CHUNG-HUA INSTITUTION FOR ECONOMIC RESEARCH

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Abstract

This paper selects 18 commercial lighting demand-side management programs in the United States and evaluates their performance. In order to achieve this objective, this paper first conducts a cost-benefits analysis for each program, i.e., proposed rate impact measurement test, total resource cost test, total utility cost test, and total customer test to evaluate them, respectively. Then, we establish a mathematical planning model--the data envelopment analysis (DEA) model--to evaluate their relative performance among the 18 programs. The results indicate that no matter what measurements we use, each program is cost-effective and can be rated excellent. Among them, Southern California Edison Co., New York State Electric & Co., and Potomac Electric Power Co. are the best, followed by Central Maine Power Co., Pacific Gas & Electric Co., and Central Vermont Public Service Co. Finally, this paper also discusses the implications of the estimated results.

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Keywords:commercial lighting, performance evaluation, data envelopment analysis, demand-side management

I. Introduction

In this paper, we have selected 18 commercial lighting utility programs and undertaken a relative performance evaluation. Because of the depressed economy in the United States in the 1990s, demand for electricity and power sales have not grown. Also, the speed of deregulation in the power market has hastened, increasing competition. The investment of the utilities' demand-side management (DSM) programs must necessarily be recovered from the rate revenue. It is obviously urgent that utilities reevaluate DSM programs. They require that resource inputs match their relevant economic benefits. By 1993, 500 utilities around the United States had already put into practice more than 2,000 DSM programs (Blevins & Miller 1993). Expenditures for electric power DSM not only have grown quickly, but occupy a substantial proportion of the total expenses of utilities. Therefore, it is important to measure the performance of DSM programs, especially for the utilities' commercial lighting programs.

For three reasons, we have focused on commercial lighting programs from various DSM programs. First, the commercial sector is an important sector for DSM activities. The load in the commercial sector increases quickly and plays an important role in power sales. Furthermore, the load pattern of the commercial sector is similar to the system as a whole. That is to say, we can effectively adjust the load pattern of the entire system once we have corrected the load pattern in the commercial sector. Second, lighting load is a major portion of the commercial load, representing three-fourths of the total. Conservation technology in the lighting apparatus of electric power has already matured, and the potential for conservation may reach 40% to 70% (Atkinson, et al. 1992). Following the above argument, many utilities have put lighting programs into practice, and we can easily acquire a comparison base. Third, commercial lighting programs are one of the important power conservation programs. The budget of commercial lighting programs often makes up 25% or more of the total budget of the utilities (Eto, et al. 1994).

In a commercial lighting program, utilities offer effective incentives and provide a direct rebate or a direct installation service for lighting apparatuses to attract commercial users to join the program. One of the main purposes of commercial lighting programs is to reduce the load. To undertake a performance evaluation of commercial lighting programs, we systematically evaluate the power savings from the lighting apparatuses of commercial users. We adopt the concept of structure evaluation to measure the performance of commercial lighting programs, which focuses on the carry-out results (performance) and measures the relevant costs and benefits of the programs. The results can provide useful information to highlight the potential of the commercial lighting program in the resource planning of utilities. It is also critical information for the power company manager, regulator, and power system planner to be used in making strategic decisions, for example, whether to maintain the status quo or withdraw investment. Moreover, it demonstrates the extent of success of the commercial lighting program on which utilities embark on existing industry alliances, consumer education, and market structure.

Because implementation of a commercial lighting program can affect the allocation of the equity of the user and utilities, it also influences the policy of the regulator. In addition, different individuals have their own particular viewpoint about the performance of the commercial lighting program. For example, regulators and utilities have different viewpoints on program performance. Even within a utility, the generation unit, power sale unit, and supervisor are not all in agreement. Therefore, this paper adopts multiple viewpoints to evaluate lighting programs in order to take into account all aspects of the performance of the programs.

We first analyze the costs and benefits of each commercial lighting program from various assessment viewpoints. We propose four viewpoints and measurements to evaluate these programs. They are consumer outgo viewpoint (rate impact measure test, RIM test), total resource planning viewpoint (total resource cost test, TRC test), internal resource allocation viewpoint (total utility cost test, TUC test), and integral production-sales planning (total customer test, TCC test). We use the cost-benefit ratio indicator rather than the absolute number indicator, e.g., load conservation, per Kwh conservation cost, avoided cost, and participation ratio. Second, we employ the data envelopment analysis (DEA) method to synthesize the four indicators given above. Because the four indexes are distinctly representative of four different assessment viewpoints, no index has an obvious base from which to directly sum up. Therefore, we set up a DEA model, using the mathematics planning mechanism, to yield a weight by which we can integrate the four measurements objectively.

This paper is organized as follows. Section one and section two are the introduction and literature review, respectively. The content of the four measurements will be discussed in section three. Section four explains the concept of the data envelopment analysis model and Pareto optimum. Section five shows the empirical results and section six offers our conclusions.

II. Literature Review

There are a number of performance evaluation papers which concern commercial lighting demand-side management programs. Some of the important ones are discussed here. Ganhli (1988) focused on energy conservation and evaluated the existing commercial lighting programs of the United States. He mainly measured the load saving of these programs. Nadel (1988) employed the engineering method and the statistics method using a questionnaire comparing the performance of the commercial lighting program of the New England Electric Systems (NEES). Then, employing ratio analysis and using load conservation ratio, per Kwh conservation cost, participation rate, and free-rider ratio indexes, he ranked 46 programs in the

United States. In 1991, he concluded that we can employ the load conservation ratio, per Kwh conservation cost, free-rider ratio, participation rate, program direct cost, and the percentage difference between the expected saving and actual saving, to measure program performance. Violette, et al. (1992) adopted similar indicators to measure the impact effect of the commercial lighting programs of the Portland Gas and Electric Corporation and Massachusetts Power Company. He employed the engineering method and ex ante/ex post questionnaire comparison method. Nadel, et al. (1994) emphasized participation ratio analysis, then investigated the key success factors of commercial lighting programs.

By contrast, Ontario Hydro (1988) proposed the concept of total user cost to evaluate supply- vs. demand-side management of utilities. Atkinson, et al. (1992) held that the rate impact measure method was one of the best ways to investigate the influence of a tariff on the existing programs. He then adopted the regulator's viewpoint to propose policy suggestions for the programs. Finally, Eto, et al. (1994) reviewed and analyzed the contents of several indicators, e.g., participation ratio, per Kwh conservation cost, and avoided cost, and proposed a total resource cost indicator to evaluate the performance of commercial lighting programs.

In sum, most of the above literature adopts traditional performance indicators, e.g., load conservation, per Kwh conservation cost, participation ratio, etc., to measure the performance of lighting programs. These may shed light on the individual aspects in some depth. However, the main weakness of the above indicators is that they only consider the cost side or the benefit side and do not combine the two sides, e.g., the concept of cost-benefit ratio. Fortunately, some authors chose the cost-benefit ratio to measure performance, often basing their work on a certain viewpoint. The main contribution of this paper is to join the various assessment viewpoints to measure the performance of commercial lighting programs, which produces different insights. Some of the other literature adopts rate analysis to evaluate performance. The rate analysis method is very appropriate in explaining a single indicator among various programs, but does not yield a simple result when we analyze multiple indicators. Therefore, we employ a mathematics planning method and set up a DEA model to integrate the various cost-benefit measurements.

III. Performance Measurement Index

There are two kinds of performance evaluation, that is, process evaluation and structure evaluation. Process evaluation is also called operation evaluation. It measures the extent of the program activity process. The key indicators include the efficiency of the operation process, adaptability to changes, budget supplement situation, user complaint situation, and handling. We can measure the flow of the utility's internal resources by the process of the program. The process evaluation method involves acquiring the internal data of utilities and the resource allocation problem. It is appropriate for a single utility in making a longitudinal performance evaluation. Because the purpose of this paper is to compare 18 utilities, we use a structure evaluation, which measures the impact of the program's system structure. It is utilized by comparing the differences in the program ex ante and ex post. There are many indicators that can be easily determined, such as load save, load save ratio, participation ratio, cost-benefit ratio, per Kwh conservation cost, etc.

This paper measures structure-type performance rather than process-type performance. We propose four cost-benefit ratio indicators based on four viewpoints, the RIM test (consumer outgo viewpoint), TRC test (total resource planning viewpoint), TUC test (internal resource allocation viewpoint), and TCC test (integrated production-sales planning viewpoint). These are shown in Table 1.

First, the RIM test (rate impact measurement) examines the status of the rate change after implementation of the commercial lighting program. This is very important because the price of electricity has a great influence on national welfare, people's livelihood, the competitiveness of industry,

Table 1 The Four Cost-Benefit Ratio Measurements

Item		Rate Impact Measure (RIM) test	Total Resource Cost (TRC) test	Total Utility Cost (TUC) test	Total Customer Cost (TCC) test
Viewpoint		consumer outgo	total resource planning	internal resource allocation	integral production-sales planning
Purpose		investigate the influence on the electricity rate	investigate the influence on resource utilization	investigate the influence on utilities' supply cost	investigate the influence on user's costs and benefits
Strength		concerned with electricity rate level	may enlarge the evaluating base by adding to external costs	result is insensitive to the future rate level	can compare between demand-side programs and supply-side programs
Weakness		the result is sensitive to the future rate level	cannot compare between demand-side program and supply-side program	the result cannot respond to resource utilization	the data is not easy to obtain on some cost items
Formula	Benefit Items	$\sum_{t=1}^{N} \frac{AC_t + REV_t}{(1+d)^{t-1}}$	$\sum_{t=1}^{N} \frac{AC_t + TC_t}{(1+d)^{t-1}}$	$\sum_{t=1}^{N} \frac{AC_t}{(1+d)^{t-1}}$	$\sum_{t=1}^{N} \frac{AC_t + BL_t}{(1+d)^{t-1}}$
	Cost Items	$\sum_{t=1}^{N} \frac{PC_t + INC_t + LOS_t + SC_t}{(1+d)^{t-1}}$	$\sum_{t=1}^{N} \frac{PC_t + INC_t + INS_t + SC_t}{(1+d)^{t-1}}$	$\sum_{t=1}^{N} \frac{PC_t + INC_t + SC_t}{(1+d)^{t-1}}$	$\sum_{t=1}^{N} \frac{PC_t + INC_t + INS_t + SC_t + BC_t}{(1+d)^{t-1}}$
Notes		t: period d: discount rate Act: utilities' avoided cost PCt: program administrative cost SCt: utilities' additional supply cost REVt: the revenue increments due to sales increments		INVt: incentive expenses BLt: the expense decrements due to purchase decrements LOSt: the revenue decrements due to sales decrements INSt: user's installation cost TCt: tax credit BCt: the additional payments due to the new equipment installments	

elections, etc. Therefore, the regulator always pays great attention to price. The main point of the rate impact measurement test is that implementation of the lighting program changes the revenues and operation costs of the utilities, which is then reflected in rate fluctuation. In other words, if revenue increments are larger than cost increments, then utilities can decrease rates, whereas if cost increments are larger than revenue increments, rates will increase. Revenue increment includes two items: utilities' avoided cost and revenues increments resulting from additional sales. Cost increments include four items: incentive expense, project administration cost, utilities' additional supply cost, and revenue decreases resulting from sales shrinkage. However, the magnitude of the last item should be zero because implementation of the commercial lighting program will slash the use of power. Furthermore, because the price of electricity is the focus of public hearings, the rate impact measurement test is able to recognize a more attractive program among several demand-side management programs. Because this test is very sensitive to the future rate level, we must reexamine the result when we evaluate the performance of the planned programs. However, we are not concerned with that here because this paper evaluates existing programs.

Next, the TRC test (total resource cost) investigates the resource efficiency of the commercial lighting program. The commercial lighting program is considered a resource application alternative, which can compete with other programs to utilize resources. Therefore, the benefit item is separate from the utilities avoided cost and must be added to the tax credit that is the decrease in tax resulting from the decrease in sales. As for the cost item, it must include utilities cost (including incentive expense, program administration cost, and utilities additional supply cost) and participation cost of the user. The reason is that users and utilities must expend manpower and capital input to establish the related facilities when a user joins a commercial lighting program, regardless of who pays the cost of facilitating the device. However, we do not regard the above as a sales decrement item because it does not change the total resource magnitude and only involves the transfer of resources. Note that we include the incentive expense of the user to subsidize the resource use. This is because when a user installs a new apparatus, he must tear down the original one at the same time or repair the existing facilities to increase their function. The merit of this method is that it avoids the problem of future rate changes. In addition, the TRC test is able to compare a supply-side program and a demand-side program if we can compute the participation cost of the supply-side program.

Third, the TUC test (total utilities cost) looks into the impact of the commercial lighting program on the utilities' output cost. A commercial lighting program is considered a type of business plan. Utilities compare the cost and performance of each of the utilities' programs. A program's benefit is the avoided cost, while program costs include program administration cost, incentive expense, and additional supply cost. We have included incentive expense because this expense is paid by utilities and should be recognized as a reimbursement to participants. However, we have excluded the user's participation cost since it is only indirectly related to the financial status of utilities. Thus, the result of the TUC test does not represent the entire resource utilization. We also have ignored variation of sales as it is a kind of transfer payment. The result of the TUC test won't be influenced by future rate changes, significantly reducing its uncertainty and complexity.

Fourth, the TCC test (total consumer cost) is conducted based on the entire performance evaluation. The program benefit is the avoided cost and the decrease in power purchases. The cost item covers all kinds of costs, including installation of the power system and use of other kinds of fuel and resources (supply-side), and provides the required services to the end user (demand-side), and so on. We recognize that all of the various costs must be passed on to the consumer via the electricity price. Program cost then includes the project administration cost, utilities' incentive expense, user's participation cost (facilitation and equipment cost), and the additional expense due to installation of new lighting equipment.

It is unnecessary to compute the traditional indicators, e.g., gross (net) savings, per Kwh conservation cost, participation ratio, etc. because they were taken into account in computing the four measurements. If we did, it would result in double counting; in fact, the four measurements above represent very well the entire performance status. Also note that we do not analyze the "program participant measurement" (program participant's viewpoint) which investigates the user's costs and benefits resulting from participation in the program. There are two reasons: (i) the majority of users do not consider cash benefits alone when making a decision about joining a commercial lighting program and (ii) utilities can't consider the user factor only and ignore the utility itself when putting this program into practice. The program participant measurement should be a reference index only. Cost items include participation cost and overpayment for electricity. The program benefits include the incentives plus the decreases in electricity expense.

Finally, we do not need to consider the variation in avoided cost resulting from alternative fuel use since the commercial lighting program does not involve a fuel substitution problem. We have also not included safety and environmental factors since the data is not available. Indeed, the commercial lighting program impacts only slightly safety and the environment where it is involved with the renewal of lighting equipment and adjustment of lamp circuits. The impact on the environment is less heavy from the supply-side management program, e.g., direct control to heat storage and air conditioners. Information on safety and environmental factors can be added to the total resource cost test measurement to make it more meaningful if the relevant data is available.

IV. Data Envelopment Analysis

In this section, we propose data envelopment analysis to evaluate relative performance among utilities. The DEA method was first described by Charnes, Cooper, and Rhodes (1978). They employed a mathematical planning model (CCR model) to measure the efficiency frontier based on the concept of Pareto optimum. The basic idea of DEA is to identify the most efficient decisionmaking units (DMU) from all DMUs. The most efficient

DMU is called a Pareto-optimal unit and is considered the standard for comparison of all other DMUs. The Pareto-optimal unit is the one such that any change that makes some people better makes others worse off (Gould and Ferguson, 1980). Conversely, a unit is Pareto-nonoptimal if some people can be made better off without harming anyone else. The multitude of the performance score of the Pareto-nonoptimal is calculated from the Pareto-nonoptimal DMU divided into the Pareto-optimal DMU. Therefore, the DEA score is a relative number, rather than absolute.

The idea of calculating DEA scores can be formulated as a linear programming problem. Denoting Z_{rt} as the *t-th* measurement of the *r-th* DMU and Z_{kt} is the score of the *k-th* DMU. E_k is calculated by the following linear problem:

$$\underset{W_t}{Max}\ E_k = \sum_{t=1}^{T} W_t Z_{kt} \qquad \begin{array}{l} t = 1,2,\ldots\ldots,T \\ r = 1,2,\ldots\ldots,K,\ldots\ldots,R \end{array}$$

$$\text{s.t.} \qquad \sum_{t=1}^{T} W_t Z_{rt} \leq 1$$

$$W_t \geq \varepsilon > 0$$

Where W_t is the weight number of the *t-th* measurements. This model is a simpler form of the standard CCR model developed by Charnes, et al. (1978). In a CCR model, if DMU employs p inputs to produce q outputs, the score of *k-th* DMU, C_k is a solution from the fractional linear programming problem:

$$\underset{U_j V_i}{Max}\ E_k = \frac{\sum_{j=1}^{q} U_j Y_{kj}}{\sum_{i=1}^{p} V_i X_{ki}} \qquad \begin{array}{ll} i = 1,2,\ldots\ldots,p & j = 1,2,\ldots\ldots,q \\ r = 1,2,\ldots\ldots,K\ldots\ldots,R & \end{array}$$

$$\text{s.t.} \quad \frac{\sum_{j=1}^{q} U_j Y_{rj}}{\sum_{i=1}^{p} V_i X_{ri}} \leq 1 \qquad U_j, V_i \geq 0$$

Where X_{ri} is the *i-th* input of the *r-th* DMU and Y_{rj} is the *j-th* output of the *r-th* DMU. U_j and V_i gives the slacks of the *j-th* output and the *i-th* input, respectively. In this paper, we consider the output measurement (numerator) only, rather than a ratio of weighted outputs to weighted inputs in the standard DEA formulation.

V. Empirical Results

We have evaluated the relative efficiency of 18 United States utilities. The DSM program expenditures of these 18 utilities amounts to more than 15% of the 3,000 utilities in the whole of the United States and are considered the important programs. Moreover, their expenditure in commercial lighting programs accounts for one-fourth of electric conservation programs. The 18 commercial lighting programs are very similar in their incentive items and program contents. Thus, we can easily compare the performance of these programs. The data is from Lawrence Berkeley Laboratory (LBL) and the Energy Efficiency Data Program (DEEP), and the time period ranges from 1992 to 1994 (see Table 2).

A. Background Analysis

The 18 commercial lighting programs began to be implemented beginning in 1985. Central Maine Power was first and Green Mountain Power last in 1991. Therefore, these 18 programs were not pioneer programs and did not suffer unstable results. As for program expenditures (including administration costs and incentive costs), the New England Electric System, Consolidated Edison, and Niagara Mohawk Power are the

Table 2 18 Commercial Lighting Programs of Utilities of the United States

State	Utility	Abbre-viation	Program Budget (Million $)	Load Saving (GWH)	Avoided Costs (Cent/kwh)	Per Kwh Consewation Costs (Cent/Kwh)	Economic Year
New York	Consolidated Edison of New York, Inc.	Con Edison	31.1	91.9	14.0	6.8	11
New York	Central Hudson Gas & Electric Co.	CHG&E	4.0	16.1	6.8	3.7	10
New York	New York State Electric & Gas Co.	NYSEG	5.5	71.5	10.0	2.5	10
New York	Niagara Mohawk Power Co.	NMPC	20.1	134.4	9.0	5.2	13
Mussachusetts	Boston Edison Co.	BECo	6.0	8.3	11.3	7.2	15
Mussachusetts	New England Electric Systems	NEES	4.4	104.2	10.0	4.4	15
WashingtonDC	Potomac Electric Power Co.	PEPCo	1.6	40.5	7.5	2.3	10
Maine	Bangor Hydro Electric Co.	BHEC	0.2	2.8	5.0	4.7	10
Maine	Central Maine Power Co.	CMP	1.4	15.7	4.6	1.8	7
Iowa	Iowa-Illinois Gas & Electric Co.	IG&E	0.1	1.4	4.8	7.6	12
Vermont	Central Vermont Public Service Co.	VPSE	1.2	4.0	12.1	3.6	14
Vermont	Green Mountain Power Co.	GMP	0.5	1.4	12.1	4.3	7
Oregon	Portland General Electric Co.	PGECo	0.9	3.2	4.7	4.5	12
Washington	Seattle City Light Power Co.	SCL	3.1	16.9	4.7	1.2	15
California	Sacramento Municipal Utility District	SMUD	0.5	2.6	11.2	4.1	5
California	Pacific Gas & Electric Co.	PG&E	12.0	130.0	8.5	1.2	15
California	Southern California Edison Co.	SCE	3.2	96.6	7.2	5.0	13
California	San Diego Gas & Electric Co.	SDG&E	10.0	66.2	7.3	2.5	15

top three companies. Iowa Power and Green Mountain Power had the lowest expenditure. In load saving, Niagara Mohawk Power, Pacific Gas and Electric, and New England Electric Systems save more than 1 million Kwh, respectively. Green Mountain Power and Iowa Power save the least load. Furthermore, the average avoided cost of the 18 utilities is $0.085. Among them, Consolidated Edison, Central Vermont Public Service, and Green Mountain Power at more than $0.12 are the highest and Central Miami Power, Portland Power and Seattle City Light at less than $0.05 are the lowest. As for the participation rate, Sacramento Utility (5.94%) is the highest and Seattle City Light (0.38%) is the lowest. Average participation (1.98%) is slightly higher than for average commercial lighting programs in the United States (1%). This indicates that these 18 programs may be regarded as successful programs.

B. Cost-Benefit Analysis

First, we find that the evaluated results of the four cost-benefit tests all surpass 1.0, which indicates that the present value of program benefits are all higher than the program cost. They are able to recover their investment and satisfy the economic principle. This is a reasonable result because an unfavorable cost-benefit program cannot possibly continue implementation in the United Stated in the 1990s. Utilities will reject acceptance of new liabilities and turn down any "stranded assets," i.e., ones they have put into the resource but which cannot be put to effective use. This becomes more evident as the power markets move toward a deregulated system and it is no longer possible to guarantee that many expenditures will be recovered from the rate base.

The results of the individual tests are discussed as follows (see Table 2): (i) RIM test: Potomac Power, Southern California Edison, and New York State Electric are the best. Their figures all run over 3.4. On the other hand, Portland Power, Bangor Hydro, and Iowa-Illinois Gas & Electric are the lowest. The figures all slightly surpass 1.0. This shows that implementation of a commercial lighting program can lower the rate level of utilities and attract users to participate. Simultaneously, users also enjoy a cheaper tariff. (ii) TRC test: Potomac Power, Southern California Edison, and New York Gas and Electric are the best DMU in utilizing resources. Their index scores all are at least 4.4. The lowest two are Iowa-Illinois Power and Bangor Hydro. (iii) TUC test: New York State Electric, Potomac Power, and Southern California Edison are the top three. Their index scores are all 7.0 or above. The lowest two are Portland Power and Southern California Edison. (iv) TCC test: The highest three utilities are Southern California Edison, Potomac Power, and New York State Electric. They all have index scores of 5.0 or above. Conversely, Iowa-Illinois Gas & Electric and Bangor Hydro are the lowest. (v) We can conclude that New York State Electric, Potomac Power, and Southern California Edison are obviously the most outstanding.

If we compare the results of the cost-benefit ratios to the background analysis, we can easily see that the best three cost-benefit utilities (New York State Electric, Potomac Power, and Southern California Edison) are not equal to the high load-saving utilities (New England Electric System, Niagara Power, and Pacific Gas & Electric). They are also different from the lowest per Kwh saving cost utilities (Seattle City Light, Pacific Gas & Electric, and Central Miami Power) and those with the highest avoided cost (Consolidated Edison Power, Central Vermont Public Service, and Green Mountain Power). These results indicate that we need to employ cost-benefit ratio analysis.

It is worth noting that the results of the four tests range from 1.0 to 4.9 (RIM test), from 1.1 to 6.3 (TRC test), from 1.5 to 7.5 (TUC test), and from 2.9 to 9.5 (TCC test), respectively. Among them, we find that the TCC test figures are the highest, the RIM test figures are the lowest, while the remaining two tests fall in the middle. The figures are obviously consistent and are reasonable for the following three reasons. First, the figure for the TCC test is larger than that of the TUC test. This is because the numerator for the TCC test is obviously larger than the numerator for the TUC test and the figures for the two denominator items are slightly different (see Table 1). Second, the TUC test figure is larger than that of the TRC test. The reason is that the numerator for the TUC test is obviously smaller than for the TRC test and their numerator items are very similar. Third, the TRC test figure is also larger than that of the RIM test. The denominator of the TRC test is larger than that of the RIM test and there are limited differences between the two numerator items.

C. Data Envelopment Analysis

We finally employ data envelopment analysis to evaluate the relative performance score among 18 utilities (Table 3). Southern California Edison, New York State Electric, and Potomac Power have the highest efficiency scores (1.0), and they are classed as efficient DMUs, because they are obviously better than other utilities on many cost-benefit ratio tests. These three utilities become the base of comparison for the others, and the efficiency scores of the remaining 15 utilities are less than 1. Among the 15 utilities, the next highest efficiency scores are Central Maine Power (0.8169), Pacific Gas & Electric (0.7946), Central Vermont Public Service (0.6109), Seattle City Light (0.5968), and Consolidated Edison Power (0.5905). Conversely, the lowest three utilities are Boston Edison (0.3218), Sacramento Utility District (0.3293), and Bangor Hydro (0.3344), respectively. As an example, the score for Central Maine Power is 0.8169. This represents the output measure of Central Maine Power, divided by the input measure, which is 81.69% of the most efficient DMU. Clearly, the efficiency level of Central Maine Power (0.8169) is higher than that of Consolidated Edison Power (0.5905).

VI. Concluding Remarks

The utilities of the United States are now faced with highly competitive pressure and high user autonomy. One of the effective strategies utilities employ is demand-side management (including commercial lighting programs) to temper user load demand and move up the user satisfaction scale, and thus able to support their market share. They will meet system load demand in

Table 3 Empirical Results of the Cost-Benefit Ratio and DEA Score

Utility	RIM test	TRC test	TUC test	TCC test	DEA score
Consolidated Edison of New York, Inc.	2.0	2.1	3.6	5.6	0.5905
Central Hudson Gas & Electric Co.	1.7	1.8	2.4	4.0	0.4317
New York State Electric & Gas Co.	3.4	4.4	7.5	8.6	1.0000
Niagara Mohawk Power Co.	1.4	1.5	3.4	5.0	0.5312
Boston Edison Co.	1.6	1.6	1.8	2.9	0.3218
New England Electric Systems	2.2	2.2	2.6	3.2	0.4390
Potomac Electric Power Co.	4.9	6.3	7.3	9.0	1.0000
Bangor Hydro Electric Co.	1.0	1.1	2.2	3.2	0.3344
Central Marine Power Co.	1.5	2.6	3.1	7.7	0.8169
Iowa-Illinois Gas & Electric Co.	1.3	1.3	3.1	3.5	0.4077
Central Vermont Public Service Co.	2.9	3.4	3.7	5.5	0.6109
Green Mountain Power Co.	1.9	1.9	2.8	4.3	0.4584
Portland General Electric Co.	1.1	1.3	1.5	3.9	0.4106
Seattle City Light Power Co.	1.7	1.9	2.6	5.6	0.5968
Sacramento Municipal Utility District	1.4	1.7	1.9	3.1	0.3293
Pacific Gas & Electric Co.	1.6	1.7	6.0	7.0	0.7946
Southern California Edison Co.	3.7	6.0	7.2	9.5	1.0000
San Diego Gas & Electric Co.	1.7	1.8	3.3	5.4	0.5735

order to lower the power supply cost simultaneously. In addition, when power market deregulation works, the budget of the demand-side management program can never again be assigned to the rate base. The result is that utilities need to reevaluate commercial lighting programs in order to decide the ranking of allocation of resources.

This paper measures the relative performance among 18 commercial lighting programs in the United States. Persons in different roles often have their own viewpoints on performance evaluation. Because of this, this paper proposes four measurements which match four different viewpoints. They are the RIM test (consumer outgo viewpoint), the TRC test (total resource planning viewpoint), the TUC test (internal resource allocation viewpoint), and the TCC test (integrated production-sales planning viewpoint). We finally employ the data envelopment analysis (DEA) method to integrate a single score to measure their relative efficiency.

Empirical results indicate that all programs are cost effective (the cost-benefit ratio is larger than 1.0) and they are not "stranded assets" (stranded assets of utilities are easily seen in supply-side programs). The results show that Potomac Electric Power, South California Edison Power Company, and New York Gas & Electric are outstanding utilities. Moreover, we also find that the figures of the TCC test > TUC test > TRC test > RIM test. These results are consistent and reasonable.

We conclude that Southern California Edison, New York State Electric, and Potomac Power are the most efficient utilities. Again, Central Maine Power, Pacific Gas & Electric, and Central Vermont Public Service rank from fourth to sixth among the 18 utilities. The poorest three utilities are Boston Edison, Sacramento Utility District, and Bangor Hydro. We must note, however, that we cannot conclude that the last ranked (i.e., Boston Edison) is an inferior program, because we have found that the 18 utilities are all cost-effective from the cost-benefit ratio test.

Moreover, we have not included externality factors (e.g., the environment and safety indicators) and the index of output quality (e.g., power supply quality and service satisfaction) in evaluating the 18 programs.

Therefore, we cannot judge whether the 18 programs are “good” or “bad” unless we further measure the service quality and the externality factors. In other words, we argue that largest output is not our unique goal. That is to say, we are not advocating only enlarged production and disregard of service quality and social-environmental issues.

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