

Measuring Market Transformation Progress & the Binomial Test: Recent Experience at Boston Gas Company

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ABSTRACT

Several utilities and government organizations are conducting market indicator studies to track the progress of energy efficiency and market transformation programs. Many of these studies, however, are still at the baseline measurement stage. This paper will present information on the development of a large number of indicators for Boston Gas Company's market transformation (MT) programs and the preliminary results of on-going market progress measurements. It will also present the Company's unique method of assessing market progress with the use of a directional statistical test, the binomial test. The paper also discusses the degree of market progress for one program based on indicator measurements to date, describes monetary incentives for the Company that are tied to the binomial test, and the collaborative process used to develop the binomial test approach.

In 1998, the Boston Gas Company undertook MT market assessment and baseline studies for four markets where they were beginning MT efforts: the residential gas heating equipment market, the commercial/industrial gas heating equipment market, the residential new construction market and the clothes washer market. These studies included measuring indicators and developing market indicator tables in collaboration with several non-utility parties. The original list of indicators developed in 1998 for measuring progress in these markets totaled 270: 38 for the residential gas heating equipment market, 72 for the commercial and industrial gas heating equipment market, 125 for the residential new construction market and 35 for the clothes washer market.

In late 1999, a second set of measurements (on all 270 indicators) was undertaken as the first to track progress of Boston Gas Company's MT efforts. Preliminary findings from this research are presented below along with lessons learned from measuring indicators of market transformation and using the binomial test to assess program progress.

INTRODUCTION

Boston Gas Company¹ began implementation of a comprehensive energy efficiency and market transformation plan in May 1997. The Company's plan (BGC PLAN) was developed through a collaborative process and called for the Company to spend \$42 million over five years on a number of innovative gas energy efficiency and market transformation programs. The Company has designed and implemented several market transformation

¹ Established in 1822, the Boston Gas Company is New England's oldest and largest distributor of natural gas, serving more than 535,000 residential, commercial, and industrial customers throughout 74 Massachusetts communities in eastern and central Massachusetts. Boston Gas is a wholly-owned subsidiary of Eastern Enterprises, located in Weston, Massachusetts.

programs. Boston Gas Company can earn monetary incentives if it is successful in removing or reducing market barriers through its MT program offerings. The Company is now implementing Year 4 of the Plan and has completed baseline measurements of indicators of market transformation as well as follow-up measurements at the end of Year 2 for four market transformation programs. This paper describes presents preliminary information on the market transformation progress for the Residential High Efficiency Gas Heating Equipment Program as well as lessons learned from measuring market progress. The Company's research is one of the few efforts underway in the nation that can report baseline as well as later measurements of market transformation indicators.

The Boston Gas Company Story

The Company's Demand-Side Management and Market Transformation Program Plan was approved in 1997. The Company worked with a number of non-utility parties in 1997 and 1998 to negotiate the incentives the Company could earn for successful implementation of market transformation programs. The main problem that faced the Company and the non-utility parties was how to devise a methodology for measuring success with moving indicators of market transformation given that little or no movement could be expected in such indicators over short time periods (such as one year). This paper tells the story of the incentive system that was developed through negotiations between the Company and the non-utility parties, describes the statistical test selected to determine if progress was real, and provides results of the incentive calculations determined from baseline and follow-up measurements.

Boston Gas Company completed baseline and market assessment studies for each of its four market transformation programs in 1998. These studies provide information for several major research areas:

- A market characterization for each program
- Analysis of the current attitudes, knowledge, and purchase decisions among recent market participants relating to decisions on adopting or purchasing high efficiency equipment or homes
- Identification of market conditions and barriers
- Baseline measurements of proximate and ultimate market transformation indicators²

A market assessment study characterizes the structure and operation of a particular market and identifies market barriers.³ A baseline study provides the baseline measurement of the proximate indicators of market transformation for a market. Boston Gas Company repeated the baseline measurements in late 1999. In the spring of 2000, the Company and

² The Boston Gas Company has Tier 1 and Tier 2 incentives for successful performance of the Company's market transformation efforts. Tier 1 refers to incentives tied to the measurement of direct program activities, e.g., number of rebates given. Tier 2 incentives are tied to the measurement of market effects, e.g., awareness of high efficiency equipment among market participants.

³ Boston Gas Company developed hypothesized market barriers for all MT programs during the fall of 1997. Two studies were used to develop an initial profile of the residential gas heating equipment market. This initial profile was then used in the development of the Company's design for its residential high efficiency market transformation effort. The studies utilized were (1) The Consortium for Energy Efficiency Report, Titled *High Efficiency Residential Gas Heating Initiative: An initiative to transform the market for residential furnaces and boilers -- Discussion Draft* and (2) *Massachusetts Market Transformation Scoping Study, Stage II Final Report*, by Arthur D. Little and the Gas Research Institute for the New England Gas Association (including support from the Boston Gas Company), dated September 30, 1997.

non-utility parties assessed the degree of improvement in the market transformation indicators and determined the amount of Tier 2 incentives earned by the Company. The methodology for calculating the Tier 2 incentive for each program was negotiated with stakeholders in 1998. The amount of the Tier 2 incentive for a particular program is tied to the degree of improvement achieved in the MT indicators.

Categories Of Indicators

Four general categories of indicators of market effects were examined in the BGC studies and are listed below. These categories were developed in conjunction with the non-utility parties.

- Product awareness and promotional activity, including attitudes and purchase intentions towards energy efficiency products and services among end-users
- Product knowledge, level of training and expertise among trade allies (the relevant market actors for the residential high efficiency heating equipment program include HVAC contractors, plumbers, design engineering firms, and distributors of gas heating equipment)
- Product performance and reliability
- Product availability and penetration

DEVELOPMENT OF THE INCENTIVE MECHANISM FOR THE COMPANY AND THE NEGOTIATION PROCESS

Overview of Incentives

Boston Gas Company can earn monetary incentives for its market transformation programs based on Tier 1 goals that are tied to program activity and Tier 2 goals that are tied to market progress (i.e., reducing or removing market barriers to energy efficiency and creating sustainable energy efficiency markets). Up to \$300,000 in Tier 2 incentives is at stake in the year 2000 and another \$450,000 three years later.

Negotiations With Non-Utility Parties

After considering a number of methods for calculating the Tier 2 incentive payment at the end of Year 2 and Year 5 of the Company's Five-Year Plan, the Company and several non-utility parties (referred to as the "Settling Parties") agreed upon a calculation method that considers whether statistically significant improvement in the Tier 2 indicators of market transformation has occurred. This is a considerable challenge because market progress and market transformation generally take time to evolve, and it is difficult to show marked improvement of such indicators in a period as short as 12 to 18 months. While it is straightforward to measure program activity (such as number of program participants or training sessions delivered), it is much more difficult to measure program outcomes over a short time period.

The Company held several meetings with non-utility parties to discuss the best way to determine if the movement in indicators over time was significant. After considering a range

of significance tests, it was agreed that the binomial test would be used to determine whether indicator movement was significant.

What Is The Binomial Test?

The binomial test (also known as the sign test) is a statistical test that can measure whether movements over time in indicators of market transformation are meaningful. The test essentially examines the preponderance of the evidence, that is, are most indicators moving in the correct direction. The test assumes that the error terms of individual indicators are not correlated, thus it is necessary to carefully select indicators. To calculate the binomial test for this type of application with indicators, first one determines for each indicator if it has moved in the correct direction between a baseline measurement and a subsequent measurement. Indicators moving in a correct direction⁴ receive a sign of 1, those that do not receive a sign of 0. Then one calculates the number of indicators having a score of 1, and compares that to a threshold value for the binomial test at a defined level of significance.⁵ An indicator category passes the binomial test at a defined level of significance if a large enough number of indicators have a sign of 1.⁶

A description of the binomial distribution can be found in most elementary statistics textbooks⁷. The binomial distribution is characterized by an event or process where there are two mutually exclusive possible outcomes, such as with the flip of a coin (“heads” or “tails”). One area in which this distribution has been very widely applied is in quality control.⁸ A binomial test was selected to test for statistically significant improvement in Tier 2 indicators because the sign test approach (“1” if improvement has occurred, “0” if not) fits the characteristics of the binomial distribution.

The Settling Parties decided that the binomial test would not include specific numerical targets for indicators (see footnote 5) specifying how large the improvement must be between Year 1 and Year 2 (which would entail a “size-and-sign” test). Fifty percent of the incentive payment for a program was tied to whether indicator improvement is statistically significant (according to the binomial test) on an overall program basis. The remaining fifty percent of the incentive payment was based on whether improvement has been statistically significant (according to the binomial test) by major indicator category.

⁴ Note that in Tables 3, 4, 5 and 6 that indicators marked with an asterisk should decrease over time in order to show program progress with reducing or removing market barriers.

⁵ The level of significance was a negotiated item between Boston Gas Company and the non-utility parties. Due to the innovative characteristics of the Boston Gas Company MT programs and lack of prior experience over time with MT indicator measurements in general, a 20% probability of a Type I error was agreed to by all parties participating in these negotiations. In 1998, if the Company and the non-utility parties had more experience with such measurements, a different probability of a Type I error might have been selected. A Type I error occurs when the null hypothesis is rejected when in fact it is true.

⁶ For Tier 2 incentive purposes, the direct inputs to the binomial test are the directionality of the results for the several indicators, and the probability level for a Type I error. In the binomial test, the number of indicators with a sign test value of “1” are compared to the number of indicators having a sign test value of “0” via a one-tailed test of significance. The sign test is the binomial test in this instance.

⁷ For example, see Hamburg, Morris, “Statistical Analysis for Decision-Making”, Harcourt, Brace and World, (New York, 1970), Chapter 2.

⁸ *Id.*, 93.

Why Was The Binomial Test Selected?

Boston Gas Company had several discussions with stakeholders involved in the deployment of its programs concerning the best way to measure progress of market transformation programs. All parties were concerned that it would be difficult to achieve statistically significant movements in indicators over a measurement period of 12 to 18 months. After discussion of many options, all parties agreed that the binomial test approach, coupled with a defined probability of a Type I error, offered many advantages. The binomial test was selected by all stakeholders for the following reasons:

- it can measure market progress across many different qualitative and quantitative measurements
- it can determine progress when little movement is expected in indicators over a short period of time
- binomial test calculations are easy to perform, the components of the test can be measured reliably, and the underlying measurements can be collected using standard market research techniques (i.e., mail surveys, depth interviews, content analyses and site surveys)
- the test can be performed on all indicators at once or for categories of indicators
- the test is useful for determining whether a program administrator has been successful in moving indicators of market transformation in a positive direction
- it allows for providing financial incentives to program administrators for success with moving individual categories of indicators as well as moving all program indicators, thus avoiding the prospect of an “all or nothing” incentive system

It is also important to note that detailed analysis of the indicators can provide useful feedback for program design and implementation.

In the spring of 1998 Boston Gas Company recognized that the use of a binomial test for determining whether statistically significant improvement in indicators of market transformation has occurred was a new approach, not documented in current literature at that time. The Company, however, believed that use of a binomial test was appropriate for use in determining market progress and for calculating incentive payments for the Company. Because there was still some uncertainty in the use and calculation of the binomial test for this particular application, the Company recognized that there might be a need to make modifications to the binomial test methodology as the second round of measurements began in 1999. As of early June 2000, no modifications to the general methodology have been necessary.

Other Incentive Issues

After much discussion, the Company and the non-utility parties agreed that fifty percent of the Tier 2 incentive calculation for a particular program should be tied to statistically significant improvement in all program indicators (in a single test of statistical significance), and fifty percent of the incentive for a program should be tied to determining whether improvement is statistically significant for each major category of indicators.⁹ This

⁹ Boston Gas Company, June 18, 1998 Filing with the Massachusetts Department of Telecommunications and Energy, “Methodology for Calculation of Tier 2 Incentive Payment for Boston Gas Company.”

was done to ensure that the incentive system would not be an “all or nothing” proposition. The Parties decided not to select specific numerical improvement targets for the end of Year 2 for each Tier 2 indicator for the following reasons:

- The calculation method adopted by the Parties for the Tier 2 incentive payment is easy to understand and calculation of the payment is straightforward.
- The baseline data and statistical confidence levels for each Tier 2 indicator were not available early enough in the methodology development to provide benchmarks for Year 1.
- The parties recognized that measurement of indicators of market transformation is a new evaluation problem, and that setting specific targets would be very difficult and time consuming given the lack of prior experience in this field, and the lack of sufficient information about the level of uncertainty surrounding indicator measurements. The parties agreed that there is much to be learned about indicators of market transformation and agreed that the information collected in the measurement process would be very useful in tracking the market effects of the Company’s four market transformation programs.

Once the Settling Parties had determined that use of a binomial test was appropriate in concept, and had determined that an overall test as well as several tests for categories of indicators would be used, steps necessary for calculating the binomial tests and the resulting incentive payments for the Company were established and filed with the Massachusetts Department of Telecommunications and Energy (DTE) in June 1998. Listed below in Table 1 is a summary of the particular steps used at Boston Gas Company. More detailed information on each of these steps can be found in this filing.¹⁰

Table 1. Summary of Steps for Calculating the Binomial Test and Incentive Payments

STEP	DESCRIPTION
1	Allocate overall maximum Tier 2 incentive payment of \$300,000 for all MT programs among the four MT programs
2	Allocate maximum incentive payment for each program among the four major indicator categories for use in the incentive calculation pertaining to indicator categories
3	Develop baseline measurements for all indicators of market transformation at end of Year 1 of programs
4	Assess levels of indicators at end of Year 2 of programs
5	Determine whether statistically significant improvement in indicators has occurred between end of Year 1 and Year 2
6	Calculate binomial tests
7	Calculate incentive payments for programs based on binomial test results

¹⁰ Id.

HIGHLIGHTS OF MARKET TRANSFORMATION INDICATORS, BINOMIAL TEST RESULTS AND INCENTIVE AMOUNTS

In the remainder of this paper we present examples of indicator measurements and the binomial test calculations for one of the Boston Gas MT programs, the Residential High Efficiency Heating Equipment Program. Table 2 below summarizes the research approaches used to collect indicator measurements. A list of the Year 1 (baseline) and Year 2 indicator measurements for the residential high efficiency (HE) heating program are provided in Tables 3 to 6. Detailed information on how these measurements were obtained can be found in a 1998 study published by Boston Gas Company¹¹.

Table 2. Research Approaches Used To Collect Indicator Measurements

Market Actor or Issue	Research Approach
Residential customers with gas heat	Mail survey
Equipment installers & distributors	Depth interviews
Quality of Equipment Installation	On site surveys of gas heating equipment
Product promotion & advertising	Content analyses of newspapers and business to business publications

Examples of findings from the baseline and follow-up measurements of indicators for this program include:

- The low awareness level of high efficiency gas heating equipment among recent market participants¹² (RMP) for gas furnaces and boilers is a market barrier. A low percentage of the RMPs in the furnace market or boiler market said that different efficiency levels were explained well to them or mentioned to them by the sources they contacted.
- Product availability of high efficiency gas heating equipment from contractors, plumbers, and distributors is not a market barrier.
- In the 1999 follow-up depth interviews, only 8 out of 31 contractors and plumbers defined the level of high efficiency for gas furnaces and boilers consistent with the definition used in the Boston Gas Company program.
- Perceived reliability of high efficiency gas heating equipment by contractors and plumbers is a market barrier, with only 11 of 40 interviewed in 1998 stating that the equipment is reliable. However, distributors interviewed in 1998 state that high efficiency equipment is reliable and suggest that the real problem is that it is difficult to find knowledgeable repair personnel to service high efficiency equipment.

Product Awareness and Promotional Activity Indicators

Listed below in Table 3 are the ten indicators selected for the product awareness and promotion category of indicators. It is important to note that in selecting indicators, it is critical to select indicators that are most likely to show whether a particular market barrier is

¹¹ Boston Gas Company, Residential High Efficiency Heating Market Assessment and Baseline Study, August 1998, prepared by GDS Associates, Inc.

¹² Recent market participants have either recently purchased gas heating equipment or have been actively shopping for such equipment in the past 24 months.

present, and it is also necessary to determine if good progress would result in an increase or a decrease in an indicator. In order to be accepted as an indicator, Boston Gas Company had to demonstrate to the non-utility parties the link between the indicator and a specific market barrier. Also all parties agreed that advertisements and articles placed in newspapers and business to business publications by Boston Gas Company or other utilities would not be considered in the content analyses. Note that in Table 3, 5 out of 10 indicators move in the desired direction.

Table 3. Awareness/Product Promotion Indicators

No.	Group or Subgroup	Indicator	Year 1	Year 2	Sign
1	RMPs	Heard about high efficiency units from listed sources	57%	61%	1
2	RMPs	Believe high efficiency equipment well-explained	30%	33%	1
3	RMPs	Received at least one price quote for high efficiency (HE) equipment	57%	60%	1
4	RMPs	Received multiple quotes for HE equipment	54%	53%	0
5	Contractors/ Plumbers	Define HE consistently with program	14 of 39	8 of 31	0
6	Newspaper articles	Discuss energy efficiency of heating equipment, benefits thereof, etc. (editorial content)	0	0	0
7	Newspaper advertising	Promote energy-efficient heating equipment (ads)	0	>0	1
8	Business-to-business publications	Discuss energy-efficient heating equipment (editorial content)	0	0	0
9	Business-to-business publications	Promote energy-efficient heating equipment (ads)	0	>0	1
10	Self-reported HE buyers	Report purchase of HE units stimulated newspaper or television ads or articles	2%	1%	0

Note: In Tables 3 to 6, HE means “high efficiency”, RMP means “recent market participant” for gas heating equipment, and PDM means “potential decision-maker”, i.e., respondent owns home and is in a position to make the purchase decision for home heating equipment.

Training, Attitudes and Performance of Market Actors

Listed below in Table 4 are the indicators selected for the category for the training, attitudes and performance of market actors. In this category there are six indicators and market progress will be demonstrated if enough of these indicators move in the correct direction over time. In this Table, 3 out of 6 indicators move in the desired direction.

Table 4. Training, Attitudes & Performance of Market Actors

No.	Group or Subgroup	Indicator	Year 1 Level	Year 2 Level	Sign
11	Self-reported HE buyers	Purchased high efficiency heating system because recommended by contractor	48%	22%	0
12	Installed HE units	Overall quality of installation index of gas heating equipment	94%	94%	0
13, 14, 15, 17	Installed HE units	Combined quality of installation indicator: Site inspector's overall assessment of exhaust vent installation, air intake installation, condensate drains and overflow connections, overall installation	Rating = 5.8	Rating = 4.3	0
16	Installed HE units	Boiler controls provide for interlock between burner and circulator	1/9	6/9	1
18	Installed HE units	Vibration absorbing equipment installed	Rating = 0.2	Rating = 1.9	1
19*	Distributors	Believe few knowledgeable repair persons available for work on high efficiency gas heating equipment units	3/5	5/11	1

Perceived Product Performance

Table 5 lists the indicators selected for the category for perceived product performance. In this category 5 out of the 8 indicators move in the desired direction.

Table 5. Perceived Product Performance & Reliability Indicators

No.	Group or Subgroup	Indicator	Year 1 Level	Year 2 Level	Sign
20*	Potential Decision-Maker	Believe differences in efficiency too small to save money in average winter	17%	16%	0
21	Potential Decision-Maker	Believe HE equipment reduces infiltration of cold air	20%	20%	0
22	Potential Decision-Maker	Believe HE is at least 10% more efficient	34%	43%	1
28	Site visit sample	Customer reports that savings meet or exceed expectations	80%	97%	1
29	Site visit sample	Customer reports being extremely satisfied with comfort	32%	10%	0
30*	Site visit sample	Customer reports problems with HE unit that affect operation	7/44	5/40	1
31,32	Contractors/ Plumbers	Combination of indicators 31 & 32. Believe High Efficiency equipment is reliable	0.05	0.52	1
33	Distributors	Believe HE is reliable	.6	.82	1

Product Availability and Penetration

Table 6 lists the indicators selected for the category for product availability and penetration. In this category there are five indicators. Five out of 5 indicators move in the desired direction.

Table 6. Product Availability and Penetration Indicators

No.	Group or Subgroup	Indicator	Year 1 Level	Year 2 Level	Sign
36*	Recent Market Participants	Believe extra time needed to obtain HE units	13%	6%	1
37	Recent Market Participants	Believe it is easy to obtain reliable information on HE gas heating equipment	34%	38%	1
38	RMPs who have not yet bought	Likely to purchase HE unit in next 6-12 months	32%	46%	1
39	GAMA Data	Penetration of high efficiency gas furnaces, GAMA - AFUE of 88% or more	47%	57%	1
40	Purchasers of residential gas heating equipment	Penetration of high efficiency gas boilers - AFUE of 85% or more (self report from mail survey)	25%	35%	1

Overall Binomial Test

Table 7 below shows the results of the binomial test for each of the four indicator categories and all categories combined. Overall 18 out of 29 indicators move in the desired direction, exceeding the threshold number of indicators needed for passing the binomial test.

Table 7. Preliminary Binomial Test Calculation – Overall and By Category

Category	# of Indicators	Indicators With Sign of “1”	Number Needed to Pass	Pass Binomial Test?
Awareness/Promotion	10	5	7	Fail
Training, attitudes, performance of market actors	6	3	5	Fail
Product performance & reliability	8	5	6	Fail
Product availability & penetration	5	5	4	Pass
Total	29	18	18	Pass

Preliminary Calculation of Tier 2 Incentive Payment for Residential High Efficiency Heating Equipment Program

To arrive at the Tier 2 incentive payment for each Boston Gas Company market transformation program, it was necessary to calculate the incentive payment due to (1) indicator improvement for the overall program and due to (2) indicator improvement for each indicator category. The preliminary incentive calculation for the Boston Gas Company Residential High Efficiency Heating Equipment Program is provided below. Table 8 below shows the preliminary incentive payment calculation, including the results of the binomial test from Table 7. Based on the market progress achieved by this program, the preliminary calculation for the total Tier 2 incentive payment at the end of Year 2 for this program is \$65,000 (where the maximum possible incentive is \$100,000).

Table 8. Preliminary Tier 2 Incentive Payment Calculation – End of Year 2 of Plan

Indicator Category	Binomial Test Results	Maximum Incentive Payment	Calculated Tier 2 Incentive
Overall Indicator test	Pass	\$50,000	\$50,000
Awareness	Fail	\$15,000	\$0
Training, Expertise, Attitudes	Fail	\$15,000	\$0
Product Availability	Pass	\$15,000	\$15,000
Product Performance & Reliability	Fail	\$5,000	\$0
Total for Column		\$100,000	\$65,000

VALUE/IMPORTANCE

The Year 2 indicator measurements for the Boston Gas Company Residential High Efficiency Heating Equipment Program tell us that the overall program has made progress in reducing market barriers (18 of 29 indicators show improvement) and the movement in product availability and market penetration indicators is very encouraging. Market progress in the specific indicator categories of (1) awareness, (2) training, expertise and attitudes of market actors and (3) perceptions of product performance and reliability, however, did not pass the binomial test and have considerable room to improve. Examples of indicators not showing improvement to date include (1) the number of articles discussing the benefits of high efficiency heating equipment in newspapers and business to business publications and (2) the proportion of contractors and plumbers who define high efficiency units consistent with the definition used in the Company's program.

In the absence of assessment methods that accommodate the problems of measuring effects over short time periods, many market intervention programs are likely to be (falsely) judged as failures. If this occurs, the energy services industry and our nation are likely to lose a number of critical opportunities to reduce barriers to the sale and use of energy-efficient products and services. The approach described in this paper provides program sponsors and policymakers with readily implemented and proven protocols for tracking the effects of market interventions and assessing their efficacy with greater sensitivity than the methods familiar from prior DSM evaluations. In using this process, care must be exercised in selecting indicators that are linked to market barriers, and a determination must be made of the direction of indicator movement that signifies that market barriers are being reduced or

removed. The approach implemented in the Boston Gas Company progress assessment process can be valuable to other organizations launching public benefits programs that are aimed at removing market barriers to adoption of energy efficient products and services.

Finally, this method of defining and tracking indicators of market transformation has demonstrated value for assessing program and market progress. It is important to understand that the binomial test approach discussed here was developed through extensive discussions with several stakeholders. In particular, the decision criteria on the level of statistical significance is a political decision to be negotiated between stakeholders considering the issues of market tracking and measurement. An alternative approach that could be used would be to pay incentives based upon achieving a sign test of “1” on a pre-set percentage of the total number of indicators. Determining threshold levels for success is always a question of balancing risks, uncertainties and the amount of investment at stake and is best left to the parties involved in such negotiations.

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