Chapter Six
Introduction to Solar Water Heating

Solar water heaters are used for a variety of purposes in residential, commercial, and industrial settings. In homes, solar water heaters can serve as the primary source of hot water for washing and bathing, and can also be used for space heating and for heating swimming pools. In institutional, commercial, and industrial settings, wherever hot water is needed, the potential exists to use solar energy as either the primary or supplemental heat source. In addition to residential use, situations that are particularly well-suited to solar water heating include schools, hotels, laundromats, and car washes, due to their patterns of hot water use.

Solar water heaters used in homes for supplying domestic hot water are typically installed with some form of back-up heating system (such as electricity or gas) to ensure a hot water supply during the nighttime and cloudy conditions. Solar water heaters can often be considered pre-heaters. Systems are commonly set up so that the solar water heater raises the temperature of water before it enters the standard water-heating tank.

In Kentucky, domestic solar water heaters used with a back-up conventional water heater can reduce the annual energy required for heating water by 50 to 80 percent or more. Since water heating accounts for one-quarter to one-third of a typical family's energy costs, this can amount to substantial savings over the course of a year (see Table 6.1). For a typical family of four that uses 70 gallons of hot water per day, the annual savings would amount to $182- $502, depending on the type and cost of fuel. The total savings over the first 20 years of operation would range from $640-$7,040 (and solar water heating systems commonly last longer than 20 years).

The economic savings offered by solar water heaters is equivalent to tax-free income, and provides a fixed cost for water heating thus protecting homeowners against fuel price increases. The more fuel prices rise, the greater the savings solar provides. Considering that the US as a whole spends $20 billion per year to heat water, the overall economic benefits from the widespread use of solar water heating could be enormous.

Figure 6.1: A solar collector on the roof of ASPI's Small Town Demonstration Center in Mt. Vernon, Kentucky, *Andy McDonald*

Prior to the birth of the modern solar industry in the 1970's, solar hot water systems in the United States were primarily located in sunny southern climates, such as Southern California and Florida. In such locations solar often provides 100 percent of household hot water needs. In most other places, the possibility of winter-time freezing of pipes and water tanks presented a significant obstacle. To cope with this problem, systems outside of the Sunbelt were often drained in the winter and other forms of heat—wood, electricity, gas - were used instead. During the 1970's solar water heater designs were developed to

Table 6.1: Potential Economic Savings Over the Life of a Solar Water Heating System for a Typical Family of Four[1]

Fuel or Energy Source for Water Heater and Price	Annual Water Heating Fuel Cost	Potential Annual Savings, (50-80%)	Payback Time*	Total Savings over 20 Years**
Propane, $1.75/gal.	$627	$314-$502	5.8- 9.6 yrs.	$3,280 - $7,040
Natural Gas, $1.10/therm	$364	$182- $291	10.3 -16.5yrs.	$640- $2,820
Electric, $0.07/kWh	$464	$232- $371	8.1- 12.9yrs.	$1,640 - $4,420

*Payback time is the number of years needed for the energy savings to equal the installed cost of the system. (Based on an installed cost of $3,000 for the solar water heater.)
**Total savings assumes a fixed price for fuel. If fuel prices rise, total savings will increase and payback time will be faster.

address the issue of freezing, thereby expanding the capability for year-round use to the rest of the United States, including Kentucky. Solar hot water systems now offer significant savings to northern households. A 1990's study of 10 solar water-heating systems in Vermont showed that about 50 percent of the energy needed to heat water each year was being provided by the sun.[2] Installing a solar water heater replaces monthly payments to the utility company with an investment that adds value to your home and provides monthly savings for decades to come. If you heat water with gas, electricity, or oil and do not have a solar water heater, in five to fifteen years the money you pay to the utility will eventually equal what you could have spent on a solar water heater. Every year after that, you'll be sending hundreds of dollars to the utility company that you could have invested or spent on other needs- if only you had installed that solar water heater.

Environmental Benefits Of Solar Water Heating

Solar water heaters offer both reliable economic returns and the benefits of environmental protection. Apart from the resources invested in manufacturing the solar water heating equipment, these systems produce essentially no pollution. This contrasts with the use of conventional water heaters powered by electricity, gas, or oil, which have a significant impact on the environment and public health. These range from the effects of mining coal, to air pollution, acid rain, climate change, and the generation of nuclear waste. When we receive our utility bills in the mail, they do not include these "external" costs to society, the environment, and public health. If these "external" costs were included in our utility bills, the economic advantages of solar water heating would become much more apparent.

The environmental costs of heating water are significant. In 1980, four percent of the energy consumed in the United States was used for residential and commercial water-heating. When we consider that nuclear power supplied 3.5 percent of the nation's energy in that year, we realize that solar water heating could potentially displace as much energy demand as is produced by the nation's nuclear power plants.[4] If we took this path, we could potentially eliminate an energy source that presents enormous threats to our environment, national security, and public health, and replace it with a renewable source that generates virtually no pollution, is widely distributed and therefore not susceptible to interruption or attack, and which would create a great demand for skilled workers.

Table 6.2: Pollution Prevented by Using a Solar Water Heater in Kentucky[3]

Emission	Family of Two, Energy Savings 50- 80% (1,900- 3,033 kWh)	Family of Four, Energy Savings 50- 80% (3,317- 5,307 kWh)
Carbon Dioxide (CO_2)	4,343- 6,933 lbs.	7,583- 12,132 lbs.
Nitrogen Oxides (NO_x)	10- 17 lbs.	18- 29 lbs.
Sulfur Dioxide (SO_2)	24- 39 lbs.	43- 68 lbs.
Mercury (Hg)	35- 55 milligrams	60- 97 milligrams

Based on adding a solar water heater to a home currently using an electric water heater, and assuming 40 gallons of hot water use per day for a family of two, and 70 gallons per day for a family of four.

Inefficiencies in the Nation's Energy System

In a conventional electric power plant, water is heated to several thousand degrees Fahrenheit to produce steam, which turns a turbine, which generates electricity, which is sent over wires to your home, where it powers your electric water heater to produce 130° F water. After accounting for inefficiencies and energy losses at the power plant and in the transmission lines, we find that it takes approximately four units of energy at the power plant to get one unit of energy into your water heater. Three-fourths of the energy produced at the power plant is wasted before it even gets to your home. A solar water heater, by contrast, captures free solar energy that would otherwise go unused, to easily heat water from 50° to 130°F. This water can then be used on-site, with no need for long-distance transmission and the energy losses that entails.

A Brief History of Solar Water Heating

In 1891, the first commercial solar water heater patent was awarded to Clarence M. Kemp of Baltimore, Maryland. His invention, "The Climax," consisted of four galvanized metal water tanks painted black and enclosed in a pine box insulated with felt paper and glazed with a single layer of glass. The Climax was connected to the house plumbing and held 32 gallons of hot water. Although the Climax provided hot water on sunny days, the water would not be fully heated until the late afternoon, and it would cool off quickly at night. The system also had to be disconnected for half of the year because it had no freeze protection.[5]

The Climax solar water heater sold well in Southern California during the 1890's. The smallest and most popular model sold for $25 - a month's wages for an average worker – and saved the typical homeowner $9 per year on coal, or more if gas was used for water

heating. By 1900, more than 1,600 Climax heaters had been installed in California.

In 1909, William Bailey began selling the Day and Night solar water heater, which provided an insulated indoor water storage tank, supplied by a separate solar collector located outside the house and facing south. The collector consisted of a coiled pipe inside a glass-covered box and had to be mounted below the storage tank. This allowed the hot water to circulate from the collector to the storage tank by natural convection. This became known as a "thermosiphon" water heater. The Day and Night heater sold for $180 plus installation, and it had the great advantage of keeping heated water warm all night, allowing for morning baths. The Day and Night heater eventually eliminated the Climax from California's market, and over 1,000 units were sold in 1920.

Since the early 1900's, the popularity of solar water-heating in the United States has waxed and waned, shifting back and forth between California and Florida. While over 4,000 Day and Night heaters were sold by the end of World War I, California's solar water heater industry collapsed during the 1920's when natural gas was discovered in Southern California. Gas companies fostered the collapse by subsidizing the purchase of gas water heaters. Florida's solar industry opened up at this time, when builder David Carruthers set up a factory to build the Day and Night water heater in Miami. The business expanded rapidly until it was shut down by a great hurricane in 1926.

Florida's solar industry was reborn in 1935, driven by Federal Housing Administration mortgage programs. "80 percent of homes built in Miami between 1937 and 1941 had solar water heaters. In the next five years, between 25,000 and 60,000 new residential heaters were installed (the estimates vary wildly), including 5,000 very large arrays on hotels, factories, and housing projects. By the time World War II began, over half of the residences in Miami heated their water with the sun."[6] Florida's solar boom was short-lived, however, as wartime restrictions on the use of copper brought the industry to an abrupt halt. In the decades following the war, cheap electricity and gas, combined with a lack of support from utilities and the government have kept Florida's solar industry a shadow of its true potential.

While support for solar water heating has been lukewarm in the United States, other countries have embraced the technology. During the early 1960's in Australia, Israel, and Japan, over 60,000 solar water heaters were being sold each year. By 1991, Tokyo had over 1.5 million solar water heaters in use. In Cyprus during the mid-1990's, 90 percent of homes had solar water heaters. Israel now requires solar water heating in all new buildings, resulting in the installation of 50,000 new heaters each year. Seventy percent of all buildings in Israel now have solar water heaters.[7]

The solar industry in the United States was revived in the early 1970's by the OPEC oil embargo. Skyrocketing oil prices and the prospect of long-term fuel shortages prompted a spurt of interest and investment in renewable energy sources. In 1974, more than 20 companies started production of flat-plate solar heat collectors in the United States. Most of these were active systems with anti-freeze protection. Federal and state tax credits instituted in 1978, combined with another oil embargo in 1979, led to the rapid growth of America's solar industry. It is estimated that over 50,000 solar water heating systems were installed in the United States in 1979.[8]

The industry's expansion was short-lived and had mixed results, however. The nature of the tax credits led inexperienced installers into the business, many of whom were just looking to exploit the tax credits and make some fast money. Many experimental solar water heater designs were tried and failed in short order. Over 100,000 solar water heaters were sold nation-wide in 1984, but the industry soon collapsed when the federal tax credits expired in 1985. The Reagan administration had refused industry appeals to gradually phase out the tax credits over a 10-year period, and instead eliminated them altogether on January 1, 1986.[9] The collapse of the industry not only meant the loss of numerous jobs, but also the professionals who could maintain the systems that had been installed.

America's experience with solar water heating in the 1970's and '80's gave solar

Figure 6.2: An old advertisement for the Climax Solar Water Heater

Solar Ratings & Certification Organization

"The Solar Ratings & Certification Organization (SRCC), www.solar-rating.org, is an independent ratings organization for solar systems and is widely recognized as the official standard in the field. The SRCC rates thermal performance of individual solar collectors as well as complete functional systems. Many state and utility rebate programs require SRCC ratings for products to qualify and system performance can be compared to others in the field using the product directory."[12]

Florida Solar Energy Center

"The Florida Solar Energy Center (FSEC), www.fsec.ucf.edu, is the primary testing lab that performs SRCC ratings. In addition to testing solar thermal systems, FSEC also has their own ratings system that is widely adopted in both Florida and the Caribbean. FSEC is also engaged in a wide range of energy efficient and renewable technologies ranging from photovoltaics to reflective roofs."[13]

energy a black eye that the industry is still struggling to overcome. This is in spite of the many qualified installers who are still working in the field, the many systems that continue to work reliably, and the millions of homes around the world that have been using solar water heaters for many decades. As of 2000, the great majority of solar thermal systems sold in the United States (including water and air heating systems) were used for swimming pool heaters (94 percent of the total). Between 1993 and 2000, over 59 million square feet of solar thermal collectors were shipped within the United States, an average of 7.4 million square feet per year. Four percent of this total was used in domestic hot water systems.[10]

Despite the setbacks that the solar water heating industry has endured, the experience of the past century has resulted in a variety of solar water heater designs that work effectively, reliably, and economically. The technology is available today and is one of the best, most secure long-term investments a homeowner can make. Numerous solar water heater systems have now been tested and certified by the independent Solar Rating and Certification Organization (SRCC). The Florida Solar Energy Center (FSEC) also has a testing and certification program for solar collectors. All solar water heater collectors that are manufactured or sold in Florida must be certified by the FSEC.[11]

Regenerating the Solar Hot Water Industry

Lessons learned over the past fifty years can help to regenerate and then stabilize the solar water heating industry. Arthur Shavit, a professor of mechanical engineering at Israel's foremost technical university, the Technion, has identified four conditions which helped to establish solar water heating in Israel:

1. Solar water heating must be cheaper than the alternatives;
2. People must know about this option;
3. Government building codes must require the use of solar; and
4. The equipment must be readily available."[14]

Further actions that could fundamentally benefit the industry:

- Any tax credits for solar collectors should be performance-based and available only for equipment certified by an entity such as the FSEC or SRCC.
- Low-interest loans should be available to the public for the purchase and installation of solar systems.
- The number of qualified installers must be greatly expanded, and the public made aware of whom these installers are.
- Property taxes and sales taxes should be eliminated for renewable energy equipment.
- Electric utilities should be given incentives to invest in demand-side management and renewable energy sources, and specifically, to support the installation of solar water heaters.
- Federal and state governments, real estate agents, developers, and home builders associations should become educated supporters of solar water heating
- Installers need to pay attention to the aesthetics of their installations. The appearance of solar systems on roofs and in other places influences their appeal to the general public, as well as the resale value of the homes on which they are installed.

Few of these conditions presently exist in Kentucky, although a low-interest financing program has recently been established through a partnership between the Mountain Association for Community Economic Development and the Kentucky Solar

Figure 6.3: A solar collector on the home of Steve and Patti Boyce in Berea, Kentucky, *Andy McDonald*

Solar Water Heater Cuts Energy Bills in Berea Home

Long-time Berea residents Steve and Patti Boyce decided that 2003 would be the year to make some energy-saving home improvements, and their investments have already begun to pay off. In the year that followed, they saw their electric bills drop by an average of 44 percent. Their home improvements included the installation of a solar water heater, energy efficient appliances, and greater reliance on their wood stove. Their first step was to convert nearly all of their lighting to compact fluorescent bulbs, which use a quarter of the energy of standard incandescent bulbs (while having much longer life-spans).

The Boyce's solar water heater utilizes a 4'x10' solar collector mounted on their roof. The collector uses a propylene glycol solution to transfer the sun's energy to the home's electric water heater via a heat exchanger. The electric water heater, heat exchanger, pumps and other equipment are located in the laundry room, which is below the collector panel.

The solar water heater was installed in October 2003, along with a new 50 gallon electric water heater. The lower element of the electric water heater was disconnected while the upper element remains plugged in. In this arrangement the solar collector provides supplemental heating to the electric water heater, reducing its energy consumption while ensuring a continuous supply of hot water, regardless of the weather conditions. A switch enables residents to turn off the electric element during sunny weather when the solar collector can provide sufficient energy to maintain hot water in the water tank.

Steve and Patti have been very satisfied with the system and have not experienced any shortage of hot water. They noted that over the Christmas holiday they had seven guests visiting for a week and there was enough hot water for everyone's needs, although people did need to take shorter showers.

The Boyce's house is located on a wooded hillside in Madison County. At first glance one would not expect this to be a good site for an active solar system like a water heater, because the house is surrounded by trees. However, a site analysis determined that one spot on the roof had access to enough open sky for the system to work well. They did remove one tree in the front yard which would have shaded the solar collector panel. The system was installed by Joshua Bills for a total cost of $3,500.

To date there have been no maintenance problems with the solar water heater. The Boyce's are considering
expanding the system to provide hot water for radiant

Figure 6.4: Steve Boyce on his roof with his solar water heater collector, *Andy McDonald*

Table 6.3: A Comparison of Electricity Use Before and After Installation of Solar Water Heater and Home Energy Efficiency Improvements

Service Period 2002 - 2003	KWH	Service Period 2003 - 2004	KWH	% Change after energy improvements
Nov. 2002	811	Nov. 2003	590	- 27%
Dec. 2002	775	Dec. 2003	854	+10%
Jan. 2003	4005	Jan. 2004	1853	- 54%
Feb. 2003	3078	Feb. 2004	1406	- 54%
Mar. 2003	2389	Mar. 2004	770	- 68%
April 2003	1112	April 2004	978	- 12%
May 2003	843	May 2004	760	- 10%
June 2003	1300	June 2004	366	- 72%
July 2003	427	July 2004	317	- 26%
Aug. 2003	379	Aug. 2004	443	+ 17%
Sept. 2003	478	Sept. 2004	310	- 35%
Oct. 2003	732	Oct. 2004	450	- 39%
Total	**16,329 kWh**		**9,097 kWh**	**- 44%**

Amount Saved on utility bills: $506
Electricity rate $0.07/kWh

Partnership.[15] These and other organizations are working to address the barriers to solar energy use in Kentucky.

End Notes

1. Formula's for calculating annual cost for heating water adapted from Tom Lane, *Solar Hot Water Systems 1977 to Today, Lessons Learned*, 26th Edition, Energy Conservation Services of North Florida, Inc., Gainesville, FL, 2003, pp.96-97.
2. "Energy Source Builder," #38, April 1995.
3. Source for pollutant data: The Cleaner and Greener Program Emissions Reduction Calculator, available on-line at: www.cleanerandgreener.org/emission_reductions.htm
4. B. Keisling, *The Homeowner's Handbook of Solar Water Heating Systems*, Rodale Press, Emmaus, PA, 1983, p. ix.
5. Daniel K. Reif, *Passive Solar Water Heaters*, Brick House Publishing Company, Andover, Massachusetts, 1983, p. 13; and Daniel J. Berman and John T. O'Connor, *Who Owns the Sun?*, Chelsea Green Publishing Co., White River Junction, Vermont, 1996, p.13.
6. Daniel J. Berman and John T. O'Connor, *Who Owns the Sun?*, Chelsea Green Publishing Co., White River Junction, Vermont, 1996, p.15.
7. Ibid, p.14.
8. Arthur Allen, "Prodigal Sun" in Mother Jones, March/April 2000. Available on-line at: www.motherjones.com/news/feature/2000/03/solar.html
9. Tom Lane, *Solar Hot Water Systems 1977 to Today, Lessons Learned*, 26th Edition, Energy Conservation Services of North Florida, Inc., Gainesville, FL, 2003.
10. Energy Information Administration. Data available on-line at: www.eia.doe.gov/cneaf/solar.renewables/page/solar/solarphoto_tab.html
11. "Passive and Active Solar Domestic Hot Water Systems," North Carolina Solar Center, Fact Sheet No. SC122, Raleigh, NC, June 2002, p.1.
12. Source: www.sunearthinc.com/industry_links.htm
13. Ibid.
14. Berman and O'Connor, p.14.
15. Mountain Association for Community Economic Development, 433 Chestnut St., Berea, KY 40403. www.maced.org. Kentucky Solar Partnership, 50 Lair St., Mt. Vernon, KY 40456. www.kysolar.org

RESOURCES: Solar Water Heating

Publications

"The Casa Juliana Solar Water Heater," Andy McDonald and David Omick, Proyecto Fe y Esperanza, 1998. Technical plans for a batch solar water heater.

Consumer Guide to Solar Energy, S. Sklar & K. Sheinkopf, Bonus Books, Inc., Chicago, 1995.

"Heating Your Swimming Pool with Solar Energy," North Carolina Solar Center, Technical Paper no. SC122, North Carolina State University, Raleigh, North Carolina, June 2002. Available on-line at www.ncsc.ncsu.edu

The Homeowner's Handbook of Solar Water Heating Systems, B. Kiesling, Rodale Press, Emmaus, PA, 1983.

Home Power (magazine), see below for contact information.

"Passive and Active Solar Domestic Hot Water Systems," North Carolina Solar Center, Technical Paper no. SC122, North Carolina State University, Raleigh, North Carolina, June 2002. Available on-line at www.ncsc.ncsu.edu

"Solar Water Heaters," Bob Fairchild, Appalachia–Science in the Public Interest, Technical Paper 9, Mt. Vernon, Kentucky.

Solar Hot Water Systems, 1977 to Today: Lessons Learned (26th ed), Tom Lane, Energy Conservation Services of North Florida, Inc., Gainesville, Florida, 2003.

Solar Today (magazine), American Solar Energy Society (see below for contact information).

Solar Water Heating, Bob Ramlow & Benjamin Nusz, New Society Publishers, British Columbia, 2006.

"Space Heating with Active Solar Energy Systems," North Carolina Solar Center, Technical Paper no. SC120, North Carolina State University, Raleigh, North Carolina, June 2000. Available on-line at www.ncsc.ncsu.edu

Organizations

American Solar Energy Society
2400 Central Ave., Suite A
Boulder, Colorado 80301
(303)443-3130
www.ases.org

The American Solar Energy Society (ASES) is a national organization dedicated to advancing the use of solar energy for the benefit of U.S. citizens and the global environment. ASES promotes the widespread near- and long-term use of solar energy. Publishers of *Solar Today* magazine (www.solartoday.org).

Florida Solar Energy Center
1679 Clearlake Road
Cocoa, Florida 32922
(321) 638-1000
www.fsec.ucf.edu

The Florida Solar Energy Center researches and promotes energy efficiency and solar energy in Florida. Their site includes project descriptions, on-line research reports, software demonstrations, news and events.

Home Power Magazine
PO Box 520
Ashland, OR 97520
(800)707-6585
(541)512-0201 (outside the U.S.)
www.homepower.com

Home Power is "the hands-on journal of home-made power." Each issue offers in-depth, clearly-written, well-illustrated articles discussing the entire array of renewable energy technologies, educating and empowering their readers toward more sustainable lifestyles.

Midwest Renewable Energy Association
7558 Deer Road
Custer, WI 54423
(715)592-6595
www.the-mrea.org

The Midwest Renewable Energy Association offers workshops and training that cover a variety of topics related to renewable energy. Their annual Renewable Energy Fair, held each year on the summer solstice in Wisconsin, offers excellent educational and networking opportunities, and is billed as the largest RE Fair in the country.

National Renewable Energy Laboratory
www.nrel.gov

The National Renewable Energy Laboratory is the nation's leading center for renewable energy research. Their web site features publications, program and project descriptions, partnership opportunities, news and events.

North Carolina Solar Center at North Carolina State University
Box 7401
North Carolina State University
Raleigh, NC 27695-7401
(919)515-5666
www.ncsc.ncsu.edu

The North Carolina Solar Center serves as a clearinghouse for solar and other renewable energy programs, information, research, technical assistance, and training for the citizens of North Carolina and beyond. The Center offers numerous publications addressing passive and active solar energy. These documents can be downloaded for free from their web site (follow the link for "Information Resources"). They will also mail printed copies upon request.

Solar Energy Industries Association
805 15th Street, NW
Suite 510
Washington, DC 20005
(202) 682 - 0556
www.seia.org

The Solar Energy Industries Association (SEIA) is the national trade association of solar energy manufacturers, dealers, distributors, contractors, installers, architects, consultants, and marketers. They work to expand the use of solar technologies in the global marketplace. On their web site you can find out how to get involved as an individual or a solar business, keep up on the latest solar policy news, and find out about contractors and incentives for buying solar yourself.

Solar Energy International
PO Box 715
76 S. 2nd St.
Carbondale, CO 81623
Phone: (970)963-8855
www.solarenergy.org

Solar Energy International (SEI) offers hands-on workshops in solar, wind and water power and natural building technologies in eleven locations. SEI also offers internet-based online courses.