PWP-005

# A REVIEW AND ANALYSIS OF ELECTRIC UTILITY CONSERVATION INCENTIVES

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November 1992

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## Abstract

State regulators have introduced stockholder incentives to induce investor-owned electric utilities to engage in more aggressive promotion of energy conservation. This paper examines and compares incentive mechanisms that have been adopted and shows that they can be usefully classified as rewarding expenditures, savings, or net benefits. The difficulties of estimating net social benefit and the informational conditions sufficient to justify different categories of incentive programs are described. The net benefit incentives currently in place offer significant expected total rewards for utility conservation activities, but provide only weak incentives for conservation on the margin. Under somewhat restrictive assumptions, an optimal incentive program would pay 100% of net-benefits and impose a fixed charge to reduce expected utility payments.

# A Review and Analysis of Electric Utility Conservation Incentives

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## I. Introduction

In July 1989, the National Association of Regulatory Utility Commissioners adopted a resolution urging state commissions to

> "... adopt appropriate ratemaking mechanisms to encourage utilities to help their customers improve end-use efficiency cost-effectively..."

Prior to this resolution only three incentive mechanisms had been adopted[1]. Subsequent to this resolution, three more utilities received approval for incentive mechanisms in 1989, and 14 more received approval in 1990 (Barakat and Chamberlin, 1991). As of October 1991, eleven states had approved demand-side management (DSM) incentive programs, an additional four states had approved at least a generic form of incentives and an additional six states were considering incentives. Table 1 shows utility expenditures on conservation incentive programs and the incentive payments at 22 utilities originally surveyed by Barakat and Chamberlin [1991] and subsequently updated. They represent most of the utility incentive programs in effect as of June 1992.

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[1] The first by Wisconsin, then San Diego Gas and Electric in September 1988 (see San Diego Gas & Electric [1990]), and the third by New York for Long Island Lighting Company in January 1989.

**Table 1. Utility Incentives and Expenditures**

| | | Incentive and Expenditures in $ Millions | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 1990 | | 1991 | | 1992 | | Total | | |
| | | Inc. | Exp. | Inc. | Exp. | Inc. | Exp. | Inc. | Exp. | Ratio |
| CA | Pacific G&E | 14.9 | 63.5 | 47.4 | 136.0 | 50.7 | 141.0 | 113.0 | 340.5 | 0.33 |
| CA | San Diego G&E | 9.2 | 17.0 | 10.7 | 36.0 | 7.1 | 45.0 | 27.0 | 98.0 | 0.28 |
| CA | So. Calif. Edison | 4.0 | 80.0 | 9.1 | 125.0 | 8.0 | 153.0 | 21.1 | 358.0 | 0.06 |
| CA | So. Calif. Gas | 1.3 | 52.0 | 3.7 | 59.0 | 6.0 | 59.0 | 11.0 | 170.0 | 0.06 |
| CO | Public Service Co. | 0.1 | 0.5 | 0.2 | 3.3 | 0.5 | 11.0 | 0.8 | 14.8 | 0.05 |
| CT | United Illuminating | 0.5 | 7.0 | 0.3 | 11.3 | 0.5 | 15.2 | 1.3 | 33.5 | 0.04 |
| ME | Central Maine Power | 0.0 | 0.0 | 1.0 | 17.0 | 1.5 | 25.0 | 2.5 | 42.0 | 0.06 |
| MA | Mass. Electric | 5.0 | 37.0 | 10.8 | 55.0 | 2.2 | 68.0 | 18.0 | 160.0 | 0.11 |
| MA | Western Mass. Elec. | 0.3 | 9.5 | 0.9 | 18.0 | 1.2 | 18.7 | 2.4 | 46.2 | 0.05 |
| MI | Consumers Power | 0.5 | 8.0 | 5.5 | 32.5 | 5.5 | 32.5 | 11.5 | 73.0 | 0.16 |
| MN | Northern States | 0.0 | 0.0 | 0.1 | 15.0 | 0.3 | 18.0 | 0.4 | 33.0 | 0.01 |
| NH | Granite State Elec. | 0.5 | 1.4 | 1.0 | 3.1 | 1.1 | 3.8 | 2.6 | 8.3 | 0.31 |
| NY | Central Hudson G&E | 0.0 | 4.5 | 0.7 | 7.0 | 2.2 | 18.0 | 2.9 | 29.5 | 0.10 |
| NY | Con Edison | 0.0 | 0.0 | 22.0 | 76.0 | 25.0 | 89.0 | 47.0 | 165.0 | 0.28 |
| NY | Long Island Lighting | 0.0 | 29.0 | 0.0 | 32.0 | 3.2 | 35.0 | 3.2 | 96.0 | 0.03 |
| NY | New York State E&G | 0.0 | 13.0 | 2.0 | 23.0 | 3.2 | 34.0 | 5.2 | 70.0 | 0.07 |
| NY | Niagara Mohawk | 1.5 | 7.6 | 9.0 | 45.0 | 7.0 | 58.0 | 17.5 | 110.6 | 0.16 |
| NY | Orange & Rockland | 0.0 | 0.0 | 2.7 | 9.0 | NYA | 10.0 | 2.7 | 19.0 | 0.14 |
| NY | Rochester G&E | 0.8 | 8.0 | 0.8 | 6.2 | 0.9 | 7.8 | 2.5 | 22.0 | 0.11 |
| OR | Pacific Power & Light | 0.0 | 0.0 | 0.3 | 0.4 | 0.3 | 0.4 | 0.6 | 0.8 | 0.75 |
| OR | Portland GE | 0.0 | 0.0 | 1.8 | 15.0 | 1.9 | 20.0 | 3.7 | 35.0 | 0.11 |
| RI | Narragansett Electric | 3.0 | 14.0 | 3.0 | 19.1 | 2.9 | 17.7 | 8.9 | 50.8 | 0.18 |
| | Sum | 42 | 352 | 133 | 744 | 131 | 880 | 306 | 1,976 | 15% |
| | Ratio | 12% | | 18% | | 15% | | 15% | | |

NYA = Not Yet Available

Table 1 shows that utility conservation incentive programs have been growing rapidly since their introduction. Expenditures on utility DSM incentive programs are projected to reach almost $1 billion in 1992, which is about one-half to two-thirds of total expenditures on utility DSM programs.[2] This is not an inconsiderable sum, even if it is still a small fraction of total utility expenditures.[3] The incentives paid to utilities in these programs have averaged about 15% of program expenditures. That is, for each $1 that utilities have spent in these programs, they have been paid on average about $1.15. The incentive payment has varied widely between programs, ranging from only 1 cent on each dollar to about 30 cents, and in one case (Pacific Power and Light) to as much as 75 cents, (but on expenditures of less than $1 million).

Debate over the value of utility conservation programs has long raged in the halls of regulatory commissions. Conservation proponents have argued that energy can be saved cheaper than it can be produced and that traditional regulation provides inadequate incentives for investment in conservation. Amory Lovins coined the term "negawatt" to describe a unit of saved energy, presumably to provide conservation with a status equal to that accorded to the kilowatts generated by utilities. Exhorting the potential for conservation, Fickett, Gellings and Lovins [1990] claim that opportunities for economic conservation are so vast that conservation "...is not a free lunch; it is a lunch you are paid to eat" (p. 67). Other evaluations of conservation opportunities have reached more somber conclusions about costs, but have nonetheless maintained that utilities can deliver the equivalent of thousands of megawatts of cheap power by increasing the efficiency with which energy is consumed (e.g. Koomey et al, 1991).

While Lovins and his followers have promoted the cost-effectiveness of conservation investments, others have focused on the perceived inadequacy of traditional regulation to provide incentives for conservation that are comparable to incentives for investment in energy generation, (e.g., Cavanaugh, 1988 and Calwell and Cavanaugh, 1989). These concerns find some support in the traditional Averch-Johnson (A-J) model of public utility regulation. The A-J model shows

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[2] Table 1 reports total 1992 incentive program expenditures of $880 million. Estimates of all 1992 utility DSM expenditures range from $1.3 billion to over $2 billion. Chamberlin and Faruqui [1991] estimate total 1990 DSM expenditures at $2 billion. Prete, Gordon and Bromley [1992] and Hirst [1992] estimate 1990 DSM expenditures at $1.2 billion, with an expected growth rate of 5% per year.

[3] In 1990, investor-owned electric utilities spent about $25 billion for plant acquisition (Energy Information Administration, 1992), so 1992 expenditures on conservation incentive programs are likely to be less than about five percent of plant acquisition costs. The average conservation expenditure in Table 1 is projected to be 6.5 percent of utility revenues for 1992. The highest is almost 20 percent.

that rate of return regulation rewards asset-building (the rate base) when the utility's allowed rate of return exceeds its cost of capital. The utility is not rewarded for minimizing cost or for maximizing the benefits of the regulated service to the customer. Traditional regulation would not allow a utility to include investments in conservation in its rate base. Conservation would make the utility worse off by reducing sales and consequently limiting the investment in generation upon which the utility could earn a return.

Moskovitz [1989] offers another view of regulatory disincentives for investments in conservation. He focuses on the tendency of regulation to set prices (rather than rate of return) which are fixed in the short run and typically exceed the utility's marginal cost of service. As a result, the utility in the short run has a financial incentive to increase production because each kilowatt-hour has a positive contribution to profit. Conservation would cause the utility to sell less and give up its profit on each lost kilowatt-hour.[4] Thus, for Moskovitz and many others, conservation is both an opportunity for profitable investments, and an opportunity that is systematically under-rewarded by the regulatory process.

Not surprisingly, there are differences of opinion on both counts. Many economists, schooled in the principle of the rational consumer, have resisted claims that consumers overlook financially attractive opportunities for more efficient energy use (e.g. Sutherland, 1991). Some argue that conservation advocates have ignored significant components of the costs of conservation alternatives (Ruff, 1988, 1992), and that conservation alternatives have not performed as well in the field as they have been advertised to on paper (Joskow and Marron, 1991). As for regulatory disincentives for energy conservation, Ruff [1992] and others have argued that energy conservation does not warrant regulation, and that ample incentives exist to provide conservation services in non-regulated markets. High electricity prices provide consumers with a strong incentive to save on their energy purchases (Gilbert and Henly, 1991), which counters Moskovitz' claim that utilities have an inadequate incentive to offer conservation services.

Assertions by both sides of the conservation debate obscure the fundamental fact that end-use efficiency embraces a wide range of activities with vastly different market characteristics. Consumers may be able to evaluate the costs and benefits of some conservation activities (e.g. the choice of a new appliance when the operating costs of the appliance are clearly labelled).

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[4] This is known as the "lost-revenue" problem and is addressed for all but one of the utilities in Table 2.

In other circumstances, consumers might have highly imperfect information about the potential for energy savings, and could benefit from intervention by an informed regulator. An example is education programs about the net savings from insulation. Imperfect information about the net benefits of conservation investments may lead landlords to under-invest in these activities because they would not be fully capitalized in rents or in the market value of the property (Dubin, 1992 reviews evidence of under-capitalization). Even in circumstances where the value of energy conservation is known, consumers may under-invest because they are constrained in their ability to borrow or because there are economies of scale in the provision of conservation that can be exploited by a regulated provider. For example, Quigley [1991] finds that pilot light management programs are highly cost-effective. The local gas utility can offer such a program and spread the cost over a significant population, whereas individual consumers may encounter "set-up" costs in managing their own pilot lights.

The purpose of this paper is not to analyze the validity of perceptions about the benefits of conservation programs, nor is the purpose to analyze causes of market failure. Instead, the focus is to compare the incentive mechanisms in place and to evaluate them as a case study of optimal incentive design. Much of the debate over the benefits and costs of conservation incentives fails to recognize that there is no "standard" conservation opportunity and that individual conservation programs have shown a wide range of benefit-cost ratios (Quigley, 1991 and Train, 1987, 1988). The goal of regulation should be to identify those opportunities (if any) where the expected benefits from conservation incentives exceed the social costs and to exclude other investments that fail to meet this standard. In this paper, we review the conservation programs that are in place and describe the elements that should be included in incentive programs to reach this goal.

The incentive mechanisms in Table 1 differ in their economics, their form, and their magnitude, although in section II we show that most can be characterized as one of three basic types. The most common of these types, shared savings (which gives shareholders a fraction of net benefits), is defined in many ways. Section III provides an economic definition of net benefits and reviews some frequently overlooked (and sometimes double counted) elements of conservation costs and benefits. Section IV reviews economic determinants of efficient conservation incentives and contrasts these efficient schemes with some currently implemented mechanisms.

## II. A Classification of Current Incentive Mechanisms: Mark-up, Bonus and Shared Savings

An incentive mechanism consists of a rule for determining the size of the incentive payment and a procedure for recovering this payment together with utility expenditures (including customer rebates). All of the programs summarized in Table 1 allow for recovery of expenditures in addition to incentive payments, either by directly expensing utility expenditures or by including expenditures in the utility rate base. Recovery mechanisms can be quite complex.[5] This paper will ignore them, thereby simplifying and clarifying the task of classification.

Most of the incentive mechanisms currently in place can be classified as one of three basic types: traditionally referred to as "mark-up", "bonus" (also known as a "bounty"), and "shared-savings." They differ in the coupling of incentives to program costs ($G$) and to the quantity of energy saved ($Q$).[6] We use the term program costs to indicate costs as they are calculated by the sponsoring utility. These will typically differ from social costs, which are the opportunity cost of resources that are involved in the program. Program costs may include transfers from one group of ratepayers to another, or other categories that are not true opportunity costs. Program costs may differ from utility expenditures. The latter are the pecuniary expenditures incurred by the utility, while the former may include items such as consumer expenditures on the DSM programs.

Mark-up incentives reward the utility with a fraction of the cost of the conservation program. Bounty incentives pay the utility in proportion to the energy saved. In a shared savings incentive mechanism, the utility earns a fraction of the difference between the value of the energy saved and the cost of the conservation program. Many programs employ one or more linear incentive schemes over different regions of expected energy savings. These are defined as follows:

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[5] To the extent that the allowed return on the rate base exceeds a utility's cost of capital, including conservation expenditures the utility's rate base provides a mark-up incentive in addition to other incentives explicitly provided by the program.

[6] Energy savings should be thought of as including capacity savings as well.

Mark-up: $I = \lambda \cdot G - \Phi, \quad G < \bar{G}, \; I < \bar{I}$

Bonus: $I = \lambda \cdot Q - \Phi, \quad G < \bar{G}, \; I < \bar{I}$

Shared Savings: $I = \lambda \cdot (a \cdot Q - G) - \Phi, \quad G < \bar{G}, \; I < \bar{I},$

where $a$ is the per-unit value of energy and capacity saved (usually the avoided cost of energy and capacity), $\lambda$, $\Phi$, $\bar{G}$ and $\bar{I}$ are program parameters, and $I$ is the incentive payment. The fixed payment, $\Phi$ in each of the three mechanisms has the property of decoupling the strength of the incentive, which is determined by $\lambda$, from the size of the incentive payment. In particular, a positive $\Phi$ can produce negative incentive payments in what is generally called a "penalty region."

Tables 2-A and 2-B summarize the incentive mechanisms of thirteen specific programs chosen on the basis of size, interest, and data availability. Tables 2-A,B give the incentive formula by specifying the type of incentive and three parameters: $\lambda$, the fraction of the incentivised quantity paid as an incentive, $\phi$, the fixed charge, and $\bar{I}$, the cap on the incentive payment.[7] Some of the programs are actually composed of several sub-programs. These sub-programs are aggregated in Tables 2-A,B under the simplifying assumption that performance is similar in each sub-program. All but three of the mechanisms reported in Tables 2-A,B fall into one of the three basic categories. These three (O&R, CMP and SCE) will be discussed shortly and are closely related to our three categories. Several of the programs have different linear incentives for different regions of net benefits and regulators in California have sponsored more than one style of incentive program at a single utility.

As has been mentioned, the lost-revenue problem penalizes utilities for selling less electricity when price is above the marginal cost of generation. This negative DSM incentive can be corrected with a general mechanism such as California's ERAM or with a mechanism that is aimed only at revenues lost through effective DSM, as is done with Western Massachusetts Electric. The only utility in our study that is not subject to either correction is Massachusetts Electric. Consequently it suffers a disincentive to DSM that should be added to the incentive reported in our tables. The form of this disincentive is a negative bonus mechanism since losses are proportional to energy saved. Since we do not know the magnitude of this disincentive we have not tried to combine it with the shared savings program that is explicitly implemented.

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[7] Some of the programs in Table 2-A do not have a cap on incentives, which is equivalent to $\bar{I}$ arbitrarily large.

**Table 2.A. Thirteen Incentive Mechanisms**

| All Programs | | Incentive Mechanism ($ million) | | | | |
|---|---|---|---|---|---|---|
| Utility | State | Mechanism | Region (Described in Terms of Net Benefit) | Incentive Cap[1] *I* | Share λ | Fixed Charge φ |
| PG&E, 1991 | CA | Shared Savings | $226 ≤ NB | $53.0 | 15% | 0 |
| | | | $151 ≤ NB < $226 | | 0% | 0 |
| | | | NB < $151 | | 15% | $15.0 |
| | | Mark-up | All Outcomes | $2.6 | 5% | 0 |
| SDG&E, 1990-91 | CA | Shared Savings | $12 ≤ NB | $5.0 Total | 33.5%[2] | 0 |
| | | | NB < $12 | | 40% | $4.80 |
| | | Bounty | All Outcomes | | 9% | 0 |
| | | Mark-up | All Outcomes | | 5% | 0 |
| SCE, 1990 | CA | Variable Bounty | $71 ≤ NB | $0.0 | 0% | 0[4] |
| | | | NB < $71 | | 17.6%[3] | $20.1[4] |
| | | Variable Mark-up | 75% ENB ≤ NB[5] | none | 5% | 0 |
| | | | NB < 75% ENB | | Variable | 0 |
| CHG&E, 1990-91 | NY | Shared Savings | All Outcomes | $.76 | 20% | 0 |
| NiMo, 1990-91 | NY | Shared Savings | All Outcomes | none | 10% | none |
| O&R, 1991 | NY | Shared Savings | $6 ≤ NB | $2.8 | 17.5%[6] | 0 |
| | | | NB < $6 | | 10% | $.62 |
| Mass Elec., 1992 | MA | Shared Savings[7] | $0 ≤ NB[8] | none | 6.7% | 0 |
| | | | NB < $0 | | 100% | 0 |
| WMECO, 1990 | MA | Bounty[9] | $16 ≤ NB | none | 3.6%[10] | $.58 |
| | | | NB < $16 | | 0% | 0 |
| CMP, 1991 | ME | Shared Savings with Mark-up[11] | $10 ≤ NB | $2.7 Total | 7.5% 7.5% | $.80 |
| | | | $0 ≤ NB < $10 | | 0% 7.5% | 0 |
| | | | NB < $0 | | 10% 7.5% | 0 |

**Table 2.B. Thirteen Incentive Mechanisms with Normalized Values**

| All Programs | | Incentive Mechanism ($ million) | | | | |
|---|---|---|---|---|---|---|
| Utility | State | Mechanism | Region (Described in Terms of Net Benefit) | Incentive Cap[1] $I$ | Share $\lambda$ | Fixed Charge $\phi$ |
| PG&E, 1991 | CA | Shared Savings | $32 ≤ NB | $7.4 | 15% | 0 |
| | | | $21 ≤ NB < $32 | | 0% | 0 |
| | | | NB < $21 | | 15% | $2.15 |
| | | Mark-up | All Outcomes | $0.4 | 5% | 0 |
| SDG&E, 1990-91 | CA | Shared Savings | $8 ≤ NB | $3.5 Total | 33.5%[2] | 0 |
| | | | NB < $8 | | 40% | $3.30 |
| | | Bounty | All Outcomes | | 9% | 0 |
| | | Mark-up | All Outcomes | | 5% | 0 |
| SCE, 1990 | CA | Variable Bounty | $10 ≤ NB | $0.0 | 0% | 0[4] |
| | | | NB < $10 | | 17.6%[3] | $2.91[4] |
| | | Variable Mark-up | 75% ENB ≤ NB[5] | none | 5% | 0 |
| | | | NB < 75% ENB | | Variable | 0 |
| CHG&E, 1990-91 | NY | Shared Savings | All Outcomes | $1.3 | 20% | 0 |
| NiMo, 1990-91 | NY | Shared Savings | All Outcomes | none | 10% | 0 |
| O&R, 1991 | NY | Shared Savings | $13 ≤ NB | $6.1 | 17.5%[6] | 0 |
| | | | NB < $13 | | 10% | $1.40 |
| Mass Elec., 1992 | MA | Shared Savings[7] | $0 ≤ NB[8] | none | 6.7% | 0 |
| | | | NB < $0 | | 100% | 0 |
| WMECO, 1990 | MA | Bounty[9] | $42 ≤ NB | none | 3.6%[10] | $1.5 |
| | | | NB < $42 | | 0% | 0 |
| CMP, 1991 | ME | Shared Savings, with Mark-Up[11] | $11 ≤ NB | $3.0 Total | 7.5% 7.5% | $0.90 |
| | | | $0 ≤ NB < $11 | | 0% 7.5% | 0 |
| | | | NB < $0 | | 10% 7.5% | 0 |

## NOTES FOR TABLES 2.A AND 2.B

Abreviations: PG&E is Pacific Gas and Electric. SDG&E is San Diego Gas and Electric. SCE is Southern California Edison. CHG&E is Central Hudson Gas and Electric. NiMo is Niagra Mohawk Power Corperation. O&R is Orange and Rockland Utilities Inc. Mass Elec. is Massachusetts Electric. WMECO Western Massachusetts Electric Company. CMP is Central Maine Power.

1. All programs also have expenditure caps.
2. The high share value is compensated for by an artificially low value for avoided cost. See text for explanation.
3. Share value derived holding program costs fixed. The tax mark-up factor was excluded for analytical simplicity.
4. Fixed Charge calculated with the assumption that rate of return is equal to the utility's cost of capital.
5. Expected Net Benefits (ENB) and Net Benefits (NB) based on number of units installed.
6. Incentive can range from an upward adjustment of ROE of 90 basis points to a downward adjustment of 20 basis points. A change in 1 basis point equals approximately a $30,800 change in ROE. The exact amount of incentive depends on the combination of energy and resource savings achieved. According to Barakat and Chamberlin, the maximum potential incentive is 17.5% of net resource savings.
7. Massachusetts Electric Company is the only utility in this table that does not provide a "lost-revenue recovery" mechanism. Consequently there is an implicit bounty mechanism being subtracted from the explicit shared-savings mechanism reported here. We are currently unable to determine the strength of this negative incentive component.
8. The incentives vary slightly from those listed here in the neighborhood of NB = 0, but the differences are slight enough that they do not significantly alter the structure of the incentive.
9. Net benefit for this bounty program is calculated as the difference between the avoided cost value of threshold energy and capacity savings and program expenditures. If the utility does not achieve the threshold savings levels, it is not eligible to earn an incentive.
10. The marginal share ($\lambda$) is determined by the corresponding increase in the incentive given a one dollar increase in avoided costs.
11. While explicitly a shared savings program, CMP is allowed to collect 2% above the cost of capital while recovering program expenditures over a ten year period. This results in the 7.5% mark-up charge that is shown after the shared savings $\lambda$.

There is considerable variation among utilities in the types of incentive programs and in the program parameters. Section IV examines some theoretical reasons to favor one type of incentive scheme over another. Some of the differences in program parameters can be explained by the different opportunities for conservation in different utility systems. A rough index of opportunities is the size of the utility. Table 2-B presents the information in Table 2-A normalized to a 10 TWh/yr utility. This reduces, but hardly eliminates, the variation in incentive programs.[8]

The shared savings mechanism rewards the utility based on the difference between the avoided cost of saved energy and the program costs, $(a \cdot Q - G)$, which is often referred to as the program net benefit (*NB*). Shared savings has an obvious advantage relative to the other two programs, which fail to account for either the cost or the benefit side of the conservation equation. Yet both bonus and mark-up mechanisms are encountered in the regulatory arena. As an example, PG&E is allowed a mark-up on two types of DSM programs (CPUC, 1990): (i) equity programs that are designed to improve the energy efficiency of poor households at little or no cost to the customer, and (ii) energy-management service programs which are typically informational in nature. Reasons given for using a markup with these programs are that energy savings in these programs are difficult to measure and that they often produce a negative net program benefit.[9]

The 1991 shared-savings mechanism of PG&E is an example of a nonlinear mechanism. The incentive payment jumps upward from zero to about $34 million when net savings reach 75% of "expected net benefits" (ENB). There is no incentive payment between 50% and 75% of *ENB*, and below 50% of *ENB* PG&E must pay a penalty equal to .15*(*NB* - .5**ENB*). As is shown in Table 2, the "normal" region supports a shared savings formula with $\Phi = 0$, while the "penalty" region has the same $\lambda$ but a positive $\Phi$. In the middle, "dead band", region, the incentive mechanism vanishes. The mechanism is clearly designed to encourage the utility to achieve at least 75% of *ENB*.[10]

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[8] Data presented in Section III suggest a lower variation among programs in actual expenditures on conservation.

[9] See PG&E Annual DSM Summary (1992). Presumably, there is an expectation that societal benefits would be positive despite negative program benefits.

[10] Experience with expenditures on conservation incentive programs shows that it is far more likely to find the utility in the normal region than in the dead-band or penalty region.

In the 1990-91 San Diego mechanism, incentives are calculated differently according to whether net benefits exceed or fall short of a "minimum performance target" (*MPT*). The mechanism can be expressed as

$$\begin{array}{ll} I = .135 \cdot NB + .2 \cdot (OTC - G/Q) \cdot Q & NB > MPT \\ I = .4 \cdot NB - .4 \cdot MPT & NB < MPT \end{array}$$

For *NB* < *MPT*, the mechanism is a standard shared savings formula. For *NB* > *MPT* the incentive appears to be more complex. The first component is a standard shared savings incentive. This is augmented by the second component, which rewards the firm for achieving an average cost of conservation that is less than an "original target cost" (*OTC*).[11] This equation can be rewritten as

$$I = .335 \cdot (\hat{a} \cdot Q - G)$$

$$\text{where } \hat{a} = \left( \frac{13.5a + 20 \cdot OTC}{33.5} \right)$$

This is a shared savings formula, but with an unusual value for the avoided cost. The value used is a weighted average of the avoided cost and the "original target cost," with the weights chosen to favor the *OTC*. The incentive scheme relies on a best estimate of San Diego's avoided cost equal to about 4.5 cents/kWh. The OTC depends on the program and ranges from about 0.4 cent/kWh to 5.4 cents/Kwh. In summary, this mechanism collapses to a shared savings formula, except that conserved energy is, in most cases, compensated at an atypically low rate.[12]

Three of the utility incentive programs in Tables 2-A,B that include non-zero fixed charges employ a formula for this charge that scales it to the size of the program. However, conditional on the program size, the charge is independent of program implementation and outcome, and thus is a fixed component of the incentive plan.

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[11] SDG&E calculates the second component of this formula using first year energy savings. However, using lifetime savings in lieu of first year savings yields identical results. Here we apply lifetime savings in both components of the incentive formula for analytical simplicity.

[12] $\hat{a}$ is approximately 2.5 cents/Kwh for all but one of the four programs included under this mechanism.

## A. Exceptions to the Classification

Orange and Rockland (O&R) provides the first example of a mechanism that does not fit within our classification scheme. Its 1991 incentive formula takes the following form:

$$\begin{aligned} I &= \lambda_1 \cdot Q \cdot (a \cdot Q - G) && \text{if } Q > Q_{40} \\ I &= \lambda_2 \cdot (Q - Q_{40}) && \text{if } Q \le Q_{40} \end{aligned}$$

The incentive function is discontinuous at $Q_{40}$, which is 40% of its energy savings goal. For savings below this level, the mechanism is a pure "bonus" scheme, although the payment is negative. For higher values of savings, the incentive is a hybrid bonus/shared-savings formula. In this region the incentive is proportional to the product of net benefit and saved energy. Since the first term in net benefit is itself saved energy, the incentive depends on the square of saved energy. Consequently the incentive function is nonlinear and becomes steeper as energy savings increases. Since it is steepness that provides motivation, motivation also increases with energy saved. It is not clear that this is desirable, but it *is* different.

Central Maine Power (CMP) provides a second exception to our classification. Its 1991 incentive formula takes the form:

$$\begin{aligned} I &= \lambda \cdot (NB - .8 \cdot NB_{90}) + 0.075 \cdot G && \text{if } NB > .8 \cdot NB_{90} \\ I &= 0.075 \cdot G && \text{if } 0 < NB < .8 \cdot NB_{90} \\ I &= 0.1 \cdot NB + 0.075 \cdot G && \text{if } NB < 0 \end{aligned}$$

where $\lambda = .5\left(1 - \frac{\text{utility expenditure}}{2 \cdot \text{gross benefit}}\right)$ and $NB_{90}$ = net benefits from the 1990 program. As in the previous three cases, this has a penalty region that uses a plain shared savings formula. Unlike the last two cases, in this case only the slope, and not the function itself is discontinuous. Also, $\Phi$ is given a positive value in the normal region and a zero value in the penalty region.

CMP's mechanism does not fit our classification both because it mixes shared savings and mark-up,[13] and because the rate of shared savings is variable.

The 1990 Southern California Edison incentive plan provides a third exception to our classification. When reduced to it simplest form, its incentive essentially works as follows:

$$\begin{aligned} I &= 0 && Q \geq .75\,\bar{Q} \\ I &= (\lambda_1 \cdot Q - \lambda_2) \cdot G, && Q < .75\,\bar{Q} \end{aligned}$$

where $Q$ is energy saved and $G$ is program expenditure. A notable feature of this incentive is that it's maximum is zero, which is paid whenever savings is at least 75% of the target level. Although an incentive with no up-side is unusual, this feature does not violate our classification scheme. The violation is that the incentive is partly based on the product of savings and costs.[14]

## III. Accounting for Conservation Costs and Benefits

Net benefit, properly defined, is the social value of energy conservation. All projects with a positive net benefit should be funded, and those whose net benefit is negative should be avoided.[15] However, the correct definition of net benefits includes many components that are often omitted from incentive mechanisms or improperly included, and all aspects pose difficult measurement problems.

The benefit of conservation is the value of the energy saved. The social costs of conservation programs are the costs borne by program participants, the utility, regulators, and

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[13] CMP's mechanism is an example of utilizing its cost-recovery provision to provide extra incentive. This is done by allowing CMP to earn a rate of return 2% above its cost of capital as it recover's its program expenditures over a ten year period. The value of 7.5% assumes that program expenditures are recovered through straight-line depreciation and that the cost of capital is 11%.

[14] The Edison program allows the company to include its expenditures in the company's rate base, which may provide a positive incentive if the allowed rate of return exceeds the cost of capital and if the company achieves a sufficiently high percentage of its target savings.

[15] Meaning that if net benefit is positive, with appropriate transfer payments all parties could be made better off.

non-participant customers. These costs include actual utility and consumer expenditures on equipment, material, and labor time. Social costs also include managerial effort, consumer disutility associated with the use of energy-efficient technologies, the costs of program administration, and possible negative consequences from higher prices resulting from conservation programs. These are potentially significant categories of social cost, but they are difficult to quantify. Payments from the utility to program participants (or, more accurately, from non-participant ratepayers to program participants), are relatively easy to quantify, but have complex implications for social cost. As pure transfers from one group to another, they do not shrink the economic "pie" of available resources and therefore are not true social costs. However, these transfers tend to be associated with social costs because they may have adverse distributional consequences and they may impair economic efficiency through secondary impacts on utility rates.[16]

## A. Costs

Table 3 summarizes, on a normalized basis, the elements of costs that are included in the programs listed in Tables 2-A,B. The cost categories in Table 3 are utility expenditures, utility transfers to consumers, customer costs, and evaluation costs. Each of these cost categories, and their relevance to social costs, is described in more detail below. In addition, this section examines how various conservation programs have accounted for some of the more elusive categories of social costs, specifically customer disutility and impacts on non-participating customers.

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[16] Transfers have to be paid for by increasing rates, which may increase the gap between price and marginal cost. When price exceeds the (social) marginal cost of energy, consumption is inappropriately penalized.

**Table 3. Program Expenditures and Definitions of Net Benefit**

| All Programs | | | Included in Net Benefit?* | | | |
|---|---|---|---|---|---|---|
| Utility | Program | Normalized Utility Expenditure ($ million) | Utility Transfers to Customers | Customer Costs | Evaluation Costs | When Measured |
| PG&E | Shared Savings | $9.98 | Yes | No | No | Ex Ante |
| | Mark-up | $7.70 | NA | NA | NA | NA |
| SDG&E | Shared Savings | $12.44 | No | Yes | No | Ex Ante |
| | Bounty† | $0.39 | No | Yes | No | NYA |
| | Mark-up† | $3.19 | No | Yes | No | NYA |
| SCE | Variable Bounty† | $8.54 | Yes | No | No | Ex Ante |
| | Variable Mark-up† | $4.43 | Yes | No | NYA | NYA |
| CHG&E | Shared Savings | $19.28 | Yes | No | Yes | Ex Post |
| NiMo | Shared Savings | $14.46 | No | Yes | Yes | Ex Post |
| O&R | Shared Savings | $20.43 | Yes | No | Yes | Ex Ante |
| Mass. Elec. | Shared Savings | $49.20 | No | Yes | Yes | Ex Post |
| WMECo. | Bounty† | $40.21 | No | Yes | Yes | Ex Post |
| CMP | Shared Savings | $20.94 | No | Yes | Yes | Ex Post |

* Note that net benefit always includes avoided cost and direct program expenditures, but may or may not include the three items examined here: transfers, unreimbursed customer costs, and program evaluation costs.

† Many utilities compute net benefit even though it is not used as part of the incentive calculation.

*Utility Expenditures*

Utility expenditures are the total costs incurred by the utility in connection with a conservation program. These include all expenditures for the acquisition of conservation equipment, associated material and labor expenses, payments to consumers, and costs associated with program management and evaluation. Utility expenditures may *include* some items, such as transfer payments to consumers, that are not true social costs, and may *exclude* other items, such as unreimbursed costs incurred by customers, that are true social costs.[17]

The third column in Table 3 shows actual (normalized) program expenditures.[18] All of the programs in Tables 2-A,B allow the utility to recover its expenditures, either by expensing or by including the expenditure in the rate base.[19] Actual program expenditures range from about $10 to $50 million on a normalized basis. Corrected for size, the most aggressive programs are the Massachusetts shared savings and bounty incentives. Aggregating all incentive programs for each utility in Table 3, they fall in a relatively narrow expenditure range of $13 to $21 million for all but the Massachusetts programs.

*Transfer Payments and Customer Costs*

Table 3 shows considerable variation in the way that conservation programs account for transfer payments between the utility and participating customers in evaluating net benefits. Three of the seven shared-savings programs in Table 3 include utility transfer payments when computing net benefits. This practice *understates* the actual net benefits of a conservation program. PG&E, Orange & Rockland and Central Hudson Gas & Electric include utility transfers in net benefits, but exclude customer costs. Excluding customer costs clearly *overstates* program net benefits, which may or may not be compensated by the error

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[17] To the extent that transfer payments contribute to pricing distortions, the adverse effects of these distortions, but not the transfer payment, should be counted as a social cost of the conservation program. Similarly, a separate account could be made of the distributive costs of transfer payments. Transfer payments may be a proxy, however, for unobservable customer costs that should be included in a net benefit calculation.

[18] Tables 2-A,B describe the incentive mechanisms, whereas the data in Table 3 are based on actual annual expenditures.

[19] The programs differ on the timing of recovery, but include allowances for interest costs.

of including utility transfer payments. Four of the seven shared-savings programs exclude transfer payments and include customer costs in the evaluation of net benefits.

Although transfer payments are a reallocation of rates from one consumer group to another rather than a resource cost, they may serve as a proxy for customer costs that are difficult to measure and often excluded from an evaluation of conservation net benefits. This is discussed in more detail under "customer disutility" below.

### *Administrative Costs*

Program evaluation is the main component of the regulatory cost of designing and monitoring conservation incentive programs. Evaluation costs are largely irrelevant to decisions about programs that have already been funded, as these are sunk costs. The main function of evaluation is to determine the desirability of subsequent DSM activities and to reward utilities for conservation activities that produce positive net benefits. About half of the utility programs listed in Table 3 include evaluation costs in the measure of net benefits. The programs in Table 3 are also split about evenly on whether program evaluation is *ex ante* or *ex post*. Issues associated with program evaluation are discussed in more detail below in the measurement of program benefits.

### *Customer Disutility*

A cost that is omitted from the incentive programs in Tables 2-A,B is the non-financial cost that consumers might incur from conservation activities -- consumer "disutility" from conservation. An example is dissatisfaction with the quality of light from a compact fluorescent bulb. To the extent that consumers incur persistent disutility from conservation, these costs properly should be deducted from the net benefits of these programs. Consumer disutility from energy conservation tends to be ignored in the evaluation of conservation programs, but one (extreme) view is that customer disutility must be large, otherwise efficient conservation would have been undertaken. According to this perspective, the net benefits of conservation should be reduced by an amount approximately equal to the pecuniary savings from these programs, because the consumer's hidden cost (disutility) must be at least that large to explain the consumer's failure to adopt the conservation technology. Another (extreme) view is that consumer disutility is small and that consumers' failure to conserve is based on easily corrected information. This view treats consumer disutility as a one-time hurdle that, once crossed, does not affect future conservation benefits, and has only an insignificant effect on the total present value of net benefits. Which side is closer to the truth often depends on the extent and depth of the conservation measures. As utilities attempt to induce increasing levels of conservation over a longer period of time, this variable is likely to assume greater importance to the evaluation of these programs.

Customer disutility is difficult to measure and consequently is normally assumed to be zero. Sometimes an attempt is made to specify measures for which disutility will be zero, for instance the purchase of a more efficient refrigerator (provided it comes in the same style and colors as other less efficient models, and is not inferior in any other respects), but once the decision is made to ignore this factor a blind eye is often turned on the question. For instance, in a recent study of supply-side measures completed by Lawrence Berkeley Laboratories, such measures as switching from electric to gas cooking, low-flow shower heads, and compact fluorescent lights were all assumed, without investigation or discussion, to have zero disutility to the customer (LBL, 1991).

Customer disutility from participation in conservation activities is a potential reason to include transfer payments in the calculation of net benefits. The minimum transfer payment needed to induce program participation is an estimate of a customer's disutility from conservation. The minimum transfer payment should be counted as a cost of the program unless one believes that consumer disutility is temporary and will not have a significant bearing on future program benefits. Of course an accurate estimate of the minimum required transfer payment is difficult to obtain. Moreover, some of the programs reviewed provide for substantial transfers that appear to be aimed more at raising consumer awareness (a one-time hurdle) than at overcoming consumer costs from participating in conservation programs.

### *Non-Participant Costs*

Conservation lowers system revenue requirements if the cost per kWh of conserved energy, $C$, is less than the system's incremental avoided cost of generation, $a$. When this condition is satisfied, ratepayers as a whole are better off when the utility invests in reducing demand rather than increasing supply.[20] However, a reduction in revenue requirements does not imply a reduction in electricity rates. Under rate of return regulation, rates correspond to the utility's average production cost. Each kWh saved by conservation reduces system costs by the utility's avoided cost of generation, $a$. The reduction in average cost, and hence the average system rate, is $a/q$ where $q$ is total sales. However, conservation also reduces the total demand available to recover the utility's costs. For each kWh saved, the system average cost, and hence the average system rate, has to increase by $P/q$ to compensate for the reduction in sales. The net effect is that for each kWh saved by conservation, rates have to increase by $(P - a)/q$ to compensate for the smaller demand base.[21] System average rates will increase with conservation unless the cost per conserved kWh is less than the avoided cost of generation by an amount that is large enough to compensate for lost revenues. Specifically, if $C$ is the per kWh cost of conservation and $a$ is the system avoided cost, conservation would lower system revenue requirements if $C < a$, but would increase rates if $C > a - P$. The avoided cost of generation is less than the average system price for most utilities with excess capacity ($a - P$ is negative), so conservation will increase rates for these utilities, even if ratepayers as a whole are better off. Conservation is likely to result in lower rates only for systems that have to add very expensive capacity to meet new demand.[22]

When conservation results in higher rates, the consumers that participate in conservation programs are better off at the expense of non-participants. Unless program participants compensate the non-participants for the higher rates, there is a subsidy from the latter to the former.[23] Although the participants could be required to compensate the non-participants, this rarely occurs.[24] Instead, conservation programs are frequently

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[20] This assumes that any consumer disutility from energy conservation is included in its cost.

[21] For an alternative derivation, let $AC$ be the system average cost and $MC$ the system marginal cost, both a function of sales, $q$. A reduction in sales of one kWh increases average cost by $(AC - MC)/q$. Under rate regulation, $AC$ is approximately $P$, the average system rate, and $MC$ corresponds to the utility's avoided cost, $a$.

[22] For example, if the system's average rate is 9 cents/kWh, and if conservation costs 3 cents/kWh, new generation would have to cost more than 12 cents/kWh for conservation not to increase rates.

[23] Investment in new generation facilities also raises distributional issues. If a utility has to build costly facilities to meet new demand, the cost is typically shared by all ratepayers. However, unlike expenditures on demand-side management, consumers pay for generation facilities in approximate proportion to the amount that they use these facilities.

[24] If a conservation program produces positive net benefits, the participants should be able to compensate non-participants in a way that leaves both groups better off.

implemented with transfer payments to induce customer participation. The transfers further increase the rates that non-participants have to pay.

In addition to the distributional impacts of conservation programs, the effects of these programs on rates can have adverse consequences for economic efficiency. When the average cost of electricity exceeds its marginal cost, a further increase in average cost tends to distort prices in the direction of encouraging too little consumption. Higher rates lead customers to reduce demand, and in some cases cause customers to bypass the regulated service. This has been a particularly important problem in the past decade, when a surplus of capacity led to electricity prices that were several times marginal generation cost in some jurisdictions.

## B. Benefits

Benefits of conservation consist of reduced costs of generation, both direct pecuniary costs and associated externalities. Both of these benefits depend on the reduction of electricity consumption. These benefits are complicated by uncertainties about the value of conserved energy, difficulties in estimation, and when and how to measure conservation: *ex post* or *ex ante*.

### *Value of Conserved Energy*

All of the conservation programs in Tables 2-A,B use avoided cost as the measure of the value of conservation, although they differ in the treatment of external costs (environmental adders). Savings include both energy and capacity. Table 4A lists the avoided costs of energy and capacity for the selected programs. The values appear generally consistent with the (correct) measure of marginal, rather than average, energy and capacity cost. The most important difference in the value of conserved energy for different utilities is the inclusion or exclusion of an adder for environmental externalities, and size of the adder. Environmental externalities are accounted for only in New York, at a rate of \$0.014-\$0.016/kWh, and in Massachusetts, at \$0.04/Kwh.[25]

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[25] California is in the process of considering environmental adders for avoided costs (CPUC, 1992).

The value of conserved energy is complicated further by uncertainty in the duration of conservation savings. All of the shared-savings and bounty programs give credit for both energy and capacity savings (mark-up programs are based only on cost). Future energy and capacity savings are discounted, with one exception. Orange and Rockland is only paid an incentive on its first year of energy savings.

Table 4A shows estimates of conserved energy and capacity from the shared-savings and bounty programs for each of the utilities. These are *ex ante* technical estimates of the savings that are expected from the equipment that was actually installed in 1991. Also shown in Table 4A is an estimate of the present discounted avoided cost from these 1991 installations. As can be expected, there is considerable variation in the expected savings from the different utility programs. Table 4B shows the estimated savings on a normalized basis. The variance is greatly reduced, but there is still about a four to one range in savings estimates excluding environmental adders. The range increases with environmental adders, mostly due to the Massachusetts utilities' high estimate of expected savings and high environmental externality.

Table 5 is a summary of the expected net benefits of programs in place in 1991 and the actual incentive payments that have been earned on these programs, all reported on a normalized basis. The data show a somewhat wider range of expected net benefits than the range of normalized costs reported in Table 4B. Actual incentive payments also show a wide variation. Expressed as a percentage of expected net benefits, the incentive payments range from less than two percent to about thirteen percent, with an average of about six percent.

**Table 4.A. Cost and Savings**

| Shared Savings and Bounty Programs | | Avoided Costs in 1992 | | | | | Lifetime Savings (1991 Programs) | | Total PDV Avoided Costs ($ M) |
|---|---|---|---|---|---|---|---|---|---|
| | | $/kWh | | | | $/kW-yr | | | |
| Utility | Mechanism | On Peak | Off peak | Env. Adder | Avg. Total | Capacity | GWh | MW-yr | |
| PG&E | Shared Savings | .035 | .030 | .000 | .032 | 42.12 | 7,241 | 1,453.0 | 426.5 |
| SDG&E | Shared Savings | .040 | .030 | .000 | .033 | 81.54 | 985 | 17.2 | 48.2 |
| | Bounty | .040 | .030 | .000 | .033 | 81.54 | 137 | 3.2 | 1.3 |
| SCE | Variable Bounty | .041 | .031 | .000 | .034 | 96.90 | 2,664 | 1306.7 | 183.4 |
| CHG&E | Shared Savings | .048 | .048 | .015 | .063 | 26.28 | 376[26] | 35.5 | 23.4 |
| NiMo | Shared Savings | NA | NA | .016 | .050 | 0.00 | 2,000[27] | NA | 100.0 |
| O&R | Shared Savings | .027 | .027 | .014 | .041 | 16.64 | NYA | NYA | NYA |
| Mass. E. | Shared Savings | NA | NA | .040 | .091 | 31.32 | 1,573 | 654.7 | 130.4 |
| WMECo. | Bounty | NA | NA | .040 | .092 | 41.48 | 708 | 228.9 | 6.71 |
| CMP | Shared Savings | .046 | .023 | .000 | .030 | 69.26 | 409 | 8.0 | 32.0 |

NA = Not Available NYA = Not Yet Available

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[26] Based on 37.6 GWh reported annual energy savings over a ten year program lifetime.

[27] Based on 200 GWh average annual savings over an assumed average ten year program lifetime.

**Table 4.B. Total Savings: Normalized***

| Shared Savings & Bounty Programs | | Normalized Total Savings | | Normalized Total $ Avoided Cost | |
|---|---|---|---|---|---|
| Utility | Mechanism | GWh | MW | Environmental Adder Included ($ million) | Environmental Adder Excluded ($ million) |
| PG&E | Shared Savings | 1,030 | 206 | 62.09 | 62.09 |
| SDG&E | Shared Savings | 684 | 12 | 33.33 | 33.33 |
| | Bounty | 95 | 2 | .88 | .88 |
| SCE | Variable Bounty | 386 | 189 | 26.54 | 26.54 |
| CHG&E | Shared Savings | 671 | 63 | 41.79 | 31.75 |
| NiMo | Shared Savings | 579 | 0 | 30.77 | 21.11 |
| O&R | Shared Savings | NYA | NYA | NYA | NYA |
| Mass. Elec. | Shared Savings | 1,014 | 422 | 83.13 | 55.85 |
| WMECo. | Bounty | 1,863 | 602 | 176.54 | 123.13 |
| CMP | Shared Savings | 449 | 9 | 35.20 | 35.20 |

* Normalization adjusts for variations in utility size measured in TWh/year.

NYA = Not Yet Available

### *Measurement of Energy Savings*

Measurement is perhaps the single most difficult problem encountered in conservation initiatives. The inability to verify energy savings is a main reason for the perceived failure of markets to provide adequate investment in conservation. If savings were verifiable, private energy service companies could write contracts with consumers to provide conservation services, and could be paid based on the savings that would result. This failure of the market does not lead to the conclusion that utilities can fill the void as providers of conservation services. Without a means to verify the results of utility conservation activities, the ability of regulators to encourage beneficial conservation and discourage uneconomic conservation expenditures is so severely constrained that efforts in this area may be without discernible benefit to ratepayers.

*Ex ante* measurement relies on engineering estimates of savings from installed conservation technologies. *Ex post* measurement is the alternative to the *ex ante* approach, and by definition entails measurement of energy use by customers after the implementation of demand-side measures. *Ex ante* cost estimates typical reflect an assessment that *ex post* measurement is too costly, although even *ex ante* measurement can be quite expensive since it involves significant calibration studies. The future of conservation incentive schemes is likely to depend on the development of means to obtain unbiased estimates of program savings at a reasonable cost. It is not essential that estimates of individual program savings be highly accurate, as repeated estimates of many programs would provide an acceptable margin of error.

Unfortunately, the benefits and costs of past conservation programs may bear little relation to the performance of future programs. Without a reliable connection between measures of past performance and expectations of future savings, regulators may be without any useful estimate to apply to future incentive programs. Moreover, because technology advocates, consultants, industry, and regulators have private interests in the outcomes of conservation programs, it is essential that measurement techniques guard against distortions in the evaluation of program benefits. Joskow and Marron [1991] report large differences between *ex ante* estimates of

**Table 5. Normalized Incentives**

| Shared Savings and Bounty Programs | | Net Benefits | Incentive | Incentive per $ Saved* | |
|---|---|---|---|---|---|
| Utility | Mechanism | ($ million) | ($ million) | With Envir. Adder | Without Envir. Adder |
| PG&E | Shared Savings | 52.63 | 7.89 | .127 | .127 |
| SDG&E | Shared Savings | 24.47 | 3.36 | .101 | .101 |
| | Bounty | .89 | .08 | .090 | .090 |
| SCE | Variable Bounty | 17.95 | .71 | .026 | .026 |
| CHG&E | Shared Savings | 24.70 | 5.12 | .122 | .160 |
| NiMo | Shared Savings | 11.69 | 1.17 | .038 | .056 |
| O&R | Shared Savings | NYA | NYA | NYA | NYA |
| Mass. Elec. | Shared Savings | 43.90 | 1.41 | .017 | .025 |
| WMECo. | Bounty | 130.80 | 3.19 | .018 | .026 |
| CMP | Shared Savings | 14.26 | 1.07 | .030 | .030 |

* The Incentive Rate is computed as the Incentive payment divided by Total Savings.

NYA = Not Yet Available

the costs of conservation and *ex post* evaluations of actual program costs, with the latter generally much higher than the former.[28] This suggests a strong bias in *ex ante* estimates and that sole reliance on such estimates would be unwise.

*Ex post* measurement of program savings does not provide "actual savings," but simply another estimate, sometimes better and sometimes worse than that provided by the *ex ante* approach. Though *ex post* measurement may provide a preferable cost/accuracy trade-off, its primary importance lies in addressing the incentive problems of *ex ante* measurement, even if the measurement is quite noisy.

Estimates of energy savings from conservation programs are confounded by the complex interactions of conservation incentives and energy consumption behavior. These include "free-riders" and "rebound." Free-riders are consumers who participate in energy conservation programs, but would have made conservation expenditures in their absence. Rebound refers to an increase in consumption brought about by lower energy costs for consumers who have invested in efficient energy-using durables.

### *Free-Riders*

Transfer payments to free riders are no more of a cost than transfer payments to customers who are genuinely induced to conserve by the transfer. But it is important to exclude free-riders from the calculation of conserved energy because free-riders absorb program costs while producing no offsetting benefit. All of the utilities surveyed claim to account for the free-rider problem, although the estimation techniques generally used are inadequate. One of the principal methods of accounting for the free-rider problem in the programs we have reviewed is what Central Maine Power (CMP) terms the "quasi-experimental" savings measurement plan. Under this plan, a participant sample is compared with a non-participant sample. For members of each sample, pre- and post-program annual consumption is metered and the change is averaged. Net savings per participant is then defined to be the difference between these two averages. No participants are actually excluded as being free-riders. CMP claims that this procedure eliminates the need for consideration of 'free-rider' issues. This is incorrect as can be seen by considering the following pair of examples. Both refer to a population where half of the consumers are likely

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[28] See also Quigley [1991].

to adopt a conservation measure in any case, while the other half are much less likely to adopt voluntarily.

In the first example, suppose that the program attracts only the customers who would adopt the conservation measure in any case. As Joskow and Marron [1991] suggest, these free-riding customers are likely to have greater energy savings and be more attracted to conservation incentives. The CMP method will attribute most of the savings to the subsidy program, thereby greatly overestimating the effect of conservation incentives on the population as a whole.

In the second example, suppose that the program was run in such a way that it managed to exclude those who would adopt in the absence of a subsidy. In this case the CMP method would underestimate the effect of incentives on the entire population, as the non-participants are biased in favor of consumers who are more likely to adopt than the average population.

The "quasi-experimental" approach is unsatisfactory for a second reason, thoroughly discussed by Joskow and Marron [1991], which is the dynamic nature of the free-rider problem. As they point out, "free riding is properly conceptualized not as a simple static decision ..., but in terms of shifts in the diffusion curve." A participant who needed to be induced to adopt the measure this year might have adopted it voluntarily next year. In this case he is a free-rider for all but the first year.

Measurements of conservation savings, whether *ex post* or *ex ante*, must be compared with predictions of how customers would have behaved without the DSM programs, and thus must account for free-riders. Procedures other than the "quasi-experimental" approach for estimating free-ridership are often employed, but generally these are more *ad-hoc*, though possibly no less exact. Rigorous statistical procedures, such as used by Train [1987, 1988] and Train and Stebel [1987], are rarely employed.

### *Rebound*

Rebound refers to an increase in energy demand caused by programs that lower the cost of energy services through increased efficiency. For example, a more efficient air conditioner is likely to be more heavily used. While the free-rider problem risks assigning too much savings to energy conservation, the risk with regard to rebound is an underestimate of savings. Not accounting for rebound would tend to lower the measured benefits of conservation programs. Some might argue that this is appropriate because energy is not saved if there is rebound. However, this overlooks the fact that the relevant measure of value is net benefit to energy consumers. Because use of rebound energy is freely chosen, it represents an improvement of consumer welfare, and thus should be counted as an increase in net benefit from conservation. *Ex post* measurement of saved energy that is not corrected for the increase in customer utility that accompanies the rebound effect will necessarily and incorrectly count rebound as a decrease, rather than an increase in consumer benefit.[29]

## IV. The Design of Efficient Incentive Programs

This analysis assumes that a mechanism is optimal if it maximizes the expected welfare of the regulator, who counts equally both consumer welfare and producer profits[30] (including any managerial disutility of effort). Under this restriction, the economic value of a conservation project that saves an amount of energy $Q$ is

$$NB = a \cdot Q - C$$

where $C$ includes all social costs incurred by the utility, program participants, and non-participants.

The design of incentive programs would be relatively straightforward if it were not for the possibility that the utility has information, that is not shared by the regulator, about program costs and benefits. For example, the cost of a conservation program may depend on the level of effort expended by utility managers. Managers know how hard they must work to make the program succeed and therefore how much compensation they (or the firm's equity holders) might

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[29] An argument in favor of *ex ante* savings estimates is that they are not affected by rebound. This may be small compensation compared to the other biases encountered with *ex ante* savings estimates.

[30] An abundant literature, for example Lewis and Sappington [1988, 1989, 1991], shows how the regulator might wish to alter incentives if the regulator wants promote the welfare of one group (typically consumers) at the expense of another (producers), or if collecting revenues from consumers incurs a social cost. For DSM programs, the regulator may put different weights on participating and non-participating consumers, as well as on the regulated firm. We ignore these important complications and instead emphasize the more basic elements of efficient mechanism design.

require, but regulators do not possess comparable information. Similarly, managers may know better than regulators how effective a conservation program is in reducing demand. To simplify matters, we focus only on the asymmetry of information between the regulator and the regulated firm.

Let $\theta$ represent a characteristic of a conservation program that describes its cost effectiveness in reducing demand, and that is known privately by the utility. The quantity of energy saved is a function $Q = Q(C_u, E, \theta)$, where $C_u$ is the utility's observable cost and $E$ is the un-reimbursed disutility of managerial effort. Total social costs may be written as

$$C = C_u + C_c + E,$$

the sum of the observed utility cost, customer cost, and unobserved effort.

### A. Case 1: The Regulator has Verifiable Unbiased Estimates

In this first case, the regulator has accurate information about the expected value and costs of conservation programs, so that information problems are minimal. Specifically, the regulator has an unbiased and publicly verifiable estimate of $C$, which includes all managerial and administrative costs, and of the value of energy savings, $a \cdot Q$. A regulator whose objective is to promote expected social welfare would desire any conservation program that has a positive expected net benefit. The regulated firm should want to pursue any program in which the firm is fully compensated for all of its costs, including managerial effort. Hence, if the regulator offers the utility a fraction, however small, of the (unbiased) estimate of program net benefits, the utility would have an incentive to engage in a DSM program, and the regulator would want the firm to do so, if and only if the program has a positive expected net benefit. Verification is important to ensure that a contract between the utility and the regulator is legally binding. Thus, with these conditions, we have

*Principle 1:* If a (risk neutral) regulator can obtain a verifiable unbiased estimate of net benefit, any shared savings incentive scheme is efficient, no matter how small the incentive.

This result and those that follow in this section are subject to an important qualification. The regulated firm should take into account the return it could earn in other activities, such as constructing new generation facilities, when choosing how much effort to allocate to DSM programs. For example, if the firm is rewarded meagerly in these other activities, a large reward for DSM programs might divert the firm's attention from other, more valuable, pursuits. The socially optimal incentive scheme should offer private incentives to the firm for each its alternative activities that are in proportion to the activity's contribution to social value.[31] This is a form of the problem of the second best, in which the optimal pricing of any one activity may depend on pricing distortions that are present in alternative activities.[32]

When the regulator has an unbiased, verifiable estimate of the social costs and benefits of conservation investments, a shared-savings program offers an exact correspondence (in expected value) between utility profits and social value, and only a modest sharing of net benefits is adequate to provide incentives to the utility to pursue socially productive conservation. In contrast, the incentives actually offered by the shared-savings programs reviewed in this paper are substantial. This suggests that either regulators are unconcerned about the distributional implications of large rewards for utility DSM programs, or, (more reasonably), they believe such rewards are necessary to compensate utilities for unobservable effort or other elements of program costs that are not known by the regulator. These considerations lead us to consider the structure of efficient incentive programs when the regulator's information is more limited. The next two cases examine separately the consequences for efficient incentive design when the regulator is imperfectly (and asymmetrically) informed about the conservation program's cost and energy savings. The last case considers the implications of non-verifiable estimates of program benefits.

## B. Case 2: The Utility Has Private Cost Information

In this case we assume that the regulator knows less about program costs than does the utility. Specifically, we assume the regulator is unsure about the effort required to make a program succeed. Since effort is a cost, we say that the utility has private cost information; in terms of our formal model, this implies that $E$ is privately known by the utility.

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[31] This qualification would not be necessary if the firm's cost of effort were properly estimated at its societal opportunity cost (meaning the societal returns that effort could generate in other activities).

[32] See Holmstrom and Milgrom [1991] for a discussion of optimal incentive design when an agent can choose to apply effort to one or more different activities.

The regulator's measure of net benefit is now necessarily flawed by the fact that it does not include the unobservable, but real, cost of effort. However, if the regulator rewards the utility with 100% of the regulator's measure of program net benefits, the utility would be motivated to apply effort to the program to maximize the program's social value. We formalize this as

*Principle 2:* If the regulator can obtain an unbiased estimate of benefits, but not of costs, and the utility has private cost information, then a shared-savings incentive scheme with the utility earning 100% of measured net benefits is efficient.

Net benefits, properly measured, include customer and utility costs, but not transfer payments. Thus, under a 100% shared savings program with net benefits measured properly, the utility would be reimbursed for transfer payments, but not for utility and customer costs ($C_u$, $C_c$, and $E$ in our notation).[33] This scheme puts the firm in the position of the residual claimant for the value of conservation savings. It is efficient because the firm will invest in conservation if and only if the value of conservation exceeded its costs, including managerial effort.[34] Note that any lessor division of net benefits would not lead the utility to make efficient choices.[35] If $\alpha$ is the firm's share of net benefits, the firm would earn

$$\Pi = \alpha \cdot (a \cdot Q - C_u - C_c) - E$$

where the quantity in parenthesis is the regulator's incomplete measure of net benefit. This can be re-written in terms of true net benefit as follows:

$$\Pi = \alpha \cdot NB - (1 - \alpha) \cdot E$$

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[33] Net benefits also should include any allocative or distributional costs that result from transfer payments.

[34] The efficiency of this scheme was first demonstrated by Loeb and Magat [1979].

[35] This is, again, subject to the qualification that the utility not have competing alternatives for managerial effort where the private and social returns do not coincide.

If $\alpha$ is not one, maximizing profit is different from maximizing net benefit. In particular, if $\alpha$ is less than one, the utility would have an insufficient incentive to exert (incompletely compensated) effort on energy conservation.

The efficient incentive program with imperfect cost information calls for a high marginal incentive based on (properly measured) net benefits. This does not imply that the utility must receive a large payment on average. The utility could be assessed a fixed charge equal to the expected level of shared savings, so that the expected total incentive payment would be zero. This would retain the desirable incentive properties implied by principle 2, yet avoid large transfers of income to the utility. Note, however, that none of the shared-savings programs reviewed in this paper offer close to 100% of marginal net benefits.[36]

A 100% shared savings incentive is equivalent to a bounty incentive in which the bounty is the entire value of the saved energy[37] and the utility is not reimbursed for costs, except for transfer payments, and is charged for customer costs. The bounty programs in Tables 2-A,B differ from the program proposed here not only in the ways noted, but also because they reward the utility for only a small fraction of the value of the energy saved (typically less than ten percent). A probable reason for the low reward is that the utility is reimbursed for its costs. Rather than levelizing the field, these bounty schemes only succeed in under-rewarding the utility for the energy it saves and over-compensating the utility for its costs. The preferred bounty mechanism would put the utility much in the position of an energy service company (ESCO), but with some important differences. First, there would be no sharing of *marginal* benefits with customers. Second, the utility should not be responsible for expenditures that are merely transfer payments between the utility and ratepayers, as an ESCO is. Third, the value of energy saved is likely to differ from the price that a customer would pay, and which would be the basis for measuring the value of an ESCO's services.

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[36] Reid and Chamberlain [1990] reach a conclusion distinctly different from the logic of Principle 2. They claim that the critical feature of incentive programs is that they offer (total) rewards large enough to grab the utility's attention, and that the marginal incentive does not matter. Yet this does not explain why incentives that are very large on the margin would not also interest a utility, nor why the prospect of gaining or losing a large sum on the margin should be less interesting than the total return.

[37] Unlike a standard "bounty" this one is based on avoided cost and not simply on physical measures of energy and capacity.

### C. Case 3: Private information about energy savings

When the utility has no estimate of conservation benefits and must rely on private information about the results of conservation programs, this presents the most difficult case for efficient regulation. The regulator can deal with private information about costs by putting the utility in the position of the residual claimant on the value of energy savings. This is much more difficult when the private information relates to program benefits. The regulator needs a mechanism to penalize attempts to profit by overstating the claimed benefits of the program.

Lewis and Sappington [1988, 1992] describe an example where a firm has no incentive to overstate conservation benefits. Their example requires that the results of the program have a measurable impact on the marginal production costs of the firm, and that these costs be increasing with output. It would be most plausible to apply their scheme to the aggregate of many conservation programs, so as to increase the accuracy of measuring the effect of conservation on total demand. Measurement error would be likely to overwhelm an attempt to apply their scheme to specific conservation programs.

Without an unbiased estimate of energy savings, there appears to be no practical way to encourage energy conservation without transferring large rents to regulated firms. If an incentive program rewards claimed energy savings, a firm has an incentive to claim large savings whether or not they are realized. A regulator can prevent this only if the regulator can observe some aspect of utility operations that is correlated with the energy savings claim. Lewis and Sappington rely on total output, but this is, of course, an aggregate statistic and unravelling the effects of conservation is difficult.[38]

Lack of information about actual energy savings is not so serious if the regulator has access to an unbiased estimate, even if it is an imprecise estimate (see Riordan and Sappington, 1988). The regulator can base rewards on *ex ante* expected energy savings or on *ex post* measured savings. Either one will be adequate if the *ex ante* estimates and the *ex post* measurements are unbiased. This also requires that the utility be approximately neutral toward

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[38] The approach presented by Lewis and Sappington [1991] can involve significant regulatory risk. Their approach requires the regulator to set the price of electricity at a level that induces the correct after-DSM demand level. Small errors in price may result in large errors in induced DSM, relative to efficient levels. Since both positive and negative errors in the amount of DSM cause inefficiency, even if the expected error in price is zero, the expected efficiency gain can be substantially negative. A new paper by Lewis [1992] takes an approach based on net benefit that avoids these problems.

the risk of rewards that differ from the correct reward for the actual energy savings. This should not be an unreasonable assumption for small conservation programs, and when applied to many programs over an extended time period the law of large numbers should make cumulative realized rewards a close approximation to the correct reward for actual savings.

An unbiased estimate of energy savings is the key to successful energy conservation programs.[39] If an unbiased estimate is available, the regulator can reward the utility with a small shared savings incentive if the cost of effort is approximately known, or with a 100% shared-savings scheme (which makes the utility the residual claimant on estimated savings) if the cost of effort is highly uncertain and the utility has private information.

## D. Case 4: The Regulator has a Non-Verifiable Estimate of Benefit

The first two cases support the desirability of shared savings incentive programs in those situations where the utility has an unbiased and verifiable measure of energy savings. Verification is necessary for the enforcement of the regulatory contract. In some situations, the regulator may be reasonably confident of the expected net benefits that may result from a conservation program, but may be unable to verify them publicly. When the only problem is verification, and not that the utility may have better information about net benefits, efficient regulation is relatively straightforward. An efficient incentive mechanism can simply encourage the utility to undertake the level of conservation that the regulator computes as optimal. An incentive program designed to produce a specified level of investment is called a forcing contract. A mark-up incentive combined with a cap on program expenditures is such a contract and could be used efficiently in this case.

*Principle 3:* If the regulator has a verifiable, unbiased estimate of costs, but *not* of benefits, and the utility has no private information, then a cost-based forcing contract is efficient.

Mark-up programs are essentially equivalent to specifying the level of expenditure that the regulator desires. If the utility is allowed to earn a percentage of every dollar that is spent

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[39] Of course *known* bias can be corrected and would not be an impediment to efficient regulation. The problem is severe when reliable estimates of conservation benefits are not feasible, either because the data are hopelessly inaccurate or because the firm has private information about the success of programs which can be exploited in the reports of measured savings.

on the program, without regard to net benefits, that is equivalent to saying that the utility should spend an amount equal to the program expenditure cap. Mark-up plans present a significant danger of inefficiency because they reward the utility only for costs incurred and not for energy saved. Yet mark-up plans may be the best that can be done when the regulator's information about expected energy savings is not publicly verifiable, but is as good as the utility's information. In that case the regulator has no need to rely on the utility for relevant information, and should simply specify the desired expenditure.

Information and education programs are candidates for a mark-up incentive if the regulator can estimate, but not easily verify, the effectiveness of these programs. It is reasonable to expect that a utility has no private information about the savings that such programs would produce or about the cost of these programs.[40] It is difficult to base rewards on an estimate of conserved energy, because one could not prove that the savings had anything to do with the program.[41]

Note, however, that a mark-up mechanism provides no incentive for the utility to choose the most effective expenditures. Thus regulators would be wise to limit mark-up plans to specific programs and to cap the amount of allowed expenditures.

## V. Conclusion

Utility conservation incentives offer potential economic gains by focusing managerial effort on least-cost planning for energy services. For economists, they also provide an exciting opportunity for the study of incentive regulation on a wide scale. This paper is a first look at the programs that have been put in place and the incentives they present for efficient conservation investment.

Most of the programs in place can be classified as one of three types, depending upon whether incentives are paid on energy savings (bounty), costs (mark-up) or net benefits (shared-savings). This study concludes that just two types, mark-up and shared-savings, are adequate to

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[40] There is the risk that a utility might distort an information/education campaign to promote its own interests (e.g. promote customer goodwill) at the expense of energy conservation.

[41] This does not preclude offering a reward that depends on the difference between a forecast of energy consumption and actual consumption at a future date, but it would be difficult to verify that actual consumption was influenced by the program.

provide efficient incentives (when unbiased estimates of savings exist), and that many existing programs are more complex than they need be. For example, the San Diego Gas and Electric plan appears to include an extra bonus for efficient investment behavior. In fact, the plan reduces to a shared-savings incentive, with the only remarkable fact being that it replaces SDG&E's estimate of avoided cost with an arbitrarily lower value.

The design of efficient incentive plans depends on what is known to the regulator and the firm about the cost and benefits of conservation programs. Simple plans that reward the firm based only on costs (mark-ups) are efficient if regulators cannot publicly verify their benefit estimate, and utilities have no private information about net benefits. These plans are merely "forcing contracts" that encourage the firm to undertake a desired level of conservation expenditure.

When a utility has private information about the compensation needed to bring forth the right amount of effort on conservation, and the regulator has an unbiased estimate of savings, an efficient incentive offers the utility 100% of measured net benefits. The regulator can recover expected payments to the firm by including a large fixed fee in the incentive plan. The plans we have surveyed differ from this standard in that the utility keeps a much smaller fraction of energy savings and is not sufficiently accountable for program costs.

Measurement of savings is the key to success of conservation programs. If adequate measurement techniques can be established, high-powered incentives will lead to efficient conservation expenditures. Problems arise if there is bias in the estimation of conservation benefits. Results reported in Quigley [1991] and Joskow and Marron [1991] imply that conservation claims are often much more optimistic than measured savings. Incentive programs can correct for predictable differences between claims and realized benefits. The more serious problem is that there may be no systematic relation between claimed and actual savings, or that measurement of actual savings may be subject to unacceptable error.

Additional issues raised in this review of conservation incentive are whether regulators are presenting utilities with a level playing field for supply as well as demand-side investments, and whether the size of conservation incentives make a difference in achieved benefits. If net benefits can be measured, ratepayers are better off with any conservation program that achieves a positive net benefit, provided they receive some share of the net benefit. Efficient conservation incentives do not penalize generation investments.[42] They merely encourage the utility to exploit another dimension of service that may benefit ratepayers. While ratepayers are even better off if they earn a larger share of conservation benefits, all parties are better off by encouraging conservation that yields a positive net benefit.

Although preliminary, this survey of DSM incentives does not offer strong support for the notion that greater incentives produce more conservation activity. Inspection of Tables 4 and 5 shows that there is little relation, on either a normalized or nominal basis, between the magnitude of incentives and the level of expected energy savings.[43] This result should not be unexpected, as energy savings should depend on many factors that are not accounted for in these tables, such as the characteristics of conservation opportunities and the experience of utility management. It remains to be seen, however, whether higher rewards for conservation activities are associated with greater savings after properly adjusting for these factors.

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[42] This assumes that conservation incentives do not cause utilities to allocate too much managerial effort to DSM at the expense of supply-side investments.

[43] The lack of a systematic relation between the size of incentives and energy savings is further confounded by the fact that there are many conservation programs in place where the utility is only allowed to expense costs (or to include costs in the rate base). These are not counted as incentive programs in our classification, yet there is no reason to believe that they are not successful in achieving positive net benefits.

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