How to Design a Gas Program Impact Evaluation

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ABSTRACT

The number and size of natural gas energy efficiency programs are increasing throughout the United States. Evaluation of such programs is increasing commensurately. There is less research history on gas programs than electric. The planning assumptions and measurement and verification techniques traditionally applied to electric measures need reconsideration for natural gas.

Specifically, gas program evaluators are finding that project-level evaluated savings varies considerably from programs' reported savings, more than it does for similar electric projects. The error ratio, a measure of this characteristic used in sampling, commonly exceeds 1.0 for natural gas efficiency programs, compared to the typical range of 0.4 to 0.6 used in planning evaluations. The higher error ratio means that gas evaluation is consistently reporting results with less statistical precision than expected. The paper addresses why this is happening and, perhaps contrary to expectations, recommends that for a given budget evaluators invest in more research per site and evaluate fewer sites, rather than spend less per site and increase sample sizes.

Gas measures can affect customer costs beyond their natural gas utility bills, especially when the projects are associated with equipment that uses or heats water. The value of non-energy benefits and costs are material (up to $9.50 per MMBtu of natural gas saved) and worth considering during evaluation. Gas measures can also affect electricity, diesel fuel, steam, and other energy uses. Evaluation results illustrate the importance of accounting for them in natural gas impact evaluation and when assessing program cost-effectiveness. The paper also summarizes natural gas realization rates and net-to-gross factors.

Programs Examined

As the number and size of natural gas energy efficiency programs increase throughout the United States, so too do the evaluations of such programs. Over the past two years, Energy & Resource Solutions (ERS) has either led or subcontracted for work on seven evaluations that included study of natural gas energy efficiency programs. All of the evaluations were completed in 2010.

The evaluations have been of both East Coast and West Coast programs and spanned most natural gas efficiency technologies. The programs have tended towards large commercial and industrial projects but have not been exclusively so. Two program evaluations were residential. The evaluated programs tended to fund retrofit technologies but two of them funded new construction projects. All of the evaluations discussed in this paper were based on site-specific measurement & verification (M&V), as opposed to methods such as program-level billing analysis.

Table 1 characterizes the evaluated program types. The evaluations ERS worked on plus one additional evaluation for which the author had detailed information encompassed all of nineteen different energy efficiency programs and parts of twenty-eight others, for a total of forty-seven different programs with gas energy efficiency projects. The evaluations were organized into thirteen unique portfolios for sample design and reporting purposes. Each portfolio is a row in Table 1 and represents a unique sample and analytical unit. In some cases the programs funded only natural gas energy saving measures; in other cases the programs funded electricity saving measures as well. The sample sizes indicate the number of projects studied that included non-zero reported natural gas energy savings.

The level of engineering rigor invested in analysis overall was high. The majority of projects were subject to an "enhanced" level of rigor or near-equivalent.[1] This gave analysts a high degree of confidence in the quality of the gas and non-gas savings estimates.

Table 1. Evaluated Natural Gas Program Characteristics

Sponsor	Portfolio or Program Type	Sample with Non-Zero Reported Therms	Site M&V Rigor
NYSERDA	Commercial/industrial new & retrofit	29	33% enhanced, 33% basic, 33% verification-basic
NYSERDA	Residential single family new construction	25	100% verification-basic with single repeated model
NYSERDA	Multifamily retrofit	6	33% enhanced, 67% verification
SCG	Commercial retrofit ("major")	19	Unspecified mix of enhanced & basic
SDG&E	Commercial standard performance contracting	6	Unspecified mix of enhanced & basic
SDG&E	Commercial/industrial bid program	7	Unspecified mix of enhanced & basic
PG&E	Commercial retrocommissioning	17	100% enhanced
SCE	Commercial retrocommissioning	4	100% enhanced
SCG	Commercial retrocommissioning	10	100% enhanced
SDG&E	Commercial retrocommissioning	3	100% enhanced
PG&E	Industrial – fabrication	29	100% enhanced-basic blend
PG&E	Agricultural & food processing	30	83% enhanced
SCG	Non-res prescriptive pipe insulation measure (esp. Dry cleaners)	66	100% enhanced (or similar)
Total		**251**	

Realization Rates

The objective of an energy efficiency impact evaluation is to determine how much energy a program's funded measures are saving. Most impact evaluations compare savings determined by the evaluation's engineers with the savings previously reported by the program administrators. Realization rate (RR) is the ratio of evaluated energy savings divided by program-reported savings. It indicates how close the program administrator's estimate of savings is to the evaluator's presumably more informed estimate of savings based on more intensive metering, consideration of actual post retrofit operating schedule, post-retrofit billing data, other information typically not available to program administrators when they forecast savings, and the evaluator's unbiased perspective. The realization rate does not account for decision-making factors like free ridership, which is measured separately. If, when approving an application, a program administrator estimates that a project will save 100,000 therms per year and an evaluator later determines that the project is saving 80,000 therms per year, the realization rate is 0.80. A "good" realization rate is near 1.0.

The realization rate varies for each evaluated project. In a simple random sample, the realization rate's coefficient of variance ($\hat{cv}$) is a measure of how much the realization rate varies. It is a normalized

[1] The California Energy Efficiency Evaluation Protocols (the Protocols) define three levels of rigor. "Enhanced" means that M&V generally follows the International Performance Measurement and Verification Protocols (IPMVP) Options B or D, that is, equipment metering with loggers and/or comprehensive calibrated simulation modeling. "Basic" rigor follows IPMVP Options A, typically spot measurements and some use of stipulated values. "Verification" is typically anything less technical than "Basic." It typically involves inspection to affirm equipment installation, capacity, and efficiency, and review of application savings calculations without new measurement. Any hyphenated rigors in Table 1 are a blend of the two.

parameter, defined as the standard deviation divided by the mean. The sample's error ratio ($\hat{er}$) is analogous to the $\hat{cv}$ when the stratified ratio estimation (SRE) approach to sample design is used instead of a simple random sample. Many impact evaluations and all of the evaluations discussed in this paper used the SRE approach, which takes advantage of the program administrator's savings estimates to reduce requisite sample sizes.[2] SRE sampling results in a more efficient sample and smaller sample sizes when there is a reasonably strong linear dependency between the two variables of interest, in this case the original program savings and the verified savings. Using the SRE approach requires the sample designer to estimate the value of the error ratio, either based on previous evaluations or the best available information. The California Frameworks recommends basing sample sizes on error ratios ranging from 0.4 to 1.0, depending on the program design. Programs with site-specific and detailed methods for estimating savings would be likely to on the low end and programs with deemed savings that are not based on site-specific information tend to have higher error ratios. The gas programs reviewed for this paper involve detailed, site-specific analysis and thus a typical error rate would be assumed to be in the range of 0.4 to 0.6.

While SRE sampling has been successfully employed in many electric evaluations, the results of the gas evaluations suggest that it may not produce the expected advantage for nascent gas programs, due to the high degree of variability in the realization rates on a project-by-project basis. The correlation between the original and verified savings is less than 0.50 for many of the programs reviewed for this paper, suggesting that the linear dependency between the original savings and the verified savings is quite weak. The error ratios were found to be 1.0 or more rather than the anticipated range of 0.4 to 0.6.

This paper presents the realization rates, values of particular interest to program planners, commissioners, and administrators, but discussion focuses on the error ratio, a key parameter for evaluators. This focus is because the there is little previous experience to use in estimating values for gas program evaluations and the findings to date differ from what one might expect based on electric program evaluation experience.

Table 2 summarizes natural gas realization rates and associated error ratios for the portfolios of programs in Table 1.

Table 2. Realization Rates and Error Ratios for Natural Gas Efficiency Programs

Portfolio or Program Type	Sample with Non-Zero Reported Therms (*n*)	Weighted Average Realization Rate* (*b*)	Error Ratio for the Realization Rate Estimate ($\hat{er}$)	Error Ratio for the Realization Rate Estimate Excluding Outliers** ($\hat{er}$)
Commercial/industrial new & retrofit	29	0.64	1.08	0.92
Residential single family new construction	25	0.92	1.14	1.14
Multifamily retrofit	6	0.91	1.08	1.08
Commercial retrofit (major)	19	0.72	1.94	1.51
Commercial standard performance contracting	6	0.33	1.14	1.14
Commercial/industrial bid program	7	0.98	0.30	0.30
Commercial retrocommissioning	17	0.53	3.20	1.00
Commercial retrocommissioning	4	0.08	na	na
Commercial retrocommissioning	10	0.93	1.26	1.19

[2] The random sampling and SRE approaches are presented in detail with relevant formulae in Chapter 13: Sampling of *The California Evaluation Framework.* Prepared for the California Public Utilities Commission and the Project Advisory Group by the TecMarket Works Team, June 2004.

Commercial retrocommissioning	3	0.21	2.06	2.06
Industrial - fabrication	29	0.68	0.30	0.30
Agricultural & food processing	30	1.07	1.40	0.62
Non-res prescriptive pipe insulation measure	66	0.08	0.29	0.29

** The realization rates shown are at the portfolio level, not just for the sample in the table. In some cases there were evaluated projects that received funding solely due to reported electricity savings and did not claim gas savings and thus are not part of* n *in Table 2, but for which engineers found gas savings during electric measure evaluation. In such circumstances the evaluation did credit the program with the gas savings and thus increase the realization rates.*
***Outliers were defined as projects with realization rates greater than 10 or less than 0.*

The complete data were not available to compute the overall weighted average realization rate, but one can note that the median realization rate is 0.68. Five of the listed portfolios were subject to electric evaluations. For comparison, the realization rates of those groups ranged from 0.45 to 1.23 and the median was 0.70. With respect to overall realization rate, the natural gas programs performed in roughly the same realm as the electricity programs.

On inspection of the individual project realization rates, natural gas realization rates had one characteristic that differed from electric programs: sixty-nine (or 27%) of the evaluated projects had a realization rate of zero. Even excluding the pipe insulation study, where evaluators determined there was a systematic flaw in the program's definition of the baseline condition, 11% of the projects had no evaluated gas savings. In the author's experience, 11% is higher than typical for electric projects and hints at a potential means of improving realization rates on these sometimes-new programs. Gas projects are subject to some market dynamics not faced by electric programs, which may contribute to the difference. For example, multiple boiler replacement projects were driven by a need to comply with new emissions regulations. While the program administrator assumed the pre-existing inefficient boiler was the baseline, evaluators concluded that the customer had to comply with the regulation and the least efficient economical action the customer could have taken to do so was to install the funded boiler. The project was evaluated to have a 0% realization rate. Such regulatory compliance issues are more likely to be applicable to gas than electric projects.

Overall, the natural gas efficiency program realization rates are in the same range as those for electric programs and have the potential to be improved with systematic changes. This is a promising finding, given that natural energy efficiency programs have had less experience to build on than electric programs.

The error ratios in Table 2[3] reveal a marked departure from the corresponding patterns typically found in otherwise similar electric program evaluations and in fact differ from the assumed error ratio at the beginning of the specific gas evaluations. As noted above a typical assumed error rate is generally assumed to be in the range of 0.4 to 0.6 for the type of programs reviewed for this paper. The median natural gas program ***êr*** in Table 2 was 1.14. All but two of the ***êr***s exceeded 1.00. Even excluding outliers,[4] the median natural gas program ***êr*** is 1.04. They were consistently high. This means that even though the average realization rates are similar to electric programs, there is much more variation in

[3] Some of the evaluation final reports included error ratios; other error ratios in Table 2 were calculated for this paper. All the realization rates were in the final reports.

[4] Seven projects in five portfolios had realization rates greater than 10 or less than 0. A single extreme result can skew the overall results in error ratio calculations. For example, one of the portfolios with a relatively reasonable sample size of 17 had an enormous ***êr*** of 3.20. The extremely high value was due primarily to a one project's RR exceeding 22.0. This was associated with a retrocommissioning project in which the project developer apparently focused on electric savings and not gas, but the evaluators concluded that there was in fact a large consequential reduction in gas use. The program-level 3.20 ***êr*** result should not be considered representative. Without the outlier project, the ***êr*** is 1.24. Removing a second project from the evaluation with a suspected similar story total brought the ***êr*** down to 1.0, a value that is still high.

performance from project to project. The evaluated results were reported with less statistical precision than anticipated and, in some cases, than stated as target relative precisions to state regulators.

There are several reasons why gas measures are likely to have high variance between reported and evaluated savings, including the following:

- Gas efficiency programs are less mature than electric ones.
- Baseline appears to have more opportunity for discrepancy with gas measures. Differing baseline definitions overall causes more dramatic changes in savings estimates than differing modeling assumptions.
- Fuel-switching is more likely to be an option for gas measures (e.g., dual-fuel boilers) than with electric measures.
- Gas is intrinsically difficult and expensive to measure. Cutting gas pipe requires specialized experts; program staff are unlikely to want to invite such liability issues into the project.
- Whole facility interval data are rarely available.
- Building simulation modeling, one of the best non-metering-based approaches, is expensive and indirect.
- Measures that include gas energy savings, such as retrocommissioning, can be hard to predict.
- Existing submetering is uncommon except for on the biggest equipment.

The difficulty, expense, and indirect nature of gas M&V all contribute to high variation between reported and evaluated savings.

The programs reviewed for this study reported savings based on a relatively high levels of engineering rigor and the evaluations likewise were conducted with high level of rigor. Still, the variability in the realization rates was quite high. The standard approaches developed and extensively used for the impact evaluation of mature electric programs may not be appropriate for the evaluation of these newer gas programs. Applying the same statistical standard and approaches to gas programs may have unintended consequences, as larger sample sizes would be required and budget constraints may result in reducing the rigor of evaluation per site. Rather than improving our understanding of gas program evaluation, this approach may indeed have the opposite effect.

One could increase statistical precision without adjusting an overall evaluation budget by increasing the sample size and reducing the amount of spending per project. This would require reducing the engineering rigor of evaluation per site and risks inadvertently obscuring the true high variation in realization rates. Switching from more comprehensive to simpler engineering rigor levels could incorrectly bias the realization rates for each project towards 1.0 because an evaluation engineer will not change a reported savings value without having a defensible basis for doing so, one that will withstand the scrutiny of a reviewing program administrator and a regulator. If the per-site budget is for just a few hours, as it is in many verification-level studies, constructing a defensible case for deviation is difficult. Furthermore, some evaluation guidelines define verification objective as determining “if it is possible” for the measure to have saved as much energy as reported, as opposed to independently calculating savings. Overall, verification-level evaluation can result in evaluated savings that tends to be near the reported savings methods and assumptions.

For example, due to exceptional circumstances, four projects in one of the portfolios were subjected to verification-level evaluation and then enhanced evaluation less than two years later. The verified and enhanced realization rates differed from one another by an average of over 100%. The verification-level realization rates were closer to 1.0 and varied less. None of the differences were due to changed operation and there were no inadvertent “errors” in the original verification analysis; it was entirely due to evaluation method and level of rigor possible to fund.

Attribution

Attribution is the study of human behavior to determine how much of participants' savings is attributable to the influence of the energy efficiency program. Attribution typically is split into two components: free ridership and spillover. Free ridership (FR) is a measure of the likelihood that the customer would have completed the project if the energy efficiency program did not exist. Spillover (SO), a contrary effect, measures the extent to which the program induces savings beyond the funded project. Spillover sometimes is further disaggregated into three components: participant on-site spillover, participant off-site spillover, and non-participant spillover. The attribution formula to compute the NTG factor is:

NTG factor = 1 – FR + SO

The NTG factor also is sometimes called the NTG ratio. The program net impact is the product of the program's reported gross savings, the RR, and the NTG factor.

The New York evaluations accounted for free ridership, participant on- and off-site spillover, and market effects spillover such as vendor spillover. Due to this last effect the New York results are referred to as adjusted net-to-gross (NTG) factor. The California evaluations varied adjustment for the spillover components.

The evaluations covered in this paper generally based results on interviews with participants and other program actors such as vendors. The measurement of net-to-gross effects and level of rigor used in collecting the data varied across studies.

Table 3 presents the results, including electric results where comparable. Note that the programs included in the evaluation portfolios for Table 3 are not always exactly the same sets of programs that are included in the portfolios of Table 2, so the results should not be directly combined.

Table 3. Attribution Factors for Natural Gas Efficiency Programs

Sponsor	Portfolio or Program Type	Natural Gas Net-to-Gross Factor	Electric Energy Net-to-Gross Factor, If Applicable
NYSERDA	Commercial/industrial new & retrofit	1.09	
NYSERDA	Residential single family new construction	1.08	
NYSERDA	Multifamily retrofit	1.00	
SCG	Commercial retrofit (major)	0.54	
SDG&E	Commercial standard performance contracting	0.43	
SDG&E	Commercial/industrial bid program	0.85	
PG&E	Commercial retrocommissioning	0.86	0.80
SCE	Commercial retrocommissioning	0.91	0.86
SCG	Commercial retrocommissioning	0.92	
SDG&E	Commercial retrocommissioning	0.68	0.75
PG&E	Industrial – fabrication	0.31	0.53
PG&E	Agricultural & food processing	0.69	0.70
SCG	Non-res prescriptive pipe insulation measure	0.72	

In summary, the NTG methods, levels of rigor, and results overall were similar to those for electric programs.

Other Energy Savings from Gas-Funded Projects

The NYSERDA and the PG&E Ag-Food evaluations analyzed electric, oil, and steam energy savings associated with gas-funded measures in some detail. The analysis only applied when (a) the project did not receive incentives associated with the electricity savings and truly was a byproduct of the predominantly gas savings measure, and (b) the electricity or non-natural gas fossil fuel savings was expected to exceed 10% of the gas savings on a Btu-equivalent basis.

The additional savings is illustrated in Table 4. In all the program evaluations the savings were significant in a few projects and zero for the majority of them. Overall, twelve out of fifty-six projects in combined NYSERDA and PG&E samples had non-zero other energy savings. At utility rates of $0.18 /kWh and $12.50 /$MMBtu_{gas}$ for example, the average NYSERDA Existing Facilities participant enjoyed an extra 22 cents of electric bill savings for every dollar savings on their of natural gas bill. This is not trivial in a cost-effectiveness analysis. Some entities may need to monetize the non-gas benefits and add them to the other non-gas impacts for simplicity; others will have the advanced benefit-cost tools to enter the non-gas energy benefits directly as kWh or Btu savings that the tool monetizes.

Table 4: Other Energy Savings, Normalized

NYSERDA Delivery Program	Evaluated Electric Impacts (kWh/ $MMBtu_{gas}$)	Evaluated Other Energy Impacts (MMbtu/ $MMBtu_{gas}$)
NYSERDA New Construction	1.8	0.00
NYSERDA Existing Facilities	15.1	0.02
PG&E Ag-Food	18.5	na

Example sources of the other energy savings contributions in the NYSERDA study were:

1. Dual-fuel boiler application. The boiler runs on oil about 60% of the time and is saving more energy than predicted. The realization rate on natural gas alone is just over 1.0.
2. Industrial tunnel washer installations at several laundry facilities that save electricity as well as natural gas.
3. Pipe insulation on ground source heat pump lines. This was a natural gas-funded measure but the insulation was installed on an electric appliance and should not have been included in the natural gas program. The natural gas impact for this measure was zero.

Non-Energy Benefits and Costs

As with Other Energy Savings, ERS quantified non-energy benefits and costs associated with the NYSERDA programs and normalized the impact per evaluated Btu of natural gas saved.[5] Table 5 shows the results by individual program. The total non-energy impact was a net additional savings of $1.07 million to participating customers. It is not shown in the table but the NYSERDA ENERGY STAR Homes program was found to have an average of $56 per home in savings due to reduced water use associated with efficient dishwashers and clothes washers. Using the same assumed gas cost of $12.50 per MMBtu, the non-energy benefits to the customers are as high as 75 cents for every dollar of natural gas savings. This obviously can have a material effect in cost-effectiveness analysis.

[5] It was found to be far more useful to normalize on the basis of evaluated rather than reported Btu savings because the realization rates varied so much from site to site.

Table 5: Non-Energy Savings, Normalized

Group Name	NYSERDA Delivery Program	Non-Energy Impact (Per Evaluated MMBtu of natural gas saved)
Con Edison C/I	New Construction	$0.00
	Existing Facilities	$9.46
	Loan Fund	$1.22
Con Edison 1-4 Res.	NY ENERGY STAR Homes	$0.91
Con Edison Multifamily	Multifamily Building (Existing)	$0.06

In addition to the quantified benefits, evaluation engineers reported clear indications of additional benefits such as increased sales that customers were unable or unwilling to value. Six of the twenty-four Existing Facilities projects in the sample had quantified non-energy benefits. None reported higher non-energy costs. Non-energy benefits included:

- Labor cost savings due to process improvements
    - The new dry cleaning process is faster
    - The tunnel washers are faster and less labor intensive than the batch washers
    - The foodservice broiler projects save labor associated with lesser cleaning requirements
- Industrial tunnel washers also save water compared to batch washers.

The above results are based on study of actual projects in the evaluation samples. In the NYSERDA study analysts also conducted an investigation of likely NEIs by technology, using secondary sources unrelated to specific projects. This effort is unrelated to specific program evaluations. Table 6 presents the NEIs for consideration for application in a fashion similar to deemed energy savings values. Blank rows are included where NEIs were postulated at the beginning of the study (positive or negative) and not found. These results are included to emphasize the significant potential measurable NEIs associated with gas measures—perhaps more significant than with electric measures—and encourage evaluators to attempt to value them and add such economic factors into benefit-cost calculations.

Table 6: Natural Gas NEIs by Technology

Measure	Unit	Savings per Unit					Total
		Water (Gall)	**Sewer** (Gall)	**Labor** (hr)	**Detergent/** (Chem/ Other)	**Footprint** (sq ft)	
	Rate	*$0.0037 /gal*	*$0.0052 /gal*	*$18/hr*	*$*	*$16.00 /sqft*	*$*
Commercial/Industrial							
Clothes washers – industrial	/MMBtu	1,253	627	0.5	$1.67	0.10	$19.55
Clothes washers - commercial batch	/MMBtu	1,475	738				$9.32
Clothes washers – laundromat	/MMBtu	1,475	738				$9.32
Boiler – condensing	/MMBtu						
Stack heat recovery to preheat boiler feed water	/MMBtu						
Single- to double-effect absorber, absorber to turbine chiller	/MMBtu	184	184		$0.73		$2.37
Improved natural gas-driven chiller (single effect to gas-driven)	/MMBtu	276	276		$1.10		$3.56
Low flow shower heads- commercial	/MMBtu	1,106	1,106				$9.86
C&I building aerators	/MMBtu	1,515	1,515				$13.51
Commercial pools	/MMBtu	67	67				$0.60
Commercial/restaurant dishwashers	/MMBtu	829	829				$7.39
Residential							
Clothes washers – home	/unit	1,560	1,560				$13.91
Dishwasher	/unit	150	150				$1.34
Boiler – condensing	/MMBtu						
Low flow showerheads – home	/unit	5,856	5,856				$ 52.21
Aerators	/unit	4,680	4,680				$ 41.73
Instant high efficiency hot water heater	/unit						

Summary and Recommendations

Overall, evaluations are revealing that gas programs have similar realization rates and net-to-gross ratios as electric programs. Error ratios for the realization rates differ markedly, with most evaluations included in this survey exceeding 1.0. Non-gas energy impacts and non-energy impacts also are material, with the value to the participants typically exceeding 25% of their natural gas utility bill savings. This savings is not evenly distributed. These findings lead to the following recommendations.

- Adjust expectations during evaluation planning for high error ratios when designing the sample.
- Resist the temptation to increase sample sizes and improve statistical precision in response to probability of high error ratios. Most impact evaluations have limited funding. Choosing to increase sample sizes encourages reduced levels of rigor and spending for each evaluated project. This is exactly the opposite of what is needed at this point in gas program evolution. The high variability in realization rates is precisely an indication that the projects need to be studied more

intensely, not less, in order to learn what is causing such gross deviations and to give this feedback to program administrators. More intensive study of fewer measures will be a better investment in the long term, even at the expense of reported precision in the short term. Rotating measures or programs of interest through the evaluation cycles will lessen the negative effects.

- Attempt to measure the effect of the installation on electricity use and on other fossil fuel sources. Data indicates that the savings can exceed 25% of the customer's natural gas savings.
- Attempt to measure the effect of the installation on non-energy costs in general, but especially if efficient washing is involved. The savings can increase the customer's and society's benefit by up to 75%.

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