DYNAMICS OF ENERGY SAVINGS DUE TO CONSERVATION PROGRAMS

Eric Hirst, Oak Ridge National Laboratory
Kenneth Keating, Bonneville Power Administration

ABSTRACT

Most analyses of utility and government conservation programs assume that program-induced energy savings are constant over time. This assumption, while convenient, is almost certainly incorrect.

The dynamics of program energy savings have two aspects. The first involves changes in savings for households who participated in a particular year. Their total and net savings depend on changes in electricity prices, incomes, general awareness of energy issues, and other conservation programs. Natural gas data from participants and nonparticipants in home energy audit programs in California, Michigan and Minnesota show, for example, small increases in both net and total savings between the first and second postaudit years. Data from evaluations of financial incentive programs for residential retrofit in the Pacific Northwest, on the other hand, show increases in total electricity savings and declines in net savings between the first and second year after retrofit.

The second aspect concerns changes in energy reductions over time for different cohorts of participants due to changes in the characteristics of participants, the conservation program itself, and the external environment. For example, the one-year net electricity savings for participants in the Bonneville Power Administration Residential Weatherization Program declined from about 4000 kWh/year for participants in 1981 and 1982 to 2500 kWh for participants in 1983 and 1984.

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INTRODUCTION

As government and utility conservation programs have grown in size and cost during the past several years, increasing attention is being given to their likely future effects. Electric utilities, in particular, have begun to consider their energy conservation programs as legitimate resources that can be compared with - and substituted for - traditional supply resources (Battelle 1984). For example, some utilities have developed integrated resource plans that include combinations of conservation programs, load management programs, alternative rate structures, renewable energy resources, purchases of power from others (e.g., cogenerators, low-head hydro facilities, and other utilities), as well as construction of their own central-station power plants. State and regional government agencies are also assessing the contributions that conservation and load management programs can make to development of least-cost energy plans (Schneider 1985).

The computer models used to develop such integrated resource plans require reliable data on conservation and load management programs, their costs, participation rates, adoption of recommended actions, and actual energy savings (Applied Energy Group; Decision Focus, Inc. 1984; Hamblin et al. 1986; Lann et al., 1985; USAM Support Center 1984). Preparation of inputs for these models requires many simplifying assumptions about these factors, generally because of limited data on program performance. In particular, analysts often assume that the net (program-induced) energy savings, characteristics of program participants, propensity to adopt recommended conservation measures, and program costs are all constant, that is, invariant with respect to time (Berry 1986). None of these assumptions is correct!

The purpose of this paper is to document the temporal changes in some of these important program-related attributes. We focus on two important issues, using data from evaluations of residential retrofit programs operated in the Pacific Northwest and the upper Midwest. The first issue involves temporal changes in electricity use for a particular group of participants (using households who participated in a Pacific Northwest retrofit program in 1981 and others who participated in home energy audit programs in California, Minnesota and Michigan in 1981). The second issue involves changes in total and net electricity savings for households who participated in the same program at different times (using participants from 1981, 1982, 1983, and 1984).

The next section discusses various factors that affect energy savings due to conservation programs and how these factors might change over time. Section 3 discusses the dynamics of energy savings for a particular group (cohort) of participants and Section 4 discusses changes in energy savings for groups that participate in a program at different times.

FACTORS AFECTING ENERGY SAVINGS

The ultimate effects and effectiveness of an energy conservation program depend on the product of three variables: participation in the program, adoption of recommended actions, and technical and operational performance of adopted actions. These variables are themselves functions of various factors:

> The conservation program (e.g., program budgets, marketing efforts, financial incentive types and levels, convenience to the customer),
>
> External environment (e.g, fuel prices, economic growth and composition, unemployment, income, availability of wood, population growth), and
>
> Participating customers (e.g., energy use, prior conservation actions, demographic characteristics).

The typical planning exercise might assume that levels of program participation are constant from year to year or follow a logistic curve. However, actual participation might follow other temporal patterns. For example, participation in the Residential Weatherization Program (Anderson 1985), managed by the Bonneville Power Administration (BPA), was: 11,000 in 1982, 79,000 in 1983, and 31,000 in both 1984 and 1985. The substantial drop in participation between 1983 and 1984 was based on a conscious decision to reduce program activity. BPA cut its budget for the program, which in turn required the participating utilities to reduce (or eliminate) their marketing efforts. The BPA decision to lower program activity levels was a consequence of the large power surplus in the region (Northwest Power Planning Council 1985) and had nothing to do with the changing characteristics of participating households.

In a similar fashion, adoption of recommended conservation measures and practices might change over time, for a variety of reasons. For example, the set of measures recommended in a program might be changed from year to year as new technologies are developed and commercialized and as experience from prior years of program operation demonstrate success and failures of measures installed in the past.

The types of households participating in a program might change over time, and these changes might lead to adoption of different measures and practices. For example, early participants in a program may have installed few measures prior to participation; therefore, their homes will have large potentials for saving energy. However, participants during later years may have already installed some measures before they signed up for the particular program.

The demographic characteristics of participants might also change over time. For example, early participants in the Hood River Conservation Project were almost exclusively single-family homeowners; later participants included larger fractions of tenants and occupants of multifamily buildings (Hirst and Goeltz 1986).

Finally, the energy savings due to installation of measures and adoption of practices might not be constant over time. The technical performance of conservation measures might degrade over time (e.g., attic insulation might settle, reducing its actual R-value). Alternatively, new high-efficiency systems may perform better over time than the systems they replace; for example, the light output from new high-efficiency lamps might decline more slowly than the output from the lamps they replaced.

Households who adopt conservation practices because of a conservation program might slip back into their former energy-inefficient habits after a while (e.g., neglecting to lower temperature settings at night). Alternatively, the energy and load reduction benefits of sophisticated computerized energy-management systems in office buildings might increase over time as building operations staff become more knowledgeable about, and experienced with, system operation.

DYNAMICS OF ENERGY SAVINGS ONE TO THREE YEARS AFTER PARTICIPATION

The bottom line for most energy conservation programs is the actual reductions in energy use that can be attributed to the program. Energy savings have two components. The total saving is the electricity reduction experienced by program participants. The net saving is that which can be directly attributed to the particular program; it is the difference between the total saving and the saving these participants would have achieved if they had not participated in the program. This latter saving is due to the effects of electricity price increases, greater awareness of energy-efficiency options, and/or participation in other conservation programs.

Hypotheses about total and net energy savings generally follow one of two very simple models. The first recognizes the likelihood that nonparticipants reduce their energy use in response to rising fuel prices. This hypothesis assumes that both participants and nonparticipants respond in the same way to rising fuel prices. The result is a constant net saving that neither increases nor decreases over time (Fig. 1)

An alternative, and in our view equally unlikely, hypothesis assumes that participants take no further conservation actions after their participation in the particular program. This assumption implies a constant total saving and therefore a diminishing net saving (Fig. 2).

Results from our evaluations of the BPA Residential Weatherization Program (RWP) suggest more complicated dynamics. Our hypothesis is that energy savings vary over time as a function of both program participation and fuel prices (as well as other factors such as income). The functional dependence of energy use on nonprogram factors may differ between participants and nonparticipants, because of prior differences between the two groups and because of participation itself.

Participation affects subsequent energy savings in two opposing ways. Installation of program-sponsored conservation measures reduces the remaining conservation potential in participant buildings. However, program-provided information on conservation measures and practices may stimulate these participants to take further conservation actions on their own, after their participation.

To explore the actual dynamics of electricity savings, we obtained data from samples of households who participated in the BPA pilot program in 1981 and samples of eligible nonparticipants. The pilot program provided free home energy audits to 7200 electrically heated homes in the Pacific Northwest and gave zero-interest loans to retrofit 4100 of these homes. Electricity billing data were obtained for four years, from mid-1980 through mid-1984 (Hirst, White and Goeltz 1985). This included one year of preretrofit data (1980/81) and three years of postretrofit data (1981/82, 1982/83, and 1983/84).

Preprogram electricity use was about 15% higher for the participants than for the nonparticipants (Table I). The reduction in weather-adjusted electricity use from years 1 to 2 was much greater for participants than for nonparticipants, 5400 vs 1600 kWh/year. This is to be expected given the $2200 average investment in retrofit measures installed in participant homes between years 1 and 2. Reductions in electricity use between years 2 and 3 were 1100 kWh/year for both groups. Reductions between years 3 and 4 were even smaller, roughly 600 kWh/year. The overall four-year reductions were 6900 kWh/year (22% of preprogram use) and 3500 kWh (12%) for the two groups.

The substantial reduction in electricity use for nonparticipants is surely due primarily to the large increases in electricity prices in the Pacific Northwest during this period. Real (net of inflation) electricity prices increased by 72% between years 1 and 4, with most of the increases occurring in years 2 and 3. [Average prices (in 1981-$) were 1.4 ¢/kWh in year 1, 1.75 in year 2, 2.25 in year 3, and 2.42 in year 4.] It seems likely that other forces were at work during this time, which also affected household electricity use: public awareness of energy issues, knowledge of the potential for

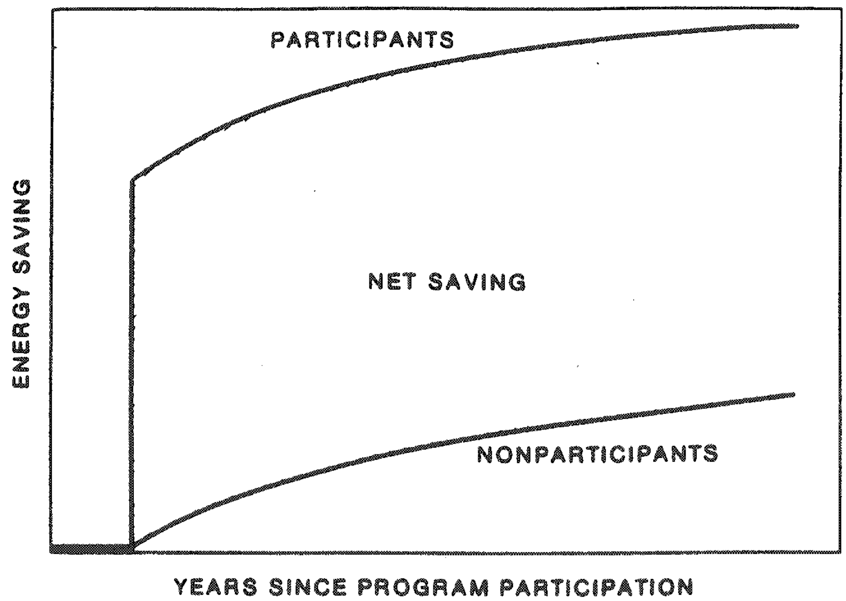

Fig. 1. Hypothetical simulation of net and total program energy savings in which net saving remains constant.

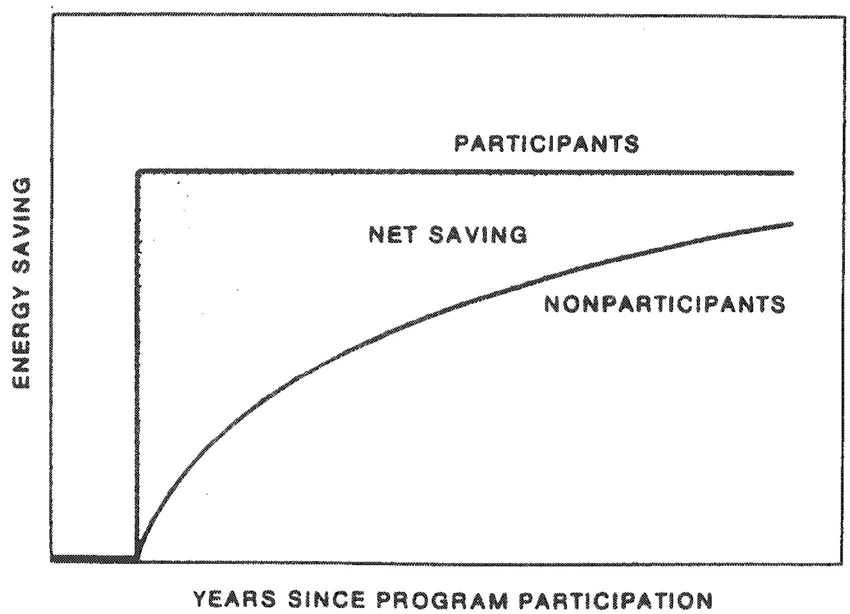

Fig. 2. Hypothetical simulation of net and total program energy savings in which total saving remains constant.

Table I. Summary (means) of weather-adjusted annual electricity use for each household in evaluation of the BPA pilot program, by group

	Audit + loan	Nonparticipants
Electricity use (kWh/year)		
year 1 (preretrofit)	29,400	25,400
year 2 (postretrofit)	23,900	23,800
year 3 (postretrofit)	22,800	22,700
year 4 (postretrofit)	22,400	21,900
Total saving (kWh/year)[a]		
year 1 - 2	5,400(17)	1,600(5)
year 1 - 3	6,500(21)	2,700(9)
year 1 - 4	6,900(22)	3,500(12)
No. of households	179	132

[a]The numbers in parentheses are the mean values of the percentage savings relative to year 1.

Source: Hirst, White and Goeltz (1985).

saving money through adoption of conservation actions, changes in household income, and overall changes in the region's economy. It is also possible that some nonparticipants adopted conservation actions because of the program; for example, nonparticipant households may have learned about appropriate measures to install from participants.

These results are at variance with the two hypotheses suggested above. Total energy savings for participants increase from year to year in the present case; this increase in savings is probably due primarily to increases in electricity prices. Net energy savings, on the other hand, decline slightly over time from 4500 kWh/year in year 2 to 4300 kWh in year 3 and 4200 kWh in year 4. Thus, net savings decrease by almost 10% between the first and third postretrofit year.

We developed a simple simulation model with the data shown in Table I to estimate likely future changes in electricity use for participants and nonparticipants. Assuming that real electricity prices remain constant after 1984 (year 4) implies that total savings for participants increase to 8400 kWh ten years after participation (Fig. 3), while net savings decline to 2700 kWh. In this scenario, the long-run net electricity saving is 60% of the first-year net saving.

These results suggest that the energy savings due to a particular conservation program are a function of electricity price trends as well as the program itself. If electricity prices in the Pacific Northwest had increased more slowly during the early 1980s, the net per household saving due to the BPA pilot program would have been larger than observed here (Table I).

Burnett (1982) evaluated a similar residential weatherization program, operated in Oregon during the late 1970s. His analysis of electricity consumption data for eligible nonparticipants and participants in 1979 showed an increase in total savings (from 4000 to 4400 kWh/year) and a decrease in net savings (from 2700 to 2300 kWh) between 1980 and 1981 (relative to 1977/78).

Our evaluation of BPA's regionwide Residential Weatherization Program (BPA 1982) gave results that differed from those presented above for the BPA pilot and Oregon programs. Total electricity savings increased while net savings remained constant between the first and second year after participation in the regionwide program (Goeltz, Hirst and Trumble 1986). The stability of net savings was probably a consequence of the stability in electricity prices during this time.

Evaluations of home energy audit programs in California, Minnesota and Michigan showed increases in both total and net energy savings (primarily natural gas) between the first and second years after receipt of the energy audit (Barnes 1983 and 1986; Hirst and Goeltz 1985; Kushler and Witte 1984).

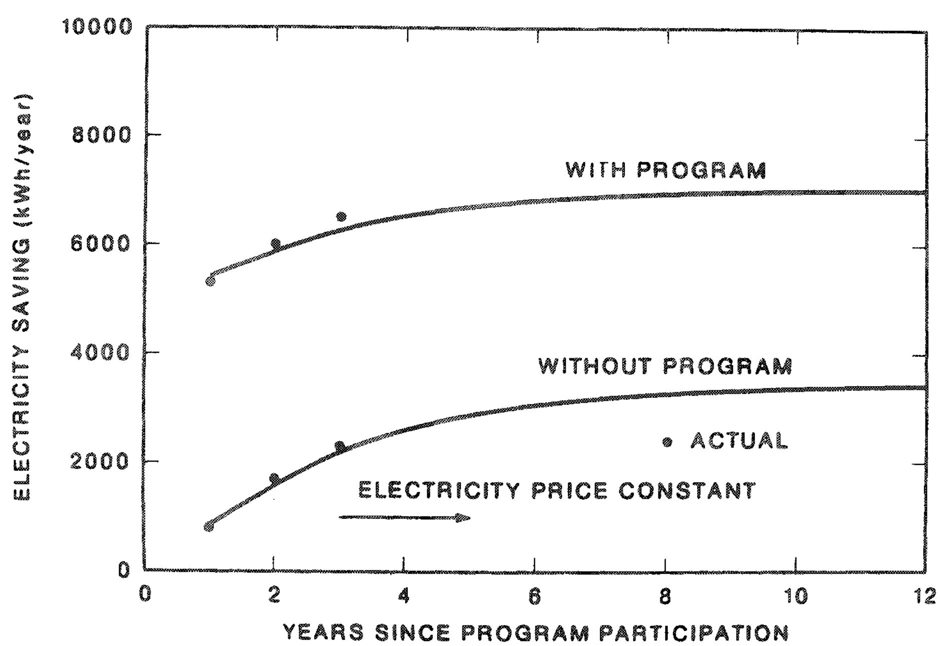

Fig. 3. Electricity savings due to the BPA pilot program as a function of time (Hirst 1986). This simulation assumes that the real price of electricity remains constant after 1984.

The increase in net energy savings is probably a consequence of the slow pace at which households install retrofit measures recommended during the energy audit (Hirst 1985). By comparison, participants in an audit+loan program install a complete "package" of measures at one time (Fig. 4). Therefore, virtually all the program-induced savings occur at one time for audit+loan programs but are spread over many months for audit-only programs.

DIFFERENCES IN SAVINGS FOR DIFFERENT YEARS OF PARTICIPATION

Net and total energy savings due to a particular conservation program can change from year to year because of changes in the characteristics of the participants, changes in program design and implementation, and changes in the external environment.

The BPA Residential Weatherization Program provides an interesting example of these changes (BPA 1982). BPA's residential retrofit efforts began with a pilot program, which operated between 1980 and 1982. The regionwide successor to the pilot program began in 1982. A special experiment was conducted in Elmhurst, Washington to compare the traditional home energy audit with a program that relied on contractors to determine which measures are suitable for each home. BPA conducted detailed evaluations of all three programs, including collection and analysis of electricity billing data for samples of participants and nonparticipants.

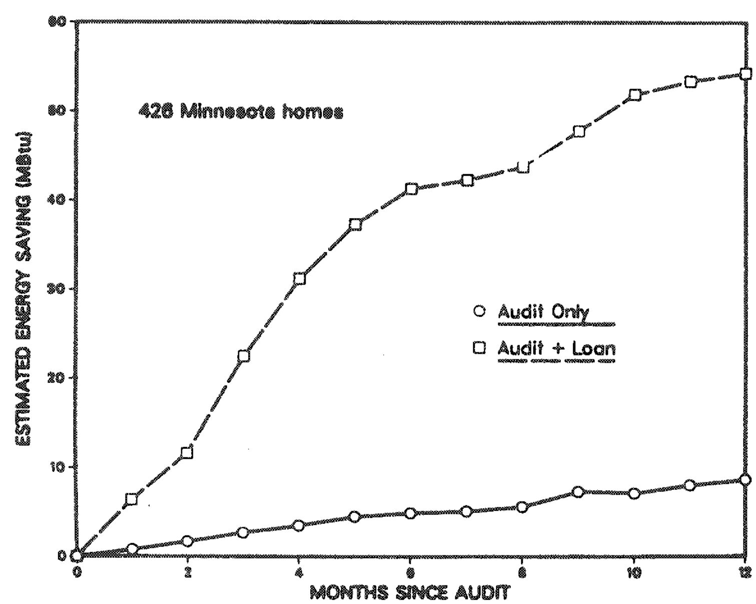

Fig. 4. Estimated energy savings due to retrofit measures installed after home energy audits for Minnesota households that received only an audit and for households that received both an audit and a low-interest retrofit loan (Hirst 1985).

Comparison of one-year total and net electricity savings across these different cohorts (Table II) shows substantial declines. It is likely that total and program-induced savings decreased from year to year because households, on their own, adopted energy conservation practices and measures before participating in the BPA program. Prior actions reduced the potential savings available for capture by BPA programs.

This hypothesis is supported by the changes in preparticipation annual electricity use, which declined from 29,000 kWh/year for households who participated in the pilot program in 1981 to 26,000 kWh and 24,000 kWh for households who participated in the regionwide program in 1982 and 1983, respectively. Average preparticipation use was 25,000 kWh for households who participated in the Elmhurst program in 1984. The general decline in preparticipation electricity use from year to year is probably due primarily to increases in electricity prices in the Pacific Northwest. As discussed in the preceding section, the real price of electricity increased by roughly 70% between 1980 and 1984.

The BPA program changed between the 1981 Pilot and the 1982 regionwide but did not change between 1982 and 1983. The pilot program offered zero-interest deferred-payment loans to finance installation of retrofit measures, while the regionwide program generally offered cash rebates. Thus, the 1981 participants faced a slightly different program than did the 1982 and 1983 participants.

The mix of utilities participating in the BPA program changed over time. The pilot program was limited to 11 small public-power utilities. The regionwide program was available to all utilities throughout the four-state BPA service area. More homes were retrofit in public utilities (vs private utilities) and west of the Cascade mountains (vs east of the mountains) in 1983 than in 1982. The 1984 participants are from Elmhurst, located west of the Cascades and served by a public utility.

Table II. Preparticipation electricity use and one-year savings (kWh/yr) for households that participated in the BPA Residential Weatherization Program

Year of participation	Preparticipation electricity use	One-year savings	
		Total	Net
1981-pilot	29,400	5,400	3,800
1982-regionwide	26,200	5,000	4,100
1983-regionwide	23,800	2,700	2,100
1984-Elmhurst	25,200	3,300	2,700

Source: Bronfman and Horowitz (1986); Hirst (1986); Goeltz, Hirst and Trumble (1986).

The characteristics of participant households changed somewhat over time. Pilot program participants were substantially different from eligible nonparticipants; participants had higher incomes and used more electricity before participating. Participants and nonparticipants in the regionwide program, on the other hand, were quite similar.

The external environment - electricity prices and incomes - changed substantially during the period considered here. As noted above, electricity prices increased sharply during the initial years (until 1983), then increased slightly in 1984 and remained flat between 1984 and 1985. Average incomes throughout the region declined during the early years and then increased after 1983.

Use of wood for space heating in these homes was probably affected by these changes in electricity prices and incomes. Although reliable data are lacking, anecdotal evidence and results from our evaluation of the regionwide program suggest that use of wood (as a substitute for electricity) increased during the first few years of this period and then stabilized or even decreased slightly.

The extent to which these changes in the program, in the utilities participating in the program, in electricity prices and incomes, and in wood use affected total and net electricity savings is unknown. However, it is virtually certain that, together, these and other forces led to the observed changes in savings from year to year. Put another way, there is no evidence to support the assumption of constant electricity savings.

CONCLUSIONS

This paper reviewed evidence, primarily from residential conservation programs in the Pacific Northwest, on the dynamics of energy savings. Assumptions often used in forecasting models and integrated planning models about program participation and energy savings may be incorrect. In particular, the assumption that program-induced energy savings for a particular group of participants and for participants in different years are constant is incorrect.

The available literature on temporal changes in program-related energy savings is almost nonexistent. [A search of the Buildings Energy Compilation and Analysis data base, maintained at Lawrence Berkeley Laboratory, identified no relevant studies beyond those discussed here (Goldman 1986).] The only studies we found that dealt with changes in energy savings related to year of participation were those conducted for the Bonneville Power Administration on their residential retrofit programs. Studies of similar programs in other parts of the country as well as studies of other types of conservation programs are much needed.

Similarly, we found few studies that examined the dynamics of savings for the same cohort of participants. Again, the BPA programs offer the most evidence, with additional data available from evaluations of loan programs in Oregon and home energy audit programs in California, Minnesota and Michigan. Here, too, more work is needed to measure the actual energy savings for several years after participation in different types of conservation programs. The limited evidence examined here suggests that energy savings after participation in an audit-only program increase slightly between the first and second years after the audit. On the other hand, energy savings decrease slightly from year to year after participation in an audit plus financial incentive program (although the magnitude of the savings is considerably greater than for participants in audit-only programs). The extent to which these findings are robust with respect to region (upper midwest vs Pacific Northwest in this case), fuel type (natural gas vs electricity), and trends in fuel prices and incomes is unknown. The dynamics of energy savings after participation in other types of programs is also, as far as we can tell, unknown.

If conservation programs are to play an important role as energy resources that can substitute for traditional supply resources, additional evidence - data and analysis - is needed to document the actual energy savings that can be attributed to these programs. Such documentation must include more than one year of participation and more than one year of postparticipation data.

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