California's Solar Water Heating Program: Scaling Up to Install 200,000 Systems by 2020

Ean Jones and Robert Mowris, Verified, Inc.

ABSTRACT

Water heating is the largest natural gas end use in California consuming 38% of residential and commercial gas. Sixty-five percent of the energy used to heat water in California can be saved with solar water heating (SWH). From 1975 through 1985 California installed approximately 159,000 SWH systems with utility incentives and tax credits. The California Solar Water Heating Efficiency Act (AB1470) authorizes \$250 million to provide incentives for 200,000 SWH systems starting in 2010. In 2007, the California Public Utilities Commission (CPUC) authorized a \$2.6 million SWH pilot program in San Diego implemented by the California Center for Sustainable Energy. The program provides quality installation standards, training, assistance, and incentives. The average installed cost is \$6,752, and average annual residential energy savings are 12.5 GJ with gas back-up and 2,793 kWh with electric back-up. The maximum residential incentive is \$1500/site. Commercial incentives are based on collector area; open-loop incentives are \$15/ft^2 and closed-loop incentives are \$20/ft^2. The lower-bound SWH effective useful life (EUL) estimate is 38.3 years and the median EUL is 72.4 years based on Weibull analysis of warranty claims for 27,000 systems in Hawaii. The TRC test is 0.76 for 38-year EUL and 1.01 for 45-year EUL. Itron evaluated four SWH scenarios using societal test cost-effectiveness and 25-year EUL. Three scenarios that include SWH cost reductions over the program duration are cost-effective. Based on the Itron analysis, the CPUC approved \$250 million for the California SWH program to install 200,000 systems by 2017 and displace 2.47 PJ/year of natural gas and 257.7 GWh/year.

Introduction

In 2006, water heating accounted for 15% of residential energy use in the United States, consuming 111 billion kWh of electricity, over 1,084.6 PJ of natural gas, 106.1 PJ of fuel oil, and 67.6 PJ of liquefied petroleum gas (i.e. propane) (USDOE 2008). In California, approximately 85% of water heating is provided by natural gas, with the balance provided predominantly by electricity (Denholm 2007). Natural gas used for water heating accounts for 38 percent or 285 PJ per year of residential and commercial natural gas consumed each year in California by customers of the investor-owned utilities and electric water heating accounts for 6% of total residential electricity consumption by customers of the investor-owned utilities in California (KEMA 2003, KEMA 2003a). Solar water heating (SWH) can save approximately 65 percent of the energy used to heat water in California (Del Chiaro 2007, KEMA 2003, KEMA 2003a). SWH 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, electricity, propane, or fuel oil used to heat water. From 1975 through 1985 California installed approximately 159,000 solar water heaters with utility incentives and tax credits (CPUC 1984). However, when world oil prices dropped in the 1980s and solar tax credits were withdrawn in 1986, most SWH companies left the business. Since 1980 the SWH industry has suffered from high initial cost, lack of incentives, permitting problems and lack of quality installation standards. The California Solar Water Heating Efficiency Act (AB1470) authorizes $250 million to transform the SWH industry and provide incentives for 200,000 solar water heaters starting in 2010 (CAB 2007). To get the program started, the California Public Utilities Commission authorized a $2.6 million SWH pilot program in San Diego implemented by the California Center for Sustainable Energy (CCSE 2007).

This paper provides an overview of the California SWH pilot program. The paper presents an analysis of the effective useful life of SWH systems based on warranty claims for 27,000 systems installed in Hawaii, and provides cost effectiveness results based on the CPUC-approved E3 calculator and four scenarios examined by Itron. The paper also discusses best practices lessons from successful U.S. and international SWH programs.

California Solar Water Heating Pilot Program

The California Solar Water Heating Pilot Program (SWHPP) began in July 2007 as an 18-month SWH incentive program implemented in the San Diego Gas and Electric (SDG&E) service area under the auspices of the California Public Utilities Commission (CPUC) and administered by the California Center for Sustainable Energy (CCSE).[1] The CPUC modified the SWH pilot program on July 2, 2008 to extend the program through December 2009 or until funding is exhausted, allow new residential and commercial construction, and extend market research work beyond San Diego to determine what type of market interventions are needed to stimulate greater adoption of SWH systems in California by improving cost effectiveness (CPUC 2006). Itron evaluated the SWH pilot program, and this paper provides an overview of the evaluation results (Itron 2009). Based on the evaluation results and cost effectiveness analysis of the SWH pilot program, the CPUC is expanding SWH incentives across the state in accordance with the California Solar Water Heating Efficiency Act (AB 1470) which authorizes $250 million for a statewide incentive program (CAB 2007).[2] The goal of the statewide incentive program is to install at least 200,000 SWH systems on homes, businesses, and government buildings by 2017. The CPUC established the pilot program to test SWH incentives and evaluate the impact incentives have on: 1) equipment and installation costs, 2) market demand, and 3) cost-effectiveness.

The SWHPP has two incentive options: the prescriptive incentive and collector area incentive. The prescriptive incentive is used for residential and small multifamily or commercial systems. To qualify for prescriptive incentives residential customers must install an SRCC OG-300-rated system (Ramlow). The maximum incentive under the prescriptive method is $1,500 and is dependent on the climate zone, orientation, and SRCC Annual Savings Rating for that system. The collector area incentive is used for large multifamily and commercial systems, and the collectors must be SRCC OG-100-certified. The collector area incentive is based on the SRCC Collector Performance and Solar Orientation Factor (SOF). For open-loop systems the incentive is $\$161.46/m^2$, and for closed-loop systems the incentive is $\$215.28/m^2$. The maximum collector area incentive is $75,000. Systems that receive a collector area incentive must have at least one month of post-installation metering. The SWHPP received 369 applications through December 2009. **Table 1** shows the distribution of applications by incentive method, retrofit,

[1] SWHPP is funded by electric ratepayers in the San Diego Gas & Electric Company (SDG&E) service area authorized by the CPUC in Decision 06-01-024 as part of the California Solar Initiative (CSI).
[2] Assembly Bill 1470 (Huffman), October 12, 2007. Funded by public benefits surcharges on natural gas ratepayers.

new construction, and incentives. The total paid incentives are $499,606 with $393,076 paid to 309 residential customers who used the prescriptive incentive and $106,530 paid to 19 commercial customers who used the collector area incentive.

Table 1. SWHPP Applications and Paid Incentives Through March 2009

Total Applications	Pending Applications	Reserved Incentive Amount	Paid Applications	Paid Incentive Amount
Retrofit				
Prescriptive	26	$35,199.00	285	$360,413.00
Collector Area	8	$148,578.00	18	$79,010.00
New Construction				
Prescriptive	6	$8,692.00	24	$32,663.00
Collector Area	1	$16,960.00	1	$27,520.00
Total	**41**	**$209,429.00**	**328**	**$499,606.00**

Source: CCSE 2009

While 89 percent of residential customers use natural gas to provide back-up water heating, only 51 of SWHPP residential applications have natural gas back-up heat. **Table 2** summarizes the residential SWH applications by fossil back-up heat. Residential SWH systems using electricity and propane back-up heat have slightly greater average costs and incentives than systems with natural gas back-up heat. The residential SWH systems using electric and propane back-up heat are installed in rural areas where freeze protection is more important, and thus, represent a different mix of system types having higher SRCC-rated savings compared to systems with natural gas back-up heat.

Table 2. Summary of Residential Solar Water Heating Incentive Applications

Fossil Back-up Heat	Percent of Total	Average Incentive	Average Savings	Average Cost
Residential Natural Gas	51%	$1,181.00	12.5 GJ	$6,634.00
Residential Electric	21%	$1,330.00	2793 kWh	$6,759.00
Residential Propane	28%	$1,291.00	14.1 GJ	$7,116.00

Source: CCSE 2009

The most common residential system types chosen by participants are as follows: 43% active glycol (closed-loop), 22% passive thermosyphon (closed-loop), 20% drainback (closed-loop), 11% direct forced circulation (open-loop), and 4% passive (open-loop) internal collector storage (ICS). The lowest installed cost residential system is $2,200 and the highest cost is $15,468 with an average cost of $6,752. Interest in the program has been relatively constant but lower than anticipated considering the incentives per system of $1,259 and federal tax credits of $2,025 (average) (Navigant 2008). If all customers claimed and received an incentive and federal tax credit, the net cost would be decreased to $3,468. The SWHPP received an average of eleven residential applications per month from July 2007 through December 2009. The program has received significantly more interest from residential customers than commercial customers. New construction was incorporated into the program in mid-2008 and is a relatively small part of the program, with only 30 residential and 2 commercial applicants through December 2009.

SWHPP Marketing and Outreach Efforts

The SWHPP implemented marketing and outreach efforts to raise awareness of the SWH incentive program including television, radio, print, web, direct mail, email, and community outreach. Consumer awareness and understanding of the benefits of SWH are critical to future development of the SWH industry. Consequently, SWHPP staff conducts training for potential SWH adopters in addition to regular and specialized training for contractors and self-installers. Since September 2007, over 550 homeowners have attended the program's SWH Basics for Homeowners workshop. The course provides a basic background on SWH system types, installations standards, and simple financials.

An important market barrier for contractors installing SWH systems is obtaining building permits. SWHPP worked to overcome this barrier by conducting training workshops with contractors and building officials. SWHPP staff held three workshops for building officials of the City of San Diego, County of San Diego, and City of Chula Vista. Additional presentations were given to the City of Oceanside, as well as local chapters of the International Code Council (ICC) and the International Association of Plumbing and Mechanical Officials (IAPMO). SWHPP coordinated SWH Inspector training sessions in collaboration with the Interstate Renewable Energy Council (IREC). SWHPP also developed training courses highlighting lessons learned from program installations to ensure that contractors apply the most current installation best practices for reliability, longevity, and performance.

Cost Effectiveness Analysis

One reason the CPUC established the pilot program was to evaluate the impact of incentives on cost-effectiveness. The key elements of cost effectiveness are equipment and installation costs, energy savings, real discount rate, avoided environmental costs, job creation, and effective useful life (EUL) of the SWH system.

Equipment and Installation Costs of SWH

Average installed SWH system costs for the California SWHPP and other regions are presented in **Table 3** (Itron 2009). Closed loop active systems are generally more expensive than open loop or passive ICS systems. SWH costs in China and India are not reflective of the same quality of systems installed in the US and Europe. Most of the installed system cost is equipment, which accounts for 57 percent of the total. Labor accounts for 23 percent of the total installation cost. Manufacturers and contractors who were interviewed stated that they did not expect these two cost components to decrease, as they believe material and fuel prices have increased and labor costs are already artificially low due to the limited market (Itron 2009).

Table 3. Average Installed SWH System Cost Comparison

Source	Average SWH Cost	Typical System Type
California SWHPP	$6,752	Closed loop active
Eugene Water and Electric Board (EWEB)[3]	$7,129	Closed loop, active
Hawaii Electric Company (HECO 2009)	$5,250	Open loop
Northern Europe (Menanteau 2007)	$6,592 - $9,229	Closed loop, active
China, India (Menanteau 2007)	$395 - $527	ICS

Source: Itron 2009

Energy Savings

The average annual energy savings for residential SWH systems reported by the SWHPP and shown in **Table 2** are based on SRCC estimated savings. The annual gas savings are 12.5 GJ, representing a solar fraction of approximately 58 to 65 percent of the California average annual natural gas water heating unit energy consumption (UEC) of 19.3 to 21.7 GJ for average residential single family customers (KEMA 2003). The annual electric savings are 2,793 kWh representing a 91% solar fraction with respect to the California average annual electric water heating UEC of 3,079 kWh. CCSE is monitoring a sample of systems installed in the program to evaluate the actual average savings.

Effective Useful Life of SWH Systems

Warranty claim information from Hawaii is used to quantify the reliability of SWH components and evaluate the effective useful life of SWH systems (HECO 2007). **Table 4** shows warranty claims in Hawaii for 25,000 to 40,000 SWH components installed on SWH systems from 1996 to 2004.

Table 4. Warranty Claims in Hawaii from 1996 to 2004

Component	Equipment	Claims	Percent	Warranty Length (years)
Collectors	~ 40,000	63	0.16%	5 & 10
Tanks	~ 27,000	24	0.08%	5
Pumps	~ 27,000	38	0.14%	1.5
Controllers	~ 25,000	36	0.14%	10

Source: HECO 2007

The Hawaii Electric Company (HECO) collected warranty claim data for systems receiving incentives under their SWH program. The Hawaii data shows 0.16 percent of collectors have warranty claims within 5 to 10 years. Approximately 0.08 percent of tanks have a warranty claims over a 5-year time frame and 0.14 percent of pumps and controllers have warranty claims within 1 to 10 years. Performance data are not yet available from the SWHPP, but equipment and installation requirements are similar to those required by the HECO incentive program, with additional freeze protection requirements. Trends in performance and reliability are expected to be similar to those seen in Hawaii.

The HECO warranty data are used to estimate failure rates and the EUL of SWH systems (Kalbfleisch 1980, Mowris 2005). **Table 5** shows the hazard rate estimate for SWH systems based on HECO data. The hazard rate is defined as the number of failures per year divided by

[3] Cost of average system in EWEB based on EWEB program data for 2008.

total installations. The time series of hazard rates is used to develop the survival function power curve fit coefficients and Weibull distribution parameters. **Equation 1** is used to calculate the survival function curves for the Weibull distribution.

Eq. 1. $\hat{v} = EXP(-\alpha * t^{\beta})$

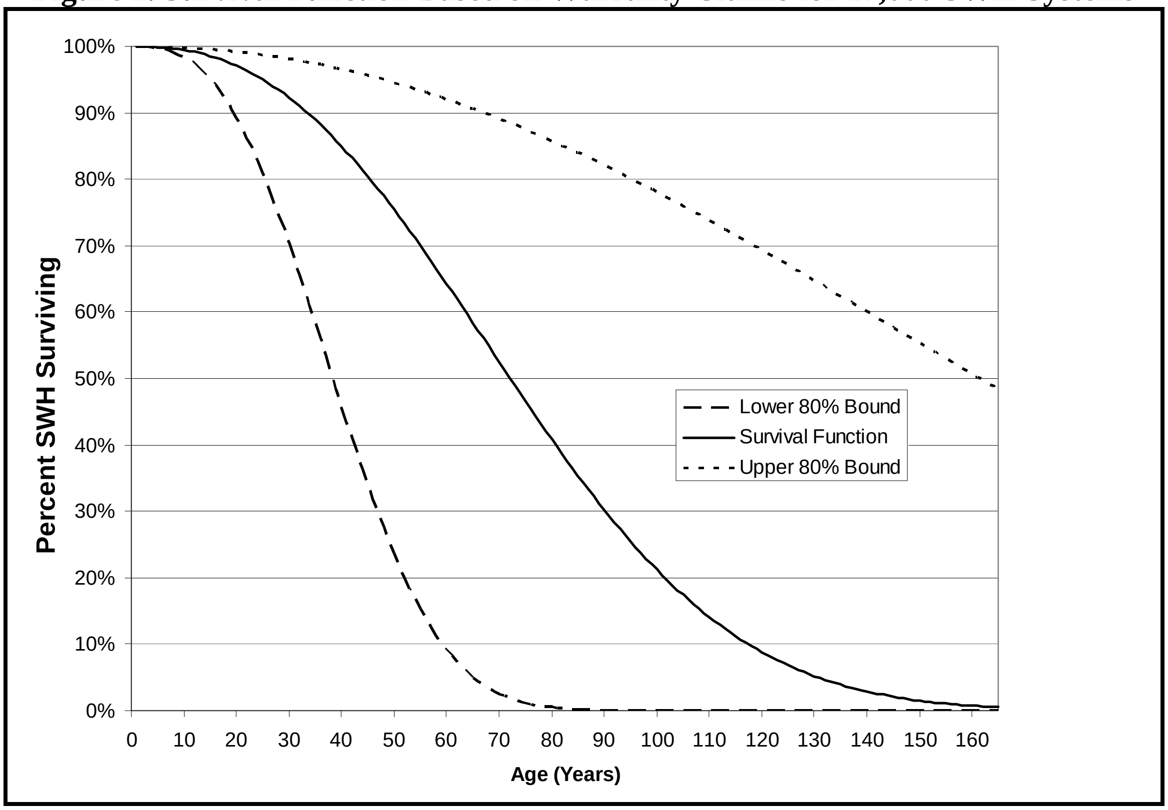
Where, α = alpha, the estimated scale parameter, t = time, years, and β = beta, the estimated shape parameter.

Figure 1 shows the survival function for SWH systems with lower and upper bounds based on the Wiebull Analysis of the HECO data (Collett 1984). The median EUL is 72.4 years, the lower bound is 38.3 years, and the upper bound is 161.4 years.

Table 5. SWH Hazard Rate Estimate Based on HECO Data from 1996-2004

	Power Curve Fit Coefficients			Weibull Distribution Parameters	
Type of Measure	**A**	**B**	**R-squared**	**α (Scale)**	**β (Shape)**
SWH removed/failed	0.00046	1458613	0.863959	0.000018753	2.458613323

Figure 1. Survival Function Based on Warranty Claims for 27,000 SWH Systems



Societal Value of SWH Programs

The societal value of the SWH pilot program is evaluated with the total resource cost-effectiveness (TRC) test using the CPUC-approved E3 calculator developed by Energy and Environmental Economics, Inc. (E3 2010). The SWHPP TRC test scenarios based on EUL for SWH displacing gas water heating are shown in **Table 6**. Inputs to the E3 model are the incentives per SWH (**Table 2**), administrative budget per SWH incentive ($0.6875 per SWH incentive dollar), societal 5% real discount rate, current SWH costs (**Table 2**), energy savings per SWH (**Table 2**), number of SWH systems installed (**Table 1**), net-to-gross ratio (1.0), and EUL of 25-years, 38-years, and 45-years (from Wiebull analysis). Based on these assumptions, the average SWHPP TRC test is 0.41 for the 25-year EUL, 0.76 for the 38-year EUL, and 1.01 for the 45-year EUL.

Table 6. SWHPP TRC Test Scenarios Based on EUL

Scenario	SF Residential TRC Test	MF Residential TRC Test	Commercial TRC Test	Average TRC Test
25-Year EUL Baseline SWH - Current SWH Cost	0.44	0.29	0.47	0.41
38-Year EUL Baseline SWH - Current SWH Cost	0.81	0.53	0.87	0.76
45-Year EUL Baseline SWH - Current SWH Cost	1.08	0.71	1.17	1.01

Source: Mowris 2010

Itron evaluated four SWH program societal test cost effectiveness scenarios displacing gas water heating as shown in **Table 7** (Itron 2009). Each scenario includes a 25-year effective useful life, 5% real discount rate, avoided pollution, green house gas (GHG) reduction benefits, job growth, and market transformation benefits. The "baseline SWH" scenario assumes current SWH costs through 2017. The other three scenarios, "business as usual," "moderate GHG" and "aggressive GHG," assume 16 percent reduced SWH costs by 2017 (Itron 2009). The SWH cost reduction is based on historical data of a 30 percent cost reduction from 1980 to 1990 (Itron 2009). Itron assumes the SWH cost can be reduced through lower equipment costs, labor costs, marketing, and permitting. The "baseline SWH" scenario has an average societal test of 0.65, and $8 per metric tonne of avoided carbon dioxide (CO_2) increasing to $161/tonne in 2042. The "business as usual" scenario has an average societal test of 1.01, and also assumes $8 per metric tonne of avoided carbon dioxide (CO_2) increasing to $161/tonne in 2042. The "moderate GHG" scenario has an average societal test of 1.30 and assumes $20/tonne of avoided CO_2 increasing to $220/tonne in 2042. The "aggressive GHG" scenario has an average societal test of 2.36 and assumes $100/tonne of avoided CO_2 increasing to $272/tonne in 2042. Based on the Itron societal test analysis, the CPUC approved the California SWH program to install 200,000 systems by 2017 and displace 2.47 PJ/year of natural gas and 257.7 GWh/year (CPUC 2010).

Table 7. SWH Program Societal Test Cost Effectiveness Scenarios

Scenario	SF Residential Societal Test	MF Residential Societal Test	Commercial Societal Test	Average Societal Test
Baseline SWH - Current SWH Cost	0.73	0.50	0.77	0.65
Business as Usual - 16% Reduced SWH Cost	1.08	0.71	1.17	1.01
Moderate GHG - 16% Reduced SWH Cost	1.37	0.92	1.49	1.30
Aggressive GHG - 16% Reduced SWH Cost	2.29	1.68	2.74	2.36

Source: Itron 2009

A study by the California Solar Energy Industries Association (CALSEIA) quantifies the societal value of SWH and demonstrates how incentives pay for themselves many times over in the form of energy savings, cleaner air, and economic development. According to CALSEIA, every $0.40 invested in SWH returns between $0.90 and $3.50 to ratepayers in energy savings, health benefits, greenhouse gas reductions, and job creation (CALSEIA 2009). The CALSEIA study quantifies the societal value of SWH in terms of: (1) direct savings from SWH versus indirect savings due to avoided water heater efficiency losses, (2) hedges against price volatility,

(3) avoided emissions and associated health benefits, (4) avoided distribution losses, (5) avoided or deferred distribution capacity, and, (6) job creation potential.

Other SWH Programs

SWH Programs in the United States

Table 8 summarizes fourteen US SWH programs offering incentives, incentives with loan options, and utility-owned systems where the customer pays a monthly fee. Nine programs offer incentives similar to the SWHPP. The incentives include a one-time upfront incentive for residential projects and performance based incentives (PBIs) for larger commercial systems. Three programs offer zero- or low-interest loans in addition to incentive payments. One program offers utility-owned systems, where the utility pays for the system and metering equipment and the customer pays a monthly fee for water heating at a rate less than electric water heating. Programs with significant installations include PG&E, SoCalGas, SCE, and SDG&E programs with approximately 158,923 installations from 1980 to 1983, and the ongoing HECO program with 47,275 installations since 1996 and average installations of 3,940 per year (CPUC 2008). The HECO and Eugene Water and Electric Board programs offer incentives plus loans to achieve greater participation rates. The Eugene program introduced a zero-interest loan option in 1995, resulting in a 67 percent sales increase from the previous year. Offering loans in addition to incentives increases participation by lowering initial cost and spreading out payments over time. If loan payments are less than bill savings, then homeowners realize immediate savings.

Table 8. Summary of US Residential SWH Programs

Implementer	Program	Start-End Year	Eligible Fuel Types	Incentive	Installs	Annual Installs
SWHPP	Rebate	July 2007	Gas, Elec., Propane	Up to $1,500/Res and $75,000/Com	369	148
PG&E	Rebate	1980-83	Electric, Gas	$720 (E) $960 (G)	66,437	16,609
SoCalGas	Rebate	1980-83	Gas	$960 (Gas)	69,153	17,288
SCE	Rebate	1980-83	Electric	$720 (Elec.)	11,879	2,970
SDG&E	Rebate	1980-83	Electric, Gas	$720 (E) $960 (G)	11,454	2,864
City of Palo Alto Utilities	Rebate	May 2008	Electric, Gas	Up to $1,500/Res and $75,000/Com	6	6
Marin County	Rebate	June 2005	Electric, Gas	$300	8	3
Redding Electric Utility	Rebate	Jan. 2002	Electric	$1,000 1st Panel, $500 2nd, $250 3rd up to 50%	29	20
Arizona Public Services (APS)	Rebate	2002-2007	Electric	$0.45/kWh of est. 1st yr savings; up to 50%	258	51
National Grid	Rebate	Aug. 2007	Electric, Gas	15% up to $1,500	30	30
Hawaii (HECO)	Rebate/Loan	1996	Electric	$1,000	47,275	8,207
Eugene WEB	Rebate/Loan	1990	Electric	$600	1,030	57
SMUD	Rebate/Loan	1980, 2005	Electric	$1,500	200	67
Lakeland Electric	Utility-owned	1997-2002	Electric	n/a	60	12

Source: Itron 2009, CPUC 1984, City of Palo Alto 2009, HECO 2009

International SWH Programs

A growing number of European municipalities, regions, and countries (e.g. Spain, Portugal, Italy, the Baden Wuerttemberg region in Germany, and some Austrian regions) are implementing **solar thermal ordinances,** legal provisions requiring owners of buildings to install a solar thermal system for new buildings or for buildings undergoing major renovation (http://www.solarordinances.eu/). Spain and Israel currently mandate SWH on all new construction. The European Solar Thermal Industry Federation (ESTIF) estimates that there are currently 15.4 GW (22 million m^2 collector area) of solar thermal capacity installed in the European Member States with 1.918 GW (2.739 million m^2) installed in 2007 (ESTIF 2008). This achievement was accomplished through incentives, training, certification, standards, and public information on the technology (ESTIA 2003).

Many successful SWH incentive programs have been implemented internationally. A report by the European Solar Thermal Industry Federation (ESTIF) provides an overview of successful incentive programs as well as case studies of European models which have succeeded or failed (ESTIA 2003). The primary features of successful SWH programs are consistent and continuing marketing support of SWH incentives. Offering consistent and long-term SWH incentives provides industry with confidence to make business investments. Programs that do not provide continuous support for SWH are likely to fail, and programs that stop and start are likely to cause more issues within the industry than having no incentive at all. Additionally, the ESTIF report stated that "By discussing, or even announcing, a support scheme in the future, the market actually decreased rather than increased" (ESTIA 2003). To develop a sustainable SWH market, the initial incentive must be high enough to stimulate market growth. Providing long-term guarantee of an incentive of any amount builds the confidence of industry participants, end-use customers, and financial organizations that may provide loans or financing to stakeholders. Creating this confidence will lead SWH businesses to invest in their companies and to hire and train new employees.

China has no government involvement or subsidies, but increasing interest in SWH. In 2004, China accounted for approximately 80 percent of world sales of collectors for SWH or heating buildings (Menanteau 2007). Some reports indicate that China has implemented quality control standards, while others indicate low quality products are still abundant in China (Milton 2005). In China, the demand for SWH is from an increase in the demand for hot water supply coupled with electricity and natural gas being unavailable in some areas. A similar situation existed in Israel in the 1950s when the government mandated that hot water only be used at certain times of day (Ramlow). This influenced households to install SWH systems.

Best Practices Learned from Successful U.S. and International Programs

A number of best practices were learned during California's first experience with large-scale SWH programs from 1980 to 1983 including the development of standards for quality installation, solar collector performance certification, and solar system performance certification. The California utilities and solar industry also learned that sizing SWH systems based on number of bedrooms in a home (as required by the CPUC-mandated program) resulted in system failures because oversized systems stagnated (SWHPP requires system sizing based on number of occupants) (CALSEIA 2008). Prior to the California large-scale SWH programs in 1980-83, there were no uniform rating systems, so the California utilities, CALSEIA, and California Energy Commission (CEC) worked together to establish testing and rating programs for solar collectors (CALSEIA 2008). Inconsistencies between state testing and rating requirements created an impediment to manufacturers who marketed in more than one state. In order to develop a uniform national standard for testing and rating solar equipment, the solar energy industry and a national consortium of utilities, state energy offices, and regulatory bodies joined together to lay the groundwork for the Solar Rating and Certification Corporation (SRCC) (SRCC 2008). In 1980 the SRCC was incorporated as a non-profit organization to develop and implement certification programs and national rating standards for solar energy equipment. SRCC is the only US certification program established solely for solar energy products. It is also the only national certification organization whose programs are the direct result of combined efforts of utilities and state organizations involved in the administration of standards and an industry association.

Recent experiences from successful U.S. and international SWH programs help identify the following five best practices to achieve success and avoid problems.

1) Incentive programs must include quality installation standards, training and verification of quality installation, technical assistance, web-based monitoring systems, and long-term warranties to increase system life.
2) Incentive programs must be established and guaranteed long-term so that the industry can make investments and grow their businesses with confidence that the support will not suddenly disappear. Programs supported with ratepayer funds are more likely to meet a long-term program design, as opposed to tax-supported programs that can be cut in times of economic hardship.
3) Incentive calculations must be designed with system performance in mind, as opposed to system size or cost. This will prevent oversized systems or over-priced systems, and will encourage higher-performing systems designed with the building owner's needs in mind. If the incentive is paid to the contractor, then the incentive needs to account for additional time for program requirements.
4) Incentive programs must be accompanied by a strong marketing campaign. Homeowners and business owners need to be made aware of the technology and benefits provided by SWH and marketing cannot be done by contractors and installers alone. A state- or utility-backed technology awareness campaign lends credibility to the industry and increases public knowledge. A joint marketing campaign between the incentive program and industry stakeholders will ensure success.
5) Contractor training and customer education should include information about comprehensive hot water energy efficiency measures including efficient plumbing, WaterSense® showerheads and aerators, Energy Star® tankless gas water heaters, and Energy Star® clothes washers and dishwashers.

Discussion

The lower-bound EUL estimate of SWH systems is 38.3 years and the median EUL is 72.4 years based on Weibull analysis of warranty claims for 27,000 systems in Hawaii. The societal value of the SWHPP is evaluated with the TRC test using the CPUC-approved E3 calculator developed by Energy and Environmental Economics, Inc. The study found an average TRC test of 0.41 for 25-year EUL, 0.76 for 38-year EUL, and 1.01 for 45-year EUL. Itron evaluated four SWH scenarios using societal test cost-effectiveness and 25-year EUL. The Itron baseline scenario assumes current SWH system costs through 2017, and the other three scenarios assume 16 percent reduced SWH costs by 2017. The Itron scenario societal tests are as follows:

0.65 for baseline, 1.01 for business as usual, 1.3 for moderate GHG, and 2.36 for aggressive GHG. Based on the Itron analysis, the CPUC approved $250 million for the California SWH program.

The cost effectiveness methods presented in this paper use different approaches to develop cost effective scenarios for SWH that provide benefit-cost ratios greater than 1.0 which is required by the CPUC to implement SWH programs. One method uses a 45-year EUL based on Weibull analysis of warranty claim data in Hawaii. The other method uses reduced system costs, increasing avoided costs of GHG emissions, and employment benefits. Both methods use a 5% real discount rate. The 45-year EUL is considerably longer than the 25-year EUL typically assumed for SWH. The longer EUL is plausible given the relatively low cost associated with replacing one or more pumps, motors, or storage tanks over 45 years.

Conclusions

The California Solar Water Heating Efficiency Act (AB1470) authorizes $250 million to transform the SWH industry and provide incentives for 200,000 solar water heaters starting in 2010. To get the program started, California implemented a $2.6 million SWH pilot program in San Diego by the California Center for Sustainable Energy. The pilot program provides quality installation standards and verification, training, technical assistance, and incentives to encourage widespread implementation of SWH in California. For residential systems, the maximum incentive is $1500 per dwelling. For larger commercial and industrial systems, the incentive is based on collector area. For open-loop systems the incentive is $161.46/m^2 and for closed-loop systems the incentive is $215.28/m^2.

The SWHPP paid a total of $499,606 in incentives through 2009, with $393,076 paid to 309 residential customers who used the prescriptive incentive and $106,530 paid to 19 commercial customers who used the collector area incentive. The program received more interest from residential customers than commercial customers. Residential customers paid an average installed SWH system cost of $6,752 and received an incentive of $1,259. If all customers claimed and received a federal tax credit, the net cost would be decreased to $3,475. SWH has the technical potential to displace up to 127.9 PJ of natural gas per year in California. The 2.74 PJ per year of projected residential natural gas savings from the SWH measure included in the AB 32 Proposed Scoping Plan and AB1470 is a conservative estimate that represents less than 2% of the combined residential and commercial market technical potential for SWH estimated by KEMA-XENERGY. The expanded SWH measure considered in the AB32 Draft Scoping Plan represents only 10% of the total technical potential natural displacement for SWH in California.

The average SWHPP system installed cost is $6,752, and except for China and India, this cost is comparable to the cost for SWH systems in the US and Europe. The average annual residential energy savings are 12.5 GJ for SWH with gas back-up and 2,793 kWh for SWH with electric back-up. The lower-bound SWH EUL estimate is 38.3 years and the median EUL estimate is 72.4 years based on Weibull analysis of warranty claims for 27,000 systems in Hawaii. Including program administration costs of $0.6875 per incentive dollar, the SWHPP TRC test is 0.41 for 25-year EUL, 0.76 for 38-year EUL, and 1.01 for 45-year EUL. Itron evaluated four SWH program scenarios using societal test cost effectiveness and 25-year EUL. The Itron baseline scenario assumes current SWH system costs through 2017, and the other three scenarios assume 16 percent reduced SWH costs by 2017. The Itron scenario societal tests are as follows: 0.65 for baseline, 1.01 for business as usual, 1.3 for moderate GHG, and 2.36 for aggressive GHG. Based on the Itron analysis, the CPUC approved the California SWH program to install 200,000 systems by 2017 and displace 2.47 PJ/year of natural gas and 257.7 GWh/year.

The following best practices lessons can be learned from successful U.S. and International SWH programs: incentives and/or low-interest loans need to be long-term, based on system performance as opposed to size or cost, and accompanied with strong marketing campaigns to stimulate demand for SWH and the supply of contractors who can provide high quality installations. In addition, incentive programs must include quality installation standards, training and verification of quality installation, technical assistance, and long-term warranties to increase system life. Contractor training and customer education should include information about comprehensive hot water energy efficiency measures including efficient plumbing.

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