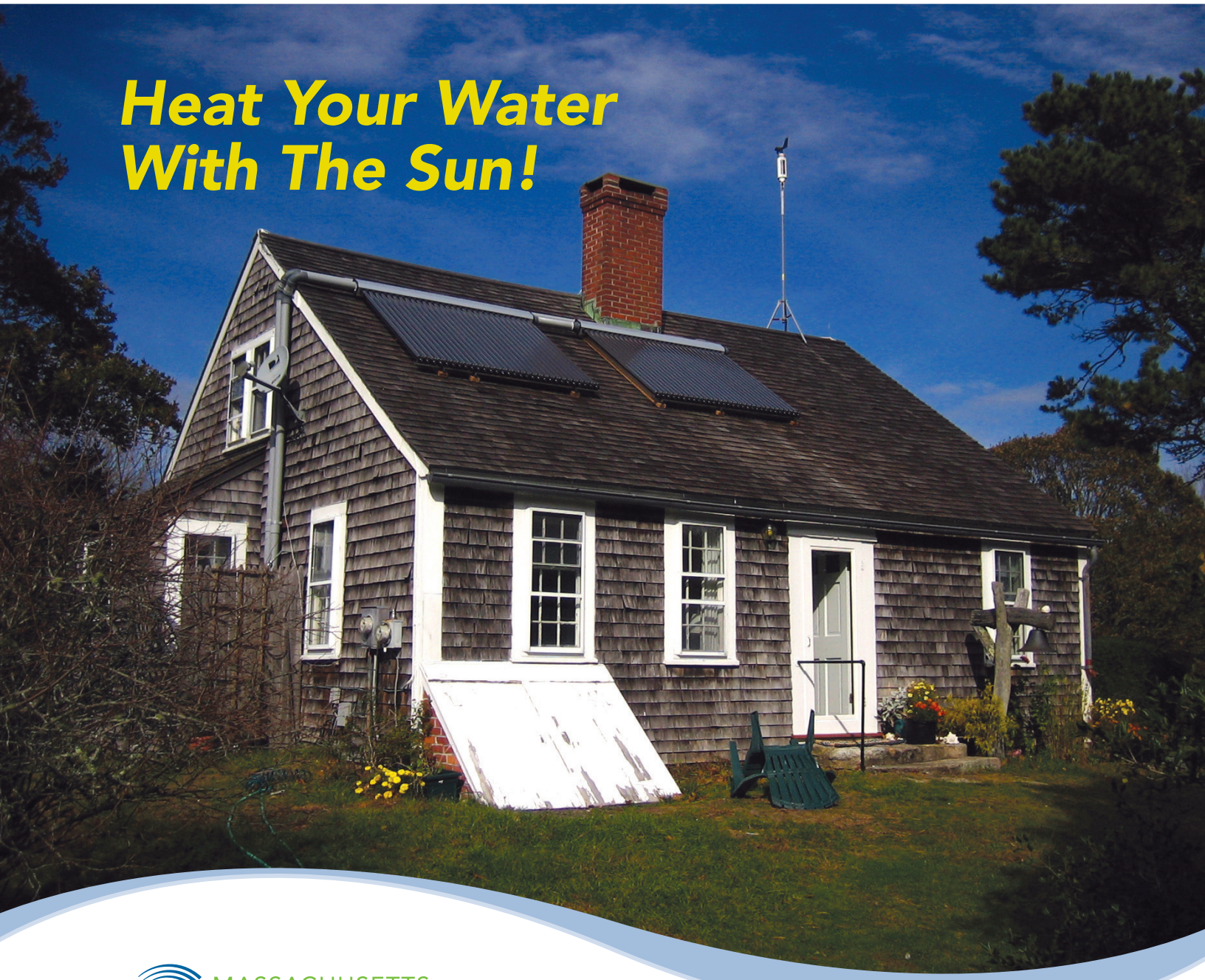
MASSACHUSETTS

Residential Guide To Solar Hot Water



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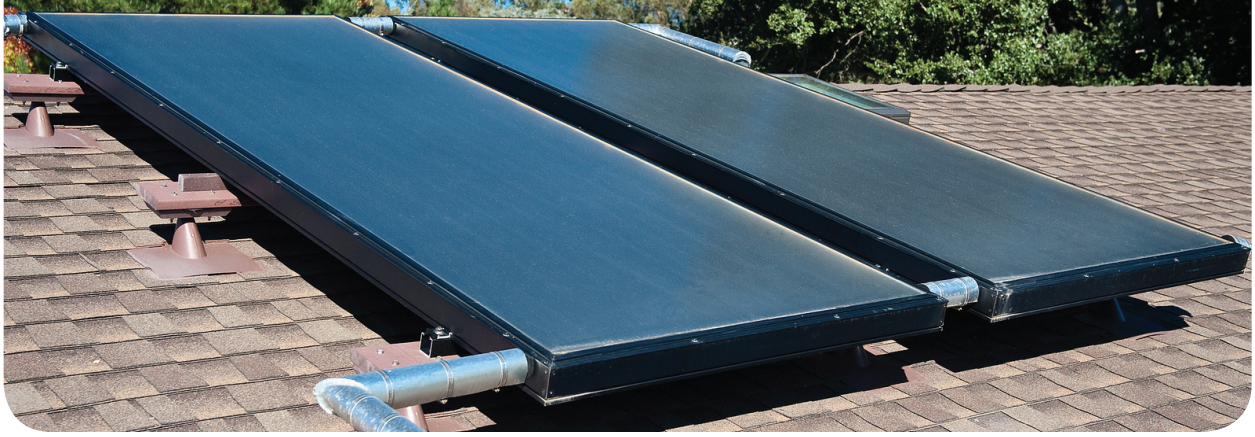

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Introduction

Solar Hot Water Today

Solar hot water (SHW) technology, also known as solar thermal, is a reliable, pollution-free method to generate heat for residential water and space heating needs. Homes and businesses around the country harness solar thermal energy to heat their water and buildings. Massachusetts initiated its first incentive program for SHW in 2011, funded through the Massachusetts Clean Energy Center.

Residents decide to install SHW systems for various reasons, including:

- Monthly savings on utility bills and fuel price stability
- Desire for energy independence and increased control over energy choices
- Concern about pollution, the environment and climate change

For many residents throughout Massachusetts, installing a SHW system is a smart investment that converts clean, free sunlight to usable heat while curbing air pollution and reducing monthly heating bills. Installing SHW also contributes to the local economy by creating local jobs and supporting local businesses.

About This Guide

The aim of this guide is to assist Massachusetts residents who are considering using solar energy to generate heat for their domestic water and space heating needs. This guide can help you determine whether SHW is technically and economically right for you. It reviews the installation process and provides advice and resources on finding an installer and securing rebates, as well as other useful information about SHW.

While this guide is intended primarily for homeowners, many of the issues discussed apply to small-scale installations in general and may also apply to businesses considering installing SHW.

Some of the regulations and incentives discussed in this guide may not apply to customers of certain Municipal Light Plants (MLPs). Customers of MLPs should contact their MLP to determine whether they pay into MassCEC's Renewable Energy Trust (a prerequisite for receiving rebates from MassCEC's Solar Hot Water programs).

About MassCEC

Created by the Green Jobs Act of 2008, the Massachusetts Clean Energy Center (MassCEC) is dedicated to accelerating the success of clean energy technologies, companies and projects in the Commonwealth—while creating high-quality jobs and long-term economic growth for the people of Massachusetts. MassCEC is a partner, clearinghouse and connector for people in the clean energy sector, making direct investments in clean energy companies, building a strong clean energy workforce, and supporting responsibly sited renewable energy projects across the Commonwealth. MassCEC works with the entire clean energy community in Massachusetts to propel promising technologies from the drawing board to the global marketplace. For more information visit: www.MassCEC.com.

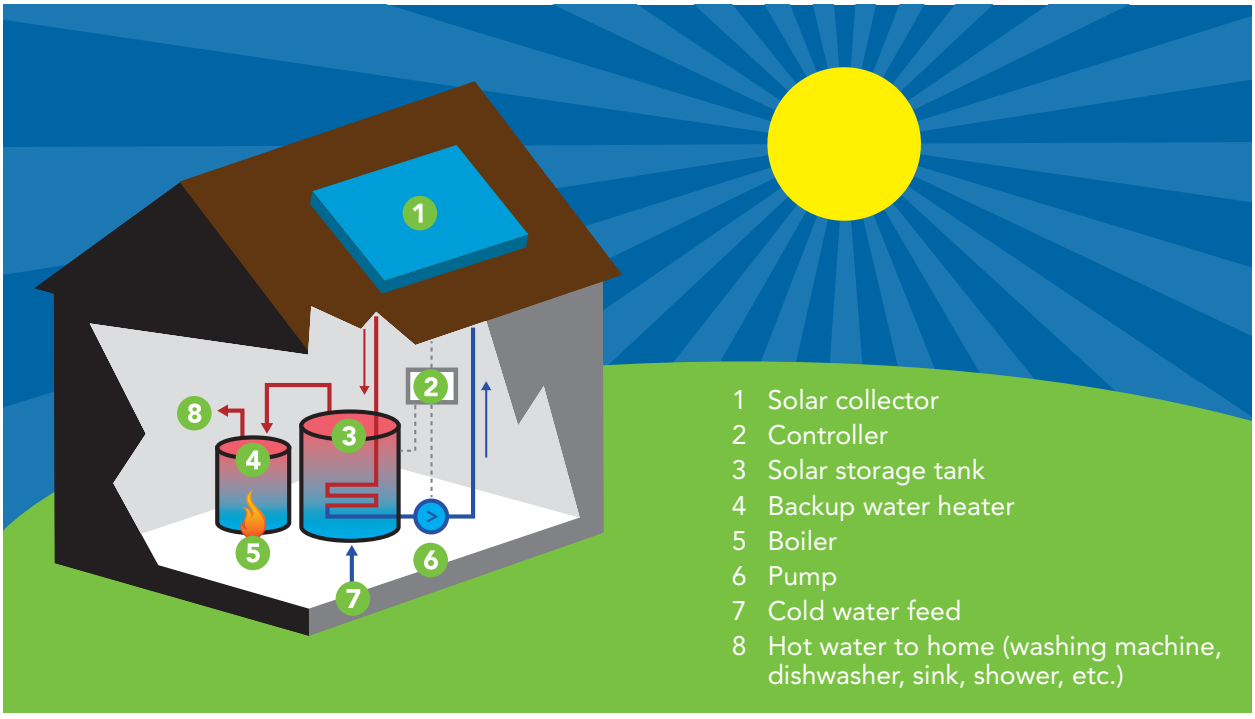
More Resources

*Visit **www.MassCEC.com/AboutSolar** for additional resources and information about solar energy technologies.*

Solar Hot Water System Components

A solar hot water (SHW) system looks somewhat similar to a solar photovoltaic (PV) system from the outside. Both solar systems feature collectors that capture energy from the sun. However, a solar PV system uses sunlight to generate electrical energy, while a SHW system uses thermal energy (heat) from the sun to heat water and space. Compared to a solar PV system, a SHW system is more efficient overall because it loses less energy when converting sunlight to heat energy for your home.

In a SHW system, thermal energy is received through collectors and transferred to water in a storage tank by a conductive fluid (typically a glycol/water mixture) that absorbs the sun's heat as it passes through the collectors. The conductive fluid is circulated through the collectors by means of a pump, or by natural convection. The heat is then transferred to a water storage tank through a heat exchanger. The heated water can then be circulated through a system for space heating or used for domestic hot water needs. A supplementary heating system (or backup) is always required in order to provide hot water at times when the hot water demand is greater than the solar thermal productivity (e.g. at night or during cloudy days). The major components and types of SHW systems are described in more detail below.



Collectors

When sunlight strikes the SHW collectors, the fluid inside the collectors captures radiant heat, and carries that heat into the home. There are two main types of collectors used for SHW systems in Massachusetts: Evacuated Tube and Flat Plate. Collectors typically last more than twenty years.

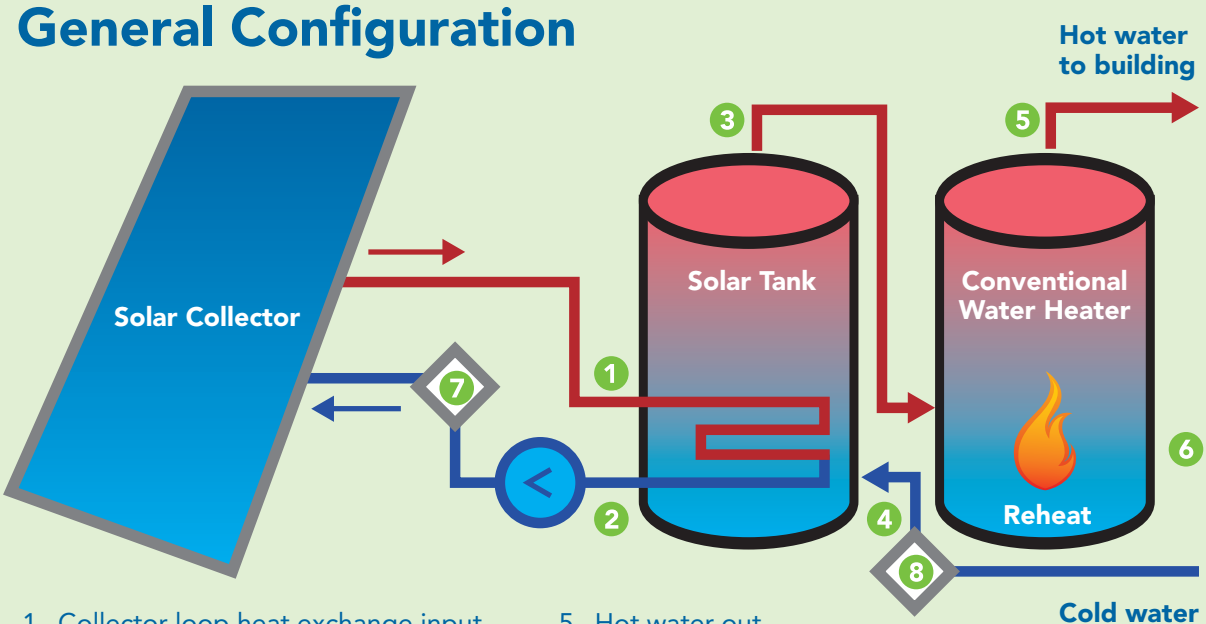
Residential Evacuated Tube System - Boston, MA

Evacuated Tube: **These collectors often have a very high efficiency design, a high heat capacity per square foot, and operate well in cold climates. However, they can be more expensive than flat plate collectors. An array of double walled glass tubes uses a vacuum to reduce heat loss, which is important in colder climates. A selective coating maximizes heat absorption in all sunlight conditions.**

Residential Flat Plate System – Saugus, MA

Flat Plate: **Flat plate solar collectors are more common in the US market. Flat plate collectors are generally less expensive than evacuated tube collectors and have proven their durability over the past 30-40 years. They consist of a dark flat-plate absorber that receives heat energy, tubes that circulate a conductive fluid to remove the heat from the absorbers, and insulating material that minimizes heat loss from the top and back of the plate. Most flat plate collectors are "glazed." An "unglazed" flat plate collector does not have an insulated cover, and is best used when ambient temperature is near to the desired temperature (as in pool heating). Glazed flat plate collectors heat water to higher temperatures relative to air temperature, and function better in Massachusetts.**

General Configuration



1 Collector loop heat exchange input
2 Collector loop heat exchange ouput
3 Collector loop top of tank
4 Cold water in
5 Hot water out
6 Optional (ambient)
7 Collector loop flow sensor
8 Water loop flow sensor

Active Systems

Active systems use a pump to circulate a heat transfer fluid that brings heat from the collectors to the heat exchanger and the tank. Active *direct circulation systems* pump the building's water through the collectors and into the tank. These systems are better suited for mild climates where there is less risk of water freezing inside the system. Active *indirect circulation systems* use a heat transfer fluid with a lower freezing temperature than water and is thus more suitable for Massachusetts' climate.

Controller

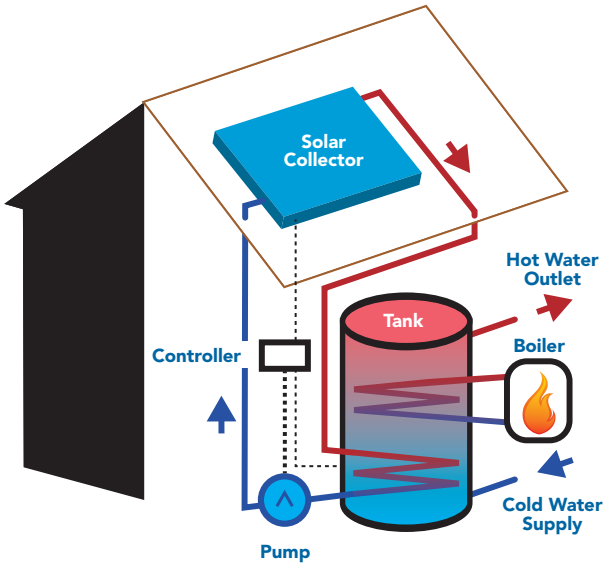
A controller switches the pump on or off in active systems. It is a simple electronic device which measures the temperature of the collectors and the temperature of the fluid in the heat exchanger. When the temperature is higher in the collectors, the controller turns on the pump to move the hotter fluid to the tank. When the temperature of the fluid in the collectors is lower, the controller turns off the pump until the fluid in the collectors reheats.

Passive Systems

Passive systems circulate the heat transfer fluid without a pump. There are two types of passive systems. *Integral collector-storage systems* only work in non-freezing climates. *Thermosyphon systems*, which are more suitable for Massachusetts, use the relative densities of hot and cold water to cause circulation between the collectors and the tank. Once the water or conductive fluid heats inside the collectors, the heated fluid rises into a tank which must be located above the collectors. The circulating liquid then cools and falls back into the collectors. These systems are typically less expensive, but can be less efficient than active systems. Passive systems also require careful planning, as the weight of the tank can destabilize the roof.

Heat Exchanger

The heat exchanger is the equipment that enables the fluid to transfer its heat to the water tank. The most common type is a "coil-in-tank" configuration (shown below), in which the heat transfer fluid passes through a spiral tube inside the tank. "Shell-and-tube" and "tube-in-tube" configurations require both fluids to be flowing in opposite directions.



Single Tank System

Solar Storage Tank

The solar storage tank acts as a holding tank for water heated by the collectors. The water stored in the tank is potable water, and can be used for all domestic hot water purposes.

Typically, the solar storage tank is an additional tank installed adjacent to the existing hot water tank, and is heated exclusively by the solar collectors. During cloudy weather, when the solar thermal system is not producing optimally, the existing water heating system automatically turns on. Alternatively, two heat exchanger spirals may be installed in a single tank (see figure above). The heat transfer fluid from the collectors heats the bottom coil. When the solar thermal system is not producing sufficient energy, the conventional system turns on to heat the top coil.

System Life

SHW systems can be expected to operate, with routine regular maintenance, for more than twenty years. However, solar storage tanks, like conventional hot water tanks, are only expected to last about ten years. Simple check-ups by the homeowner can ensure that the system is consistently operating at maximum efficiency. An installer will leave detailed instructions on the required maintenance at the time of installation. See *System Maintenance* (Section *How to Go Solar*) for more information.

Sizing and Optimizing Your Solar Hot Water System

It is critical to understand your home's hot water usage in order to install a solar hot water (SHW) system that is appropriately sized and cost effective. In Massachusetts, a SHW system typically provides 50-80% of a household's hot water needs. SHW systems cannot provide 100% of a household's hot water needs due to variations in thermal production during the year – a system sized to produce 100% of hot water needs in the winter would overheat in the summer months, which could damage the system. A SHW system installer can accurately design a suitable system for your specific needs.

Sizing a System for Domestic Water Heating

Daily domestic hot water use is typically about twenty gallons per person per day. In Massachusetts, approximately one square foot of collector area produces one gallon of hot water each day. Therefore, a system for three people might require sixty square feet of collector area (equal to about two collectors) to accommodate a hot water demand of sixty gallons. The recommended capacity of a solar hot water tank is approximately 1.25 times the estimated daily water consumption. An installer will assess the needs of individual households and sites based upon estimated daily usage and system efficiency.

Sizing a System for Space Heating

The amount of hot water needed each day for space heating depends on the characteristics of the current space heating system. Factors such as the total size (sq ft) of the residence, solar thermal system efficiency, and desired thermostat temperature must be considered to determine appropriate system requirements. A SHW system can typically provide up to 40% of a household's space heating needs. SHW systems cannot provide 100% of a household's space heating needs due to the times when the sun is not shining and because the solar resource is greatest during the summer months when space heating demands are lowest.

Mounting

For most Massachusetts homeowners, rooftop installations are the easiest and most practical way to use SHW to heat their water and homes, although mounting the SHW collectors on the ground is also a viable option. Rooftops provide a ready location for SHW collectors, which are less likely to be damaged than if the collectors are mounted on the ground. Roofs in New England are usually tilted to shed water and snow, which helps to keep SHW collectors clear from debris. A roof's elevation de-

creases the likelihood of shade falling on the array, and allows for the recommended five hours of direct sunlight per day.

Roof Condition

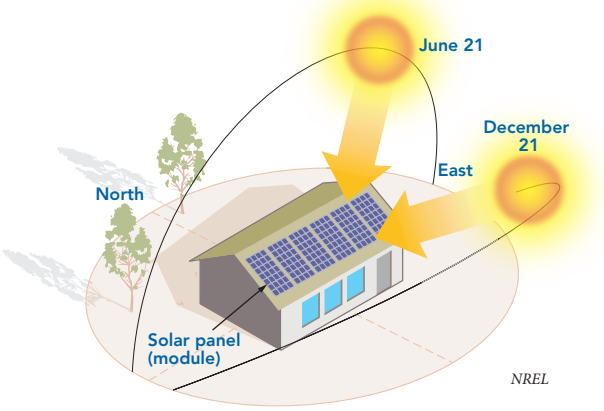
Since it is both time-consuming and costly to remove a system once it is in place, homeowners should evaluate the condition of their roof and shingles before a system is installed to ensure structural integrity over the life of the SHW system. Make any necessary roof repairs before a SHW system is put in place. Some installers recommend replacement if the roof has a remaining lifetime of eight years or less.

The actual heat generated by a SHW system is a function of its size, efficiency, sun exposure, and a variety of other factors discussed below.

Roof direction

Roof-mounted SHW systems should be oriented as close to due south as possible in order to maximize annual production. The ideal collector orientation is facing due south. Systems whose orientation is not due south have less direct sun exposure throughout the day, resulting in lower heat output; however, systems can still perform economically even if their orientation is not perfect.

Sun's Path During Summer and Winter



Tilt

The ideal tilt is equal to the latitude of the site. For maximum annual production in Massachusetts, SHW collectors should be installed at approximately a 40 degree angle to the horizon. Most homes in New England have roofs that are pitched at 33 degrees or more to shed snow and ice. An installer may be able to design structural components to optimize tilt and will help to determine if the added efficiency from optimizing the tilt of the panels will be worth the cost.

Shading

SHW systems are slightly more tolerant of shading than PV systems, but should be sited to maximize their direct exposure to sunlight and to avoid shading by a home's structural elements (such as chimneys), nearby trees and vegetation (including smaller trees that could later become obstacles) or other buildings. Collectors should receive at least 5 hours per day of unobstructed sunlight (75% shade-free).

Economics of Solar Hot Water

The financial return on investing in a SHW system in Massachusetts can be very favorable for homeowners with a suitable site and where the cost of the fuel traditionally used to heat water is expensive. SHW systems in Massachusetts can have a three to twenty year simple payback period, and will continue to produce financial returns long after the system is paid off. SHW systems that offset electric water heating systems will generally be the most cost effective (3-7 year paybacks) because of the high price of electric water heating. SHW systems that offset oil or propane water heating generally have paybacks ranging from 6-12 years. SHW systems that offset natural gas water heating are currently (in 2012) less cost effective than other systems, due to the low price of natural gas.

Upfront Cost and Incentives

Like most renewable energy systems, SHW systems involve an upfront cost, but lower future expenditures on fuel, since sunlight is a free resource. A new conventionally-fired domestic hot water system can cost between $800 and $2,000 (ACEEE). A typical medium sized residential SHW system will likely cost $7,000 - $10,000.[1] To reduce these high upfront costs, there are several state and federal incentives, further described below. For up to date information, please visit the Database of State Incentives for Renewables & Efficiency (DSIRE) webpage, at www.dsireusa.org.

FEDERAL TAX CREDIT: Most owners of new residential SHW systems qualify for the federal Residential Renewable Energy Tax Credit, the value of which is 30 percent of total system costs.

MASSACHUSETTS TAX CREDIT: Most owners of new residential solar SHW systems in Massachusetts qualify for a state personal income tax credit for the lesser of 15 percent of the total cost of the solar hot water system or $1,000.

MASSACHUSETTS SALES TAX EXEMPTION: Equipment purchased for a residential SHW system in Massachusetts is usually exempt from the sales tax.

MASSACHUSETTS PROPERTY TAX EXEMPTION: Homeowners with a SHW system are eligible for a property tax exemption on the value added to their home by the system, for a period of 20 years. Homeowners are encouraged to discuss this with their installer and the local tax assessor's office.

1 Estimate from 2011 Commonwealth Solar Hot Water pilot program averages. Actual costs will vary based on system size, site characteristics, permit fees, and any optional equipment additions. Up to date cost information can be found at MassCEC.com/SolarHotWater.

Homeowners considering installing a SHW system are advised to consult a professional to determine if the potential project would be eligible for available tax incentives, how these tax incentives may impact one another, and the taxability of any rebates or revenues received for a project. System paybacks will vary depending on the net system cost.

COMMONWEALTH SOLAR HOT WATER REBATE: MassCEC offers a rebate for residential and commercial SHW projects. The rebate value is based on collector performance and the number of collectors installed. The current rebates are typically $1,100-$1,400 for a residential system, and are capped at $3,500. For further information about this rebate, along with relevant rebate level and participation guidelines, see the MassCEC's Commonwealth Solar Hot Water program page at www.masscec.com/solarhotwater.

OTHER INCENTIVES: Other incentives are administered by utility companies or local agencies. An option available to all Massachusetts residents is the Mass Save HEAT Loan program, which offers zero-interest loans for up to 7 years for the installation of SHW systems. Visit the DSIRE webpage for more information about loan and rebate programs offered through utility companies or local agencies.

Long-Term Costs and Savings

Avoided Energy Costs

The most fundamental benefit a homeowner will receive from a SHW system is the heat generated which will directly displace heating fuel or electricity that the homeowner would otherwise purchase. Fuel cost increases, rising demand for fuel or electricity, and fuel supply constraints can all cause the cost of purchasing fuel or electricity to increase over time. An owner of a SHW system avoids these future energy cost increases by utilizing free sunlight as their fuel. Investing in a solar domestic hot water system typically eliminates approximately 25% of total residential monthly utility costs.

System Maintenance

As is the case with any appliance, SHW systems require some maintenance over their lifetime. Bi-annual system check-ups are important, but are not expensive or time consuming. Installers that apply for MassCEC rebates are required to provide a labor warranty to protect the equipment against defective workmanship, component breakdown, or significant degradation in energy production. In addition, the SHW equipment must have appropriate manufacturer's warranties.

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Environmental Benefits of Solar Hot Water

The use of SHW systems to generate heat dramatically reduces the environmental impact of the myriad personal, industrial, and commercial processes which rely on fossil fuels to heat water and space.

SHW systems do not emit carbon dioxide or any other greenhouse gases (GHGs) while operating and do not require intensive extraction operations to provide fuel or dispose of residual waste. Compared to the mix of fossil fuel heat sources typically used to satisfy hot water needs in New England, a typical SHW system for a family of four who currently use an electric water heater will prevent 3,400 pounds of greenhouse gas emissions each year. In addition, SHW systems reduce the production of particulate matter that contribute to respiratory problems, which is important as Massachusetts has among the highest rates of asthma in the country.

Alexey Sergeev

Tudor Stanica/Bigstock

How To Go Solar

1 Energy Efficiency

In Massachusetts, energy efficiency is considered to be our "first fuel" when it comes to making fiscally sound, environmentally friendly choices about energy use, and it is the most cost effective way to reduce a home's total electricity use and cost. The Commonwealth Solar Hot Water Rebate Program requires homeowners to schedule an energy audit before receiving a SHW rebate. Massachusetts utilities offer free energy efficiency audits, advice and services to customers. Call Mass Save at 1-866-527-7283 or visit www.masssave.com for more information.

2 Installer Selection

How to Find an Installer

Massachusetts has a large number of experienced professionals who install SHW technologies. MassCEC maintains a list of SHW installers that have successfully submitted applications through the Commonwealth Solar Hot Water Program, which can be found at www.masscec.com/solarhotwater. Some installers are a one-stop shop for SHW; a single installation company can provide both plumbing and solar thermal expertise. Other SHW contracting companies do not have a licensed plumber in house, and will subcontract a licensed plumber for the portions of the job that require one. The SHW installer will conduct a site assessment and design a system specific to the home or building's needs. Installers should provide a formal write-up of their proposal that includes a timeline and expected costs.

Seek Multiple Bids

As with any home improvement project, a homeowner should seek multiple bids to find someone he or she is comfortable working with and to ensure they are getting the best price possible. In order to get the most appropriate and cost effective system for a home, make sure to receive and compare the recommendations and estimates of at least two or three installers. For reference, compare your system cost and specifics with similar projects awarded through the Commonwealth Solar Hot Water Program (visit www.masscec.com/solarhotwater for a list of awarded project specifications).

Ask for References and Licenses

Potential SHW customers should ask if the installer can provide customer references, and—if possible—should visit one or more of the installer's previous installations. According to Massachusetts law, a primary vendor must be a registered home improvement contractor, have a licensed construction supervisor on staff, and have a licensed plumber to connect the SHW system to the domestic hot water system. In addition, there are various training and certification

programs which many installers go through, such as those offered by the North American Board of Certified Energy Practitioners (NABCEP).

Require Liability and Workers' Compensation Insurance

For liability protection homeowners should insist that a vendor carry a certificate of insurance for general liability insurance. A homeowner should also verify that workers' compensation insurance is carried to protect against liability for any on-site, work related injuries. These are required to obtain a building permit.

Require Warranties

Homeowners should ensure that equipment and workmanship are covered under appropriate warranties. It is recommended that customers request equipment warranties that, at a minimum, meet the requirements outlined below. These warranties are required for systems that receive a rebate from MassCEC.

- Workmanship: at least a 2-year comprehensive installation warranty
- Solar Collectors: 10-year manufacturer's warranty
- Other System Components: 2-year warranty for other system components

Obtain a Written Contract

The written contract with an installer should, at a minimum, specify the exact equipment to be installed, all applicable warranty information, the project's start and completion dates, the itemized budget with any exclusions or potential adders, a list of any subcontractors that are going to be used, and a progress payment schedule. Contracts should include contingencies for approval of rebates and other relevant incentives.

3 Design

Prior to installation, the installer will prepare a design for the SHW system. Where SHW is being incorporated into new construction, it is advantageous to integrate the SHW design process into the overall site planning and building design process to realize certain construction efficiencies and ensure optimal orientation and tilt of the system.

4 Permitting

The installer is responsible for obtaining local permits before the installation of a SHW system. When an installation results in a structural change to an existing building, as is commonly the case, a SHW system is subject to the Massachusetts Building Code. The licensed plumber is responsible for ensuring that the installation meets state plumbing code requirements. Towns with historical districts may require additional approvals, which should be completed in the design phase of the project. All issued paperwork, including invoices, should be kept as documentation even after the project is completed.

5 Rebates and Incentives

MassCEC's Commonwealth Solar Hot Water Program will only pay rebates for project applications approved prior to commencing construction. Rebate applications are submitted by the installer on the system owner's behalf. For more details on the procedural, technical, and other requirements of the Commonwealth Solar Hot Water Rebate Program, visit www.MassCEC.com/Solarhotwater or contact an installer. Massachusetts and federal tax credit information can be found at www.dsireusa.org, by selecting Massachusetts or Federal Incentives.

6 Construction

Once a contract is signed, the necessary permits have been issued, and rebate approval has been received from MassCEC (if applying for a Commonwealth Solar Hot Water rebate), the installer will install the SHW system. Installation typically involves delivery of materials to the site, site preparation, and installation of the SHW collectors and solar storage tank. SHW installations can occur over a short period of time relative to other construction projects. As noted above, the written contract should be clear about the timeline of the project.

7 Inspection

Once a SHW system is fully installed, building and plumbing inspections may be required to review the system to verify that the installation meets state and local code requirements.

8 Post-Installation System Testing and Education

When the installation is complete, the installer should test the equipment to confirm that it is operating properly. Homeowners should also ensure that the installer provides copies of any technical equipment manuals and warranties. Finally, the installer should educate the owner about safety, operations, and maintenance requirements.

9 Ongoing System Maintenance and Performance Metering

Maintenance in a correctly installed system is not time consuming. To ensure the SHW system functions properly, the system owner should periodically look to make sure no obvious obstructions, such as leaves or branches, are blocking the collectors from the sun. System "check-ups" should be performed every two years. These check-ups should be very inexpensive and brief. During the check-up, electrical parts should be examined thoroughly, and may need to be replaced after 10 years. The system's plumbing should also be checked for corrosion and freeze damage.

Some system owners may choose to install metering equipment on their SHW system. The meter measures temperatures and flow rates in order to track energy production. A performance monitoring system will help homeowners and installers ensure the system is functioning at maximum efficiency.

Homeowner's Solar Hot Water Checklist

Preliminary Questions

- ☐ Do I know how much energy I currently consume to heat my water and home, and how much it costs?
- ☐ Do I know how much hot water my household consumes per day?

> **On average, people consume 20 gallons of hot water per day. Consider whether your household may have additional hot water demands.**

- ☐ Do I have a south-facing roof?
- ☐ Do I know where there is shading on my roof (or on my property) during different times of the day and at different times of year?

Purchasing and Contracting

- ☐ Am I comfortable with the installer's knowledge and experience?
- ☐ Does the installer have credible references?
- ☐ Is the installer adequately insured to protect me, as well as the company's employees and subcontractors?
- ☐ Does the contract include performance specifications for the system being installed, including an estimate of the energy that will be produced annually or under different conditions?
- ☐ Does the installation contract clearly lay out what is included and what is not included in the price?
- ☐ Does the proposed payment schedule protect me by allowing payment to be withheld until the system passes local code inspections, and is shown to be operating properly?
- ☐ Are all warranties clearly stated with information on how to use them if necessary?

Post Installation

- ☐ Has the installer tested and turned on the system?
- ☐ Have all necessary inspections occurred?
- ☐ Has the installer left reference materials and equipment operating manuals?

Solar Hot Water Resources and Links

Commonwealth Solar Hot Water Program Webpage

www.masscec.com/solarhotwater

- ✓ **COMMONWEALTH SOLAR HOT WATER RESIDENTIAL AWARDED PROJECTS DATABASE:** This excel file contains information on all projects that have been awarded through the CSHW residential program, including project size, type, costs, installers, etc.

- ✓ **SOLAR THERMAL INSPECTION CHECKLIST**

Energy Savers

www.energysavers.org

The U.S. Department of Energy's maintains an "Energy Savers" webpage for consumers. It has extensive information on SHW.

MassSave

www.masssave.org

For information on the Mass Save Heat Loan program, and other energy efficiency incentives, visit Mass Save and click "For Your Home."

DSIRE

www.dsireusa.org

For up to date information on state and federal solar hot water incentives, visit the Database of State Incentives for Renewables & Efficiency.

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