SOLAR PIONEERS

A Case Study of the Southeast Como Neighborhood Solar Thermal Project

GREEN INSTITUTE

CLEAN ENERGY RESOURCE TEAMS (CERTS)

ABSTRACT

Contrary to conventional wisdom, Minnesota's climate is surprisingly favorable for solar hot water systems. The Southeast Como Neighborhood Improvement Association (SECIA) initiated the Southeast Como Neighborhood Solar Thermal Pilot Project with the goal of helping to jump-start solar thermal in the Twin Cities by installing 20 residential solar hot water systems. A local solar installer agreed to give a bulk purchase discount for the project. By the end of the project, 16 single-family systems and one multi-family system were installed. Many homeowners faced unexpected costs of $2,000 or more above the contractor bid of $6,000 due to required engineering studies and structural improvements for installing the panels on older homes. An economic assessment indicates that while other hot water conservation strategies may have more favorable financial returns, solar hot water systems can be more economic than solar electric systems. This is especially true for high-occupancy households or apartment buildings with a large hot water demand and homes that have electric hot water heaters. Other conclusions and recommendations are detailed in the report.

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INTRODUCTION

Our current energy system will require a fundamental transformation in order to mitigate some of the more severe consequences of global warming. Scientists agree that a 50% to 85% reduction in greenhouse gas emissions from current levels is necessary to reverse global warming trends. As a society, we are just starting to realize how fundamental this change will be, and beginning to take the first steps. The 2007 Next Generation Energy Act signed by Governor Pawlenty mandates that 27% of Minnesota's electricity come from renewable sources by 2025, and requires reductions in electricity usage of 1.5% per year.[1] In addition, the Act set a goal of an 80% reduction in greenhouse gases by 2050 from 2005 levels and created the Minnesota Climate Change Advisory Group to develop a plan to meet these goals.[2]

"Talking a good story is not enough. We need to make significant changes for the environment."

Homeowner who installed system

Minnesota is on a policy path to do its share to reduce greenhouse gas emissions, but it will require the full participation of all Minnesota citizens to implement this policy. An "all hands on deck" approach is necessary. The Solar Pioneers in Minneapolis and St. Paul are playing a leading role in that effort.

Members of the Southeast Como Improvement Association (SECIA) saw that Minnesota's strong solar resources could be utilized to help their community meet goals for reducing greenhouse gas emissions and saving energy. Thus they initiated the Southeast Como Solar Thermal Pilot Project to help jumpstart city-wide installations of solar hot water heaters.

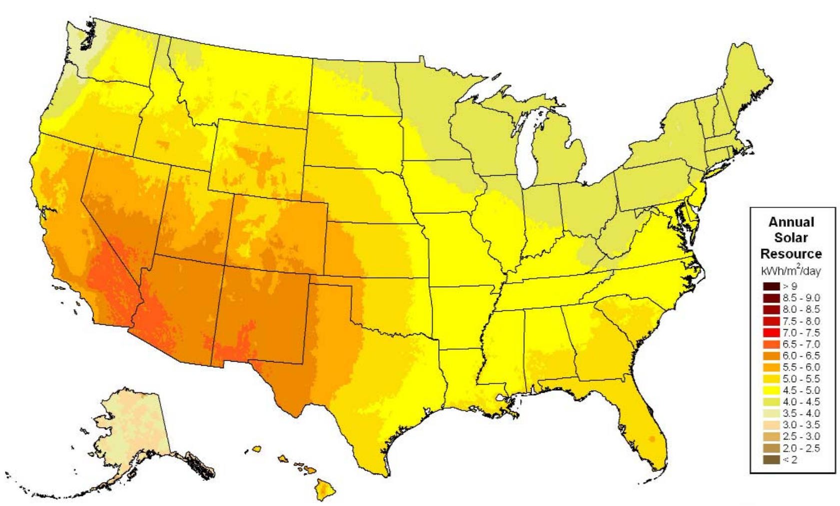
With the goal of facilitating the installation of 20 systems in and around the Como neighborhood, SECIA recruited neighborhood residents and a multi-unit apartment building owner for the project. The group partnered with a local solar installer in order to receive lower rates on evaluation and installations costs. Participants in the program were referred to as "Solar Pioneers" because it was hoped they would help lead the way for others to install solar.

This report documents the SECIA project. Because solar is not yet in widespread use in Minnesota, we provide background on Minnesota's solar resources and the technologies used to channel this resource to heat water. The project's goals and the implementation of those goals are documented, including some of the challenges faced in installing the systems. We also examine the expected energy savings and economics of a typical system. Overall conclusions and recommendations are made based on the SECIA experience. Finally, the appendices provide additional information on solar thermal markets throughout the world, the solar permitting process used in different parts of the country, and selected resources for finding more information on solar.

We hope this report will be beneficial to other communities considering similar initiatives. Community-based energy initiatives can play a prominent role in helping to shape a clean energy future. It is the goal of the Metro Clean Energy Resource Teams (CERTs) Network to help strengthen and expand these efforts.

Figure 1

U.S. average annual solar resources for flat plate collector at latitude tilt (kWh/m2/day)[a]



MINNESOTA'S SOLAR RESOURCE

The sun, the central energy producer of our solar system, is a tremendous energy resource. Located approximately 143 million km from Earth, only a tiny fraction of the Sun's energy reaches our planet. However, this small percentage provides more energy in fifteen minutes than the human race uses in an entire year.[3]

Minnesota has average solar resources of about 4.5 kilowatt-hours per square meter per day (kWh/m2/day).[4] Within the state, solar resources vary only about 10-15%, from the highest in the southwest to the lowest in the Northeast.[5] Although Minnesota's solar resources are lower than other parts of the U.S. *(Figure 1)*, our cold climate means that we use more energy to heat water. Thus solar hot water systems installed in Minnesota can compare favorably to other parts of the world. The solar output of a typical residential system was modeled for 5 cities with a range of climatic conditions and solar resources *(Figure 2)*. With the exception of Phoenix, a single-panel system installed in Minneapolis has the greatest energy savings of any of the other cities. A two-panel system installed in Minneapolis can save even more energy than one installed in Phoenix, although a system installed in Arizona would typically be less expensive than one installed in a cold-climate like Minnesota.[6]

Minnesota's solar resources are superior to those of Germany, a country with three times the installed capacity of solar hot water systems as the entire United States *(Figure 3)*. Because of strong government support, Germany has 6.2 million square meters of collectors for domestic hot water and space heating, with a heat output of 4,656 megawatts thermal. This compares to 1,554 megawatts thermal in the U.S.[7] Nearly 4% of all German homes have solar thermal systems, saving the country an average of 71 million gallons of oil each year.[8]

Solar energy availability varies significantly throughout the year, especially in northern climates. Installing a solar panel at greater tilt angle can increase output during winter months, when the sun is lowest in the sky *(Figure 4)*.

SOLAR THERMAL SYSTEMS

Solar thermal is a technology distinct from its cousin solar electric, or photovoltaic (PV). PV

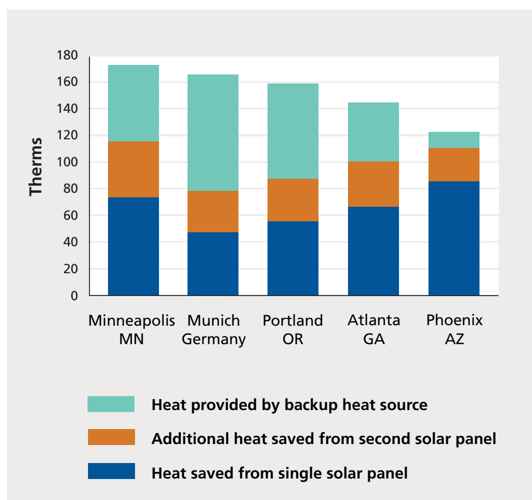


FIGURE 2

Solar output for one and two panel solar hot water systems in five major cities [b]

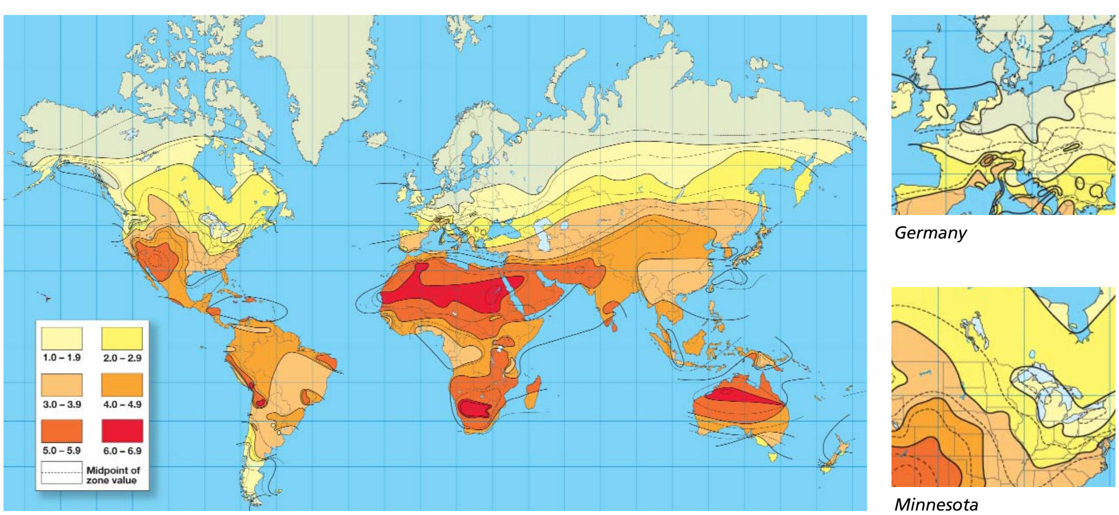


FIGURE 3

World solar resources, winter peak for worst case month at latitude tilt (kWh/m2/day) [c] solar panels use special materials to directly convert sunlight to electricity. In contrast, solar thermal systems directly capture and utilize heat energy from the sun. Solar thermal is divided into passive and active solar systems. Passive solar design strategies – such as windows that maximize winter heat gain but are shaded in summer, reflective roofs, and use of building materials for heat storage – can, in conjunction with a high-performance building envelope, reduce energy used for heating and cooling by over 50 percent with no operating costs.

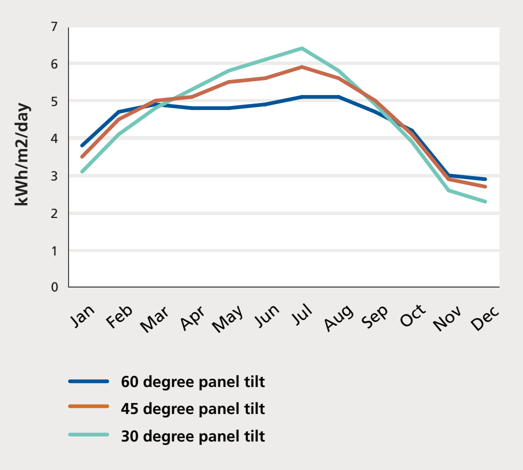
One of the simplest active solar thermal technologies is a solar hot air heater, which directly heats air for space heating. These systems work best for pre-heating air for commercial or industrial buildings with large ventilation (make-up air) requirements. In such cases, a type of solar thermal technology called a transpired air collector ("Solar Wall") can be a very cost-effective investment.

The majority of solar thermal systems use solar panels to heat water or other liquids because the heat carrying capacity of liquids is far greater than air.[9] This heated fluid can then be used for a variety of residential, commercial or industrial applications, including the generation of steam.

Solar hot water systems are the most common application of solar thermal. They can be used in single- or multi-family residences, offices, industrial buildings, schools, hospitals, or wherever there are hot water demands. Solar pool heating is a particularly cost-effective application. Solar hot water systems have an advantage over space-heating systems because they can be utilized during the summer when the solar resource in Minnesota is the greatest. Otherwise, the heat generated during the summer is wasted.

FIGURE 4

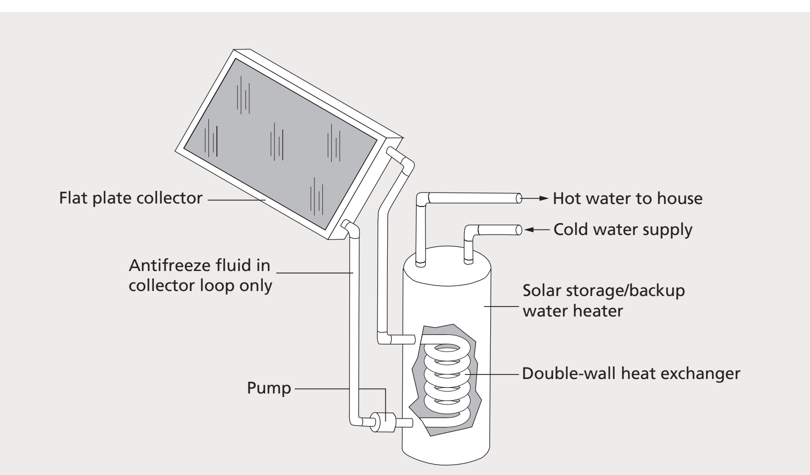
Average monthly solar resource for Minneapolis at various panel tilt angles (kWh/m2/day) [d]



Although there are many types of solar hot water systems,[10] the one most common in cold climates is the closed-loop active glycol system *(Figure 5)*. These systems contain food-grade glycol antifreeze as the heat transfer medium, and thus are a safe bet for Minnesota's freeze-prone climate. All of the systems installed in the Southeast Como project were the closed-loop active glycol system.

FIGURE 5

Active, closed-loop solar water heater [e]



Of all the components of a solar hot water system, the solar panel, or solar collector, is the most crucial. There are two main types of collectors utilized to heat water for domestic use.

Flat plate collectors are the most common type of collector for domestic solar water heating with a long and proven track record *(Figure 6)*. These collectors are insulated, weatherproof boxes that contain an absorber plate. This plate is heated by the sun and transfers that heat to a the heat transfer fluid (antifreeze mixture) that flows through tubes located in or near the absorber plate. They can produce temperatures up to about 180 degrees F. These were the type of panels used for the Southeast Como project.

Evacuated tube collectors are also well suited for domestic hot water heating. Evacuated-tube collectors are made up of rows of parallel, transparent glass tubes. Each tube consists of a glass outer tube and an inner absorber. The air is withdrawn (evacuated) from the space between the tubes to form a vacuum, which reduces heat loss and increases efficiency.

Although more expensive than flat plate collectors, evacuated tube collectors heat to higher temperatures and thus can be used in commercial applications that require temperatures of between 170º and 350ºF. They also produce more heat per square foot than flat plate collectors, and work well when limited space is a consideration. One drawback is that the gaskets sealing the vacuum can deteriorate over time and can render the collector tube useless. In contrast, flat plate collectors can last for 30 years or more.

In addition to the collectors, systems require a **hot water storage tank**. This tank is most frequently used in tandem with traditional hot water heaters. The water is preheated in the solar tank by **heat exchangers** before entering the home's original hot water heater. Special tanks designed for solar have integrated heat exchangers built inside the tank. Insulated **copper pipes and miscellaneous plumbing** connectors link the collector panel on the roof with the hot water tank, typically in the basement in Minnesota homes. An **expansion tank** to relieve excess pressure is required as a system safety control mechanism for active glycol systems. A **circulating pump** circulates the heat transfer fluid from the collectors on the roof to the solar hot water tank. **Temperature sensors** in the collector and tank are connected to a controller, which turns on the pump when the fluid in the collector is 15°F or so hotter than the water in the tank. Some controllers, with the appropriate sensors, can also measure the amount of energy being produced by the system.

GOALS OF THE SOUTHEAST COMO SOLAR HOT WATER PILOT PROJECT

The Southeast Como Improvement Association (SECIA) is a Minneapolis neighborhood organization located near the University of Minnesota on the border with St. Paul. They have an active membership and a history of strong involvement in environmental issues, including initiating a community gardening program, coordinating neighborhood efforts to construct rain barrels, and facilitating neighborhood involvement in local and regional air quality issues.

Justin Eibenholzl, the SECIA Environmental Coordinator, helped to initiate the SE Como Solar Hot Water Pilot Project. Justin and neighborhood residents recognized that solar thermal systems had to the potential to increase residential energy savings, promote job development, and reduce greenhouse gas pollution. In order to encourage the citywide installation of solar hot water heaters, SECIA initiated the Southeast Como solar hot water project as a pilot program. The program's goals were to:

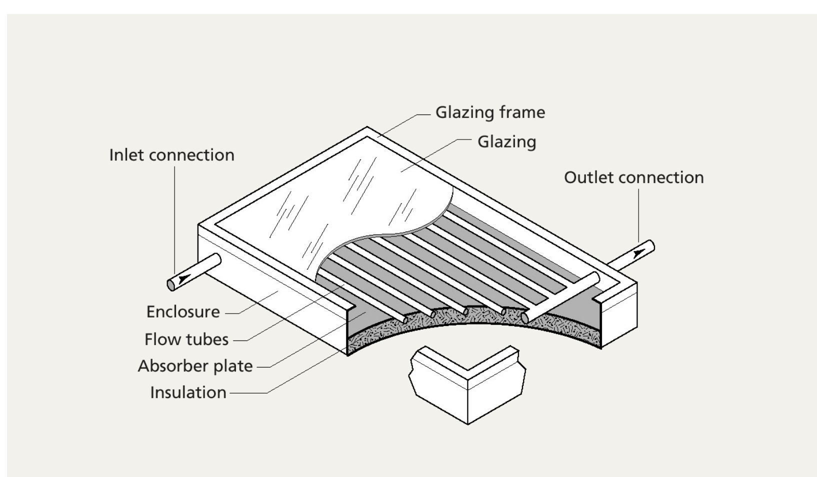
- Demonstrate that neighborhoods and communities can save money and improve the environment by installing solar hot water systems

Evacuated tube collectors

photo: National Renewable Energy Laboratory, U.S. Department of Energy

FIGURE 6

Flat plate collector [f]



BENEFITS OF SOLAR HOT WATER SYSTEMS

Save on energy bills

Although solar hot water heaters have a higher up-front cost when compared to traditional water heaters, solar "fuel" is free. Once the system has paid for itself in offset fuel costs, a home-owner can thus heat water for free. Systems are also reliable and require minimum maintenance throughout their 30+ year lifetime.

Add value to your home

Installing a solar hot water system can increase the equity of a home. One study showed that for every \$1/year in saved energy, energy saving improvements to the home can add \$20 to the value of a home.[34] In the case of solar thermal, a system could add approximately \$3,000 to the home's value.

Be your own renewable energy producer

Solar hot water systems use clean, non-polluting solar energy to heat water. They are one of the few options for urban homeowners to easily generate their own energy. Systems that displace natural gas reduce carbon dioxide – the main contributor to global warming – by about 1,300 lbs/year, while systems that displace electric water heaters reduce carbon dioxide by about 4,300 lbs/year.[26]

"Ethically I am concerned about the environment and pollution. I thought this would be a good way not only to help the environment but also to promote environmental ethics to others."

Apartment building operator who installed system

- Aggregate solar thermal installations and attempt to take advantage of economies of scale in material, labor, construction, engineering and permitting costs
- Provide support to a group of interested homeowners and help facilitate the installation of their systems
- Achieve installation of a larger number of systems than if individual homeowners tried to navigate the process themselves
- Install 20 residential systems by June 2006

SIGNING UP FOR SOLAR

In the spring of 2006, SECIA recruited homeowners for the solar thermal project by providing information and organizing presentations on the feasibility and benefits of domestic solar hot water systems. Initially, residential or business property owners in the Como neighborhood or one of the adjacent neighborhoods (Marcy-Holmes, Prospect Park, St. Anthony Park in St. Paul, City of Lauderdale, and Northeast Park & Beltrami) were eligible; the project was later opened up to all residents and businesses in the Minneapolis/St. Paul area.

SECIA identified a solar installer located in the neighborhood, Innovative Power Systems (IPS), to install all the systems. IPS agreed to reduce their typical cost for installing systems by about \$1,500 because of the opportunity to sell and install many systems at once. Although they would typically give a bid based on site-specific conditions, for simplicity IPS agreed to an "all-in" price of \$6,000 for program participants.

The pilot program generated a lot of interest from neighborhood residents who came to the initial informational presentations, with over 200 expressing interest in participating. Many cited environmental concerns and a desire to take personal action against global warming as reasons for their interest. Others were interested in lowering their natural gas bills, while some were attracted to the project because they found the technology to be new and exciting. One participant said that he wanted to add solar hot water systems to his apartment building in order to make the building more attractive to prospective tenants. Federal tax credits were important for many residents because they helped make the projects more financially viable.

Site evaluations

Of those who initially expressed interest, 39 decided to move ahead and submit a \$200 deposit to IPS for a solar site evaluation. IPS agreed to provide these site evaluations for \$60 instead of their normal \$195 fee, in part due to the fact that their office was located near the Southeast Como neighborhood and they could complete several evaluations in one day. For those that didn't move ahead after the site visit, \$140 of the original \$200 deposit was returned.

When evaluating sites for the Southeast Como project, IPS paid close attention to the placement and orientation of the proposed solar thermal panels. Shading is one of the most important factors in determining the feasibility of a solar system, especially in a dense urban area. To ensure adequate heat production from the system, a solar array must be mounted in a location that has little or no shading for at least four hours each day. Collectors should face as close to true south as possible; however, a variation of up to 30 degrees will not significantly reduce the panel's performance.[11] The tilt of the collectors should also be considered. Matching the collector tilt with the latitude for a given location will maximize year-round solar production; in Minneapolis this angle is 44.9 degrees. To maximize for winter production when the sun is lower in the sky and produces less heat, the tilt angle should be 15 or so degrees greater than this optimal angle (60 degrees for Minneapolis).

Of the 39 individuals who submitted a deposit for a site evaluation, 7 were unable to continue with the process due to poor site conditions. Because the number of participants in the project tripled the business of IPS, there were a number of delays in scheduling evaluations as IPS worked to increase their capacity. In total, 18 participants ended up depositing a down payment of $2,800 to start installation, with all but one of them completing the installation *(Figure 7)*. Five of the installations (including a 24-unit apartment building) were in St. Paul, the rest in Minneapolis.

Increasing energy efficiency

To complement their solar hot water systems, participants were encouraged to save hot water through increased energy efficiency. Lowering their hot water demand meant members could produce a greater fraction of their energy with solar.

A few simple ways for households to save on hot water include:

- Ensuring that hot water tanks and pipes are properly insulated to avoid excess heat loss. Adding an insulation jacket to a hot water heater can save about 4%-9%of water heating costs. Jackets cost $10-20 and can pay for themselves in lower energy bills in less than one year.[12]
- Fixing leaky faucets and other appliances. A faucet that leaks 30 drops of water every minute will waste approximately 100 gallons of water in a month.[13]
- Installing low-flow showerheads and flow-restrictors on faucets. Most newer fixtures are already low-flow, but replacing older fixtures that are not low-flow can save 25%-60% of the water used from these fixtures.
- Increasing the efficiency of household appliances that use hot water. A new efficient dishwasher can use 50% less hot water than an older less efficient model. The best way to save hot water from clothes washing is to wash in cold water, using newer detergents designed for cold-water use. If hot water is used, a front-loading washing machine uses approximately 10-20 fewer gallons of hot water per load than a conventional top loading machine. It also spin-dries the clothes better, requiring less energy for drying.
- Adjusting the thermostat on a home water heater to 120°F if the dishwasher contains its own hot water heater. This saves on energy that would otherwise be required to keep household water hot enough to do dishes.

PROJECT PARTICIPANTS

200	*Expressed interest in participating*
39	*Deposited $200 for a solar evaluation*
18	*Invested $2,800*
1	*Backed out*
16	*Home installations*
1	*Installation on 24-unit apartment building*
17	*Total Installations*

FIGURE 7

Participants in SE Como solar pilot project

A drain-water heat recovery system is another opportunity for large hot water savings. This type of device captures the waste heat that would normally go down the drain to pre-heat cold water. These devices cost approximately $600, and can pay back their initial cost in 3-7 years. One study indicated savings of 25%-35% of total hot water heating needs.[14] They are also compatible with solar hot water systems.

The average household spends about $256/year on natural gas for heating hot water.

Homeowners needing to replace an existing hot water heater can also save significant energy through purchasing a high-efficiency condensing natural gas hot water heater, or an instantaneous (tankless) system. Tankless hot water heaters are also compatible with solar hot water systems, and can save the homeowner even more energy. For those heating their home with boilers, an indirect water heater may save energy. These systems use the existing boiler to heat domestic hot water via a heat exchanger.

Sizing the system

Systems are typically sized to provide close to 100% of the hot water demands in the summer, when the sun is strongest. In the winter, less solar heat is generated, and a back-up water heater provides the extra energy. On an annual basis, the typical solar system provides between 50%-80% of the total hot water usage, with the back-up producing the rest. It is possible to provide a greater percentage of solar heat by putting up more panels, but this approach has diminishing economic returns. As no additional heat is needed during the summer months, the additional panels produce heat that is wasted.

It is theoretically possible to use hot water from solar thermal systems to produce air conditioning, although there are no systems yet available for residential application. This option would allow for greater utilization of the solar energy during the summer months.[15]

Contractors often follow a guideline of about 20 square feet of collector area for the first two family members and 12-14 square feet for each additional person. For active systems the size of the solar storage tank increases with the size of the collector, typically 1.0 to 1.5 gallons per square foot of collector for Minnesota's climate. As storage tanks are only made in certain sizes, this means a 60, 80 or 120-gallon tank.

Tilt-mounted solar hot water panels

photo: National Renewable Energy Laboratory, U.S. Department of Energy

In practice, two 4 by 8 foot flat plate collectors (64 square feet) to heat domestic hot water will work for the majority of households. Smaller households may not fully use the heat from two panels, but the incremental cost of an additional panel is usually justified because it is only a portion of the full cost of installing a system. IPS took this "one-size-fits-most" approach, and used the same two-collector, 80-gallon tank system in each of their installations.

SYSTEM PERMITTING AND INSTALLATION

Because a relatively small number of solar hot water systems are installed each year in Minnesota, cities do not have a specific permit for solar hot water systems. By state law, municipalities with populations over 2,500 are required to adopt and enforce the state building code, which dictates many provisions for permitting. Thus, cities have only limited flexibility in setting permitting requirements. The state building code also requires all solar hot water systems to be certified by the Solar Rating and Certification Corporation (SRCC).[16]

Cities pay some of the permit fee revenues to the state, and use the rest to pay their own administrative costs. In the case of the Southeast Como project, homeowners were required to secure a general construction permit based on the value of the system. This permit was estimated to cost about $165. In addition, a plumbing permit was required, about $65. Reportedly, some City of Minneapolis staff are evaluating if an additional mechanical permit should be required for future installations. A mechanical permit is currently required for furnaces, boilers, and appliances where a connection to the gas line is necessary.

A cost unanticipated by IPS was an independent engineering assessment to ensure the panels would not compromise the structural integrity of the house. The City of Minneapolis required this due to concerns that the older homes in the city would not be able to bear the additional loads of the panels. The panels themselves weigh about 300 pounds, which is not a significant additional load given the size of the panel. However, of greater concern is the wind load. Strong winds have the potential to rip off the panels or damage the underlying roof structure if the panels are not properly supported. This is particularly true for panels not installed at the angle of the roof, a significant percentage of the installations. These panels were installed on brackets to increase the tilt of the panels, and thus maximize solar collection during the winter, when the sun is weakest and lowest in the sky. However, the brackets can also significantly increase wind load. Panels mounted flush to the roof have less potential to add wind load. The engineering assessment itself cost $260 to $830, depending on the complexity of the situation.

In addition to this evaluation, the engineer in all cases recommended structural improvements to the roof structure that represented further unanticipated additional costs for the system installation that were not included in IPS's original bid. Thus SECIA and IPS went back to the program participants to ensure that they still wanted to continue, given the additional costs. All but one participant agreed to continue, and that participant had other reasons for dropping out. Nonetheless, the additional costs to the homeowners were significant in many cases. Although some homeowners were willing to do the upgrades themselves to save money, one homeowner paid $4,000 for the upgrades. The typical cost was about $1,500 for those that hired others to install the structural upgrades.

In order to support the project and at the urging of SECIA, the Minneapolis City Council took the one-time action of rebating participants the cost of the permits, about $265. Although less than the cost of the independent engineering assessment, the subsidy did help to offset some of the unanticipated costs for participants.

The City of St. Paul agreed to waive the engineering assessment requirement for three installations in St. Paul that did not use tilt brackets (i.e., the panels were installed flush with the roof). This is because flush-mount systems have significantly less wind loads than the systems on brackets. However, they indicated that they may require them in the future, and they did require them for the two installations that had brackets.

Total installed costs for the single-family homeowner participants in the Southeast Como project were between $6,000 and $10,500 *(Figure 8)*. Based on the original bid of $6,000, about 50% of the cost is equipment, 40% labor, and 10% permits and other fees. The largest equipment costs were for the panels ($950) and the solar storage tank ($750).

With the Southeast Como project, once permitting issues had been resolved there were also a number of delays in installation. IPS hired contractors for the plumbing connection work, but did the rest of the system installation themselves. A shortage of solar installers in the industry means IPS must train all of their own installers, and required additional labor to complete the SE Como projects. Several participants were installing systems as part of home remodeling projects, and delays in the remodeling outside the control of IPS pushed back the solar installation as well. These factors in total resulted in the final systems being completed in February 2007 instead of the original goal of June 2006.

MAINTENANCE COSTS

Once installed, systems like those in the Southeast Como project have very minimal maintenance costs. Over the 30+ year lifetime of a solar hot water installation it is estimated that the homeowner will need to replace the water pump after 10-15 years, at a cost of $100-$300. Additionally, excess heat can cause glycol deterioration, and thus the glycol antifreeze must be checked and potentially changed once every

FIGURE 8

Total costs for participants

TOTAL COSTS FOR PARTICIPANTS

	Typical cost	Range
Initial contractor bid	*$6,000*	*$6,000*
Engineering assessment	*$500*	*$0 – $830*
Structural upgrades	*$1,500*	*$0 – $4,000*
Rebate from City of Mpls	*($265)*	*$0 – ($300)*
Total	***$7,735***	***$6,000 – $10,500***

MAINTENANCE COSTS

Maintenance Activity	Frequency	Cost
Change antifreeze heat-exchange fluid	*Every 3-5 years*	*$100-$200 / 5 years*
Replace pump	*After 10-15 years*	*$100- $300*

FIGURE 9

Maintenance costs for a solar hot water system[9]

3-5 years at an estimated cost of $100-$200 per time. *Figure 9* summarizes these costs. Deteriorated glycol can corrode system components. It is possible for the homeowners to carry out maintenance work themselves or hire a certified solar thermal installer to complete the work.

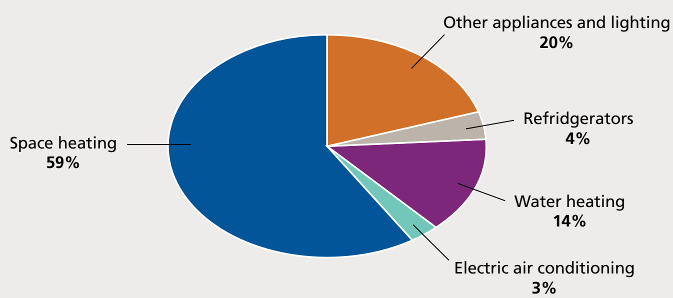
ECONOMICS

While some homeowners paid system costs out of savings, most commonly it was financed through a home-equity loan. One participant financed their system as part of a home remodeling project using a SECIA Neighborhood Revitalization Program (NRP) low-interest loan program, run by the Center for Energy and the Environment.

A 30% federal tax credit is available for all solar systems installed between January 1, 2006 and December 31, 2008. As of the publication of this report, the credit had not yet been extended beyond 2008. This tax credit is not a deduction, but a rebate against the homeowner's tax liability, received when the homeowner files taxes the year following installation. The complete cost of the system, including equipment and installation, may be applied to the credit. The rebate for residential systems is capped at $2,000. Commercial applications have no cap.

FIGURE 10

Major categories of household energy consumption in Northern climates[h]



Minnesota also exempts solar-energy system equipment from state sales tax. The savings from the sales tax exemption was included in the bid given by IPS.

In order to receive federal and state tax incentives and credits, all solar thermal systems must meet Solar Rating Certification Corporation (SRCC) requirements. For federal tax credits, systems must also acquire at least 50% of the energy to heat water from the sun.[17]

In order to calculate the financial benefits of a solar system, the output of the system must be estimated. This in turn depends to a certain extent on hot water usage – a single person household will use less water and thus achieve less savings than a family of four. The average person uses about 20 gallons of hot water per day, and the average U.S. household uses about 53 gallons of hot water per day.[18] The energy to heat this water can be significant. After space heating, water heating is typically the second single largest user of energy in the home, accounting for approximately 14% of total home energy use in cold climates *(Figure 10)*.[19] For households with natural gas hot water heaters, this is about 197 therms, or $256/year at recent natural gas prices.[20]

For a given climate and system design, the energy saved by a solar hot water system will depend on the following factors:

- The actual hot water demand of the household (e.g., smaller households will not always be able to use all of the heat produced by the system, or households that go on vacation don't use hot water during that time)
- Any partial shading from nearby trees or other obstructions that could reduce the system output
- The tilt angle of the panel (panels tilted at a high angle will receive more sun in the winter and less in the summer)
- The efficiency of the back-up hot water heater (the less efficient the back-up system, the more energy that will be saved by producing it from solar)

As an engineering rule of thumb, IPS estimates output of 2 therms/square foot of collector space, or 128 therms/year for the single-family systems installed for the SE Como project. Since some of the systems were partially shaded, reducing output, and others serve smaller households that will not be able to utilize all the heat produced, IPS estimates an actual output of 86 therms (a one-third reduction). For an 80% efficient back-up natural gas heater, this represents energy savings of 107 therms (i.e., it would have taken 107 therms of natural gas to produce the 87 therms of heat from the solar hot water heater). Green Institute verified this estimated output by two methods, and came up with similar estimates of around 92 therms produced, or 115 therms/year savings for a 3-person household.[21] This is slightly lower than found in a recent evaluation of cold-climate solar hot water systems.[22] At recent gas prices, this saves the homeowner about $150/year, or a 28-year simple payback assuming a $4,200 initial cost ($6,000 minus $1,800 tax credit). This does not take into consideration the energy used to power the circulating pump, which can decrease the savings.

Because there is so much uncertainty over the future cost of natural gas, Green Institute developed a simple financial model to calculate payback under different assumptions for system cost, output and energy price projections *(Figure 11)*. Our assumptions for system costs and output are consistent with the experience of the SE Como participants, as detailed above,[23] except that we assumed a $6,000 initial cost, which was only true for a few participants. We also assumed utilization of the tax credit ($1,800).

The starting point for our natural gas price projections is the U.S. Department of Energy's Energy Information Office (EIA). A comparison with six other private-sector projections of natural gas prices shows the EIA projections are generally representative of industry consensus.[24] However, natural gas prices are expected to be highly volatile, so even the best predictions are rough estimates. Therefore we calculated payback for several projections, in constant 2006 dollars. These projections are referenced against historic natural gas prices *(Figure 12)*. Some installers use a high gas escalation rate of up to10%/year when calculating payback for their customers, so this is included as an upper bound for our analysis.

While a 10% escalation may prove to hold true for the short term, it is highly inconsistent with long-term predictions of gas prices. We also calculated payback for a solar hot water system displacing an electric hot water heater rather than a natural gas system. These results were replicated for various initial system cost and annual output assumptions. Finally, a solar electric, or photovoltaic (PV), system was modeled for comparison purposes.

Although no electric water heaters were involved with the SE Como project, the economics are more attractive for using solar with existing electric water heaters than for natural gas heaters. However, even under the most aggressive price

FIGURE 11

Years required to pay back original system costs under various system cost, output and energy price scenarios [i]

SCENARIO	ENERGY PRICE ASSUMPTIONS			
	Projected gas	*High projected gas*	*Very high gas*	*Electric*
Typical output (115 therms, $6,000)	*36 yrs*	*30 yrs*	*16 yrs*	*17yrs*
Increased costs (115 therms, $8,000)	*40+ yrs*	*36 yrs*	*18 yrs*	*23 yrs*
5 occupants (140 therms, $6,000)	*31 yrs*	*26 yrs*	*14 yrs*	*14 yrs*
Single occupant (60 therms, $6,000)	*40+ yrs*	*40+ yrs*	*22 yrs*	*29 yrs*
No federal tax credit (115 therms, $6,000)	*40+ yrs*	*36 yrs*	*18 yrs*	*23 yrs*
With $1000 state incentive (115 therms, $6,000)	*33 yrs*	*27 yrs*	*14 yrs*	*15 yrs*
Solar electric (PV) system (1 kW, $9,000)	–	–	–	*37 yrs*

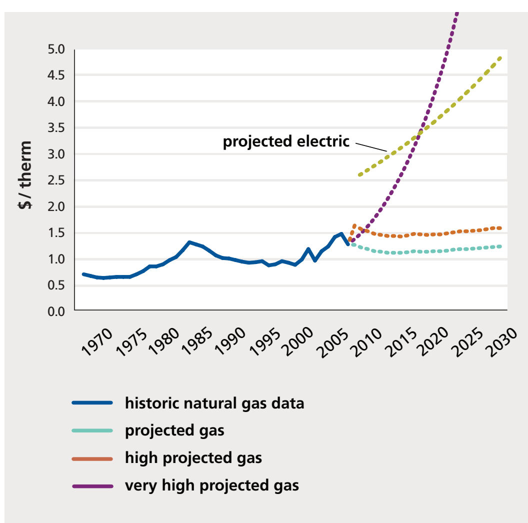


FIGURE 12

Historic natural gas prices and projections used for economic analysis (2006 $) [j]

Key to energy price assumptions:

Projected gas: U.S. Energy Information Administration (EIA) projections, Annual Energy Outlook 2007

High projected gas: EIA projections + 30%

Very high gas: Current prices ($1.30/therm) + 10% annual increase

Electric: 8.5 cents/kWh + 3% annual increases, converted to $/therm in the chart for comparison purposes

WENDY MENKEN'S EXPERIENCE

Wendy said she participated in the Southeast Como project because "it's important to bite the bullet. Talking a good story is not enough; we need to make significant changes for the environment."

Wendy was one of the many Minneapolis residents who required additional roof engineering before the system could be installed. Although she was initially not aware that older houses often need structural engineering, she decided to move ahead with the installation despite a higher cost because of the environmental benefits, her commitment to the project, and the potential to realize energy savings over the long-run. Because Wendy was installing her system as she was remodeling her home, she incorporated the roof engineering requirements into the remodeling designs. The designs included additional roof support for her solar thermal panels and indoor piping from the solar panel to the hot water heater in the basement. She is pleased with the arrangement because the solar hot water will offset extra gas costs from her addition. Wendy reports that she has found that there is more hot water available in the afternoon and guesses that a large family could alter their routine in order to take advantage of this.

As with many participants, Wendy found that the federal tax credit made a big difference in the affordability of the system. She also appreciated that the City waived the permit fees. However, she wished that homeowners could be provided with a checklist and schematic and clarifying documents that would explain the technical aspects of a solar hot water installation and aid residents when they review the system with a structural engineer.

increase assumptions, the payback for solar is not likely to be as attractive as for other energy conservation or energy efficiency opportunities, as shown above. A state incentive, similar to what currently exists for solar electric (about 20% of the cost of a system), would improve the payback for homeowners and induce additional homeowners to install solar.

Clearly, dollars spent on a solar hot water system are not spent for economic reasons alone. People are willing to pay more for energy provided by the sun, just as people will pay more for organic food. Not all consumer purchases are made based on payback. Rarely, for example, is a decision to purchase a car based on financial return. Solar hot water systems do provide an attractive opportunity for homeowners interested in generating their own energy.

A simple payback analysis also does not take into account that a solar hot water system can add to the value of a home. The homeowner can capture this value when the house is sold. A study of energy-efficiency home improvements indicates that a solar hot water system could add $3,000 to the value of a home, just based on the energy savings potential of the system alone.[25] A homebuyer is willing to accept a longer "payback" on the system, because they can roll the higher home price into their 20-40 year mortgage. This way they can pay for the benefits a solar installation provides over the life of the mortgage.

Finally, this economic analysis does not take into account the potential value of greenhouse gas reductions of solar hot water systems. Because using electricity to heat hot water results in about triple the carbon dioxide emissions as heating with natural gas, these benefits would be greatest for solar installed with existing electric hot water heaters.[26] While carbon reductions from installing solar hot water systems would help the state meet its greenhouse gas reduction goals, it is less clear at this time how these reductions would financially benefit the homeowner who installs the system. Providing state incentives could help compensate homeowners for providing these greenhouse gas reduction benefits.

CONCLUSIONS AND RECOMMENDATIONS

The following conclusions and recommendations are provided for those considering similar projects, as well as policymakers, state and local government officials, advocates and others interested in advancing solar and energy efficiency in the state.

Minnesota's climate is surprisingly favorable for solar hot water systems

Minnesota has better solar resources than Germany, a country with three times the capacity of solar domestic hot water and space heating systems than the entire United States. Due to our cold climate Minnesota has a large hot water heating load, and a two-panel solar hot water system installed in Minnesota can save more energy than a similar system in Phoenix. However, systems installed in Minnesota can cost more than those in Arizona.

There is considerable interest in solar hot water systems

A significant number of people expressed interest in the Southeast Como Project. Although many ultimately decided not to invest in a system, those who did showed great commitment. Despite substantial unplanned costs, only one project participant dropped out. Many reported that they remained with the project because they were committed to its vision, the environmental benefits, and the potential to realize energy savings.

Environmental mediators can help facilitate the introduction of an unfamiliar technology

Solar thermal is a technology that is not yet widely adopted, and thus unfamiliar to many. Participants said the Southeast Como Improvement Association provided valuable information on the technology and worked with contractors and others to reduce system costs and address other issues as they arose.

Homeowners must be made aware of possible additional costs

Specifically, the engineering assessment and additional structural improvement costs were an unforeseen expense that contributed significantly to the overall cost of the project. Thus, it is

Flush mounted solar hot water panels

photo: National Renewable Energy Laboratory, U.S. Department of Energy

important that homeowners are aware that older homes may require significant modifications before they can be retrofitted with solar hot water systems.

Homeowners in older houses should consider flush-mounted systems

The largest unforeseen cost increase was due to structural improvements required by the engineers who examined the increased roof loads caused by installing the solar panels on existing roofs. Most of the increased structural load was not due to the weight of the panels, but because of increased wind loads (i.e., wind catching the solar panels and causing stress on the roof system). Solar panels installed flush with the roof (at the same tilt as the roof) will have less wind load than panels installed on a bracket to increase their tilt. The flush-mounted panels will thus generally require less structural bracing to accommodate the installation. This may come at some loss of output, but modeling suggests flush-mounted systems would have less than an 8% reduction in output. This does not account for any additional reduction in output due to flush-mounted systems' lesser ability to shed snow during winter months.[27] Flush-mounted systems are also more aesthetically pleasing, as they can blend in better with the existing building structure.

A streamlined method for permitting solar hot water systems should be investigated

Local governments, or ideally the state, could investigate ways to streamline the permitting of solar hot water systems. For example, templates could be developed for a standard bracing system that would be modeled after previously demonstrated, effective bracing systems. Homeowners would then chose from specific bracing options available for each type of roof and thus save on the cost of engineer-designed bracing systems. It may be that flush-mounted panels don't require as much attention, because their structural load is much less than panels on tilt mounts. For instance, if city inspectors, instead of outside engineers, could sign off on the standardized bracing systems, homeowners could save additional money by effectively eliminating the need for engineer involvement and/or approval. Cities may be able to further expedite the process by bundling the permitting for plumbing and structural engineering.

Growth within the solar thermal industry is necessary to meet future demands

The contractor for the Southeast Como project said that the increase in sales from this large project was challenging due to a lack of certified installers. Century College in White Bear Lake is planning to offer solar installer certification courses in 2008. This should contribute to an increase in the number of qualified installers. Contractors in this growing industry must also be able to meet the high customer service expectations of homeowners.

New-home construction or remodeling is the best opportunity to install solar hot water

One of the largest expenses can be the structural improvements to the house, as well as the work required to find a suitable pathway for the pipes from the roof to the basement. The best time to do this work is during construction of a new home, or during the remodeling of an existing one. Solar can then be explored as part of a larger picture of improving a home's environmental performance, such as through the recently introduced MN GreenStar certified new homes and remodeling program.

Energy efficiency can be a more economic way to save hot water than solar

Even under the best circumstances, solar hot water has paybacks exceeding 13 years, and depending on hot water load and the cost of natural gas, paybacks could exceed 40 years. There are other emerging technologies besides

LOCALLY-PRODUCED SOLAR PANELS: SOLAR SKIES

As global warming concerns raise public interest in renewable energy technologies, Minnesota's solar thermal industry continues to grow. Solar Skies Manufacturing is one of two new solar thermal panel-manufacturing plants to open recently in Minnesota (the other is the Rural Renewable Energy Alliance in Pine River, producing solar air heaters). Solar Skies' 20,000-sq/foot facility is located in Starbuck in West-Central Minnesota, and currently produces about 20 collectors per day with the capacity to reach 1,000 per month without adding additional shifts.

Any of the firm's current 10 employees can attest to the fact that this Minnesota-based firm is unique. Unlike many manufacturing plants that produce large batches of a single type of panel, Solar Skies employs a flexible manufacturing system that allows them to easily customize the size or design of the panels they produce. Customers or installers can thus order collectors that are built to meet their solar hot water system needs.

In addition, while their factory has only been producing panels since March of 2007, the design for the panels being produced is anything but new. Alternate Energy Technology, one of the top five solar collector manufacturers in the country, has licensed their collector design and manufacturing process to Solar Skies. While the firm has modified the production method to make it more streamlined and adaptable, the collectors being produced and distributed throughout the Midwest are based on a design that has been installed on homes throughout the United States for nearly 30 years.

solar that offer promise in reducing hot water usage. Although not widely adopted in Minnesota, drain-water heat recovery technology can be a very economic means of capturing heat that typically goes down the drain. Drain-water heat recovery systems are very compatible with solar hot water heaters, and can result in even more water savings than just a solar hot water system alone. More information is necessary on this product in order for homeowners to better evaluate if this technology is right for them. Other more well-known conservation efforts, such as hot water heater insulation jackets and high efficiency fixtures, can save considerable energy at low cost as well.

The financial return is best for high hot water usage homes and multi-family buildings

The more hot water used in a household, the more that can be produced by solar. A single-occupant household uses less water than average, and thus has less potential for savings from a solar hot water system. Homes with larger households and multi-family buildings can benefit most from solar hot water systems. Although not investigated in this report, solar thermal can also be attractive for any commercial or institutional building with large hot water loads, such as schools with swimming pools.

Financial return on solar hot water systems can be superior to solar electric systems

With the current cost of solar electric (photovoltaic), solar hot water can offer better financial returns than solar electric. Nonetheless, this return is still not as high as for other energy conservation investments, and is highly dependent upon future prices of natural gas. However, financial return is only one way of evaluating a project, and does not take into account the increased value a solar system can add to a home, or the future value of carbon credits. Solar hot water systems are an attractive option for the homeowner interested in self-generating energy.

Households with electric hot water heaters can most benefit from solar hot water systems

Even at current high natural gas prices, it is still nearly twice as expensive to heat with electric than natural gas. This means the economic return is higher for solar hot water systems that displace electric hot water heaters.

A state incentive for solar would help to further expand solar installations

The state currently promotes solar electric through a state rebate program, which has been very successful in increasing the number of solar electric installations in the state. A similar program could help expand solar thermal installations as well as support local manufacturers of solar thermal panels. An increased volume could in turn help to drive installed costs down and support the sustained growth in the industry. The continuation of the federal tax credit is also currently necessary to support further industry growth.

The best way to save hot water from clothes washing is to wash in cold water, using newer detergents designed for cold-water use.

APPENDIX A:
BACKGROUND ON THE US AND WORLD SOLAR THERMAL INDUSTRY

America's first energy crisis

Although solar thermal systems have been around since the 1700s, they became very prominent in the 1970s and 1980s. In 1974, in partial response to the first OPEC embargo, Congress passed the Solar Heating and Cooling Demonstration Act and the Solar Energy Research, Development and Demonstration Act. With the goal of lessening American's dependence on foreign energy, these laws served to initiate aggressive renewable energy research and development in the United States.

After the second oil crisis of 1977, President Jimmy Carter established a national renewable energy research facility and created four renewable energy centers, located around the country. These renewable energy centers were charged with supporting the commercialization of renewable energy technologies through business education, training, and industry support. Thanks to the work of a consortium of Midwest leaders, including U.S. Senator Hubert Humphrey, Minnesota was chosen as the location for one of the commercialization facilities.

FIGURE 13

Top 20 countries' installed capacity of glazed flat-plate and evacuated tube collectors (2005)[k]

	Total capacity (MW_{th})	Capacity per 1,000 population (kW_{th})
China	52,500	40
Turkey	6,300	86
Japan	4,900	38
Germany	4,656	56
Israel	3,346	498
Greece	2,133	192
Brazil	1,890	10
Austria	1,691	205
United States	1,554	5
Australia	1,192	59
Taiwan	998	42
India	875	1
France	576	9
Spain	558	13
Cyprus	549	657
Italy	362	6
Switzerland	258	36
Denmark	230	42

In 1978, federal legislators passed some significant energy legislation, including a law establishing tax incentives for solar hot water systems. This federal tax incentive was a 40% investment tax credit applicable to individuals and businesses. In 1979 Minnesota augmented this legislation with an additional 20% state tax credit.

Problems within the industry

In response to these incentives, and a new public interest in renewable energy, a huge number of solar hot water manufacturers and installation companies were formed around the country. While the majority of these companies were reliable firms that installed quality systems, there were also a number of businesses that arose solely to take advantage of the new tax credits. They often sold poorly designed collectors that had not been adequately tested and installers often did not install systems correctly. In addition, a lack of monitoring technology on the systems meant many homeowners had no way to ensure that their hot water heaters were functioning properly.

Establishment of standards

To counter these problems, a number of states developed regulatory guidelines for solar thermal manufacturers and installers; however, these regulations were often inconsistent and provided opportunities for tax credits to be misused. As a result, Minnesota worked with California, Florida, New York and Arizona beginning in the fall of 1979 to develop a uniform set of guidelines for the solar thermal industry. This coalition of states eventually became the Interstate Renewable Energy Council (IREC), an organization that continues to work to support renewable energy via education, stakeholder coordination, and workforce development. The IREC orchestrated the establishment of the Solar Rating and Certification Corporation (SRCC). This national certifying organization provides a uniform set of guidelines for the development and installation of solar hot water systems.

Based on these guidelines, Minnesota then developed its own certification program. While similar to the SRCC, it also allowed home built solar hot water systems. This further encouraged the growth of the industry and by 1984 there were approximately 5,000 solar hot water systems installed in Minnesota. The result of these policies led the U.S. to lead the world in solar thermal installations.

However, a lack of support from the Reagan Administration for renewable energy technology development and commercialization meant that by

April of 1982 all of the regional renewable energy centers had been closed. When the federal tax credits for solar thermal systems were allowed to expire without renewal in 1985, the solar hot water industry declined significantly.

Worldwide solar thermal market growth

Today countries like Germany and China lead the world in installed capacity and production. As of 2005, an estimated 86,300 megawatts thermal (MW_{th}) of flat-plate and evacuated tube collectors have been installed worldwide. This represents the equivalent energy output of 86,000 large coal-fired power plants. China currently leads the world in the number of flat-plate and evacuated tube systems; their installed capacity of 52,500 MW_{th} currently accounts for 48% of the world market. Turkey, Japan, Germany, Israel and Greece also boast high solar thermal capacities. In terms of market penetration – installed capacity per 1,000 inhabitants – Cyprus is a world leader, followed by Israel, Austria, Barbados, Greece, Turkey, Australia, Germany, Denmark, Taiwan and finally China.[28]

Worldwide solar thermal capacity is also growing at a rapid rate. China, Australia and New Zealand, and Europe boast the highest annual growth rates: between 1999 and 2005 China's capacity grew an average of 22%, Australia and New Zealand increased by 18% and Europe by 15%. Europe has the most developed and sophisticated market for solar thermal applications and, as a result, solar thermal markets have expanded considerably in a number of countries. Most notable of the European countries are Belgium and the Czech Republic, whose thermal markets have grown at rates of 87% and 83% respectively. In 2005 other nations such as Austria and Germany saw a market growth of 25%, while Italy saw an increase of 22%, and Switzerland a growth of 20%.[29] Besides European markets, only the markets in Tunisia (328%), India (250%), and Mexico (25%) have increased significantly. While China's solar thermal market has historically increased at an annual rate of around 22%, in 2005 the world's largest market grew by only 7%.[30]

Growth in solar thermal installations and a high level of market penetration can often be attributed to forward-thinking policies and government incentives that support these systems. In Israel, for example, all new dwellings and businesses are required to install solar water heaters.[31]

Current US solar thermal market

There were approximately 370,092 medium- and high-temperature domestic systems providing hot water or space heating for residential homes in 2005. In one year these systems produced roughly 1,873 GWh of energy and offset 579,157 tons of CO_2 *(Figure 14)*. In addition, the U.S. has a considerably greater capacity of low-temperature, unglazed, polymer-based solar pool heating systems. However, it is difficult to calculate how much these systems actually displace in fossil energy, as they are often used to increase the length of the outdoor swimming pool season instead of displacing the use of fossil fuels for heating pools.

In recent years, the market in the U.S. has been growing rapidly, nearly doubling between 2005 and 2006 *(Figure 15)*. This has been spurred by a new 30% federal tax credit for residential and business installations. With a solid base of high-quality manufacturers that have survived the lean years, the current growth spurt in the industry can deliver high-quality installations. Sustaining the growth will depend upon the continuation of the federal tax credits, which as of the writing of this report has an uncertain future. As with the tax credits for wind, establishing certainty with federal government policy is important for ensuring sustainable growth within the industry.

Minnesota's solar resources are superior to those of Germany, a country with three times the installed capacity of solar hot water systems as the entire United States.

FIGURE 14

US flat plate and evacuated tube collector statistics (2005)[l]

Total area	*2,220,553 m2*
Total capacity	*1,554 MW_{th}*
Number of systems	*370,092*
Collector yield	*187 GWh/year*
Energy savings – oil equivalent	*212,247,864 liters/year*
CO_2 savings	*579,157 tons/year*

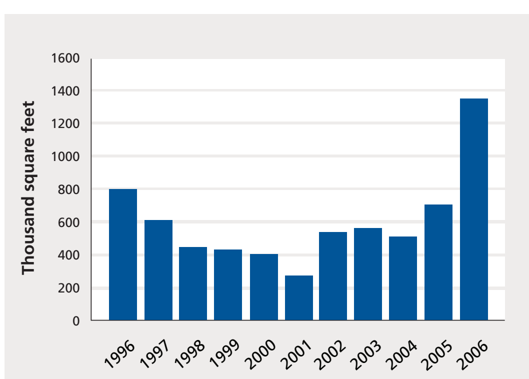


FIGURE 15

U.S. shipments of medium temperature solar thermal panels, 1996-2006[m]

APPENDIX B:
SOLAR PERMITTING IN OTHER STATES

Oregon

As an organization that administers solar programs for 80% of the utility customers in Oregon and works with over 600 contractors, the Oregon Energy Trust has been involved in facilitating solar thermal installation projects in the state. A study by the Trust highlighted the inconsistent permitting requirements between cities and regions in Oregon. Because jurisdictions were found to employ different permit fee assessment methods, they tend to require different documentation and widely varying permitting fees. The average cost of a residential solar thermal permit ranges from $65, for plumbing only costs, to $85 for a flat fee and $303 for a valuation based fee. This inconsistency makes it difficult to plan and bid projects across jurisdictions.[32]

Santa Monica, California

In January 2007, Santa Monica, California launched a city initiative to become energy self-sufficient by 2020. Part of their goal is to become a "net zero" electricity importer, and the city announced a plan to support the installation of 17,500 municipal, business and household solar systems. Santa Monica has waived all permit fees and is working with the city council to have an expedited permitting process approved. Although oriented towards solar, the program has a strong energy efficiency component, and a requirement for program participants is to assess energy efficiency opportunities. When these upgrades are bundled with solar, it can improve the overall return on investment. The city also offers its residents packages that take advantage of pre-negotiated, discounted energy-efficient appliances, solar products and simple financing. Pre-qualified "preferred partners" will then do the installation. The city launched a website to publicize the program: www.solarsantamonica.com.

For communities upstate of Santa Monica in the San Francisco Bay Area, a Sierra Club study found that permit fees can range from $65 to $900. While green development professionals are advocating for state legislation that will standardize permitting, the process is slow and complex because local governments apply different revenue-collection methods in calculating their permit fees.[33]

Chicago, Illinois

Chicago has developed a permitting system meant to reward contractors and residents that incorporate green aspects into construction projects. The city has a Green Permit Department that handles green building projects and a Green Permit Specialist focusing on green building certification and energy who acts as a liaison between the Green Permit Department and contractors. This liaison has been critical in helping to expedite the permit process for green buildings in Chicago. It should be noted that the permitting process in Chicago generally takes much longer than in Minneapolis, St. Paul, and surrounding communities, so there may be less to gain from a streamlined process in Minnesota.

What is also unique about Chicago's program is that single-family homes or 2- and 3-unit buildings are not required to acquire permits for simple domestic solar hot water systems. Customers deal directly with their contractor on the project and are only required to purchase a permit and present plans if the contractor demonstrates that the system requires roof construction or upgrades. To augment this process, the Chicago Center for Green Technology provides support and additional information for homeowners working with contractors. To-date, there have been no reported problems with low-quality installations.

APPENDIX C:

SOLAR THERMAL RESOURCES

Web Resources

Minnesota Department of Commerce. Has a variety of publications on solar and energy efficiency. In addition, they host the Energy Information Center, which has Energy Specialists waiting to answer questions at the phone number below.

651-296-5175 or 800-657-3710 (toll-free)

www.commerce.state.mn.us click on "Energy Information Center"

Hiring a renewable energy dealer: A guide. (Minnesota Department of Commerce) Provides a list of questions homeowners should ask their renewable energy dealer before purchasing a system and describes what a customer should expect throughout the system installation process. Also contains a list of contractors in Minnesota who can install systems.

www.state.mn.us/mn/externalDocs/Commerce/Hiring_a_Renewable_Energy_Dealer_121302010223_How2Hire.pdf

Database of State Incentives for Renewables and Efficiency (DSIRE). Provides information on federal as well as state incentives.

www.dsireusa.org

Solar Energy Industry Association. Produces the outstanding "SEIA Guide to Federal Tax Incentives" with detailed information on how it works. Also has information about solar industry trends and updates on the federal solar energy tax credit.

www.seia.org

Minnesota Renewable Energy Society. Conducts workshops on solar hot water systems, hosts an annual solar homes tour, and has information on solar on their website.

www.mnrenewables.org

Rocky Mountain Institute Home Energy Briefs: Water Heating. Excellent overview of opportunities to save hot water through conservation and guide for choosing a new, efficient hot water heater.

www.rmi.org/sitepages/pid119.php

Books

Solar Water Heating: *A Comprehensive Guide to Solar Water and Space Heating Systems.* This Wisconsin native's excellent book is informed by the author's years as an installer and a workshop leader for the Midwest Renewable Energy Society, of which he is a founding member.
Bob Ramlow, New Society Publishers, 2006 www.newsociety.com/bookid/3916

Solar Hot Water Systems: *Lessons Learned 1977 to Today.* A very practical how-to guide by a long-time solar installer.
Tom Lane, Energy Conservation Services of North Florida, 2004 www.ecs-solar.com

The Solar House: Passive Heating and Cooling. Gives a concise introduction to the concepts of passive solar, as well as other sustainable technologies such as ground source heat pumps (geothermal), pellet stoves, and active solar thermal systems.
Daniel D. Chiras, Chelsea Green Publishing Company, 2002 www.chelseagreen.com

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[2] *www.mnclimatechange.us*

[3] *German Solar Energy Society (DGS). 2005. "Planning and Installing Solar Thermal Systems: A guide for installers, architects and engineers." James & James/Earthscan: London, UK.*

[4] *For a fixed panel installation, installed at latitude tilt. See U.S. DOE, National Renewable Energy Laboratory maps: www.nrel.gov/gis/solar.html#collector*

[5] *Minnesota Department of Commerce (MN DOC). 2006. "Solar Energy Incentives." Minnesota Department of Commerce Energy Information Center. www.state.mn.us/mn/externalDocs/Commerce/Solar_Financial_Incentives_092905091412_solarincentives.pdf Accessed June 6, 2007.*

[6] *A climate without long freeze periods such as Phoenix is suitable for using solar hot water systems that are less expensive (such as a thermosiphon system) than systems that are typically used in freeze-climates such as Minnesota.*

[7] *Weiss, Werner et al. "Solar Heat Worldwide: Markets and Contribution to the Energy Supply 2005." International Energy Agency, Solar Heating and Cooling Programme. April 2007.*

[8] *DENA German Energy Agency. 2006. "The German solar thermal industry." Renewables Made in Germany. www.renewables-made-in-germany.com/en/solar-thermal/. Accessed June 15, 2007.*

[9] *The heat capacity of a given volume of water is over 3,000 times that of the same volume of air (given values of 4.2 & 1.0 joules/g/∝K for specific heat and 1.0 & 0.0013 g/cm3 for density, for water and air respectively).*

[10] *Bob Ramlow (2006) gives an excellent overview of the various types of solar thermal systems (see Appendix for citation).*

[11] *Ramlow, Bob and Benjamin Nusz. 2006. Solar Water Heating: A comprehensive guide to solar water and space heating systems. New Society Printers: Gabriola Island, BC, Canada.*

[12] *Rocky Mountain Institute. "Home Energy Brief #5: Water Heating." 2004. www.rmi.org/sitepages/pid119.php*

[13] *Ibid.*

[14] *J. J. Tomlinson. Buildings Technology Center, Oak Ridge National Laboratory. "GFX Evaluation." 2000. www.eere.energy.gov/buildings/emergingtech/pdfs/gfx_prefindings.pdf*

[15] *Technologies such as absorption chillers can utilize medium or high temperature hot water to produce chilled water. Desiccant cooling systems can be assisted with solar as well. Solargenix Energy, headquartered in Chicago, has designed a solar thermal driven air conditioning system for commercial applications.*

[16] *Minnesota Rules, Chapter 1325.*

[17] *The borrower's guide to financing solar energy systems: a federal overview. www.state.mn.us/mn/externalDocs/Commerce/Financing_Solar_Energy_Systems_121702033111_solarfinancing.pdf*

[18] *Paul, D.D. et al. "Residential Hot Water Usage: A Review of Published Metered Studies." Gas Research Institute. 1994.*

[19] *U.S. DOE Energy Information Administration. "Total Energy Consumption in U.S. Households by Climate Zone, 2001." Residential Energy Consumption Survey. www.eia.doe.gov/emeu/consumption. The average household energy usage for heating hot water is 157 therms for Minnesota's climate zone; it is somewhat more for households heating with natural gas (197 therms) and somewhat less for households heating with electricity (97 therms), although there is some debate over whether households with electric hot water heating actually consume that much less energy (see: Paul, D.D. et al. "Residential Hot Water Usage: A Review of Published Metered Studies." Gas Research Institute. 1994). The author found 197 therms to be somewhat high compared to modeled hot water usage for Minnesota's climate; for example, RETScreen predicts natural gas usage of 172 therms/year for a 3-person household.*

[20] *U.S DOE Energy Information Administration. "Water-Heating Energy Consumption in U.S. Households by Climate Zone, 2001." Residential Energy Consumption Survey. www.eia.doe.gov/emeu/consumption. Average 2006 residential natural gas prices for the Midwest were approximately $1.30/therm (EIA). Current (Oct. 2007) CenterPoint Energy pricing is about $0.85/therm.*

[21] *The software used to estimate output was RETScreen 4.1 (www.retscreen.net) and SolarPro (www.mauisolarsoftware.com).*

[22] *Aldrich found solar production of 78 therms and savings of 96 therms in a Wisconsin 4-person family application (Aldrich, Robb and Gayathri Vijayakumar. "Cost, Design and Performance of Solar Hot Water in Cold-Climate Homes." Solar 2006 conference presentation. American Solar Energy Society.). www.carb-swa.com/Projects/Articles/Solar.pdf*

[23] *$250 operating costs every 10 years, 100 therms/year output, 25+ year system life.*

[24] *U.S. Department of Energy, Energy Information Administration, "Annual Energy Outlook 2007." Pg. 111. 2007.*

[25] *Nevin, Rick, et al., ICF Incorporated. "More Evidence of Rational Market Values for Home Energy Efficiency." The Appraisal Journal. October 1999. $3,000 additional value based upon 115 therms savings per year, at $1.30 per therm, and $20 additional home value per $1 saved, per Nevin's report.*

[26] *The average carbon intensity of electricity in Minnesota is about 1.59 lbs CO_2/kWh (EIA, "Updated State-level Greenhouse Gas Emission Factors for Electricity Generation," 2001), or 465 lbs/MMBtu of useful energy produced at 100% conversion efficiency, while natural gas has a carbon content of about 117 lbs CO_2/MMBtu (NREL, "Power Technologies Energy Data Book," 2006). Thus a typical solar hot water heater will annually avoid 1346 lbs CO_2 if displacing natural gas, and 4278 lbs CO_2 if displacing electric, assuming 92 therms (=9.2 MMBtu) of useful output from the system, or 115 therms of natural gas avoided at 80% efficiency.*

[27] *Based on Green Institute modeling utilizing RETScreen 4.1, comparing 30 degree tilted panels (roughly a 4:12 roof pitch) with 60 degree tilted panels. Depending on the hot water load, a 30 degree or 45 degree panel tilt can actually produce more solar hot water than a 60 degree tilt.*

[28] *Weiss, Werner, Irene Bergmann and Gerhard Faninger. 2007. "Solar Heat Worldwide: Markets and Contributions to the Energy Supply 2005." International Energy Agency Solar Heating and Cooling Programme. www.iea-shc.org/solarenergy/statistics.htm.*

[29] *Hug, Rolf. 2007. "Solar thermal in Europe: expanding markets, better political framework conditions and state-of-the-art technical solutions." The Solarserver: Forum for Solar Energy. www.solarserver.de/solarmagazin/index-e.html.*

[30] *Weiss, Werner, Irene Bergmann and Gerhard Faninger. 2007. "Solar Heat Worldwide: Markets and Contributions to the Energy Supply 2005." International Energy Agency Solar Heating and Cooling Programme. www.iea-shc.org/solarenergy/statistics.htm.*

[31] *Ramlow, Bob and Benjamin Nusz. 2006. "Solar Water Heating: A comprehensive guide to solar water and space heating systems." New Society Printers: Gabriola Island, BC, Canada.*

[32] *Renewable Energy System Permit Fees in Oregon. www.energytrust.org/library/reports/0609 _SolarPermitFees.pdf*

[33] *Solar Electric Permit Fees in the Greater San Francisco Bay Area. lomaprieta.sierraclub.org/global_warming/fee_study.htm*

[34] *Nevin, Rick, et al., ICF Incorporated. "More Evidence of Rational Market Values for Home Energy Efficiency." The Appraisal Journal. October 1999.*

REFERENCES TO FIGURES

[a] *U.S. DOE, National Renewable Energy Laboratory (NREL), June 1, 2007.*

[b] *Modeling was done using RETScreen version 4.0 (www.retscreen.net). Major assumptions included: 3 family household with 180 liter/day hot water usage, inlet water temperatures as predicted by RETScreen, AET-32 collector panels, local climate data used to predict output, panels installed at latitude tilt.*

[c] *Image produced by SunWise Technologies with data compiled from U.S. DOE, NREL and NASA.*

[d] *U.S. DOE, National Renewable Energy Laboratory, National Solar Radiation Data Base 1961-1990 (NSRDB), rredc.nrel.gov/solar/old_data/nsrdb/1961-1990.*

[e] *Image courtesy DOE.*

[f] *Image courtesy DOE.*

[g] *Personal correspondence, Ralph Jacobson, Innovative Power Systems, October, 2007.*

[h] *U.S. DOE, Energy Information Administration, for climate zones with over 7,000 average annual heating degree days.*

[i] *Notes on the assumptions for the scenarios: payback calculations include operating costs over the life of the system; modeling conducted by author confirmed 115 therm output for 3 person household; $8,000 was a typical cost for homeowners in the SE Como pilot project, including additional engineering and structural improvement costs; RETScreen modeling indicated a 5-occupant household and a 1-occupant households would save about 140 therms and 60 therms respectively; $1000 state incentive would reduce the amount of the federal tax credit by $300, as the basis for calculating the tax credit is reduced by other incentives; electric hot water system payback calculation assumes that the electric water heater is 100% efficient compared to 80% efficiency of a natural gas hot water heater, thus only saving 92 therms instead of 115 (115*0.8); solar PV assumes 1286 kWh annual output, per NREL's "PV-WATTS" estimator and no annual operating costs, $9,000 initial costs based on recent installations in Minnesota.*

[j] *Historic prices from U.S. DOE, Energy Information Administration (EIA), projections from EIA, "Annual Energy Outlook 2007," February 2007.*

[k] *Weiss, Werner et al. "Solar Heat Worldwide: Markets and Contribution to the Energy Supply 2005." International Energy Agency, Solar Heating and Cooling Programme. April 2007.*

[l] *Weiss, Werner et al. "Solar Heat Worldwide: Markets and Contribution to the Energy Supply 2005." International Energy Agency, Solar Heating and Cooling Programme. April 2007.*

[m] *U.S. DOE, Energy Information Administration, "Solar Thermal and Photovoltaic Collector Manufacturing Activities 2006", October 2007. Medium temperature collectors include flat plate and evacuated tube.*

ABOUT GREEN INSTITUTE

The Green Institute is a 501(c)3 nonprofit based in Minneapolis, Minnesota. The Institute is dedicated to "sustaining the environment and our communities through practical innovation." Our programs include the ReUse Center and Deconstruction Services, the Phillips Eco-Enterprise Center, Community Energy, and GardenWorks. Recent initiatives include: Minnesota GreenStar, Certified Green Homes and Remodeling, in partnership with the Builders Association of the Twin Cities and the National Association of the Remodeling Industry – Minnesota; and the Metro Clean Energy Resource Teams Network.

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ABOUT THE CLEAN ENERGY RESOURCE TEAMS (CERTS)

The CERTs program is a four-year-old community-based initiative that engages community leaders in determining their energy future by connecting them to technical resources to identify and carry out community scale energy efficiency and renewable energy projects. CERT teams are helping put clean energy projects in place all over Minnesota. The teams themselves are diverse groups of people who all share common goals for their communities' energy future. There are six existing regional teams covering all of Greater Minnesota, and a growing number of smaller, county and city-level teams.

In late 2007 a Twin Cities Metro CERTs Network was formed, coordinated by Green Institute. The Metro CERTs Network will help connect, provide support for, and increase the effectiveness of Metro-area local efforts in conducting community energy planning and implementing community-scale energy efficiency and clean energy projects. The goals of the Metro CERTs Network are to:

- *Create a network to support and encourage collaboration among Twin Cities community-based energy projects and planning efforts*
- *Provide organizing support to help local efforts get off the ground*
- *Connect local efforts with technical resources*
- *Help the state achieve their energy efficiency and renewable energy goals*

www.cleanenergyresourceteams.org