Solar Heating and Cooling Conference
Hawaii Hotel CHW and DHW case study
1. Chromasun Overview


3. Hawaiian Hotel Case Study

4. Economics in Other States

5. Q & A
So what’s in the Chromasun toolbox?

Experienced team
engineering and solar experience

Efficient Chromasun MCT-HT
the only flat panel suitable for high temperature heat pumps

HVAC and Heat Pump makers
a reliable gas/solar alternative to electric.

Solar Installers
Chromasun: solar-enhanced heating & cooling for commercial & industrial facilities

Three Technical Approaches

Segment A
Process Heat
- Steam, pressurized H₂O
- Boiler pre-heat
- Hydronic Heating
- Domestic Hot Water

Large market (some segments better developed than others)

Segment B
Solar Heat-Pumping
- CHW & DHW, or
- CHW & HHW, or
- CHW & process heat
- Single-effect Absorption Chillers (COP 2.20)
- Co-fired with NG

Under-developed market

Segment C
Solar Cooling
- Chilled Water (heat reject to outside)
- Double-effect Absorption Chillers (COP 1.35)
- Co-fired with NG for reliability & economics

Under-developed market
Chromasun’s Previous Solar Experience

- **Peter Le Lievre (CEO) and Andrew Tanner (VP of Engineering)** were co-founders and engineers at Ausra, now Areva Solar.
Objective: miniaturize the successful utility-scale Fresnel concentrating optic and make it into a rooftop-friendly product
Chromasun’s Micro-Concentrator (MCT)

4 ft x 11 ft (1.2M x 3.4M)
4.9 lb / sq ft (24 kg / M²)
(220 lb each) (100 kg)
No external moving parts
Maximum Temp: 400 ºF (200 ºC)
Maximum Pressure: 40 Bar
Solar Concentration: 20X
3rd Party Certified (SRCC)
How the MCT Collector Works

Solar Light Path

Hermetically Sealed Glass Enclosure

Stainless Steel Receiver Pipe

Self Tracking Fresnel Mirrors
The MCT: Superior Efficiency at Higher Temperatures

Solar Collector Comparison
(Global = 1000W/m², DNI = 850W/m²)

Collector Efficiency [%] vs Temperature Difference (Tm-Ta) [degC]

- Chromasun MCT
- Viessmann Flat Plate
- Kingspan Evac Tube
- Ritter CPC

Flat Plate Collector
Evacuated Tube Collector
The MCT: Superior Efficiency at Full and Partial Sun

MCT

Flat Plate

Collector Efficiency [%]

Temperature Difference (Tm-Ta) [°C]

Solar Strength (Watts / M²)

Collector Efficiency [%]

Temperature Difference (Tm-Ta) [°C]
Chromasun 10 MW* Capacity Factory (San Jose, CA)

Chromasun MCTs are made in the USA

* Single Shift
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Re-Examine an Old Paradigm

The Typical Commercial HVAC Setup

- Chillers
- Boilers
- reheat
- DHW

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How do traditional Heat Pumps work? (e.g. an air-conditioner)

Heat pumps push heat in the “wrong” direction  Electro-mechanical force drives the process

We experience this as cool air inside  Heat is pumped into an already warm environment as a waste product
How does our Solar Thermal Heat Pump work?

Difference #1: 
*Thermal energy drives the system*

Difference #2: 
*Pumped heat is used, not wasted*
How do Chromasun Systems work?

Gas can drive the heat pump...

...or solar energy, or both!
Segment B: Solar Heat Pumping (Heating & Cooling) (DHW focused)

Solar Energy:
- Sunlight
  - Chromasun MCT Hi-temp Solar Panels

Thermal Input:
- 1.00 BTU @ 115°C / 240°F and/or NG / LPG / Oil
- 0.60 BTU @ 7°C / 44°F
- 1.60 BTU @ 54°C / 130°F

Building Systems:
- Cooler Building
- Chromasun THP® NH₃ Multi-Fire Absorption Chiller
- Backup Co-fire Boiler

Heat Balance Equation: 1.00 + 0.60 = 1.60
Chromasun MCT Showcase

Santa Clara University
Benson Building

- 60 MCT panels
- 2,682 square feet
- 120KWt peak
- 410 Mbtu/h
- 6,727 therms PA

Boiler feedwater preheat application

- HHW and DHW (2,880 GPD) for main cafeteria

Installed 2011
Crow Canyon Medical Center

Danville, CA

50RT Thermax Chiller

- 75 MCT panels
- 3,352 square feet
- 150KWt peak

Annual Outputs
- 340 MWH CHW
- 3,840 therms DHW

Installed 2012

Tour available at this conference!
Solar/Heat Pump Installations

Over 300 commercial / industrial systems worldwide. (IEA 2009 study)

Chromasun (50RT) California

Festo/DLR (500RT) Europe

Proterra (40RT) Canada

Solid (50RT) Europe

Solid (175RT) Europe
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Beachside Resort, Hawaii

Hawaii Hotel Case Study

- 50 RT gas/solar heat pump solution (150 MCTs)
- Annual Electricity offset: 278 MWh*
- Propane Gross Offset: 177,700 gallons (before absorber consumption)
- Net LPG Consumption cut by 58%
Chromasun Technical Integration with Facility – P&ID
Hawaiian Hotel Solar Contribution

### Solar Array Production

**Weather Data-file**

Hawaii (SW island)

<table>
<thead>
<tr>
<th>Solar Array Operational Availability</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
</tr>
</thead>
<tbody>
<tr>
<td>CF</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
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<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>

**Chromasun Collectors**

- Count: 150
- Oper. Temp.: 120 °C
- Model: MC1-H123b
- Peak Rating: 1.9 kW<sub>TH</sub>

### Production Potential (MWh<sub>TH</sub>)

<table>
<thead>
<tr>
<th></th>
<th>Load Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan</td>
<td>26.8</td>
</tr>
<tr>
<td>Feb</td>
<td>29.2</td>
</tr>
<tr>
<td>Mar</td>
<td>30.7</td>
</tr>
<tr>
<td>Apr</td>
<td>30.8</td>
</tr>
<tr>
<td>May</td>
<td>29.5</td>
</tr>
<tr>
<td>Jun</td>
<td>29.6</td>
</tr>
<tr>
<td>Jul</td>
<td>29.5</td>
</tr>
<tr>
<td>Aug</td>
<td>32.1</td>
</tr>
<tr>
<td>Sep</td>
<td>32.0</td>
</tr>
<tr>
<td>Oct</td>
<td>29.4</td>
</tr>
<tr>
<td>Nov</td>
<td>26.8</td>
</tr>
<tr>
<td>Dec</td>
<td>26.7</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>353.0</strong></td>
</tr>
</tbody>
</table>

### Monthly Solar Production

![Graph showing monthly solar production]

### Key Metrics

- Average Monthly: 29.414 MWh<sub>TH</sub>
- Max Monthly: 32.088 MWh<sub>TH</sub>
- Min Monthly: 26.704 MWh<sub>TH</sub>
- Peak Output: 0.285 MWh<sub>TH</sub>

**Total Array Size**

- 9,000 Ft<sup>2</sup>
- 836 M<sup>2</sup>

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Hawaiian Hotel – Thermal Dynamics (Int’l units)

Heat-Pump Thermal Input
kWh
- Solar Portion: 352,968
- Gas Portion: 2,036,842
- Combined: 2,389,811

CHW

121 °C
116 °C
7.0 °C
13.0 °C
21.1 °C
54.4 °C
DHW or HHW

Chromasun’s Thermally-Driven Heat-Pump (Absorption Chiller)

<table>
<thead>
<tr>
<th>Heat-Pump Fuel Offset (kWh)</th>
<th>Existing Chiller Efficiency (COP)</th>
<th>Heat-Pump Production (kWh)</th>
<th>H-P Cool Efficiency (COP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>47,062</td>
<td>4.500</td>
<td>211,781</td>
<td>0.600</td>
</tr>
<tr>
<td>230,842</td>
<td>4.500</td>
<td>1,038,790</td>
<td>0.510</td>
</tr>
<tr>
<td>277,905</td>
<td>4.500</td>
<td>1,250,571</td>
<td>0.523</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Heating Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar</td>
</tr>
<tr>
<td>Gas</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

Direction of Net Heat Flow

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Hawaiian Hotel – Thermal Dynamics (US units)

Chromasun’s Thermally-Driven Heat-Pump (Absorption Chiller)

**Heat-Pump Thermal Input (Therms)**
- Solar Portion: 12,047
- Gas Portion: 69,517
- Combined: 81,564

**Cooling Results**

<table>
<thead>
<tr>
<th>Heat-Pump Fuel Offset (kWh)</th>
<th>Existing Chiller Efficiency (COP)</th>
<th>Heat-Pump Production (Therms)</th>
<th>H-P Cool Efficiency (COP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>47,062</td>
<td>0.154</td>
<td>7,228</td>
<td>0.600</td>
</tr>
<tr>
<td>230,842</td>
<td>0.154</td>
<td>35,454</td>
<td>0.510</td>
</tr>
<tr>
<td>277,905</td>
<td>0.154</td>
<td>42,682</td>
<td>0.523</td>
</tr>
</tbody>
</table>

**Heating Results**

<table>
<thead>
<tr>
<th>Heat-Pump Heat Efficiency (COP)</th>
<th>Heat-Pump Production (Therms)</th>
<th>Existing Boiler Efficiency (COP)</th>
<th>Heat-Pump Fuel Offset (Therms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar: 1.600</td>
<td>19,275</td>
<td>0.700</td>
<td>27,535</td>
</tr>
<tr>
<td>Gas: 1.360</td>
<td>94,543</td>
<td>0.700</td>
<td>135,061</td>
</tr>
<tr>
<td>Total: 1.395</td>
<td>113,818</td>
<td>0.700</td>
<td>162,597</td>
</tr>
</tbody>
</table>

**Direction of Net Heat Flow**

- CHW (Cooling Hot Water)
- DHW or HHW (Domestic Hot Water or Hot Hot Water)
### Chromasun System Turnkey Economics

**Assumptions**

<table>
<thead>
<tr>
<th>Description</th>
<th>Approx. Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Installed Cost</td>
<td>$1,740,000</td>
</tr>
<tr>
<td>HI Grant in lieu of State Tax Credit</td>
<td>$(350,000)</td>
</tr>
<tr>
<td>HI (Hawaii Energy) HEEP SHW CBI</td>
<td>$(30,000)</td>
</tr>
<tr>
<td>Federal MACRS w/50% bonus</td>
<td>IRS: Sec. 48; Bulletin 2011-16; Pub 946 $(600,000)</td>
</tr>
<tr>
<td>Federal ITC 30%</td>
<td>IRS Sec. 48(a)(3) $(500,000)</td>
</tr>
</tbody>
</table>

**Total Cash Cost (net of incentives)**

<table>
<thead>
<tr>
<th>Description</th>
<th>Approx. Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total Cash Cost</strong></td>
<td><strong>$260,000</strong></td>
</tr>
</tbody>
</table>

**Utility Savings Cash Flows**

<table>
<thead>
<tr>
<th>Description</th>
<th>Year 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boiler Energy Savings</td>
<td>$458,466</td>
</tr>
<tr>
<td>Absorber Energy Purchases</td>
<td>$(196,013)</td>
</tr>
<tr>
<td>Electricity Savings</td>
<td>$91,709</td>
</tr>
</tbody>
</table>

**Year 1 Savings**

<table>
<thead>
<tr>
<th>Description</th>
<th>Approx. Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Year 1 Savings</strong></td>
<td><strong>$354,161</strong></td>
</tr>
</tbody>
</table>

**Key Economic Assumptions**

- **Cooling Energy**
  - $0.330 / kWh (inflation factor = 5% / yr)
- **Heating Energy**
  - $2.58 / LPG-gal (inflation factor = 5% / yr)
- **Existing Boiler / Chiller COPs**
  - 0.70 / 4.50
- **DHW Consumption**
  - Avg 62,368 GPD, with a 60.0 ºF temperature gain
- **Chromasun Solar THP Capacity**
  - 50 TR (cooling) @81% capacity factor
- **Combined Tax Rate**
  - 40%

**Simple Payback**

1.2 Years

**Project IRR**

50%
## Chromasun Comparison to Solar PV and SHW Flat-plate

<table>
<thead>
<tr>
<th></th>
<th>Chromasun</th>
<th>Solar PV</th>
<th>SHW Flat-plate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net Utility Offset (annual)</td>
<td>-</td>
<td>$354,161</td>
<td>-</td>
</tr>
<tr>
<td>Total Collectors</td>
<td>150</td>
<td>3937 (787 kW&lt;sub&gt;DC&lt;/sub&gt;)</td>
<td>930</td>
</tr>
<tr>
<td>Array Size (sq.ft.)</td>
<td>9,000</td>
<td>75,590</td>
<td>71,640</td>
</tr>
</tbody>
</table>
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Typical Chromasun THP Economics (with combined heating & cooling) (Hospitality Sector)

Cuts heating fuel consumption in half + electricity savings
Offsetting 100% of DHW and a portion of CHW loads

• **TurnKey Purchase Option**
  – 1½ - 3 year paybacks (HI); 2-4 year payback (CA & AZ)
  – Significant offset to chiller electricity
  – Strongest economic value requires appetite for tax incentives
  – Performance Guarantee & O&M options available

• **Power Purchase Agreement**
  – Zero-capital outlay, immediate savings from day 1
  – Pay-as-you-go by the meter; means equipment and performance risk is on Chromasun
  – Pricing based a negotiable discount to public tariff: Chromasun takes all risk for all utility price changes. Client discount remains the same, regardless of the market.
  – Substantial utility discounts available
  – Financing resources available now
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THANK YOU

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Performance Tracking

Solar Resource Monitoring

BTU Metering by TRANE
Testing program – began 2009

Santa Clara University, California
SoCalGas - Los Angeles
SRCC – Menlo Park, California
GE Global Research – Bangalore, India
Australian National University
GE Global Research - Munich, Germany