What Does a Negawatt Really Cost?
Further Thoughts and Evidence

by

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INTRODUCTION

We have received many comments, both first hand and second hand, about our paper "What Does a Negawatt Really Cost? Evidence From Utility Conservation Programs" which was published in the Energy Journal in 1992.[1] Some of these comments have been favorable while others have been critical. This note is an effort to respond to what we believe are the most important criticisms of our study. In this context we will discuss a recent evaluation of the Bonneville Power Administration's (BPA) Residential Weatherization Program which was prepared by Oak Ridge National Laboratory and published in December 1992 (Brown and White (1992)).[2] This program is especially interesting to examine in light of what we feel to be the most significant criticisms of our earlier work. These criticisms relate to the effects of improved measurement and evaluation techniques, program maturity, learning, and economies of scale on program costs and performance. Because the BPA program has been in existence since 1980 and has been accompanied by a reasonably careful cost accounting and ex post measurement protocol, its experience provides some evidence regarding the importance of these factors.

Almost nobody who offered us comments questioned the validity of the computations that we presented in our paper. Many people agreed that the cost accounting and energy savings measurement issues that we identified were indeed significant problems that needed to be addressed more comprehensively. There was also broad agreement that the actual costs per kWh saved that are being

[1] The Energy Journal, Volume 13, No. 4, 1992, 41-74. The results of this research are summarized in our paper "What Does Utility-Subsidized Energy Efficiency Really Cost?", Science, Vol. 260, April 16, 1993, pp.281/370.

[2] Marilyn A. Brown and Dennis L. White, Evaluation of Bonneville's 1988 and 1989 Residential Weatherization Program: A Northwest Study of Program Dynamics, ORNL/CON-323, December 1992.

achieved by utility conservation programs are significantly higher than the most optimistic technical potential (TP) estimates that are frequently cited in the media, before state regulatory agencies, and in other government forums. With one exception (Amory Lovins), everyone agreed that the Lovins/RMI numbers, in particular, drastically understate the true costs of energy conservation programs. Indeed, a number of people told us (confidentially, of course) that the Lovins/RMI numbers were becoming an embarrassment to the energy conservation community because they had no relationship to reality.

Most of the criticisms that we received focused instead on whether or not our sample is representative of current utility experience and, more importantly, whether our results are indicative of the future performance of utility programs. Unfortunately, these criticisms were long on speculation about the present and future and short on hard empirical evidence.

Neither the criticisms that we have received, nor more recent utility reports or studies that we have reviewed, lead us to change any of the conclusions that we reached in our paper. The total cost of energy efficiency improvements facilitated by utility programs are, on average, significantly higher than the numbers frequently quoted and used in the media, before regulatory agencies, and in utility planning models (e.g., the RMI and EPRI numbers referred to in our paper and similar TP studies). Proper accounting of program costs, accurate measurement of energy savings attributable to the programs, and proper consideration of the interaction between these programs and normal market processes would reduce significantly the overall societal benefits attributed to utility conservation programs; as a result, some programs that appear cost effective on paper would be found to be wasteful in reality. While we think that there is more than a free snack out there that utilities can help to capture. the free banquet with caviar and champagne that the public is often promised is not likely to be achievable with current practices.

We <u>have</u> seen and heard evidence that utilities are responding to our findings by improving cost accounting, energy savings measurement techniques, and evaluation protocols. We do not find this surprising since responsible utilities and regulators should respond to the infirmities in energy savings measurement and program evaluation techniques that we identified. Of course, we would not have bothered with our study if we had not expected that it would have a positive effect on the quality of these programs by leading utilities and regulators to question some of the assertions of energy conservation gurus.

However, we have not yet seen any hard evidence that leads us to believe that the broad adoption of better cost accounting and energy savings measurement techniques will change our basic conclusions about the real costs of utility-sponsored energy conservation programs. Better cost accounting and measurement protocols will have two countervailing effects. First, accounting for all of the costs and adjusting engineering estimates of energy savings with credible ex post measures of actual savings will work to <u>increase</u> the measured cost per kWh saved compared to TP estimates and the costs of energy savings currently reported by many utilities. Second, better measurement techniques could help to refine utility conservation programs so that the incidence of expenditures that are not cost effective and the burden of program costs on general ratepayers are reduced. While this would certainly be a welcome outcome, these refinements will have to be very significant to compensate for the current practice of underestimating costs and overestimating savings.

A number of our critics have argued that the data upon which we have relied may be representative of the past, but are not representative of the future and that the future is very bright indeed. We recognize, of course, that it is easier to examine what has happened in the past than it is to predict what will happen in the future. We must point out, however, that many conservation advocates conveniently neglected to inform anyone about the "transition problems" that would have to be addressed when they promoted these programs in the late 1980s and induced utilities to spend billions of dollars in the 1990-91 period covered by our data. Absent credible empirical support we see no reason to assume that the projections that they are making in 1993 for the 1995-96 period will be any more accurate than the predictions that they made in 1987 for 1990 and 1991. Moreover, while the notion that there will be significant cost savings due to better information, learning, and economies of scale is theoretically appealing, it is also possible that utilities have gone after the cheapest conservation opportunities first (the low hanging fruit) and that it will get more costly over time to achieve energy conservation goals. The evidence from BPA's Residential Weatherization Program, as we discuss below, is much more consistent with the latter hypothesis than with the learning by doing hypothesis.

SHOULD UTILITIES BE PROMOTING ENERGY CONSERVATION?

There is one issue that we want to put to rest before we address some more technical issues. We have read a number of papers and received a number of comments that suggest that some people have interpreted our paper as arguing that utilities have no role in promoting cost effective energy conservation investments by their customers. This represents a misinterpretation of the implications of our analysis and of our conclusions. We believe that utilities do have a useful role to play in promoting cost effective energy conservation. Our papers simply argue that if utilities are going to spend general ratepayer money to finance energy conservation they are going to have to pull their socks up. In particular, they must make a more serious effort to estimate customer and utility conservation costs, to develop and apply credible techniques to measure the energy savings achieved, to account for changes in service quality, to account properly for free riders, and to design their programs so that market barriers are reduced with the smallest possible impact on overall rate levels. Furthermore, it is important that utilities make rate design changes that better align prices and marginal costs so that electricity consumers get the right price signals and that utilities identify the most efficient mechanisms for getting their customers to invest in cost effective energy conservation opportunities.

While we believe that utilities do have a potentially important role to play in facilitating the diffusion of cost effective energy conservation opportunities, we see serious deficiencies in the way many of these programs have been conceptualized and structured. In particular, we think that the au courant framework of "integrated least cost planning" that views consumer conservation investments as a "utility resource" that utilities must "acquire" from their customers is the source of a lot of sloppy thinking (and wasteful expenditures) and is unlikely to lead to satisfactory outcomes in the long run. Furthermore, as competition evolves in the electric power industry this approach, which leads to higher rates and pervasive cross-subsidies, will simply be unsustainable.

Energy conservation should be conceptualized as a <u>customer</u> service and a <u>customer</u> resource, not as a <u>utility</u> resource that is equivalent to a utility "supply source." The customer will own the conservation devices, decide how to utilize them, and when to scrap them. Nobody has yet invented a "negawatt meter" to measure energy savings in a way that is remotely equivalent to a meter that measures the kWhs that come out of a power plant and into a customer's home or business. Measurement problems may be a serious market barrier, but these barriers can only be overcome by improving energy savings measurement capabilities, at least in a statistical sense, not by making up numbers. The "integrated least cost planning" framework makes it too easy to forget that the consumer is generally in the best position to forecast the use of equipment placed in her home or business and to evaluate the overall benefits and costs of investments in conservation when presented with the information necessary to make these evaluations. Placing the utility in the position of deciding how millions of customers should use electricity, and then using general ratepayer funds to subsidize consumers so that they behave in ways that some engineering model says they should behave, reflects a central planning mentality that is doomed to failure.

A decentralized customer service and customer resource perspective naturally leads one to focus a lot more on why consumers behave as they do and how utility initiatives of different types are likely to affect consumer behavior and ameliorate real market imperfections. This framework recognizes that the payments that consumers are required to make for energy conservation investments made on their behalf play an important <u>selection</u> role that makes it possible to exploit the "hidden information" that customers have about their energy use patterns and investment plans. Customers who bear the costs of conservation will have an incentive to agree to pay only for truly cost-effective investments. Thus, the arguments about who should pay for utility conservation programs do not only raise equity issues (cross-subsidies, non-participant burdens, etc.), but raise very important efficiency issues.

An approach to utility conservation programs that requires customers to pay the bulk of the costs of conservation investments made on their behalf, in one way or another, out of the savings that they realize or expect to realize, makes it necessary to convince customers that the savings are really there when all relevant factors are taken into account. This approach will lead to real energy savings rather than just paper savings and will relieve regulators of the very difficult task of measuring actual savings, imputing customer costs, dealing with free riders, and changing customer behavior over time. It will also require utilities to think about the evolution of their conservation programs into real businesses where the bill for conservation services provided to Mrs. Smith is sent to Mrs. Smith for payment and not divied up and sent to all of her neighbors. In the end we want least cost outcomes, not nice computer printouts produced by integrated least cost planning software.

IS OUR SAMPLE UNREPRESENTATIVE?

It has also been argued that our paper is based on an unrepresentative sample of "immature" conservation programs. The implication is that if we had examined a more representative sample of utility programs we would have come up with different results. This criticism is simply unfair. The appendix to our paper lists the names of the utilities included in the sample. Several of these utilities have had conservation programs in place, especially for residential customers, for nearly a decade (e.g. Long Island Lighting). Others are often pointed to as conservation leaders in the utility industry (e.g. Central Maine Power, Massachusetts Electric, and PG&E). To the extent that our sample is biased it is probably biased toward the more mature and highly regarded programs. As our discussion of the BPA weatherization program will make clear, the results for what is probably the most mature and most studied energy conservation program in the country support rather that refute our primary findings and conclusions.

Critics have pointed to a more recent study by Flanigan and Weintraub[3] as providing a more representative sample of utility programs and results that are inconsistent with our own. These critics are wrong. Flanigan and Weintraub have assembled data for a sample of utility programs that were prescreened as being "successful" and "the best." 60% of the utilities included in our sample have programs that are included in the Flanigan and Weintraub sample, including all of those that we had identified ourselves as being highly regarded. Unlike Flanigan and Weintraub, however, we examined all of the conservation programs for the utilities we selected not just those that these utilities identified as being successful. We also included utilities that were not generally known as being "the best."[4]

F&W's findings are, with one important exception, not very different from our own. The cost per kWh saved computed based on the cost and savings numbers provided to them by utilities varies widely, in their case from a fraction of a cent to nearly 12 cents per kWh saved.[5] They recognize that proper accounting for actual energy savings achieved by these programs is very important, that the care with which savings are measured varies widely across utilities, and that "...just when you think you've got significant levels of savings, you unfortunately may not!" They commend two utilities for doing an excellent job in measuring actual net savings. One utility "takes credit" for 56% of engineering estimates and the other 28%. They say that "caution must be taken to determine whether savings are based on

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[3]T. Flanigan and J. Weintraub, "The Most Successful DSM Programs in North America," The Electricity Journal, May 1993 (forthcoming).

[4]Programs for some of these utilities also made it on to Flanigan and Weintraub's list of "the best" utility programs. The sample also includes Canadian utilities, at least one of which has been critivized extensively for the waste and inefficiency associated with its conservatiuon program.

[5]Since we did not limit our own analysis only to programs that had been prescreened for success we find a substantially larger variance. Nevertheless, 60% of the utilities in our sample have at least one program in Flanigan and Weintraub's sample. However, we examined all of the programs of those utilities represented in the Flanigan and Weintraub study not only those selected by the utilities as "successes."

engineering estimates...or whether process and impact evaluations have been conducted, and whether the savings have been adjusted for free ridership, unusual weather, snapback..., measure persistence and attrition, etc." (p. 54). Our papers make exactly the same points.

F&W also appear to recognize that the costs reported by the utilities in their sample are not directly comparable because they pay different fractions of the total cost of the conservation measures included in the programs. Indeed, F&W report only the costs incurred by utilities, consciously ignoring customer costs, which they recognize may be large (page 60).

Unfortunately, these important points are ignored in F&W's analysis of "low cost energy savings" (pp. 62-63). Meaningful measurement of the cost of energy saved by utility conservation programs should include all of the utility and customer costs incurred in connection with the programs. It should also reflect accurate measurement of the actual savings achieved. The cost of saved energy figures reported by F&W generally satisfy neither of these criteria.

F&W calculate the cost per kWh saved by the programs in their sample using the energy savings and program cost information reported by the utilities. All we can infer from the data that they present is that, on average, the cost per kWh savings figures that they report are likely to understate significantly the true total cost of these programs. Precisely how significantly the reported cost per kWh saved will understate the true cost will vary from program to program. The primary problems with F&W's effort to put a cost effectiveness twist on the cost per kWh saved numbers they report are:

(a) The energy savings reported for many of the utility programs are based on engineering estimates of energy savings rather than careful ex post measurement. As we have emphasized in our earlier work, and F&W appear to recognize elsewhere in their paper, these savings numbers are likely to be "derated" when careful measurement protocols are put in place. The two exemplary programs that they identify have discounted ex ante engineering estimates significantly.

These discounts are typical of programs that use sound ex post measurement techniques. Few of the programs that are common to our samples have adopted such measurement techniques, however. F&W provide no indication that many other programs in their sample do not suffer from the same measurement problems. As a result, most of the cost per kWh figures reported are likely to embody a significant overestimate of the energy savings achieved resulting in an associated underestimate of the cost per kWh saved.

(b) F&W include only reported utility costs and exclude customer costs. It makes absolutely no sense to exclude customer costs when performing a cost effectiveness analysis. This approach would violate the criteria for measuring cost effectiveness adopted by every state regulatory agency of which we are aware. As a result, the cost per kWh saved figures reported F&W are biased downward even further.

(c) F&W accept uncritically the costs reported to them by utilities as fully reflecting all of the costs the utility itself incurs in connection with these conservation programs. But our analysis, which includes several programs in the F&W sample, found that many utilities did not account fully even for all of their own costs. The failure to include all utility costs again biases downward the cost per kWh figures reported.

Of course, even if F&W had included only those utility programs that fully accounted for all utility and customer costs costs and provided accurate measures of the energy savings the programs achieved, they have not presented enough information to perform a proper cost effectiveness analysis. They have no utility-specific avoided cost information which is necessary to perform such an analysis. We eschewed making cost effectiveness judgements in our work due both to the infirmities of the information available to make credible calculations of the cost per kWh saved and the difficulties of integrating such information with avoided cost information for a large number of utilities.

WILL UTILITY PROGRAMS PERFORM BETTER IN THE FUTURE THAN IN THE PAST?

As we have already mentioned, several commentators have suggested that while our evidence may be representative of what has happened in the past, it is not representative of how utility conservation programs will perform in the future. They argue that utilities are getting better at the conservation business, accounting for all costs more systematically, and measuring energy savings and free riders more accurately. Better information, learning by doing, and economies of scale, it is argued, will help to drive down the costs of utility energy conservation initiatives over time. While the Lovins/RMI numbers do not represent realistically achievable goals, it is argued that energy savings and associated program costs consistent with the EPRI numbers are an achievable goal.

We are optimists and are inclined to believe that things will get a lot better in the future if utilities and regulators respond to the lessons learned from experience. However, we have seen little evidence to convince us that this happy prediction of the future is based on anything other than blind faith. The best that we can say is that it is certainly too early to tell and, as we will discuss presently, there is evidence to suggest that improvements in cost accounting, measurement of energy savings, and the benefits of experience will <u>not</u> lead to better ex ante projections of the costs of conservation "resources" used for planning purposes or to progressively lower measured costs of meeting conservation goals.

We do want to note that several of the utilities that we included in our survey, as well as others for which we have obtained some information subsequent to our study, have taken the issues that we have addressed seriously. They are paying more attention to cost accounting issues, introducing and refining protocols to measure savings actually achieved, and evaluating the evolution of the market to account for free riders. Efforts are being made to drop programs that are not cost effective. More and more regulators and utilities are coming to recognize that it is important to require customers to make a significant contribution to the costs of the investments made on their behalf, both for incentive reasons and to moderate the rate impacts associated with general ratepayer funding of conservation subsidies. We believe that our work has made at least a modest contribution to stimulating this evolution.

All of this being said, the progress being made in dealing with these issues, especially with regard to measuring energy savings and accounting for free riders, is still relatively slow. Developing good delivery mechanisms and adequate measurement and evaluation programs can take many years. Further, a regulatory requirement to rely on ex post measurement protocols rather than ex ante engineering model predictions necessarily takes time to implement effectively. Several people, for example, pointed to California as a state where, subsequent to the initial circulation of our paper, the Commission decided to require utilities to adopt comprehensive ex post measurement and evaluation techniques. We agree that this is a good development. However, this fact was apparently presented to us as evidence that our study is not representative of current utility programs, and by implication, that this meant that our conclusions are inapplicable to current and future programs. The logic of this argument escapes us. Furthermore, because developing these protocols takes time, the California Commission's rules are not yet in effect for current programs and approved ex post measurement protocols developed in response to the Commission's order have not yet been integrated into the utility programs. As a result, more recent data for California continues to reflect whatever strengths and weaknesses existed during the period covered by the data in our study.

EVIDENCE FROM THE BPA RESIDENTIAL WEATHERIZATION PROGRAM

A recent evaluation of BPA's Residential Weatherization Program can help to shed some factual light on some of these issues.[6] The BPA has been running a residential weatherization program for

[6]Brown and White (1992), Ibid.

customers with electrically heated homes since 1980. This is the only program of which we are aware that has been in operation for such a long period of time. The program has applied high standards to cost accounting, measurement of energy savings, and overall program evaluation. The BPA accounts both for utility (BPA + host utility) costs and customer costs. It also accounts for certain administrative costs. Unlike many other utility programs, the BPA program has been concerned about measurement issues from its inception. Accordingly, each cohort of participants has been matched with a control group of non-participants. The program then makes use of ex ante engineering models to predict participant savings for planning purposes as well as ex post measurement of savings derived from comparisons between the participants in the program and the control group to evaluate actual program performance ex post. These comparisons between participant and control groups have been made both for the first year following the installation of weatherization equipment and in two subsequent years as well. This makes it possible to examine whether the savings measured for the first year persist over at least the early part of the expected life of the capital investments made to conserve electricity. Additional stability and comparability in the data results from the fact that measurement and evaluation has been the responsibility of Oak Ridge National Laboratory, probably the most experienced group in this business, for many years. While we are not entirely comfortable with the way the control groups are selected and utilized, the only component of our list of desirable program attributes that is missing from the BPA program is an explicit accounting for free riders.

The BPA program provides financial incentives to residential, electric space heat customers to install a variety of measures to increase energy efficiency. "The underlying assumption of Bonneville's weatherization efforts is that installation of retrofit measures will lead to substantial reductions in residential energy use, and that the value of these savings will justify the Bonneville, utility, and household costs of implementation." (Brown and White, page 1.1) The program is typical in that it relies on rebates provided by BPA and the host utility, with only modest customer contributions required. Customer contributions accounted for 22% of program costs (including administrative costs) in 1988 and 26% in 1989. The BPA's efforts in this area began with a pilot program in 1980. All together there are six "program cohorts" that have been analyzed. The most recent analysis focuses on the 1988 and 1989 programs.

The 1991 Northwest Conservation and Electric Power Plan[7], which covers the BPA region, lists single family residential weatherization as a "resource" with an expected cost of 3.4 cents per kWh (real levelized cost in $1991).[8] This is very close to the cost reported by EPRI for residential space heating conservation opportunities as reported in Figure 1 in our Energy Journal paper and is derived from engineering analyses that are not unlike those relied upon by RMI and EPRI. Brown and White (1992) also indicate that BPA's regional ceiling price for conservation "resources" is 5.9 cents per kWh saved (again real levelized cost in $1991).[9] We take this to be BPA's assessment of the regional avoided cost of new electricity supplies against which conservation investments are to be compared for cost effectiveness. Thus, if the ex ante engineering assumptions of program costs used for planning purposes are a good approximation to the actual cost per kWh saved achieved by the program, expenditures on residential weatherization induced by the program should be very cost effective. The question is how do the ex ante projections compare to the ex post performance of the program?

Table 1 provides some information drawn from Brown and White (1992) on the measured cost per kWh saved and the relationship between pre-retrofit estimated savings based on audits and engineering models and the post-retrofit measured savings based on comparisons between participants and controls.

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[7] 1991 Northwest Conservation and Electric Power Plan, Volume 1, page 15, Northwest Power Planning Council, Portland, Oregon.

[8] The number reported in the publication is 3.2 cents/kWh saved. This appears to be in $1990. We have adjusted this value and all others reported below to reflect $1991 price levels (using the CPI) so that the numbers are comparable with one another and with those reported in our paper.

[9] The number in Brown and White is 5.6 cents per kWh saved, expressed in $1990 (p. 2.11).

The first column reports the estimated life-cycle costs for the 1988 and 1989 weatherization programs based on the ex post measured savings and assuming that measured savings for the first post-retrofit year persist over the entire expected life of the measures. The second column contains similar figures that have been adjusted to reflect deterioration in measured program savings over time. We will return to this column presently. The third column lists BPA's avoided cost ceiling. The final column is the ratio of ex post savings calculated by comparing the participant and control groups and the ex ante engineering estimates of the energy savings achieved by the program.

Let us start our discussion of Table 1 with the fourth column. It is evident that the ex post measured savings are substantially less than the engineering estimates. Measured savings are only 30% to 40% of the savings projected ex ante by the engineering models.[10] Moreover, in comparing the gross savings based on billing records with the engineering predictions for each participant, Brown and White find that the correlation between the two is only 0.1 (pp. 4.2 and 6.2). Thus, despite many years of experience both with ex ante forecasting and ex post measurement, BPA is still using engineering models that perform poorly both in tracking individual usage patterns and in estimating actual savings.[11] This is consistent with the conclusions in our papers. Experience and program maturity does not yet appear

[10] Assuming measurements are accurate, the difference between measured and projected savings can be broken down into two components: actual forecast error and unobserved conservation by members of the control group. If members of the control group install conservation devices on their own (i.e., naturally occurring conservation), then the energy savings estimated by a measurement program will correctly reflect the aggregate energy savings resulting from the program. With a well-chosen control group, the naturally occurring conservation in the control group should exactly offset the naturally occurring conservation that would have occurred in the treatment group (i.e., free riders). The measured savings thus accurately reflect the net *aggregate* effect of the program. To calculate net energy savings per device, the number of devices must be adjusted downward to eliminate free riders. Measured savings divided by this reduced number of devices yields the correct savings per device. To calculate costs per kWh, as reported in the text, measured savings are the appropriate denominator. The appropriate numerator, however, is total costs less the costs that free riders would have incurred themselves. Since the ORNL study does not estimate free riders, we have been unable to make that adjustment here.

These calculations would be complicated if "free drivers" are also responsible for conservation in the control group. In general, we are skeptical of the "free driver" argument, although it is obviously an empirical issue.

[11] We are puzzled and troubled by the fact that experience has not improved the accuracy of the engineering models.

to have solved this problem.

Let us turn next to the first column in Table 1. This column displays the measured cost per kWh saved for the 1988 and 1989 programs based on total program costs (BPA, host utility, customer and administrative costs) and the net measured savings for the first post-retrofit year attributable to the conservation program. The net measured savings for the first post-retrofit year are assumed to persist over the life of the conservation measures. The measured cost per kWh saved is 5.5 cents/kWh ($1991) for the 1988 program and 9.1 cents/kWh for the 1989 program. The 5.5 cent figure is 62% higher than the 3.4 cent value used by the Northwest Power Planning Council for planning purposes. The 9.1 cent figure is 168% higher than the 3.4 cent cost used for planning purposes. Both the 1988 and 1989 measured costs far exceed the TP values reported by EPRI for residential heating conservation opportunities. The 1988 program is barely cost effective compared to the BPA's 5.9 cent ($1991) avoided cost ceiling, while the 1989 program fails the cost effectiveness test by a significant margin.

Contrary to the assertions of some of our critics, these high measured costs and the large differences between measured costs and engineering estimates cannot be attributed to program immaturity, startup problems, or a failure to consider economies that result from learning by doing. BPA's program has been in existence for a decade and has been studied and refined more extensively that almost any conservation program of which we are aware. Indeed, the experience with the BPA weatherization program since 1980 makes it clear that one cannot assume that costs will necessarily fall over time. This is an empirical issue that can only be resolved by analyzing the relevant data.

Table 2 reports the measured cost per kWh saved computed based on ex post comparisons between participants and control groups for each of the six BPA program cohorts studied since 1980. Let us focus initially on the first column, which presents information on the measured cost per kWh saved as reported by Brown and White (in $1991) in the first post-retrofit year for each program cohort. The data make it clear that the cheapest savings were achieved in the earliest years. Program costs in the post-1983 cohorts are significantly higher than in the earliest cohorts and have increased steadily over time. If the BPA is getting better at delivering conservation services it must then be that it is getting harder to find cost effective conservation opportunities over time as the "low hanging fruit" is picked and BPA must climb higher up the tree to find fruit worth picking. There are a variety of reasons why this might happen, including the diffusion of conservation investments by consumers through ordinary market forces as they respond to higher electricity prices and the increased availability of information about conservation opportunities.

Unlike many other programs, the BPA tracks energy use by both participants and the control groups in the second and third post retrofit years. This makes it possible to examine the persistence of program savings over time and to test the validity of cost estimates that assume that first year savings persist over the entire life of the measures. Table 3 displays the net measured savings for each program cohort by year as reported by Brown and White.

Focusing only on column 1, we see that the first year measured annual energy savings that the programs have achieved has declined over time. It is also the case that annual pre-retrofit consumption of both participants and non-participants is much higher in the earlier period than in the post-1983 period (Table 7.4, p. 7.5); the "natural" reduction in average pre-retrofit consumption between the early and later years is slightly larger, in fact, than the average net savings achieved by these programs during the 1980s. This suggests that the characteristics of the remaining target population for these weatherization retrofit programs has changed over time. In particular, there are fewer conservation opportunities in the remaining stock of retrofit opportunities. The "low hanging fruit" may have been picked first and/or customers have made conservation investments on their own over time in response to market forces.

Table 3 also demonstrates that it is dangerous to base cost calculations on energy savings achieved in the first year, assuming that these savings will persist throughout the life of the investment. Table 3 indicates that, on average, the measured savings within each cohort decline (i.e. deteriorate) by roughly

10% per year over time.[12] [Brown and White refer to a 15% average annual rate of deterioration that is computed in a different way.]. Data are unavailable to determine whether the savings continue to decline after the third year.

The measured cost per kWh saved calculations that we discussed earlier were based on the assumption that energy savings measured in the first year persisted over the full life-cycle of the conservation measures. Since the BPA studies provide evidence that these savings deteriorate over time, the values for the cost per kWh saved reported in the first column of Tables 1 and 2 are too low. Given the unexpectedly high costs of the post-1983 programs, an adjustment for the deterioration of savings over time is important because modest increases in program costs could lead these programs to fail traditional cost effectiveness tests. In second column of Table 1 and Table 2 we have adjusted the measured costs per kWh saved to reflect the assumption that the present value of energy savings is 20% lower than what is implied by the assumption that the savings persist at first year levels forever. This adjustment is consistent with the data reported in Table 3. Readers can apply any other adjustment that they feel is more reasonable.

An examination of Tables 1 and 2 makes it clear that adjustments in the measured costs to reflect

[12] Consistent with a previous footnote, the reader may wonder whether the deterioration in savings is due to reduced savings from installed devices, increased conservation by the control group, or other factors. The ORNL study does not directly address this issue, so we cannot say for sure. For the 1988 program, we do have the following data:

	Year 1 Savings (kWh)	Year 2 Savings (kWh)	Difference (kWh)
Participants	1773	1274	500
Control	-404	-729	325
Difference	2177	2003	175

(Brown and White 1992, Table 4.5, p. 4.11)

From year 1 to year 2, savings among participants decreased, as did savings among the control group. In this case, at least, the reduction in net savings results not from increased conservation among the control, but from substantially lower savings by the participants.

the deterioration in measured savings over time indicates that none of the post-1983 programs were cost effective as the cost per kWh saved exceeded BPA's 5.9 cent avoided cost ceiling price.

CONCLUSION

It is not our purpose to pick on the BPA program. The program has been responsibly implemented in a region where electricity prices have often been too low to provide consumers with appropriate incentives to conserve. Furthermore, the application of more comprehensive benefit-costs techniques, rather than the simple cost effectiveness tests that have been adopted to justify utility expenditures on conservation in the central planning world of "integrated least cost planning," could lead to a more favorable evaluation if the reasons for the significant differences between engineering estimates of energy savings and ex post measured savings are better understood. This is an issue, however, that we will have to leave to another paper.

The results from the BPA program, a mature program that has followed the cost accounting and savings measurement protocols that we have suggested, are perfectly consistent with our own study. Ex post measured savings are 30% to 40% of ex ante engineering estimates. The measured cost per kWh saved is much higher than was indicated in the ex ante engineering studies used for planning purposes. Appropriate cost accounting and savings measurement does matter because it means the difference between programs that look highly cost effective to the planner, may turn out to be wasteful when all relevant costs and behavior are accounted for.

TABLE 1

BPA RESIDENTIAL WEATHERIZATION PROGRAM RESULTS
Most Recent Cohorts Studied

Program Cohort	Measured Cost/kWh Saved ($1991 cents)	Adjusted Cost/kWh Saved ($1991 cents)	Avoided Cost Ceiling ($1991 cents)	Measured/Estimated Savings
1988	5.5	6.9	5.9	0.42
1989	9.1	11.4	5.9	0.31

Source: Computed from Brown and White (1992, p. x) with adjustments for inflation and deterioration in savings over time as discussed in the text.

TABLE 3

MEASURED ANNUAL KWH SAVINGS IN POST-RETROFIT YEARS

Program Cohort	Year 1	Year 2	Year 3
Pilot (1980-82)	3,840	3,790	3,410 (-11.2%)
Interim (1982-83)	4,200	3,600	2,500 (-40.5%)
1985	2,610	2,565	2,600 (-0.4%)
1986	3,060	2,112	2,140 (-30.1%)
1988	2,180	2,000 (-8.3%)	N/A
1989	1,330	N/A	N/A

Note: Numbers in parenthesis are changes from year 1 savings estimates.

Source: Brown and White (1992), Table 7.5, p. 7.7.

TABLE 2

BPA RESIDENTIAL WEATHERIZATION PROGRAM RESULTS
All Cohorts

Program Cohort	Measured Cost/kWh Saved ($1991 cents)	Adjusted Cost/kWh Saved ($1991 cents)
Pilot (1980-82)	4.4	5.5
Interim (1982-83)	3.2	4.0
1985	5.2	6.5
1986	5.3	6.6
1988	5.5	6.9
1989	9.1	11.4

Source: Computed from Brown and White (1992, Table 7.6, p. 7.10) with adjustments for inflation and deterioration in savings over time as discussed in the text.