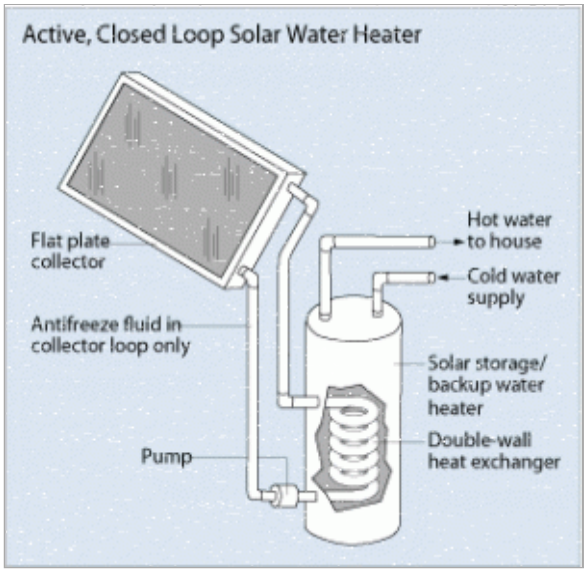
Anti-Freeze – Solar Hot Water

Last Updated: 06/29/2018

Scope



Install an indirect (anti-freeze) active solar thermal system.

- First determine that the roof and utility room space are suitable for solar hot water components.
- Follow the requirements for all local codes.
- Choose an accredited solar water heating installation company.
- Size the system according to the home's hot water demands.
- Mount the system on an unshaded, southern exposure if possible.
- Ensure that the roof mounting system avoids water intrusion and damage to the roof structure.
- Choose an indirect (anti-freeze) active solar thermal system if you are installing a solar hot water system in a climate that commonly experiences freezing temperatures at any point during the year. (See the Climate section for more information.)

See the **Compliance Tab** for related codes and standards requirements, and criteria to meet national programs such as DOE's Zero Energy Ready Home program, ENERGY STAR Certified Homes, and Indoor airPLUS.

Description

Indirect (anti-freeze) active solar thermal systems are probably the most common choice for freeze-prone areas in the U.S. Solar indirect systems circulate antifreeze fluid through the collector, and a heat exchanger transfers the heat from the antifreeze solution to the tank. The heat exchanger may be coiled around the tank, or it may be inserted inside the tank. Some systems utilize an external heat exchanger mounted and attached to the side of the tank (see Figure 1).

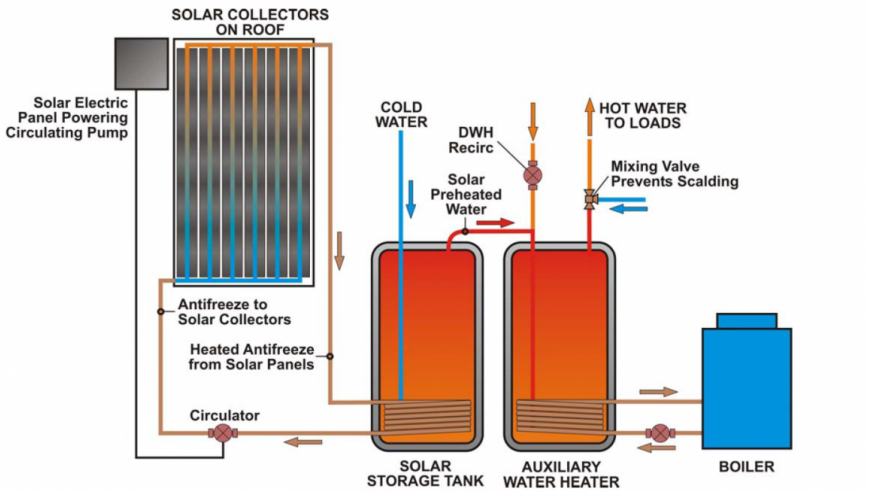


Figure 1. Two-tank indirect solar system.

Propylene glycol is the most common antifreeze solution for solar thermal systems; however, this type of system requires periodic maintenance of the antifreeze solution (every 3-5 years). The closed circulation loop is pressurized with appropriate charge pressure based on the height of the collector (e.g., 20-30 psi) to help minimize flow resistance against gravity.

Mounting

Solar collectors are usually mounted at an angle equal or close to the geographical latitude of a given site. In some situations, collector mounting may require brackets or racks to provide optimal inclination or southern exposure direction. Some manufacturers offer roof integrated collector designs; however, these require planning ahead for roof membranes that may be custom-specific to the installation. Generally, there are three methods for attachment to the roof: spanner, truss lag bolt and J-Bolt. The truss lag bolt requires the least amount of components for the mounting assembly.

Metal and tile-type roofs may require specialized mounting depending on their architectural design.

Controls

Active solar systems with a circulation loop require a controller that determines pump operation. This is accomplished by a couple of sensors – one installed at the collector outlet and one at the bottom of the storage tank. A temperature differential of eight degrees (8°F), with the collector hotter than the tank, is usually the turn-on setting to activate the pump. A correct positioning and secured attachment of the temperature sensors for optimal temperature conduction is critical in addition to the wiring connection method. A water-tight connection on temperature sensors is important for an uninterrupted signal to the controller and to provide long-term reliable operation. Figure 7 (left) shows the correct type of weather-proof connector that should be used with exterior wire connections. Common electrical wire twist ties are not suitable to withstand the outdoor elements. Wiring used for sensors installed outdoors should have a UV-rated exterior jacketing.

Ball valves are the preferred design type for use in solar system isolation and servicing. Ball valves featuring a full bore internal diameter do not present added flow restriction in the solar hot water circulation loop.

Documentation

Providing system documentation in form of a durable “Customer Manual” with instructions on proper operation and maintenance is highly advised. Written proof of warranty and product registration is also recommended.

Maximizing Savings and Monitoring Feedback

Minimizing electric auxiliary heating element activation of a storage water heater is of key importance for achieving maximum energy savings. A digital or mechanical timer can be beneficial to cut-off heating element activation during selected daytime hours. Some installers provide a dedicated water heater auxiliary heat element cut-off switch (240 VAC, 2-pole, 30A) as a simple means to allow home owner to increase savings. An in-line sight glass flow meter with a visual indicator installed (added cost) in the solar circulation loop helps to determine if the pump is operating correctly. Builders and homeowners may also inquire about controllers with built-in monitoring capabilities and energy metering devices (e.g., Stecca, Metrima).

To ensure that other components of the home are ready for a solar thermal system, use the following guides:

- **Utility Room Space**

- **Mounting Surface for Pumps and Gauges**
- **Solar Bypass Valve**
- **Solar Plumbing and Wiring Chase**
- **Architectural Drawing**

Install an Indirect (Anti-Freeze) Solar Hot Water System

1. Select an approved manufacturer that has been certified and listed by an accredited institution such as the **Florida Solar Energy Center – FSEC**. Solar systems certified by SRCC (OG-300) may qualify for tax credits or additional rebate incentive programs. The North Carolina-based organization **Database of State Incentives for Renewable Energy (DSIRE)** maintains a database of state, local, utility and federal incentives and policies that promote solar renewable energy.
2. Size the solar thermal system accordingly to provide at least 50% of the homes' water heating energy needs. Solar system selection should be certified by the **Solar Rating Certification Corporation (SRCC)**, the **International Association of Plumbing and Mechanical Officials (IAPMO)**, or be labeled with Energy Star.
3. A solar thermal collector is preferably mounted on an unshaded southern exposure orientation; however, eastern or western orientations are not to be ruled out. The use of a sun chart or approved analysis tool is recommended to determine seasonal shading.
4. Solar water heating system installations should comply with local building and plumbing codes. Installation should be executed by a trained certified installer. The **North American Board of Certified Energy Practitioners (NABCEP)** provides a national database on their website that lists certified solar contractors. In addition, the **Solar Energy Industry Association (SEIA)** provides a map listing of products, companies and solar services.
5. Collector mounting on a roof substrate requires special attention to avoid water intrusion or damage to the roof structure. Builders and installers should take into consideration mounting and positioning of the collector to comply with wind zones, particularly in coastal areas.
6. Plumbing lines to the collector are to be kept at minimal length, preferably < 25 feet, and are usually routed through attics where they are continuous with sleeved insulation. Exterior plumbing lines are also possible with an architectural chase for better visual appeal.

Ensuring Success

Installation of a solar thermal system is no more difficult than the assembly of any other building component when proper design precautions are taken into consideration. Builders are encouraged to work with solar installers and manufacturers to select a package with high performance. Building aesthetics and minimal use of floor space are a high priority to customers in new homes.

Selection of a solar contractor should be based on credentials, local company service territory, years of experience and trust. A warranty and maintenance agreement of at least two years is recommended.

Climate

Solar thermal system performance is dependent on the solar radiation resources available in a region. See the figure below for average annual daily solar energy resources available in the United States.

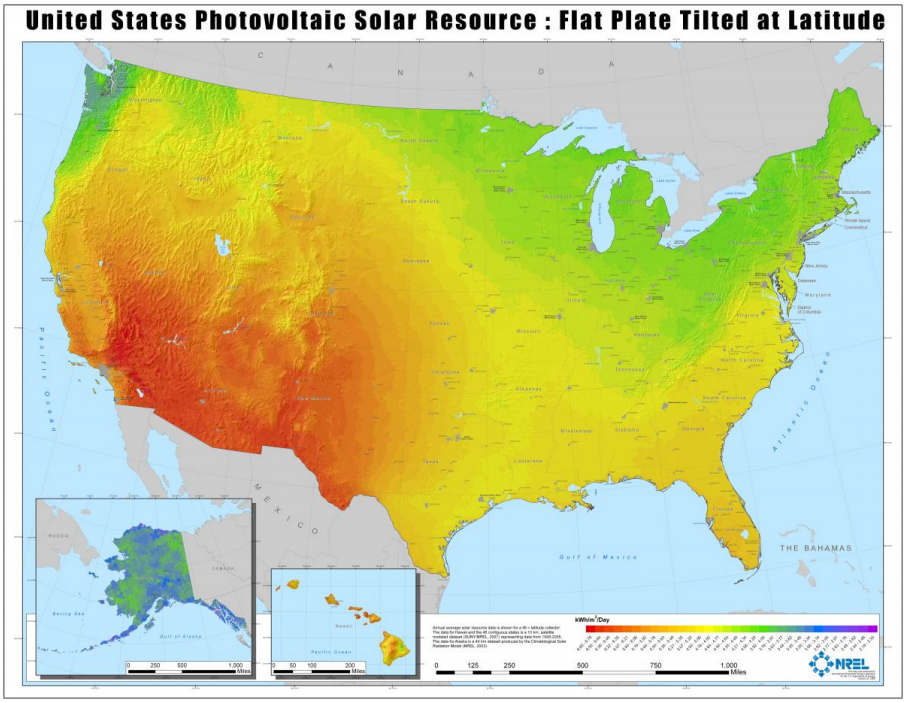


Figure 2. Average annual solar resources in the United States.

Water heating energy use varies according to the region and amount of hot water gallons used in a residence.

	Electric Consumption (kWh/Yr.)	Annual Cost ($)	Natural Gas Consumption (Therms/Yr.)	Annual Cost ($)
California	4387	$648	244	$242
Colorado	4109	$463	227	$189
Florida	3317	$382	186	$339
Georgia	3282	$363	184	$295
New York	4729	$864	261	$356
Texas	3269	$362	184	$313

Table 1. Expected annual energy use and annual cost ($), for a typical household using 60 gallons/day, for selected states. *Simulations performed in EGUSA (Colorado and New York water heater location in basement, others located in garage).

Overheat and Freezing

Solar thermal water heating system failures may originate from extreme cold and hot temperature conditions. Antifreeze solutions with distilled or deionized water are typically rated for up to 350 ?F. Collector and pipe freezing is another major obstacle that solar thermal systems face to avoid operation interruption and to ensure a long-term service life. Increased probability for pipe freezing is higher in mid and northern states, as shown in the figure below. The use of a proper antifreeze mixture is critical to avoid pipe and collector freezing. Pipes should be insulated with a minimum of ¾" insulation (closed cell preferred) and those exposed to UV should be protected by using a form of jacketing (UV inhibited ABS, PVC or aluminum).

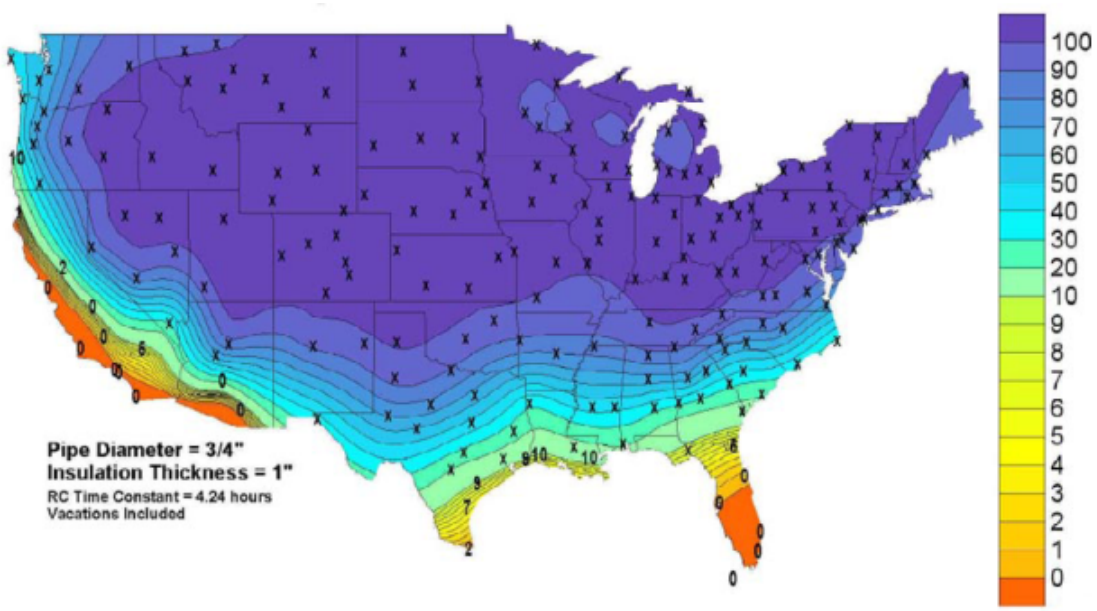


Figure 3. Probability of at least one pipe freeze in 20 years.

Training

Right and Wrong Images

None Available

CAD

None Available

Compliance

The Compliance tab contains both program and code information. Code language is excerpted and summarized below. For exact code language, refer to the applicable code, which may require purchase from the publisher. While we continually update our database, links may have changed since posting. Please contact our webmaster if you find broken links.

Installation of a solar thermal system requires building code compliance. Requisites for code compliance may differ by area, city, or county. Refer to the local governing code ordinance for specific plumbing and electrical rules.

DOE Zero Energy Ready Home

The DOE Zero Energy Ready Home program specifies as a mandatory requirement that homes be constructed as solar ready for the installation of solar photovoltaic panels (with some exceptions, see the **DOE ZERH National Program Requirements**). Solar thermal water systems are recommended but not required.

2009, 2012, 2015, and 2018 IECC

Section 401.3 A permanent certificate shall be posted on or near the electrical distribution panel that lists types and efficiencies of water heating, heating, and cooling equipment, as well as insulation R values, and window U and SHGC factors.

Retrofit: 2009, 2012, 2015, and 2018 IECC
Section R101.4.3 (Section R501.1.1 in 2015 and 2018 IECC). Additions, alterations, renovations, or repairs shall conform to the provisions of this code, without requiring the unaltered portions of the existing building to comply with this code. (See code for additional requirements and exceptions.)

2009, 2012, 2015, and 2018 IRC

M2301 Solar Energy Systems (Solar Thermal Energy Systems in 2015 and 2018 IRC) - See requirements for solar water heating systems.

2015 IRC and 2018 IRC

Appendix U (Appendix T in 2018 IRC) Solar Ready Provisions - Prepare the home for solar installations in accordance with these specifications.

Retrofit: 2009, 2012, 2015, and 2018 IRC
Section N1101.3 (Section N1107.1.1 in 2015 and 2018 IRC). Additions, alterations, renovations, or repairs shall conform to the provisions of this code, without requiring the unaltered portions of the existing building to comply with this code. (See code for additional requirements and exceptions.)

Appendix J regulates the repair, renovation, alteration, and reconstruction of existing buildings and is intended to encourage their continued safe use.

2009, 2012, 2015, and 2018 International Mechanical Code (IMC)

Follow the requirements for solar water heating systems found in the IMC, Chapter 14, Solar Systems (Solar Thermal Systems in 2018 IMC).

More Info.

Access to some references may require purchase from the publisher. While we continually update our database, links may have changed since posting. Please contact our webmaster if you find broken links.

Case Studies

1. **Best Practices Case Study: Shaw Construction Burlingame Ranch Ph.1, Aspen, CO**
   Author(s): PNNL
   Organization(s): PNNL, BSC, NREL
   Publication Date: December, 2010
   Case study describing a multi-family town home project constructed for the City of Aspen, Colorado, with assistance from the U.S. DOE Building America research team Building Science Corporation and the National Renewable Energy Laboratory.

2. **Building America Top Innovations 2013 Profile: Community Scale High-Performance with Solar: Pulte Homes, Tucson, AZ**
   Author(s): PNNL
   Organization(s): PNNL, IBACOS, BSC
   Publication Date: January, 2013
   This case study about a DOE Building America 2013 Top Innovation features a community-scale project in Tucson, AZ, where solar water heaters generated enough hot water per year to recoup the cost of the system within 4 to 6 years.The homes were built by Pulte with technical assistance from DOE Building America research partners...

References and Resources*

1. **Best Practices Series, Volume 6, High Performance Home Technologies: Solar Thermal and Photovoltaic Systems**
   Author(s): Baechler, Gilbride, Ruiz, Stewart, Love
   Organization(s): Pacific Northwest National Laboratory, Oak Ridge National Laboratory
   Publication Date: June, 2007
   Report providing an introduction to current photovoltaic and solar thermal building practices.

2. **Cost, Design, and Performance of Solar Hot Water in Cold-Climate Homes**
   Author(s): Aldrich, Vijayakumar
   Organization(s): CARB, Steven Winter Associates, SWA
   Publication Date: May, 2006
   Report describing the monitored long-term performance of two solar domestic water heating systems in northern climates.

3. **Dynamic Maps, GIS Data, & Analysis Tools (Webpage)**
   Author(s): National Renewable Energy Laboratory
   Organization(s): NREL
   Publication Date: September, 2014
   Website with prepopulated information about the United States renewable resources.

4. **Heat your Water with the Sun**
   Author(s): National Renewable Energy Laboratory
   Organization(s): NREL
   Publication Date: December, 2003
   Provides consumers with general information on solar water heating systems and how to select a contractor.

5. **Residential Solar Hot Water Systems**
   Author(s): North Carolina Solar Center
   Organization(s): North Carolina Solar Center
   Publication Date: September, 2014
   Brochure with information on residential solar hot water systems.

6. **Solar Water Heaters**
   Author(s): Department of Energy
   Organization(s): DOE
   Publication Date: May, 2012
   Website describing how solar water heaters -- also called solar domestic hot water systems -- can be a cost-effective way to generate hot water for your home.

7. **Solar Water Heating Installation Requirements, Energy Trust of Oregon, V 27**
   Author(s): Energy Trust of Oregon
   Organization(s): Energy Trust of Oregon
   Publication Date: August, 2013
   Outlines the minimum criteria for a solar water heating system installed by a Solar Water Heating Program trade ally under Energy Trust of Oregon's Solar Water Heating Program.

*Publication dates are shown for formal documents. Dates are not shown for non-dated media. Access dates for referenced, non-dated media, such as web sites, are shown in the measure guide text.

Contributors to this Guide

The following authors and organizations contributed to the content in this Guide.

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