Solar Powered Water Heating Technology Research

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Global Capacity and Energy Yield

Global solar thermal capacity in operation and annual energy yields

Solar Collector Configurations
Minichannel tubes and Solar Energy

Diagram showing solar energy input to both a flat plate and a flat tube with minichannels. The temperature profiles for copper round-tube flat plate and aluminum minichannel tube are also shown.
Types of Minichannel Tubes

Aluminum Minichannel Condenser versus RTPF Condenser

Equal Capacity: 7 kW
Improved Thermal Efficiency

Fig. 10. Cross-section profile of the CPC concentrator for the minichannel-based solar collector. Three sample rays out of 50,000 are shown for (a) $\theta = 0^\circ$ and (b) $\theta = 35^\circ$.

Aluminum Minichannel Collector

Selective coating: Black chrome (EC series): $\alpha = 0.95$, $\varepsilon = 0.12$
Closed-Loop System

Diagram showing the components of a closed-loop system, including:
- Solar irradiance
- Solar collector
- Outlet temp
- Inlet temp
- Flow rate
- Pump
- Control logic
- Water storage tank
- Internal heat exchanger coil
- Tank temp
- Discharge valve
- Hot water out
- Cold water in
Thermal Efficiency Improvement: 12%, approximately

Prototype Collector Cost

10 ft. by 4 ft. (3.7 m²) aluminum minichannel solar collector

- Aluminum minichannel tubes = $440
- Headers = $28
- Collector frame and glass purchased = $500
- TIG welding = $1056
- Total = $2024, or $50.6/ft² (or $544.65/m²)
- Estimated cost for mass produced unit: $14.43/ft² (or $155.32/m²)

Average conventional collector $51.42/ft² (or $553.50/m²) *

* GTM Research and SEIA, 2011
Copper Extrusion

Copper minichannel tubes manufactured by Prof. Kraft, at Ohio University
Low-Grade Steam Generation

(a) Temperature [°C] / Flow rate [L/min]
- T Collector in
- T Collector out
- T Steam
- T Ambient
- Flowrate

(b) Solar Irradiance [W/m²]
- Solar Irradiance
Industrial Heat Applications
(Prof. Winston’s group)

Installation in Mongolia
Non-imaging optics-based External Compound Parabolic Concentrator (XCPC)
Sugar Refinery in Dubai
High Temperature + Electric Power

650 Celsius (1202 °F)
Factors Influencing Policy

San Bruno Explosion (2010)
California's Aliso Canyon blowout led to largest U.S. methane leak ever
Changes in Incentives
CPUC approved Advice No. 4953 (April 29, 2016)

SoCalGas:

Step 1 incentive level of $70/therm for Single Family

$25/therm for Commercial/Multifamily applications.

<table>
<thead>
<tr>
<th>Step</th>
<th>Incentive per annual therm displaced ()For SoCalGas only</th>
<th>Maximum Incentive Single-Family Residential Projects ()For SoCalGas only</th>
<th>Budget Allocation (in millions)</th>
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<tr>
<td>1</td>
<td>$29.85 ($70.00)</td>
<td>$4,366 ($10,238)</td>
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<td>4</td>
<td>$3.23 ($0)</td>
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California Solar Initiative Thermal Program Handbook Rev 18.2.0
What does this mean?

- Water heating is the most significant residential end use for natural gas in California.

- Natural gas is used to heat water in nearly 90 percent of homes.

- Represents 49% of the average 354 therms of annual household consumption.

- $173 \text{ therm/yr} \times $70 / \text{ therm} = $12,110 \text{ (Max. Incentive of $10,238)}$

- Average cost of SWH system in residential sector in California is $8,364

The system is paid in one year!
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