Solar Thermal Systems: Solar Heating R&D
National Renewable Energy Laboratory
Sandia National Laboratories

U.S. Department of Energy
Solar Energy Technologies
Presentation Outline

• Description of solar thermal R&D activities in:
  – Low-cost passive solar hot water systems
    • Polymer integral collector-storage (PICS) systems
  – Low-cost active solar systems
    • Cold-climate solar water heating systems
    • Combined heating and cooling (CHC) systems
Solar Thermal Systems Participants

• National Laboratories
  – National Renewable Energy Laboratory
  – Sandia National Laboratories

• Industry
  – FAFCO (California)
  – Davis Energy Group / SunEarth (California)
  – DuPont Canada Inc. (Ontario)
  – SRP (Arizona)
  – Energy Laboratories Inc. (Florida)

• Universities
  – University of Minnesota
  – University of Colorado
  – University of Central Florida
**Solar Thermal Systems R&D Goals**

**Near-Term (2006):**
- Mild-climate solar water heating systems that deliver energy at $0.04 - $0.06/kWh

**Mid-Term (2010):**
- Cold-climate solar water heating systems that deliver energy at $0.05 - $0.06/kWh

**Long-Term (2015-2020):**
- Solar space heating and cooling systems that deliver energy at $0.04 - $0.05/kWh

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Low-Cost Passive Solar Thermal Systems
Solar Water Heating

Common System Types

Passive

Active

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Passive Solar Water Heating

Integral Collector-Storage (ICS) System

Gasket   Glazings
Box
Insulation
Storage tanks
Innovative, Low-Cost Solar Water Heaters

Project Goal:
Cut the delivered, life-cycle energy cost of solar water heating systems in half by the year 2005.

Innovative, Low-Cost Solar Water Heaters

- **Hardware cost reduction**
  - Polymer technology
  - Parts integration
- **Installation cost reduction**
  - Lighter collectors, flexible bundled piping
  - Integrated balance of system
- **Marketing cost reduction**
  - New construction: SWH as standard feature or option
  - Do-it-yourself / Home improvement stores

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Technical Challenges (Barriers):

• Polymer durability – the **key** technical challenge

• System performance
  – Overheating protection
  – Heat exchanger sizing and placement

• Building code issues
  – Use of plastics, e.g., flammability
  – Structural concerns, e.g., roof weight, wind loading

• Manufacturing process design
  – Thermoforming and rotomolding temperature tolerances
Innovative, Low-Cost Solar Water Heaters

Project Phases:

• **Concept Generation / Exploratory Research**
  – Identification of general system configurations which could conceivably reach the project’s cost goal

• **Concept Development / Prototype Test**
  – Development of detailed designs for promising concepts and construction and evaluation of prototypes

• **Advanced Development / Field Test**
  – Development of second-generation prototypes and conducting limited field testing and evaluation

• **Engineering / Manufacturing Development**
  – Construction of manufacturing facilities and evaluation of “near-final” systems in “real-world” applications
Davis Energy Group/SunEarth Design

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Material Durability Testing
Durability Testing

Outdoor

Accelerated Laboratory Chambers

Ultra-Accelerated, Natural Sunlight

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**UV-Screened Polymeric Glazing Construction**

<table>
<thead>
<tr>
<th>Layer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Screening Layer (UV absorbers)</td>
</tr>
<tr>
<td>Optional Bonding Layer (adhesive, etc.)</td>
</tr>
<tr>
<td>Candidate Polymeric Glazing</td>
</tr>
<tr>
<td>Another Polymeric Element (e.g., absorber)</td>
</tr>
</tbody>
</table>

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GE HP92WDB 20-mil thick PC Film

No Korad UV screen; 8.2 months Ci5000 exposure

With Korad UV screen; 10 months Ci5000 exposure

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Low-Cost Active Solar Thermal Systems
Geographical Limitations of ICS Systems

Probability of at Least One Pipe Freeze in 20 Years
Always Occupied (No Vacations/Draws made every day)

Pipe Diameter = 3/4"
Insulation Thickness = 1"
RC Time Constant = 4.24 hours
Residential Solar Water Heating

Common System Types

Passive

Active

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Active Solar Water Heating

Flat Plate Collector

Indirect Circulation Solar System
Active Solar Water Heating System R&D

DuPont Canada

University of Minnesota

Labs and Industry

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Low-Cost Solar Water Heaters for Cold Climates

Polymer Flat Plate Collector

DuPont / University of Minnesota Collaboration
Polymeric Absorber and Heat Exchanger Testing

- Nylon 6,6
- HTN
- Polybutylene
- Polypropylene
- Teflon
- Copper

Tensile strength testing
- Polyethylene
- Polypropylene

New In-situ optical device for measuring scale
University of Minnesota
For some polymers, hot chlorinated water significantly reduces strength.
- Alternate PB formulation (with additives) shows less degradation.
- Loss of strength occurs very rapidly in nylon 6,6.

Materials tested at U of MN in FY2003.
Polymer Tube Scaling

NATIVE

Teflon

AFTER
540 Hr exposure to hard water

Copper
Polymer Tube Scaling (cont.)

• Calcium carbonate accumulates on all polymers tested.

NATIVE

AFTER
540 Hr exposure to hard water

Nylon 6,6

PB

1 µm

10 µm
• Results indicate nylon 6,6 enhances scaling.
• Mass of scale on PP, PB, HTN, Teflon and copper tubes are similar.
Combined Heating and Cooling Systems
Features of polymer-based SWH systems:

- Year-round load: ✔ good system utilization
- New materials: ✔ lower cost
- Simple systems: ✔ higher reliability
Combined space heating and cooling systems

• Year-round load: ✔ good system utilization
• New materials: ✔ lower cost
• Simple systems: ✔ higher reliability
Combined Solar Heating & Cooling System
Albuquerque, NM
Unglazed Collector 126 ft², \( \Delta T_{HX} = 5 \)
Combined Heating and
Cooling Systems

Unglazed Collector Space Heating &
Hot Water Savings
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