Getting to the Right Delta: Adjustment and Decomposition of Billing Analysis Results

Ken Agnew, KEMA Inc, Madison, WI
Mimi Goldberg, KEMA Inc, Madison, WI

ABSTRACT

Billing analysis provides an empirically based, cost-effective approach to measuring the impact of energy efficient heating and cooling retrofits. Estimates of gross savings, that is, savings with respect to a standard installation baseline, can be derived from billing analysis output using engineering equations. The application of these engineering equations to billing analysis output requires careful attention to what effects are present in the billing analysis output. The presence of take back and quality installation measures affect post-installation consumption and thus affect the application of engineering equations to the billing analysis output.

This paper examines two different approaches for estimating gross program impacts and the potential for bias in both approaches. We quantify the nature of the biases in each approach. We also show that the two approaches produce biases that mirror each other and bracket the unbiased result. We show that, in theory, it is possible to derive a bias-adjusted result by combining the two different approaches. Additional challenges are discussed related to the application of engineering equations to pre-post billing analysis output.

As an application, we show how these methods were used for an impact evaluation of the New Jersey Clean Energy Program CoolAdvantage air conditioner rebate program. The program promoted quality installation and all such programs have the potential for the presence of take back. The methods discussed here were used to confirm the billing analysis impact estimate and assess the presence of take back and the success of quality installation efforts.

Introduction

This paper examines two different approaches for producing billing analysis estimates of gross program impacts. Both approaches use engineering equations to produce impact estimates relative to the appropriate standard installation baseline. The post-only approach builds an estimate from post-program consumption and an engineering-based estimate of the percentage change in consumption due to the increase in efficiency. The pre-post approach decomposes the change in consumption, the delta, to isolate the program portion of the impacts. While effectively based on the same engineering equations, the two approaches generate impact estimates that incorporate potential biases in opposite directions.

Both approaches have limitations in addressing common features of program participant data. In this paper we seek to identify and quantify the biases inherent in each of the two approaches. We then establish the conditions under which the combined results of these two different approaches allow a bias-adjusted estimate of efficiency related savings assuming a standard installation baseline.

We apply this framework to billing analysis results from an evaluation of the NJ CoolAdvantage program, a central air conditioner rebate program. The framework allows us to confirm the estimate of efficiency related savings and address questions about the effects of Quality installation Verification and take back on the impact estimates.

Background

The primary purpose of the analysis discussed in this paper was to update the New Jersey protocols for the NJ Clean Energy HVAC programs (KEMA 2009). In particular, this paper focuses on the CoolAdvantage program, a central air conditioner rebate program. The program rebated high efficiency central air conditioners with a Seasonal Energy Efficiency Ratio (SEER) of at least 14. The program also had a quality installation verification component (QIV) to ensure optimal charging and airflow. If installers were not certified by North American Technician Excellence (NATE), the rebate application collected documentation related to charging and airflow. QIV measures are justified on theory that new units are not always installed with optimal charging and airflow and thus additional savings can be gained relative to a standard installation.

The NJ CoolAdvantage protocol (NJCEP, 2007) equations are standard engineering equations related to change in unit efficiency. The equations are driven by the annual runtime of the unit or equivalent full load hours (EFLH). The protocols provided an EFLH of 600 hours for the purpose of calculating program savings. The goal of the evaluation was to validate this number based on data from program participants. With an appropriate estimate of EFLH, estimates of efficiency related savings are easily derived.

Methodology

The most direct way of validating EFLH uses an estimate of post-installation consumption and engineering equations to estimate program participant EFLH. This approach has a simple directness to it. It works within the protocol framework while providing empirical validation. This approach also has a potential shortcoming. The estimate of post-installation consumption may include the program-related effects of take back or additional savings related to QIV. This would affect the subsequent estimates of EFLH and impacts.

Take back refers to a reduction in program impacts due to a change in consumption patterns related to the new installation. With a new, efficient CAC, the cost of cooling is decreased. Economic theory tells us that participants will reallocate those savings. One option for the participant is to increase the amount of cooling purchased. The increased consumption “takes back” some of the program’s efficiency-related impacts. Conversely, the QIV component included in the CoolAdvantage program design could result in a decrease in post-installation consumption and an increase in program impacts beyond impacts related to efficiency improvements.

The equations used to estimate EFLH and efficiency-related impacts assume a measure of consumption that is not affected by either take back or QIV-related savings. We know, however, that the estimate of post-installation consumption derived from the billing analysis will include the effects of take back and QIV to the extent that they are present. The presence of either of these factors would inject bias into the resulting gross impact estimates.

In the case of the NJ CoolAdvantage program, it was unclear the extent to which either take back or the QIV efforts were a factor. The magnitude of take back for a program like this is difficult to assess. The ultimate efficacy of the QIV activities is also up for question (Titus 2006; Wirtshafter et al. 2007),

To evaluate the potential bias in the post-only estimate of impacts, we also estimated impacts using a pre-post billing analysis on the same data. The pre-post approach derives a gross efficiency impact estimate from the change in consumption associated with the installation. The pre-post approach has the advantage of being based on actual change attributed to the installation of program measures. The approach also has the added challenge of identifying the efficiency level of the existing unit to facilitate breaking out the standard to qualifying efficiency portion of the change in consumption.

The pre-post analysis was not our primary approach to the evaluation because it was less suitable to the updating of the protocol equations. In addition, there were initial concerns that there would be insufficient pre-installation data points to allow the pre-post approach to work. The pre-post billing analysis did however offer the opportunity to look into the possibility of quantifying the effect issues like QIV savings and take back.

The methods discussed here lay out the two approaches by which gross efficiency savings are derived from billing analysis output. More importantly, we track the potential biases resulting from the presence of take back and QIV savings. We do not discuss the billing analysis process used to estimate both post-installation consumption and pre-post change in consumption. The specifics of that process are not essential to the issues discussed here. The methods discussed below only require that both kinds of billing analysis output represent the average program retrofit participant.

Impacts based on Post-installation Consumption Estimate

The engineering equation at the root of both approaches describes cooling consumption as a function of capacity, efficiency and run time (EFLH). This standard engineering equation provides the relationship between the post-installation estimate of consumption and EFLH. The equation, in this case for a unit qualifying for the program, would be

$$kWh_Q = CAPY_Q * C * \frac{1}{SEER_Q} * EFLH \qquad \textbf{Eqn. 1}$$

where

kWh_Q = Annual qualifying unit kWh, post-program
$CAPY_Q$ = Qualifying unit capacity, in tons
C = Conversion factor of 12
$SEER_Q$ = Qualifying unit SEER
$EFLH$ = Equivalent full load hours of cooling

The combination of the capacity and SEER provides the level of hourly load when the unit is running. The EFLH value indicates how many effective hours of this level of usage took place. To update the protocol value for EFLH, we plug in the post-only billing analysis estimate of consumption and nameplate capacity and efficiency data available from program tracking data, and solve the equation for EFLH.

$$EFLH^* = \frac{1}{\overline{\overline{CAPY}}_Q} * \frac{1}{C} * \overline{\overline{SEER}}_Q * \hat{k}Wh_Q . \qquad \textbf{Eqn. 2}$$

where

$EFLH^*$ = Updated estimate of EFLH using post-only billing analysis consumption
$\overline{\overline{CAPY}}_Q$ = Median program capacity, in tons
$\overline{\overline{SEER}}_Q$ = Median program SEER
$\hat{k}Wh_Q$ = Post-only estimate of cooling consumption in a normal weather year

The same basic equation provides the framework for quantifying the change in consumption associated with a change in unit SEER.

$$\Delta kWh_{S-Q} = CAPY_Q * C * \left(\frac{1}{SEER_S} - \frac{1}{SEER_Q} \right) * EFLH \qquad \textbf{Eqn. 3}$$

where

ΔkWh_{S-Q} = Change in kWh consumption standard to qualifying efficiency

$SEER_S$ = Standard install unit SEER of 11

The equation calculates the change in consumption associated with the change in SEER. The combination of capacity and the change in SEER calculates the avoided hourly consumption while EFLH provides the hours of run-time across which those savings are realized.

The estimate of impacts from the post-only approach uses this equation.

$$EstSav_{post} = \overline{\overline{CAPY}}_Q * C * \left(\frac{1}{SEER_S} - \frac{1}{\overline{\overline{SEER}}_Q} \right) * EFLH^* \qquad \textbf{Eqn. 4}$$

where

$EstSav_{\text{post}}$ = Estimate of change in annual unit kWh consumption, standard to qualifying efficiency using post-only billing analysis.

By combining the EFLH equation and the efficiency equation, we see that efficiency-related savings are effectively a percentage adder on post-installation consumption.

$$EstSav_{post} = \left(\frac{\overline{\overline{SEER}}_Q}{SEER_S} - 1 \right) * \hat{kWh}_Q = p_{post} * \hat{kWh}_Q \qquad \textbf{Eqn. 5}$$

where

p_{post} = Post-only percentage -- percentage of post-installation consumption that is equal to standard to qualifying efficiency impact.

For this equation to provide an unbiased estimate of program savings, the estimate of post-installation consumption should not include the effects of either take back or QIV savings.

Impacts based on Pre-post Delta Estimate

The pre-post approach also uses the equation that quantifies the change in consumption associated with a change in unit SEER. Equation 3 can also expresses savings given an increase in SEER from existing unit to qualifying unit efficiency.

$$\Delta kWh_{X-Q} = CAPY_Q * \left(\frac{1}{1000} \right) * \left(\frac{1}{SEER_X} - \frac{1}{SEER_Q} \right) * EFLH \qquad \textbf{Eqn. 6}$$

where

ΔkWh_{X-Q} = Change in Annual kWh consumption, existing unit to qualifying efficiency

$SEER_X$ = Existing Unit SEER

These two equations can be combined to create an equation that defines the standard efficiency to qualifying efficiency increment as a percentage of the pre-post delta which is the existing efficiency to qualifying efficiency increment.

$$\Delta kWh_{S-Q} = \Delta kWh_{X-Q} * \left(\frac{1}{SEER_S} - \frac{1}{SEER_Q} \right) \bigg/ \left(\frac{1}{SEER_X} - \frac{1}{SEER_Q} \right) = \Delta kWh_{X-Q} * p_{pre-post} \quad \textbf{Eqn. 7}$$

where

ΔkWh_{X-Q} = Change in Annual kWh consumption existing unit to qualifying efficiency

$p_{pre-post}$ = Pre-post percentage – percentage of full existing to qualifying efficiency delta that is standard to qualifying efficiency.

The pre-post percentage is effectively the mirror to the post-only percentage. Each percentage is applied to its appropriate billing analysis output (post-only consumption and pre-post delta) and produces an estimate of program impacts. The post-only percentage will generally be small as it represents savings as a percentage of annual consumption. The pre-post percentage can be anywhere between zero and one hundred depending on where standard efficiency falls between the existing and qualifying unit efficiencies.

Post-only Approach Bias

Both of these approaches face challenges when applied to real-world data. The post-only estimate of savings is completely dependent on the post only estimate of consumption and the related estimate of EFLH. If the effect of take back is present in the estimate of post-installation consumption then the consumption is too high by the magnitude of the take back effect. The following equations show the estimated consumption as a combination of ideal post-installation consumption and take back.

$$Observed\ post\text{-}install\ consumption = \hat{k}Wh_Q = \tilde{k}Wh_Q + tb \qquad \textbf{Eqn. 8}$$

where

$\tilde{k}Wh_Q$ = Ideal post-installation consumption (no take back),

tb = Average annual increase in kWh due to take back.

Applying the post-only percentage to this post-installation consumption that includes take back generates an estimate of impacts that is inflated by take back at the rate of the post-only percentage.

$$p_{post} * (\ Observed\ post\text{-}install\ consumption) = p_{post} * (\tilde{k}Wh_Q + tb) = \tilde{\Delta} kWh_{S-Q} + p_{post} * tb \qquad \textbf{Eqn. 9}$$

where

$\tilde{\Delta} kWh_{S-Q}$ = Standard to Qualifying impact accounting for take back,

QIV impacts would have the same basic effect on consumption and savings estimates but in the opposite direction. QIV measures decrease the post-installation consumption from what it would have been without the QIV. This has the opposite effect as take back on EFLH and impacts. The magnitude of QIV savings would enter the final estimate of gross impacts as a downward bias at the rate of the post-only program proportion, p_{post}.

Thus the primary issue with the post-only estimate of efficiency-related savings is the two potential biases associated with the presence of take back and QIV in the estimate of post-installation consumption. The two biases enter the savings formula in the same way except for the expected direction of effect. In practice, this means the two biases effectively combine to produce a single net bias. If reduction in consumption due to QIV is greater than the increase due to take back then the net bias in the estimate of gross savings will be down by the post-only percentage times the net reduction in consumption. On the one hand, if both biases are present they will partially cancel each other out. On the other hand, separating the two biases is difficult.

Pre-post Approach Bias

While post-only impact estimates rely only on post-installation consumption, pre-post estimates rely on the relationship between pre- and post-installation consumption. Looking at the post-only impact estimates, we saw that effects that either increased or decreased post-installation consumption caused clear quantifiable biases on the resulting impact estimates. The pre-post scenario faces the same effects increasing or decreasing the post-installation consumption because they affect the delta. In addition, the pre-post approach grapples with the challenge of defining pre-installation consumption with respect to efficiency.

Figure 1 provides a simple schematic that helps illustrate the equation that breaks out the program portion of the pre-post delta. The equation is in terms of SEER, but the general concepts are easier to discuss looking at the different load levels associated with the different SEER levels.

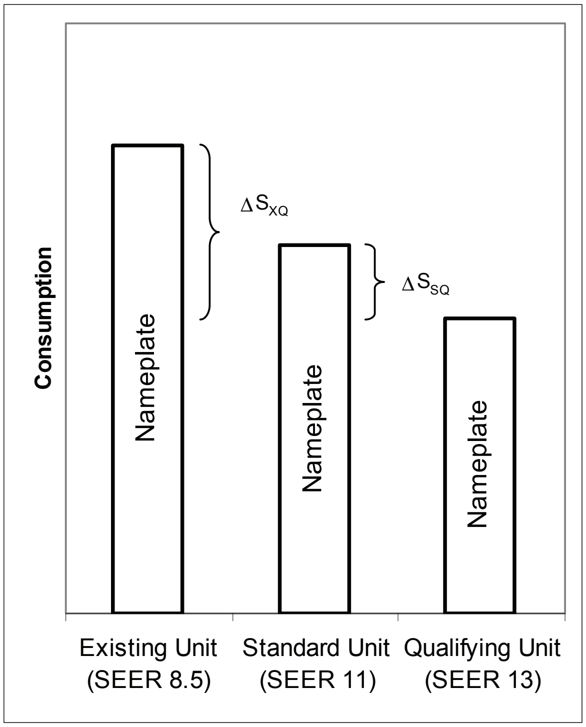

Figure 1 Relationship Between Existing, Standard and Qualifying Units

The overall change in SEER is from existing to qualifying efficiency, represented in consumption terms by ΔS_{XQ}. The part attributed to the program is the standard to qualifying efficiency portion, represented by ΔS_{SQ}. The pre-post percentage calculated above in equation 7 is effectively the ratio, $\Delta S_{SQ}/\Delta S_{XQ}$ but in terms of SEER. It identifies the program portion of the pre-post delta if the only difference between pre- and post-installation consumption is unit efficiency. If pre- and post-installation consumption reflect the expected consumption given the SEER levels in the equations, then the equation appropriately splits out the program impacts from the existing to the qualifying unit. Unfortunately, as we found with the post-only approach, in the presence of either take back or QIV, post-installation consumption is not simply efficiency-adjusted pre-installation consumption.

The pre-post approach thus faces the same challenges that beset the post-only approach. Both take back and QIV savings change the magnitude of the pre-post delta. The basic framework assumes that the pre-post delta represents a change in usage that is driven entirely by a change in efficiency level. If the qualifying unit consumption in Figure 1 were greater due to take back the observed existing to qualifying delta would be smaller. The following equation shows the relationship.

$$\textit{Observed pre-post change} = \Delta kWh_{X-Q} = \widetilde{\Delta} kWh_{X-Q} - tb \qquad \textbf{Eqn. 10}$$

where

$\widetilde{\Delta} kWh_{X-Q}$ = Ideal pre-post delta (no take back)

If we apply the pre-post program percentage, pre-post estimated savings is

$$p_{pre\text{-}post} * (\textit{observed pre-post change}) = p_{pre-post} * (\widetilde{\Delta} kWh_{X-Q} - tb) = \widetilde{\Delta} kWh_{S-Q} - p_{pre-post} * tb \qquad \textbf{Eqn. 11}$$

where

$\widetilde{\Delta} kWh_{S-Q}$ = Standard to qualifying impact accounting for take back,

Similar to the post-only approach, the bias is in proportion to the applied percentage. However, the direction of the pre-post approach bias is the opposite of the post-only approach bias. Because the delta is smaller, the presence of take back will produce an estimate of impacts that is biased down by the program portion of take back.

The pre-post is, in fact, similar but opposite to the post-only approach in every respect. QIV and take back have mirror effects on the pre-post approach impact estimates. In the pre-post approach, the presence of QIV savings increases the pre-post delta and thus increases the impact estimate. Also, just as with the post-only approach, practically speaking, QIV and take back become a single bias reflecting the net effect of which ever bias is greater. If reduction in consumption due to QIV is greater than the increase due to take back then the combined net bias in the estimate of gross savings will be altered by the net QIV-related reduction in consumption. In the post-only scenario this produces a downward bias. In the pre-post scenario, it produces an upward bias. The combined biases that characterize the pre-post and post-only results will always be in the opposite direction regardless of the mix of take back and QIV.

Combined, Bias-corrected Savings Estimate

The resulting post-only and pre-post estimates bracket the unknown, unbiased estimate. Because the biases are the same underlying combined effect scaled by two different percentages (p_{post} and $p_{pre\text{-}post}$) we can use the percentages to break out the difference. Table 1 summarizes the conclusions thus far and shows how the difference between the post-only and the pre-post results is split out based on the relative magnitude of the post- and pre-post percentages.

Table 1 The Effects of Take Back and QIV on Billing Analysis results

	Billing Analysis Approach		Difference
	Pre-post	Post-only	
Efficiency-related Savings Effect	S	S	0
Take Back Effect	$-TB*p_{pre\text{-}post}$	$+TB*p_{post}$	$-TB*(p_{pre\text{-}post}+p_{post})$
QIV Savings Effect	$+QIV*p_{pre\text{-}post}$	$-QIV*p_{post}$	$QIV*(p_{pre\text{-}post}+p_{post})$
Combined Take Back and Savings Effect	$(-TB+QIV)*p_{pre\text{-}post} = -C*p_{pre\text{-}post}$	$(TB-QIV)*p_{post} = C*p_{post}$	$-C*(p_{pre\text{-}post}+p_{post})$
Theoretical Billing Analysis Estimate	$S-C*p_{pre\text{-}post}$	$S+C*p_{post}$	$-C*(p_{pre\text{-}post}+p_{post})$
Total billing analysis estimate	$\Delta kWh_{S\text{-}Q}=SAV_{pre\text{-}post}$	$\Delta kWh_{S\text{-}Q}=SAV_{post}$	D
Expected Bias-adjusted savings from pre-post Delta	$SAV_{pre\text{-}post} - D*p_{pre\text{-}post}/(p_{pre\text{-}post+}p_{post})$		
Expected Bias-adjusted savings from post-only Consumption	$SAV_{post} + D*p_{post}/(p_{pre\text{-}post+}p_{post})$		

Additional Pre-post Challenges

As we have just seen, post-installation consumption effects produce quantifiable biases in the impact estimates derived from the post-only and pre-post approaches. If we assume the post-installation effects are the only issues to be dealt with then deriving an unbiased estimate of efficiency-related savings is a tractable problem. Unfortunately, the pre-post approach impact estimate faces additional challenges related to the characterization of the pre-installation load. First, there's the problem of the unknown existing unit SEER.

Returning to Figure 1 and equation 7, it's simple to identify the effect of a varying existing unit SEER level. A lower existing unit SEER produces a bigger denominator in equation 7 and, correspondingly, a smaller pre-post percentage, $p_{pre\text{-}post}$. Assuming a greater existing unit SEER value has the opposite effect, decreasing the denominator and increasing the $p_{pre\text{-}post}$. Thus, the estimate of existing unit SEER is essential to the pre-post approach and directly affects magnitude of the impact estimate. This adds an additional moving part to the framework developed above to derive an unbiased estimate of efficiency related savings.

A more comprehensive look at the implications of QIV in the billing analysis framework raises additional questions about the pre-post based impact estimate and the existing unit SEER level. Figure 2 provides a schematic that illustrates the issue.

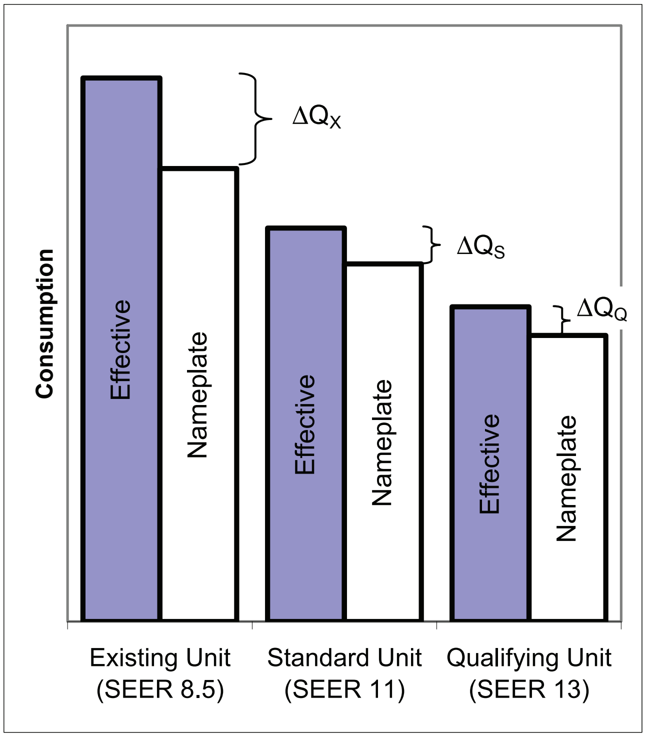

Figure 2 Relationship Between Existing, Standard and Qualifying Units, QIV (Degradation) Included

Figure 2 shows the nameplate consumption as in Figure 1. It also shows the consumption reflecting some increase level of inefficiency due to incorrect installation (charging, airflow etc) for new units or simple degradation for the existing unit (ΔQ). The level of usage associated with this "effective" SEER should always be higher than the nameplate SEER because the nameplate SEER implies optimal conditions. It simplifies the discussion to refer to all of these deltas as degradation. Figure 2 illustrates two other important points. The standard and qualifying units have degradation deltas that represent a similar percentage of usage. Both units are new. Assuming a similar installation process, it is reasonable to assume a similar level of degradation from optimal. The existing unit is portrayed with a greater level of degradation. This reflects the fact that this unit received a standard installation but has had its full life in the field to degrade. The assumption is that the existing unit will always have a greater level of degradation than the two newly installed units.

Recall that the engineering equation that breaks out the standard-to-qualifying portion of the existing-to-qualifying delta describes the relationship between the three units' nameplate SEER. If we consider unit degradation, the observed overall delta from the billing analysis reflects something else altogether. In terms of Figure 2, assuming no QIV took place, the observed delta reflects the relationship between the three units' *effective* SEER. The SEER-based equation will still work, but only under certain restrictive assumptions. If the degradation at each unit is the same on a percentage basis with respect to nameplate SEER, then the important relationships remain the same and the equation decomposes the delta properly.

The degradation of the existing unit, however, should always be greater than the degradation at either the standard or qualifying units. This degradation implies the pre-installation consumption should be identified with lower SEER level reflecting the existing unit effective SEER. This in turn increases the denominator of the pre-post existing to standard ratio and, thus, decreases the program portion of the observed delta. If the adjustment to the lower, effective SEER level is not made, the pre-post approach estimate of impacts will be inflated. Assuming standard and qualifying units are set at nameplate levels, the existing unit SEER level should be set at existing unit nameplate SEER level plus the marginal effective SEER decrease due to degradation relative to the standard and qualifying effective SEERs. Ultimately, since none of these values are known, existing unit SEER should be set lower than the expected nameplate SEER for those existing units.

Application

The primary purpose of the evaluation of the CoolAdvantage Program was to update the protocols for the program as it was taken over by the NJ CleanEnergy program, a statewide effort. A retrospective impact evaluation was a second part of the effort, to set a baseline from the existing programs. The evaluation took place after the changeover of the programs to the statewide entity and this was of particular importance with regard to QIV aspect of the program. Getting further information on this effort was a challenge as those personnel who ran the programs were no longer running programs with the utilities. While QIV-related savings are listed in the protocols and the rebate application includes places for data gathered related to the QIV process, there was no information in the tracking data received from the programs. QIV has proven challenging for programs to implement so it should not be taken for granted that this aspect of the program was in fact successful. The retroactive impact evaluation worked within these challenges.

Table 2 provides the results of the post-only CoolAdvantage billing analysis. These results reflect the standard unit baseline but do not include free ridership. The table provides a benchmark estimate based on the 2007 Protocol values. This result is based on an EFLH of 600 hours and a QIV/sizing factor of 23.8 percent of the post-installation consumption estimate. The protocol values produce an estimate of efficiency savings of 409 kWh and QIV/sizing savings of 358 kWh for a total estimated savings of 767 kWh. The efficiency-related savings reflect the difference in consumption from the standard in place at the time, SEER 11, and the program measures of at approximately SEER 14.

Table 2 Gross 2005/2006 CoolAdvantage Ex-Post Per-Unit Impact Estimates Baseline SEER=11

Source for Hour (EFLH) Estimate	Post-Program Cooling Usage (kWh)	Effective Full Load Hours (EFLH)	EFLH Confidence Interval (+/-, 90%)	Impact of Efficiency Improvement (kWh)	Combined QIV/Sizing Savings Percentage	QIV/Sizing Savings as Percentage of Usage	Impact of Proper Sizing and QIV (kWh)	Total CAC or Heat Pump Cooling savings (kWh)
Protocols	1,500	600		409	19.3%	23.8%	358	767
Impact Evaluation	1,252	501	17	341	0.0%	0.0%	0	341
					8.4%	9.2%	115	456
					19.3%	23.8%	298	640

The impact evaluation post-only billing analysis provided an estimate of participant CAC usage in the post-program period of 1,252 kWh. This produced an updated estimate of 501 hours for cooling EFLH with a 90 percent confidence interval of plus or minus 17 hours. This reduced level of EFLH produced an efficiency-related impact of 341 kWh.

To facilitate comparisons of results between post-only and pre-post results, the post-only results used the identical pooled time-series cross-section specification as the pre-post with the exception of the variables necessary to capture the change. Table 3 provides estimates of the program portion of the delta from the pre-post billing analysis. Because the existing unit SEER was unknown we produced estimates across a range of existing unit SEERs. To put these SEER values in context, the EIA Residential Energy Consumption Surveys from 1987 and 1990 put average new unit SEER at 9 and 9.3 (EIA 2000), respectively. These values provide a rough guideline of nameplate SEER assuming an estimated useful life of 15 to 18. If we take degradation into account the effective SEER would be lower.

Table 3 Pre-Post Billing Analysis Total Cooling Savings Assuming Replaced Unit SEER

Assumed SEER of Replaced Unit	Total CAC or Heat Pump Cooling savings from Pre-Post Billing Analysis (kWh)
6.5	235
7.0	272
7.5	313
8.0	362
8.5	420
9.0	489
9.5	574
10.0	679
10.5	815
11.0	996

Setting existing unit SEER at 8 provided a pre-post impact estimate of 362 kWh. The post-only impact estimate was 341 kWh. Within the framework developed in this paper we can conclude:

- The bias-adjusted, gross impact estimate lies between these two values -- approximately 350 kWh given the post-only and pre-post percentages used to derive the impact estimates. This is not statistically different than the original post-only estimate.
- The combined take back and QIV effect was approximately 2.7 percent of post-installation consumption in the direction of QIV. That is, whatever take back consumption was present, when combined with QIV, the 2.7 percent QIV effect remained. Survey data revealed little evidence of take back among participants. This indicates there was minimal take back in the post-installation period and smaller than expected QIV savings.

These results are based on an assumed existing unit SEER of 8. Setting existing unit SEER at 7.8 would indicate a balance between the take back and QIV effects. Below 7.8 the effect of take back would be greater than the QIV effect. An existing unit SEER above 8 would produce QIV savings greater than 2.7 percent, net of take back.

Though it is impossible to establish a single estimate of effective existing unit SEER, comparing the post-only and pre-post impact estimates still provides a comprehensive indication of the level of potential bias in the post-only impact estimate. Within the range of realistic effective exiting unit SEERs, there is limited evidence of bias in the post-only estimate of gross impact for the CoolAdvantage program.

Conclusions regarding the separate effects of take back and QIV are more difficult given their combined expression in impact estimates. Separate evidence, in this case the survey data related to take back, can help solidify conclusions. As long as AC programs include a quality installation component, estimates of cooling impacts will in most cases have the potential for these conflicting effects. Other applications of billing analysis with the potential for take back but without potential savings due to quality installation will allow for more confident statement with regards to the presence of bias.

Conclusion

This paper focuses on getting to the right delta when doing billing analysis. There's more to billing analysis than weather normalizing and reporting the pre-post delta. Attention must be paid to what the delta represents. In this paper we discuss two billing analysis approach that produce impact estimates that reflect a standard installation baseline. We explore the biases that enter into impact estimates due to the presence of the effects of take back and QIV in the post-installation consumption. We quantify these effects in both a post-only billing analysis approach and a pre-post billing analysis approach. We further discuss the implications of unit degradation on estimates developed in the pre-post framework. Finally, we establish the conditions under which the results of these two different approaches allow an unbiased estimate of gross savings.

For an application of these ideas we look at results from an evaluation of the New Jersey CoolAdvantage HVAC program. The final result for this program was based on post-installation usage and engineering equations to support, and remain consistent with, Protocol guidelines. The pre-post results were primarily developed as a check of the post-only results. The combination of the post-only and the pre-post results support the gross impact results produced with the post-only approach. We also checked for evidence of take back and quality installation savings for the cooling program. The combination of the post-only and pre-post results along with additional information indicate that there was little take back in the post installation consumption and that QIV savings were not realized at expected program levels.

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