Paying Your Fair Share – A Billing Analysis and Literature Review of Condominium Submetering

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ABSTRACT

Anyone familiar with the sight of Waikiki Beach on Oahu has surely noted the high-rise condominium towers lining the beach. Now imagine, in Hawaii, where electricity prices are three times as high as on the mainland, not having to pay for the actual amount of electricity you have consumed. This is the case for many master-metered condominium buildings in Hawaii, and it eliminates much of the motivation for condo owners to conserve electricity. Condominium submetering is designed to shift responsibility for the electric bill to the condo owner, by converting a previously master-metered building into individual submetered units.

As a provisional estimate, deemed (i.e., pre-authorized) savings for submetering in Hawaii is set at 10 percent of pre-submetering energy use. The analysis presented in this paper uses a fixed effects regression model to determine whether this 10 percent is an appropriate value. Monthly billing data for several submetered sites were used to model energy use as a function of submeter installation, other energy efficiency upgrades, and monthly indicators. Preliminary results suggest that the 10 percent savings value currently in use may be on the low end of electricity savings realized by tenants of submetered buildings.

In addition to billing analysis, reviews of existing literature and savings rates from other jurisdictions were conducted to provide context and comparison for the findings of this analysis. The results of this study provide an estimate of the savings that can be achieved through submetering and may help make the argument for introducing submetering in jurisdictions where it has not yet gained traction.

Introduction, Background, and Summary of Findings

This paper presents the results of a condominium submetering billing analysis conducted as part of a larger evaluation of Hawaii Energy's conservation and efficiency programs. The analysis focused on the installation of submeters on residential condominium buildings completed in program years 2011 (PY2011) and 2012 (PY2012).[1] This paper also presents some findings from a literature review of submetering studies in other jurisdictions.

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 condominium submetering program is currently a part of their commercial program offerings and provides a rebate of $150 per meter to

[1] Hawaii Energy's program year runs from July 1 to June 30. For example, program year 2011 refers to program activities undertaken between July 1, 2011 and June 30, 2012.

install submeters in a previously master-metered building (Hawaii Energy 2012).[2] This allows the building owner to reduce their variable costs while transferring the responsibility of the energy bill to the tenant to encourage conservation. The program also offers energy efficiency education to tenants as part of the submetering process to further encourage energy conservation. This paper presents the first independent evaluation of savings associated with Hawaii Energy's condominium submetering offering since it began as a pilot program in 2010.

Our analysis focused on the condominium submetering projects that have been completed since Hawaii Energy began this offering in 2010. Total numbers of completed submetering projects and condo units for PY2011 and PY2012 are shown in Table 1.[3] Over these two program years 12 buildings had completed submetering projects that covered 2,113 condominium units. In our final model, only five sites had sufficient post-installation billing data to be included in the analysis.

Table 1: Condominium submetering projects

Program year	Number of submetering projects completed	Number of units submetered
2011	5	425
2012	7	1,688
Total	12	2,113

The annual savings estimate as a percent of annual energy usage for condominium submetering found as a result of this analysis is shown below in Table 2, along with a 95 percent confidence interval. Our impact estimate of 22.7 percent is more than double the provisional *ex ante* savings value of 10 percent included in the Hawaii Energy PY2012 Technical Reference Manual (TRM).[4] Given that the savings estimates are so different, we plan to re-evaluate this measure in the next program evaluation cycle using more sample points and may then recommend an update to the TRM deemed savings value if appropriate.

Table 2: Savings estimate and 95% confidence interval

Estimated savings (percent of annual energy use)	95% conf. interval LOWER BOUND	95% conf. interval UPPER BOUND	2012 TRM savings (percent of annual energy use)
22.7%	18.4%	27.1%	10%

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

Details on the billing analysis steps and results are provided below.

[2] The incremental cost for a submeter is quoted at $750 in the PY2012 TRM.
[3] Although submetering was offered starting in PY2010, no projects were completed until the PY2011 cycle.
[4] "Hawaii Energy – Technical Reference Manual No. 2012". Hawaii Energy. http://www.hawaiienergy.com/information-reports

Billing Regression

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

1. An indicator variable for the months in which the submetering project had been completed
2. An indicator variable for other Hawaii Energy program participation at the submetered sites
3. Monthly dummy variables to control for external factors[5]

Interactions between the first and third independent variables were examined and ultimately not included in the model. The final model was estimated using the linear values of the dependent and independent variables.[6] While a number of different specifications were explored, the final fixed effects model was specified as follows:

$$kWh_{it} = \beta_1 Sub_{it} + \beta_2 Other_{it} + \beta_3 Month_{it} + e_{it}$$

Where:

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

Sub = Indicator variable for post-period submeter installation period

$Other$ = Indicator variable for post-period of any other program participation

$Month$ = Vector of indicator variables for each month excluding December

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

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

$[\beta_1, ..., \beta_3,]$ = 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 submetering projects were provided by Hawaii Energy for participants in program years 2011 and 2012. Utility electricity billing data were provided from June 2008 to June 2013.

Weather or temperature data were not included in the final model specification since these variables did not provide much additional explanatory power and temperatures are relatively constant throughout the year in Hawaii. However, monthly indicator variables were included in the final model specification to capture any seasonal or monthly effects that may

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

exist. An indicator variable to control for participation in other Hawaii Energy programs was also included, so as not to double count savings that should be attributed to other programs.

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)
Sub	Indicator variable for months after submetering project was completed (equals 1 if in post-submetering period; else equals 0)
Other	Indicator variable for months after other Hawaii Energy program participation (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)

The billing data were of very high quality and so no data cleaning was required to remove outlier or erroneous data points. Only one data screen was employed to remove sites with fewer than 8 months of post-submetering billing data. This left us with only 5 sites on which to conduct analysis. Ideally, the billing analysis would be conducted on sites with a full 12 months of post-submetering data; however, that would have left us with an unusably small sample due to the dates of completion for these submetering projects. For this reason, we plan to conduct a more robust analysis in mid-2014 that will include a full calendar year of post-installation data for all projects completed in PY2012.

Billing Model Estimation Results

The results from the billing regression model are shown below in Table 4. All of the estimated coefficient values are of the expected sign (either negative or positive) and the primary variable of interest (Sub) is statistically significant at the 5 percent level. A little over half of the monthly indicator variables are statistically significant at the 5 percent level as well. The coefficients on monthly indicators show that kWh usage varies by month, with February and March showing statistically significant lower usage per month, on average, than December (the omitted variable).

The coefficient of interest with respect to submetering 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, condominium buildings experienced an estimated base decrease of 14,195 kWh per month after installation of submeters. This translates to an average annual savings of 170,342 kWh due to the submeter installation, or 2,018 kWh per condo unit. This is equivalent to a reduction in energy costs of $670.40 per year per tenant.[7]

Note that this result captures all changes in usage in the post period (except other program participation) and attributes them to the submeter 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 (such as change in occupancy), then the savings estimates derived from the model will overstate the actual energy savings of submetering. However, we believe that many external factors, such as occupancy changes, are likely to cancel each other out across all buildings included in this analysis.

Table 4. Regression results

Variable	Coefficient	Std. Error	t-statistic	p-value
(β_1) Sub	-14,195.15	1,389.90	-10.21	0.00
(β_2) Other	1,903.57	1,966.10	0.97	0.33
(β_3) January	-2,283.76	2,182.73	-1.05	0.30
(β_3) February	-3,850.22	2,182.45	-1.76	0.08
(β_3) March	-5,254.97	2,148.79	-2.45	0.02
(β_3) April	-212.91	2,190.40	-0.10	0.92
(β_3) May	3,434.88	2,097.12	1.64	0.10
(β_3) June	4,937.97	2,190.92	2.25	0.02
(β_3) July	6,030.20	2,190.92	2.75	0.01
(β_3) August	7,159.12	2,190.92	3.27	0.00
(β_3) September	8,065.30	2,190.92	3.68	0.00
(β_3) October	4,845.19	2,190.92	2.21	0.03
(β_3) November	1,728.07	2,190.92	0.79	0.43

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

The coefficient on Sub (β_1) in Table 4 above was used to calculate the annual savings attributable to submetering. The data used in the model was on a monthly basis, so the coefficient estimate of -14,195.15 indicates that an average of 14,195 kWh in savings were realized in each month that submeters were installed. To get an annual savings value as a percent of annual usage, this number was simply multiplied by 12 and divided by average annual usage at the sampled sites (749,199 kWh). The formula used to calculate the change in energy use as a percent of annual energy use is shown below:

$$Percent\ change\ in\ energy\ use\ due\ to\ submetering = \frac{Coefficient\ on\ Sub * 12}{749{,}199}$$

Table 5 below shows the estimated annual savings as a percent of annual energy use for PY2011 and PY2012 submetering projects along with a 95 percent confidence interval and the

[7] Assuming an effective rate of $0.332208 for residential service from Hawaiian Electric. http://www.hawaiianelectric.com/vcmcontent/StaticFiles/FileScan/PDF/EnergyServices/Tarrifs/HECO/EFFRATESJAN2014.pdf.

existing savings value in Hawaii Energy's PY2012 Technical Reference Manual (TRM). The estimated savings found in this analysis is more than double the current *ex ante* savings value of 10 percent included in the TRM.[8] Given that the savings estimates are so different, we plan to re-evaluate this measure in the next program evaluation cycle using more sample points, additional months of post-installation data, and any relevant building characteristics that are available. We may then recommend an update to the TRM deemed savings value if appropriate. For the PY2012 evaluation cycle, we opted to treat submetering as a custom measure and used the billing analysis results to count toward program impacts. In the next evaluation cycle for PY2013, the goal is to determine an appropriate deemed value and maintain the measure as prescriptive based on the results of the analysis on a larger sample size available for the PY2013 evaluation.

Table 5: Billing regression savings estimate and 95% confidence interval

Estimated savings (percent of annual energy use)	95% conf. interval LOWER BOUND	95% conf. interval UPPER BOUND	2012 TRM savings (percent of annual energy use)
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Comparison to Existing Literature

In addition to comparing our findings to the existing deemed savings used by Hawaii Energy, we also reviewed the existing literature on submetering impacts. Many of the studies we reviewed corroborated our findings with savings in the range of 15 to 30 percent of annual energy use. A study of submetered buildings in Toronto, Ontario found savings of 27 percent for electrically heated units and 34 percent for non-electrically heated units (Navigant Consulting Ltd 2012). Navigant used a fixed effects methodology and split the data into two groups based on their primary heating fuel type. This analysis involved a subset of 22 buildings that were switching from bulk-meters to submeters, including 608 units with gas heating and 64 with electric heating. The Navigant billing model expressed the electricity consumption (kWh) of building *i* in month *t* against weather (HDD and CDD) and building/unit characteristics (e.g. occupied unit square-footage). The average difference in kWh during pre- and post-installation months was expressed as a monthly conservation impact per square-foot.

Another study of submetered buildings in Toronto was conducted by Dewees & Tombe (2011). This analysis determined kWh savings from sub-metering using a billing regression on data split into two groups, summer months (May-Oct) and winter (Nov-April). The data included six years of pre-installation billing data and 19 months of post. A statistical smoothing technique was used to correct the data before modeling. Dewees & Tombe regressed controls for weather (HDD and CDD), monthly indicator variables, a submetering pre/post indicator, and unit characteristics (heated area, occupancy, etc.) against the log of kWh usage. Due to the functional form selected, the coefficient estimates were expressed as elasticities of demand for electricity (kWh).

[8] "Hawaii Energy – Technical Reference Manual No. 2012". Hawaii Energy. http://www.hawaiienergy.com/information-reports

Using this procedure, the authors analyzed the impact of submetering on a luxury condominium in Toronto, Ontario. Its 40 units had all electric appliances including electric heating, air conditioners, hot water heaters, laundry appliances, and stoves. The billing data included observations from 2001 through 2009 with submetering completed in 2008. The billing regression resulted in an average building kWh usage reduction of 20 percent. They were also able to determine that conservation was more substantial in the summer months even after controlling for HDD and CDD, with kWh savings of 21 percent in the summer and 11 percent in the winter. The authors hypothesized that this difference was due to more conservative use of lighting and appliances in summer months.

In addition to these studies, we examined the submetering savings value currently in use by New York State Energy Research and Development Authority (NYSERDA). NYSERDA has conducted many case studies over the years to evaluate the savings associated with its submetering projects. They currently estimate that up to 20 percent of energy usage can be reduced by installation of submeters (NYSERDA 2013).

An important caveat to these studies when making a comparison to savings for Hawaii is that these cases of submetering were conducted in locations with both a heating and a cooling season. Hawaii only has a cooling season that would affect energy use, and so we might expect the impact from submetering to be slightly lower in Hawaii than the impacts found in other climates.

Summary and Conclusions

Using a billing regression model and a sample of PY2011 and PY2012 submetering projects, we estimated annual savings from this measure of 22.7 percent of annual energy usage. This equates to an average annual savings of 170,342 kWh due to the submeter installation, or 2,018 kWh per condo unit. In monetary terms this is equivalent to a reduction in energy costs of $670.40 per year per tenant.

The estimated savings of 22.7 percent is significantly greater than the 10 percent ex ante savings value provisionally in use by Hawaii Energy for PY2012, as that value lies well outside the 95 percent confidence interval of our savings estimate. As this is the first evaluation of this measure, we expected that our findings might differ from the deemed value. The small sample size available for this analysis may be one reason for the difference, but it may also be the case that the 10 percent in the TRM is not a realistic savings value. Until we are able to analyze this measure using more sample points, we are not recommending a change to the deemed value in the TRM. However, we did credit the program with the estimated savings from this analysis in PY2012, by treating submetering as a custom measure.

A review of existing literature on submetering savings shows that our estimate of 22.7 percent may be a more realistic measure of the savings that can be expected from these projects. A number of studies have found savings for submetering in the range of 15 to 30 percent of energy use, indicating that the existing TRM value of 10 percent is likely too low and corroborating our findings. Additional analysis of submetering projects in Hawaii will help solidify an estimate for this program and allow Hawaii Energy to claim the full amount of savings that its customers have realized.

References

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