Low Cost Dispatchable Heat for Small Scale Solar Thermal Desalination

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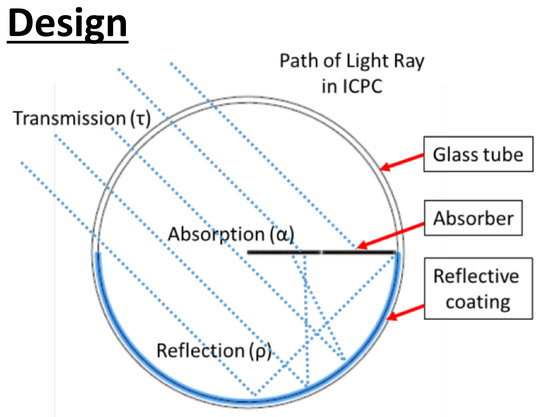
Background

The Department of Energy (DOE) sponsored a new round of solar thermal based desalination processes, which aims to reduce the levelized cost of water (LCOW) by lowering the levelized cost of heat (LCOH). This will result lower overall capital and integration costs for solar-thermal desalination. Our project aims to produce current state-of-the-art and near-commercial systems with repeatable results, which will become market available by the end of the project. The success of the demonstration array will pave the pathways to a medium temperature solar thermal source (>120°C) that can meet the challenges for small-scale plants processing low-volume, high-salinity water, like brine from oil and gas operations target a LCOW of $1.50 per cubic meter.

Furthermore, at the estimated LCOH of $0.015/KWh$_{th}$, the mass produced product will be able to directly compete with commercial natural gas prices in California ($0.03/KWh$_{th}$). This will allow the solar thermal as an affordable alternative renewable energy source to enter the market of medium temperature industry and food processing.

Compared to conventional methods of using tracking to achieve such a required temperature, we choose to promote the thermal efficiency of stationary vacuum devices by using non-tracking optical concentrators. This results in a cost efficient, easily assembled solution that is mass production ready.

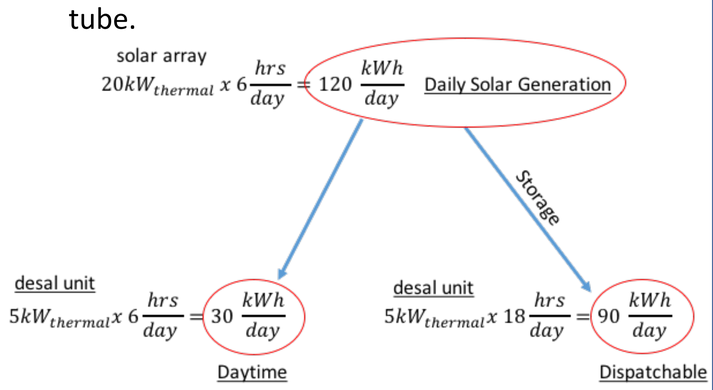
Design

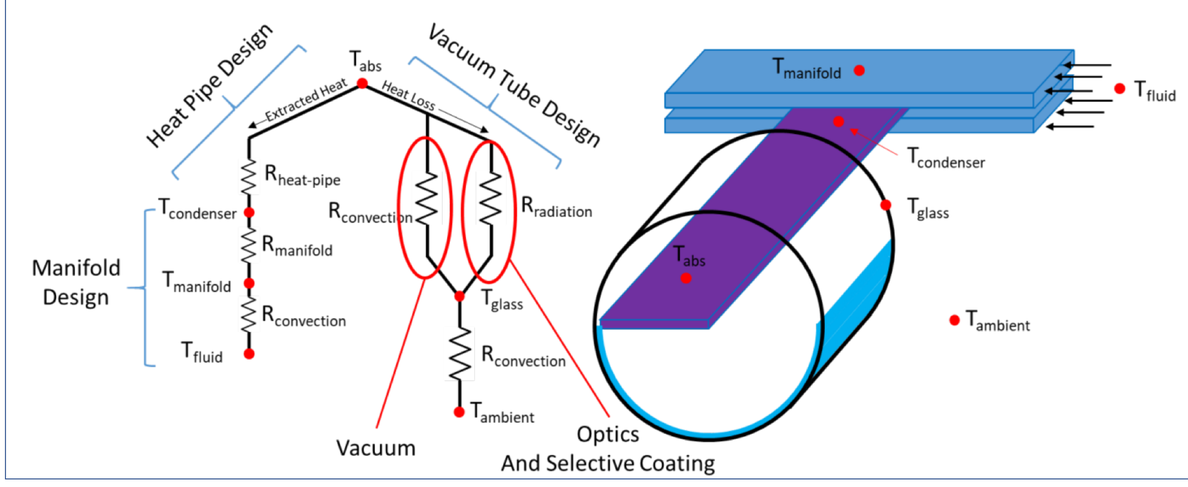


The proposed design incorporates a solar thermal Integrated Compound Parabolic Concentrator (ICPC) with a low cost heat pipe absorber in a horizontal orientation, inside a vacuum tube with integrated optics.

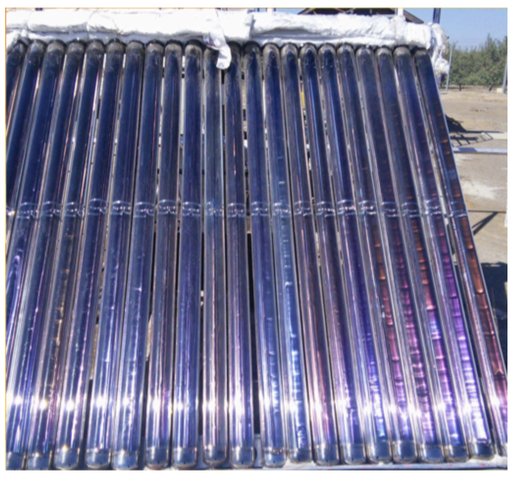
From one layer of dusting on the glass tube, the optical efficiency of the system will only suffer a minimal drop in the harsh environment. This is due to the reflector being fully protected from degradation caused by weather by the glass tube.

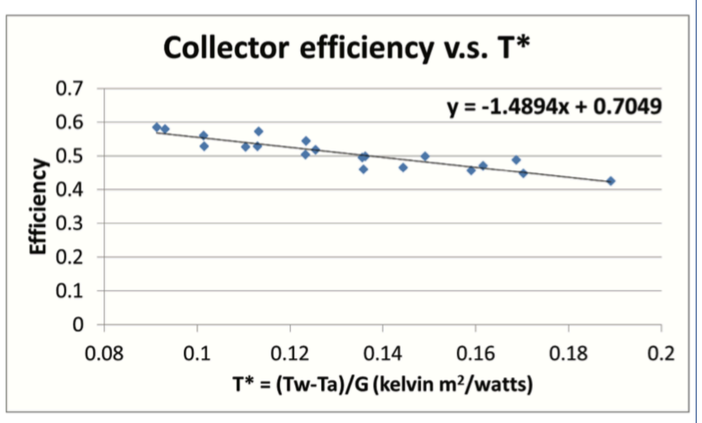
By pairing this portable ICPC solar thermal system with phase change material (PCM) storage media, we can produce dispatchable heat 24/7. The array is sized to store ¾ of the energy harvested throughout the day in the PCM storage system.





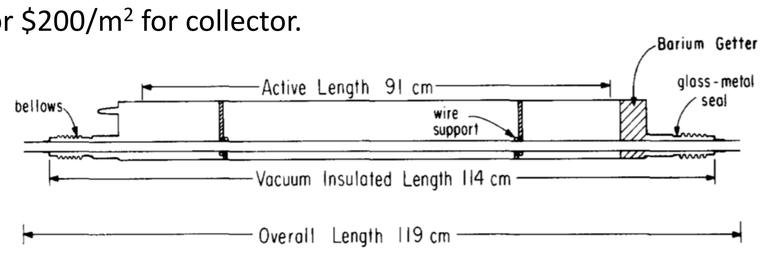
Previous Generation





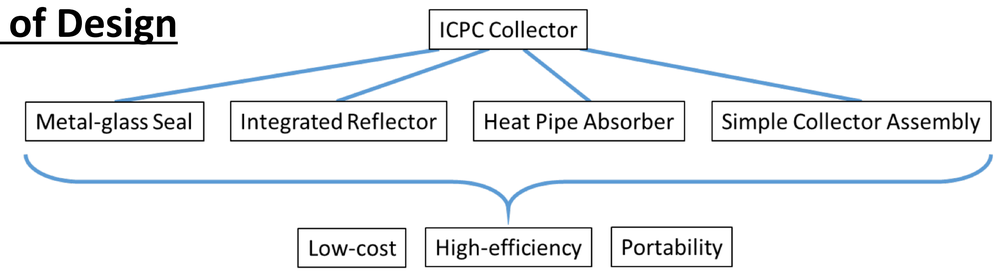
The previous generation of the ICPC built and developed by UC Solar in 2015, was at the price point of $20/tube or $200/m² for collector.

Side view of the 1984 ICPC project, which was more than $5000/tube or $110,000/m² for collector.

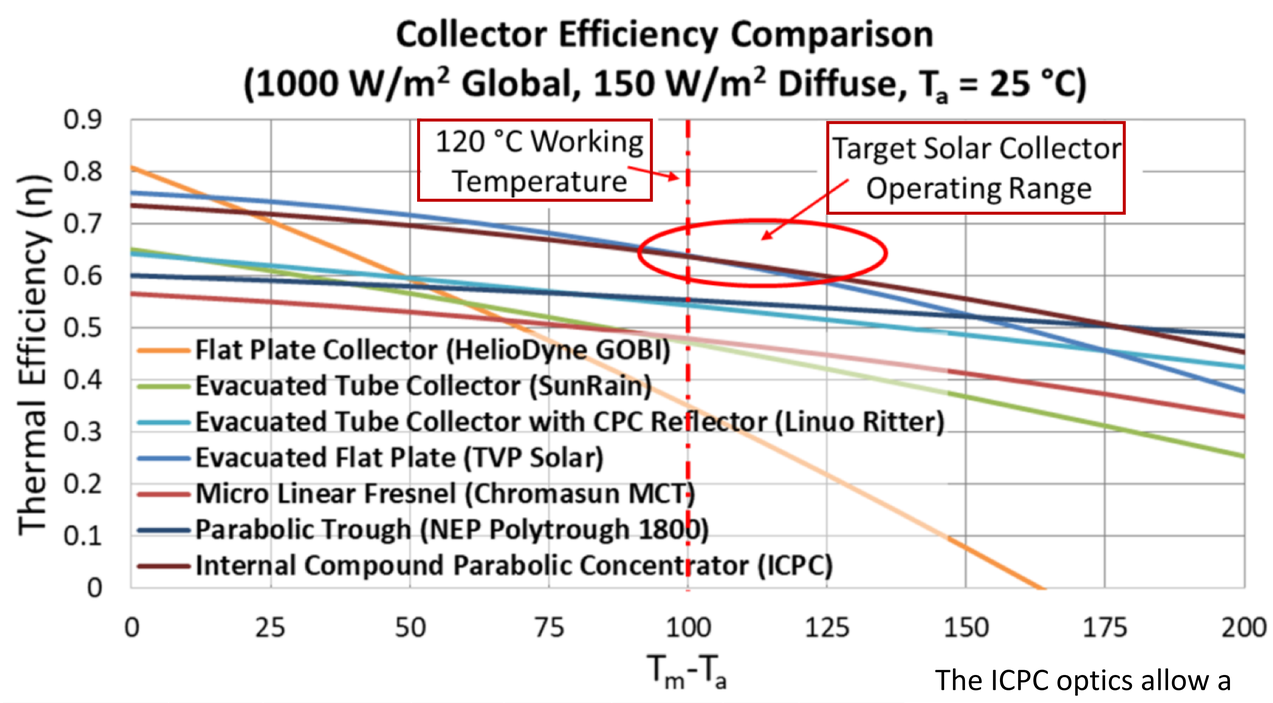


Snail, Keith A., Joseph J. O'Gallagher, and Roland Winston. "A stationary evacuated collector with integrated concentrator." *Solar Energy* 33.5 (1984): 441-449.

Benefits of Design



Previously, the ICPC was not economical because of the high prices of metal-glass seals and internal reflectors due to manufacturing limitations. We have access to two existing technologies for metal-glass seals for our current UC Solar applications, one of which costs approximately $2.00/tube (outer diameter of 100 mm). In this project, we will improve the process of metal-glass sealing techniques to $0.50/glass tube (outer diameter of 70 mm).

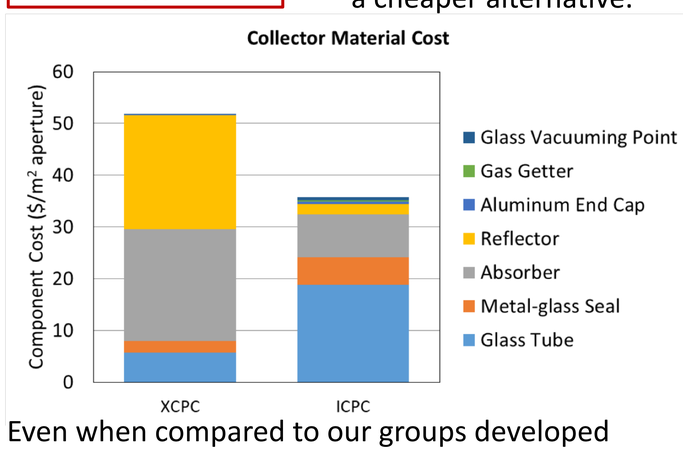


System by Collector Type	Concen-tration Ratio	Manufacturer	Collector Cost ($/m²)	Total direct cost ($/m²)*	Efficiency @ 120 °C**	O&M ($/m²)	LCOH ($/kWh$_{th}$)
Vacuum Tube (all-glass)	1/π	SunRain	248[18]	328	25%[19]	5	$0.073
CPC (shallow)	0.7	Linuo Ritter Paradigma	110[20]	190	41%[21]	5	$0.030
Flat Plate	1	Viessmann	100[22]	180	15%[23]	5	$0.072
Vacuum Tube (metal-glass)	1	Viessmann	300[24]	380	56%[25]	5	$0.036
Evacuated Flat Plate	1	TVP Solar	350[26]	430	65%[27]	5	$0.035
CPC	1.4	Artic Solar	160	240	60%[3]	5	$0.023
Linear Fresnel	20	Chromasun	180[28]	260	58%[29]	15	$0.035
Parabolic Trough	24	SkyFuel	170	350	60%[30]	15	$0.041
DOE Target			100	180	74%	5	$0.015
ICPC	1	N/A	70	150	64%	5	$0.015

The ICPC optics allow a working temperature of **120°C** with a collector thermal efficiency of about **65%**. With an operating temperature range of 100-200°C that beats commercialized solar thermal competitors in efficiency and an overall LCOH that is ***HALF the price*** of natural gas in California, the proposed design opens the door to solar thermal technology with a cheaper alternative.

Current price of Natural Gas in California: **$0.03/KWh**

ICPC Collector Cost Breakdown		
Component	**Cost ($/m²)**	**Assumptions**
Glass Tube	18.80	Bulk glass tubes
Metal-glass Seal	5.31	Bulk aluminum, low melting point glass
Absorber	8.33	Minichannel heat pipe and supports
Reflector	2.00	External mirror-coated reflector
Evacuation	1.33	Including barium gas getter
Tube Assembly	15.00	Labor, machinery depreciation, rental
Manifold & Rack Mount	10.00	Module-level plumbing & parts
Module Assembly	9.26	Racking, labor, and packaging
Total	**70.03**	Per m²

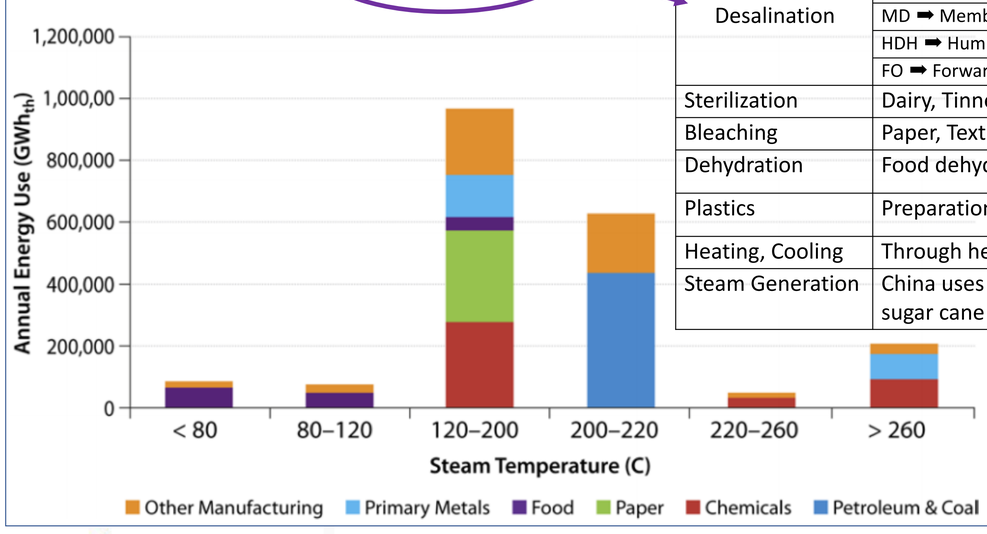


Even when compared to our groups developed XCPC's component cost, the proposed design is about $17/m² aperture cheaper.

Applications

And many more!

Process	Description
Desalination	MSF ➡ Multi-Stage Flash
	MED ➡ Multi-Effect Distillation
	MD ➡ Membrane Distillation
	HDH ➡ Humidification / De-hudification
	FO ➡ Forward Osmosis
Sterilization	Dairy, Tinned food
Bleaching	Paper, Textile
Dehydration	Food dehydration through drum drying
Plastics	Preparation, distillation, extension, drying
Heating, Cooling	Through heat exchangers, and chillers
Steam Generation	China uses steam to combat air pollution, sugar cane factories, etc.



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