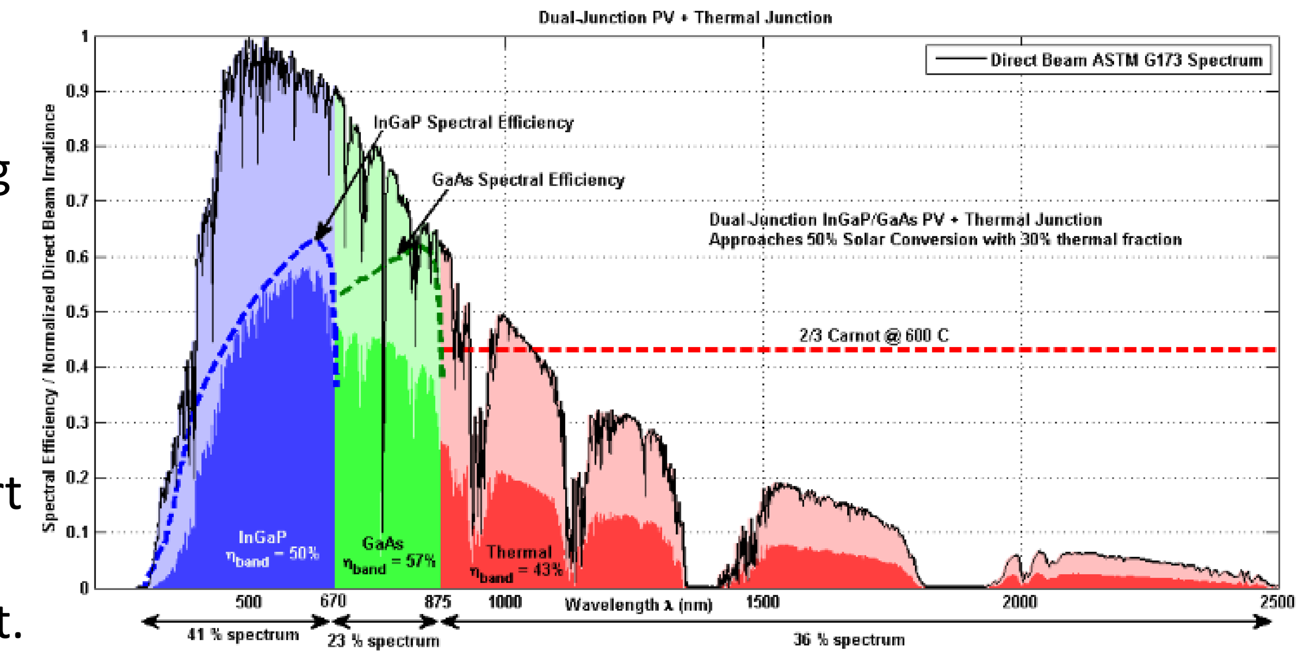


Thermal Energy Storage (**TES**) provides a cost effective solution for *dispatchable* power when combined with a Concentrating Solar Power (**CSP**) system, but the cost of current CSP systems is a barrier to deployment.

By combining cheap, high efficiency PV with lower efficiency and more expensive CSP in hybrid systems, a middle ground can be reached where CSP subsystems with TES can be deployed for less than standalone systems today.

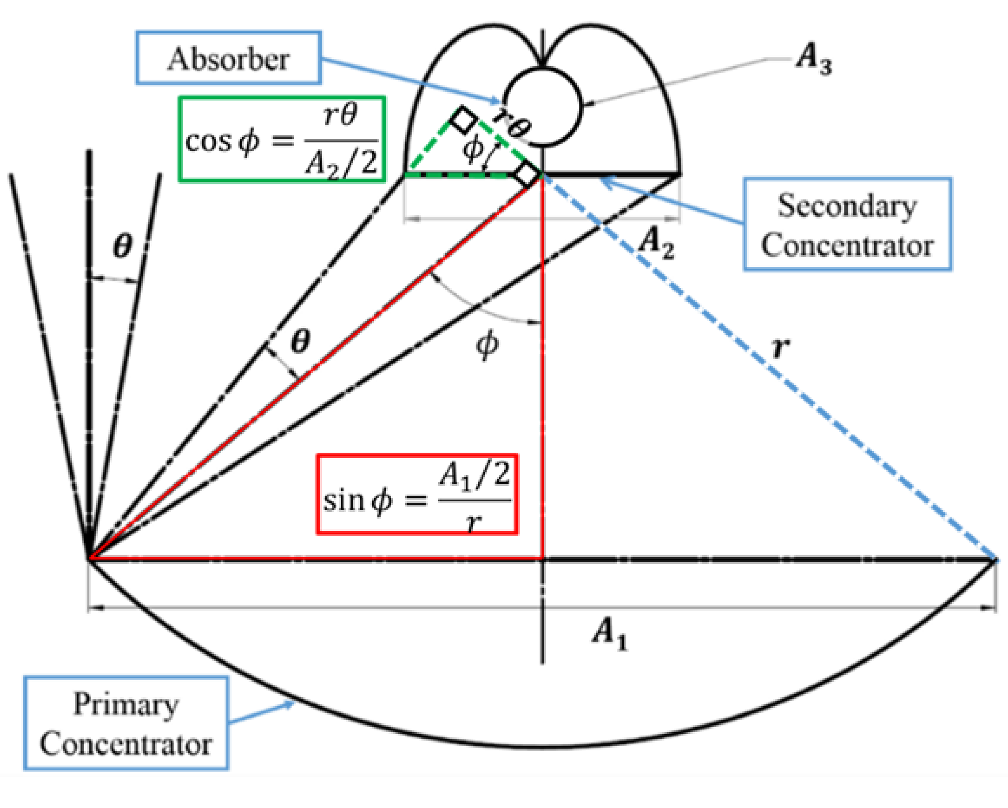
2. Operating Principle

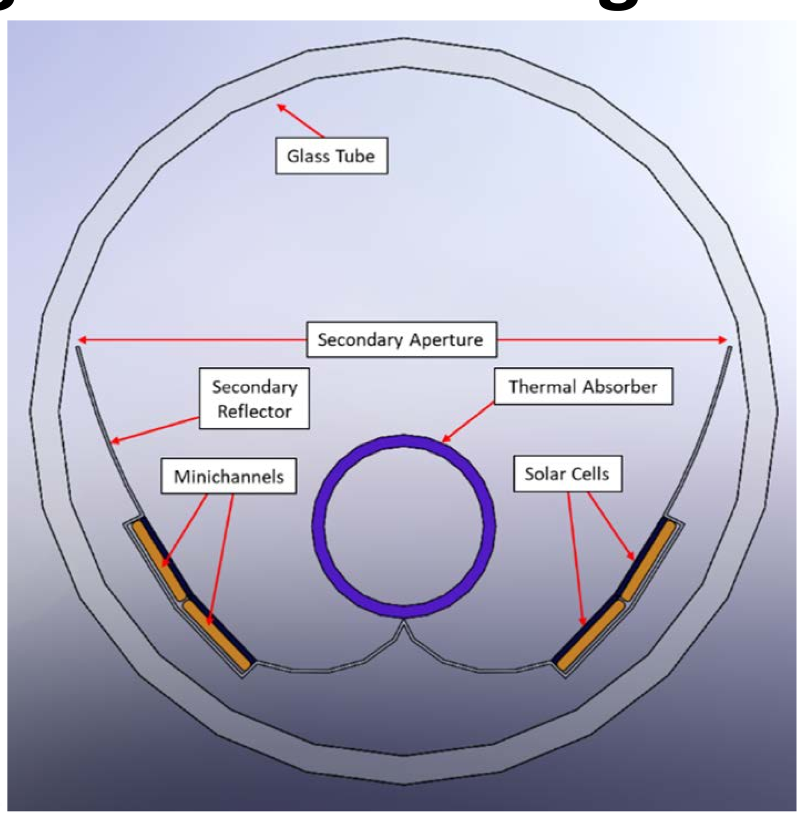
- PV semiconductor materials are highly efficient at converting incoming photons within a certain spectral band (near the bandgap) into electricity, but convert photons outside this band mostly into heat.



- CSP systems are wavelength independent but require high temperatures to generate useful Carnot conversion efficiencies. $\eta_{Carnot} = 1 - T_C/T_H$
- By directing UV/VIS toward a CPV system and the remainder towards a CSP subsystem using a technique known as *Spectral Beam Splitting* (**SBS**), the CPV and CSP subcomponents can be thermally isolated and operated independently at their respective temperatures for maximum conversion. The plot above approaches 50% conversion of the solar spectrum!

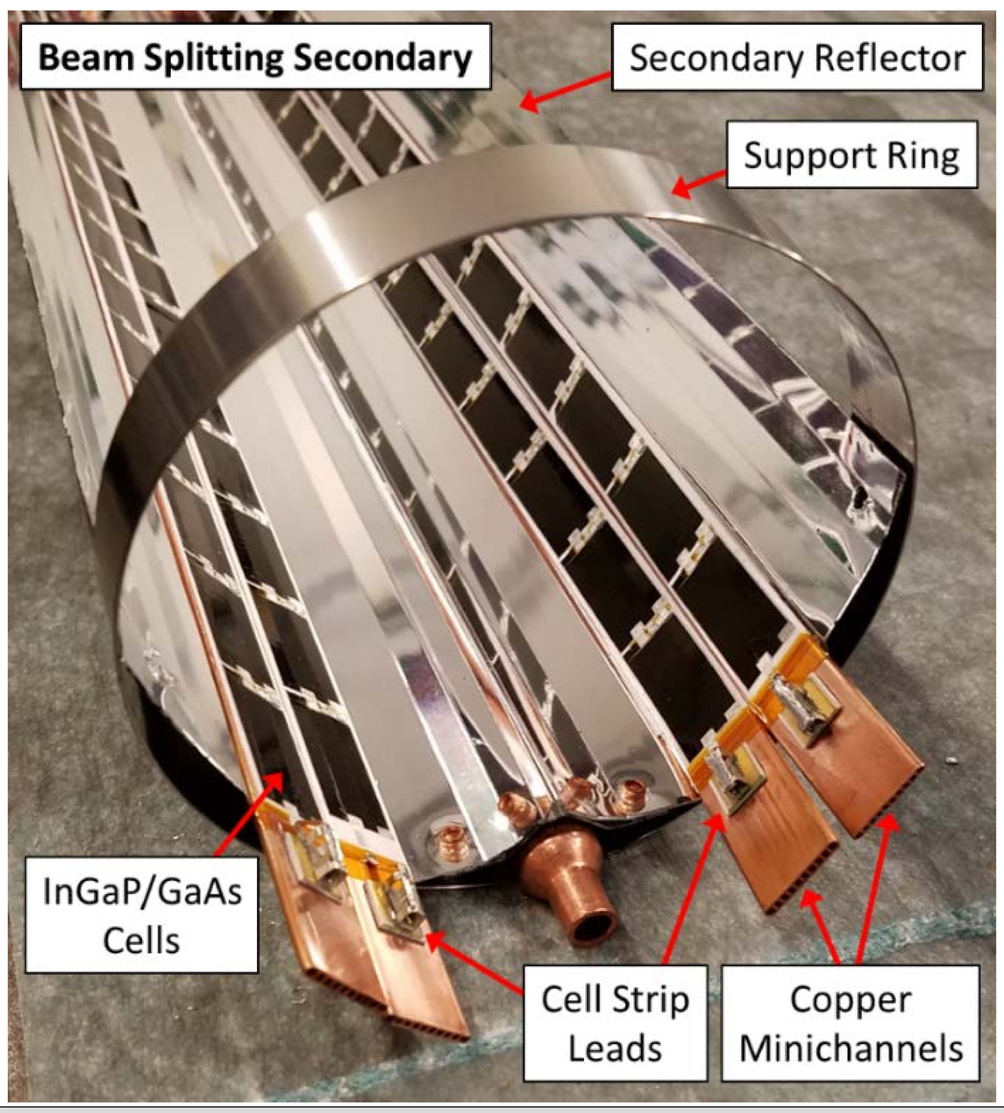
3. Two-stage Parabolic Trough Collector Design

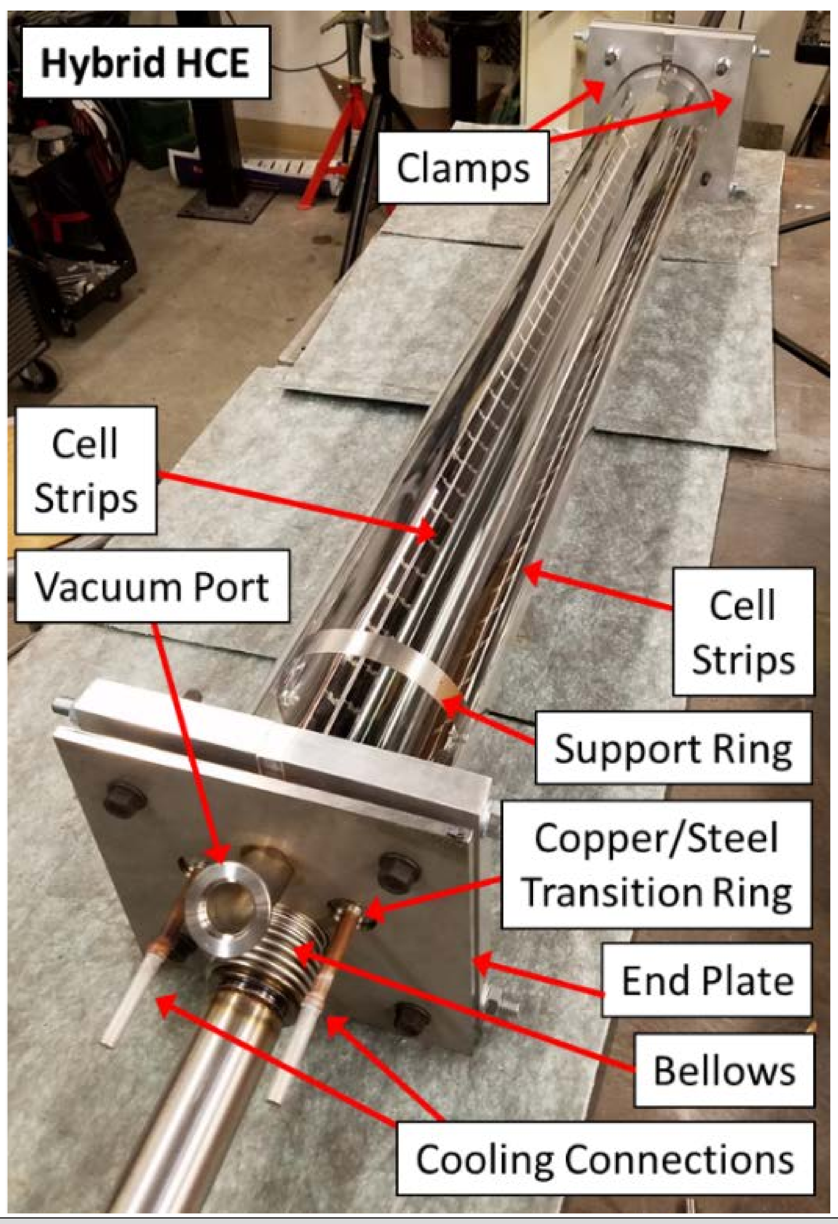




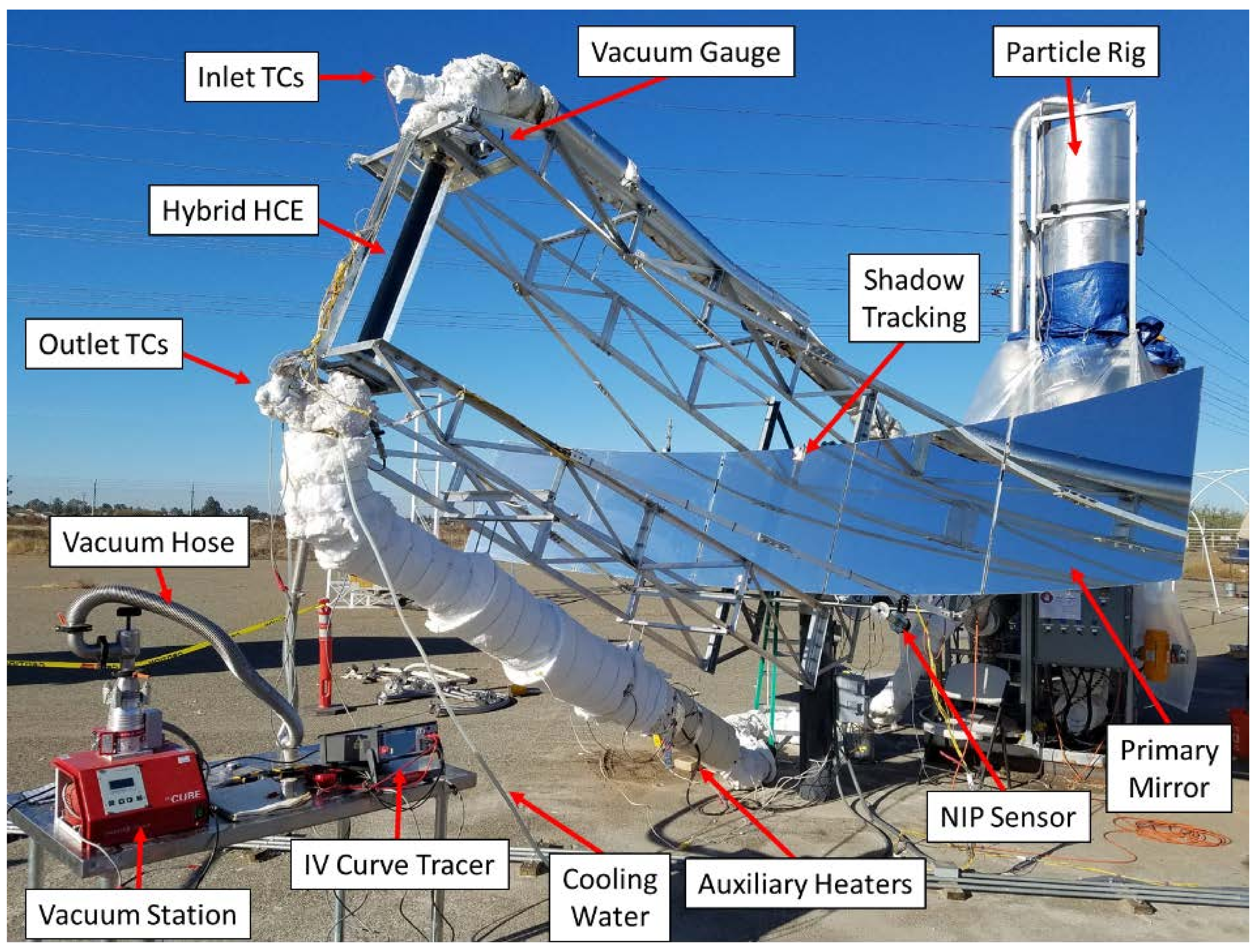
Light from the primary mirror reaches the secondary aperture at 45X concentration. Dual Junction InGaP/GaAs back-reflecting solar cells generate electricity and provide an additional 1.1X concentration for sub-bandgap photons. The design achieves **50X** concentration (compared to 23X for a conventional trough) which enables high temperature operation (650 °C), even under partial (spectral split) illumination.

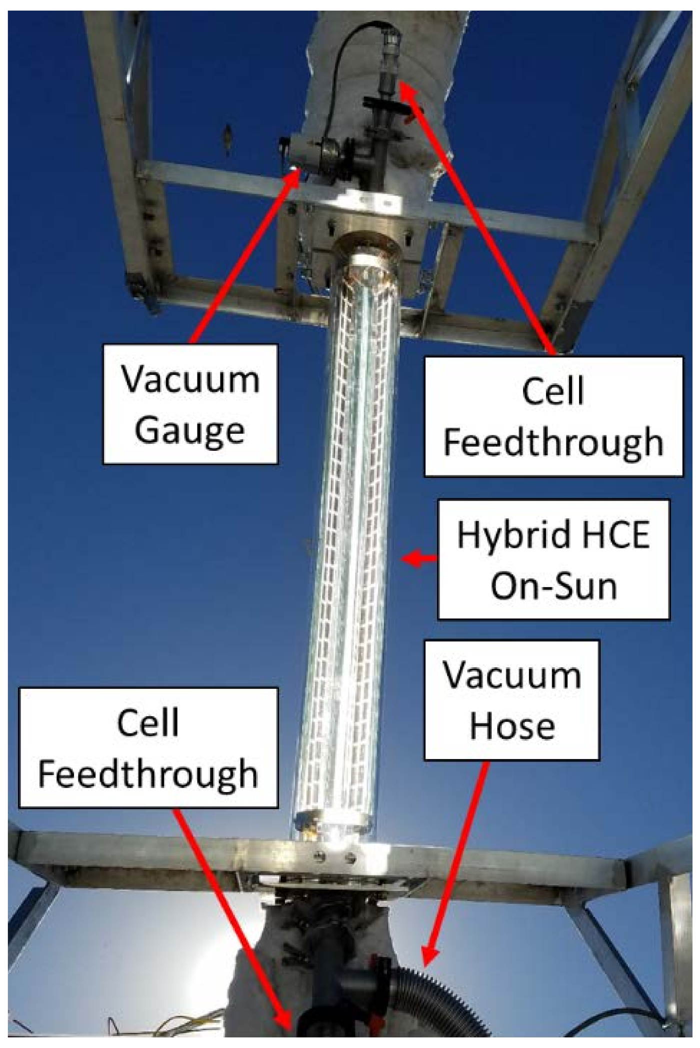
4. Prototype Development

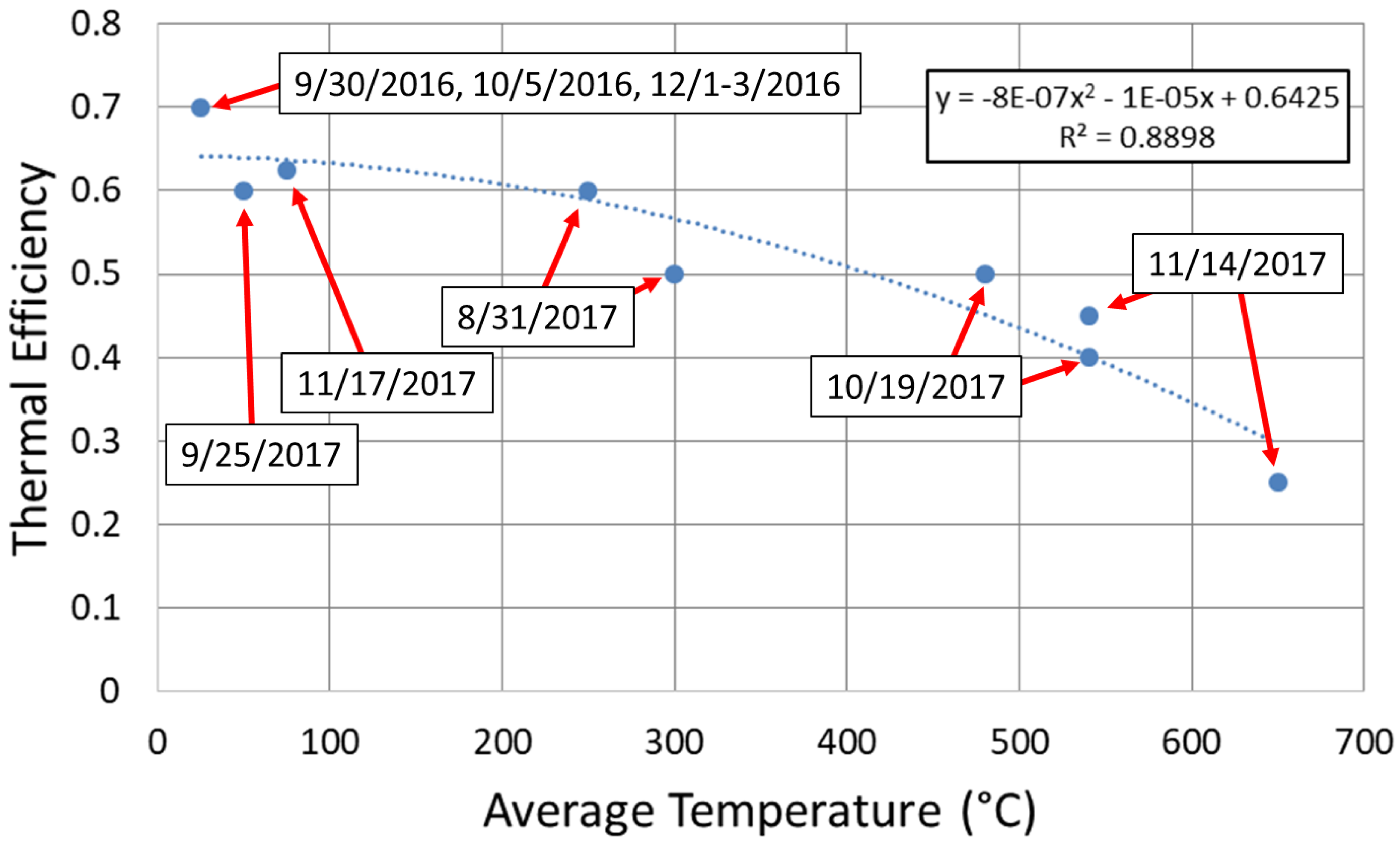




5. Experimental Performance







The collector was tested up to **685 °C** using a particulate heat transfer fluid (HTF). The cells were kept cool at ~ 40 °C and had a net solar to electric efficiency of 6% (~21% based on incident light on cells). We also developed and tested a non-hybrid, thermal-only version of the collector for industrial process heat (**IPH**) or **CSP.**

6. Project Outcomes

- ✓ A **two-stage linear parabolic trough** system demonstrated 50X geometric concentration, enabling high temperature operation of the CSP system.
- ✓ **Back-reflecting solar cells** implemented as spectrum splitting devices, thermally decoupling the CSP and CPV systems and maximizing exergy production.
- ✓ **Solid particle heat transfer media** operated through > 50 meters of pipe and flex hose, enabling high temperature operation of the CSP system.

Surpassed 400 °C oils, 580 °C molten salts, in the realm of tower temperatures with a linear system.

Exciting opportunity for high temperature IPH and CSP!

7. Acknowledgements:

This work was funded in part by the Advanced Research Projects Agency-Energy (ARPA-E), U.S. Department of Energy, under Award Number DE-AR0000464 awarded to Gas Technology Institute. This research was performed in partnership with the **Gas Technology Institute (GTI)** and **MicroLink Devices**.

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