Smart, Clean and Ready to Go

How Solar Hot Water Can Reduce Pollution and Dependence on Fossil Fuels

ENVIRONMENT MAINE
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Executive Summary

Solar water heating has the potential to reduce America's dependence on fossil fuels and curb pollution that causes global warming and respiratory problems. By taking advantage of America's full potential to produce hot water for homes and businesses from solar energy, **the nation could reduce natural gas consumption by 2.5 percent and electricity use by nearly one percent, while avoiding 52 million metric tons of carbon dioxide pollution per year**—equivalent to emissions from 13 coal-fired power plants or 9.9 million cars.

The United States should take aggressive steps to encourage the installation of solar water heaters on homes and businesses and to promote other solar water heating technologies that can make an even bigger dent in our consumption of fossil fuels.

Solar water heating is a proven technology that can reduce energy use throughout our economy.

- Solar water heaters—which typically use rooftop collectors to capture the sun's heat—have been in use for more than a century. Solar water heaters can replace 50 to 85 percent of the energy used for hot water and can operate in all climates.

- Solar water heating technologies can also be used to provide hot water for industry, to provide space heating for homes or entire neighborhoods, or even to cool buildings.

Tapping America's full potential to use solar energy for domestic and commercial hot water would reduce America's energy use and emissions of global warming pollution.

- Approximately 40 million homes, as well as 50 to 75 percent of all commercial roof space, can host solar water heaters, according to the National Renewable Energy Laboratory.

- Achieving America's full potential for domestic and commercial solar water heating could:

- Save 578 billion cubic feet of natural gas, or 2.5 percent of U.S. natural gas use;
- Save 35 billion kilowatt-hours of electricity, or just under 1 percent of U.S. consumption;
- Prevent 52 million metric tons of carbon dioxide pollution—equivalent to emissions from 13 coal-fired power plants or 9.9 million cars.

- These figures do not include potential savings from industrial solar water heating, solar space heating or solar cooling, all of which use solar collectors similar to those used to produce hot water. A European study estimated that the European Union could provide nearly half of its low-temperature heat—which currently accounts for one-third of total energy use—with this broad range of solar thermal technologies by 2050 under an aggressive research and development scenario.

Solar water heating delivers a variety of benefits to the economy.

- Solar water heating could reduce energy bills by $9.9 billion annually, saving residential customers 3.2 percent and businesses 1.6 percent of their current energy expenditures.

- Residential solar water heaters in parts of the country pay back their initial investment in four to eight years, providing long-term savings for consumers and protecting consumers and businesses from the risk of wild swings in fossil fuel and electricity prices.

- Solar water heating increases America's energy security, reduces the environmental and public health costs of fossil fuel-related pollution, and creates jobs. Europe's solar thermal industry, for example, employs 40,000 people and brings in $4.1 billion in annual sales.

Despite the recent resurgence of solar water heating in the United States, America trails far behind the world leaders in using this energy-saving technology.

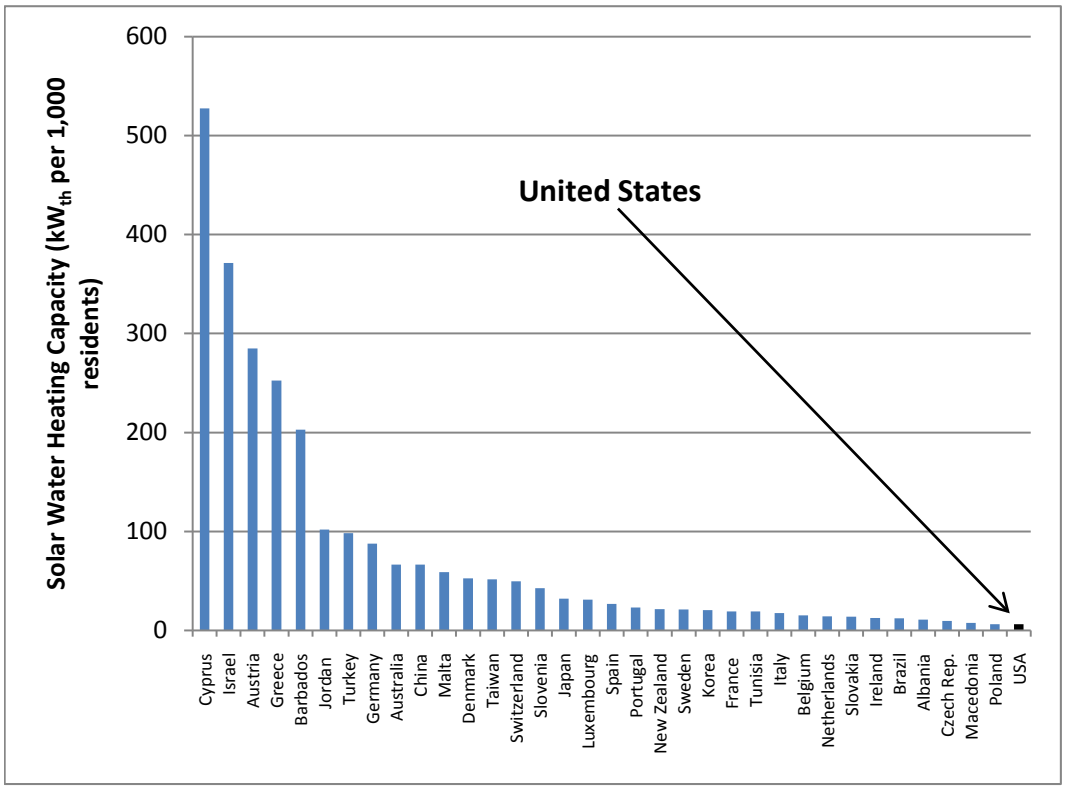
- America ranks 35th in the world for per-capita solar water heating capacity (excluding heated swimming pools), trailing such nations as Barbados, Taiwan, Tunisia and Albania.

- On a per-capita basis, Cyprus has 83 times as much solar water heating capacity as the United States, Germany has 14 times as much, and China 10 times as much.

- Other nations are taking the lead both in widespread adoption of solar water heating and in innovation. Solar water heaters are mandatory on most new buildings in Israel and Spain, tens of millions of solar water heaters have been installed across China, and European nations are pioneering new types of solar water heating systems that can provide even greater reductions in energy consumption.

Smart public policy can overcome the barriers to widespread adoption of solar water heating in the United States and reap the energy savings and emission reductions that would result. Local, state and federal officials should take actions to promote solar water heating, including:

Figure ES-1. Installed Solar Water Heating Capacity by Country 2008 (kilowatts thermal per 1,000 residents)



- Adoption of strong building energy codes that encourage builders to use technologies such as solar water heating to dramatically reduce fossil fuel consumption in homes and commercial buildings.

- Adoption and implementation of strong electric and gas utility energy efficiency requirements that encourage the deployment of solar water heating and other clean energy technologies.

- Adoption of innovative financing tools that ensure that those who install solar water heaters benefit from their investments immediately, as opposed to having to wait for years to break even on their investments.

- Provision of financial incentives—including tax credits and grants—to reduce the cost of solar water heaters in the short-term.

- Adoption of policies to require new homes to be "solar ready" or even to require solar water heaters on new buildings, as Hawaii has recently done.

- Aggressive government support for solar water heating, including the installation of solar water heaters on government buildings and increased investment in research and development of solar water heating technologies.

- Steps to develop the solar water heating industry, including workforce training programs, incentives for domestic manufacturing of solar water heating equipment, and efforts to educate the public and businesses about the benefits of solar water heating.

Introduction

Hot water is at the core of our modern way of life.

That might seem to be an exaggeration at first blush. Sure, hot showers, clean clothes and coffee are nice, but they could hardly be considered pillars of our economy.

Scratch the surface, however, and you quickly discover that the simple act of heating water is a fundamental part of the processes that power our homes, produce the goods we use on a daily basis, and support a high quality of life.

Power plants heat water to produce the steam that powers the turbines that generate the vast bulk of our electricity. Factories use hot water or steam to prepare processed foods, clean equipment, facilitate chemical reactions, and for many other purposes. Commercial establishments heat water to wash clothing and cook food. And many American homes use boilers to create the hot water or steam used to keep warm on cold winter nights.

Today, America produces most of its hot water by burning natural gas, oil or coal—deepening our dependence on fossil fuels.

There is, however, another alternative: free energy from the sun.

Solar water heating is a tried and tested technology that has been used for more than a century. Small-scale solar water heaters are ubiquitous in countries such as Israel and are being installed by the millions in China. Countries such as Austria and Germany are pioneering ways to use solar energy to provide hot water for industry and to provide heat and hot water for entire neighborhoods, even in the dead of winter.

Over the last decade, America has begun a clean energy revolution, with rapid increases in the deployment of wind power, solar photovoltaics, energy efficiency technologies and a range of other clean energy solutions. While the number of homes and businesses using solar water heating has increased as well, America remains far behind many other nations.

The time has come for that to change. The environmental impacts of our fossil fuel dependence—from ruptured coal ash ponds in Tennessee to the BP oil spill in the Gulf of Mexico to the threats to water supplies posed by shale gas drilling in the mid-Atlantic—are increasingly evident. The urgency of addressing global warming

continues to grow. And our economy continues to suffer from high fossil fuel costs and the need for new jobs that investments in green energy can create.

Solar water heating won't solve these problems on its own. But America needs every tool we can find to break our dependence on fossil fuels and reduce our impact on the environment. Solar water heating is one such powerful tool.

Solar Water Heating: A Clean Energy Solution for America

When most Americans think of solar energy, they envision photovoltaic panels on rooftops or, sometimes, vast fields of mirrors in the desert. These technologies generate electricity and represent an important tool for reducing our nation's dependence on fossil fuels.

Solar energy, however, can do much more than generate electricity—it can also be used to heat water for domestic, commercial or industrial use. Solar water heating is an important clean energy solution for America, one that can be used in every part of the country and for many different purposes.

Why Heat Water with Solar Energy?

Heating water with solar energy is an extremely efficient way to capture the energy of the sun. Solar water heating systems deliver a series of benefits to the environment and consumers:

- **Reduced dependence on fossil fuels** – Residential solar water heating systems can reduce fossil fuel needs for water heating by 50 to 85 percent.[1] Neighborhood-scale solar water heating systems that include seasonal storage can nearly eliminate the need for fossil fuel use for hot water and for space heating. (See page 12.)

- **Low and stable fuel costs** – While solar water heaters come with a large upfront price tag (about $6,000 for residential systems, not including government incentives)[2] they guarantee stable fuel costs over their lifespan, which is typically around 20 years.[3]

- **Reduced pollution** – In addition to curbing fossil fuel use, solar water heating systems reduce emissions of global warming pollution, as well as pollutants from the burning of fossil fuels that contribute to smog and other air pollution problems.

What Is Solar Water Heating?

There are, broadly speaking, two types of solar energy technologies—those that take advantage of the sun's light and those that tap the energy in the sun's heat. Solar photovoltaics and "daylighting" are examples of harnessing the sun's light.

Solar thermal technologies are those that use the latter approach, harnessing the energy in the sun's heat. There are numerous ways to capture thermal energy from the sun—through the heating of air, solid substances, or water. **Solar water heating** technologies use water as the medium for capturing or utilizing the sun's heat.

Solar water heating is most often thought of as a way to provide hot water to households or businesses. However, the same technologies used to produce hot water for domestic use can also be employed to produce heat for a variety of other applications. In this report, we will define solar water heating to include the full range of technologies that capture the sun's heat in water for commercial, residential, and industrial applications.

Water heated by the sun can also be used to generate electricity, as with concentrating solar power (CSP) power plants, which are frequently located in desert areas. CSP plants use mirrors to focus the sun's rays on water or a transfer fluid that is then used to produce steam for a turbine. There are many promising CSP technologies, which are featured in Environment America Research & Policy Center's 2008 report, *On the Rise: Solar Thermal Power and the Fight Against Global Warming*, available at www.environmentamerica.org. This report focuses on technologies that produce hot water for direct use, rather than for generating electricity.

The technology involved in solar water heating is relatively simple. Solar collectors, often installed on rooftops, are used to capture the sun's heat. The simplest solar collectors—typically used for heating swimming pools—heat water directly in unglazed, dark-colored tubes exposed to the sun. Collectors used for domestic hot water are often flat panels, in which tubes containing water are placed against a dark background and enclosed in glass coated with a special glaze that prevents heat from escaping. In cold climates, a freeze-proof heat-transfer fluid is used in the panels instead of water. More sophisticated collectors use racks of evacuated tubes to reduce heat loss from the system—enabling the collectors to produce higher-temperature water and to produce hot water under a greater variety of conditions, including cloudier skies and cooler temperatures.

An evacuated tube collector provides hot water to a Vermont farm home. Courtesy of DOE/NREL; Credit: Alan Ford

The solar collector is only one part of a solar water heating system. Other critical parts of the system include the equipment used for carrying fluid to and from the collector (which may be either gravity-fed or use pumps), controls to assure proper

functioning of the system, and the storage tank. Insulated storage tanks—especially the large tanks used in neighborhood-scale systems—can be used to store heat from the collector until it is needed, even across seasons.

Solar Water Heating in the United States and Around the World

Solar water heating has a long history in the United States. Indeed, the world's first commercial solar water heating system was patented in the United States in 1891.[4] In the early part of the 20th century, solar water heaters were common in sunny states such as Florida and California. But the increased availability of cheap natural gas and electricity in the mid-20th century decimated the solar water heating industry in the United States.

In other parts of the world, however, solar water heating continued to advance, playing an increasingly important role in meeting local energy needs. In Israel, solar water heaters became widespread during an energy supply crisis in the 1950s and the government made them mandatory on new buildings in 1980. Today, more than 1.6 million Israeli households—representing 85 percent of all households—have solar water heaters, enough to cut the nation's total primary energy consumption by 3 percent.[5]

Other nations have also taken advantage of the benefits of solar water heating. As of 1999, 92 percent of all households and half of all hotels on the island nation of Cyprus used solar water heaters, and solar water heating has made serious inroads in other Mediterranean countries, including Greece and Turkey.[6] In 2006, Spain became the second country in the world (after Israel) to require the use of solar water heaters.[7] China, meanwhile, has experienced a solar water heating boom in recent years, with solar water heaters becoming nearly ubiq-

Rooftop solar collectors supply hot water to tens of millions of households in China. Here, solar collectors line rooftops in the city of Xi'an. Photo Credit: Kerry Snyder

uitous on rooftops in some cities. Nearly one in 10 Chinese families now has a solar water heater.[8]

Worldwide, approximately 70 million homes now use solar water heaters, as do a growing number of businesses.[9] In the United States, solar water heating is most popular in Hawaii—which, as an island state, is completely dependent on imported fuels. The state accounts for roughly one-fourth of U.S. solar water heating systems and now requires solar water heaters on new homes, with some exceptions (see page 22).[10]

Elsewhere in the United States, however, solar water heating has been slow to take hold, despite its great potential. Interest has revived recently, with consistent increases in solar water heating installations over the last five years, including a 10 percent

Figure 1. Installed Solar Water Heating Capacity by Country 2008 (Gigawatts thermal)[15]

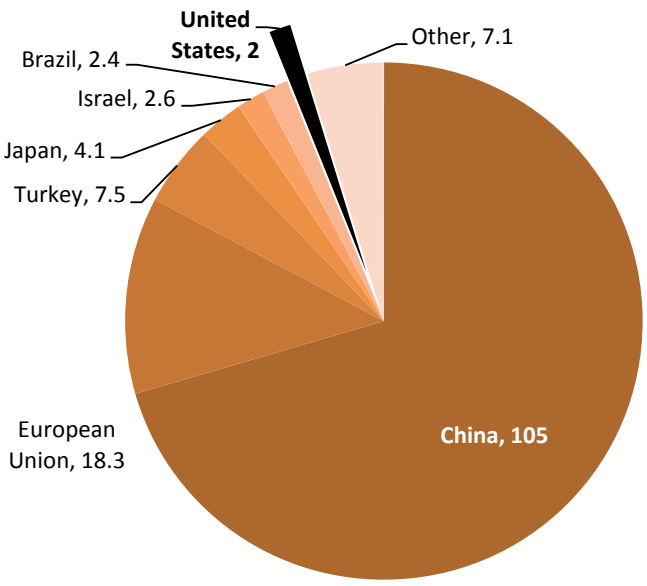
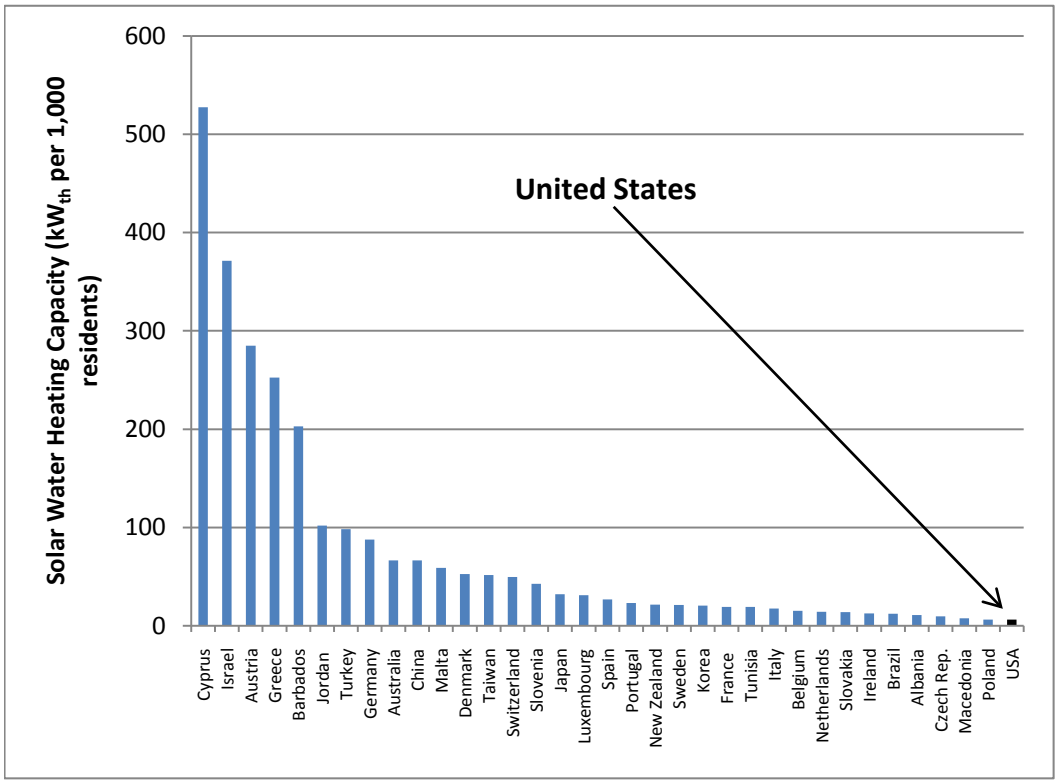


Figure 2. Installed Solar Water Heating Capacity by Country 2008 (kilowatts thermal per 1,000 residents)[1]



The United States ranks 35th in the world for per-capita solar water heating capacity, behind such nations as Barbados, Taiwan, Tunisia, Slovakia and Albania.

increase in 2009.[11] Despite this progress, America still lags far behind the world leaders in solar water heating capacity, ranking seventh in the world for solar water heating installations.[12] On a per-capita basis, moreover, the United States ranks only 35th (excluding swimming pools), trailing such nations as Barbados, Taiwan, Tunisia, Slovakia and Albania.[13] On a per-capita basis, Cyprus has 83 times as much solar water heating capacity as the United States, Germany has 14 times as much, and China has 10 times as much.[14]

Uses of Solar Water Heating

Solar collectors can be used to reduce the need for fossil fuels to heat water throughout our economy.

Solar water heaters on employee housing in Yosemite national park Courtesy of DOE/NREL, Credit: Jim Schwerm

Residential and Commercial Water Heating

Solar water heaters are a perfect fit for many homeowners, as well as for businesses that use large quantities of hot water. Water heating accounts for 20 percent of household energy consumption and nearly eight percent of energy use in commercial buildings.[17]

Solar water heating systems are smaller, technologically simpler, less expensive, and more efficient at capturing the energy in sunlight than solar PV panels. Solar water heaters require rooftops with direct exposure to sunlight and proper orientation. A National Renewable Energy Laboratory study estimated that 50 percent of residential buildings nationwide could use solar water heating systems.[18] Solar water heating systems can be installed in any climate, although different types of systems work better in different parts of the country.

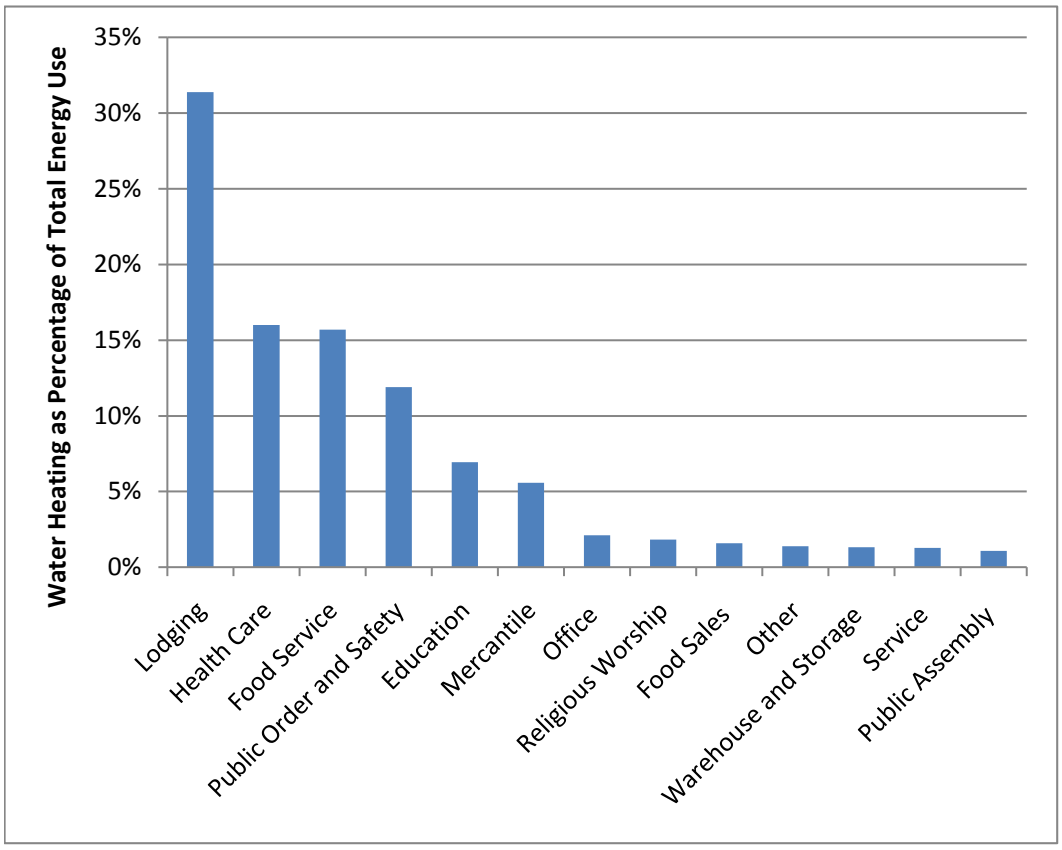
In addition to providing hot water for domestic use, solar energy can also be used to heat swimming pools. Indeed, solar water heating has become a common way to heat swimming pools, accounting for the vast majority of all solar water heating capacity in the United States.[19]

Solar water heating can also be an effective solution for businesses that use large amounts of hot water, such as laundries, hotels and food service businesses. In these businesses, water heating can account for a significant share of overall energy use. (See Figure 3.)

Solar water heaters have begun to make inroads into the commercial market. For example, the World's Largest Laundromat in Berwyn, Illinois, installed a solar water heating system designed to produce 2,400 gallons of hot water every day after natural gas prices spiked in 2001.[21] Baseball's Boston Red Sox recently installed a solar water heating system at historic Fenway Park, which produces more than a third of the hot water used at the facility.[22]

The commercial sector has several

Figure 3. Percentage of Energy Use for Water Heating by Type of Commercial Building, U.S., 2003[20]



advantages over the residential market when it comes to solar water heating. Commercial buildings are more likely to have flat roofs than residential buildings, increasing the share of rooftops that could host solar collectors. In addition, the high-efficiency heat collectors often used for commercial solar heating applications can be installed in large numbers and coupled with mirrors to enhance their effectiveness. These measures can reduce the cost per square foot of these high-efficiency collectors to 50 percent or more below the average cost of residential units.[23]

Industrial Process Heat

Solar energy can also be used to provide hot water or steam for industrial uses.

The creation of "process heat" uses more energy in America's manufacturing sector than any other single activity.[24] Melting iron in a mill or cooking cement in a kiln obviously requires heat, but so do distilling ingredients in a pharmaceutical plant, pasteurizing milk in a food processing plant, or bleaching cloth at a textile mill.

Uses of process heat are classified by the temperatures required. About 30 percent of process heat is used at "low" temperatures—below the boiling point of water—and another 27 percent is used at "medium" temperatures—between 100 and 400°C.[25] Solar energy can play a role in helping to meet much of the low- and medium-temperature needs of industry, as it is most useful for processes occurring at less than 250°C.[26] In certain key industries—such as food, textiles, and paper—60

percent or more of process heat is needed at these temperatures.[27] Solar water heating is potentially well-suited for several uses of industrial heat, including cleaning, drying, preheating of boiler water, and sterilization.[28]

Worldwide, approximately 90 solar process heat systems are currently in place, including several in the United States.[29] The largest solar process heat system in operation in the United States is located at a Frito-Lay factory in California. It uses a 5-acre field of solar concentrators to create steam, which heats the oil used to cook the company's SunChips brand of snack foods.[30] At full capacity, the system can produce 14.7 billion BTUs of energy per year, equivalent to the annual natural gas use of 340 average American homes.[31]

Rooftop collectors similar to those used for residential hot water are appropriate for some industrial applications, while large-scale collector arrays similar to those used for concentrating solar power plants can serve large scale, high temperature uses. For fairly low temperature uses, process heat can actually be generated at the same time as electricity through the use of photovoltaic/thermal collector arrays, which capture the waste heat generated by sunlight striking photovoltaic panels.[32]

Neighborhood-Scale Solar Water Heating

Solar water heating systems can work in any climate to provide hot water for domestic use. But solar energy can make an even bigger impact if it can be used to reduce the use of fossil fuels for space heating, which accounts for an even greater share of home energy use than water heating. The creation of neighborhood-scale solar "district heating" systems can achieve that goal.

A district heating system is one in which steam or hot water from a central plant is piped to residential and commercial buildings in a city, neighborhood, industrial park or college campus. In other words, instead of each individual building having a furnace or boiler, all the buildings in a district heating system receive heat from one central power plant.

Solar energy can help to power district energy systems. In Europe, several housing developments have been built with solar district heating systems. In these systems, rooftop solar collectors heat water, which is then piped to a central storage tank. The storage tank is typically designed with thick concrete walls and buried underground so that it can retain heat for use in times of day when the sun is not shining or even, with the installation of seasonal storage, colder months of the year.[33] The solar district heating system in Friedrichshafen, Germany, which uses seasonal storage to supply heat and hot water to more than 500 apartments, covers approximately 25 percent of the neighborhood's space heating and water heating energy needs; other solar district heating installations in Germany provide an even greater fraction of home heating or hot water.[34] Such systems are even viable in extremely cold climates. A 52-unit housing development in Alberta, Canada, is using solar energy to supply 80 percent of the complex's space heating and hot water needs.[35]

Solar district heating has gotten the greatest traction in Europe, but the largest such project is currently being built in the United States. The 900,000-square-foot Fletcher Business Park in western North Carolina uses 640 solar thermal collectors to heat and cool the facility's buildings.[36]

Solar energy collectors can also be used to augment steam production in existing district heat systems, reducing the need to burn fossil fuels.

Solar Cooling

Solar water heaters can even, surprisingly, help to cool buildings. Absorption chillers use heat energy—which can be provided by hot water from a solar water heating system—to drive an evaporation/conden-

sation cycle that produces chilled water. Fans then blow across pipes containing the chilled water to provide refrigerated air.

Solar cooling systems are uncommon today, but represent a useful way to maximize the benefits of solar water heating. The Steinway & Sons piano factory in New York City, for example, recently installed the world's largest solar cooling system. During the summer, the system cools and dehumidifies the factory, preventing moisture from affecting the precision parts of the company's world-famous pianos, while during the winter the system helps heat the facility.[37]

Solar Combisystems

Rare in the United States, but increasingly common in northern Europe, solar "combisystems" provide hot water, space heating, and sometimes cooling to individual homes or businesses. Combisystems typically include larger collectors and larger storage tanks to meet the increased demand for heat. Solar combisystems are particularly useful when combined with highly efficient home designs, which reduce the size of the system needed and the demand for auxiliary heating from natural gas or other sources.

Solar water heating can work in any climate. In Alberta, Canada, the Drake Landing housing development is equipped with a solar district heat system that serves the majority of the complex's heat and hot water needs. Credit: Natural Resources Canada

Solar Water Heating Can Save Energy and Reduce Global Warming Pollution

Solar water heating has the potential to deliver significant reductions in fossil fuel use and global warming emissions.

As described in the previous section, solar energy can be used for virtually any application in which hot water is needed, whether for the generation of electricity or production of process heat for industry. Solar water heating can even be used to cool buildings, and can be applied on a neighborhood scale to provide both heat and hot water to residents.

Little analysis, however, has been done in the United States of the potential for use of solar water heating in industrial applications, the integration of solar energy through district heating, solar cooling, or the use of solar combisystems. While these technologies are promising and may have the potential to make a large contribution to America's energy needs in the future, that contribution is not quantified in this report. (See Figure 4.)

Millions of Homes and Businesses Are Candidates for Solar Water Heating

Based on an analysis of rooftop availability by the National Renewable Energy Laboratory (NREL), an estimated 40 million homes in the United States have the capability to use solar water heaters. California leads the nation with an estimated 5.6 million homes capable of solar water heating, followed by Texas (3.8 million) and Florida (3.1 million). All three of these states have excellent climates for solar water heating, with NREL estimating that a solar water heater could meet an average of 60 percent of a home's water heating needs in California, 65 percent in Texas and 70 percent in Florida.[39]

Commercial buildings could make similar, widespread use of solar water heaters. According to the NREL analysis, between 50 and 75 percent of commercial roof space, depending on the region, is capable of hosting solar water heaters.[40]

Energy Savings from Solar Water Heating

Solar water heating can make a meaningful contribution to reducing America's dependence on fossil fuels.

Were the United States to achieve its full potential for solar water heating in individual residential and commercial buildings, as assessed by the NREL study, the nation could achieve the following annual savings (based on 2008 energy consumption patterns):

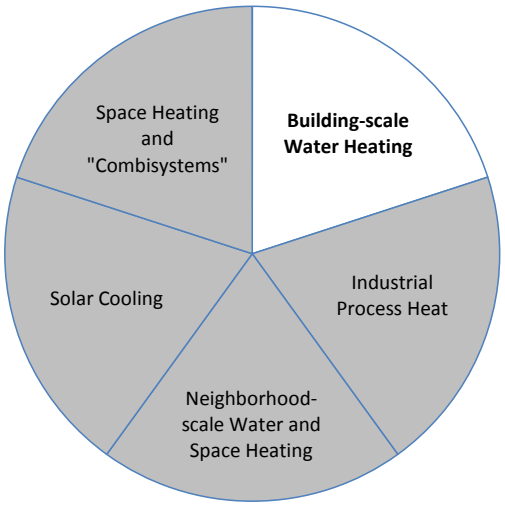
- 508 billion cubic feet of natural gas, equivalent to 2 percent of total U.S. natural gas use;
- 35 billion kilowatt-hours of electricity, equivalent to just under 1 percent of total U.S. electricity demand.

Savings would also extend to other sources of energy used to supply hot water, including fuel oil and propane.

Including the reductions in fossil fuel use that would result from reductions in electricity consumption, the impact of solar water heating is even more significant, with the potential to reduce U.S. natural gas consumption by as much 578 billion cubic feet, or 2.5 percent.[41]

This reduction in fossil fuel use would also save individuals and businesses money

Figure 4. Solar Water Heating Technologies Included (light) and Not Included (shaded) in This Analysis



Assessing America's Solar Water Heating Potential

The analysis in this report is based on work by the National Renewable Energy Laboratory (NREL), which estimated the potential for solar water heating based on the estimated percentage of rooftop space available for solar collectors and the share of a building's water heating needs those systems could meet.[38] This analysis updates the energy savings figures from the NREL study based on 2008 energy consumption patterns and extends the analysis to include a state-by-state breakdown of potential savings.

The estimates included in this report reflect a conservative estimate of America's potential to use residential and commercial solar water heating. Consistent with the NREL analysis, our estimate of solar water heating potential is based on the level of energy production expected from a low-cost solar water heating system. Higher efficiency systems are currently available and would offset a greater share of energy demand if implemented on a broad scale. In addition, as noted above, this analysis does not include many technologies that can contribute to meeting America's energy needs, such as solar space heating and cooling.

by reducing energy bills. Solar water heating could reduce commercial energy bills by 1.6 percent, and residential energy bills by 3.2 percent—an annual savings of $9.9 billion.[42]

Solar water heating can make an even greater impact in parts of the country with a large share of roofs with the potential to host solar collectors and with sunny climates. California, for example, could reduce its consumption of natural gas by 5.2 percent—not including reduced natural gas consumption at power plants. Maryland, North Carolina, and Vermont are among the other states with the potential to achieve a significant reduction in natural gas use from a transition to solar water heating. (See Table 1.)

Table 1. Percentage Reduction in State Natural Gas Use from Maximizing Solar Water Heating Potential (Excluding Natural Gas Used to Supply Electricity)

State	Percent of Total Natural Gas Consumption
California	5.2%
District of Columbia	4.9%
Maryland	4.3%
North Carolina	4.1%
Vermont	3.8%
Arizona	3.6%
Idaho	3.2%
Minnesota	3.2%
Tennessee	3.2%
Virginia	3.2%

In some parts of the country, particularly the Southeast and Northwest, electric water heaters are very common. In these regions, solar water heating can make a significant contribution to reducing electricity demand. In Florida, for example, maximizing the state's potential for solar water heating could reduce total electricity consumption by 2.8 percent. (See Table 2.)

Table 2. Percentage Reduction in State Electricity Use from Maximizing Solar Water Heating Potential

State	Percent Reduction in Electricity Consumption
California	5.2%
Florida	2.8%
Maryland	1.4%
Oregon	1.3%
Georgia	1.3%
North Carolina	1.2%
Delaware	1.2%
Virginia	1.2%
Texas	1.2%
Washington	1.1%
District of Columbia	1.1%

Solar water heating alone cannot solve America's energy challenges, but it can make an important contribution toward reducing energy use and saving consumers money. A 2003 study by the American Council for an Energy Efficient Economy found that a short-term program to reduce natural gas and electricity consumption through improved energy efficiency could result in large reductions—as much as 20 percent—in natural gas prices.[43] Similarly, solar water heating technologies—particularly solar cooling—can reduce peak demand for electricity, reducing the need for expensive expansion of transmission and distribution infrastructure.

The energy savings described here are also only the beginning of what is possible should the United States take an aggressive approach to developing the full range of solar water heating technologies. A recent analysis in Europe, for example, projects that solar energy could meet nearly half of the continent's demand for low-temperature heat—which currently accounts for a third of Europe's total energy consumption—by the middle of this century by pursuing an aggressive policy path that emphasizes research and development.[44]

(See "Solar Water Heating Potential: The Big Picture.")

Emission Reductions from Solar Water Heating

Solar water heating can also reduce emissions of global warming pollution and pollutants that contribute to smog and other air quality problems.

Maximizing America's potential for solar water heating in the residential and commercial sectors would result in a 0.9 percent reduction in the nation's fossil fuel-related carbon dioxide emissions, curbing emissions by 52 million metric tons per year. That is the equivalent of the annual emissions produced by 13 typical 500 MW coal-fired power plants or 9.9 million passenger cars.[46]

In addition to curbing emissions of carbon dioxide, which contributes to global

Solar Water Heating Potential: The Big Picture

Solar water heating can help meet energy needs throughout America's economy—not just the need for hot water in homes and businesses. As yet, there has been little analysis of the full potential for solar thermal energy to displace fossil fuel use in the American economy. But in Europe, where solar thermal systems are more common, solar water heating has received more attention as a major potential contributor to a clean energy future.

A 2009 report in Europe analyzed the potential for a broad range of solar thermal technologies, which include the solar space heating, cooling and industrial process heat technologies described in this report. Among their conclusions:

- The demand for low-temperature heat for residential, commercial, and industrial use accounts for approximately one-third of the European Union's final energy demand. Low-temperature heat is the type that can be most effectively provided by solar water heating systems.

- Should Europe pursue an aggressive policy path of research and development, the European Union could avert as much as 3.6 percent of its low-temperature heat demand through the use of solar thermal technologies by 2020. By 2030, solar thermal's contribution to low-temperature heat demand could rise to 15 percent, and by 2050, its contribution could increase to 47 percent.

- By 2030, under an aggressive research and development policy scenario, solar thermal technologies would make a meaningful contribution toward reducing energy demand not just for hot water, but also for space heating, industrial heat, and air conditioning.[45]

The European analysis shows that the potential for curbing energy consumption through the use of solar water heating and similar thermal technologies is far greater than currently appreciated.

warming, solar water heating also averts emissions of other pollutants—including smog, soot, and mercury.

The states that can achieve the largest emission reductions through the use of solar water heating tend to be those that have the greatest overall energy use, as well as those that are both widely dependent on electricity for water heating and that obtain much of that electricity from coal. (See Table 3.)

Solar water heating can play an important role today in curbing fossil fuel use and emissions of global warming pollutants, and it can play an even bigger role in the years to come as new technologies are developed. Maximizing that potential, however, will require strong action to overcome the barriers that have prevented the emergence of solar water heating as a major contributor to America's energy needs.

Table 3. Top 10 States for Potential Carbon Dioxide Emission Reductions from Solar Water Heating (Million Metric Tons Carbon Dioxide)

State	Total
California	8.0
Texas	6.2
Florida	4.3
Georgia	1.7
New York	1.6
North Carolina	1.6
Ohio	1.5
Illinois	1.5
Pennsylvania	1.4
Virginia	1.4

Realizing the Potential for Solar Water Heating in the United States

The United States is currently well behind many other nations in both the use of solar water heating and in the development of new solar water heating technologies. By removing the barriers that inhibit investment in solar water heating, and by investing in the development and deployment of new technologies, the United States could take an important step toward weaning itself off fossil fuels and reducing our impact on the environment.

Solar Water Heating: A Winning Investment

Cost is commonly thought to be the major barrier to the increased deployment of solar water heaters. But that is not the case—in many parts of the United States, particularly those with strong sunlight and high electricity or natural gas costs, solar water heating is a winning investment. In Hawaii, for example, which recently required the inclusion of solar water heaters on most new homes, solar energy is cost-effective everywhere, with simple payback times of 4.3 to 8.5 years.[47] Payback times of seven to eight years have been estimated for typical residential installations in Florida.[48]

Commercial establishments that use large quantities of hot water—such as laundries, hotels and food services—can also achieve reasonable returns on their investments in solar water heating.

Federal and state incentives—including tax breaks and upfront incentives—can further reduce the cost of solar water heating systems, making them even more attractive to consumers and businesses. But consumers are not the only ones to benefit from solar water heating. The installation of solar water heaters delivers economic benefits that extend well beyond the individual business or homeowner. Among them:

- The value of solar water heating as a hedge against higher natural gas prices, reducing the exposure of consumers and businesses to the historically wild swings in gas prices.
- The value of reduced need for investment in natural gas pipeline capacity.
- The value of avoided emissions of

pollutants such as carbon dioxide and methane, which contribute to global warming, and of pollutants that produce health-threatening smog and soot.

- The value of increased energy security and reduced prices of electricity and natural gas that result from lower demand.[49]

Barriers to Solar Water Heating

If cost is not the main barrier to the spread of solar water heating, then why haven't solar water heaters become more common on American rooftops?

The answer is that there are many barriers that have prevented the nation from taking full advantage of the potential for solar water heating. Among them:

- **Knowledge barriers:** The most basic obstacle to the spread of solar water heating is lack of knowledge. Plumbers or heating contractors may not be aware of the potential uses of solar water heaters or may not be trained to install them. Consumers or businesses may be unaware of how to go about integrating solar water heating into their buildings, or of how much energy and money solar technologies can save.

- **Regulatory barriers:** In some places, installing solar collectors on one's roof isn't just a challenge; it's against the law. Restrictive homeowners' association rules may prevent the installation of solar energy.

- **Upfront costs:** One common reason that people do not invest in clean energy or energy efficiency technologies is that the costs occur immediately, while the benefits occur over the entire life of the system. In essence, buying a solar energy collector is like buying more than a decade's worth of energy all at one time. Even if the overall cost is lower, it can be difficult for many families and businesses to spend so much at once.

- **Capital availability:** A related obstacle is the fact that some homeowners or businesses that wish to install solar energy systems may not be able to obtain the credit necessary to finance the installation. Banks, especially given the recent credit crunch, may be unwilling to lend to homeowners to finance the installation of a solar energy system. As a result, lower-income households, people with poor credit, and many small businesses miss out on the opportunity to install solar energy.

- **Length of tenure:** Homeowners or businesses may be unwilling to invest in solar energy systems due to concerns that they will move out of their current location before the solar system pays itself off, or that the remaining value of the system will not be received upon resale.

- **Split incentives:** When the owner of a building is different from the person who pays the utility bills, the owner has less incentive to install a solar energy system. Unless they can be confident that they will receive the benefits of their purchase, landlords will have little reason to consider solar water heating technologies.

Public policy can help consumers surmount each of these barriers to capturing the benefits of solar water heating.

Raising the Profile of Solar Water Heating

In recent years, the United States has experienced a boom in investment in "green tech," or new technologies to address environmental and energy challenges. The venture capitalists who once spurred the creation of innovative communications and computing technologies are now turning their attention to new ways to produce electricity from renewable sources, store energy for later use, and power automobiles, among other advances.

The surge in investment in green technologies has come as a result of clear policy support from federal and state governments. The federal government has funded basic research into green technologies, launched partnerships to turn those ideas into workable solutions, and even provided loan guarantees to innovative green tech firms. Some state governments have taken similar steps in the hopes of gaining the investment and "green jobs" that will result from the emergence of new clean energy industries.

Solar water heating, however, has not yet benefited from this same focused attention on the part of federal or state governments—at least not in the United States. The U.S. Department of Energy has worked to incorporate solar water heating into designs for "zero-energy homes" and green commercial buildings, and these are important steps forward. But innovative solar water heating technologies such as industrial process heat, solar cooling and solar "combisystems" are not currently the focus of significant federal investment.

Solar heating and cooling technologies currently receive approximately three percent of the U.S. Department of Energy's total solar energy budget—only $6.5 million in fiscal year 2010, or less than 25 cents per American per year.[50]

The failure to invest in research and development of the broad range of solar thermal technologies means that it is more likely that overseas firms will be the first to develop expertise and manufacturing capacity for these products—giving them a head start in the clean energy race. It also means that the United States will have to wait longer to experience the benefits of these energy saving technologies.

Recommendations: Taking Advantage of America's Solar Water Heating Potential

Local, state and federal governments can adopt a series of public policies to expand access to solar water heating, helping consumers to surmount many of the obstacles standing in the way of clean, renewable energy.

The adoption of **strong building energy codes** by state and local governments can encourage builders to include solar water heating in new residential and commercial buildings. The technology exists to dramatically reduce energy use in new buildings, and even to achieve zero net-energy buildings, which produce as much energy as they consume. Building energy codes should be continually updated and strengthened to ensure that new buildings reduce, rather than add to, America's dependence on fossil fuels. The International Codes Council, a body that publishes model energy codes for states and municipalities to adopt, has taken a strong step in this direction by adopting a 2012 code that reduces energy use 25 percent from the 2009 code, and 30 percent from the 2006 code.[51]

Energy efficiency targets (frequently called Energy Efficiency Resource Standards, or EERSs) are policies used by a number of states to promote electricity and

natural gas savings. These policies require utilities to pursue efficiency measures each year to reduce gas or electricity demand. Natural gas EERSs should be written to encourage utilities to promote solar hot water systems as an efficiency technology for their customers. States without an EERS for natural gas utilities should adopt one, ensuring that installing solar hot water systems to save natural gas is recognized as an efficiency option for utilities.

Innovative financing tools, such as **Property Assessed Clean Energy (PACE)** financing, can reduce the up-front cost of solar water heating systems for homeowners and businesses. PACE programs use municipal financing to pay for the upfront cost of renewable energy installations, with the cost of the system paid back over time on property tax bills. PACE financing enables homeowners and businesses to gain economic benefits from renewable energy immediately—as opposed to years in the future—and ensures that they will receive benefits even if they move out of their building sooner than expected. PACE financing has become an increasingly popular tool in recent years, with at least 23 states and Washington, D.C., having adopted legislation enabling local governments to implement PACE programs.[52] Federal mortgage officials have stalled implementation of PACE financing plans around the country because of concerns over energy loans' ability to preempt existing mortgages.[53] With appropriate safeguards in place, such concerns are unwarranted, since PACE financing improvements add significant value to the homes being improved. The federal government should lift its restrictions on this initiative.

Financial incentives for the installation of solar water heating systems, such as tax credits for individuals and businesses, can reduce the initial cost of installing solar water heaters. Businesses and individuals are currently eligible for tax credits equivalent to 30 percent of the cost of installing solar water heating technology, while states such as California provide additional up-front incentives to consumers. A total of 44 states offer some type of financial or tax incentive for solar water heating.[54] These incentives are critical to growing the market for solar water heating and helping to develop the infrastructure of manufacturers and installers of solar water heating equipment that will be needed to achieve broader market penetration. State and federal governments should continue to provide financial incentives for solar water heating.

Solar-ready homes policies require that all new homes are designed to accommodate solar electricity or hot water. These policies make it easier and less expensive for homeowners to implement solar energy when it suits them. New Mexico, for example, adopted legislation in 2007 authorizing new construction standards that require the proper strength and orientation of roofs, wiring, and other provisions to allow the future integration of solar energy.[55] Similar policies could require homebuilders to offer solar as a standard option on new homes, just as they do choices of paint color or countertop.

Solar water heating requirements for new buildings have been effective at making solar water heaters a daily fact of life in nations such as Israel and, more recently, Spain. As of January 2010, Hawaii, where approximately one-quarter of all homes already have solar water heaters, will require the use of solar water heating in all new residential construction, with a few exceptions.[56] Other states—particularly those with a strong solar resource and high energy prices—would benefit from the broader use of common-sense technologies like solar water heating.

Solar access laws ensure that residents and businesses who want to install solar energy equipment retain access to sunlight and that their actions are not prohibited

by local governments or homeowners' associations. Thirty-seven states have some form of solar access law.[57] All states should adopt laws that both safeguard the rights of homeowners and businesses to install solar collectors and that establish ground rules over access to sunlight.

Government agencies can **lead by example** by installing solar water heaters on government buildings. Buildings such as prisons, schools and hospitals are excellent candidates for solar water heating, as are many government office buildings. For example, the Federal Reserve Bank in Miami recently installed a solar water heating system to provide hot water for its kitchen and cafeteria.[58] State, local and federal governments should ensure that solar water heating is included in newly built or renovated government buildings.

In addition to supporting efforts to expand the reach of existing solar water heating technologies, federal officials should invest in **research and development** of new solar thermal technologies, including industrial process heat, space heating and cooling, and solar district heat. These technologies, implemented successfully around the globe, have the potential to tap significant energy savings, but also present unique challenges for implementation. Solar thermal technologies currently attract little notice or funding (outside of worthwhile efforts such as the Department of Energy's buildings program) and should receive additional support.

Efforts to **build a solar thermal industry** are critical to ensuring that the nation reaps the benefits of solar water heating. Developing a strong solar thermal industry requires, first and foremost, strong, consistent policy support. California, for example, had a thriving solar water heating industry into the mid-1980s, when a withdrawal of federal incentives and low fuel prices caused the industry to shrivel. Now, more than two decades later, the industry must be rebuilt.

Europe's solar thermal industry, which is far more advanced than that of the United States, employs more than 40,000 people, with sales of $4.1 billion in 2008.[59] Federal and state governments, in coordination with the solar industry, should develop and implement an industry roadmap for solar water heating that combines focused investments in research and development, incentives for the **development of domestic manufacturing capability**, and **workforce training efforts** to complement the financial incentives and other policy supports described above.

Finally, federal and state governments should launch **public education efforts** to inform individuals and businesses about the potential benefits of solar water heating technologies.

By taking these steps, the United States can begin to take advantage of the tremendous potential of solar water heating to reduce our nation's dependence on fossil fuels and curb emissions of pollutants that contribute to global warming and harm public health.

Appendix A: Tables

Table A-1: Technical potential for energy savings from solar hot water, site energy

State	Energy Savings (site, physical units)			
	Natural Gas (million cu ft)	LPG (million gallons)	Oil (million gallons)	Electricity (billion kWh)
Alabama	5,334.6	5.7	1.1	0.9
Arizona	14,419.5	19.2	0.7	0.8
Arkansas	6,768.8	6.0	0.0	0.3
California	127,229.3	76.4	0.0	1.9
Colorado	11,830.2	12.4	0.4	0.5
Connecticut	2,037.1	2.7	13.1	0.2
Delaware	1,185.1	0.5	0.1	0.1
District of Columbia	1,561.3	0.2	0.0	0.1
Florida	12,987.6	13.4	0.0	6.4
Georgia	10,829.0	5.8	0.9	1.8
Idaho	2,850.7	3.2	0.1	0.1
Illinois	16,894.8	12.9	0.0	0.8
Indiana	8,974.1	8.1	0.0	0.5
Iowa	5,540.5	6.4	0.3	0.3
Kansas	5,535.3	7.3	0.3	0.3
Kentucky	5,024.8	4.2	0.8	0.6
Louisiana	6,848.0	8.2	0.0	0.5
Maine	742.0	1.3	6.9	0.1
Maryland	8,430.9	2.9	0.4	0.9
Massachusetts	3,310.7	4.6	21.0	0.3
Michigan	13,964.6	11.7	0.0	0.7
Minnesota	12,812.3	14.6	0.7	0.6
Mississippi	3,012.6	2.8	0.6	0.4
Missouri	9,128.1	12.3	0.6	0.6
Montana	1,836.2	1.9	0.1	0.1

Table A-1 Cont'd

State	Energy Savings (site, physical units)			
	Natural Gas (million cu ft)	LPG (million gallons)	Oil (million gallons)	Electricity (billion kWh)
Nebraska	3,680.9	4.2	0.2	0.2
Nevada	5,943.1	6.3	0.2	0.2
New Hampshire	676.3	1.1	5.0	0.1
New Jersey	11,655.8	1.9	12.2	0.5
New Mexico	5,854.3	6.2	0.2	0.2
New York	16,084.3	18.7	49.0	0.5
North Carolina	9,849.3	5.4	0.8	1.7
North Dakota	1,124.5	1.3	0.1	0.1
Ohio	14,581.2	12.6	0.0	0.7
Oklahoma	8,292.7	7.9	0.0	0.4
Oregon	5,605.9	2.9	0.2	0.7
Pennsylvania	14,535.9	3.1	20.9	0.7
Rhode Island	582.2	0.8	3.6	0.0
South Carolina	4,961.0	2.7	0.4	0.8
South Dakota	1,440.1	1.8	0.1	0.1
Tennessee	7,340.5	6.2	1.2	0.9
Texas	60,016.3	57.6	0.0	4.2
Utah	6,056.0	5.7	0.2	0.2
Vermont	325.9	0.6	2.7	0.0
Virginia	9,509.5	4.2	0.6	1.4
Washington	8,772.7	4.3	0.3	1.0
West Virginia	2,853.0	1.0	0.2	0.3
Wisconsin	7,475.2	6.1	0.0	0.4
Wyoming	1,391.4	1.3	0.0	0.1
U.S.	507,696.3	408.3	146.4	

(thousand short tons)

Table A-2: Technical potential for energy savings from solar hot water, primary energy

State	Energy Savings (primary, physical units)			
	Natural Gas (million cu ft)	LPG (million gallons)	Oil (million gallons)	Coal (thousand short tons)
Alabama	6,382.5	5.7	1.5	239.7
Arizona	16,517.5	19.2	0.7	202.6
Arkansas	7,214.1	6.0	0.1	87.2
California	134,774.9	76.4	1.3	111.6
Colorado	13,095.5	12.4	0.5	122.2
Connecticut	2,606.4	2.7	13.4	18.1
Delaware	1,358.1	0.5	0.1	33.5
District of Columbia	1,720.0	0.2	0.1	30.8
Florida	35,218.5	13.4	25.2	1,084.9
Georgia	12,984.4	5.8	1.6	493.0
Idaho	2,965.3	3.2	0.1	20.0
Illinois	17,153.2	12.9	0.2	240.1
Indiana	9,103.1	8.1	0.3	203.6
Iowa	5,616.5	6.4	0.4	99.0
Kansas	5,631.0	7.3	0.4	124.5
Kentucky	5,801.1	4.2	1.1	177.6
Louisiana	7,535.6	8.2	0.1	137.7
Maine	955.0	1.3	7.0	6.8
Maryland	9,428.6	2.9	0.9	234.6
Massachusetts	4,344.0	4.6	21.6	32.9
Michigan	14,151.8	11.7	0.4	288.4
Minnesota	12,962.6	14.6	0.8	256.6
Mississippi	3,530.5	2.8	0.7	118.5
Missouri	9,769.8	12.3	0.7	178.5
Montana	1,907.9	1.9	0.1	12.5
Nebraska	3,735.2	4.2	0.2	83.6
Nevada	6,211.7	6.3	0.3	41.9
New Hampshire	871.7	1.1	5.2	6.2
New Jersey	12,245.2	1.9	12.5	109.1
New Mexico	6,476.8	6.2	0.2	68.3
New York	17,568.1	18.7	50.1	32.4
North Carolina	11,853.2	5.4	1.4	458.3
North Dakota	1,140.8	1.3	0.1	28.0
Ohio	14,787.2	12.6	0.5	325.3
Oklahoma	9,252.1	7.9	0.0	146.2
Oregon	6,254.4	2.9	0.3	113.1

Table A-2 Cont'd

State	Energy Savings (primary, physical units)			
	Natural Gas (million cu ft)	LPG (million gallons)	Oil (million gallons)	Coal (thousand short tons)
Pennsylvania	15,175.3	3.1	21.3	193.2
Rhode Island	740.5	0.8	3.7	5.0
South Carolina	5,974.5	2.7	0.7	231.8
South Dakota	1,470.6	1.8	0.1	31.1
Tennessee	8,482.0	6.2	1.6	261.1
Texas	74,155.1	57.6	1.1	992.6
Utah	6,270.4	5.7	0.3	37.4
Vermont	424.3	0.6	2.8	3.1
Virginia	10,881.9	4.2	1.2	420.0
Washington	9,754.1	4.3	0.5	171.1
West Virginia	2,933.0	1.0	0.3	126.3
Wisconsin	7,587.2	6.1	0.1	115.2
Wyoming	1,452.0	1.3	0.1	10.6
U.S.	578,425.2	408.3	184.0	8,565.7

Table A-3: Energy savings as a percent of total consumption, global warming pollution reductions

State	Energy Savingsas Share of Total Consumption (site)		
	Carbon Dioxide Emissions (million metric tons)	Natural Gas (million cu ft))	Electricity
Alabama	1.3%	1.0%	0.8
Arizona	3.6%	1.0%	1.4
Arkansas	2.9%	0.6%	0.6
California	5.2%	0.7%	8.0
Colorado	2.3%	0.9%	1.0
Connecticut	1.2%	0.6%	0.3
Delaware	2.5%	1.2%	0.1
District of Columbia	4.9%	1.1%	0.2
Florida	1.4%	2.8%	4.3
Georgia	2.5%	1.3%	1.7
Idaho	3.2%	0.5%	0.2
Illinois	1.7%	0.5%	1.5
Indiana	1.6%	0.4%	0.9
Iowa	1.7%	0.6%	0.5
Kansas	2.0%	0.9%	0.6
Kentucky	2.2%	0.7%	0.7
Louisiana	0.5%	0.6%	0.7
Maine	1.2%	0.6%	0.1
Maryland	4.3%	1.5%	1.0
Massachusetts	0.9%	0.6%	0.5
Michigan	1.8%	0.6%	1.4
Minnesota	3.2%	0.9%	1.3
Mississippi	0.8%	0.9%	0.4
Missouri	3.1%	0.7%	0.9
Montana	2.4%	0.5%	0.1
Nebraska	2.2%	0.7%	0.4
Nevada	2.2%	0.7%	0.5
New Hampshire	1.0%	0.6%	0.1
New Jersey	1.9%	0.6%	1.0
New Mexico	2.4%	1.1%	0.5
New York	1.4%	0.4%	1.6
North Carolina	4.1%	1.3%	1.6
North Dakota	1.8%	0.6%	0.1
Ohio	1.8%	0.5%	1.5
Oklahoma	1.2%	0.8%	0.8

Table A-3 Cont'd

State	Energy Savingsas Share of Total Consumption (site)		
	Carbon Dioxide Emissions (million metric tons)	Natural Gas (million cu ft))	Electricity
Oregon	2.1%	1.4%	0.6
Pennsylvania	1.9%	0.5%	1.4
Rhode Island	0.7%	0.6%	0.1
South Carolina	2.9%	1.0%	0.8
South Dakota	2.2%	0.8%	0.1
Tennessee	3.2%	0.9%	1.0
Texas	1.7%	1.2%	6.2
Utah	2.7%	0.8%	0.4
Vermont	3.8%	0.5%	0.1
Virginia	3.2%	1.2%	1.4
Washington	2.9%	1.2%	0.9
West Virginia	2.6%	0.8%	0.4
Wisconsin	1.8%	0.5%	0.7
Wyoming	1.0%	0.4%	0.1
U.S.	2.2%	0.9%	51.7

Appendix B: Methodology

This analysis provides an estimate of the potential for solar water heating to reduce energy consumption and emissions in the United States. It only includes potential savings from the use of solar water heaters to meet hot water needs in the residential and commercial sectors.

Estimates of the share of rooftops that are able to host solar water heaters and the fraction of hot water needs that can be met with solar water heating (solar fraction) are based on P. Denholm, National Renewable Energy Laboratory (NREL), *The Technical Potential of Solar Water Heating to Reduce Fossil Fuel Use and Greenhouse Gas Emissions in the United States*, March 2007. The estimates in the NREL report are made by census region, with separate estimates for the four largest states—New York, Texas, California, and Florida. In keeping with the NREL study, we used the estimate for the solar energy fraction associated with a low-cost, lower-efficiency water heating system, as opposed to a higher cost system that would be able to produce a higher fraction of a building's energy needs. As a result, these estimates reflect a conservative estimate of the potential for solar water heating in the United States.

Energy Savings Estimates

To estimate the energy savings that would result, by state, from maximizing the potential for residential and commercial solar water heating, we applied the solar fractions from the NREL study to state-specific estimates of total water heating energy use derived as described below.

Residential – The total number of homes that can host solar water heating systems was estimated by applying the regional estimates from the NREL study to the number of single-family homes in each state from the U.S. Census Bureau, *2006-2008 American Community Survey*, downloaded from www.census.gov, 7 June 2010.

Average energy use for water heating for single-family homes was estimated based on the weighted average fuel consumption for single-family homes as calculated from public use microdata from the U.S. Department of Energy, Energy Information Administration, *Residential Energy Consumption Survey (RECS) 2005*, February 2009. Average energy consumption was calculated for each of the major

fuels (natural gas, oil, electricity and liquefied petroleum gas) and for each census region and for the four largest states.

The solar fraction from the NREL study was then applied to the average energy use for water heating per single-family home and multiplied by the number of homes eligible for solar water heating to arrive at a total estimate of energy savings for each type of fuel by region or state.

Commercial – Estimated energy savings in the commercial sector were based on statistics for total energy use in the commercial sector by state in 2008 from U.S. Department of Energy, Energy Information Administration, *State Energy Data System (SEDS)*, downloaded from www.eia.doe.gov, 4 August 2010. We then estimated total commercial energy consumption for water heating by fuel by multiplying the energy use data from SEDS by the share of end-use energy devoted to water heating by region from U.S. Department of Energy, Energy Information Administration, *Commercial Buildings Energy Consumption Survey (CBECS)*, September 2008. The potential energy savings from solar water heating in the commercial sector was estimated by multiplying the estimate for water heating energy consumption by the estimate of the share of commercial roofs that can host solar water heaters (from the NREL study) and by the solar fraction (again, from the NREL study).

Energy savings from the residential and commercial sectors were combined to arrive at an overall estimate of energy savings (in BTU), and were converted to their native units (gallons of oil, cubic feet of natural gas, kilowatt-hours of electricity) based on conversion factors in U.S. Department of Energy, Energy Information Administration, *State Energy Data 2008: Consumption Technical Notes*, 30 June 2010. These are the basis of the estimates for site energy savings in this report

Cost Savings Estimates

Cost savings were computed from the site energy savings, using the cost per BTU of various fuels given in U.S. Department of Energy, Energy Information Administration, *Annual Energy Outlook 2010*, 11 May 2010. Savings were computed on a state-by-state basis, assigning each state the energy prices listed for its census division in 2010. Savings for each fuel were computed by multiplying the BTUs of that fuel conserved by the price per BTU. All dollar amounts are given in 2008 dollars.

Percentage savings for the residential and commercial sectors were calculated out of total national residential and commercial energy expenditures, respectively, in 2010, again from the *Annual Energy Outlook 2010.*

Primary Energy Savings

To estimate the full impact of solar water heating on fossil fuel consumption, it was necessary to convert electricity savings at the place of installation (site energy) to the amount of fossil fuel consumption averted at the power plant (primary energy). This required multiplying the amount of electricity saved by state by an estimate of the amount of coal, natural gas, or oil used per unit of delivered electricity for each regional electric grid.

These estimates are complicated by the geographic mismatch between the census region definitions used in much of our analysis—the Electric Market Module (EMM) definitions used in the Energy Information Administration's (EIA) *Annual Energy Outlook 2010*, which supplied our estimates of gas, oil and coal use per unit of delivered electricity for each regional grid—and the definitions of electric reliability regions used by EIA in its electricity databases (most notably the Form 861 database) that enable one to estimate the share of delivered electricity in each state that came from each regional grid. To address this geographic mismatch, we did the following:

For states in a single EMM region, fossil fuel consumption per unit of electricity was estimated by dividing the use of each fuel in the region by total electricity sales, with both data points coming from *Annual Energy Outlook 2010*. For states with utilities in more than one EMM region, we used a weighted average, with the emission factors from the various EMM regions in the state weighted by the percentage of electricity sales by utilities in each region. Utilities were assigned to EMM regions using EIA's Form 861 database for 2005 (the last year in which Form 861 used the same regional definitions as used in *AEO 2010*). The one exception to this was Iowa, where the 2004 version of Form 861 was used. Electricity sales by utility were based on the 2007 edition of the Form 861 database.

These state-by-state estimates of fossil fuel use per unit of electricity sales were then multiplied by the amount of electricity saved through the use of solar water heating to arrive at a total estimate of primary energy savings. We recognize that this method does not account for imports or exports of electricity between regional grids, but it is a useful approximation of primary energy savings resulting from reductions in electricity consumption. (It is also important to note that our methodology diverges from that of the NREL study, which estimated emission reductions based on the assumption that solar water heating would replace the marginal fuel in each electric grid, most often natural gas.)

Carbon Dioxide Emission Reductions

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