A PLACE IN THE SUN

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

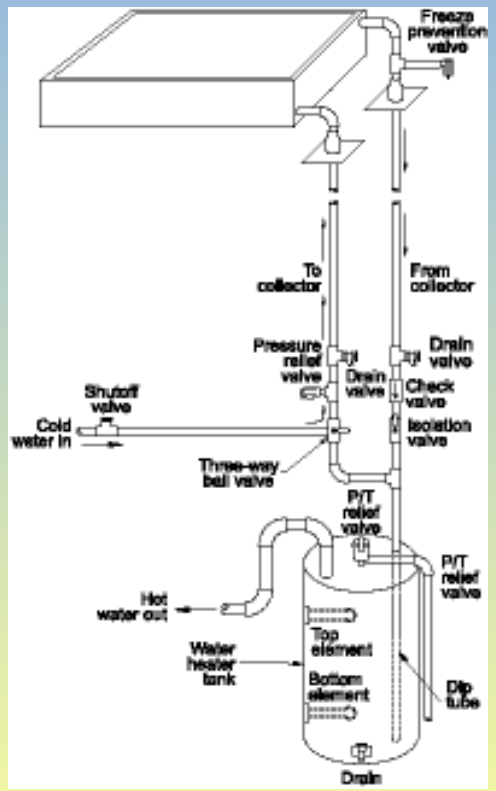
Long-Term (2015-2020):

• Solar space heating and cooling systems that deliver energy at $0.04 - $0.05/kWh

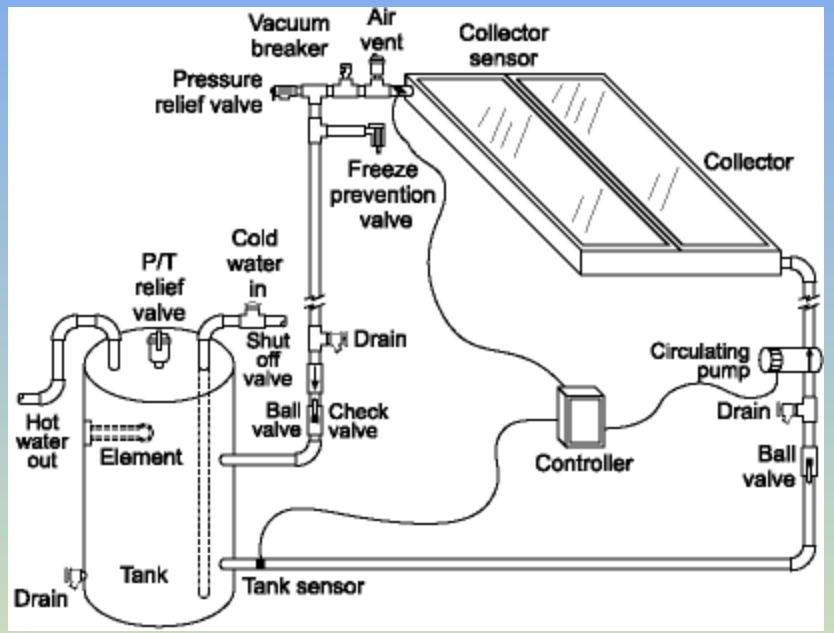
Low-Cost Passive Solar Thermal Systems

Solar Water Heating

Common System Types



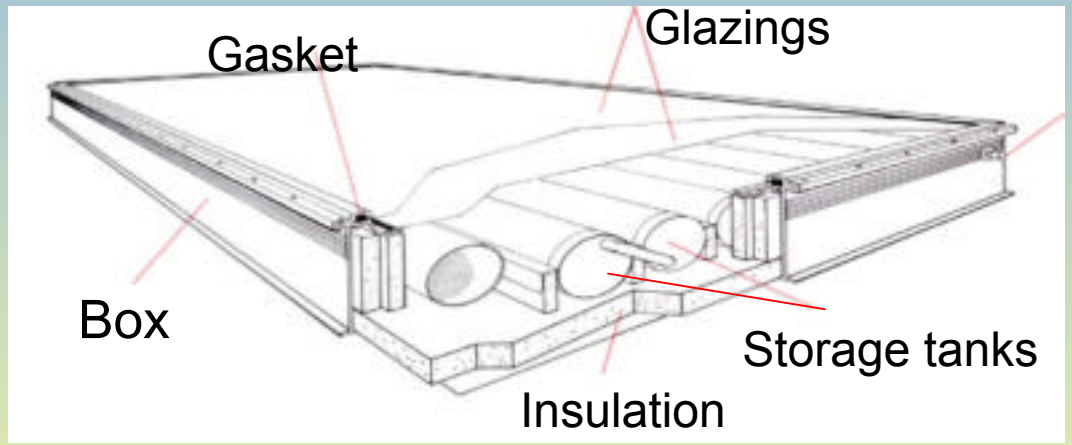
Passive

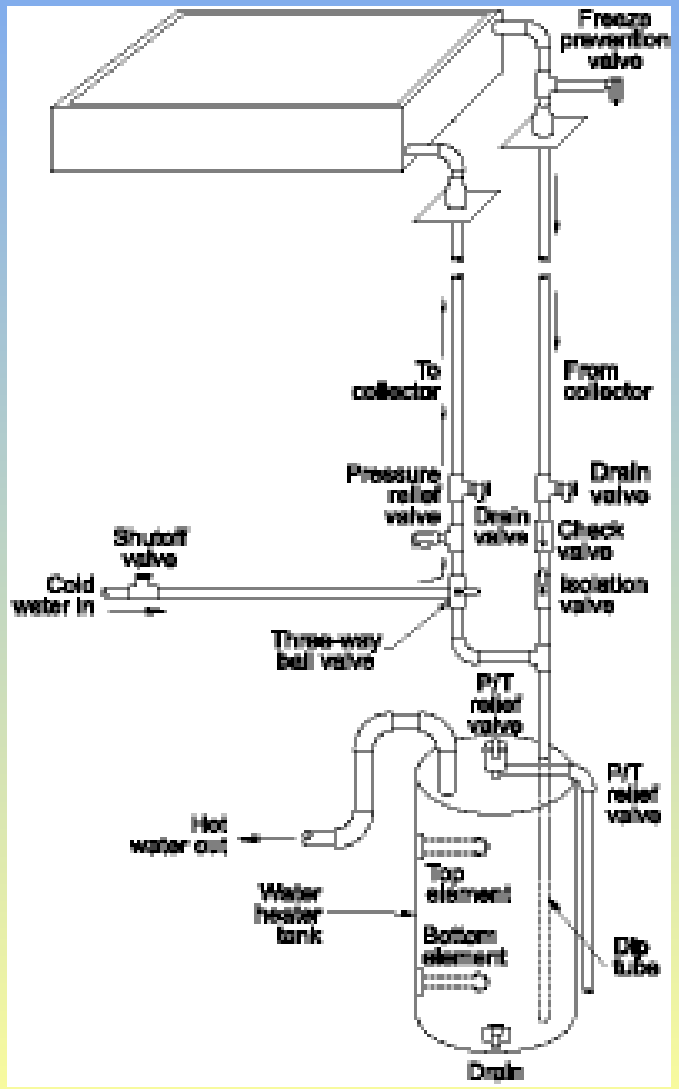


Active

Passive Solar Water Heating

Integral Collector-Storage (ICS) System





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.

Source: Solar Buildings Technology Program: 5-Year Strategic Plan, January 31, 1998

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

Technical Challenges (Barriers):

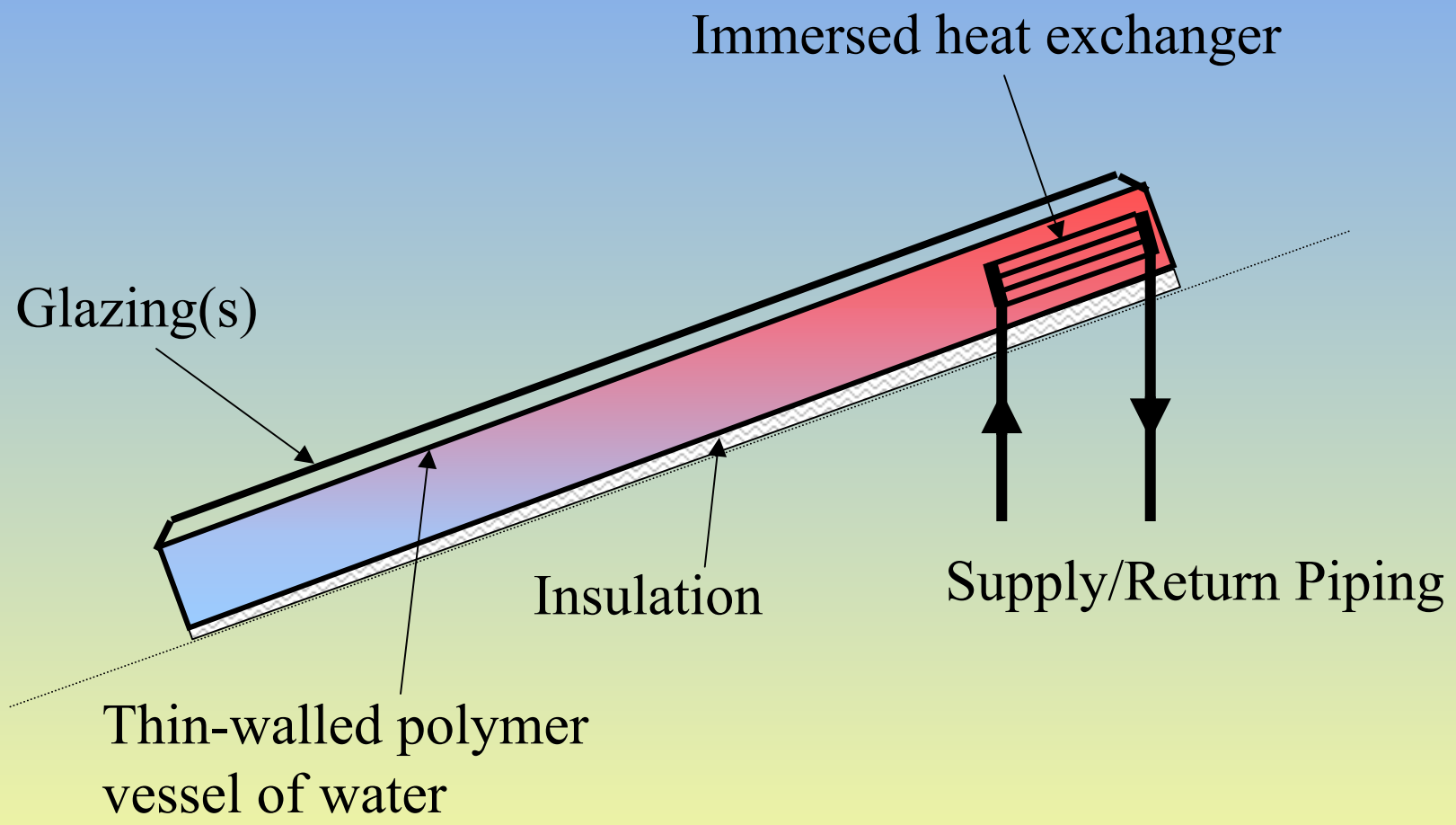
- Polymer durability – the **key** technical challenge
- System performance
  - Overheating protection
  - Heat exchanger sizing and placement
- Building code issues
  - Use of plastics, e.g., flammability
  - Structural concerns, e.g., roof weight, wind loading
- Manufacturing process design
  - Thermoforming 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

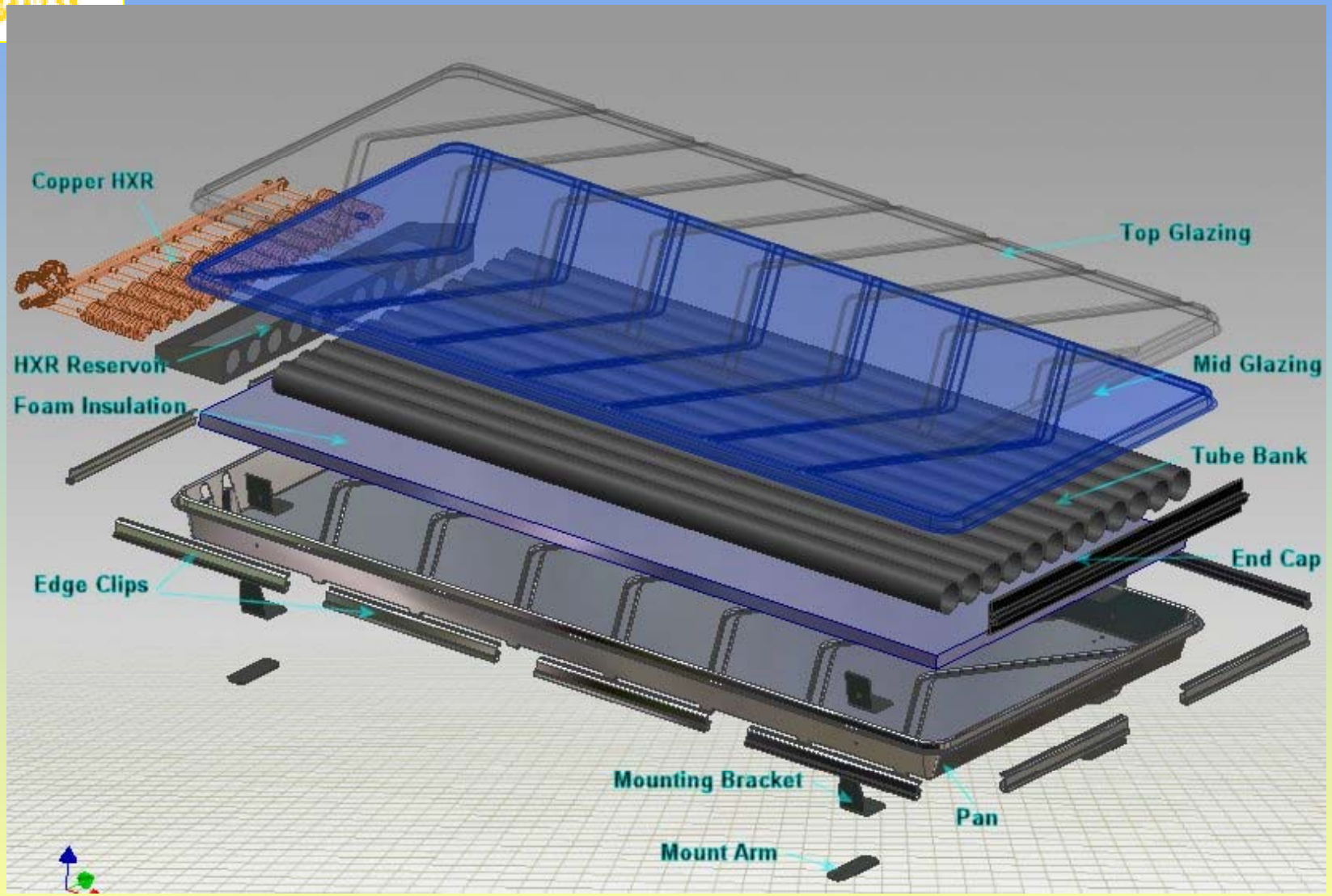
Unpressurized Integral Collector Storage



Davis Energy Group/SunEarth Design

Davis Energy Group/SunEarth Field Test

FAFCO Design



FAFCO Prototype

Material Durability Testing

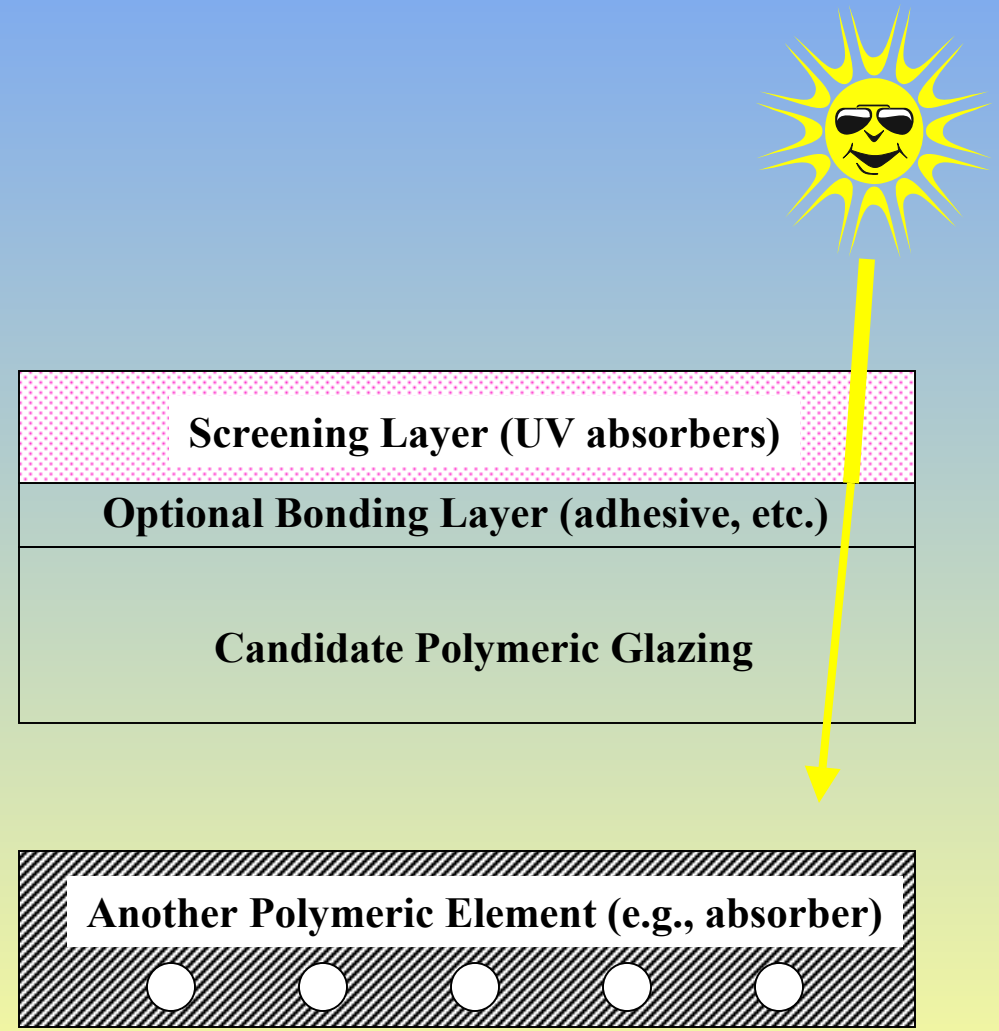
Durability Testing

Outdoor

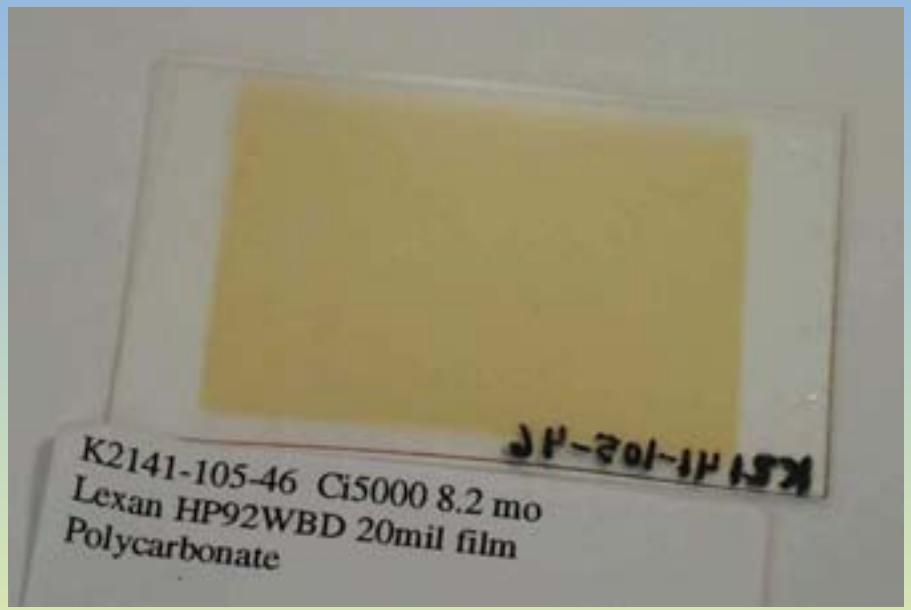
Accelerated Laboratory Chambers

Ultra-Accelerated, Natural Sunlight

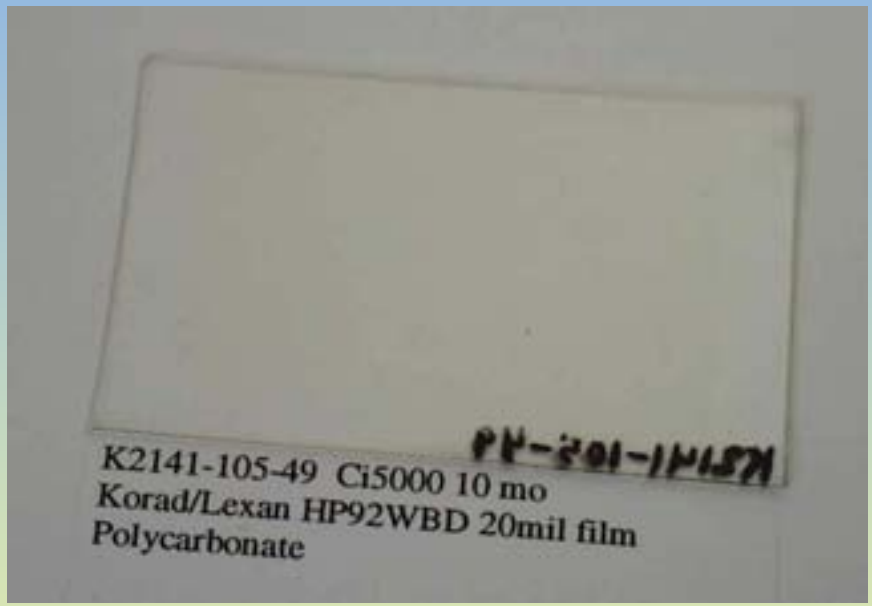
UV-Screened Polymeric Glazing Construction



GE HP92WDB 20-mil thick PC Film



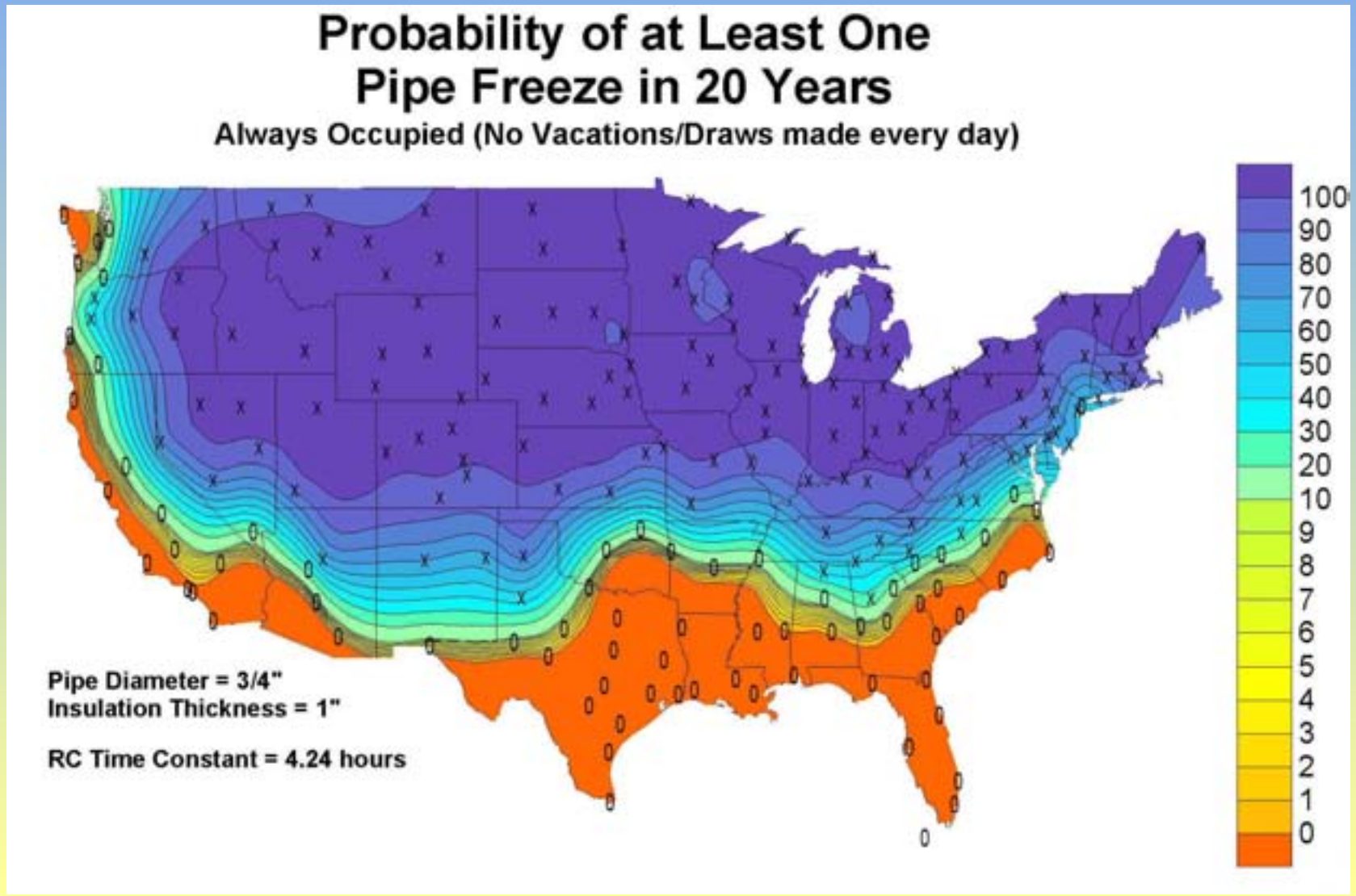
No Korad UV screen; 8.2 months Ci5000 exposure



With Korad UV screen; 10 months Ci5000 exposure

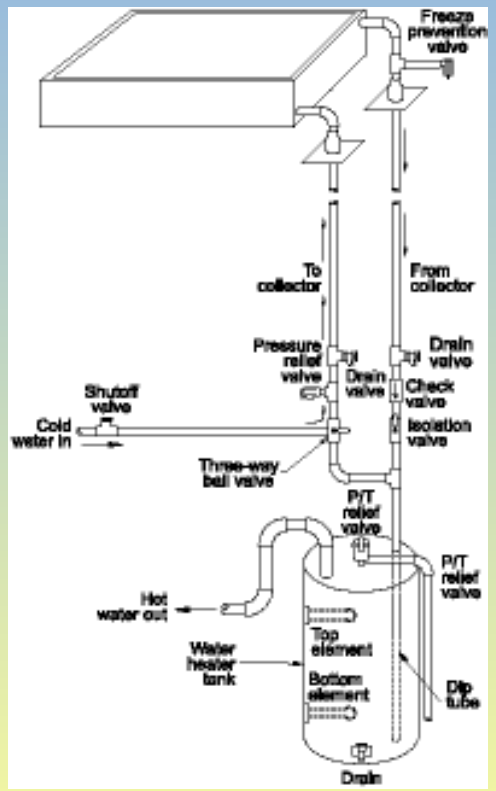
Low-Cost Active Solar Thermal Systems

Geographical Limitations of ICS Systems



Residential Solar Water Heating

Common System Types



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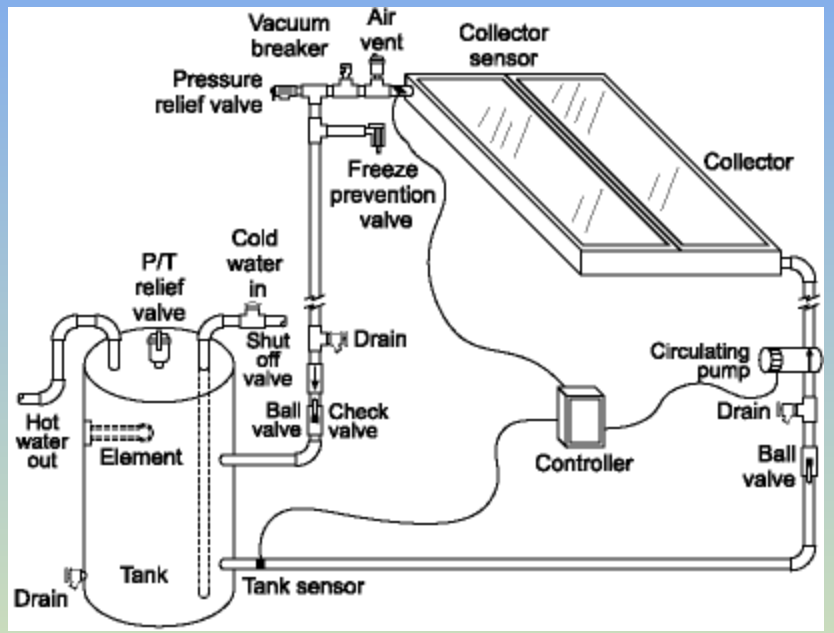
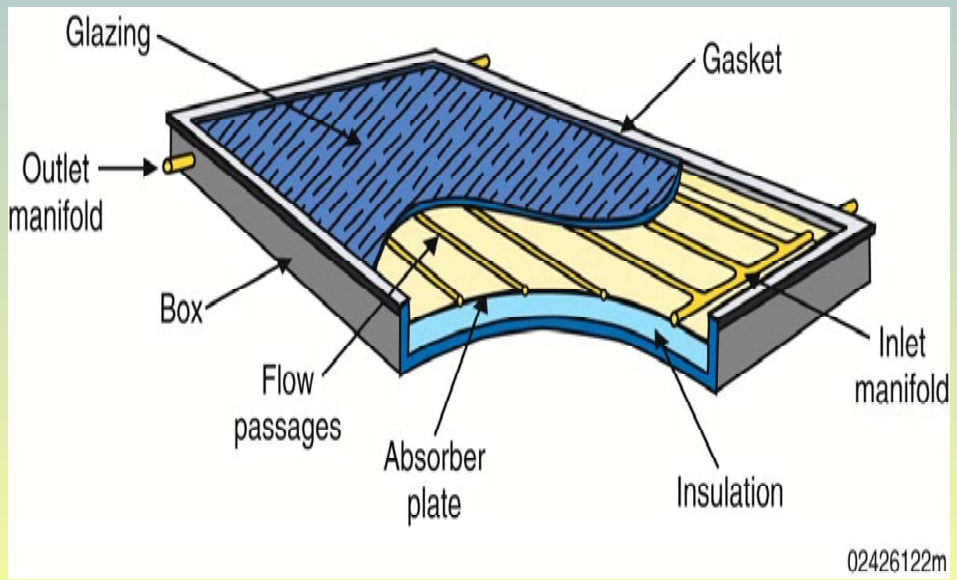
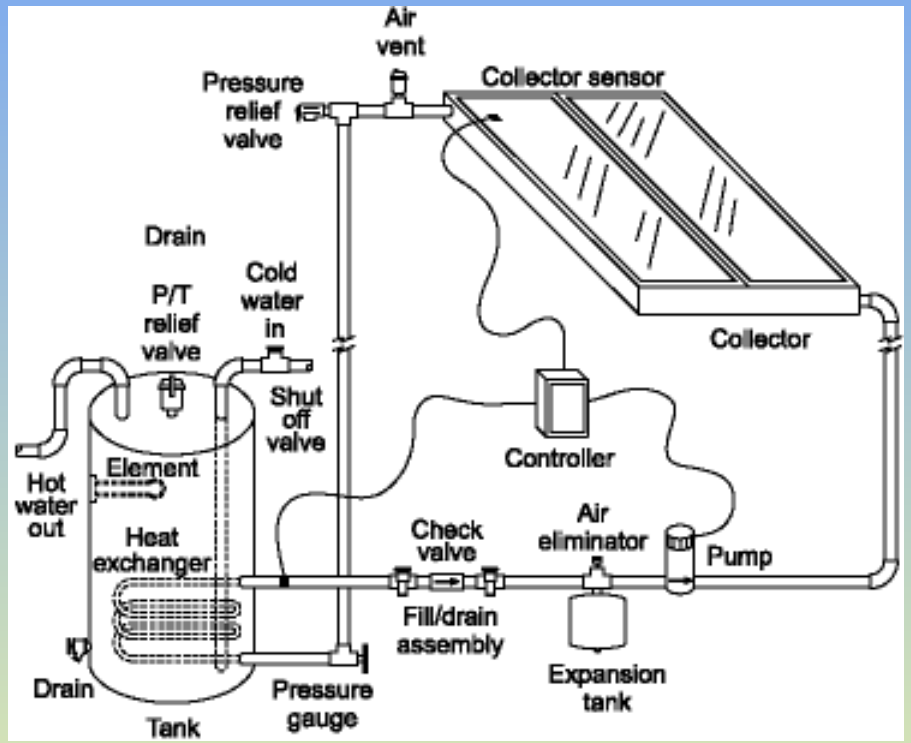


Active

Active Solar Water Heating

Flat Plate Collector

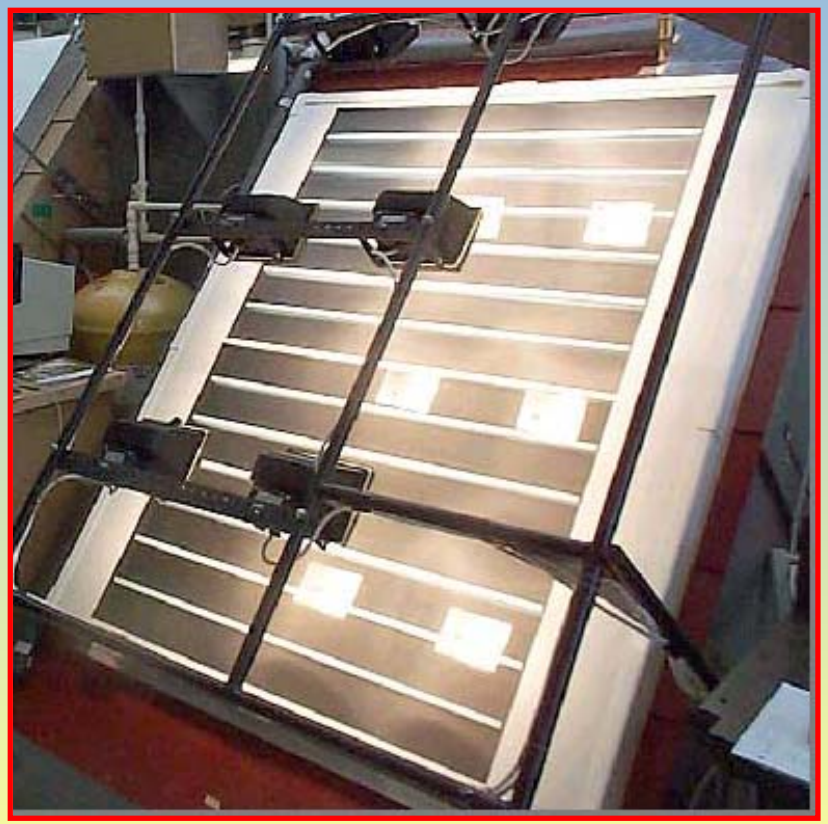




Indirect Circulation Solar System

Active Solar Water Heating System R&D

DuPont Canada

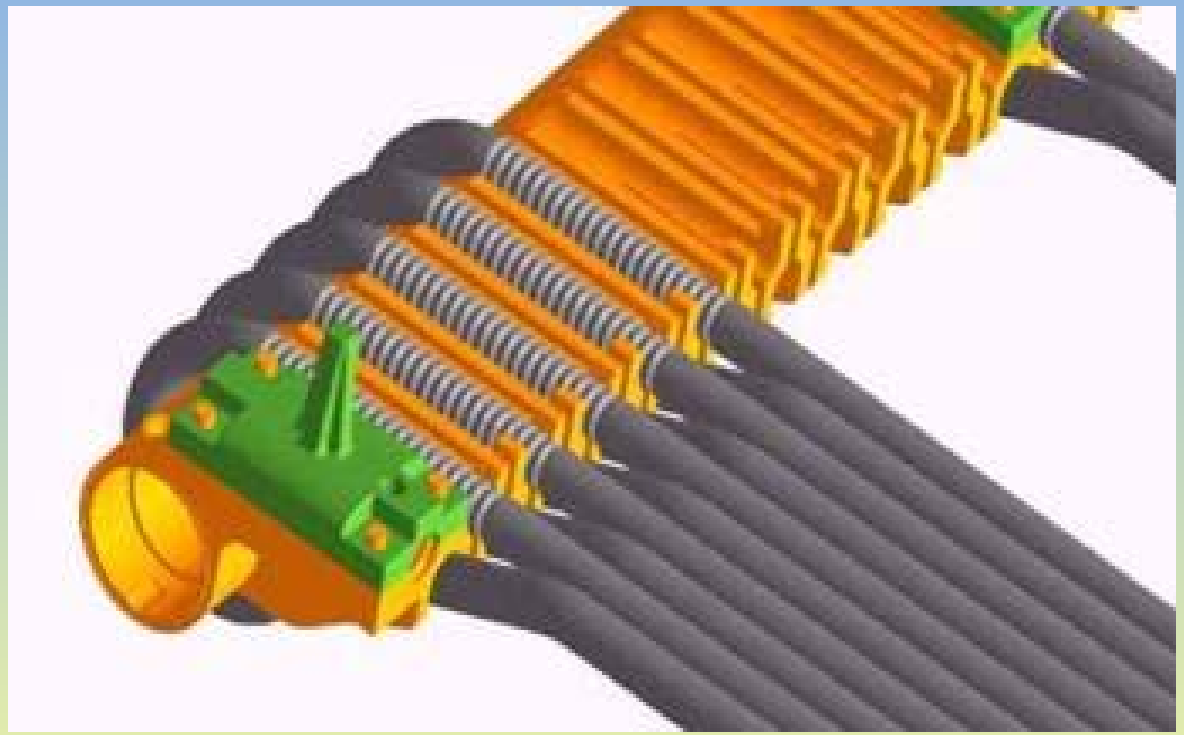


University of Minnesota

Labs and Industry

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

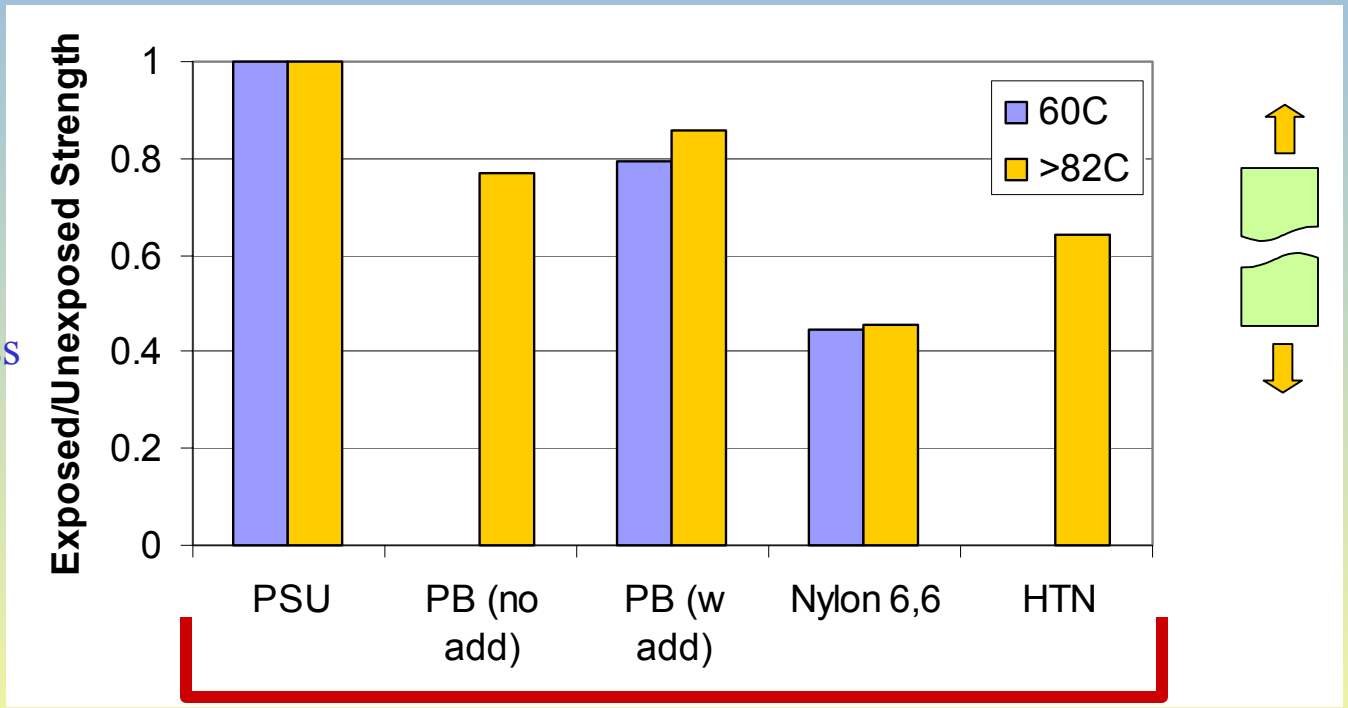
New In-situ optical device for measuring scale
University of Minnesota

Polymeric Absorber and Heat Exchanger Testing

Strength after aging in Hot, Chlorinated H_2O

- 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.

Strength after 300-1200 hrs in ORP=825 mV

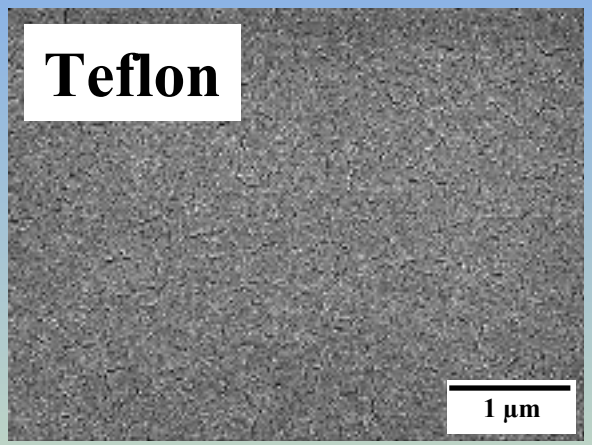


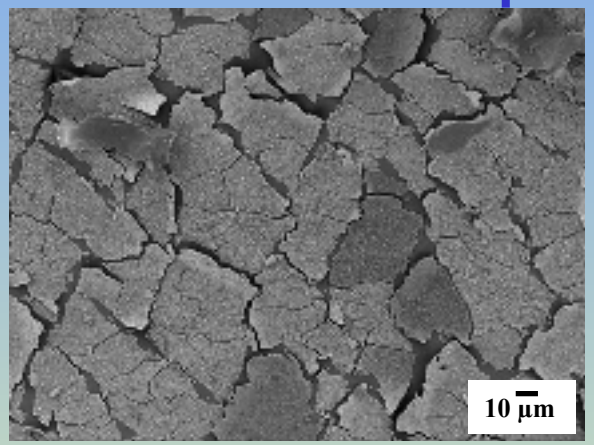
Materials tested at U of MN in FY2003

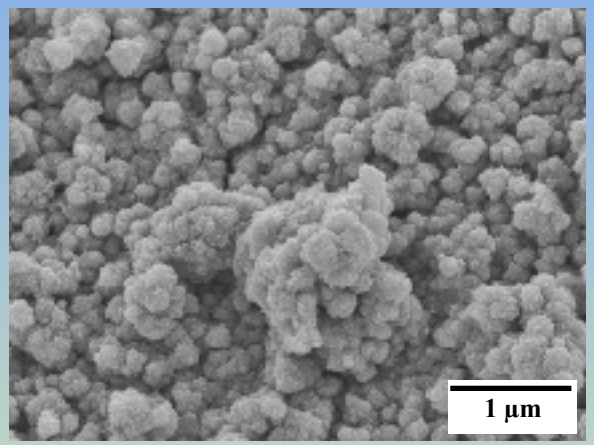
Polymer Tube Scaling

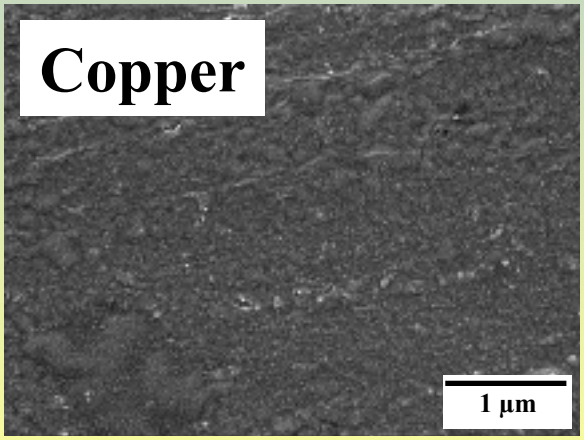
NATIVE

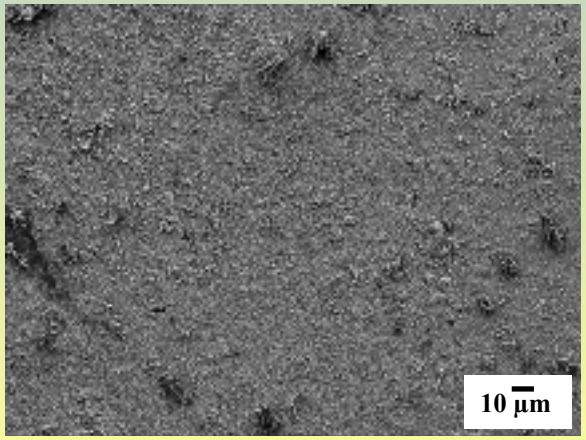
AFTER
540 Hr exposure to hard water

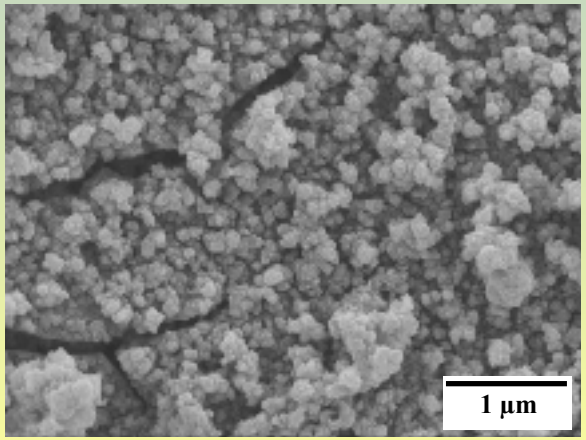










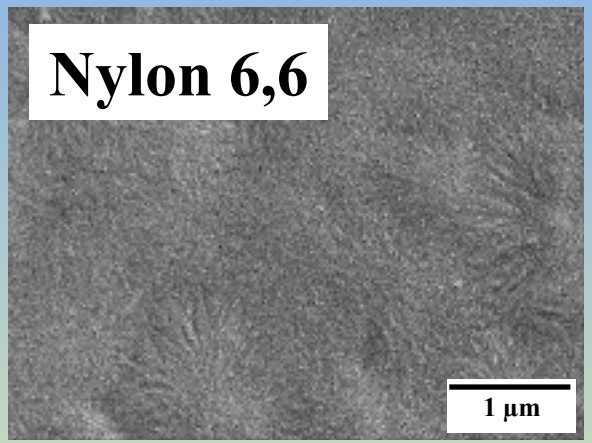


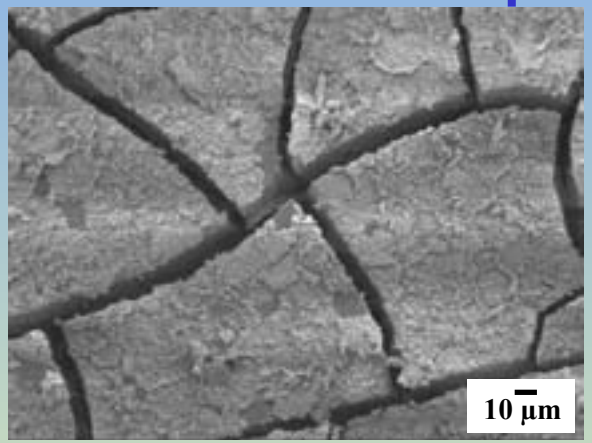
Polymer Tube Scaling (cont.)

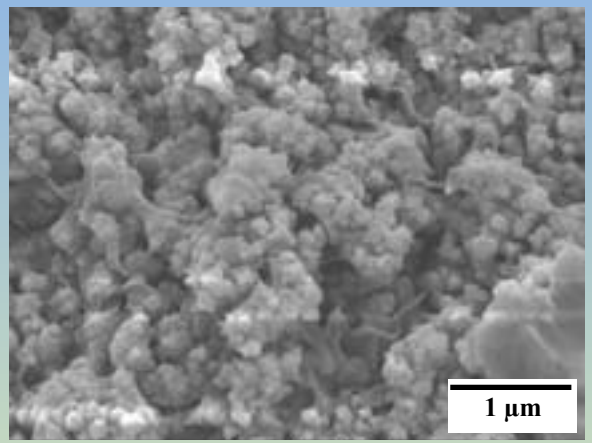
- Calcium carbonate accumulates on all polymers tested.

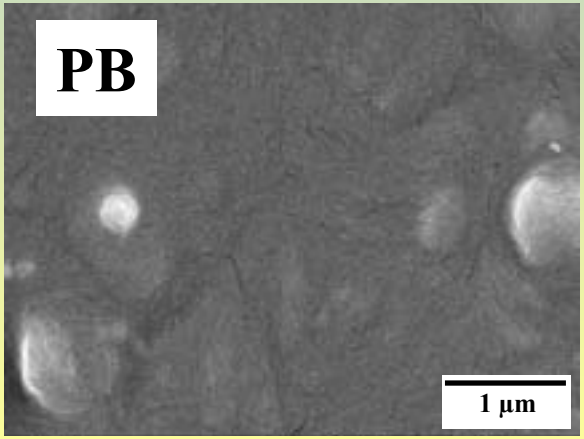
NATIVE **AFTER**

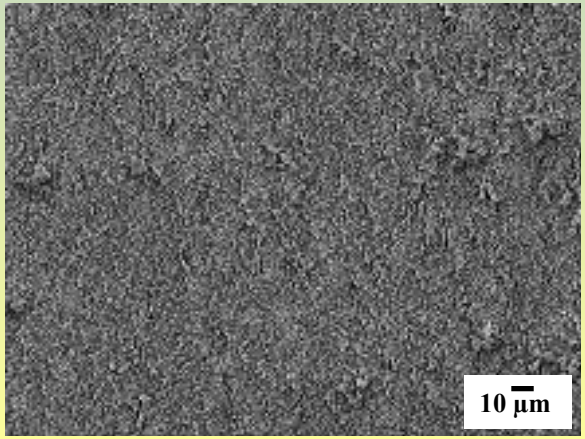
540 Hr exposure to hard water

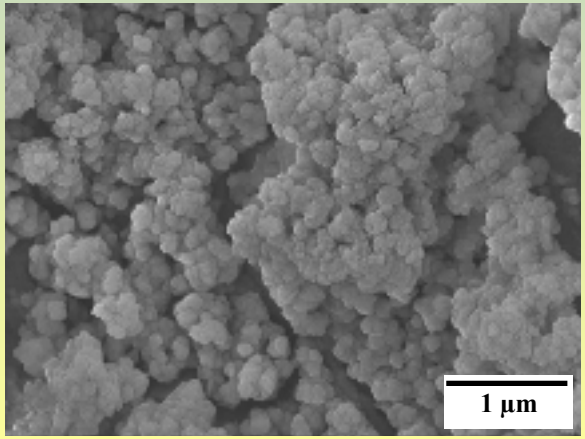




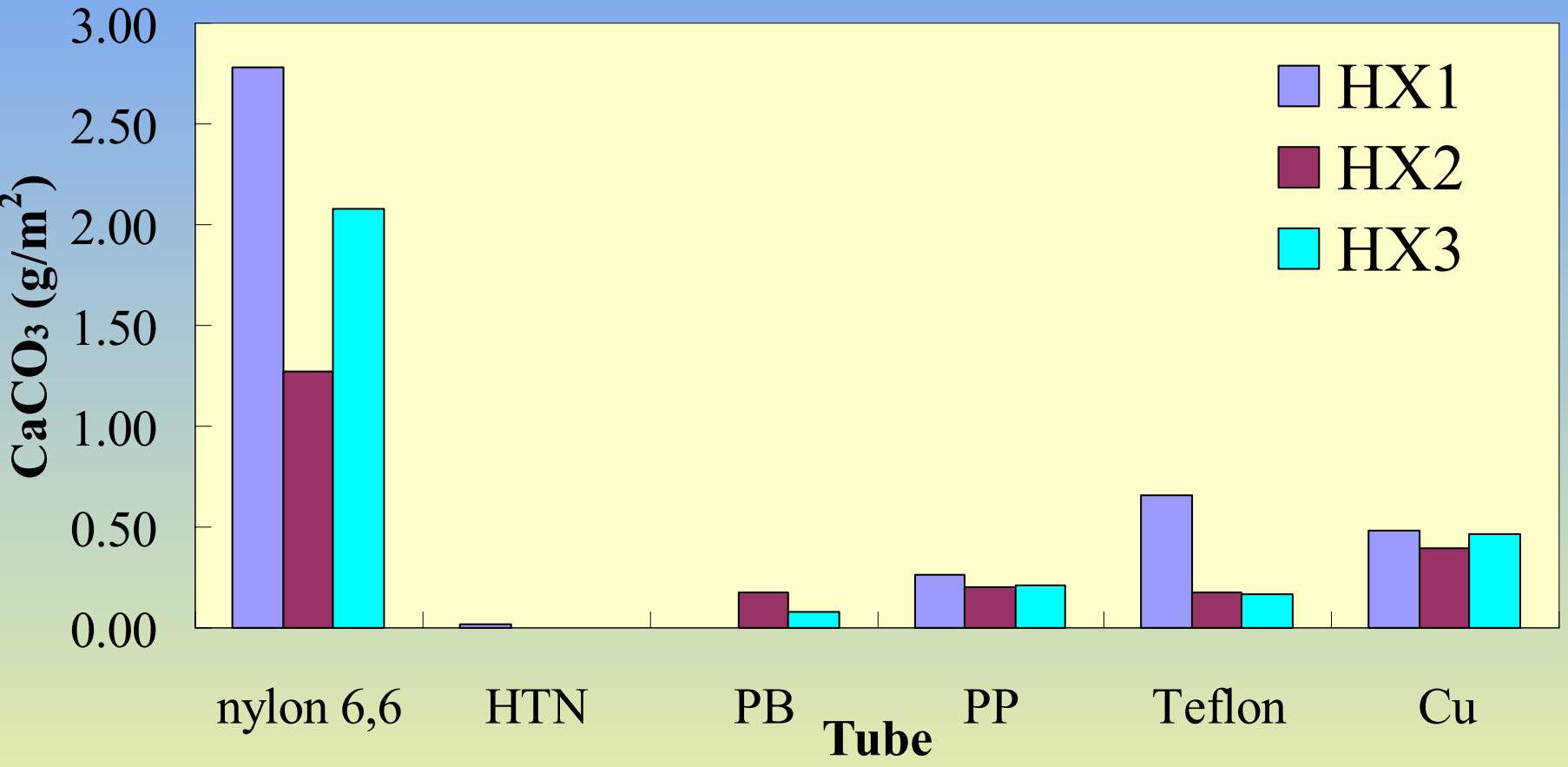








Polymer Tube Scaling



- 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

Solar Thermal Systems R&D Approach

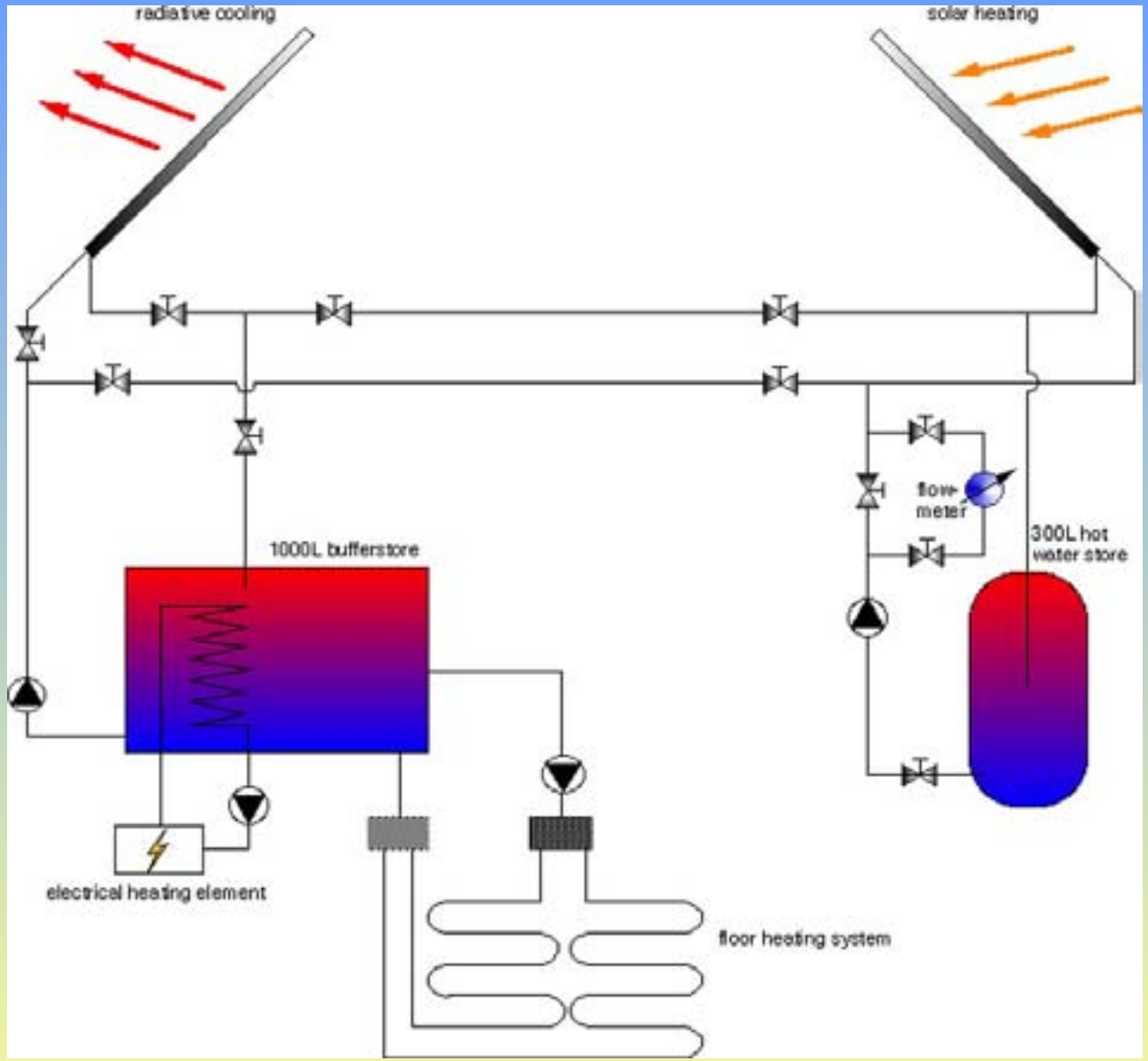
Features of polymer-based SWH systems:

- Year-round load: ☑ good system utilization
- New materials: ☑ lower cost
- Simple systems: ☑ higher reliability

Solar Thermal Systems R&D Approach

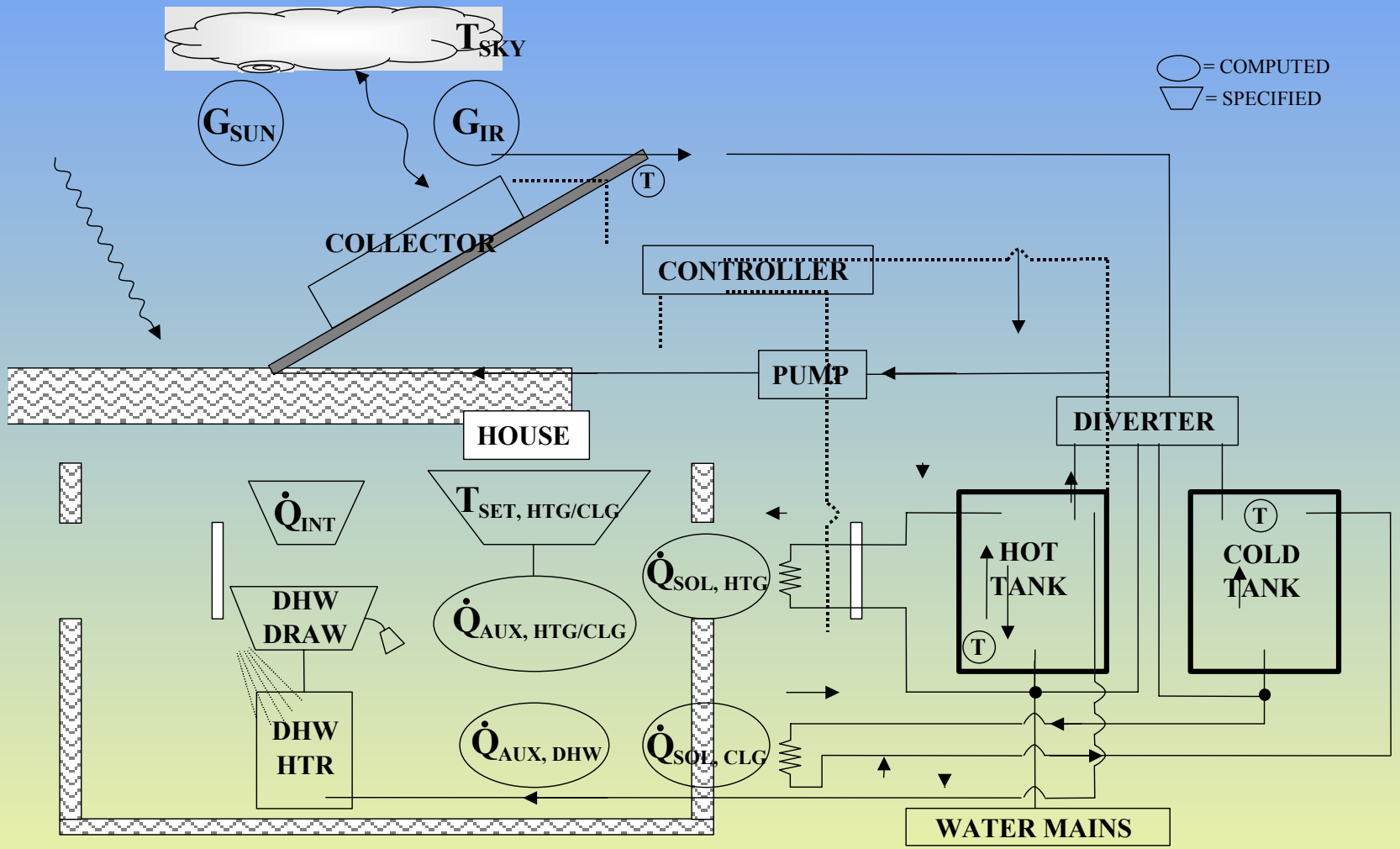
Combined space heating and cooling systems

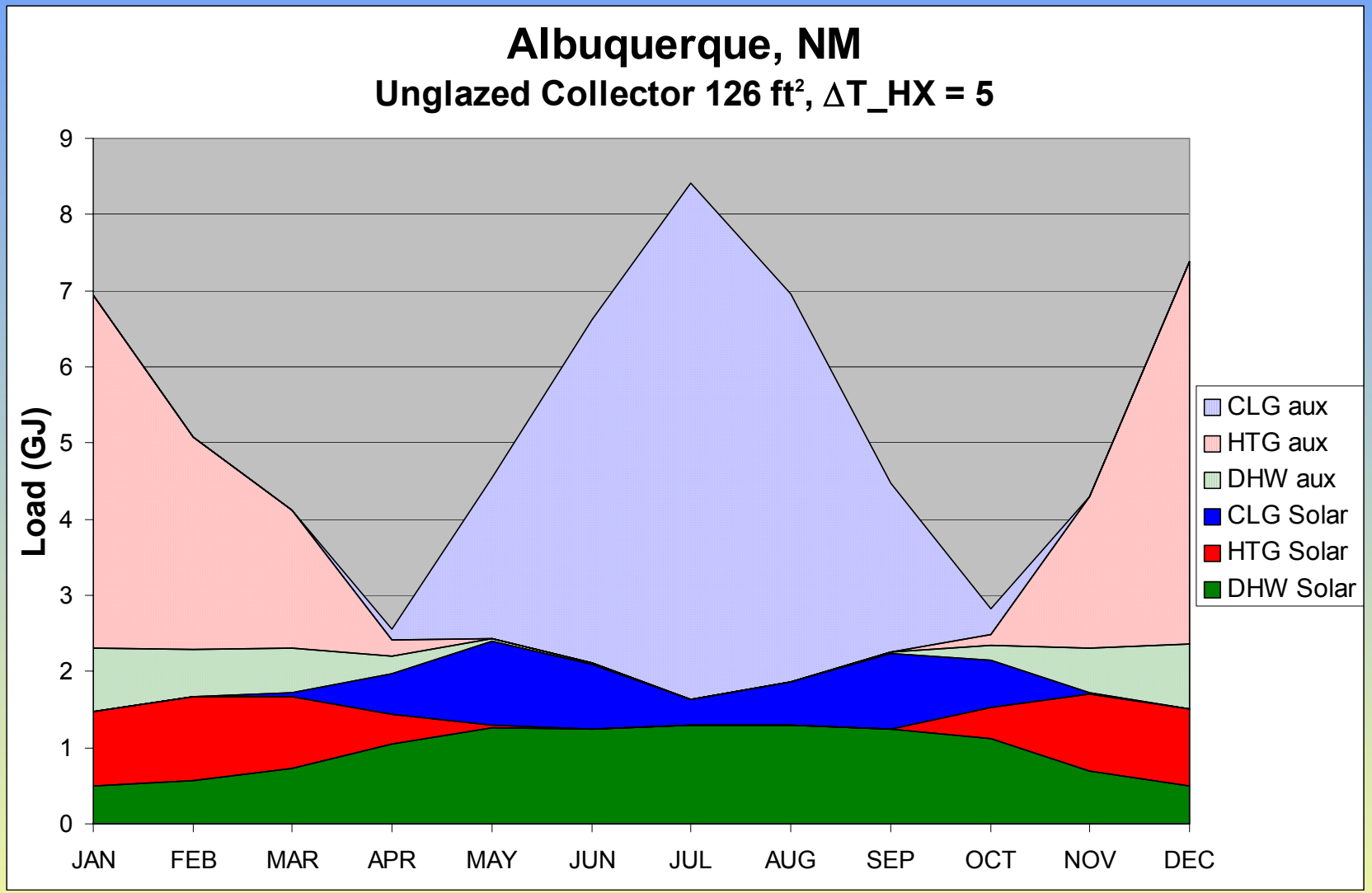
- Year-round load: ☑ good system utilization
- New materials: ☑ lower cost
- Simple systems: ☑ higher reliability

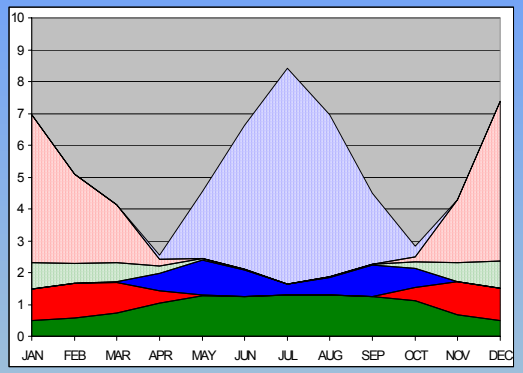
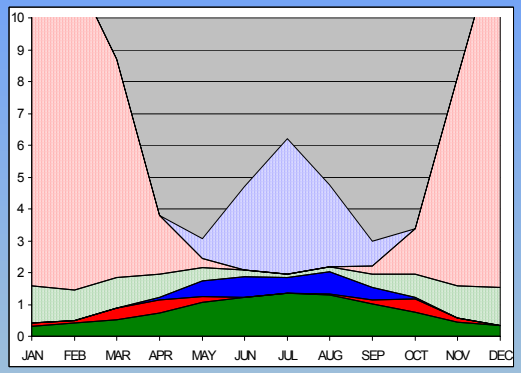
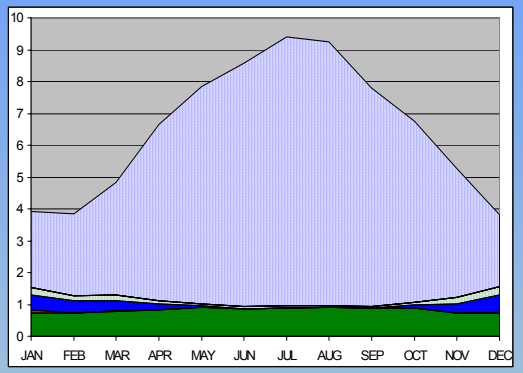
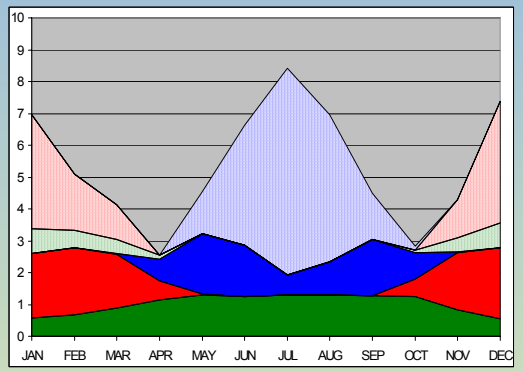
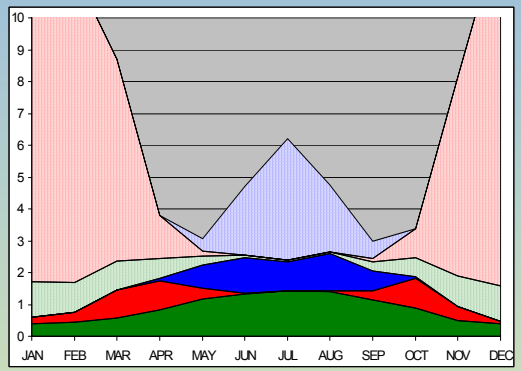
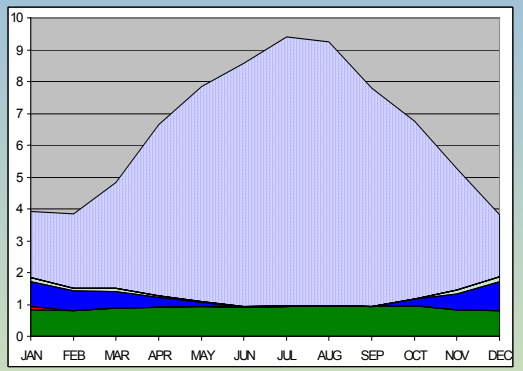
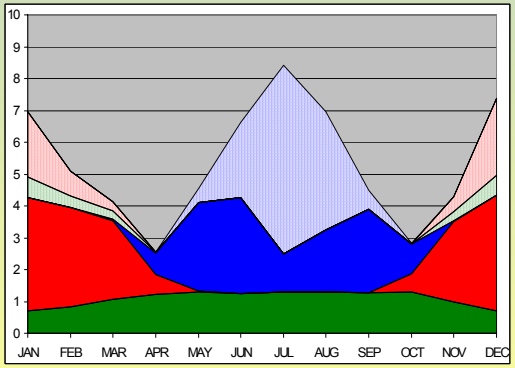
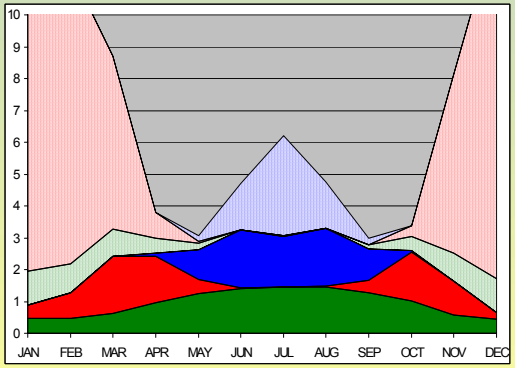
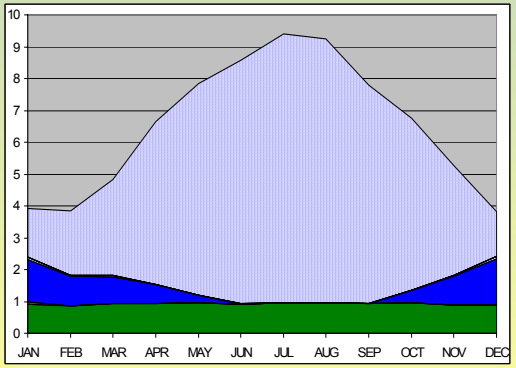


Combined Solar Heating & Cooling System

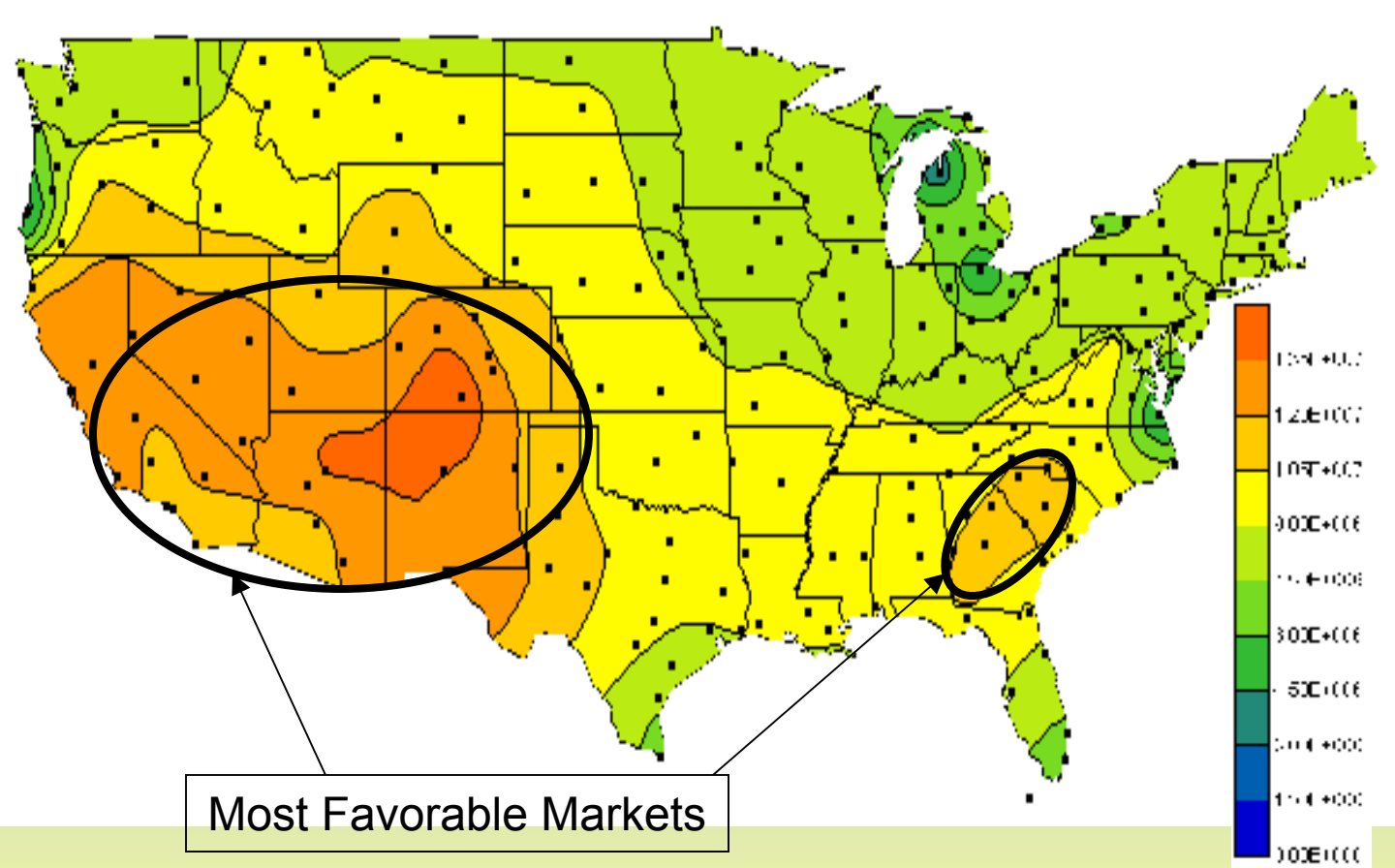
TRIPLE PLAY MODEL




Albuquerque, NM
Unglazed Collector 126 ft², ΔT_HX = 5
Load (GJ)
0
1
2
3
4
5
6
7
8
9
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
CLG aux
HTG aux
DHW aux
CLG Solar
HTG Solar
DHW Solar

	Albuquerque, NM	Madison, WI	Miami, FL
125 ft^2			
250 ft^2			
500 ft^2			

Combined Heating and Cooling Systems



Unglazed Collector Space Heating &
Hot Water Savings

Solar Thermal Systems R&D Goals

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