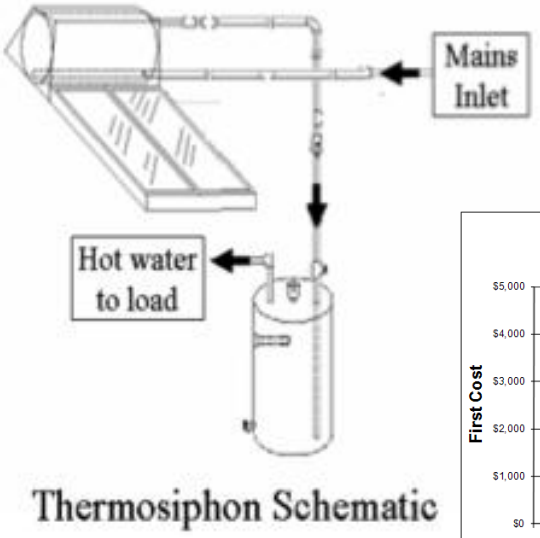
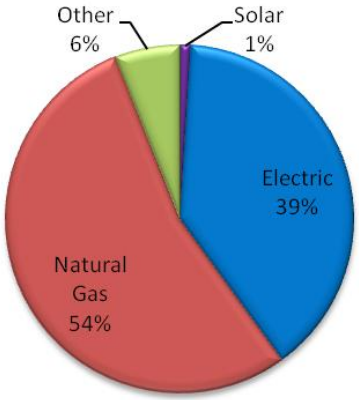
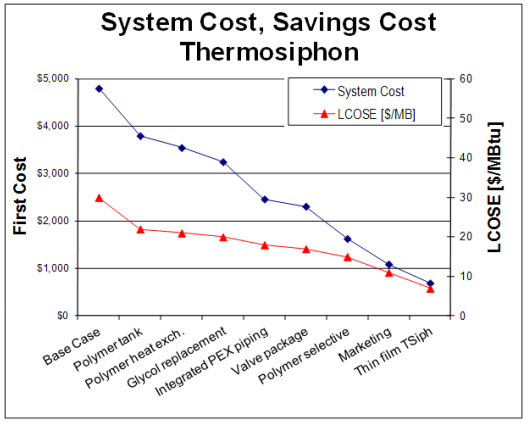
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

NREL
NATIONAL RENEWABLE ENERGY LABORATORY



Thermosiphon Schematic





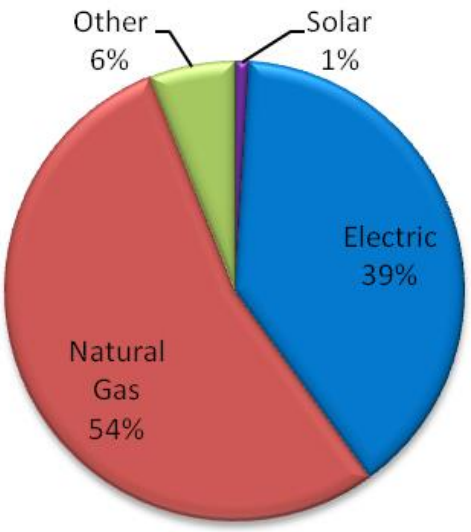
Ultra low-cost RhoTech Solar system – System Components

Low Cost Solar Water Heating R&D

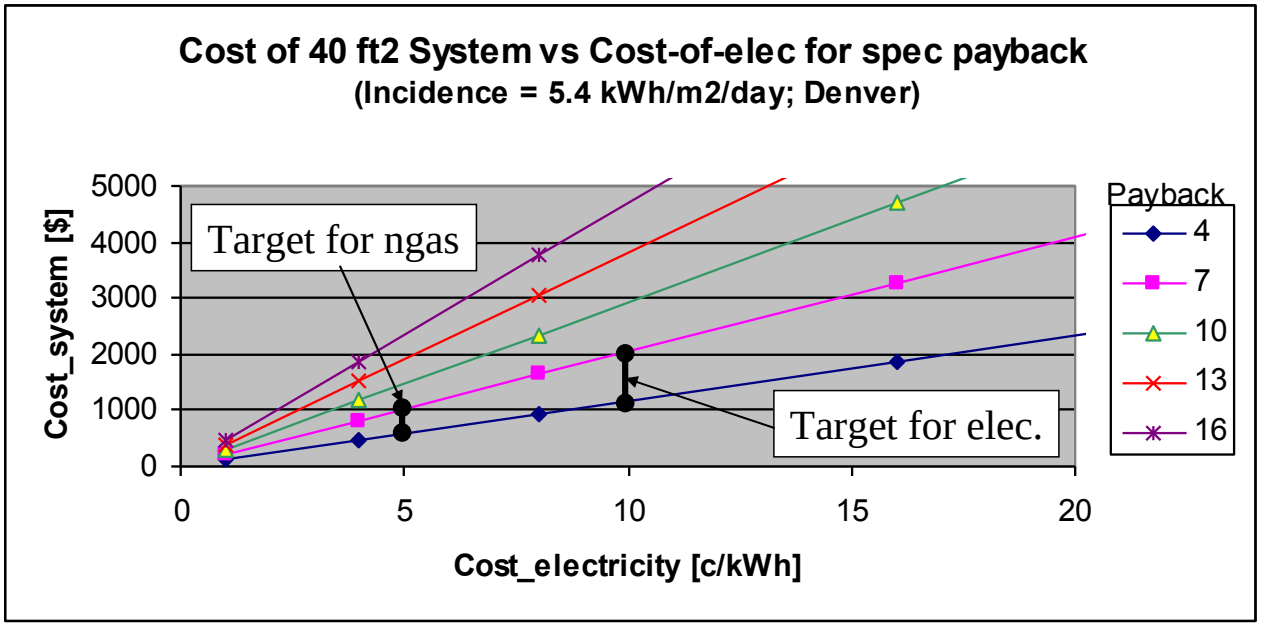
Kate Hudon
National Renewable Energy Laboratory
Kate.hudon@nrel.gov 303-275-3190
April 3, 2013

Purpose & Objectives

Problem Statement: The major market barrier for solar water heaters (SWHs) is installed cost. This project addresses this barrier by working with an industry research partner to evaluate innovative solutions that reduce the installed cost of a SWH by a factor of 10, to reduce payback to between 4 and 7 years and be cost-competitive with natural gas water heater technologies.



Water Heater Market Share



Purpose & Objectives

Impact of Project: The endpoint of this project is a qualified and operational SWH system that has fully demonstrated the feasibility of a low cost SWH solution.

- Final product development will take place in the private sector, via a BTO low cost solar water heating FOA.
- The market impact could be significant, with a 2030 technical savings potential of 2 quads. This will provide ~10% of the BTO goal of 50% savings by 2030.*

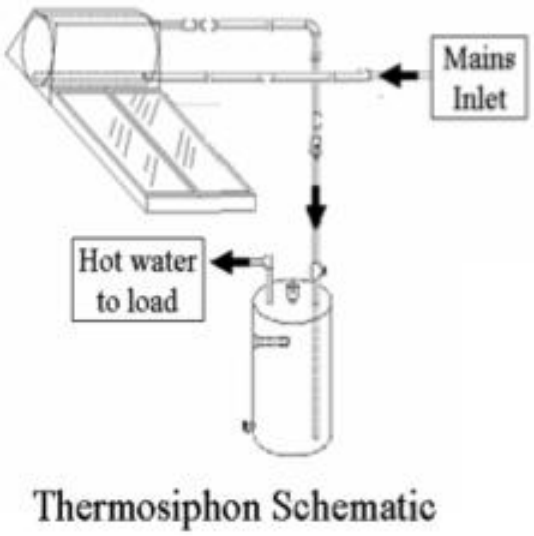
Project Focus: This project aligns with BTO Program goal of combining major industry with national laboratory technical expertise to enable broad market adoption of key innovations needed to achieve 50% savings by 2030.

* BTO Prioritization Tool results: 2030 Impact

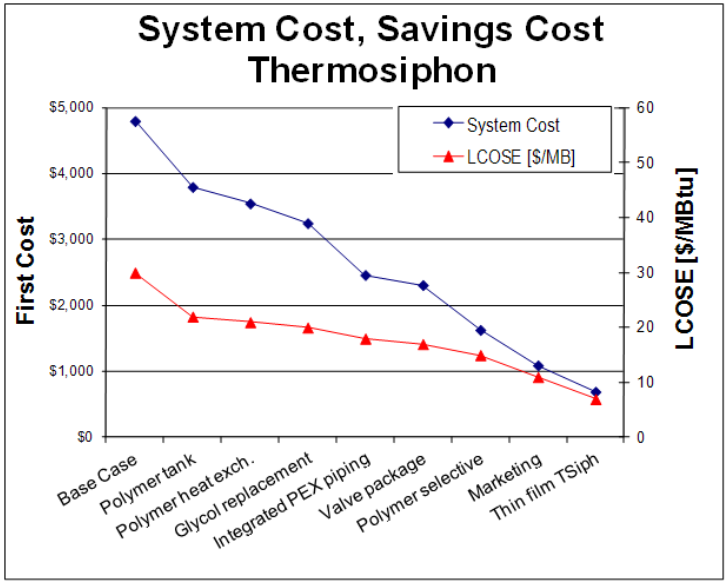
Approach

Approach: The technical approach to solving the objectives of this project has two components:

- Cost-shared R&D with industry partner RhoTech Solar (USA)
  - Passive, thermosiphon designs
  - Thin-film polymeric materials
- New International Energy Agency (IEA) task for low cost SWH research and development, led by NREL
  - Collaborative research effort (technical and financial advantages)



Thermosiphon Schematic



Approach

Key Issues: Large weight and cost reductions can be achieved by replacing metal & glass with polymeric materials, requiring the following issues to be addressed:

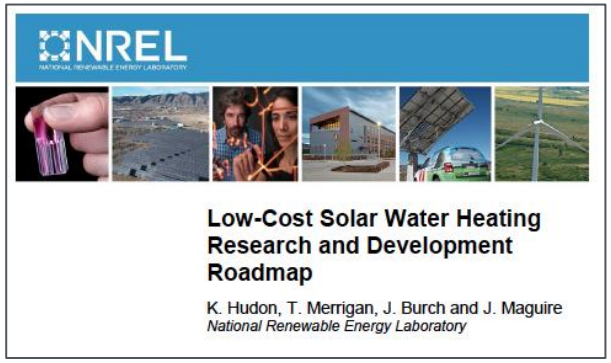
- Overheat protection
- Freeze protection (to ensure broad market applicability)
- Innovative glazing designs using thin-film polymers
- Materials testing to demonstrate durability
- Simple system designs for increased reliability, reduced cost, and easy installation.

Distinctive Characteristics: This approach is unique because it combines the knowledge of an innovative industry partner with NREL's SWH and materials technical expertise.

- The current SWH industry is reluctant to make significant design changes, and is not investing in low cost solutions.

Accomplishments:

- NREL published a "Low-Cost Solar Water Heating Research and Development Roadmap"
  - Technical pathways to broad market success



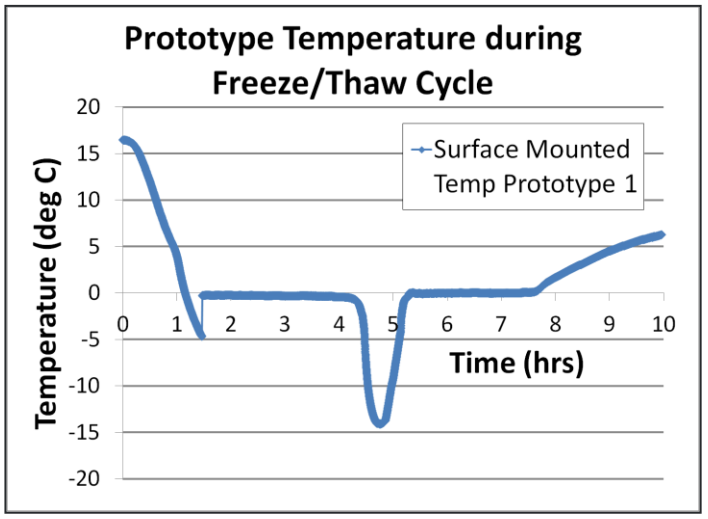
- RhoTech Solar fabricated 4 unglazed prototypes
  - Three prototypes installed for field testing
    - Prototypes currently being instrumented
    - Data will be collected in April/May 2013
    - Results will be used by NREL to calibrate simulation models
  - One prototype for installation on NREL's Solar Thermal Outdoor Test Facility
  - Four Gen1 glazed prototypes will be fabricated this summer, and installed in Sept 2013

Unglazed Prototype in Santa Cruz, CA

Accomplishments and Progress

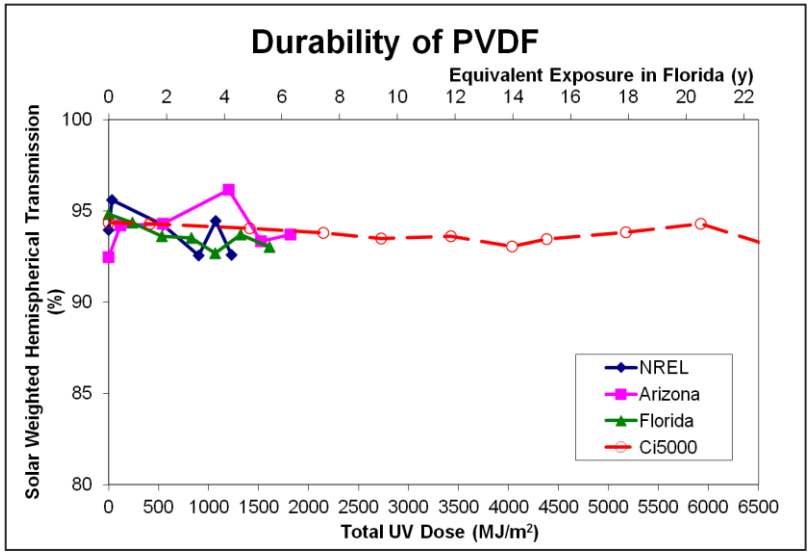
Accomplishments:

- Prototype Freeze/Thaw Testing
  - Three unglazed prototypes are currently being tested in a research freezer at NREL
  - Prototypes will undergo up to 500 freeze/thaw cycles to determine if the system is freeze tolerant
  - Back-up solution replaces the water in the collector with brine
- Initial results
  - Initial testing has begun
  - No failures/leaks have been observed
  - Testing will be complete in May



Accomplishments:

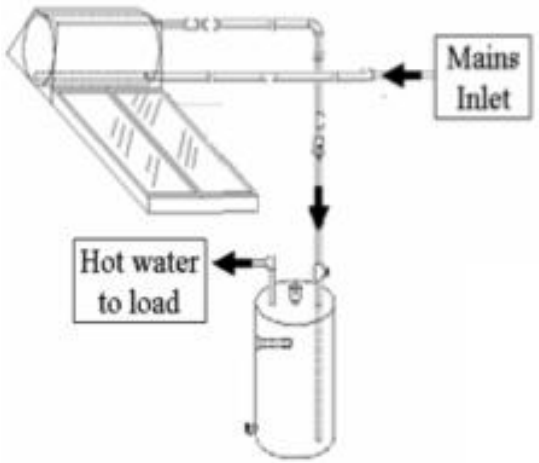
- Materials testing at NREL according to ASTM D882, standard test method for thin-film plastic sheeting.
  - Glazing material: PVDF and PET
  - Absorber material: PE film
  - Materials testing: UV exposure, high-temp, impact, and transmission tests.
    - PDVF test results shows 20 years without transmission degradation
    - Pull tests will be performed to determine degradation of material properties.
- Polymer Heat Exchanger (HX) testing performed by RhoTech Solar
  - PP/PE copolymer tubing
  - Boiling/burst test
  - Back-up material: PSU (*polysulfone)*



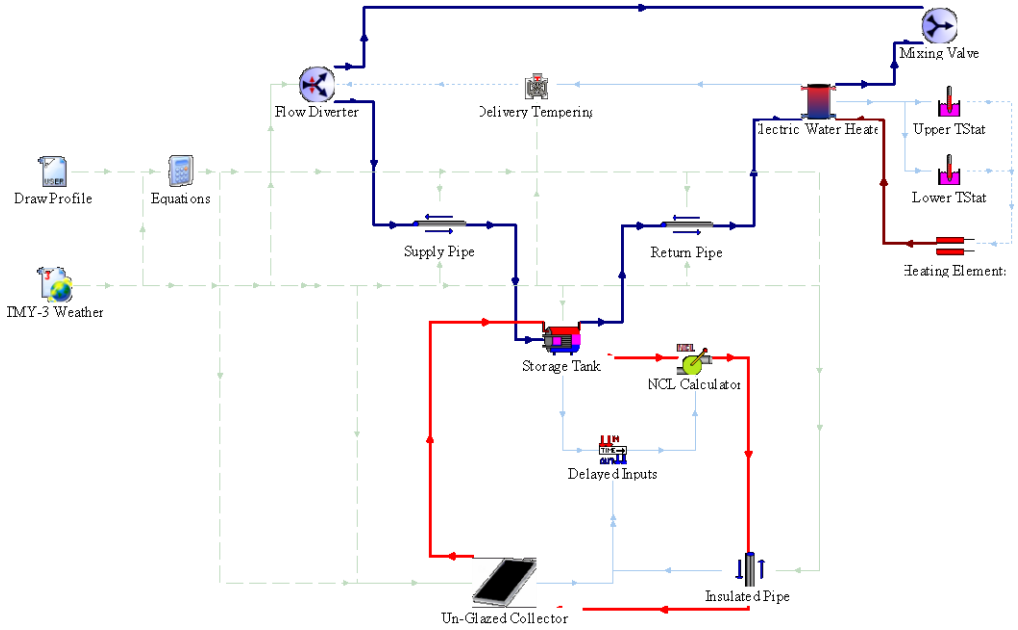
RhoTech Solar Polymer HX

Accomplishments:

- System Modeling
  - Component-based modeling (TRNSYS)
  - NREL developed improved natural convection methods for accurate thermosiphon modeling
  - Unglazed/glazed models currently underway
  - Models will be used to determine annual thermal performance



Thermosiphon Schematic



Accomplishments and Progress

Progress on Goals:

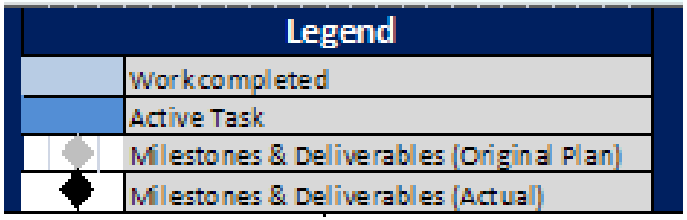
Goal	Status
Installed Cost: b/w $1,000 and $3,000	Current installed cost estimated at ~$1,200.
System Performance: thermal efficiency of 20% for **unglazed** system, 32% for **glazed** system	June 2013 Milestone for **unglazed**, and November 2013 Milestone for **glazed**.
Reliability: Demonstrate 15 years materials lifetime	Glazing material shows no reduction in transmission over 15 year lifetime. Absorber material Milestone in December 2013.

Awards/Recognition: Strong interest in participating in the IEA task has been expressed from the following countries:

- Germany, Austria, South Africa, Mexico, Spain

Project Plan & Schedule

- Project start date: FY12 Q3
- Planned completion date (CRADA): FY15 Q4
- Planned completion date (IEA Task): FY18 Q3



Task / Event	FY2012 Q1 (Oct-Dec)	FY2012 Q2 (Jan-Mar)	FY2012 Q3 (Apr-Jun)	FY2012 Q4 (Jul-Sep)	FY2013 Q1 (Oct-Dec)	FY2013 Q2 (Jan-Mar)	FY2013 Q3 (Apr-Jun)	FY2013 Q4 (Jul-Sep)	FY2014 Q1 (Oct-Dec)	FY2014 Q2 (Jan-Mar)	FY2014 Q3 (Apr-Jun)	FY2014 Q4 (Jul-Sep)
Project Name: Low Cost Solar Water Heater R&D												
Q3 Milestone: Establish CRADA with Rhotech Solar												
Q1 Milestone: Unglazed Prototype fabriation and delivery to NREL												
Q3 Milestone: Thermal Performance of Unglazed system												
Q4 Milestone: Glazed Prototype fabrication (Gen1). Delivery and Installation at NREL												
Q1 Milestone: Thermal Performance of Glazed system (Gen1)												
Q4 Milestone: Glazed Prototype fabrication (Gen2). Delivery and Installation at NREL												
Q4 Milestone: Thermal Performance of Glazed system (Gen2)												
Current work and future research												
Materials Testing												
Freeze/Thaw Testing												
Model Development - Unglazed System												
Model Development - Glazed System												
Submit paper to SHC2013 conference												
IEA Task Definition Phase												
IEA Task												

Project Budget

Project Budget: The project budget is $961k for FY13 ($150k from FY13 and $811k C/O funds from FY12)

Variances: None.

Cost to Date: $330k of the $961k FY13 budget has been spent to date.

Additional Funding: $200k (cost-share from industry partner)

Budget History					
FY2010		FY2011		FY2012	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$0	$0	$0	$0	$589k	$83k

Project Integration, Collaboration & Market Impact

Partners, Subcontractors, and Collaborators: The industry partner for the CRADA work is RhoTech Solar (USA).

Technology Transfer, Deployment, Market Impact: The purpose of this project is to evaluate the feasibility of a low cost SWH that can compete in the natural gas market. If feasibility is demonstrated, final product development will be transferred to the private sector in the form of a FOA. This will lead to the appropriate deployment of the technology.

Communications:

- A public webinar was held by NREL at the beginning of this project to collect feedback for a roadmap document.
- The Low Cost SWH R&D Roadmap was published as an NREL technical report in 2012.
- The work was presented at the International Energy Agency (IEA) ExCo Meeting in Nov 2012, and the IEA Task 39 Experts Meeting in March 2013.
- Initial research results will be presented at the SHC2013 conference in September 2013.

Next Steps and Future Plans

Next Steps and Future Plans:

- NREL will continue to work with RhoTech Solar to develop key innovations for low cost SWH design.
- Once performance, reliability, and market acceptance goals are verified, NREL will work with BTO to transfer final product development to industry partners including:
  - Business case workshops
  - Technical workshops
  - FOA challenge for breakthrough product development based on lessons learned from early market success.
- NREL will move on to the next technical challenge for building integrated renewal energy once the hand-off to industry is complete.
- NREL will continue to work with the IEA to enable international collaboration of low cost solar water heating solutions.