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Application of Risk Analysis to Evaluating M&V Requirement for Energy Efficiency Program

Gang Tan **Salil Gogte** **Dakers Gowans**
Nexant Inc.
44 South Broadway, White Plains, NY 10601

Cherie Gregoire
NYSERDA
17 Columbia Circle, Albany, NY 12203

ABSTRACT

Since 2005, CIPP of **New York Energy $mart**[SM] has waived the monitoring requirement for lighting projects with small projected savings that are 600,000 kWh/yr or less. There is potential to further increase the threshold savings with additional administrative efficiencies, but also with increased risk that the estimated savings may not be realized. This paper presented a risk analysis of the threshold for small lighting projects by running a Monte Carlo simulation. The preliminary result of this study shows that increasing the size of lighting project savings for which M&V is waived to 1,400,000 kWh per year would introduce an error of only ±5% to the sum of all lighting savings. The error introduced at the program level would be approximately ±2%. The lessons from this experiment may be used to conduct large-scale risk analysis to optimize evaluation cost allocations for more complex energy efficiency program portfolio.

INTRODUCTION

New York Energy $mart [SM] **Program** is a partnership between the New York State Energy Research and Development Authority (NYSERDA) and the Public Service Commission (PSC). Prior to mid-2003 the Commercial and Industrial Performance Program (CIPP) of **New York Energy $mart** [SM] required all lighting retrofit projects to monitor a sample of lighting fixtures to determine the annual operating hours. Since the change in kW is known with confidence, the measured operating hours lead to confidence in the calculated kWh savings.

Starting in 2003, the program began waiving the monitoring requirement for lighting projects with small projected savings. Since 2005 small projects are defined as those with savings of 600,000 kWh per year or less. The use of stipulated savings reduces both the applicant's and NYSERDA's M&V and review costs. There is potential to further increase the threshold kWh per year savings for small lighting projects with additional administrative efficiencies, but also with increased risk that the estimated savings may not be realized.

A pilot risk analysis of the threshold for small lighting projects was conducted. The goal of the pilot is to demonstrate the application of risk analysis techniques to set limits on M&V requirements. The lessons learned from this experiment can be used to conduct large-scale risk analysis on savings reported by **New York Energy $mart** [SM] programs to determine how limited evaluation dollars can be targeted to achieve the greatest reduction in uncertainty of the savings for the portfolio. Besides demonstrating the value of a risk analysis approach to evaluation planning, this pilot will also help CIPP staff select the annual kWh savings limit for lighting-only projects that qualify for the stipulated M&V approach (IPMVP, 2002).

The Monte-Carlo simulation method was used for this pilot risk analysis. Monte-Carlo methods are stochastic techniques based on the use of random numbers and probability statistics to investigate levels of risk. The Department of Energy's Federal Energy Management Program has explored the use of Monte-Carlo simulation to assess savings uncertainty and the program has used the results to augment the M&V decision-making process in the energy savings performance contracts. In a paper (Mathew et al., 2006) describing the process, the Department of Energy's Federal Energy Management Program explains that a Monte-Carlo simulation for lighting projects would require applying probability distributions to one or more inputs (e.g., wattages, fixture counts, operating hours, measurement precision, etc.), reflecting the uncertainty of the inputs. The simulation will yield a probability distribution of energy savings, which is an expression of the savings uncertainty. The source of the input probability distributions could be derived from empirical data, standard statistical formulae, or may be simply based on engineering expertise.

The Commercial/Industrial Performance Program promotes energy-efficiency and demand reduction through capital improvements. The program supports the development and expansion of the energy service company (ESCO) industry by offering performance-based incentives for energy projects delivering verifiable annual electric energy savings. The Commercial/Industrial Performance Program projects are required to make four milestone submittals: Project Application (PA), Detailed Energy Analysis (DEA), Project Installation Report (PIR), and Measurement and Verification (M&V). DEA includes a detailed analysis of projected energy savings, during which the baseline condition is established. PIR is submitted after the retrofit is completed and energy savings are revised to reflect as built conditions. If required, monitoring does not occur until the M&V stage; savings estimates until then are based on assumed operations and the change in equipment efficiency, which is generally known with good certainty.

METHODOLOGY

Monte Carlo simulation (Mun, 2006) is a widely used technique for dealing with uncertainty in many aspects of business operations, physics, and mathematics. The simulation is a procedure in which random numbers are generated according to probabilities assumed to be associated with a source of uncertainty, such as interest rates or, more appropriately for our purposes, energy savings. For this study, the uncertainty in energy savings was assumed to be solely due to the uncertainty of lighting annual operating hours if no M&V monitoring activities are required. This study followed the procedure below to conduct the pilot risk analysis:

1. Draw a sample of lighting projects that were completed with full measurement and verification.
2. Statistically summarize how the annual kWh savings of the sample projects changes from the Project Application (PA) stage to the Measurement and Verification (M&V) stage.
3. Apply the statistic summary results as the stochastic inputs to the Monte-Carlo simulations by using a commercial risk software package, CrystalBall ™.

Sampling

By the middle of November 2006, the Commercial/Industrial Performance Program had funded more than one thousand projects, in which approximately 507 projects involved lighting retrofits. The sample was drawn from a sub-population of the 507 projects in order to reduce data acquisition costs. As a result, sample bias may be introduced because the sample cannot represent the characteristics of the entire program, such as the distribution of all technical consultants. The following procedure was used to select a sample of Commercial/Industrial Performance Program projects for the pilot risk analysis:

1. From the program's tracking database, filter all the CIPP projects involving lighting retrofits;
2. Generate the sub-population for the lighting CIPP projects;
3. Select projects from the sub-population that have made an M&V submittal.
4. Twenty projects were selected to develop the statistical summary for the annual kWh savings changes from the PA stage to the M&V stage.

Note that by limiting the sample frame to a sub-population of projects dominated by lighting the sample may not be representative of the full program. Because this study was conducted as a pilot, this limitation was accepted in order to demonstrate the utility of the risk analysis approach. The sample of projects is listed in Table 1. The projects are ranked by the magnitude M&V electric savings (high to low) achieved by lighting measures. Five of the projects selected, or 25% of the sample involved the replacement of non-lighting equipment; the risk analysis was performed on the lighting portion only.

Table 1: Pilot risk analysis sample projects

Sample Number	Project Total M&V kWh/year Savings	Lighting Portion M&V kWh/year Savings
1	10,285,384	10,285,384
2	3,576,084	3,576,084
3	3,503,893	3,370,459
4	2,644,664	2,644,664
5	1,833,399	1,833,399
6	4,645,342	1,511,607
7	1,495,232	1,495,232
8	1,486,724	1,486,724
9	1,394,167	1,394,167
10	1,244,211	1,244,211
11	1,069,463	1,069,463
12	898,624	898,624
13	3,031,740	881,851
14	827,702	827,702
15	785,944	785,944
16	767,675	720,467
17	808,477	715,167
18	605,076	605,076
19	586,068	586,068
20	511,437	511,437

MONTE-CARLO Simulation

By summarizing the changes in the energy savings for the twenty sample projects from the PA stage to the M&V stage, the probability distribution for four parameters were obtained:

1. The lighting project contract size (from the PA stage);
2. Three energy savings change ratios from PA to M&V stage[1], including the ratios of DEA/PA, PIR/DEA, and M&V/PIR.

Table 2 shows the distribution of the contracted energy savings for the sampled projects. Table 3 shows the ratios of the energy savings for two consecutive submittals. The ratios represent the change from the previous submittal.

Table 2: Energy (kWh/year) savings contract size of twenty sample projects

Contract Size (PA savings range)	Number of Projects	Percentage of Sample Projects
300,000 - 600,000 kWh	2	10%
600,000 - 900,000 kWh	3	15%
900,000 - 1,200,000 kWh	3	15%
1,200,000 - 1,500,000 kWh	5	25%
1,500,000 - 1,800,000 kWh	1	5%
1,800,000 - 2,100,000 kWh	1	5%
2,100,000 - 3,000,000 kWh	2	10%
3,000,000 - 4,000,000 kWh	1	5%
>4,000,000 kWh	2	10%
Total	20	100%

Table 3: Energy (kWh/year) savings change ratios over the four stages for twenty sample projects

Sample Number	Energy Savings Change Ratios - DEA/PA	Energy Savings Change Ratios - PIR/DEA	Energy Savings Change Ratios - M&V/PIR
1	0.96	0.98	0.96
2	0.66	1.18	1.00
3	1.18	1.00	0.94
4	1.14	1.00	1.00
5	0.96	1.01	0.93
6	1.15	1.46	0.93
7	1.00	1.00	1.02
8	0.62	1.06	1.00
9	1.00	1.00	1.12
10	0.80	1.00	1.05
11	1.02	0.89	1.10
12	1.00	1.02	0.95
13	0.30	1.00	1.84
14	1.15	1.01	0.58
15	0.73	0.87	0.89
16	1.00	1.53	1.19
17	1.22	0.96	0.87
18	1.00	0.98	1.00
19	1.00	1.00	1.13
20	0.57	1.00	1.00

A key intermediary step in a Monte Carlo analysis is to select a probability distribution of the variables that contribute to uncertainty. For this pilot risk analysis, these were; contracted project size in kWh per year savings, and change in savings from one submittal stage to the next. Based on an examination for the probability distribution of the contract size and the energy savings change ratios for the twenty sample projects, the following discrete uniform or triangular mathematical probability distribution models shown in Figure 1 was used to approximate their actual distribution.

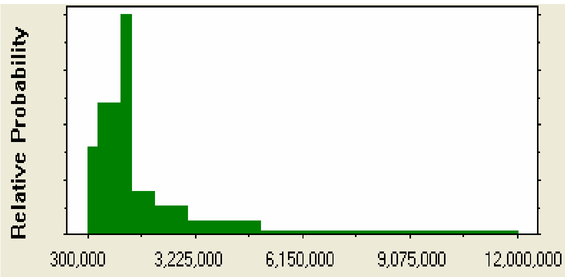
To obtain a large population of replicates, a total of 50,000 simulated CIPP lighting projects, with the inputs following the probability distributions shown in Figure 1, were simulated in this study by applying the commercial software package[2] CrystalBall ™, although the program had funded only about 507 projects. For each simulated project, four random numbers (one contract size and three energy savings change ratios) were generated. The energy savings for DEA, PIR, and M&V stages are calculated using the following equations:

[1] For example, the energy savings change ratio from PA to DEA is defined as the ratio of the DEA approved kWh/year savings to the PA approved kWh/year savings.

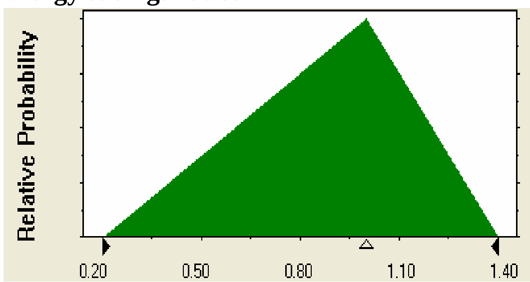
[2] For more information, please check the link: http://www.crystalball.com/index.html

$$
\begin{aligned}
&DEA - kWh\ Savings = (PA - kWhSavings) \times (EnergyChangeRatio - DEA / PA) \\
&PIR - kWh\ Savings = (DEA - kWhSavings) \times (EnergyChangeRatio - PIR / DEA) \qquad (1) \\
&M\ \&V - kWh\ Savings = (PIR - kWhSavings) \times (EnergyChangeRatio - M\ \&V / PIR)
\end{aligned}
$$

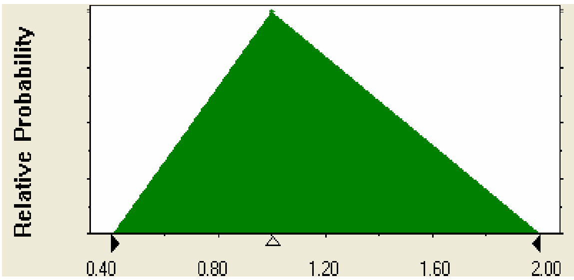
Figure 1: Probability distribution of contract size and energy savings ratios



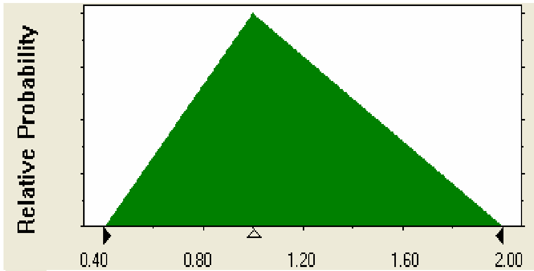
1). probability distribution of contract size; *x-axis: kWh/year, y-axis: relative probability*



2). probability distribution of savings change ratios (DEA/PA); *x-axis: ratio, y-axis: relative probability*



3). probability distribution of savings change ratios (PIR/DEA); *x-axis: ratio, y-axis: relative probability*



4). probability distribution of savings change ratios (M&V/PIR); *x-axis: ratio, y-axis: relative probability*

Since the Commercial/Industrial Performance Program had approximately 500 completed lighting projects as of mid-November 2006, this study separated the 50,000 simulated CIPP lighting projects into 100 groups, each representing a simulated CIPP portfolio of lighting projects. Then, this study next conducted a sensitivity analysis to statistically summarize the error[3] in kWh per year savings as the threshold for requiring full M&V is varied. The error is the difference between the PIR estimated and the M&V reported savings. This study assumed that NYSERDA would tolerate an error of ±5% for all the CIPP lighting projects. In a series of steps, the threshold for requiring M&V was raised, and then the error was checked. If it was less than 5%, the threshold was raised again. The sensitivity analysis results under nine threshold scenarios are summarized in Table 4. It can be seen that the threshold of 1,400,000 kWh per year is the optimum limit for small lighting projects that can waive M&V requirement, if a ±5% error is acceptable.

Table 4: Sensitivity analysis results under nine threshold scenarios

Threshold (kWh/year)	Error Mean	Error Stdev	95% Confidence Interval of Error	Within 5% Error Tolerance
600,000	-0.3%	0.12%	-0.54% ~ -0.08%	Yes
800,000	-0.7%	0.23%	-1.15% ~ -0.26%	Yes
1,000,000	-1.2%	0.32%	-1.85% ~ -0.60%	Yes
1,200,000	-1.9%	0.43%	-2.72% ~ -1.03%	Yes
1,400,000	-3.2%	0.61%	-4.38% ~ -1.99%	Yes
1,500,000	-3.9%	0.72%	-5.32% ~ -2.49%	No
1,600,000	-4.1%	0.75%	-5.55% ~ -2.62%	No
1,800,000	-4.4%	0.76%	-5.92% ~ -2.93%	No

[3] This study assumed that the energy savings obtained through M&V is the "true" energy savings. The error comes from the projects that are waived M&V and therefore report final project savings based on PIR.

Threshold (kWh/year)	Error Mean	Error Stdev	95% Confidence Interval of Error	Within 5% Error Tolerance
2,000,000	-4.8%	0.78%	-6.34% ~ -3.28%	No

RESULTS AND DISCUSSION

Based on the pilot risk analysis study, if the Commercial/Industrial Performance Program used 1,400,000 kWh per year savings as the threshold above which M&V is required, and then the program savings for lighting projects will be under-reported by 3.2% +/- 1.2% at the 95% confidence interval. Because non-lighting measures account for approximately 47% of program savings, the program savings will be underreported by 1.7%, compared with the program savings if the current M&V threshold of 600,000 kWh per year or less is continued to be used. Table 5 summarizes this analysis.

Table 5: kWh Savings by applying the 1,400,000 kWh/yr threshold

	2005 CIPP End of Year kWh Savings	2005 CIPP kWh Savings if Applying the 1,400,000 kWh/yr Threshold	Error (%)
Lighting	332,102,257	321,537,464	-3.2%
Non-lighting	290,172,738	290,172,738	0.0%
CIPP Total	622,274,995	611,710,202	-1.7%

This study was conducted as a pilot to demonstrate the application and utility of Monte Carlo risk analysis for requiring M&V. In order to use the study's results with confidence, additional sample lighting projects should be added to the sample drawn from a sub-population and the simulations should be re-run. An actual uncertainty that NYSERDA can tolerate should be investigated, instead of the assumed value ±5% in this paper.

In this study, discrete uniform or triangular mathematical probability distribution models were used to approximate the sample projects' contract energy savings or stage energy savings ratios. More and further research is necessary to improve the probability models and make them more statistically represent the population's 'real' distribution.

Furthermore, this paper didn't address the uncertainties in the measured savings but assumed they are accurate. Following research will be conducted to investigate and quantify the potential uncertainties within the measurements.

Although this pilot study has limitations for its practical implementation, risk analysis can help evaluate the M&V requirement and possibly reduce the M&V expense. Thus risk analysis will optimize the capital allocations for public benefit programs. According to the results of FEMP's (Federal Energy Management Program) study, typically, annual M&V costs will be 3 – 15% of the savings[4]. Increasing the M&V threshold from 600,000 kWh per year to 1,400,000 kWh per year for CIPP will save significant M&V costs for project applicants as well as program administration costs.

Energy Efficiency continues to be a vital component of the United States' energy strategy since most greenhouse gas emissions result from the use of energy. There are effective energy efficiency programs running in the Nation. Significant money has been spent on M&V evaluation for these programs in order to evaluate program impacts. Especially for some large-scale energy efficiency program portfolios, spending more money and human efforts on the programs that contribute the majority to energy savings impacts or that contain enormous uncertainty in their reported energy savings will upgrade the entire program's savings accuracy.

Although the goal of this pilot study is to demonstrate the application of risk analysis techniques to set limits on M&V requirements, the lessons learned from this experiment can be used to conduct large-scale risk analysis on savings reported by the program portfolio to determine how limited evaluation dollars can be targeted to achieve the greatest reduction in uncertainty of the savings for the portfolio. Using risk analysis tools, program administrators can optimize the allocation of evaluation resources.

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[4] Federal Energy Management Program, U.S. Department of Energy, *Introduction to Energy Savings Performance Contracting (ESPC) and DOE Super ESPCs*, Miami, Florida, January 13-14, 2004. Online link: http://www1.eere.energy.gov/femp/docs/DO_MV_Part4.ppt#308

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