INTRODUCTION

EVERY DAY, WE ARE BARRAGED WITH INFORMATION about global warming, global pollution, wars over energy resources, species depletion … the list goes on and on. Tragically, most people — and certainly most governments — are doing very little about it.

This book tells some of the things we can do. First it talks about using technologies we already have to lower our energy consumption. Then it details renewable energy options for replacing fossil fuels and nuclear energy sources. It shows that as individuals we can change the world!

Most North Americans don't think about our energy consumption very much. We don't think about the energy used to create our society or the energy required to produce the products we consume. We get our heating fuels automatically delivered to our homes. Our electrical energy flows to us through silent wires that are everywhere. It's all very easy and painless. Sure, we think about our energy consumption when we pay our bills once a month, or we think about it when we refuel our vehicles at the gas station, but in most cases we just accept these costs as inevitable. Our society uses a lot of energy; we want as much as we can get; and we want it cheap.

The United States consumes more energy per capita than any other country in the world. Other developed countries with similar lifestyles, and with equal gross national products, consume up to 50 percent less energy. We obviously have the technology today to use a lot less energy than we do. Some experts say that

we can reduce our consumption by up to 75 percent today. They surmise that if we would put our greatest minds to the problem, we could do even more.

Lowering our energy consumption and using renewable energy would accomplish several things. Decreased use of fossil fuels and nuclear energy would have a positive impact on our environment by reducing carbon emissions that contribute to global climate change. It would also reduce the production of pollution that contributes to acid rain, nuclear waste and other environmental contaminants. A more subtle result of these changes is that power would be transferred from the superrich to the common people. The people who run the world are the people with the most money. Many of them get their money by selling fossil fuels. These are the people who control the governments and the mass media of the world. By reducing their power we decrease their influence and increase our personal freedom.

It is unlikely that we can look to governments for leadership in the transition to renewable energy that must be made. The changes will come from the bottom up. It is up to us to do what we can.

This book presents detailed information about solar thermal applications for homes and small businesses. Heating water with the sun may seem like a simple endeavor, and it is. Solar water heaters heat water using the energy of the sun. A solar water heating system is composed of a solar collector and a water-storage tank. Depending on the type of solar energy system, it may have several other components as well. Most systems use pipes, pumps, system controllers, heat transfer fluids (also called solar fluids), various valves, heat exchangers, pipe insulation and mounting hardware. Exact system components will be detailed in the following chapters as we describe the different systems available.

Of all the renewable energy options open to us, the technology of solar water heating is the most mature. It is an industry with proven technologies, established manufacturing facilities, and qualified and experienced technicians. These technologies and applications have been proven over many years and thousands of installations. However, it took time for these technologies to mature. And during that time, we made some mistakes. Some of the technologies and designs that are included in this book are bad ideas. We have included their descriptions so you can recognize them and know how they work if you are doing repairs. We have also included these descriptions because you may read or hear about a certain design, and you will want to know if it is good or not. Their descriptions should be used only for reference and maintenance.

It does not take a rocket scientist to design, install or use a solar water heater. Although it is simple, certain factors must be taken into consideration to ensure satisfactory reliability and performance. The single most important consideration is your climate. Others include the hardness of your water; hot water demands (the load); aesthetics; specific location factors such as trees, shading and mounting options; availability of components; and price. With more than 40 years of combined experience in designing, selling, installing and servicing solar water heaters, we have found that most systems work great for a very long time. Problems that do occur are generally caused by poor-quality components, by the wrong design or wrong components for the climate or specific situation, or by poor workmanship. The bottom line is that if you choose the right system for your climate and install it properly, using quality components, you will end up with a renewable energy system that will most likely last you for the rest of your life. It will end up being one of the best investments you ever make.

The first chapter, a short history of solar energy, puts into perspective how we got to where we are today. As you read about the history of solar energy technologies in Chapter 1, you will see that the largest application of these technologies in the world has been in solar water heating.

1

HISTORY

THE SUN IS THE CENTER of our solar system. The energy it releases warms our planet and powers all life on earth. Through photosynthesis, solar energy is transformed into organic matter — the food that makes our life possible. The fossil fuels we use are actually stored solar energy. Solar energy is also incredibly abundant. Half a day's sunlight falling on the US provides enough energy to run our country for one year.

We often think that modern societies were the first to use solar energy. Not true. Early cave dwellers preferred caves that had openings facing southeast. This allowed the morning sun to warm them up without overheating in the warm months. Native Americans in the Southwest oriented their pueblo dwellings so the low winter sun would heat the buildings by direct solar radiation. Cliffs and overhangs blocked the sun during the summer months, helping to keep the dwellings cooler when the sun was high in the sky.

The ancient Greeks, with a climate that was sunny almost year round, built their houses to take advantage of the sun's rays during the moderately cool winters and to avoid the sun's heat during the summer. Modern excavations of many classic Greek cities show that individual homes were oriented toward the south and entire cities were planned to allow equal access to the winter sun. It is interesting to note that by 500 bc, when the Greeks had almost completely deforested their whole country and needed to find a reliable alternative fuel source, they chose solar energy.

The Roman Empire advanced solar technology by adapting home-building design to various climates, using clear window coverings, such as glass, to enhance the effectiveness of solar heating and expanding solar architecture to include greenhouses and huge public bath houses. Solar architecture became so much a part of Roman life that sunrights guarantees were eventually enacted into Roman law. This society depleted its forest resource as well.

After the fall of the Roman Empire, the use of glass to enhance solar gain in buildings was mostly forgotten. Interest in passive solar architecture and greenhouses was rekindled during the Renaissance. As technologies advanced, glass manufacturing was revived, resulting in an increased use of glass windows. This also made large greenhouses possible for agricultural purposes as well as for recreation.

In the 1700s, a leading naturalist named Horace de Saussure began to experiment with solar hot boxes. These precursors to today's active solar collectors were simple insulated boxes painted black on the inside and with one side made of glass. They were very similar to today's solar cookers and, in fact, many early experimenters used their hot boxes for cooking. Many of the solar principles we use today were identified during those early experiments. Unfortunately, these experiments resulted in few successful applications.

During the late 1800s, domestic water piped directly into homes became more common. Like today, this water supply was cold. People soon wanted hot running water. At first, all water heaters were either coal or wood fired. In 1891 Clarence M. Kemp patented the world's first commercial solar water heater, called the "Climax." It was a black-painted water tank mounted in an insulated box with one side made of glass.

The Climax was instantly popular in California, where it could be used year round. Thousands of Climaxes and similar systems were installed in a short time. They all fall into what we now call "batch-type" solar water heaters: the sun heats the water directly in the tank(s) and the hot water is stored right in the collector tank(s).

In 1909 a California engineer named William J. Bailey began selling a new system he called the "Day and Night" solar water heater. It consisted of a solar collector and a separate storage tank mounted above the collector. His tanks were among the first to be insulated for better heat retention, and his collectors consisted of a pipe grid attached to a flat plate and enclosed in a compact, glazed and insulated enclosure. Cold water dropped into the collector, where it was heated by the sun. As the water was heated, it rose into

the insulated storage tank for later use. Today, we call these heaters "flat plate" collectors.

In 1913 a freak cold snap hit southern California and many Day and Night collectors froze and burst. To eliminate future freezing problems, Bailey installed a coil of pipe within the storage tank to act as a heat exchanger. Then he used an alcohol and water mixture as the antifreeze solution for his heat exchange medium. As the sun warmed the solar fluid (or heat transfer fluid), it rose to the storage tank heat exchanger. As the heat from the solar fluid was transferred to the water in the storage tank, the solar fluid cooled and dropped back to the collectors for further heating. This system is described today as a "closed-loop" solar water heating system.

Between 1920 and 1930, huge deposits of natural gas were found in the Los Angeles area. To capitalize on this new, cheap fuel source, Bailey began to manufacture a thermostatically controlled gas water heater. Sales of his gas water heater took off, and sales of solar water heaters plummeted. Gas companies offered generous incentives to hook up to their new gas lines, further hindering sales of solar heaters. Bailey made his last batch of solar water heaters in 1941.

During this same time period, entrepreneurs took the California solar water heater designs to Florida and met with great success. In a building boom between 1935 and 1941, up to 60,000 systems were installed. More than half the population of Miami used solar water heaters by 1941, and 80 percent of the homes built between 1937 and 1941 were solar equipped.

World War II all but halted solar water heater installations. Copper was a major component of solar water heaters, and the use of copper was frozen for all nonmilitary use. When the war was over, solar companies came back, but other factors soon led to their decline. Existing solar water heaters were too small to meet the new, increased demand for automatic washing machines, automatic dishwashers, and other similar appliances. In a final blow, electrical rates fell to half the cost they had been before the war, making electric water heating much more affordable. In an aggressive campaign to increase electrical consumption, Florida Power and Light even offered free installation of electric water heaters. By this time, many of the original, aging solar water heaters were experiencing leaking tanks and plugged pipes. Many homeowners found it cheaper to install an inexpensive electric water heater than to fix their solar water heating systems.

In the United States, the 1950s and '60s were years of unbridled energy consumption. For all but a few people, solar

energy was a nonissue. This changed with the first Arab oil embargo in 1973, when Americans experienced long lines at gas stations, limited supplies of other oil products, such as heating fuel, and energy prices that doubled and tripled. President Jimmy Carter helped make energy efficiency and the use of renewable energy a national priority, symbolized by his donning a sweater and installing a solar water heater on the White House roof.

The oil embargo profoundly changed the United States. Coming at the end of the Vietnam War, it added to America's realization of its vulnerability. For the first time since World War II, Americans looked at the way they used energy. Consumers began to demand higher energy-efficiency standards in everything from homes to automobiles. People also looked to renewable energy sources to replace some of the fossil fuels they were using.

The whole nation took on the challenge of reducing its dependence on oil from the Middle East. Renewable energy sources were rediscovered, and new companies sprouted everywhere to fill the growing demand. Government spending on renewable energy research and development increased from about $1 million to more than $400 million. While this was a small fraction of the attention and money given to the nuclear industry, it was a dramatic change nonetheless.

During the late '70s and early '80s, installing solar energy systems was seen as patriotic. The federal government, as well as many state governments, passed legislation encouraging the use of solar energy systems through tax credits. Federal incentives combined with state incentives (where available) often offset more than 50 percent of the cost of many renewable energy systems. A new renewable energy boom began. People looked to wind-powered electric systems, active space heating systems, advanced passive solar-heating systems, the newly emerging solar electric systems, and advances in energy-saving technologies as well as the old reliable solar water heaters.

Most of the solar energy companies that sprang up in the 1980s were reliable firms that installed quality systems. Unfortunately, with the general public's headlong plunge into the use of renewables, a few companies selling inferior products and doing inferior work joined the fray. Some brought products to the market without proper testing. Others just wanted to make a quick buck and didn't care if they were taking advantage of well-intentioned consumers. Although most renewable-energy systems were of good quality, the minority that weren't gave solar a bad name.

The young solar industry was experiencing the typical growing pains that

come with most emerging technologies and took steps to correct the problems. The federal government, as well as many state governments, also stepped in to ensure higher quality.

This move toward renewable energy did not sit well with those who profited from selling fossil fuels. After the most expensive presidential campaign ever, financed in part by oil interests, Ronald Reagan became president of the United States. His presidency heralded a return to fossil fuels. One of his first acts as president was to remove the solar water heater that President Carter had installed on the White House. Between 1981 and 1986, Reagan effectively gutted the US solar industry. He negotiated a repeal of the tax credit legislation for renewables that was in effect. He reduced funding for renewable energy by 90 percent. He also spearheaded a massive campaign to discredit renewable energy. The result was a 91 percent drop in the sales of solar hot water collectors between 1984 and 1986. The solar market in North America from the 1980s through the late 1990s was primarily supported by customers who wanted to invest in renewable energy for environmental reasons. For an in-depth analysis of this subject, I invite you to read *Who Owns the Sun?* by Daniel Berman and John O'Connor. Their thorough and thought-provoking book will change the way you look at energy and politics forever.

While North America was abandoning its use of renewable energy, virtually all other developed nations in the world continued to embrace renewables and energy efficiency. As a result of this continued effort, our European and Asian trading partners reduced their energy consumption in relation to gross national product by as much as one half that of North Americans. And while maintaining a similar lifestyle, they also reduced the energy need to half that of the United States. Some countries, such as Israel, require that solar water heaters be installed on all new dwellings and businesses. Developing nations are also embracing renewable energy technologies over traditional fossil-fuel energy sources. Although their track record is not perfect, their attitude toward renewable energy is

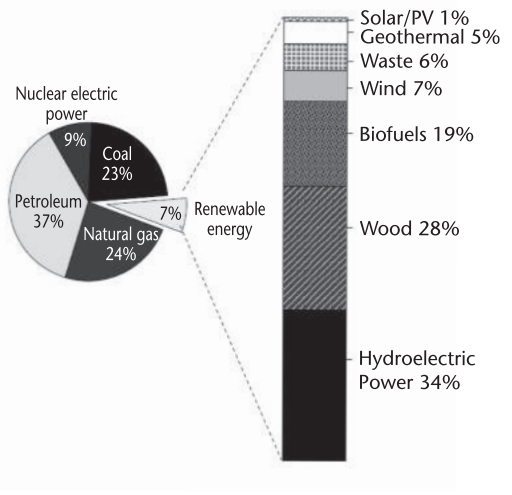

Figure 1.1: *US energy consumption, 2008*

significantly better than that of North Americans.

In Figure 1.1, you can see the breakdown of the total energy consumption for the US in 2008. Renewable energy accounted for only seven percent! Solar, both thermal and electric, made up only one percent of the renewable energy share — only 0.07 percent of the total.

Now that we've covered history and the present, we need to look at our future. If what happened in the past carries on through tomorrow, we are headed down a dark and dirty path. One percent of only seven percent is not good enough and needs to change now. Let's do all we can to make our children's future brighter.

2

CONSERVATION AND THE ECONOMICS OF SOLAR WATER HEATING

WHATEVER BROUGHT YOU to this point, whether it was the realization that we are trashing our environment or the simple need to lower your living expenses, now you are here and you want to do something. But what to do first? The answer is simple: start by conserving the energy you use to heat water. Three general principles that are easy to follow will also save you money: reduce losses, increase efficiency and reduce consumption.

To start, examine your heating system from top to bottom and look for places where heat might leak out. Heat losses in the system end up wasting the energy you just used to heat your water. Many losses can be reduced with just a bit of cheap insulation. For instance, insulate all your hot pipes. If you are working on a new construction, insulating the hot pipes is easy. Even if you don't have access to all your pipes, insulating the ones you can get at will make a noticeable difference. You should also insulate your water heater. A tank type water heater heats a whole batch of water. As this water sits there waiting for use, it slowly cools down. The more you insulate it, the better it will retain its heat. Heat losses can also come from leaks. A faucet that leaks 30 drops of water a minute will waste almost 100 gallons a month. Fix leaky faucets promptly.

Next, try to increase the efficiency of everything in your home that uses hot water, for instance, the washing machine and the dishwasher. Upgrading these appliances to more energy-efficient models will significantly reduce the amount of energy

consumed. A frontloading washing machine uses half the hot water of a standard top-loading model. This results in saving 10 to 20 gallons of hot water in each load you do. You can save thousands of gallons of hot water a year.

Finally, you can conserve energy by simply using less. Former US Vice President Dick Cheney is famously quoted as saying that the "American way of life is non-negotiable." We couldn't disagree more. Simple behavior modifications can dramatically reduce the amount of energy we consume without a significant change in daily habits. For instance, when washing dishes in the sink by hand, don't let the water run while rinsing. Fill one sink with wash water and the other with rinse water. Soak pots and pans instead of letting the water run while you scrape them clean, and if you are using a dishwasher, wash only full loads. Use cold water with the garbage disposal. Cold water solidifies grease, allowing the disposal to get rid of it more effectively. You can take short showers instead of baths. You should first install a low-flow shower head. Most standard showerheads use three to four gallons per minute. Even if you take a relatively brief five-minute shower, you can consume 20 gallons of hot water. Low-flow showerheads will use half of that. A family of four can save well over 1,000 gallons a month. If you are particularly attached to your showerhead, you can install a flow restrictor that will reduce the number of gallons per minute that it uses. For only a couple of dollars, you can reduce your load substantially.

Reducing losses, increasing efficiency and reducing consumption: these are the first steps. More important than quick fixes, though, is the notion of conscious consumption. We have forgotten the financial and environmental costs of hot water. If everyone recognized that whenever we turn on the hot water faucet we are using energy produced by nonrenewable sources, this would reduce energy consumption more than any other measure.

People often say to us, "I have done a lot of energy conservation and now I am ready to invest in a renewable energy system. What should I do next?"

Today, homeowners and business people can choose from a wide range of renewable energy technologies. Popular options include photovoltaic (solar electric) systems, wind electric systems and solar water heaters. In almost every case, a solar water heating system is the best place to start. It provides a higher return on your investment than most other types of renewable energy systems. A solar water heater works 12 months a year, providing hot water to your home or business with little or no additional cost, thus offsetting your previous bill for heating water with

conventional energy sources. Depending on your particular situation, the savings in conventional fuel can pay for the cost of the solar water heating system in as little as three years. Most often the payback is five to ten years — still a great investment, even without taking into account the ecological benefits of not burning all that fossil fuel.

In fact, since you've already bought this book, it's time to let you in on a little secret. Solar water heaters don't cost anything. They're FREE! Of course, it may sound absurd, but it's true. Now, we're not recommending that you run over to the nearest solar distributor and just take a system. Don't do that. We are just asking you to take a step back and think about solar in a different way. With a little change in perspective, you will see that in the end, solar water heaters have a net cost of zero dollars.

There are two ways to take this in. The first one is easy: when you install a solar water heater you are increasing your home's value. You gain in equity what you spent on the cost of installation. Many solar water heaters have a life span of 30 to 40 years, and sometimes longer. In most cases, the solar collectors will outlast your roof. So if you decide to sell your home, you should get back most of what you paid for the cost of installation. Though there isn't a lot of data on this fact, the general rule we have seen is that for every $100 in annual energy savings you can expect an additional $2,000 in resale value of the property. For instance, if your solar water heater saves you $200 a year, your fair market value should increase by $4,000. Here in Wisconsin, and in many other states, renewable energy systems are exempt from property taxes. Like any other home improvement, this is an investment, but the added value doesn't carry an additional annual cost.

Yet, just because something retains its value over time and you don't have to pay taxes isn't usually reason enough to go out and buy it. The second part of this shift in perspective takes a bit more explanation, but we assure you it is even more convincing.

The True Cost of Fossil Fuel

We'll start by comparing solar with the alternatives. Unless you are reading this to find out how to fix your existing system, you probably heat your water with some type of fossil fuel, such as natural gas, propane or electricity.

When you purchase fossil fuels, you do not pay anywhere near their whole cost. Because our taxes subsidize the oil companies, for instance, the true cost of gas is not reflected in the price we pay at the pump. Let us say it again: oil companies don't pay taxes on all the money they

earn, so we must all pay higher taxes to make up for it. It goes without saying that if they paid their fair share of taxes, our tax rates would be lower, and the price we pay for gas would be higher. The same scenario holds true for all other fossil fuels and electricity.

How can this be? First, the fossil fuel companies are among the richest corporations in the world, with tremendous influence in politics. For nearly a century they have manipulated the government into granting them numerous tax breaks and outright payments that are not enjoyed by any other class of corporation. The end result is that they pay little if any tax but significantly influence how our tax dollars are spent. They have managed to get the government to pay for lots of expensive research for their industry.

The costs to the environment of using fossil fuels are also hidden. Burning fossil fuels releases carbon into the atmosphere, leading to global climate changes that will disrupt life as we know it on every corner of the Earth. The costs of dealing with these changes will be astronomical and are directly linked to burning fossil fuels. When we burn fossil fuels, especially coal, we release into the atmosphere chemicals that cause acid rain, polluting our rivers, lakes and soil. Acid rain kills wildlife, trees and vegetation and degrades our buildings, roads and anything else exposed to it. Although we are already paying some of the costs to fix these problems, we are not paying them all. Eventually, someone will have to pay them.

Then there are health-related costs. Whenever we burn any fossil fuel, we release air pollutants that harm our health. Our health insurance costs go up to help pay for the care required by those most affected. Our taxes are increased to help pay for those who cannot afford their own care, and our general health care costs go up for the same reason. Again, we do not pay these costs at the pump or with our utility bills.

Some of our electricity is generated in nuclear power plants. The waste generated by these plants is one of the most toxic substances known to humanity. We have no clue how to safely dispose of it. We can send people to the moon, but we have not figured out how to deal with these incredibly toxic waste products. Undoubtedly, if we do figure out a way to safely dispose of them, it will be incredibly expensive. This cost is not included when we pay our electricity bill. We also invite you homeowners and renters to read the fine print of your insurance policies. Note that if there is ever an accident involving nuclear fuel or waste, your insurance policy does not cover that. Ask the people living around the Three Mile Island nuclear power plant, whose lives were devastated

by the nuclear accident there, how they feel. We will guarantee you that they are not happy. Many lost everything.

Assigning a true cost to the use of fossil fuels relates directly to solar water heaters and any other renewable energy system. Admittedly, it costs money to invest in renewable energy equipment. Often, people will look at that cost and say that it is just too much more than using fossil fuels. When you get to this point, please remember the above discussion. How much higher should the costs of fossil fuels really be? Twice as expensive? Three times? Four times? Experts who have spent considerable time researching this issue have calculated that these costs are five times more than the bill we pay at the pump or meter.

While these true costs are not reflected in our bills, we do see that the price we pay tends to increase every year. In order to understand where fossil fuel prices are heading, we first have to understand what has happened in the past. Having a handle on energy price inflation is basic to understanding the economic impacts of investing in solar thermal energy systems.

A Brief History of Fossil Fuels

Soon after oil was first discovered in the mid-1800s there was a glut, keeping its price very low. With the advent of mass-produced automobiles, there was a steady demand for oil, and prices became stable, rising at a rate at or slightly above the inflation rate. During World War II, fossil fuels were diverted to the war effort, so they became hard to get and more expensive. After the war, fuel again became plentiful and relatively inexpensive. During the postwar period, per-capita consumption of fossil fuels skyrocketed.

It is important to note that until the 1970s, almost all the oil used in the United States was produced here. In 1970 the United States reached peak oil production while demand continued to escalate. About 1996, imported oil overtook domestically produced oil for use in US consumption.

The Oil Embargo

Beginning in 1973, political factors caused a shortage of oil in the worldwide market, followed by a global recession. The shortage continued through the early 1980s. The OPEC oil embargo made people think about how they used energy, and energy conservation became common practice. For the first time, people began to talk about running out of oil on a large scale. In fact, though, during this period there was plenty of oil available and in the ground. The oil spigots could have been opened at any time and the crisis would have been over in a day. In fact, this is essentially what happened in the mid-1980s.

Peak Oil and Natural Gas

Today we are facing an oil shortage much different than that of the '70s and '80s. We are entering the era of peak oil. There are many good books on this subject, such as *The Party's Over* by Richard Heinberg, so we will not go into a lot of detail here. But essentially, today we are at a turning point in the history of modern civilization because the production of oil is at its peak; it will never grow larger, as it has in the past. At the same time, worldwide demand for oil is growing faster than at any time in history. As a result, the price of oil will continue to rise while the supply will decrease. It is important to note that Earth's oil supply is not entirely depleted. About one-half of all the oil there ever was is still left in the ground. The reality is that we have reached peak oil production, while demand for oil continues to rise at record levels. For some time there will still be oil to be had, but producing it will become increasingly more expensive.

You are probably wondering why we have been discussing oil at such length. Though oil is rarely used to heat water, the price of oil affects the price of all other forms of energy. When it goes up, they do too. This is especially true for electricity. It takes large amounts of oil to mine coal, the basic feedstock of most of our electrical generating capacity in the US. It takes oil to mine and process uranium to feed our nuclear power plants. Oil is used in the natural gas exploration and distribution industry. Our society is completely and utterly dependent on a constant flow of cheap oil. As we enter the peak oil era, its price will continue to rise, with no end in sight.

The same holds true for natural gas, which is used to heat water. We have now reached peak natural gas production in North America, where all the natural gas used in the United States is produced. We will never be able to produce more natural gas than today, even if demand rises (which it is doing). When the United States reached peak oil production in 1970, this was a significant milestone, but it was not devastating to our economy or culture. The oil companies could inexpensively import oil from other parts of the world. All they had to do was to build inexpensive oil tankers to ship foreign oil to the US. This is not the case for natural gas. It takes very sophisticated and expensive ships to import natural gas from foreign sources. Also, expensive and sophisticated terminals must be built at both the shipping and receiving ports. This infrastructure is not in place and it will take many years and a substantial investment to create it. This will significantly affect the price of natural gas in the future. The bottom line is that the cost of natural gas

will also continue to rise, with no end in sight.

Life-Cycle Costing

People often ask, "Why would I consider purchasing a solar water heater that costs several thousand dollars when I can purchase a gas or electric water heater for only several hundred dollars?" The answer lies in the fact that they do not think about life-cycle costing. Life-cycle costing adds the original cost of a piece of equipment to its operating cost over the equipment's lifetime, or at least over a certain amount of time. Using an analysis like life-cycle costing gives an accurate analysis of the real overall cost of a purchase and allows you to make accurate and informed comparisons.

This is why it is important to figure out the energy inflation rate. We know, for example, that natural gas prices will increase rapidly. The question remains: by how much? The energy inflation rate is simply the percentage more you have to pay each year for the same amount of energy. The average energy inflation rate over the past 35 years for natural gas in the residential sector was about 7.5 percent. At the time of this writing, natural gas prices have been flat for a little while. This is primarily a result of a bad economy in which manufacturing has declined, so the use of natural gas has declined too.

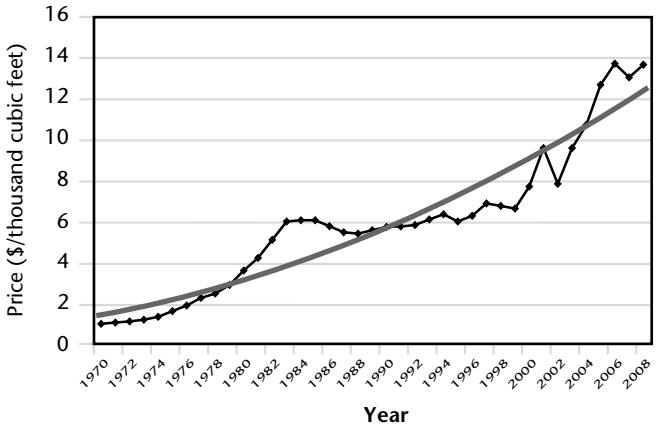

Figure 2.1: *US residential gas price trends*

Do not be fooled into thinking that there is no longer a problem with natural gas supplies. The fact is that the production of new wells is not keeping up with depletion of older wells.

Figure 2.1 graphs the price of natural gas over that time period. You can see the effects of the oil embargo in the late '70s and early '80s and how the surplus led to a rate decrease. You can also see what has been happening lately — the sharpest rate increases since the oil embargo, with inflation rates that surpass those of that era. Over the past five years natural gas has increased at an average rate of 10 percent, and this is just the start.

When calculating energy savings, you can't just use the cost of energy during the first year for each additional year because we know that the cost is rising at such a sharp rate. The lowest energy inflation rate that should be used is the historical

average of about 7.5 percent for natural gas and oil and 5.5 percent for electricity. However, using this rate does not take into account the fact that dwindling supplies and increased demand will have a strong impact on rate increases. Conversely, using an inflation rate in the 20 percent range, as we have seen in the last couple of years, may result in unrealistic estimates. We made that mistake before, during the oil embargo. Nevertheless, it is best to err on the side of caution and try to be conservative in your estimates without being unrealistic. When estimating life-cycle costs, we use 10 percent as the energy inflation rate for natural gas and fuel oil, and 7 percent for electricity. We believe that this is the lowest it will realistically be over the next 30 years. Most likely we will see the next 30-year average in the 15- to 20-percent range.

In Figure 2.2 you can see an example of life-cycle costing. This example compares both an electric water heater and a natural gas water heater to a solar water heater. All three systems are producing exactly the same amount of hot water. But solar water heaters have *no operating costs.* You do not have a monthly bill to pay because the solar resource is free. Like any other piece of mechanical equipment, they do require some maintenance, but this amounts to only about $2 per month.

As you can see in the table, viewing the systems in the long term makes for a more fair comparison. The cost of the solar water heater is equal to the operating cost of the electric water heater after only 11 years and the natural gas water heater after 15 years. This number is commonly referred to as the payoff date, because you would have paid for the system with the money saved from not having to purchase energy from the utility. However, we want to stress that this is a misstatement. As we said before, a solar water heater is paid off the second you install it because of what you have gained in equity.

Nevertheless, the notion of a payoff date is still a good way to think about the cost of a solar water heater. For instance, imagine yourself ten years from now. You will have taken just as many showers, washed just as many loads of clothes, essentially used the same amount of hot water, but you had a choice whether to heat this water with polluting coal or with clean energy from the sun. You would have paid the same amount over that time period. In other words, a solar water heater will not cost you a penny more. The bottom line is that over a ten year period the two systems cost essentially the same to purchase and operate. It is in this sense that the solar water heaters are free. Taking cold showers and not washing your clothes isn't a realistic alternative.

After the payoff date, the solar water heater will produce free energy for the duration of the system. It truly is free because you have already offset the cost of installation with money saved. With scheduled maintenance, many solar water heaters will have at least a 40-year life expectancy, so over that time frame the savings from the solar water heating system will be about $190,000. That is a lot of money to save from a one-time investment of $9,000. Because of the cumulative effect of energy inflation, the savings add up quickly, totaling quite an impressive figure. Obviously, it makes economic sense to choose the solar water heater over the electric water heater.

Another way to look at the payoff date is to introduce the idea of pre-payment. Imagine that you were approached by a salesman who gave you a deal. If you pay for the next 10 years' worth of hot water right now, you can get the following 30 years for free. This is what is being offered by a solar water heating system. Up until the pay-off date you are simply buying the hot water from a renewable resource. You are going to use hot water in any case, so why not make the responsible choice? Choose solar.

At the time of writing, a federal tax credit for solar water heaters pays for 30 percent of the cost of an installed system. Many states and utilities also offer rebates for solar. These rebates can drive down the initial installation cost of the systems and will consequently reduce the payoff time. Figure 2.2 also shows the life-cycle cost for a system that was eligible for federal and state incentives. In this case the payoff date is only six years away when compared to an electric water heater and nine years when compared to natural gas. Your eligibility for the various financial opportunities may have a significant impact when making a life-cycle analysis.

Deciding on what fuel inflation rate to use will also affect a comparison like this. If we had a crystal ball that would accurately predict future fuel prices, we would obviously have a more accurate prediction of the actual outcome of the comparison. If energy inflation rates rise at more than just the ten percent used above, the payoff time will be reduced. If the past couple of years are indicative of the future energy inflation rate and it turns out to be 20 percent, the system would be paid off in 7 years. Conversely, if the inflation rate dropped down to the historical average of 7.5 percent, it would take 10 years to pay off the system.

In addition, the life-cycle example does not include the cost of borrowing if the solar energy system or the electric or natural gas water heater has to be financed. Many of us don't have $9,000 readily available to spend on a system that heats

	Electric Water Heater	Natural Gas Water Heater	Solar Water Heater	Solar Water Heater with rebates
Annual Energy Produced	4,300 kWh	200 therms	200 therms or 4300 kWh	200 therms or 4300 kWh
Cost per Unit	$0.11	$1.25	$0.00	$0.00
Energy Inflation Rate	6%	10%		
Installed Cost	$1,500.00	$1,500.00	$9,000.00	$5,000.00
Maintanence	$0.00	$0.00	$2.00/month	$2.00/month
Cost to Operate 1st year	$473.00	$250.00	$0.00	$0.00
2nd year	$501.38	$275.00	$0.00	$0.00
3rd year	$531.46	$302.50	$0.00	$0.00
4th year	$563.35	$332.75	$0.00	$0.00
5th year	$597.15	$366.03	$0.00	$0.00
6th year	$632.98	$402.63	$0.00	$0.00
7th year	$670.96	$442.89	$0.00	$0.00
8th year	$711.22	$487.18	$0.00	$0.00
9th year	$753.89	$535.90	$0.00	$0.00
10th year	$799.12	$589.49	$0.00	$0.00
Total Cost of Energy Consumed	$6,234.52	$3,984.36	$0.00	$0.00
Life Cycle Cost After Ten Years	$7,734.52	$5,484.36	$9,240.00	$5,240.00
After 15 Years	$15,162.17	$7,854.50	$9,360.00	$5,360.00
After 20 Years	$26,128.25	$12,955.00	$9,480.00	$5,480.00
After 30 Years	$72,232.43	$34,598.80	$9,720.00	$5,720.00
After 40 Years	$191,814.80	$90,018.51	$9,960.00	$5,960.00

Figure 2.2: *Life-cycle costing comparison*

water. That means you are off to the bank to take out a loan. The added interest will add some time to the payoff date, but only about a year.

And remember, the price of energy shown on your monthly utility bill overlooks the real cost of burning fossil fuels. Every year it is in use, the solar water heater used in the comparison above would eliminate one to two tons of greenhouse gases for an electric water heater and one ton of greenhouse gases for a natural gas water heater. If the environment had a dollar value, what would it be?

Cash-Flow Analysis

Another way to look at the economics of solar water heaters is to look at a cash-flow analysis. This looks at the impact an investment will make on your cash flow. We all have some method of making money, and we get a certain amount of

money regularly as income. Then we spend this income to get the things we need and want. These are our expenses. A sound cash flow is a balance where our expenses do not exceed our income.

A solar water heating investment is different from most investments because the value of the free energy that a solar water heater harvests reduces a bill you would otherwise pay each month. If you heat your water with fossil fuel, you have a hot water bill each month that is part of your normal cash flow. When you install a solar water heater, your hot water bill is reduced. The savings gained from the solar water heater pays for the solar investment.

Figure 2.3 gives an example of a cash-flow analysis for a solar water heater that was used to offset an electric water heater. We used the same starting costs as in the life-cycle analysis but factored in some available rebates. Assume that you need to borrow the entire $5,000 to pay for the solar water heating system at 6 percent interest and make equal monthly payments for ten years. As you can see, the monthly loan payments initially exceed what is saved from not having to purchase electricity. However, over time the two columns level out, making much more comparable figures. Eventually the monthly loan payments are less than the monthly utility bill, meaning that you will actually have more money in your pocket from month to month. You would see a small negative impact on your cash flow for the first six years, and a positive cash flow impact thereafter. After ten years, when the loan has been completely paid off, your cash flow per month is greatly increased

	Electric Water Heater Monthly Savings	Solar Water Heater Monthly Payment	Cash Flow Impact per Month
Monthly Bill			
1st year	$39.42	$55.51	-$16.09
2nd year	$41.78	$55.51	-$13.73
3rd year	$44.29	$55.51	-$11.22
4th year	$46.95	$55.51	-$8.56
5th year	$49.76	$55.51	-$5.75
6th year	$52.75	$55.51	-$2.76
7th year	$55.91	$55.51	$0.40
8th year	$59.27	$55.51	$3.76
9th year	$62.82	$55.51	$7.31
10th year	$66.59	$55.51	$11.08
11th year	$70.59	$0.00	$70.59

Figure 2.3: *Cash flow analysis — solar vs. electric*

Figure 2.4: *Cash flow analysis — solar vs. natural gas*

	Natural Gas Water Heater Monthly Savings	Solar Water Heater Monthly Payment	Cash Flow Impact per Month
Monthly Bill			
1st year	$20.83	$55.51	-$34.68
2nd year	$22.91	$55.51	-$32.60
3rd year	$25.20	$55.51	-$30.31
4th year	$27.72	$55.51	-$27.79
5th year	$30.50	$55.51	-$25.01
6th year	$33.55	$55.51	-$21.96
7th year	$36.90	$55.51	-$18.61
8th year	$40.59	$55.51	-$14.92
9th year	$44.65	$55.51	-$10.86
10th year	$49.12	$55.51	-$6.39
11th year	$54.03	$0.00	$54.03

and will continue to increase as energy prices rise.

Figure 2.4 demonstrates a comparison between solar and natural gas. The cash-flow impact is slightly greater because natural gas tends to be less expensive than electricity. Nonetheless, the additional monthly cost diminishes over time, and after the loan is paid off in ten years all the savings contribute to increasing positive cash flows. Since the system is expected to last about 40 years, you can plan on seeing many years when you will have more money to spend on a monthly basis. When you finance the system, you are essentially locking in your monthly payments. You know what you will have to pay each month and will not be affected by the continually rising cost of energy. Some view this as a retirement investment. They pay off the system now when they have the cash flow to do so, and when they retire, their utility bills and monthly expenses will be greatly reduced.

The point of this analysis is to show you that you should not get hung up on the upfront cost of a solar heating system because the investment does not significantly impact your cash flow. You could have a solar water heater today for only an additional $20 a month.

At the start of this chapter we told you that we would demonstrate how you can get a solar water heater for free. The point of the life-cycle costing and cash-flow examples is to show that no matter how you look at it, a solar water heater will not cost you any more than its alternative. All you have to do is install the system and you can start saving today.