CALSEIA
CALIFORNIA SOLAR ENERGY INDUSTRIES ASSOCIATION

916-747-6987 info@calseia.org
P.O. Box 782, Rio Vista, CA 94571

The Value Proposition of Solar Water Heating In California

Photo credit: Heliodyne, Inc.

January 2009

The California Solar Energy Industries Association (CALSEIA) commissioned this study to analyze and quantify the value of Solar Water Heating. The report to provide data to inform evaluations of solar water heating that are underway at the California Public Utilities Commission, the California Air Resources Board, the California Energy Commission, and local governments. A statewide incentive program was authorized by AB 1470 (Huffman, 2007) to create a new incentive program for solar water heating technologies, specifically (from Section 2862 of the Public Utilities Code):

> "It is in the interest of the State of California to promote solar water heating systems and other technologies that directly reduce demand for natural gas in homes and businesses.
>
> It is the intent of the Legislature to build a mainstream market for solar water heating systems that directly reduces demand for natural gas in homes, businesses, and government buildings. Toward that end, it is the goal of this article to install at least 200,000 solar water heating systems on homes, businesses, and government buildings throughout the state by 2017, thereby lowering prices and creating a self-sufficient market that will sustain itself beyond the life of this program.
>
> It is the intent of the Legislature that the solar water heating system incentives created by the act should be a cost-effective investment by gas customers. Gas customers will recoup the cost of their investment through lower prices as a result of avoiding purchases of natural gas, and benefit from additional system stability and pollution reduction benefits."

The incentive program authorized by AB 1470 is not yet in place, pending an evaluation of a pilot program underway in San Diego, California. The purpose of commissioning this report is to provide information on the value of Solar Water Heating for deliberations underway at the California Public Utilities Commission as it completes its evaluation of the San Diego Solar Water Heating Pilot Program.

Acknowledgements

CALSEIA expresses appreciation to the following California solar companies who contributed funding for this analysis: Aztec Solar, AMECO Solar, Diablo Solar, FAFCO, Heliocol, Heliodyne, Hydronic Specialties Company, Rheem Water Heating, Sierra Pacific Home and Comfort, Solarcraft Services, Sun Earth, Sun Light & Power, Veismann Manufacturing

ABOUT LORI SCHELL

Lori Smith Schell, Ph.D., serves as President of Empowered Energy. Dr. Schell has over 20 years of experience in the energy industry, including policy analysis work done at the U.S. Department of Energy and Los Alamos National Laboratory.

Prior to founding Empowered Energy, Dr. Schell was the Director of Energy Risk Management for Trigen Energy Corporation, a leading provider of district heating systems and energy-efficient combined heat and power solutions for large industrial firms, universities, governmental agencies, and municipalities. In this role, Dr. Schell orchestrated the hedging of electricity sales and natural gas purchases for Trigen's three dozen operating units, supported by in-depth commodity market analysis and commodity contract oversight. Aggregating Trigen's emissions allowances into a corporate portfolio, Dr. Schell negotiated and set the peak market price for vintage 2003/2003 NOx emissions allowances. Dr. Schell also represented Trigen on the Board of Directors of the Independent Power Producers of New York, Inc. (IPPNY).

Dr. Schell earlier served as the Manager of Regulatory Affairs & Market Analysis for Air Products and Chemicals, Inc., a Fortune 300 global producer of industrial gases and chemicals. While at Air Products, Dr. Schell provided expert witness testimony in numerous natural gas pipeline proceedings at the Federal Energy Regulatory Commission (FERC), on behalf of a coalition of up to nine industrial natural gas end-users. Dr. Schell filed testimony opposing the first major natural gas pipeline to file for market-based rates, on the basis of inadequate market analysis and lack of adherence to FERC policy guidelines.

Dr. Schell received a Ph.D. in Mineral Economics and Operations Research from the Pennsylvania State University and a B.A. in Economics from the University of Washington. After completing her Ph.D., Dr. Schell joined Benjamin Schlesinger and Associates, Inc., where she provided contractual, regulatory, and deliverability risk evaluation for a dozen project-financed natural gas-fired cogeneration projects.

ABOUT CALSEIA

The California Solar Energy Industries Association supports the expanded use of all solar technologies, including residential, large-scale solar projects, and solar generation within a community (sometimes called distributed generation). Solar technologies include solar thermal, solar electric, and solar pool heating. Each of these technologies contribute to reducing demand for natural gas and electricity, reduce pollution in the community, and contribute to reducing greenhouse gas emissions. The solar industry is also creating new opportunities for jobs at all skill levels for a variety of jobs: administration, financing, installation, inventory/warehouse, etc. CALSEIA was founded in 1977 and has participated in the formation and implementation of California solar policy since that time. California is a California non-profit corporation.

Table of Contents

List of Figures

List of Tables

The Value Proposition of Solar Water Heating in California: Description of Methodology

January 2009

I. INTRODUCTION

National and California-specific statistics emphasize the significant amount of energy used for the simple task of heating water. In 2006, water heaters accounted for 15% of residential energy use in the United State, consuming 111 billion kWh of electricity, over 1 trillion cubic feet of natural gas, 725 million gallons of fuel oil, and 700 million gallons of liquefied petroleum gas.[1] In California, approximately 85% of water heating is provided by natural gas, with the balance provided predominantly by electricity.[2] Natural gas used for water heating accounts for 38% of the 5,000 million therms of residential natural gas consumed each year in California by customers of the major investor-owned utilities ("IOUs"); electric water heating accounts for 6% of total residential electricity consumption by customers of the major IOUs in California.[3]

Solar water heating systems use the sun to provide a portion of the total hot water requirement for residential and commercial customers, reducing the quantity of natural gas (or electricity) used to heat water.[4] The benefits quantified in this analysis assume that the solar water heating system is displacing hot water that would otherwise be provided by a natural gas-fired water heater; additional benefits would result if electric or propane water heaters were to be included in the analysis.

The purpose of this analysis is to expand on previous analyses of solar water heating ("SWH") that have derived the benefits of SWH solely in terms of natural gas savings. The present analysis takes a more comprehensive approach by quantifying the value of SWH in terms of: (i) Direct natural gas savings from SWH vs. indirect natural gas savings due to avoided natural gas-fired water heater efficiency losses; (ii) the value of SWH as a price hedge against natural gas price volatility; (iii) avoided natural gas-related emissions and associated health benefits; (iv) avoided natural gas distribution-related losses; (v) avoided or deferred natural gas distribution capacity; and, (vi) job

---

[1] U.S. Department of Energy, June 2008, Table A4 (pp. 122-123) and Table G1 (p. 215). Note that swimming pools are not included in these consumption statistics; swimming pools are included in the "Appliance" end-use category rather than in the "water heating" end-use category. *See* Residential Energy Consumption Survey Glossary, http://www.eia.doe.gov/emeu/recs/glossary.html.

[2] Denholm, p. 3.

[3] KEMA-XENERGY, April 2003(a), p. 2-16 (natural gas) and p. 2-7 (electricity).

[4] Information about the different types of solar water heaters and their operations are provided in Appendix A.

creation potential. All values quantified in this analysis are stated in terms of cents per therm ("cents/therm") of SWH provided, with separate values calculated for commercial and residential SWH systems.

This analysis quantifies the benefits of SWH to California *today* as 111-345 cents/therm of SWH for commercial installations and 94-285 cents/therm of SWH for residential installations, without including the future benefits related to reduced reliance on natural gas imports, increased energy security, and the impact of ever-declining natural gas use on natural gas and electricity prices.[5] The quantified benefits related to displacing a natural gas-fired water heater include natural gas savings, avoided emissions (and related health benefits), and job creation potential, among others, and are expected to increase over time with increasing natural gas prices and SWH penetration levels. Some of the quantified benefits are based on transparent market prices (*e.g.*, of natural gas), and some are based on values derived from the literature (*e.g.*, health benefits). The analysis assumes private investment in water heaters, with benefits that accrue to all Californians.

The results of the SWH analysis are summarized in the "waterfall" charts in Figure 1 (commercial installations) and Figure 2 (residential installations).

[5] Although these attributes of SWH clearly provide additional value, the value of these attributes have not been quantified as part of this analysis.

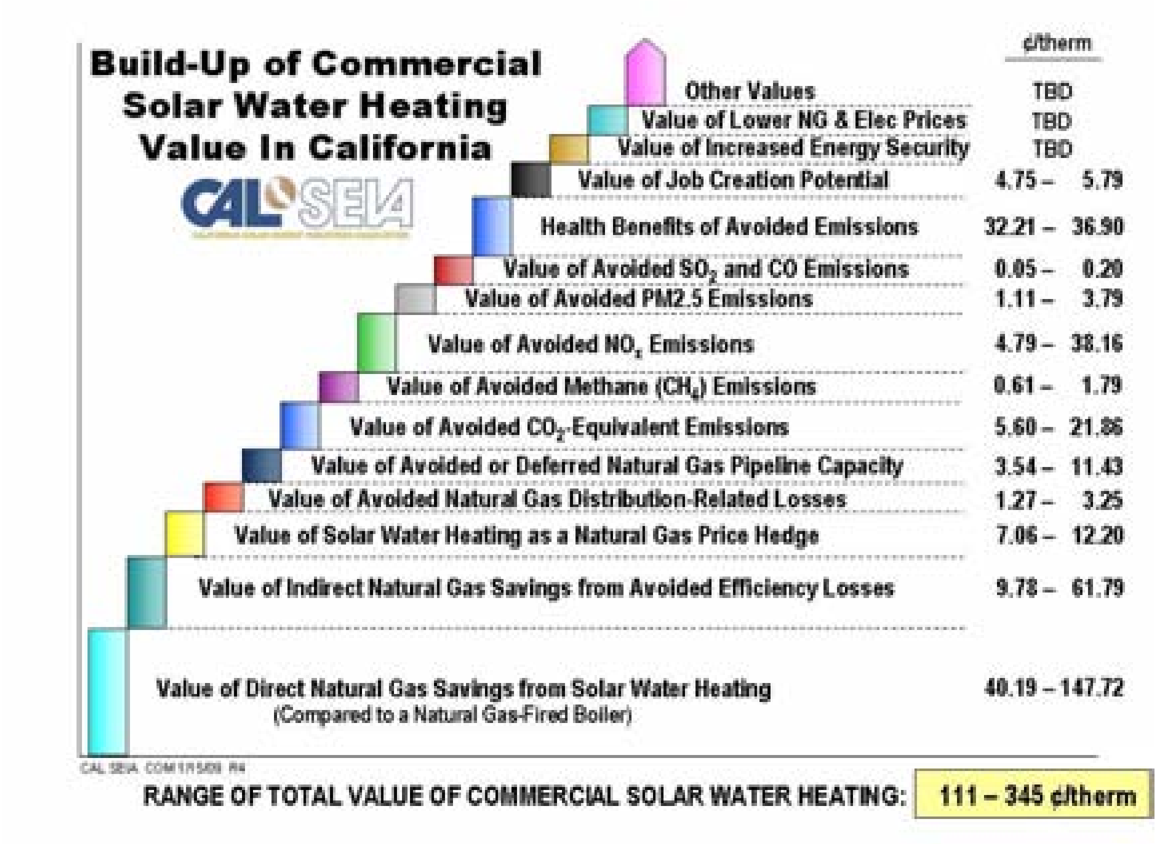


Figure 1. Build-Up of Commercial Solar Water Heating Value in California

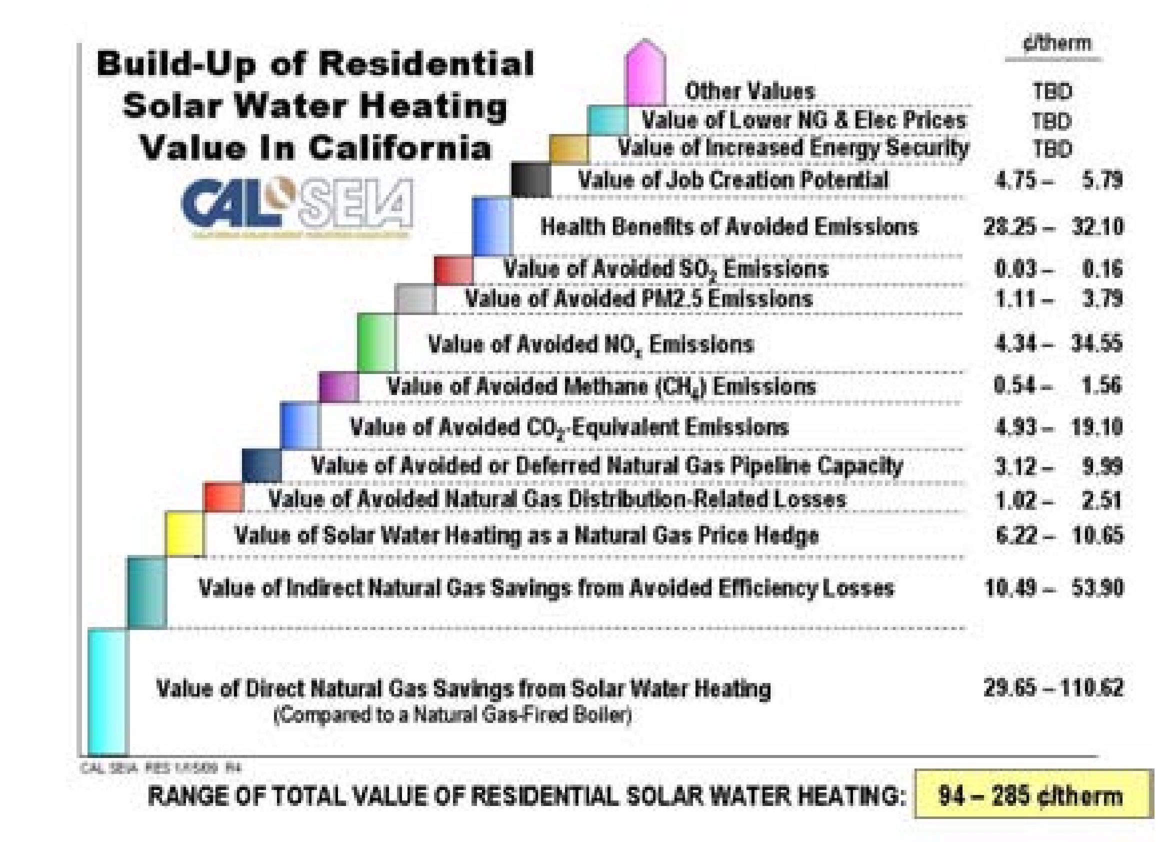


Figure 2. Build-Up of Residential Solar Water Heating Value in California

II. SOLAR WATER HEATING VALUE ELEMENTS

A. Value of Avoided Natural Gas Use

1. Water Heating Provided Directly by SWH

a. Residential Solar Water Heating Systems

For the purposes of this analysis, typical residential hot water usage is assumed to be 41,045 Btu per day, to ensure consistency with standard SWH rating conditions.[6] SWH system is assumed to have a solar collector of 40 square feet (“ft^2”).[7] The solar collector is assumed to generate 1,000 Btu of hot water per square foot per day (“Btu/ft^2-

[6] Standards for SWH systems are set by the Solar Rating and Certification Corporation (“SRCC”). The SRCC has a SWH rating and certification program for both residential and commercial SWH systems. *See* SRCC, June 16, 2008, and SRCC, December 5, 2008, for additional details.

[7] “A typical residential SWH system occupies about 40-64 ft^2 of roof space” (Denholm, p. 8). The lower square footage is used in this analysis because the resultant SWH production rate approximates the assumptions used by the California Air Resources Board (as discussed below).

day”). Over the course of a year, therefore, the SWH system would generate about 146 therms of hot water.[8] This compares to the approximately 183-206 therms per year of natural gas used by conventional natural gas-fired water heaters in a typical California home.[9]

Assuming no SWH system losses, the 146 therms per year of solar-heated water would directly displace 146 therms of hot water that would otherwise come from a natural gas-fired water heater. However, the efficiency losses inherent in the natural gas-fired water heater must be taken into consideration in determining the actual annual natural gas savings. Simply put, if the natural gas water heater had an energy efficiency of 60%, the 146 therms of solar-heated water would save over 240 therms of natural gas (*i.e.*, 146 therms of natural gas-fired hot water displaced/0.60 efficiency of the natural gas-fired water heater). Thus, the SWH system yields natural gas savings in two ways: (i) Directly, from the hot water generated by the SWH system that would otherwise have come from natural gas-fired water heating; and, (ii) indirectly, from the avoided efficiency losses associated with the displaced hot water from the natural gas-fired water heater.

In reality, determining the direct and indirect natural gas savings attributable to the SWH system is more complicated than the simple example given above. The SWH system requires an auxiliary natural gas-fired water heater and may require energy for its own operation, both of which reduce the net natural gas savings attributable to the SWH system. The Solar Energy Factor (“SEF”) is a metric that measures the output of a SWH system as a multiple of its total energy input (*i.e.*, energy used by the auxiliary natural-gas fired water heater + energy used by the SWH system).[10] A SEF of 2.00, therefore, indicates that the energy output of the SWH system is double that of the (non-solar) energy input to the system. All else equal, a higher efficiency natural gas-fired water heater will result in a higher SEF because the energy input required by the auxiliary water heater is lower. For the same reason, however, the total natural gas savings attributable to the SWH system will also be lower.

The SEF and resultant natural gas savings for a residential SWH system that displaces hot water provided by two natural gas-fired water heaters having different efficiencies are summarized in the table below:

---

[8] The calculation is 40 ft^2 x 1,000 Btu/ft^2-day x 365 days/year x (1 therm/100,000 Btu) = 146 therms/year of solar-heated water generated.

[9] California Energy Commission, June 2004, p. 22 (excluding swimming pools).

[10] The Solar Fraction is another common metric that identifies what proportion of the total hot water load is provided using solar energy. Starting on January 1, 2009, residential SWH systems must have a Solar Fraction of 0.50 and be certified by the SRCC in order to carry the ENERGY STAR® label. For additional information, go to http://www.energystar.gov/index.cfm?c=new_specs.water_heaters .

Table 1. Examples of Natural Gas Savings from Residential SWH[11]		
	Case 1	Case 2
Natural Gas-Fired Water Heater Efficiency	0.60	0.67
Solar Energy Factor	2.00	2.15
Total Natural Gas Savings (therms/year)	175	154
Direct Natural Gas Savings (therms/year)	105	103
Indirect Natural Gas Savings (therms/year)	70	51
Natural Gas Therms Saved per Therm of SWH	1.20	1.05

The range of values illustrated in Figure 2 reflects the 60-67% range of natural gas-fired water heater efficiencies shown above, as well as the range of natural gas and emissions prices discussed below.

b. Commercial Solar Water Heating Systems

Commercial SWH systems range in size from 500 ft^2 to 50,000 ft^2.[12] For the purposes of this analysis, a commercial SWH system with a 500 ft^2 collector is assumed to displace hot water generated from a small (Type 1) natural gas-fired boiler. Using similar assumptions to those that were used for the residential SWH system, the commercial SWH system will generate 2,281 therms per year of hot water.[13] The same type of calculations discussed above must also be applied to calculate the natural gas savings attributable to the commercial SWH system.

Effective January 1, 1994, the minimum thermal efficiency of a small natural gas-fired boiler in California was raised to 80%.[14] Eighty percent is therefore used as the high end of the efficiency range for small natural gas boilers, with the low end of the range assumed to be 70% for pre-existing boilers. Taking into account the related efficiency loss and the energy required to run the SWH system yields the following results:

---

11 The 67% efficiency used in Case 2 became the federal standard for small natural gas-fired storage-type water heaters effective January 20, 2004. *See* California Energy Commission, December 2007, p. 89.

12 Navigant Consulting, p. 40.

13 The calculation is 500 ft^2 x 1,000 Btu/ft^2-day x 365 days/year x (1 therm/100,000 Btu) x1.25 output gain (due to daytime use, higher system utilization, and smaller SWH system size relative to load) = 2,281 therms/year of solar-heated water generated.

14 California Energy Commission, December 2007, p. 88.

Table 2. Examples of Natural Gas Savings from Commercial SWH		
	Case 1	Case 2
Natural Gas-Fired Boiler Efficiency	0.70	0.80
Solar Energy Factor	4.25	4.80
Total Natural Gas Savings (therms/year)	3,126	2,728
Direct Natural Gas Savings (therms/year)	2,188	2,183
Indirect Natural Gas Savings (therms/year)	938	546
Natural Gas Therms Saved per Therm of SWH	1.37	1.20

Thus, hot water generated by the commercial SWH systems would directly save nearly 2,200 therms per year of natural gas plus an additional 546-938 therms per year indirectly by avoiding the efficiency losses that would occur if those nearly 2,200 therms had been generated by the natural gas-fired boiler. The range of values illustrated in Figure 1 reflects the 70-80% range of natural gas-fired boiler efficiencies shown above, as well as the range of natural gas and emissions prices discussed below.

c. Direct vs. Indirect Natural Gas Savings from SWH

The value of the natural gas savings from SWH systems dominates the build-up of SWH value in California, in part because of the tremendous swings in natural gas prices over the past several years. The value of natural gas savings from SWH systems is calculated using a price range of $4.20-$15.40/MMBtu of avoided natural gas, which represents the actual range of natural gas futures prices on the New York Mercantile Exchange ("NYMEX") over the past three years. The NYMEX natural gas futures price is the main pricing reference for natural gas prices in the United States, with regional natural gas prices typically tied to the NYMEX price (at an onshore Louisiana location) plus or minus a transportation cost adjustment. In this analysis, no transportation cost adjustment has been made because this so-called "basis difference" is itself highly volatile, at times being positive and at times being negative between the NYMEX pricing point and the California border.

The NYMEX natural gas futures price provides the Value of Direct Natural Gas Savings from SWH because it represents the fuel cost associated with the displaced hot water from the natural gas-fired water heater or boiler. Converting the NYMEX natural gas futures price range of $4.20-$15.40/MMBtu into cents/therm of SWH requires grossing up the natural gas price by the ratio of natural gas therms saved per therm of SWH, as identified in Table 1 and Table 2 (above). This conversion yields a range of Value of Direct Natural Gas Savings from SWH of 40.19-147.72 cents/therm of SWH for commercial SWH systems and 29.65-110.62 cents/therm of SWH for residential SWH systems.

The Value of Indirect Natural Gas Savings from Avoided Efficiency Losses is calculated as a separate value component and is based on the therms of natural gas lost per therm of hot water generated by the natural gas-fired water heater or boiler, valued over the NYMEX natural gas futures price range. As discussed above, the efficiency range for a residential natural gas-fired water heater is assumed to be 60-67% as compared to 70-80% efficiency for a small commercial natural gas-fired boiler. The resulting range of Value of Indirect Natural Gas Savings from Avoided Efficiency Losses is 9.78-61.79 cents/therm of SWH for commercial SWH systems and 10.49-53.90 cents/therm of SWH for residential SWH systems.

d. Natural Gas Price Hedge Value of SWH

Natural gas futures prices are notoriously volatile, as reflected in the $4.20-$15.40/MMBtu range of NYMEX prices over the past three years. Since solar energy as a fuel source is cost-free, SWH systems provide a natural hedge that allows customers to avoid natural gas price volatility for each SWH therm generated. Customers have greater ability to meet established household or commercial budgets because of the fuel price hedge value provided by SWH systems.

Additional value is attributed to SWH due to its cost-free fuel source that allows its customers to avoid the volatility in natural gas prices. Solar-derived energy acts as a hedge against volatile natural gas prices. The value of this hedge is based on the market premium that one would pay to obtain fixed-price natural gas supplies over the long term, which is a more traditional means of smoothing out the volatility in natural gas prices.

This size of the market premium required to "lock in" fixed natural gas prices depends on long-term natural gas price forecasts and on how volatile natural gas prices are in the shorter term. Based on past market studies, the Value of Solar Water Heating as a Natural Gas Price Hedge is calculated to be 7.06-12.20 cents/therm of SWH for commercial SWH systems and 6.22-10.65 cents/therm of SWH for residential SWH systems.[15]

2. SWH Natural Gas Savings in the "Climate Change Proposed Scoping Plan"

In October 2008, the California Air Resources Board ("ARB") issued its "Climate Change Proposed Scoping Plan," pursuant to the provisions of AB 32, The California Global Warming Solutions Act of 2006 ("AB32 Proposed Scoping Plan").[16] Solar Water Heating is included in the AB32 Proposed Scoping Plan as a natural gas energy efficiency measure, with the following state-wide projections for 2020:

[15] Bolinger and Wiser, January 7, 2008, p.8, estimated the hedge value to be 59-89 cents/MMBtu of natural gas, similar to estimates made in their previous analyses. *See*, for instance, Bolinger, *et al.*, January 2004, p. 8, where the estimated hedge value was 50-80 cents/MMBtu.

[16] The ARB approved the AB 32 Proposed Scoping Plan on December 11, 2008, with limited modifications; the modifications did not affect the SWH provisions discussed herein.

- 200,000 SWH installations (residential and commercial)[17]
- 130 therms per year of natural gas saved each year per SWH installation
- 26 million therms of residential natural gas use saved each year
- 0.14 million metric tons of CO_2-equivalent emissions avoided[18]
- 0.3 tons per day of NO_x emissions avoided
- 0.03 tons per day of PM2.5 emissions avoided.[19]

The 200,000 SWH installations assumed in the AB 32 Proposed Scoping Plan reflects the statewide 2017 goal for SWH installations established in AB 1470, the Solar Hot Water and Efficiency Act of 2007.

The AB 32 Proposed Scoping Plan does not incorporate the expanded SWH measure that was being considered in the June 2008 draft version ("AB32 Draft Scoping Plan"). The expanded SWH measure envisioned 1.75 million SWH installations in California by 2020, 1 million in newly constructed homes and 750,000 retrofits. The 1 million SWH installations in new homes would have resulted from a policy mandating SWH in 5% of new homes by 2010 and in 75% of new homes by 2020.[20] Such an expanded SWH measure was projected to save 1.2 billion therms per year of natural gas while avoiding 1 million metric tons of CO_2-equivalent emissions per year, 3 tons per day of NO_x emissions, and 0.3 tons per day of PM2.5 emissions.[21]

3. Relative Size of 2020 SWH Penetration in AB 32 Proposed Scoping Plan

KEMA-XENERGY, Inc. did several studies estimating the technical potential for SWH in California to displace natural gas by 2011 in both residential and commercial markets. Technical potential is usually defined as "the *complete* penetration of all measures analyzed in applications where they are deemed *technically* feasible from an *engineering* perspective."[22] As such, technical potential represents an upper bound on natural gas displacement by SWH, which would subsequently be winnowed down based on economic potential, maximum achievable potential, program potential, and naturally occurring potential.[23] The KEMA-XENERGY studies, however, only estimate the (maximum) technical potential.

---

17 Although the AB 32 Proposed Scoping Plan references both residential and commercial SWH installations, the 130 therms per year of natural gas saved each year per SWH installation clearly reflects the natural gas savings from a residential SWH system.

18 California Air Resources Board, October 2008(c), pp. I-25 – I-26.

19 California Air Resources Board, October 2008(a), p. 88.

20 California Air Resources Board, June 2008(a), pp. C-69 – C-70.

21 California Air Resources Board, June 2008(b), p. A-29.

22 KEMA-XENERGY, April 2003(a), p. 1-4.

23 KEMA-XENERGY, April 2003(a), p. 1-5.

- For the residential market, KEMA-XENERGY estimated a technical potential for SWH to displace 971 million therms of natural gas in single-family homes with natural gas-fired water heaters and another 22 million therms of natural gas in multi-family residences having a natural gas-fired boiler.[24]

- For the commercial market, KEMA-XENERGY estimated a technical potential for SWH to displace 219 million therms of natural gas in hotels, schools, hospitals, offices, hotels, warehouses, hospitals, restaurants, food stores, retail establishments, and other commercial entities.[25]

- Combining the residential and commercial markets, the KEMA-XENERGY studies estimate that SWH has the technical potential to displace up to 1,212 million therms of natural gas per year in California.

Thus, it can be seen that the 26 million therms per year of projected residential natural gas savings from the SWH measure included in the AB 32 Proposed Scoping Plan is a conservative estimate that represents less than 2% of the combined residential and commercial market technical potential for SWH estimated by KEMA-XENERGY; even the expanded SWH measure that was being considered in the AB32 Draft Scoping Plan represented only about 10% of the total technical potential natural displacement for SWH in California.

B. Value of Avoided Emissions

1. SWH Avoided Emissions in the AB 32 Proposed Scoping Plan

The AB 32 Proposed Scoping Plan calculates total annual avoided emissions attributable to SWH for CO_2, NO_x, and PM2.5 in 2020, assuming 200,000 SWH systems are installed in California by that time. This analysis relies on the underlying emissions rates in the AB 32 Proposed Scoping Plan for each of those avoided pollutants in order to calculate the physical units of avoided emissions attributable to each therm of hot water from the SWH installation. The physical units of avoided emissions per therm of SWH are then valued at a specified emissions allowance price to determine the value of each type of avoided emissions per therm of SWH. Industry emissions rates of SO_2 for natural gas water heaters and of SO_2 and CO for natural gas boilers are used to value the avoided SO_2 and CO emissions for SWH. Note that each of the avoided emissions identified in this analysis is related to the fact that less natural gas is combusted by the natural gas-fired water heater or boiler because of the hot water generated by the SWH.

---

24 KEMA-XENERGY, April 2003(b), Appendix G: Non-Additive Measure-Level Results – Natural Gas.

25 KEMA-XENERGY, May 14, 2003, Appendix D: Non-Additive Measure-Level Results.

2. Value of Avoided CO_2 Emissions

The AB 32 Proposed Scoping Plan estimates that the 200,000 SWH systems in California in 2020 will result in a reduction of 0.14 million metric tons of CO_2-equivalents ("$MMTCO_2E$") per year. This number is derived based on:

- An assumed 130 therms per year of natural gas savings per SWH system.
- A residential/commercial emissions rate of 5.3156×10^{-4} $MMTCO_2E/MMBtu$ of natural gas combusted, which is equal to the standard emissions rate of 117 lb/MMBtu of natural gas combusted. Converting the CO_2-equivalent emissions rate to lb/therm (1 MMBtu = 10 therms) yields a CO_2-equivalent emissions rate of 11.7 lb/therm of natural gas combusted.

As discussed previously, each residential SWH therm avoids the need for 1.05-1.20 therms of natural gas, depending on the efficiency (60-67%) of the natural gas-fired water heater that would otherwise provide the hot water. Similarly, each commercial SWH therm avoids the need for 1.20-1.37 therms of natural gas, assuming 70-80% efficiency for a small natural gas-fired boiler. These ranges of natural gas savings per therm of SWH result in avoided emissions of CO_2-equivalent emissions of 13.99-16.03 lb per therm of SWH for commercial SWH systems and 12.33-14.01 lb per therm of SWH for residential SWH systems.

The "price" range for CO_2-equivalent emissions is assumed to be $8-$27.27/ton. The lower end of the range is based on the carbon penalty imposed by the California Energy Commission in its energy procurement proceedings. The upper end of the range is based on the equivalent of $100/ton of carbon, a carbon price often discussed in the literature.[26] Based on this price range for CO_2-equivalents, the Value of Avoided CO_2-Equivalent Emissions for SWH is 5.60-21.86 cents/therm of SWH for commercial SWH systems and 4.93-19.10 cents/therm of SWH for residential SWH systems.

3. Value of Avoided NO_x Emissions

The AB 32 Proposed Scoping Plan estimates that the 200,000 SWH systems in California in 2020 will result in a reduction of 0.3 tons per day of NO_x emissions, based on the AB 32 Proposed Scoping Plan's assumed 130 therms of natural gas savings per residential SWH system. Using the 130 therms of natural gas savings per year solely to derive the underlying NO_x emissions rate for a residential natural gas-fired water heater, that emissions rate can be determined to be 0.0842 pounds/MMBtu of natural gas-fired hot water output. Recall that each residential SWH therm of hot water results in 1.05-1.20 therms of natural gas savings, with an associated reduction in NO_x emissions of 0.004 lb/day and 0.0035 lb/day per SWH therm, respectively.

---

[26] *See* Duke, *et al.*, 2004, p. 9.

The NO_x emissions rate for a small natural gas-fired boiler is set at 0.093 pounds/MMBtu of hot water output, based on the limit set by several California pollution control districts.[27] Recall that each commercial SWH therm of hot water results in 1.20-1.37 therms of natural gas savings, with an associated reduction in NO_x emissions of 0.07 lb/day and 0.08 lb/day per SWH therm, respectively.

Valuing the range of avoided NO_x emissions at a California NO_x Emissions Reduction Credit ("ERC") price range of $47,000-$374,384/pound/day,[28] the Value of Avoided NO_x Emissions is 4.79-38.16 cents per SWH therm for commercial SWH systems and 4.34-34.55 cents per SWH therm for residential SWH systems.

4. Value of Avoided PM2.5 Emissions

The AB 32 Proposed Scoping Plan estimates that the 200,000 SWH systems in California in 2020 will result in a reduction of 0.03 tons per day of PM2.5 emissions, which is one-tenth the size of the reduction in NO_x emissions. Therefore, the underlying PM2.5 emissions rate for a residential natural gas-fired hot water heater can be determined to be 0.00842 pounds/MMBtu of hot water output, one-tenth of the NO_x emissions rate. Lacking any additional information, this PM2.5 emissions rate is also (conservatively) used for the small natural gas-fired boiler.

There is not yet a market for PM2.5 emissions allowances in California. Therefore, the avoided PM2.5 emissions have been valued at the California PM10 ERC price of $120,000-$410,959/pound/day, which likely understates the value, given the more insidious health-related effects of PM2.5 as compared to PM10. Using this range of PM10 ERC prices, the Value of Avoided PM2.5 Emissions is 1.10-3.79 cents/therm of SWH for both residential and commercial SWH systems.[29]

5. Value of Avoided SO_2 Emissions

The SO_2 emissions rate for a natural gas-fired water heater is estimated to be 0.00059 pounds/MMBtu of natural gas combusted.[30] As was the case for PM2.5

---

[27] *See*, for instance, Ventura County Air Pollution Control District, p. 4308-2; South Coast Air Quality Management District, p. 1146.2-3; and San Joaquin Valley Unified Air Pollution Control District, p. RULE 74.11:1.

[28] All emissions prices used in this analysis are based on Market Price Index ranges reported online by CantorCO2e Environmental Brokerage. For consistency, the ERC prices referenced in this analysis have all been converted to $/lb/day, though some are reported in terms of $/ton/year; ERCs are purchased once and apply for the life of the project.

[29] The Value of Avoided PM2.5 Emissions is the same in cents/therm of SWH for both residential and commercial SWH systems because (i) the assumed emissions rate for both applications is the same and (ii) the natural gas savings per therm of SWH for each application is used in both the numerator and the denominator of the calculation, thereby cancelling itself out. The same effect is evident for the same reasons in the Value of Avoided SO_2 Emissions.

[30] American Gas Association, December 2001, p. 18.

emissions, the SO_2 emissions rate for a natural gas-fired water heater is also used for the natural gas-fired boiler. The Value of Avoided SO_2 Emissions of 0.03-0.16 cents per SWH therm is based on the California ERC price range for SO_2 of $40,275-$244,751/pound/day for both residential and commercial SWH systems.

6. Value of Avoided CO Emissions

The CO emissions rate for a natural gas-fired boiler is estimated to be 0.0044 pounds/MMBtu of hot water output; CO emissions from a natural gas-fired hot water heater are assumed to be negligible since no associated CO emissions rate was found in the literature. The Value of Avoided CO Emissions for commercial SWH systems of 0.02-0.04 cents/therm of SWH is based on the California ERC price range for CO of $4,214-$8,337/pound/day.

C. Value of In-State Health Benefits due to Avoided Emissions

The health benefits of reduced NO_x and SO_2 are based on an extensive study of reduced emissions in the power plant sector by Abt Associates. Using California-specific health benefits estimates and California power plant emissions data, an in-state health benefits value of 1.32 cents per pound of avoided NO_x and SO_2 in California was derived. This value was multiplied by the calculated annual pounds of avoided NO_x and SO_2 due to SWH to arrive at a range of value of 1.48-1.70 cents/therm of SWH for commercial SWH systems and 1.18-1.34 cents/therm of SWH for residential SWH systems.

The health benefits of PM2.5 are significantly higher than those of NO_x and SO_2, given the significant health damage that can occur from PM2.5 particles lodging deep in the lungs. The in-state health benefits of avoided PM2.5 of 30.73-38.16 cents/therm of SWH from commercial systems and 27.07-30.76 cents/therm of SWH from residential systems are derived from California-specific calculations of the health-related economic value of reducing PM2.5 emissions.[31]

By combining the in-state health benefits of reduced NO_x and SO_2 emissions with the in-state health benefits of reduced PM2.5 emissions attributable to direct and indirect natural gas savings from SWH, the total range of Value of Health Benefits of Avoided Emissions is calculated as 32.21-36.90 cents/therm of SWH from commercial systems and 28.25-32.10 cents/therm of SWH from residential systems.

D. Value of Avoided (or Deferred) Natural Gas Pipeline Capacity

The natural gas savings associated with SWH will increase in direct proportion to the number of SWH systems installed across the state. The natural gas savings will

---

[31] *See* Hall, *et al.*, 2006; California Environmental Protection Agency and California Air Resources Board, May 12, 2002, May 31, 2003, and March 21, 2006.

ultimately result in a reduced need for new natural gas transmission and distribution facilities, or at the least in a deferment of new investment.

The Value of Avoided (or Deferred) Natural Gas Pipeline Capacity is based on the avoided cost analysis done by Energy and Environmental Analysis, Inc. ("E3") for the California Public Utilities Commission ("CPUC").[32]

- The range of values is based on the range of "Gas Transportation Marginal Costs" in 2008 for Pacific Gas and Electric Company, Southern California Gas Company, and San Diego Gas & Electric Company in the E3 avoided cost analysis.

- The range of "Gas Transportation Marginal Costs" is discounted by 50% to reflect the statistical capacity value of the natural gas savings attributable to SWH.

- The range of "Gas Transportation Marginal Costs" is adjusted to reflect the therms of natural gas savings per SWH therm associated with SWH displacing hot water from either a residential natural gas-fired water heater or commercial natural gas-fired boiler.

The resultant range of the Value of Avoided (or Deferred) Natural Gas Pipeline Capacity is 3.54-11.43 cents/therm of SWH from a commercial system and 3.12-9.99 cents/therm of SWH from a residential system.

1. Value of Avoided Natural Gas Distribution-Related Losses

Natural gas distribution results in a certain percentage of the natural gas being lost or unaccounted for ("LAUF"). In the E3 avoided cost analysis, this percentage ranges from 1.40% to 2.41% for the three California (natural gas) IOUs. Weighting each utility's LAUF percentage by its combined core residential and core commercial natural gas deliveries results in a weighted average LAUF percentage for the three IOUs of 1.76%. Natural gas savings are grossed up by this LAUF, resulting in a range of Value of Avoided Natural Gas Distribution-Related Losses of 1.27-3.25 cents/therm of SWH from commercial systems and 1.02-2.51 cents/therm of SWH from residential systems.

2. Value of Avoided Methane (CH_4) Emissions

The Value of Avoided Natural Gas Distribution-Related Losses is based on the "lost" market value of that percentage of natural gas that the IOUs recognize in their natural gas tariff rates. The 1.76% weighted average LAUF percentage for the IOUs is very similar to the estimated 1.4% of gross natural gas production that is lost to the atmosphere as fugitive emissions during natural gas "extracting, processing, transmitting,

---

32 Energy and Environmental Analysis, Inc., March 20, 2006 (Microsoft Excel workbook), and October 25, 2004, pp. 116-123.

storing, and distributing."[33] Natural gas is 75-95% methane[34] and methane "is 21 times as potent as CO_2 as a global warming pollutant."[35] Avoiding natural gas use avoids the associated fugitive methane emissions, which contributes an additional value of 0.61-1.79 cents/therm of SWH from a commercial system and 0.54-1.56 cents/therm of SWH from a residential system.

E. Value of Job Creation Potential

The base case Value of Job Creation Potential of 4.75-5.79 cents/therm of SWH in Figure 1 and Figure 2 is calculated based solely on the cost of installing and maintaining medium-temperature SWH systems in California, assuming increased market penetration through 2020. The Value of Job Creation directly reflects the benefits of increased in-state employment due to SWH system installations that avoid natural gas use. The Aggregate annual installations of both residential and commercial SWH systems are estimated through 2020 based on the following assumptions:

- Total square feet of medium-temperature SWH collectors installed in the U.S. is based on the U.S. Department of Energy's cumulative "Annual Shipments of Solar Thermal Collectors by Type" from 1998-2007.[36]

- The annual growth in medium-temperature SWH collectors in the U.S. through 2016 is as estimated by Navigant Consulting;[37] a 25% annual growth rate is assumed from 2016-2020.

- California's share of total U.S. SWH installations is assumed to be a constant 16%, which is twice the 8% share for California assumed by Navigant Consulting.[38] The decision to double the California share is to reflect the positive market impact of AB 1470 on SWH installations in California; AB 1470 had not become law at the time of the report by Navigant Consulting.

- Based on the above assumptions, California's total installed SWH collector area in 2017 is projected to be 7.98 million ft^2, nearly identical to the 8 million ft^2 that results from multiplying the 200,000 SWH installations in 2017 (targeted in AB

---

[33] Spath and Mann, February 2001, pp. 8-9.

[34] Spath and Mann, February 2001, p. 8. The Value of Avoided Methane (CH_4) Emissions is calculated based on methane having a density of 0.717 kg/m^3 (Wikipedia) and making up 75% of total the energy content of natural gas.

[35] California Air Resources Board, October 2008(b), p. 194.

[36] U.S. Department of Energy, p. 10.

[37] Navigant Consulting, p. 40.

[38] Navigant Consulting, p. 41.

1470 and incorporated into the AB32 Proposed Scoping Plan) times an average residential SWH collector size of 40 ft^2.

The installation of a medium-temperature residential SWH system is estimated to require 32 hours of labor per installation, assuming a two-person crew for 1.5 days or a three-person crew for 1 day.[39] Ongoing annual maintenance is assumed to require one-tenth of the labor of the initial installation. Labor costs are estimated at $86.77/hour for installation and maintenance.[40] The Job Creation Potential is calculated by dividing the total labor cost for installation and maintenance of SWH systems in a given year by the SWH therms generated by those same SWH systems in that year, calculating each year's value separately through 2020.

As a sensitivity, it should be noted that the Value of Job Creation Potential would increase to 12.35-25.81 cents/therm of SWH if the expanded SWH measure explored in the AB 32 Draft Scoping Plan were to be implemented. Recall that the expanded SWH measure assumed 1.75 million SWH installations in California by 2020 through SWH mandates for new residential construction; achieving this number of SWH installations would require California to capture 60% of the total U.S. SWH installations projected by Navigant Consulting within a matter of several years.

Note that if new SWH manufacturing capacity is brought to California as the penetration rate of SWH systems increases, the future value of Job Creation Potential would be even higher than calculated for the two cases above due to the employment value of the manufacturing process; this manufacturing value has not yet been calculated and is not included in the Value of Job Creation Potential in Figure 1 and Figure 2.

F. Value of Lower Natural Gas and Electric Prices

The greater the number of SWH systems that are installed in California, the greater will be the resultant natural gas savings. As natural gas consumption for water heating declines, a threshold of natural gas savings may occur such that natural gas prices in California begin to soften. Because the benefits of this price impact would predominantly occur in future years, the value of this price impact associated with natural gas savings from SWH is not included in the waterfall charts in Figure 1 and Figure 2. The discussion below outlines how this price impact could be quantified.

---

39 Industry estimate. Note that Loudat (p. 68) estimates that one job is created for every 36 SWH installations, assuming financing and a 35% Energy Conservation Income Tax Credit applied to a SWH installation having a 25-year life.

40 $86.77/hour is based on the average of the statewide median annual wages for (i) one-quarter of a solar installation manager ($50,000-$72,800/year), (ii) an experienced solar thermal installer ($52,000/year), (iii) an entry level solar thermal installer ($31,200/year), (iv) one-quarter of a solar designer or engineer ($50,00-$83,200/year), and (v) one-tenth of a solar representative or estimator ($40,000-$62,400) (Centers of Excellence, p. 8), each assumed to carry a 50% burden rate. The 50% burden rate is meant to represent the cost of employee benefits and office support staff.

For discussion purposes only, the potential impact on natural gas prices is calculated based on 26 million therms of natural gas savings in 2020 as a result of the 200,000 SWH installations projected under AB 1470 and incorporate into the AB 32 Proposed Scoping Plan. Assuming statewide natural gas demand of 2,500 million MMBtu in 2020, the 26 million therms of natural gas savings would represent a reduction of just over 0.1% of the total volume of natural gas demand in California.

Using an economic study that calculated that natural gas prices change from 0.8-2.0% for each 1% change in natural gas demand,[41] the 0.1% decline in total California natural gas consumption would result in a 0.001-0.002% reduction in natural gas prices. Based on the $4.20-$15.40/MMBtu range of NYMEX natural gas futures prices used previously, the natural gas price reduction would range from $0.00003-0.00032/MMBtu. When applied to the 2,500 million MMBtu of statewide natural gas demand, the annual value of the natural gas savings attributed to SWH would range from $87,000-$800,000 in 2020; the value of related reductions in electricity prices has not been quantified.

G. Other Items Not Yet Quantified

In addition to the benefits of SWH that have been quantified above, there are other benefits that have not been fully quantified. Primary among these are the (related) value of reduced reliance on imported natural gas and the value of increased energy security. Although the extrinsic market value of natural gas savings attributable to SWH has been quantified, the intrinsic value of reduced natural gas import reliance and increased energy security has not been quantified.

III. IMPACT OF ZERO NET ENERGY GOALS ON SWH INSTALLATIONS

The term "zero net energy" refers to a residential or commercial building that "employs a combination of energy efficiency design features, efficient appliances, clean distributed generation, and advanced energy management systems to result in no net purchases of energy from the grid."[42] The CPUC has set a goal "to achieve a statewide standard of zero net energy (ZNE) for all new homes built in 2020"[43] and to have new construction of commercial buildings "increasingly embrace zero net energy performance (including clean, distributed generation), reaching 100 percent penetration of new starts in 2030."[44]

SWH systems can play a significant role in achieving California's ZNE goals, as recently acknowledged by the ARB in its AB 32 Proposed Scoping Plan:

41 Wiser, *et al.*, January 2005, p. 18.

42 California Public Utilities Commission, September 2008, p. 13.

43 California Public Utilities Commission, September 2008, p. 13.

44 California Public Utilities Commission, September 2008, p. 31.

> "Solar water heating is an enabling technology for zero net energy buildings [footnote omitted], and successful implementation of the zero net energy targets will require significant growth and improvements in California's SWH system manufacturing and installation industry. Looking out to the [AB 32] 2050 emission reduction goals, solar water heating will be even more essential because the technology can provide carbon-free water heating. At this time, California's SWH industry is still quite small and not well established, lacking the experience and economies of scale to deliver cost-effective solar water heating for most applications [footnote omitted]. This needs to change if California is to meet its GHG reduction targets."[45]

IV. Comparison of the SWH Value Proposition and Existing SWH Incentives

The Solar Water Heating Pilot Program is now being implemented in San Diego Gas & Electric Company's franchise territory under the auspices of the CPUC; the program is being managed by the California Center for Sustainable Energy. The SWHPP provides incentives of up to $1,500 per SWH system to residential and non-residential customers who install qualifying SWH systems that offset at least 60 therms of natural gas (or 1,200 kWh of electricity) otherwise used by an existing water heater or boiler.[46]

To determine the value of the $1,500 incentive over the life of a residential SWH system, the same 146 therms per year of hot water that was assumed earlier in this report for a residential SWH system is used. Over 25 years, the residential SWH system will then provide 3,650 therms of hot water. Dividing the $1,500 in incentives by the 3,650 therms yields a (non-discounted) incentive value of 41 cents per therm of solar-heated water provided. This incentive value is less than half of the lower end of the calculated 94-285 cents per therm range of value provided by residential SWH systems (as illustrated above in Figure 2).

The same calculation for the assumed commercial SWH system yields a (non-discounted) incentive value of 2.6 cents per therm of solar-heated water provided, a fraction of the calculated value of 111-345 cents per therm for commercial SWH systems (as illustrated above in Figure 1).[47]

V. Conclusions

Solar water heating that displaces hot water generated by natural gas-fired boilers and water heaters provides significant value to California today, as demonstrated by the

---

45 California Air Resources Board, October 2008(b), p. C-118.

46 California Center for Sustainable Energy, October 12, 2007, pp. 2, 6, and 11.

47 2.6 cents per therm = $1,500 / (2,281 therms/year x 25 years) for a commercial SWH system.

waterfall charts in Figure 1 and Figure 2 and by this description of the underlying methodology. The California Air Resources Board has recognized the natural gas savings and emissions-reduction value of solar water heating in its recently approved AB 32 Proposed Scoping Plan. The present analysis places a monetary value on those attributes quantified by the ARB and extends the recognition of solar water heating benefits to additional attributes such as job creation potential and hedge value against volatile natural gas prices.

Itron, Inc. ("Itron") is currently in the process of performing the cost-benefit analysis for the Solar Water Heating Pilot Project. The California Solar Energy Industries Association ("Cal SEIA") is in discussions with Itron as to how best to incorporate the findings of this analysis into that cost-benefit analysis. In addition to the benefits for all Californians identified here, there are additional benefits that may be relevant only for individual homeowners, such as the positive impact on house resale value of solar installations (due to utility bill savings)[48] and the California property tax exemption for solar systems.[49]

*   *   *   *   *

This analytical work supporting this analysis was carried out by Lori Schell of Empowered Energy and funded by the California Solar Energy Industries Association.

[48] Black, July 2004, p. 1.

[49] *See* California Revenue and Taxation Code, Section 73.

SELECT REFERENCES

Abt Associates, Inc., October 2000, "The Particulate-Related Health Benefits of Reducing Power Plant Emissions." http://www.abtassociates.com/reports/particulate-related.pdf

American Gas Association, December 2001, "Impacts of Minnesota Energy Code on Residential Water Heater Installations: Energy Cost, Emissions, Safety and Electric Reliability." https://www.aga.org/NR/rdonlyres/B1AC0422-F047-4FE8-8C81-79FECEF3D9A8/0/0112MINNENERGYCODEIMPACT.pdf

Black, Andrew J., July 2004, "Why is a Solar Electric Home Worth More?," Presentation made at Solar 2004, Portland, Oregon, to the American Solar Energy Society. http://www.debsolar.com/HomeWorthMoreASES04.pdf

Bolinger, Mark and Ryan Wiser, January 7, 2008, "Memorandum: Comparison of AEO 2008 Natural Gas Price Forecast to NYMEX Futures Prices." http://eetd.lbl.gov/ea/ems/reports/53587_memo.pdf

Bolinger, Mark, Ryan Wiser, and William Golove, January 2004, "Accounting for Fuel Price Risk When Comparing Renewable to Gas-Fired Generation: The Role of Forward Natural Gas Prices," Ernest Orlando Lawrence Berkeley National Laboratory, Environmental Technologies Division, LBNL-54751. http://eetd.lbl.gov/EA/EMP/reports/54751.pdf

California Air Resources Board, October 2008(a), "Climate Change Proposed Scoping Plan." http://www.arb.ca.gov/cc/scopingplan/document/psp.pdf

California Air Resources Board, October 2008(b), "Climate Change Proposed Scoping Plan Appendices, Volume I: Supporting Documents and Measure Detail." http://www.arb.ca.gov/cc/scopingplan/document/appendix1.pdf

California Air Resources Board, October 2008(c), "Climate Change Proposed Scoping Plan Appendices, Volume II: Analysis and Documentation." http://www.arb.ca.gov/cc/scopingplan/document/appendix2.pdf

California Air Resources Board, June 2008(a), "Climate Change Draft Scoping Plan Appendices, Appendix C: Sector Overviews and Emission Reduction Strategies." http://www.arb.ca.gov/cc/scopingplan/document/draftscopingplanappendices.pdf

California Air Resources Board, June 2008(b), "Climate Change Draft Scoping Plan, Public Health Analysis Supplement, Attachment A: Public Health and Environmental Benefits of Draft Scoping Plan Measures." http://www.arb.ca.gov/cc/scopingplan/document/ph_statewide_a.pdf

California Center for Sustainable Energy, October 12, 2007, "Solar Water Heating Pilot Program Handbook." http://energycenter.org/uploads/SWHPP-PROGRAM-AND-TECHNICAL-HANDBOOK-071012.pdf

California Energy Commission, December 2007, "2007 Appliance Efficiency Regulations," CEC-400-2007-016-REV1 (Revised December 29, 2007). http://www.energy.ca.gov/2007publications/CEC-400-2007-016/CEC-400-2007-016-REV1.PDF

California Energy Commission, November 2007, "California Energy Demand 2008-2018, Staff Revised Forecast, Staff Final Report," CEC-200-2007-015-SF2. http://www.energy.ca.gov/2007publications/CEC-200-2007-015/CEC-200-2007-015-SF2.PDF

California Energy Commission, October 2007, "Government Actions and Innovation in Clean Energy Technologies: The Cases of Photovoltaic Cells, Solar Thermal Electric Power, and Solar Water Heating," Public Interest Energy Research Program (PIER) Project Report, CEC-500-2007-012. http://www.energy.ca.gov/2007publications/CEC-500-2007-012/CEC-500-2007-012.PDF

California Energy Commission, June 2004, "California Statewide Residential Appliance Saturation Study: Volume 2, Study Results, Final Report," Consultant Report, 300-00-004. http://www.energy.ca.gov/reports/400-04-009/2004-08-17_400-04-009VOL2B.PDF

California Environmental Protection Agency and California Air Resources Board, March 21, 2006, "Proposed Emission Reduction Plan for Ports and Goods Movement in California." http://www.arb.ca.gov/planning/gmerp/march21plan/march22_plan.pdf

California Environmental Protection Agency and California Air Resources Board, May 31, 2003, "The Economic Value of Respiratory and Cardiovascular Hospitalizations," Final Research Report, Contract Number 99-329. http://www.arb.ca.gov/research/apr/past/99-329.pdf

California Environmental Protection Agency and California Air Resources Board, May 3, 2002, "Staff Report: Public Hearing to Consider Amendments to the Ambient Air Quality Standards for Particulate Matter and Sulfates." http://www.arb.ca.gov/research/aaqs/std-rs/pm-final/pm-final.htm

California Public Utilities Commission, September 2008, "California Long Term Energy Efficiency Strategic Plan: Achieving Maximum Energy Savings in California for 2009 and Beyond." http://californiaenergyefficiency.com/docs/EEStrategicPlan.pdf

California Revenue and Taxation Code, Section 73. http://www.leginfo.ca.gov/cgi-bin/displaycode?section=rtc&group=00001-01000&file=70-74.7

CantorCO2e Environmental Brokerage, various emissions, various California markets. http://CantorCO2e.com

Centers of Excellence, June 2008, "Emerging Industry & Occupations Report: Solar Study/2008," California Community Colleges Economic & Workforce Development. http://www.coeccc.net/solar/documents/Emerging_solar_08.pdf

Chen, Cliff, Ryan Wiser, and Mark Bollinger, March 2007, "Weighing the Costs and Benefits of State Renewable Portfolio Standards: A Comparative Analysis of State-Level Policy Impact Projections," Ernesto Orlando Lawrence Berkeley National Laboratory, Environmental Energy Technologies Division, LBNL-61580. http://eetd.lbl.gov/EA/EMP/reports/61580.pdf

Del Chiaro, Bernadette, and Timothy Tellen-Lawton, April 2007, "Solar Water Heating: How California Can Reduce Its Dependence on Natural Gas," Environment California Research & Policy Center. http://www.environmentcalifornia.org/uploads/0q/Nn/0qNnGUUcug5fYHvxfjZxRw/Solar-Water-Heating.pdf

Denholm, P., March 2007, "The Technical Potential of Solar Water Heating to Reduce Fossil Fuel Use and Greenhouse Gas Emissions in the United States," National Renewable Energy Laboratory, Technical Report, NREL/TP-640-41157. http://www.nrel.gov/docs/fy07osti/41157.pdf

Duke, Richard, Robert Williams and Adam Payne, 2004, "Accelerating Residential PV Expansion: Demand Analysis for Competitive Electricity Markets," *Energy Policy*. http://www.sciencedirect.com/science/article/B6V2W-4C6TH1K-1/2/cbca1c88be2b5d8b92a7034ab0f93939

Energy and Environmental Economics, Inc., and Rocky Mountain Institute, October 25, 2004, "Methodology and Forecast of Long Term Avoided Costs for the Evaluation of California Energy Efficiency Programs," report prepared for the California Public Utilities Commission. http://www.ethree.com/cpuc_avoidedcosts.html

Energy and Environmental Economics, Inc., March 20, 2006, "Avoided Cost Calculation Spreadsheets, Updated Electric and Gas Avoided Costs – 2006 Update (5/23/06 Draft Decision): Natural Gas Avoided Costs." http://www.ethree.com/cpuc_avoidedcosts.html

Hall, Jane V., Victor Brajer, and Frederick W. Lurmann, March 2006, "The Health and Related Economic Benefits of Attaining Healthful Air in the San Joaquin Valley," Institute for Economic and Environmental Studies, California State University-Fullerton. http://business.fullerton.edu/Centers/iees/reports/SJVFinalReport.pdf

KEMA-XENERGY Inc., May 14, 2003, "California Statewide Commercial Sector Natural Gas Energy Efficiency Potential Study (Study ID #SW061): Final Report,

Volume 2 of 2: Appendices."
http://www.calmac.org/publications/Commercial_Gas_EE_report_V2_Appendices.pdf

KEMA-XENERGY Inc., April 2003(a), "California Statewide Residential Sector Energy Efficiency Potential Study (Study ID #SW063): Final Report, Volume 1 of 2: Main Report." http://www.calmac.org/publications/Res_EE_Potential_Study_V1.pdf

KEMA-XENERGY Inc., April 2003(b), "California Statewide Residential Sector Energy Efficiency Potential Study (Study ID #SW063): Final Report, Volume 2 of 2: Appendices A through L."
http://www.calmac.org/publications/Residential_Potential_Study_Vol2.pdf

Loudat, Thomas A., March 11, 2002, "Report of the Hawaii Energy Efficiency Task Force, Appendix D: The Economic and Fiscal Impacts of the Hawaii Solar Water Heating System Energy Conservation Income Tax Credit."
http://hawaii.gov/dbedt/info/energy/publications/etf.pdf

Navigant Consulting, September 15, 2008, "Economic Impacts of Extending Federal Solar Tax Credits: Final Report," Prepared for the Solar Energy Research and Education Foundation (SEREF).
http://www.seia.org/galleries/pdf/Navigant%20Consulting%20Report%209.15.08.pdf

San Joaquin Valley Unified Air Pollution Control District, "Rule 4308 – Boilers, Steam Generators, and Process Heaters – 0.075 MMBtu/hr to 2.0 MMBtu/hr (Adopted October 20, 2005)." www.valleyair.org/rules/currntrules/r4308.pdf

Solar Rating and Certification Corporation, December 5, 2008, "Summary of SRCC Certified Solar Collector and Water Heating System Ratings." http://www.solar-rating.org/SUMMARY/Dirsum.pdf

Solar Rating and Certification Corporation, June 16, 2008, "Directory of SRCC Certified Solar Water Heating System Ratings." http://www.solar-rating.org/RATINGS/OG300DIRECTORIES/OG300DIRFULL.pdf

South Coast Air Quality Management District, "Rule 1146.2. Emissions of Oxides of Nitrogen from Large Water Heaters and Small Boilers and Process Heaters (Adopted January 9, 1998) (Amended January 7, 2005) (Amended May 5, 2006)."
http://www.aqmd.gov/rules/reg/reg11/r1146-2.pdf

Spath, Pamela L. and Margaret K. Mann, February 2001, "Life Cycle Assessment of Hydrogen Production via Natural Gas Steam Reforming." National Renewable Energy Laboratory Technical Report, NREL/TP-570-27637.
http://www.nrel.gov/docs/fy01osti/27637.pdf

U.S. Department of Energy, Energy Information Administration, October 2008, "Solar Thermal Collector Manufacturing Activities 2007."
http://www.eia.doe.gov/cneaf/solar.renewables/page/solarreport/solar.pdf

U.S. Department of Energy, Energy Information Administration, June 2008, "Annual Energy Outlook 2008 – With Projections to 2030," DOE/EIA-0383(2008).
http://www.eia.doe.gov/oiaf/aeo/pdf/0383(2008).pdf

Ventura County Air Pollution Control District, "Rule 74.11 – Natural Gas-Fired Residential Water Heaters – Control of NOx (Adopted 4/9/85)."
www.arb.ca.gov/drdb/ven/curhtml/r74-11.pdf

Wiser, Ryan, Mark Bolinger, and Matt St. Clair, January 2005, "Easing the Natural Gas Crisis: Reducing Natural Gas Prices through Increased Deployment of Renewable Energy and Energy Efficiency," Ernest Orlando Lawrence Berkeley National Laboratory, Environmental Technologies Division, LBNL-56756.
http://eetd.lbl.gov/EA/EMP/reports/56756.pdf

APPENDIX A

U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy[50]

"A Consumer's Guide to Energy Efficiency and Renewable Energy: Solar Water Heaters"

U.S. Department of Energy - Energy Efficiency and Renewable Energy

A Consumer's Guide to Energy Efficiency and Renewable Energy

Solar Water Heaters

Solar water heaters—also called solar domestic hot water systems—can be a cost-effective way to generate hot water for your home. They can be used in any climate, and the fuel they use—sunshine—is free.

How They Work

Solar water heating systems include storage tanks and solar collectors. There are two types of solar water heating systems: active, which have circulating pumps and controls, and passive, which don't.

Most solar water heaters require a well-insulated storage tank. Solar storage tanks have an additional outlet and inlet connected to and from the collector. In two-tank systems, the solar water heater preheats water before it enters the conventional water heater. In one-tank systems, the back-up heater is combined with the solar storage in one tank.

Three types of solar collectors are used for residential applications:

- **Flat-plate collector**
  Glazed flat-plate collectors are insulated, weatherproofed boxes that contain a dark absorber plate under one or more glass or plastic (polymer) covers. Unglazed flat-plate collectors—typically used for solar pool heating—have a dark absorber plate, made of metal or polymer, without a cover or enclosure.

- **Integral collector-storage systems**
  Also known as ICS or *batch* systems, they feature one or more black tanks or tubes in an insulated, glazed box. Cold water first passes through the solar collector, which preheats the water. The water then continues on to the conventional backup water heater, providing a reliable source of hot water. They should be installed only in mild-freeze climates because the outdoor pipes could freeze in severe, cold weather.

- **Evacuated-tube solar collectors**
  They feature parallel rows of transparent glass tubes. Each tube contains a glass outer tube and metal absorber tube attached to a fin. The fin's coating absorbs solar energy but inhibits radiative heat loss. These collectors are used more frequently for U.S. commercial applications.

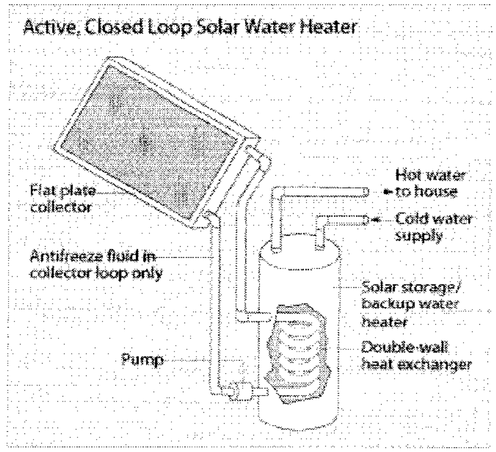
There are two types of active solar water heating systems:

- **Direct circulation systems**
  Pumps circulate household water through the collectors and into the home. They work well in climates where it rarely freezes.

- **Indirect circulation systems**
  Pumps circulate a non-freezing, heat-transfer fluid through the collectors and a heat exchanger. This heats the water that then flows into the home. They are popular in climates prone to freezing temperatures.

---

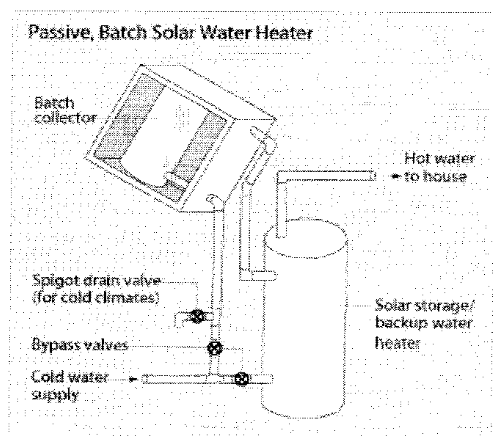
50 Full Document Available Online at: http://apps1.eere.energy.gov/consumer/your_home/water_heating/index.cfm/mytopic=12850



Passive solar water heating systems are typically less expensive than active systems, but they're usually not as efficient. However, passive systems can be more reliable and may last longer. There are two basic types of passive systems:

- **Integral collector-storage passive systems**
  These work best in areas where temperatures rarely fall below freezing. They also work well in households with significant daytime and evening hot-water needs.

- **Thermosyphon systems**
  Water flows through the system when warm water rises as cooler water sinks. The collector must be installed below the storage tank so that warm water will rise into the tank. These systems are reliable, but contractors must pay careful attention to the roof design because of the heavy storage tank. They are usually more expensive than integral collector-storage passive systems.



Solar water heating systems almost always require a backup system for cloudy days and times of increased demand. Conventional storage water heaters usually provide backup and may already be part of the solar system package. A backup system may also be part of the solar collector, such as rooftop tanks with thermosyphon systems. Since an integral-collector storage system already stores hot water in addition to collecting solar heat, it may be packaged with a demand (tankless or instantaneous) water heater for backup.

For more information about solar water heating system components, see the following information:

- Heat Exchangers for Solar Water Heating Systems
- Heat-Transfer Fluids for Solar Water Heating Systems

Selecting a Solar Water Heater

Before you purchase and install a solar water heating system, you want to do the following:

- Consider the economics of a solar water heating system
- Evaluate your site's solar resource
- Determine the correct system size
- Determine the system's energy efficiency
- Estimate and compare system costs
- Investigate local codes, covenants, and regulations.

For information about specific solar water heater models and systems, see the Product Information resources listed on the right side of this page (or below if you've printed the page).

Installing and Maintaining the System

The proper installation of solar water heaters depends on many factors. These factors include solar resource, climate, local building code requirements, and safety issues; therefore, it's best to have a qualified, solar thermal systems contractor install your system.

After installation, properly maintaining your system will keep it running smoothly. Passive systems don't require much maintenance. For active systems, discuss the maintenance requirements with your system provider, and consult the system's owner's manual. Plumbing and other conventional water heating components require the same maintenance as conventional systems. Glazing may need to be cleaned in dry climates where rainwater doesn't provide a natural rinse.

Regular maintenance on simple systems can be as infrequent as every 3–5 years, preferably by a solar contractor. Systems with electrical components usually require a replacement part after or two after 10 years. For more information about system maintenance, see the following:

- Solar Water Heating System Maintenance and Repair
- Solar Water Heating System Freeze Protection
- Scaling and Corrosion in Solar Water Heating Systems

When screening potential contractors for installation and/or maintenance, ask the following questions:

- *Does your company have experience installing and maintaining solar water heating systems?*

Choose a company that has experience installing the type of system you want and servicing the applications you select.

- *How many years of experience does your company have with solar heating installation and maintenance?*
  The more experience the better. Request a list of past customers who can provide references.

- *Is your company licensed or certified?*
  Having a valid plumber's and/or solar contractor's license is required in some states. Contact your city and county for more information. Confirm licensing with your state's contractor licensing board. The licensing board can also tell you about any complaints against state-licensed contractors.

For contractor information, see the Professional Services resources listed on the right side of this page (or below if you've printed it out).

Improving Energy Efficiency

After your water heater is properly installed and maintained, try some additional energy-saving strategies to help lower your water heating bills, especially if you require a back-up system. Some energy-saving devices and systems are more cost-effective to install with the water heater.

Other Water Heater Options

- Conventional storage water heaters
- Demand water heaters
- Heat pump water heaters
- Tankless coil and indirect water heaters

Learn More

Evaluation Tools

- Solar Benefits Model
  DOE Building Energy Software Tools Directory
- Solar Water Heating Project Model
  RETScreen International

Financing & Incentives

- Database of State Incentives for Renewable Energy
- Federal Tax Credits for Energy Efficiency
  ENERGY STAR®

Product Information

- Solar Thermal Systems
  Florida Solar Energy Center
- Certified Solar Collectors and Systems
  Solar Rating and Certification Corporation

Professional Services

- Solar Energy Industries Association

State & Local Resources

- State Chapters

Solar Energy Industries Association

Related Links

- Solar Hot Water
  Florida Solar Energy Center

Reading List

- *The Borrower's Guide to Financing Solar Energy Systems: A Federal Overview* (PDF 501 KB). (September 1998). U.S. Department of Energy. This booklet provides an extensive overview of government-authorized special financing programs available to consumers interested in installing solar energy systems for heat and electricity.
- *Heat Your Water with the Sun* (PDF 603 KB). (December 2003). DOE/GO-102003-1824. U.S. Department of Energy.