Saying Mahalo to Solar Savings: A Billing Analysis of Solar Water Heaters in Hawaii

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ABSTRACT

Over the last several years, the market share for solar water heaters has steadily increased in the state of Hawaii. The Hawaiian government mandated that all new homes have solar water heaters installed, and the state offers incentives to homeowners who opt to purchase solar water heaters for their existing homes. The evaluation of savings and market conditions associated with this equipment is important as other markets consider the energy savings potential of solar water heating technology. This paper provides the results of a billing analysis used to estimate savings of residential solar water heaters in the state of Hawaii and feedback from consumers and contractors on the remaining potential.

The billing analysis was conducted with a monthly panel data regression model using utility billing data and program tracking data for 2,457 customers who installed solar water heaters during program year 2009, estimating changes in household electricity consumption between the pre- and post-installation periods.

The results of this paper are significant because they help provide an updated savings value for solar water heaters in Hawaii and give a current assessment of market conditions. While Hawaii's climate is unique, these savings and market findings can assist other regions in tapping solar water heater potential in their markets. These results will be of interest to other states with sunny climates that have a high solar energy potential.

Introduction, Background, and Summary of Findings

This paper presents the results of a solar water heater billing analysis conducted as part of a larger evaluation of Hawaii Energy's conservation and efficiency programs. The analysis focused on the residential installation of solar water heaters for the program year 2009 (PY2009) and 2010 (PY2010).[1] This paper also presents some findings on the condition of the market for solar water heaters in Hawaii.

The Hawaiian market for solar energy efficiency equipment is somewhat different from the rest of the country. To start, Hawaii's climate and abundance of sunshine make it an ideal locale for the success of a measure like solar water heaters. In addition, the high energy prices that Hawaiian consumers face provide even more reason to invest in a technology like solar water heating.

Interest in solar water heating and renewable energy as a whole has a long history in Hawaii. As early as 1976, Hawaii provided energy tax credits for residents and businesses that purchased and installed renewable energy systems, including solar water heaters. In 1996 a

[1] Hawaii Energy's program year runs from July 1 to June 30. For example, program year 2009 refers to program activities undertaken between July 1, 2009 and June 30, 2010.

rebate was made available through the public benefit fund of Hawaii Energy Efficiency Programs. The public benefits fund was originally collected and administered by Hawaii Electric Company (HECO) and Maui Electric Company (MECO). Since 2009, the energy efficiency programs and rebates have been administered through Hawaii Energy. Rebates for solar water heaters are currently funded by the public benefits fee paid into by ratepayers along with some funding from the American Recovery and Reinvestment Act (ARRA).

Hawaii Energy is a third-party organization that implements conservation and energy efficiency programs throughout Hawaii. They operate a portfolio of programs that cover the residential and commercial sectors, with some programs targeted specifically toward new construction and residential low-income customers. The solar water heater program is currently a part of their residential program offerings. The last time these programs were evaluated was in 2008 when KEMA, Inc. conducted an impact evaluation of the 2005-2007 program cycle of the residential and commercial portfolio.

Our analysis focused on the solar water heater program since coming under the control of Hawaii Energy in 2009. Total solar water heater program participation for PY2009 and PY2010 is shown in Table 1. In our final model, participants from PY2010 are used as a control group to determine the savings realized by PY2009 participants, as the PY2010 participants had not yet installed the solar water heater in 2009 (the year used for the billing analysis). Including the PY2010 customers in the sample provides an additional control for external influences (e.g., economic conditions, household and structural changes) that may impact energy use.

Table 1. Solar Water Heater Participants

Program Year	Number of Participants
2009	3,607
2010	2,695
Total	6,302

The annual savings estimate for solar water heaters found as a result of this analysis is shown below in Table 2, along with a 95 percent confidence interval. Our impact estimate of 1,912 kWh is close to the current *ex ante* savings value of 2,066 kWh included in the Hawaii Energy PY2010 Technical Reference Manual (TRM).[2] Given that the savings estimates are so close, we did not recommend any change to the TRM value currently in use by the program.

Table 2. Savings Estimate and 95% Confidence Interval

Annual Savings (kWh)	95 % Conf. Interval LOWER BOUND	95 % Conf. Interval UPPER BOUND	Current TRM Value (kWh)
1,912	1,714	2,111	2,066

Source: Analysis by Evergreen Economics of data provided by Hawaii Energy

[2] The PY2010 TRM savings value of 2,066 kWh is based on the 2008 evaluation by KEMA Inc. of the 2005-2007 Hawaii demand side management programs, which included a solar hot water heater metering study.

Billing Regression

For the billing regression, we developed a fixed effects billing regression model using monthly panel data to estimate changes in household electricity consumption between the baseline ("pre") and post-measure-installation periods. The billing regression model relates normalized monthly electricity consumption by household by month to:

1. An indicator variable for the months in which the solar water heater was installed
2. Monthly dummy variables to control for external factors[3]
3. Interaction terms between the indicator for solar water heater installation and monthly dummy variables

Interactions between the first two independent variables were examined and ultimately included in the model. The final model was estimated using the linear values of the dependent and independent variables.[4] While a number of different specifications were explored, the final fixed effects model was specified as follows:

$$kWh_{it} = \beta_0 + \beta_1 SWH_{it} + \beta_2 Month_{it} + \beta_3 Month_{it} * SWH_{it} + e_{it}$$

Where:

kWh = Normalized monthly electricity consumption for each month (in kWh)

SWH = Indicator variable for post-period solar water heater installation period

$Month$ = Indicator variables for each month excluding December

$Month * SWH$ = Interaction terms between indicator for post-period solar water heater installation and monthly indicators

i = Index for household (i = 1,..., n)

t =Index for monthly time period (t=1,2,..., T)

$[\beta_0, ..., \beta_3,]$ = Coefficients to be estimated in the model

$[e]$ = Error term assummed normally distributed

Data Used in Analysis

Monthly electricity billing data and information related to the timing of solar water heater installation were provided by Hawaii Energy for participants in program years 2009 and 2010. Utility billing data were provided from April 2008 to July 2011.

Weather or temperature data were not included in this analysis since water heater use is not greatly affected by daily outdoor temperature and temperatures are relatively constant throughout the year in Hawaii. However, monthly indicator variables were included in the final

[3] December was excluded to avoid perfect collinearity between independent variables.
[4] As opposed to the alternative of first transforming the dependent variable and/or the independent variables by the natural log function.

model specification to capture any seasonal or monthly effects that may exist. Variables included in the billing regression model are defined below in

Table 3.

Table 3. Description of Model Variables

Variable	Description
kWh	Normalized monthly electricity consumption by month (calculated by scaling usage from number of meter read days to the average number of days per month)
SWH	Indicator variable for months after solar water heater installation (equals 1 if in post-installation period; else equals 0)
Month (January, February, March, etc.)	A vector of indicator variables for month of year (equals 1 if observation falls in that month; else equals 0)
Month_SWH (Jan_SWH, Feb_SWH, Mar_SWH, etc.)	A vector of indicator variables for month of year and solar water heater installation (equals 1 if in post-installation period and observation falls in that month; else equals 0)

Data screens were employed to ensure that only participants within a reasonable consumption range were included in the analysis. This data screen was based on monthly kWh usage and participants were selected for analysis if their monthly usage fell between 50 and 3,000 kWh. The effect of implementing this screen on the data is shown in Table 4 below.

Table 4. Summary of Data Screens

Program Year	Total Participants	Participants with Billing Data	Participants Meeting kWh Criteria
2009	3,607	3,606	2,457
2010	2,695	2,693	1,951
Total	6,302	6,299	4,408

Source: Analysis by Evergreen Economics of data provided by Hawaii Energy

This data screen was used in the final model presented in this paper. Column four of Table 4 shows the number of individual participants included in the final model. Pre- and post-installation data were included for all 2,457 PY2009 participants shown in this table. The 1,951 participants from PY2010 were included as a control group, and as such only their pre-installation billing data were included in the analysis.

Billing Model Estimation Results

The results from the billing regression model are shown below in Table 5. All of the estimated coefficients are of the expected sign (either negative or positive) and the primary variable of interest (SWH) is statistically significant at the 5 percent level. About half of the monthly indicator variables are statistically significant at the 5 percent level as well. The coefficients on monthly indicators and interaction terms show that kWh usage varies by month, with February, March, April, and May showing statistically significant lower usage per month, on average, than December (the omitted variable).

The coefficient of interest with respect to solar water heater energy savings is β_1 (the coefficient on the post-installation indicator). This coefficient is negative, indicating that, after accounting for monthly variations in electricity usage and holding all else constant, participants experienced an estimated base decrease of 159.37 kWh per month after installation of a solar water heater. This translates to an annual savings of 1,912 kWh due to the solar water heater installation.

Note that this result captures all changes in usage in the post period and attributes them to the solar water heater installation. To the extent that there are external influences that are reducing energy use outside the program and are not controlled for in our model, then the savings estimates derived from the model will overstate the actual energy savings of the solar water heaters.

Table 5. Regression Results

Variable	Coefficient	Std. Error	t-statistic	p-value
(β_0) Constant	845.62	4.56	185.59	0.00
(β_1) SWH	-159.37	8.43	-18.90	0.00
(β_2) January	13.14	6.56	2.00	0.05
(β_2) February	-27.05	6.79	-3.98	0.00
(β_2) March	-33.46	6.63	-5.04	0.00
(β_2) April	-39.69	6.86	-5.78	0.00
(β_2) May	-33.50	7.04	-4.76	0.00
(β_2) June	-7.60	6.23	-1.22	0.22
(β_2) July	-1.12	6.24	-0.18	0.86
(β_2) August	11.26	6.32	1.78	0.08
(β_2) September	7.61	6.31	1.21	0.23
(β_2) October	1.69	6.38	0.27	0.79
(β_2) November	4.93	6.57	0.75	0.45
(β_3) January_SWH	8.37	11.77	0.71	0.48
(β_3) February_SWH	-6.30	12.06	-0.52	0.60
(β_3) March_SWH	4.81	11.45	0.42	0.68
(β_3) April_SWH	-7.80	11.82	-0.66	0.51
(β_3) May_SWH	5.20	11.82	0.44	0.66
(β_3) June_SWH	-10.30	11.17	-0.92	0.36
(β_3) July_SWH	-1.37	11.28	-0.12	0.90
(β_3) August_SWH	-2.33	12.51	-0.19	0.85
(β_3) September_SWH	-0.16	12.25	-0.01	0.99
(β_3) October_SWH	6.43	12.26	0.52	0.60
(β_3) November_SWH	4.54	12.31	0.37	0.71

Source: Analysis by Evergreen Economics of data provided by Hawaii Energy

The coefficient on SWH (β_1) in Table 5 above was used to calculate the annual savings attributable to solar water heaters. The data used in the model was on a monthly basis, so the coefficient estimate of -159.37 indicates that an average of 159.37 kWh in savings were realized in each month that a solar water heater was installed. To get an annual savings value, this number was simply multiplied by 12. The formula used to calculate annual savings is shown below:

Estimated change in annual energy use due to Solar Water Heater = Coefficient on SWH * 12

Table 6 below shows the estimated annual savings for solar water heaters installed by PY2009 participants along with a 95 percent confidence interval and the existing savings value in Hawaii Energy's PY2010 Technical Reference Manual (TRM).

Table 6. Billing Regression Savings Estimate and 95% Confidence Interval

Annual Savings (kWh)	95 % Conf. Interval LOWER BOUND	95 % Conf. Interval UPPER BOUND	2010 TRM Savings (kWh)
1,912	1,714	2,111	2,066

Source: Analysis by Evergreen Economics of data provided by Hawaii Energy

Comparison to Existing Savings Values

These billing regression results are slightly lower than, although generally consistent with, the savings value calculated in the PY2010 TRM. The TRM value for solar water heater savings is 2,066 kWh annually and assumes an average household occupancy of 3.77 people. The average household occupancy reported by the surveyed PY2009 participants was 3.53, which is slightly lower than that assumed by the TRM. A lower occupancy is generally associated with less hot water use and consequently these households may see slightly smaller annual savings than the TRM suggests.

In addition, the annual kWh consumption of the sample households is lower than the average found in earlier solar water heater impact evaluations. The average annual base consumption in the model data was 10,147 kWh, whereas the annual base consumption found in the 2001-03 Impact Evaluation prepared by KEMA was 11,096 kWh. The kWh savings reported by KEMA for solar water heaters in that report was 2,201 kWh. The small difference in occupancy and base consumption between these groups may explain some of the difference in savings found by our analysis. Despite these differences, the TRM savings value of 2,066 kWh does fall within the 95 percent confidence interval of our estimated savings, indicating that our analysis confirms the existing value for solar water heaters.

Solar Water Heater Market Findings

The solar water heating market provides considerable opportunity for energy savings in Hawaii. Based on the findings in this analysis, installed residential solar water heaters can save the average Hawaii household nearly 20 percent on their annual electric bill, which is equivalent to about $500 to $700 annually, depending on the electricity rate for each island.[5] The expected lifetime of a solar water heater is 15 years, and the savings will persist over that time. These savings have been significant enough that the Hawaii State Senate passed SB no. 644, which requires all new single-family residences constructed after January 1, 2010 to include a solar water heater system. Despite this requirement for new residential homes, there is still a large market for retrofitting solar water heaters in existing homes. The current estimates are that roughly 75 percent of homes in Hawaii do not have a solar water heater system.

The Hawaii Energy solar water heater program recently transitioned its focus to retrofitted solar water heating systems in order to comply with the new Senate Bill that mandated solar water heating on all new homes. The retrofit market often consists of those customers that

[5] Average residential electricity rates in Hawaii for 2010 varied from $0.2547 on Oahu to $0.3711 on Lanai.

are the most difficult and costly to serve and, as a result, the incentive program is even more vital to installations of solar water heaters for this market segment. The incremental cost of a solar water heater is listed as $6,600 in the PY2010 TRM and has a rebate amount of $750. The additional electricity cost savings provided by the solar water heater adds an extra incentive for retrofit customers.

At the end of 2009 there was a significant rush of solar water heater installations by new construction builders and customers in order to take advantage of the rebate before the expiration date. There was also an initial boost in install rates at the beginning of the 2010 program year, and again at the end of calendar year 2010. In March 2011, Hawaii Energy was approved to use ARRA funding to double the cash rebate amount for solar water heater systems, which resulted in 800 systems being sold in one month and completely exhausting the additional approved funds.

The current solar water heater program is strong, and interviews with solar water heater contractors reveal that they see it as a reliable technology, which requires little more than routine maintenance. To assist in this routine maintenance, Hawaii Energy has started offering a rebate for solar water heater tune-ups in PY2011 at a cost of $250 to participants after a $50 rebate. In addition to contractor satisfaction with the equipment, participant surveys revealed that 97 percent of PY2009 participants and 96 percent of PY2010 participants were "somewhat satisfied" or "very satisfied" with their solar water heater purchase. Together these two results indicate that solar water heaters have a positive market presence in Hawaii.

Summary and Conclusions

Using a billing regression model and a sample of 2009 and 2010 solar water heater participants, we estimated annual savings from this measure of 1,912 kWh. This generally confirms the savings value of 2,066 kWh in use by Hawaii Energy for PY2010, as that value lies within the 95 percent confidence interval of our savings estimate. The slight difference may be explained by lower occupancy rates and/or lower household energy consumption in our analysis sample relative to the values found in previous impact evaluations. For these reasons, we did not recommend any changes to the current *ex ante* value of 2,066 kWh used by Hawaii Energy for solar water heaters.

The market for solar water heaters in Hawaii now relies heavily on retrofitting water heating systems in existing homes due to the recent legislation requiring solar water heaters in all new construction projects. Our research found that there is still considerable potential in the retrofit market, and that incentives can be a substantial driver toward replacement. Additionally, interviews with contractors revealed that solar water heaters are a reliable technology that requires little maintenance and surveys of participants revealed high satisfaction rates with the installed equipment.

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