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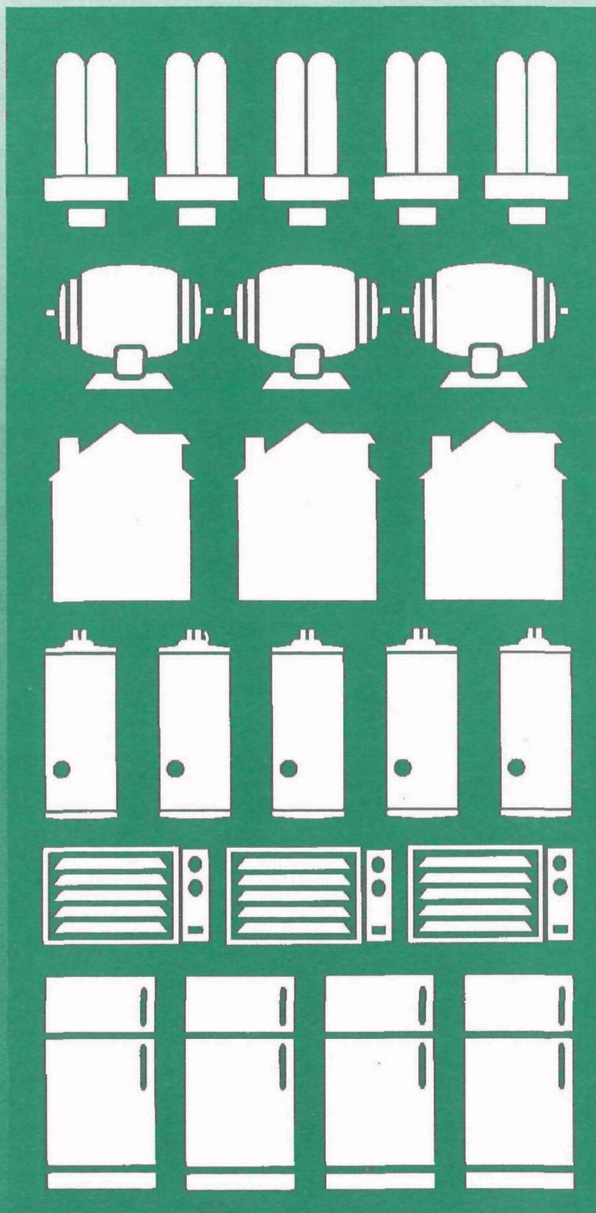
EPA 430/8/B-92-002
March 1993

EPA

Conservation Verification Protocols

A Guidance Document for Electric Utilities Affected by the Acid Rain Program of the Clean Air Amendments of 1990



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ACID RAIN
PROGRAM

If you are interested in obtaining more information on the Acid Rain Program, or in receiving a copy of the Conservation Verification Protocols Reporting Form and Instructions, call:

ACID RAIN HOTLINE

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or write to:

Acid Rain Division (6204J)
U.S. EPA
401 M Street, S.W.
Washington, D.C. 20460

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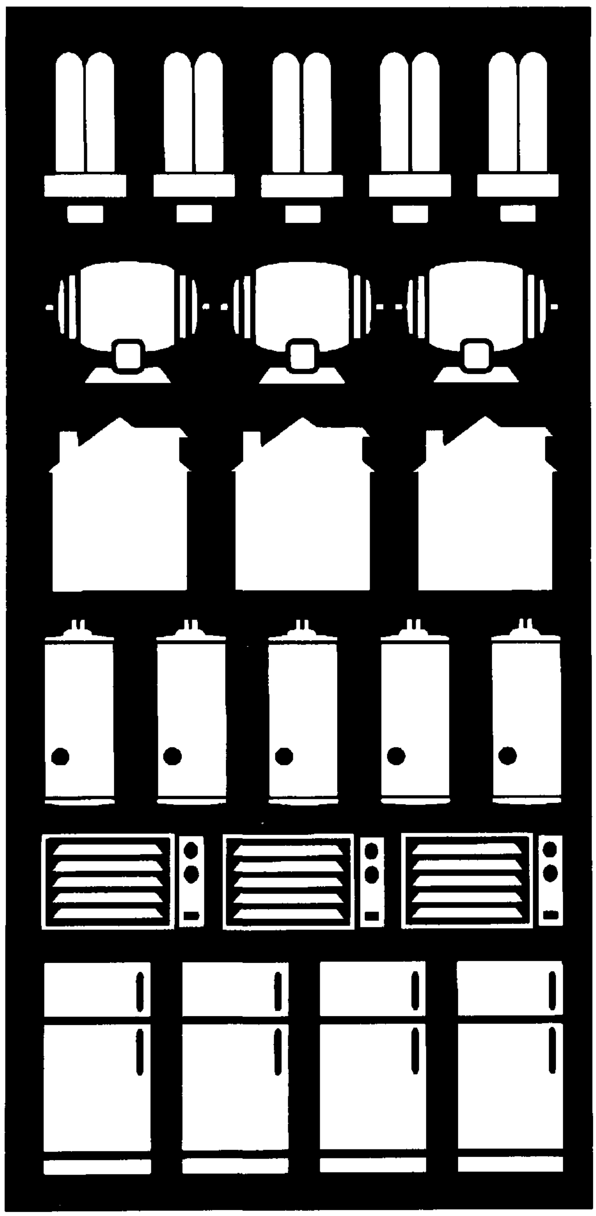

ACID RAIN
PROGRAM

CONSERVATION VERIFICATION PROTOCOLS:

A Guidance Document for Electric Utilities
Affected by the Acid Rain Program of the
Clean Air Act Amendments of 1990

EPA

ACID RAIN DIVISION
U.S. ENVIRONMENTAL PROTECTION AGENCY
JANUARY 1993

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The Conservation Verification Protocols (CVP) were developed and written as a team effort. Barry Solomon was the Project Officer, under the direction of Joe Kruger, Renee Rico and Brian McLean at the Acid Rain Division of EPA. Alan Meier was the Project Leader at Lawrence Berkeley Laboratory (LBL), which assisted EPA in the development of the CVP. Also instrumental was the role of the Conservation Verification Subcommittee of EPA's Acid Rain Advisory Committee, ably chaired by Stan Hulett, which provided valuable guidance, advice, and direction for the content of the CVP. The current Subcommittee membership is listed in Appendix E of this report. Membership of the Subcommittee has included Tom Buckley, Cary Bullock, John Fox, Larry Frimerman, Bill Harding, Jeff Harris (of the Northwest Power Planning Council), Liz Hicks, Eric Hirst, Stan Hulett, Marty Kushler, Steve Nadel, Bob San Martin, Vince Schueler, Sam Swanson, and Steve Wiel (now with LBL). Other people who have given important input to the CVP include Joe Eto, Chuck Goldman, Jeff Harris, Barbara Litt, and Ed Vine of LBL, and Dan Blank, Marilyn Brown, Paul Centolella, Pat Curran, Bill Gavelis, Phil Hanser, John Hoffman, John Hughes, Phil Hummel, Ken Keating, Anne Gumerlock Lee, Rick Morgan, Gil Peach, Judy Tracy, Lloyd Wright, Roger Wright, and Cathy Zoi.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

OFFICE OF
AIR AND RADIATION

Dear Reader:

One of the goals of the Acid Rain Program is the promotion and use of energy-efficient strategies for utility compliance. Because the Acid Rain Program employs a market-based system of flexible compliance, this program allows utilities to choose least-cost strategies, including the use of energy conservation programs. In addition to the overall flexibility, Congress provided EPA with two specific provisions that provide additional incentives for conservation, the Conservation and Renewable Energy Reserve, and the Reduced Utilization planning requirements.

One important step in promoting the use of energy conservation programs is the development of rigorous yet flexible quantification methods for verifying that utility conservation programs are reducing energy consumption. Good verification will lead to increased confidence that these programs produce reliable energy savings, and increase knowledge about what kinds of programs are the most successful.

Our Protocols, which are designed for application to the Acid Rain Program as well as for review and adoption by rate-making authorities, have three goals:

- Conservation verification protocols should be strongly oriented toward **measurement** of energy savings, rather than engineering estimates.

- Conservation verification protocols must be **flexible** since energy conservation is a diverse activity.

- Verification of energy savings should be **cost effective** and should require a level of data and analysis appropriate for specific measures and programs.

Since the practice of verification of energy conservation savings based on program evaluations is rapidly evolving, EPA expects to revise these protocols, perhaps several times over the coming years. We look forward to working with all interested parties to increase the success of energy efficiency programs and acid rain control.

Eileen B. Claussen
Director, Office of Atmospheric Programs, EPA

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Executive Summary

The Conservation Verification Protocols (CVP) have been prepared by EPA as part of its mission to implement the Acid Rain Program of the Clean Air Act Amendments of 1990. The Acid Rain Program has a goal of reducing SO2 emissions by 10 million tons from the 1980 level. Beginning in the year 2000, most electric utilities that burn fossil fuels will have to hold enough SO2 emission allowances to cover their emissions.

Energy efficiency programs can be an important component of utility acid rain compliance strategies because they can help meet customer demand for electricity with reduced emissions of SO2. In addition, the Acid Rain Program has two explicit conservation incentives, which are linked through opportunities to earn or save a new tradable commodity, the emission allowance. The verification of energy efficiency savings under these incentives is thus essential to the credibility of the market approach. Most investor-owned utilities that qualify for these incentives will probably have their energy savings verified by procedures specified by their state Public Utility Commission (PUC). The primary users of the CVP under the Acid Rain Program are expected to be public-power utilities.

The CVP is designed to be rigorous without being burdensome on the utility or the regulator. The CVP has the added benefit of helping to ensure the cost-effectiveness of utility conservation programs and SO2 emission reduction measures, as well as the reliability of energy savings from the measures.

Conservation Incentives in the Acid Rain Program

The Conservation and Renewable Energy Reserve (CRER) is a special pool of 300,000 emission allowances, which is available to utilities that meet electric demands with either conservation or renewable energy generation. To qualify for the CRER, a utility must have at least one affected unit, a least-cost plan, and net-income neutral rates for conservation measures (to be certified by the U.S. Department of Energy). In addition, the utility can only receive credit for demand-side energy conservation measures.

The Reduced Utilization provision applies to the 110 Phase I plants who must lower their emissions in 1995-1999. In contrast to the CRER, this provision allows for supply-side efficiency measures and does not require least-cost planning or net-income neutrality. There is no prescribed limit to the number of allowances that these utilities can save through conservation.

Verifying Energy Savings: The CVP Approach

The CVP allows for two general savings paths (Figure 1): Monitored Energy Use, or Stipulated Savings. The Monitored Energy Use Path is the preferred verification approach and its goal is to measure energy use in such a way as to infer net energy savings, i.e., the savings attributable to the utility conservation program. The Stipulated Savings Path includes procedures for estimating savings, as well as simple equations and standard values for estimating stipulated energy savings from a limited number of conservation measures for which expected energy savings are well understood. This path also includes criteria for developing program-specific engineering estimates that may be used by a utility in limited cases. Finally, the CVP also includes guidelines for verifying the persistence of energy savings from conservation measures.

Path I: Monitored Energy Use

The preferred verification approach is to infer energy savings through the measurement of energy use. The key features of this verification path include:

- Specifying a reference case;
- Adjusting for differences in factors such as weather, operating hours, and production rates;
- Determining net energy savings;
- Establishing the appropriate statistical confidence in the savings.

The reference case is the set of conditions and levels of service from which the energy savings are to be estimated. To develop the reference case, the energy use of a group not participating in the conservation program is often used.

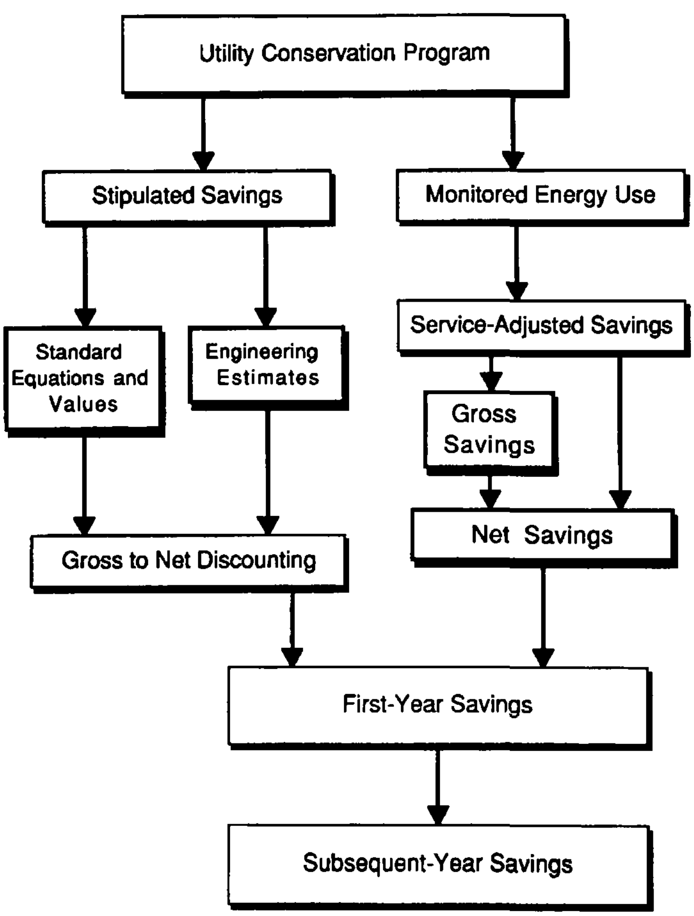
Raw energy savings, i.e., simple differences in metered energy use, nearly always require adjustments to account for differences in metering periods, weather, indoor temperature, and levels of service. The CVP requires these adjustments for both the reference case and the customers participating in the conservation program.

The CVP requires estimation of net energy savings, i.e., the savings attributable to the utility conservation program. A standard method for estimating net savings involves comparing the gross savings of customers participating in the program to the change in energy use of a similar group not participating in the program (the "comparison group"), some of whom may have installed similar conservation measures on their own initiative. The comparison group will normally be considered the reference case. If this approach is not followed, the CVP allows for other ways to develop a reference case and to derive net savings. For example, net savings may be estimated indirectly through market research, surveys, and inspections of non-participants.

There will be uncertainty about the magnitude of energy savings from utility conservation programs, because of the many factors that can bias estimates of energy savings. An objective of the CVP is to award allowances for savings that occurred with reasonable certainty. The CVP requires that the savings be expressed in terms of the utility's confidence, based on statistical analysis, that the true savings were equal to or greater than those for which it applied. Based on the state of the art of energy conservation evaluation, a 75% confidence (or 1-tailed hypothesis test) is required.

Energy savings that have been adjusted for levels of service and that satisfy the 75% hypothesis test are considered "first-year savings" if the reference case captured net savings (e.g., through use of a comparison group as discussed above).

Figure 1. Overview of Verification Options



Subsequent-Year Savings

A major uncertainty in utility conservation programs is how long the energy savings persist over time. Three options are available for verifying savings in subsequent years: monitoring and inspection, inspection only, and a default.

If monitoring and inspection is used to verify persistence of savings, a utility must continue to meet the 75% hypothesis test used for the first year. It must measure energy use in the 1st and 3rd subsequent years. After year 3, the utility may continue to receive full credit for its savings for the lifetime of the measure.

If the inspection only option is used, a utility can receive credit for at least 75% of the energy savings in subsequent years for up to half of the measure's lifetime. In the case of "passive conservation measures" (e.g., wall insulation), a utility may receive credit for 90% of the savings for the full lifetime of the measure.

The default option provides for 50% of the 1st-year savings to continue in subsequent years if the utility discontinues any form of monitoring or inspection, for half the lifetime of the energy conservation measure.

Path II: Stipulated Savings

While the CVP is oriented toward measurement of energy savings, in some cases utilities may use simple algorithms that have been provided for a limited number of technologies. In other cases, they may develop their own engineering estimates. In such cases, a utility may convert gross savings into net savings through simple multiplication by a default factor, or by documenting an actual "gross-to-net" ratio. Subsequent year savings for the this path are estimated by the same procedure used in the Monitored path (see previous discussion).

The rationale for the Stipulated Savings approach is that the performance of some measures is well understood and may not be cost effective to monitor. Use of stipulated savings in these limited circumstances should prove very attractive to small utilities and ones with new conservation programs. The initial list in the CVP contains 7 measures for which there are stipulated savings: constant-load motors, exit sign lights, amorphous metal transformers, commercial lighting, new refrigerators, street lights, and water heater insulation blankets.

In circumstances in which extensive measurement and analysis are not cost effective or feasible, an engineering estimate of energy savings will be acceptable. These circumstances include any of the following situations:

- Measurement costs would exceed 10% of program cost.
- Program-wide energy savings are expected to be 5000 MWh/year or less and no customer accounts for more than 20% of total savings.
- Energy savings are expected to be less than 5% of use of the smallest isolatable circuit (e.g., residential lighting efficiency improvements).

Purpose and Philosophy Behind the Approach

The U.S. Environmental Protection Agency (EPA) has prepared the Conservation Verification Protocols (CVP) as part of its mission to implement the Acid Rain Program authorized by Title IV of the Clean Air Act Amendments of 1990. Two cornerstones of the Acid Rain Program are SO_2 emission allowance trading and energy efficiency improvements as part of compliance strategies of affected electric utilities. These cornerstones are linked through two explicit incentives for energy conservation that are described in more detail in the Acid Rain rules: the Conservation and Renewable Energy Reserve (CRER) discussed in the Allowance System Rule (40 CFR Part 73), and the Reduced Utilization (RU) provision for Phase I affected units discussed in the Permits Rule (40 CFR Part 72). These two incentive programs allow electric utilities to earn or save allowances through qualified conservation measures.

Each emission allowance gives its holder (usually a power plant) the right to emit one ton of SO_2 during or after a specified year, after which the allowance must be retired. Alternatively, a holder of allowances can bank them for future use or sell them to another person at a negotiated price. Allowances issued by EPA under the Acid Rain Program may have considerable market value. Consequently, energy savings achieved under these incentive provisions need to be verified by either the electric rate regulator or the EPA.

The main goal of the CVP is to credit electric utility conservation programs for energy savings that they caused, as a part of an SO_2 emissions reduction strategy. An ancillary goal is to describe consistent procedures for measuring and verifying these savings.

The CVP is intended to describe good practice for impact evaluators of electric utility energy conservation programs. It is not intended to be prescriptive. While the formal federal verification requirements will end when the CRER and RU programs expire, users may want to continue to follow the CVP or to use them in other applications such as state-level conservation programs. A good verification program should be rigorous without being burdensome on the utility or the regulator. The CVP will have the added benefit of helping to ensure the cost-effectiveness of utility conservation programs and SO_2 emission reduction measures, as well as the reliability of actual energy savings from these programs. Eventually, energy savings should be as reliable for providing energy services to utility customers as energy production measures are currently.

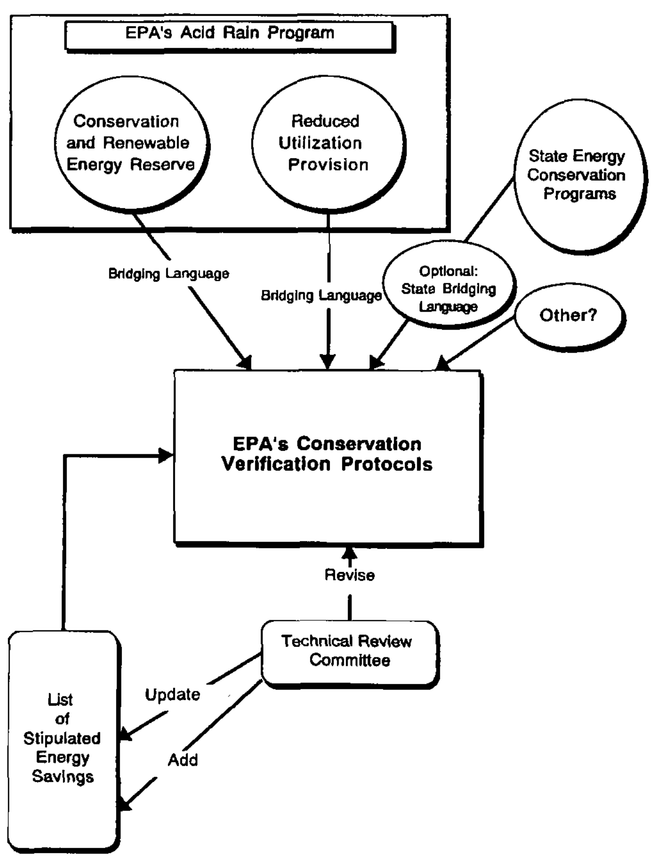
The CVP has been written to be accessible to all electric utilities: large and small, public and private. In addition, it can be used by utilities well versed in evaluation of energy conservation programs, as well as those who are new to this field.

The CVP described herein is intended to provide stronger motivation for monitoring energy savings from conservation measures and programs. The CVP embodies an incentive structure designed to encourage more and improved measurement and less reliance on estimation of energy savings, while allowing for simple verification procedures through engineering estimates and stipulated savings (i.e., standard algorithms for calculating energy savings from specific measures) when that approach best fits the circumstances of the utility. The stipulated savings approach, while generally much less expensive and time consuming to implement, is designed to be conservative and will often result in less energy savings credit than will a conventional verification procedure. More typically, representative customer groups will be analyzed by the utility to determine the energy savings.

The CVP is a guidance document for electric utilities, which may be revised periodically. Moreover, as explained in Section I of this report, many utility applicants to the CRER will not have to use the CVP Consequently, use of the CVP is not a requirement, though the reader should note that under EPA's Allowance System Rule applicants to the CRER must demonstrate to the satisfaction of the EPA Administrator that in the case of qualified energy conservation measures, energy savings have been actually secured. EPA will consider the CVP as a source of guidance for reasonable conservation verification procedures. The Rule allows, but does not require, applicants that do not qualify to have verification performed by their state public utility commission (the criteria for which are explained in Section I) to do so through use of the CVP.

The CVP has been designed to create a single set of protocols with sufficient flexibility to accommodate Acid Rain Program provisions as well as future applications by other federal or state agencies. Thus, the CVP is self-standing and independent of the individual regulatory programs. This necessitates language linking the individual allowance provisions and the CVP. Section I also specifies the administrative details unique to each regulatory program, such as the timing, reporting and auditing, etc. Figure 2 illustrates the relationship between the allowance schemes and the CVP.

Figure 2. Relationship Between EPA's CVP and Acid Rain Program Allowances



Energy conservation is a diverse activity. No general protocols for verifying energy conservation savings can anticipate every kind of conservation technology, program, or activity that will be undertaken by utilities. Procedures for verifying the energy savings must therefore be flexible enough to accommodate verification of the common conservation measures as well as new efficiency options. For example, utility programs have focused on residential and commercial buildings while the Clean Air Act will also permit utility conservation programs in the industrial sectors. Evaluation and verification techniques developed for the residential and commercial sectors will not be directly transferable to the industrial sectors. For these reasons, the CVP will give general guidelines for verifying energy savings rather than specification of the verification procedure for each kind of measure.

The CVP is strongly oriented toward measured energy savings rather than engineering calculations. Metering and evaluation may consist of utility bill analysis, periodic inspections of retrofitted equipment and confirmation of their continued operation. The cost of savings verification will depend on the kind of program and the verification procedures used by the utility. If the anticipated extra cost of evaluation reverses the cost-effectiveness of the conservation program, then a less stringent evaluation will be permitted. For purposes of discussion, it is generally expected that 5-10% of the program cost will be devoted to savings verification. No specific measurement technology is required; a utility can use whatever approach will achieve the verification requirements at lowest cost. It is anticipated, however, that most utility verification programs will rely on a mixture of utility billing data, simple submetering, as well as stipulated savings (to be explained below). In limited cases engineering estimates of energy savings can be used by a utility.

A rapidly-increasing body of literature quantifying the field energy savings from various conservation measures is emerging. In some cases, the savings are sufficiently reliable that a comprehensive verification program may not be needed. A preliminary list of these measures, with stipulated energy savings or a stipulated energy savings formula, has been developed by EPA. The stipulated savings may come from several sources. Where laboratory measurements have proven to be reliable indicators of field electricity use, extensive metering may not be necessary. Finally, the stipulated savings will be given for some measures when reasonably reliable savings have been achieved over a wide range of verifications. The savings will be discounted, however, to reflect uncertainty that occurs when field verification is not undertaken, savings that would have occurred without the aid of the utilities, and to encourage utilities to verify the savings from their own programs.

While the list of measures with stipulated savings is not comprehensive, it will reduce the monitoring and verification burden and allow utilities to focus on DSM programs where impacts are less predictable. The provision for stipulation also offers some energy savings credit to conservation programs that were undertaken without adequate verification plans. The list and the stipulated savings will be subject to periodic, professional reviews and revisions.

This document uses considerable specialized vocabulary, some of which has not gained general acceptance. The ultimate reference for meanings of terms not explicitly defined in this document is the recent report by Hirst and Sabo.[1] A list of definitions of the most important verification terms is presented in Appendix A.

The practice of verification of energy conservation savings based on program evaluations is rapidly evolving. While an increasing number of state governments are instituting verification standards for their investor-owned utilities, even the leading states have been reassessing their own protocols. Additionally, Section 111 of the Energy Policy Act of 1992 will accelerate these activities, since it amends the Public Utility Regulatory Policies Act of 1978 and defines integrated resource planning to require the verification of energy savings achieved through conservation. The Agency strongly believes that the CVP needs to remain flexible in order to allow utilities ample freedom to evaluate their energy conservation savings in the most cost-effective manner. Thus, EPA expects to revise the CVP based on comments from the public and other information, in 1993 and possibly again in later years.

[1] E. Hirst and C. Sabo, *Electric-Utility DSM Programs: Terminology and Reporting Formats* (ORNL/CON-337), Oak Ridge National Laboratory, Oak Ridge, TN, October 1991.

Linkage with the Acid Rain Program

Section 1

Background

The purpose of this section is to provide background and context for the CVP by linking it with EPA's Acid Rain Permit and Allowance System rules that were promulgated in December 1992 (40 CFR §§ 72.43 and 72.91, and Part 73, Subpart F, respectively). Application requirements and applicability criteria will be discussed, along with the differences between the Conservation and Renewable Energy Reserve (CRER) and the Reduced Utilization (RU) provision and who is responsible for verification of energy savings. For a more complete discussion of these issues, the reader is referred to 40 CFR §§ 72.43 and 72.91, and Part 73, Subpart F.

The overall goal of the Acid Rain Program is to achieve significant environmental benefits through reductions in emissions of SO_2 and NO_x, the primary causes of acid rain. To achieve this goal at the lowest cost to society, the program employs both traditional and innovative, market-based approaches for controlling air pollution. In addition, the Program encourages energy efficiency and pollution prevention.

Title IV of the CAAA sets as its primary goal the reduction of annual SO_2 emissions by 10 million tons below the 1980 level. To achieve these reductions, the law requires a two-phase tightening of the restrictions placed on fossil-fuel-fired power plants. Phase I begins in 1995 and affects 110 mostly coal-burning electric utility plants located in 21 eastern and midwestern states. Phase II, which begins in the year 2000, tightens the annual emissions limits imposed on these large, high-emitting plants, and sets restrictions on smaller, cleaner plants fired by coal, oil, and natural gas. The program affects existing plants with an output capacity of 25 megawatts or greater, and new utility units under 25 megawatts that use fuel with a sulfur content greater than 0.05%.

The Acid Rain Program creates a new tradable commodity, the SO_2 emission allowance. The verification of energy efficiency savings under the CRER and RU programs is essential to the credibility of the market approach. Once these programs end, EPA's requirements for continuous emissions monitoring of SO_2 will provide automatic verification of emissions reduction (40 CFR Part 75).

Conservation and Renewable Energy Reserve (CRER)

The CRER is a special pool of 300,000 total allowances taken from the Phase II allocations, which is available to utilities that meet electric demands with either conservation or renewable energy resources. Congress established this Reserve to provide an early "jump start" to energy efficiency and renewable energy strategies for reducing SO_2 emissions. There are several criteria that an electric utility must meet in order to qualify for a share of these bonus allowances in the CRER, which are issued on a first-come, first-served basis (see also Table 1):

- A utility must own or operate one or more affected power plant units, or be at least the partial owner or operator of an affected unit (see 40 CFR § 73.82 (a), and EPA's proposed rule on Acid Rain Allowance Allocations and Reserves at 57 FR 29965-30024 for a list of these affected units and EPA's proposed yearly base allowance allocations).
- Beginning July 1, 1993, a utility with at least one Phase I affected unit may apply to the CRER for allowances for verified energy savings (post-hoc) that occur from January 1, 1992 to December 31, 1994, or until all the allowances in the Reserve are allocated, whichever occurs first (40 CFR §§ 73.82 (g)(1), 73.80 (b)).
- Beginning July 1, 1993, a utility with only a Phase II affected unit (or units) may apply to the CRER for allowances for verified energy

savings (post-hoc) that occur from January 1, 1992 to December 31, 1999, or until all the allowances in the Reserve are allocated, whichever occurs first (40 CFR §§ 73.82 (g)(1), 73.80 (b)).

- A utility must have a "least cost plan" or planning process for meeting future electric needs, which may consider social and environmental externality costs (40 CFR § 73.82 (a)(4)).
- Investor-owned utilities must be subject to a rate-making process that ensures net income neutrality, including a provision allowing the utility's net income to be compensated in full for lost sales attributable to its conservation program (40 CFR § 73.82 (a)(9)). The U.S. Department of Energy will begin certifying the net income neutrality of State Public Utility Commissions' (PUCs') electric rate-making procedures on January 1, 1993 (40 CFR § 73.82 (g)(2). Bonus allowances may be awarded conditionally pending DOE certification (40 CFR § 73.84 (c)).
- Utilities applying to the CRER must use qualified demand-side energy conservation measures (listed in Appendix A(1) of 40 CFR Part 73, Subpart F) that were installed on or after January 1, 1992, or measures that do not appear on the list but which qualify because they meet the requirements of 40 CFR § 73.81.
- Qualified measures must be consistent with a utility's least-cost plan or least-cost planning process; must be funded in whole or in part by the utility; must increase customer end-use efficiency; must not increase the use of any other fuels (other than renewables, industrial waste heat or gases); and must not be programs that are solely informational or educational (40 CFR §§ 73.81 (a)(2)(i), 73.81 (b), 73.82 (a)(3)).

A qualified electric utility will earn allowances from the CRER based on a formula that assumes an emissions rate of 0.4 pounds of SO_2/mmBtu (or .004 pounds/kWh). Verified conservation savings of 500 MWh, for example, would earn one allowance.

Table 1.
Qualifying Criteria and Applicability for Electric Utilities Using Energy Efficiency Incentives Under Title IV of the CAA

FEATURE	CRER BONUS ALLOWANCES	REDUCED UTILIZATION
Who May Apply?	Owner/Operator of Any Affected Unit	Owner/Operator of Phase I Affected Units
Utilities Must Have a Least-Cost Plan and Net Income Neutrality?	Yes	No
Type of Efficiency Measures That Qualify	Demand-Side Measures Only	Both Demand- and Supply-Side
Emission Rate at Which Allowances Earned/Saved	004 lbs/kwh (4 lbs/mmBtu)	Average Emission Rate of Phase II Units During Phase I Year
How Many Allowances Available?	300,000 Total	No Limit
Timing of Program	1992-94 (Phase I Utilities) 1992-99 (Phase II Utilities)	1995-1999 (Phase I)

Reduced Utilization (RU) Provision

Congress recognized in establishing the Acid Rain Program that during Phase I utilities might circumvent SO_2 emissions reductions by shifting load to units not regulated in Phase I. To avoid this potential problem, the rules implementing the CAAA require that during Phase I, a unit whose utilization is reduced below its 1985-87 baseline level must surrender allowances representing a shift of emissions to unregulated units, unless such under-utilization is accounted for in one of several ways. One way to account for under-utilization is through energy conservation. The RU conservation option may be especially valuable to some utilities, since it allows them to account for reduced load at Phase I units (and avoid surrendering allowances) by receiving credit for system-wide energy savings. Unlike the CRER program, under RU a Phase I affected unit would effectively receive credit for conservation at the SO_2 emission rate of the units to which load would otherwise have been shifted (primarily Phase II units). An affected utility could thereby potentially save allowances at a much greater rate than could be earned based on the formula-based CRER.

The criteria for a utility to use energy conservation under the RU provision (40 CFR § 72.43) have fewer restrictions than do the criteria under the CRER (Table 1). This provision is applicable only to electric utilities with Phase I affected units, and that file RU plans with EPA pursuant to § 72.43. Such utilities may use both demand-side measures and supply-side (i.e., power generation, transmission, or distribution efficiency) measures that result in verified energy savings to reduce utilization of Phase I units below 1985-1987 baseline levels. The supply-side conservation measures are listed in Appendix A(2) of 40 CFR Part 73, Subpart F; supply- and demand-side measures installed as early as January 1, 1988 may qualify, as long as the energy savings that occur during the RU period of 1995-1999 because of those measures are verified.

Verification of energy savings is required for each year in which energy conservation measures contribute to the RU. A Phase I unit may be attributed the savings from any conservation measures (other than improved unit efficiency measures) instituted within the unit's utility system.[1] A RU plan must be filed with EPA by November 1 of the year in which RU occurs. An initial estimate of energy conservation savings must be filed in the annual compliance certification report by March 1 of the following year. The utility unit's designated representative must submit the verification results as part of a confirmation report by July 1 of each year for which an affected unit's annual compliance certification report is submitted to the EPA. Thus the first possible verifications would take place in the first 6 months of 1996 for energy savings that occur in 1995, following submittal of a RU plan by November 1995. The EPA Administrator may grant, however, for good cause shown, an extension of the time to file the confirmation report. If the energy savings do not result in utilization of Phase I units below baseline levels such savings do not have to be verified.

In contrast to the CRER program, a utility using the RU provision does not have to meet the least-cost planning or net income neutrality requirements, and since it is freeing up its own allowances, there is no limit to the amount of conservation for which it may receive credit. Finally, unlike the demand-side measures, which are installed at the customer side of the meter, the supply-side conservation measures at the power plant or in the transmission and distribution system will result in energy savings that are all directly caused by the electric utility. Consequently, "net" energy savings, as discussed in the next section, can be assumed by utility applicants to equal "gross" energy savings in the case of supply-side conservation measures. Separate application forms for RU plans will be available at a future date.

Criteria for Deferring Conservation Verification to States

The primary users of the CVP are expected to be public-power utilities. Most investor-owned utilities in states that qualify for the CRER will probably have their energy conservation savings verified by procedures specified by the PUC, and EPA recognizes that it would be burdensome to require these utilities to use two separate verification procedures. Therefore EPA will defer the conservation verification requirement to PUCs based on criteria discussed in the Allowance System Rule (40 CFR § 73, Subpart F) and summarized below.

EPA will require state PUC verification of energy savings claims of electric utilities if the PUC uses periodic evaluation of energy savings to determine any type of performance-based rate adjustment for conservation programs (40 CFR § 73.82 (c)(1). For RU conservation (40 CFR § 72.43), use of qualifying state PUC verification is optional. The Agency believes that the verification performed by state regulators is likely to be fairly rigorous when the evaluation of energy savings will be used to determine the cost of the conservation incentives to the ratepayers. In the case of both "shared savings mechanisms" and "lost revenue adjustment mechanisms", regula-

[1] If certain conditions are met, a unit that is part of a holding company system may be attributed savings from conservation within any part of the holding company system. See 40 CFR § 72.43(b)(2)(iv).

tors must evaluate energy savings achieved by utility conservation programs in order to determine the proper adjustment to a utility's rates necessary to recover lost revenues or to provide a financial award.

Under this approach for deferring conservation verification to a state, the use of engineering estimates of energy savings is allowed. The requirement to periodically modify performance-based rate adjustments through the evaluation of net energy savings, however, will help to ensure that a State is committed to good evaluation practices. EPA recognizes that evaluation of energy savings is a young and rapidly evolving field and that many States and utilities begin their evaluation programs with engineering estimates. Most evaluation experts agree that while engineering estimates are useful, they should be supplemented with statistically valid measurements of the decrease in energy use resulting from utility energy conservation programs (i.e., net savings). These measurements should reflect both the actual number of measures installed and an ex post estimate of the energy savings achieved per measure.

EPA believes that this approach toward conservation verification and deferral to state PUCs is consistent with the approach of the Acid Rain Program, which encourages flexibility but insists upon appropriate measurement standards. While a minimum standard for deferring conservation verification to states is being established, EPA is not prescribing standard verification methods or techniques. States have the flexibility to design their own verification protocols, as many have. Because of the diversity of evaluation methods and the ongoing evaluation activities of state agencies, electric utilities, and other professionals, EPA believes that this approach will be more effective in ensuring good practice than would mandating specific methods or requiring universal use of the CVP.

Forms and Data Requirements for Users

Users of the CVP should summarize their verifications results on the CVP Reporting Forms for the CRER and RU, to be published by EPA in early 1993. Applicants to the CRER should send this Form and any attachments (or a state PUC-approved conservation verification, where applicable), to EPA at the address provided at the end of the Form Instructions. Applicants should call the Acid Rain Hotline (617-674-7377) in February 1993 to receive a copy of the CVP Reporting Form and Instructions. EPA will begin its review of the verified conservation savings claims as the CRER application period opens on July 1, 1993, on a first-come, first-served basis. EPA will review applications to determine whether they meet the requirements of Subpart F of 40 CFR § 73. Verification claims may be based on the CVP, a state PUC-sanctioned method, or other methods. Use of other methods, however, is likely to increase the time period for verification by EPA of an application compared to that needed when the CVP or state PUC-sanctioned method is used, because EPA would need to evaluate the alternative method as well as the application claim. Deficient verification claims will lose their place in line for bonus allowances if they must be sent back to the applicant for revision (see 40 CFR § 73.84(b)). Nonetheless, there is no deadline for sending in applications to the CRER (although the program has a limited duration), nor is there a prescribed reporting period for conservation results.

A detailed evaluation of an energy conservation program requires a large amount of data and statistical analyses. In an attempt to minimize the reporting burden for verification, EPA is requesting applicants to submit general summary data (as will be indicated on the CVP Reporting Forms). Further data collection is needed for the stipulated measures, for information that is not required to be submitted to the EPA, but that should be maintained in a utility's files in case an audit is initiated by the Agency (40 CFR § 73.82 (c)(3)). An audit of a conservation verification might be used to determine whether an incorrect number of allowances was disbursed to a utility, or to collect more detailed information about the performance of energy conservation programs and SO_2 emissions offsets or reductions. Adequate verification programs by utilities should minimize the number of audits conducted by the EPA. If such an audit determines that an applicant's energy savings claims were overstated during the verification, EPA may reduce the allocation of allowances or require their surrender by the applicant (40 CFR § 73.82 (c)(4)).

Verifying Energy Savings

Introduction

As indicated earlier, the philosophy of the CVP is to present general verification procedures rather than specific requirements. This approach offers utilities the maximum amount of flexibility in developing verification methods (and may be the only possible solution given the range of energy efficiency programs and measures covered by the CVP). Nevertheless, some consistency of method is needed in order to permit quantification of the energy savings and objective evaluation of energy savings claims. Two general savings verification paths are described: stipulated and monitored. The two paths are shown earlier in Figure 1 and are discussed in detail below. This section also discusses requirements for determining the persistence of energy savings, and procedures for quantifying the impact of supply-side efficiency improvements.

Path I: Stipulated Savings

The CVP is oriented towards the estimation of savings based on measurement of energy use. In certain cases, however, the utility may use the simple Stipulated Savings methods given in Appendix D to earn credit for the applicable conservation measures instead of relying on a monitoring program. These Stipulated Savings methods are of two different types: (1) algorithms for calculating energy savings for specific measures; and (2) a set of criteria for using best-engineering practices.

Stipulated Savings for Specific Measures

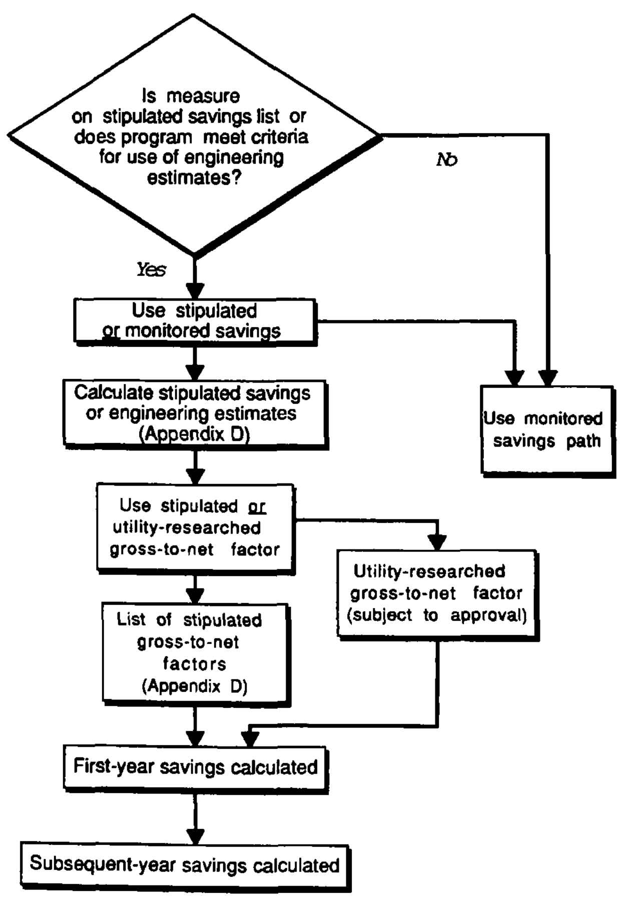
The rationale for the list is that the performance of some conservation measures is well understood and may not be cost effective to monitor. Use of Stipulated Savings in these limited circumstances should prove especially attractive to small utilities and ones with new conservation programs (although the energy savings assumptions are often conservative). The Stipulated Savings List contains the following kinds of measures:

- Common measures whose savings are well-documented in the literature (e.g., refrigerators).
- Measures where instantaneous metering is an acceptable proxy for first-year savings (exit sign lights).
- Measures where short-term metering is an acceptable proxy for first-year savings (transformers).

In some cases the laboratory test, "label", or other pre-specified efficiency parameter may be a reliable indicator of energy use or savings. For stipulated measures, the utility may calculate energy use and savings based on these values rather than through metering. For example, in a refrigerator rebate program, the utility could calculate energy savings by calculating the differences between the maximum energy use dictated by the federal standard and the labeled consumptions of the refrigerators purchased in its high-efficiency program. This verification procedure would be much less costly than metering because the utility would need only to tabulate labeled values and count installations.

The approach for calculations of stipulated energy savings is outlined in Figure 3. The calculations in the stipulated measures result in gross energy savings. The utility may convert the Gross Savings into Net Savings through simple multiplication by a default factor (the "gross-to-net conversion factor") given in the list of stipulated gross-to-net factors shown in Appendix D; alternatively it can use its own adjustment factor based on its research. The stipulated gross-to-net factors range from 0.6 - 0.9, and are based on

Figure 3. Stipulated Savings Path



experience with utility conservation programs. It should be noted, however, that net energy savings estimates for similar conservation programs can vary widely, and if a utility develops its own estimate through internal research (see pp. 24-26) it may be able to claim larger net savings than if it uses the stipulated value. The utility may use this factor if it can demonstrate the legitimacy of its analysis to the EPA. Subsequent-year savings for stipulated measures are estimated with the same procedure as in the monitored savings path (see the discussion later in this section).

Good-Practice Engineering Estimates

In certain circumstances, measurement of energy savings is not feasible or practical. These circumstances include any of the following situations:

- Program-wide energy savings are expected to be 5000 MWh/year or less (earning 10 or less allowances).
- Extremely small anticipated energy savings per customer, spread over many customers. (An example might be a residential program involving distribution of compact fluorescents.) Such savings may be difficult to observe in a billing analysis or submetering.
- High cost of monitoring and verifying energy savings. A utility may still want to apply for verified energy savings even though verification through monitoring would cost significantly more than 10% of the total program costs.

Determination of energy savings through energy monitoring is the preferred means of verification. When this is not feasible, in limited circumstances engineering estimates of savings may be substituted. The precise conditions in which engineering estimates can be used are specified in the list of Stipulated Savings.

Path II: Monitored Energy Use

The preferred verification approach is to measure energy use in such a way as to infer energy savings. The following sections describe the key steps in developing a method for converting energy consumption measurements into energy savings. These steps include:

- Specifying a reference case against which to measure savings.
- Adjusting for several factors, such as weather, indoor temperature, and industrial production levels.
- Determining net energy savings, i.e., the energy savings resulting from the conservation program that would not have happened without the utility intervention.
- Establishing the confidence in energy savings.

This discussion concludes with an overview of acceptable measurement procedures and the appropriate duration of metering. No particular measurement technique, however, is prescribed. The intent of the CVP is to suggest what may generally constitute good-practice verification procedures. The discussion begins with specification of the reference case from which to measure the energy savings. Subsequent steps describe the adjustments and other methodological issues.

Reference Case

The "reference case" is the set of conditions and levels of service from which the energy savings are to be estimated. The principal element of the reference case is measured energy use. By definition, the reference case consists of the untreated group's energy use adjusted to service levels from the treated group. This differs from many definitions of reference cases, where the untreated (pre-retrofit) energy use and service levels establish the reference case. In the CVP, service levels from the treated case are preferred as the reference because service levels often change as a result of the retrofit and are more likely to prevail for the subsequent years. (A formulation of this definition is given in Appendix B.)

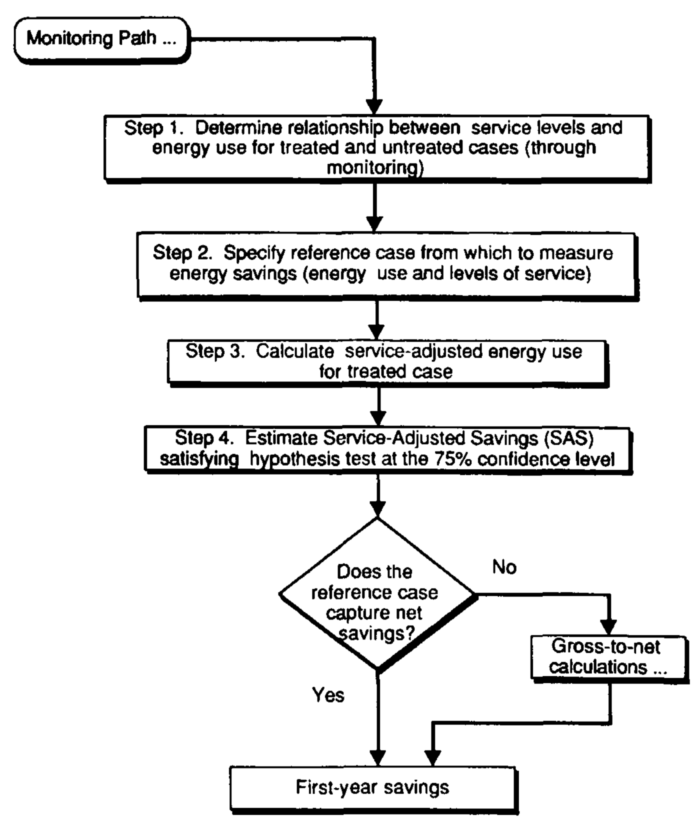
In simple situations such as a conservation program in single-family homes, the reference case is the energy use of the pre-retrofit condition or a comparison group. The reference case, however, also includes levels of service that can affect the level of energy use (and hence estimates of energy savings) such as weather, operating hours, and industrial output. For an insulation program of electric-heated homes, the reference case might consist of the space heating energy use of the homes prior to retrofit, adjusted to the long-term average number of degree-days. More complex situations will rely on data from surveys or inspections. For example, the reference case for a building lighting retrofit program might consist of a similar group of buildings unaffected by the program. In addition, the operating hours and illumination levels should be surveyed in order to adjust for yearly variation.

The specification of the reference case will also determine if the utility is estimating gross or net energy savings. If the reference case captures the impact of the conservation program (rather than only the technology), then the utility may follow the Net Savings path as shown in Figure 1. For example, if the reference case is a similar group of customers that did not participate in the program, then the utility is estimating net energy savings.

Service Adjusted Energy Use and Savings

Raw energy savings, that is, simple differences in metered energy use, will nearly always require adjustments to account for differences in metering periods, weather, and levels of service. These adjustments, to derive the "service-ad-

Figure 4. Steps to Calculate Service-Adjusted Savings



justed energy use" (SAEU) and "service-adjusted savings" (SAS), are described below while the general approach is shown in Figure 4. The major steps involve calculating the SAEUs for the reference case and for the treated case. The difference between the SAEU of the reference case and the SAEU of the treated case is the SAS.

The energy consumption of many activities depends on the level of service required. For example, a house's space heating energy use depends (among other factors) on the outside and inside temperatures, a factory's energy use will depend on the number of products manufactured in that period, and a restaurant's energy use will depend on the number of customers served. Some of the most important service factors are:

- severity of heating or cooling season
- indoor temperature
- operating hours
- conditioned floor area
- production rate (or mix)
- illumination levels

A relationship between the level of service and energy use can usually be developed. For example, space heating energy is a function of the degree-days, and lighting energy use depends on the number of operating hours and the conditioned floor area. These relationships can often be derived through simple regressions of energy use and the level of service determined through measurements, surveys, and other data. For example, EPRI[1] presents one formula quantifying the relationship between energy use and various factors determining the level of service, but other functions may be needed for industrial or special commercial applications. Although there is some uncertainty, these relationships may be used to normalize energy use in two periods with different levels of service. A more detailed description, presented in steps, is given in Appendix B.

When estimating energy savings, energy use should be adjusted to the treated ("post-retrofit") levels of service in all cases except for weather variables or where a long-term average differs from the measurement period. This practice accounts for the fact that energy-efficiency improvements are often made in buildings at the same time that service levels are improved.

Gross and Net Savings Distinctions

The intent of the CVP is to estimate the net energy savings from conservation programs. The utility may specify the reference case such that it captures the net savings. For example, the reference case may be the energy use of an untreated group of similar customers. In this case, the net energy savings for the first year ("first-year savings") emerge directly from the SAS calculation.

The net effects can also be estimated indirectly through market research, surveys and inspections of non-participants. Based on these methods, a utility can determine a "gross-to-net" conversion factor. (Multiplying the gross savings by the "gross-to-net conversion factor" yields net savings.)

A special case of net savings arises when the treated group of customers is effectively the entire population (leaving no untreated group available for comparison). This might occur when a utility targets the sole factory manufacturing a certain product. In this situation, the utility may still receive net savings credits by constructing a plausible scenario of what the customer would have done without intervention by the utility program. This scenario might be based on market research, surveys, economic models, or indexes of investment activity.

Confidence in Estimated Savings: Satisfying a 75% Hypothesis Test

There is always uncertainty in the savings associated with energy conservation measures. Uncertainty occurs over the reliability of energy savings estimates, the interaction effect of multiple conservation measures on total energy savings, and the persistence of energy savings over

[1] Electric Power Research Institute, *Impact Evaluation of Demand-Side Management Programs, Volume 1: A Guide to Current Practice,* EPRI CU-7179, Palo Alto, CA, February 1991, Prepared by RCG/Hagler, Bailly, Inc.

time. For purposes of the emissions allowances, the objective is to award allowances for savings that occurred with reasonable certainty. The CVP requires that the savings be expressed in terms of the utility's confidence that the true savings were equal to, or greater than, those for which it applied. In other words, in order to qualify for 100 allowances using the CVP, a utility must be reasonably confident that the true savings equaled or exceeded 100 allowances. The utility must demonstrate that the true savings are equal to or greater than the requested allowances with a 75% confidence. Sampling procedures to calculate the savings with the 75% confidence test are presented in Appendix B, while the critical values for the t-statistic are shown in Appendix C.

The procedure described in Appendix B, while differing from that usually employed by electricity rate regulators (who typically require confidence plus or minus precision), offers utilities more flexibility, smaller sample sizes, and the opportunity to claim some legitimate savings even when the evaluation itself was not as successful as planned. Hanser and Violette discuss this procedure and compare it to other confidence determinations.[2] The CVP takes this approach because while it is not based on usual statistical standards, it reflects the state-of-the-art for reasonable impact evaluation of savings from utility conservation programs. The Service-Adjusted Savings satisfying the 75% hypothesis are considered the "first-year savings" if the reference case captured the net effects (see Figure 4). If only gross savings were measured, then a further adjustment is needed (see earlier discussion on gross and net savings distinctions).

Acceptable Measurement Procedures

Energy savings must be derived from the difference between a reference case and a treated condition. A variety of different methods are acceptable for measuring this difference. For whatever method is chosen, a utility may use a variety of analytical techniques, such as billing analysis, econometric modeling, submetering, or some combination of techniques. Several common methods are:

- Measurement of energy use pre/post-installation of conservation measures with a treated group compared to pre/post- with a comparison group.
- Measurement of energy use pre/post-installation of conservation measures with a treated group only (i.e., the treated group is its own comparison group).
- Measurement of energy use post-treated/post-untreated (i.e., cross-sectional analysis).
- Flip-flop of measures (old device is still in place and can be switched on for a short period).

The conventional verification procedure for a retrofit project involves measuring energy use before and after the conservation retrofit. In general, however, this procedure yields gross energy savings (rather than net) because it does not control for what would have happened to energy use if the retrofit did not occur. Treated versus untreated groups might be used to estimate savings from a conservation program applied to new building construction. This procedure could also supplement a before/after measurement to provide net energy savings estimates. A flip-flop procedure allows for alternating measurements of the original equipment and the replacement unit. One good candidate technology for flip-flop measurements would be where the conservation measure consists of installing a heat pump in a home already equipped with resistance heating. External controls would periodically switch from one system to another, thus permitting estimates of energy savings during only one heating season. A flip-flop procedure is generally best applied when only one or two technologies are involved.

Combinations of these procedures are also acceptable (and may even be necessary for estimating net energy savings). For example, a Net Savings analysis of a retrofit program will need to measure the energy use of participants before

[2] P. Hanser and D. Violette, "DSM Program Evaluation Precision: What Can You Expect? What Do You Want?" *Proceedings, Fourth National Conference on Integrated Resource Planning*, pp. 299-313, National Association of Regulatory Utility Commissioners, Washington, D.C., September 13, 1992.

and after the treatment, in addition to the energy use of a group of non-participants.

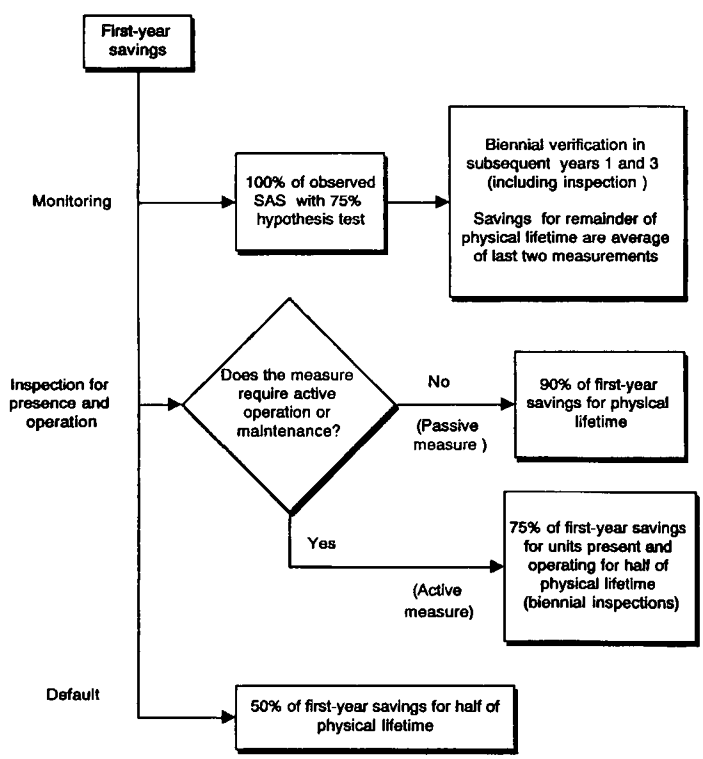
Duration of Metering

Metering is necessary to determine both the first-year energy savings and the extent to which those savings persist over the measure's lifetime. Very different considerations apply to these periods.

First-year energy savings calculations must be based on a sufficiently long period to cover any natural cycle of activities that influences energy savings. For example, the "natural cycle" for a space heating retrofit is one winter. Briefer metering periods are acceptable under the CVP, however, if they can be reasonably extrapolated to the whole year. For conservation measures applied to constant loads (or those automatically controlled), instantaneous power determinations are satisfactory.

Once all of these procedures are completed by the utility, the result is the calculation of first-year energy savings.

Figure 5. Subsequent-Year Verification Options



Subsequent-Year Savings

The persistence of energy conservation savings over time is uncertain. This uncertainty stems from both the deterioration in a conservation measure's technical performance, and behavioral factors such as the energy user's shifting preferences and maintenance practices. The limited research that has been conducted on persistence of energy savings indicates that conservation programs often overestimate measure persistence, particularly in the commercial sector and for residential compact fluorescent lamps.[3]

Three options are available for verifying subsequent-year energy savings: monitoring, inspection, and a default. Figure 5 shows these options as a flow chart, which are applicable to both the Stipulated Savings and the Monitored Energy Use paths. Various discounting factors have been inserted so as to make monitoring attractive. By monitoring, a utility can obtain credit for a greater fraction of the savings and for a longer period. In contrast, the default option greatly restricts the allowable savings. This reflects decreased certainty that savings persist when they are not monitored by the utility.

For all three options, the gross-to-net conversion factor is calculated once for the first-year

[3] See, e.g., L.A. Skumatz, et al. "Bonneville Measure Life Study: Effect of Commercial Building Changes on Energy Using Equipment", *SRC No. 7619-R2*, Synergic Resources Corp., Seattle, WA, December 1991; Northeast Utilities, *A Survey of Other Utilities for Measure-Life and Persistence-of-Savings Issues*, Conservation and Load Management Dept., NU, Hartford, CT, March 1992; E. Vine, "Persistence of Energy Savings: What Do We Know and How Can it be Ensured?", *Energy—The International Journal*, Vol. 17, No. 11, 1992, pp. 1073-84; K.M. Keating, "Persistence of Energy Savings", in E. Hirst and J. Reed, eds., *Handbook of Evaluation of Utility DSM Programs*, ORNL/CON-336, Oak Ridge National Laboratory, Oak Ridge, TN, December 1991, pp. 89-99.

savings. The same conversion factor is used in all subsequent years to convert estimates of gross savings. For example, if a utility through examination of a comparison group (or other accepted technique) determines that 15% of the treated group would have implemented the measure even without a utility incentive (a gross-to-net conversion factor of 0.85), then this factor carries to all subsequent-year savings. Thus it is not necessary to follow the comparison group beyond the first year.

All three options make certain assumptions about the lifetimes of specific conservation measures. The lifetime of a conservation measure is the median length of time (in years) that a measure produces energy savings (see Appendix D). Stipulated lifetimes are provided for the most common conservation measures. When a stipulated lifetime is not given, the utility must estimate a lifetime. A measure may be physically present for many years beyond the time it is saving energy at its designed level. If significant degradation in performance occurs, then the effective lifetime is shortened.

Utilities may shift from one verification path to another in subsequent years. It is expected that these shifts will be from the monitoring options to less extensive verification procedures. These shifts are permissible; once a shift is undertaken, however, a utility cannot reverse itself and return to a stricter option and receive continuous credit from the latter.

Option 1: Monitoring Subsequent-Year Savings

The monitored savings verification option, which includes a requirement for inspection of installed measures, credits the utilities with the greatest possible savings. This recognizes the greater confidence in the existence and accurate estimate of the savings derived from monitoring. In addition, the utility receives credit for savings that occur after it terminates monitoring.

The monitoring option requires that the verified savings requested by the utility continues to meet the 75% hypothesis test used for the first-year savings calculation. As mentioned previously, conversion of Gross Savings into Net Savings can be done through the first-year default conversion factor or by the utility- researched factor, and the first-year values can be used in all Subsequent-Year Savings. A utility may, if it wishes, re-evaluate the gross to net conversion factor and use updated values.

Verifications should be conducted every other year (biennially) after the first-year verification, for a total of three verifications after the retrofit. Savings in off-years (i.e., when no verification is performed) will be calculated at the inspection or default rate for no Subsequent-Year Savings verification. When the next monitoring verification is performed, however, the utility may recoup uncredited savings that occurred in the off year, based on the average of the last two measurements. More frequent verifications are also acceptable. The savings from the fourth year onwards are calculated as the average of the two subsequent-year verifications until the end of the measure's lifetime.

Option 2: Inspection for Presence and Operation of Subsequent-Year Savings

Surveys of the treated group (or representative samples) must be undertaken to confirm that the conservation measures are both present and actively operating in subsequent years. A measure is considered to be inoperative if its performance is found to be significantly impaired, that is, about half of the first-year savings are not occurring. For example, clogged coils in a commercial refrigeration system and broken time clocks for a thermostat setback control are reasonable evidence of performance deterioration beyond an acceptable limit.

The first-year savings must be reduced by the fraction of sites found to have non-functioning measures or where measures were removed. For example, if an "active conservation measure" was determined to have been removed from 10% of the sites inspected, then the subsequent-year verified savings for that year must be reduced by 10%. Following this adjustment, where applicable, the utility may claim 75% of first-year savings for half of the measure's physical lifetime.

Certain conservation measures do not need regular maintenance and are unlikely to be removed once they are installed. In this sense, they are "passive conservation measures" whose energy savings are likely to continue with a high degree of certainty (assuming correct installation). For calculation of subsequent-year savings, passive measures will receive 90% of first-year energy savings without further inspection. Utilities will receive these savings for the measure's physical lifetime.

A utility may use the passive measure path shown in Figure 5 if it demonstrates that the measure can be reasonably expected to remain in place and performing to first-year levels without requiring active maintenance or operation. Examples of passive measures include: building shell insulation, pipe insulation, and window improvements.

Option 3: Default Subsequent-Year Savings

If the utility decides not to continue any monitoring or inspection, it is still eligible for the default savings. These savings consist of 50% of first-year savings, but are limited to half of the measure's lifetime (as discussed previously).

Supply-Side Efficiency Improvements

Supply-side efficiency improvements can also be verified with these protocols. Common supply-side improvements include boiler upgrades, transformer substitution, transmission and distribution improvements, and generator repowering. In most cases the supply-side technology will convert fuel or heat into electricity. In some cases, such as transformers, supply-side efficiency improvements will involve technologies that modify some feature of the electricity, i.e., voltage, current, or power factor. In these situations, the inputs and outputs are electricity. An efficiency improvement will translate directly into increased electricity available for distribution with less or equal input energy. With energy as both the input and output, measurements of energy savings from the improvement are considerably easier to perform and the evaluations more straightforward.

Standard methods for measuring input and output energy and efficiencies exist for the major supply-side measures. For example, overall heat rate measurement methods are specified by the Federal Energy Regulatory Commission (FERC), and boiler rates are covered by the appropriate professional associations, such as American Society of Testing Materials.

The electricity savings from supply-side efficiency improvements should be verified using the same procedures as outlined in earlier Sections. A reference case must be specified, with careful attention to the levels of service for that piece of equipment. For supply-side measures, service factors may include capacity factor, operating hours, ambient temperature, and fuel type. Service adjusted energy use for the pre- and post-treatment cases must be calculated, and service-adjusted savings estimated from these two values.

For example, if a Phase I utility boiler reduces its heat input because of improved unit efficiency, the reference case is the pre-retrofit, annual, average heat rate as reported in 1992 in the EPA's National Allowance Data Base Version 2.1 (NADB).[4] This heat rate is the applicable boiler's Btu consumed per kilowatt-hour averaged from 1985 to 1987. To calculate the energy savings from the improved heat rate, the utility should take the product of the NADB baseline heat rate and the unit's baseline annual kilowatt-hour generation, and subtract from it the product of the new heat rate and current annual generation. The new heat rate should be taken from the hourly heat rates that will be included in the quarterly monitoring reports to the Acid Rain Division of the EPA, weighted by the unit's generation.

[4] U.S. Environmental Protection Agency, Acid Rain Division, "National Allowance Data Base", Version 2.1. EPA, Washington, D.C., July 1992.

Appendix A

Definitions

The following definitions are used in the CVP. Note that all energy savings described in this document are assumed to be electricity. Several types of energy savings are used in this document. Since each has a different meaning and application, the definitions are listed together below. Definitions for other terms are listed alphabetically following the energy savings terms.

Energy Savings

Raw, metered energy savings: The simple difference in metered energy use between the treated customers and the comparison group during the relevant periods. Essentially no processing has been undertaken, so the periods need not be similar and no normalizations have been performed. (The "savings" can even be negative.) This term is rarely used in this document but is defined to emphasize the distinctions in the definitions of gross and net energy savings (below).

Gross energy savings: The difference in energy use after adjusting for changes in levels of service and periods of measurement. Typical service adjustments include differences in weather (degree-days), operating hours, factory output, customers, illumination levels, floor area, inside temperature, etc. Periods of measurement for the treated and comparison groups will often differ and need to be normalized to a common length (typically a year). Gross energy savings seek to quantify the savings from the technologies applied, so the comparison groups consist entirely of similar installations that did not receive the conservation measures.

Net energy savings: The energy savings attributable to the energy conservation program. A standard method for estimating net energy savings involves comparing the gross energy savings for the treated group to the change in energy use of a similar group not participating in the program, some of whom may have implemented similar conserving (or increasing) measures on their own initiative.

First-year energy savings: A specific period of a conservation program's energy savings. Soon after installation, the conservation measures begin saving energy. For purposes of verification, however, the savings are divided into the "first-year" and "subsequent-year". The "first-year" begins after the conservation program is being deployed in a routine manner and the conservation measures are operating in their normal modes.

Service-adjusted savings (SAS): The reduction in energy use from the reference case due to the conservation measure. The SAS includes adjustments for changes in service that may have occurred between the untreated and treated groups.

Subsequent-year energy savings: The energy savings occurring in the annual periods following the first-year.

Stipulated Savings: Energy savings for specified measures (or procedures) that a utility may use instead of savings determined through monitoring.

Other Terms

Active conservation measure: Conservation measures that require regular maintenance, and may be removed once installed.

Date of installation: The date on which the conservation measure begins normal operation.

Gross-to-net conversion factor: A number that, when multiplied by the gross energy savings, yields net energy sav ings. The factor is typically (but not always) between 0 and 1, and determined by analysis conducted by an electric utility company.

Level of service: Conditions describing the quality of energy-related services provided by an electric utility at the point of end use.

Lifetime: The median length of time (in years) that a measure produces energy savings.

Lighting circuit: The electrical service to a group of lights serviced by its own circuit breaker or panel. In large buildings, lighting circuits are often 277 Volts; in smaller buildings 120 Volts is more common. In complex buildings, the lighting circuit is the combination of circuits servicing the lights of a distinct area, such as one or more floors.

Passive conservation measure: Conservation measures that do not require regular maintenance, and that are unlikely to be removed once installed.

Reference case: The energy use and set of designated levels of services from which the savings are estimated.

Service-adjusted energy use: The estimated energy use of a given group after adjusting to different levels of service.

Start date: The date on which the program begins normal operation.

Appendix B

Service-Adjusted Savings and Hypothesis Test

General Approach for Service-Adjusted Savings

The goal of the Service-Adjusted Savings (SAS) is to estimate the energy savings due exclusively to the conservation measures and not from any changes in levels of service. It begins with the assumption that the estimate is based on the difference in energy use between an untreated and an untreated group. The approach seeks to adjust energy use in the untreated and treated groups to a similar level of services before estimating the difference. It is sometimes convenient to think of the untreated case as the "pre-retrofit" and the treated case as the "post-retrofit" case. This analogy applies for very simple situations but requires modifications when the level of services changes or the verification involves cross-sectional analysis (such as those used for estimating the energy savings from new construction programs).

Service-Adjusted Energy Use (SAEU)

The energy use for a given installation can generally be described as a function of the level of services supplied. Some of the common service levels determining the variation in energy use are:

- severity of heating or cooling season
- indoor temperature
- operating hours
- conditioned floor area
- production rate (or mix)

Other levels of service may be more appropriate for special end uses or applications. The key aspect is that changes in these levels of services are responsible for differences in energy use. The relationship between service levels and energy use can be expressed as a function:

$$E_i = f_i\,(S_i)$$

For lighting energy use, the function might be of the form, $E_i = \alpha + ßH_i$, where α and ß are constants and H_i is the number of hours per year the site operates. (These coefficients might have been derived from a regression of submetered data.) The coefficients, α and ß, reflect a level of efficiency of delivery of that service which is unique for the hardware and operating procedures in place. This relationship must be derived through monitoring and (where appropriate) market research data for both the treated and untreated conditions:

$$E_{treat} = f_{treat}\,(S_{treat})$$

$$E_{unt} = f_{unt}\,(S_{unt})$$

The coefficients in the functional relationship will be different for the two situations because they reflect the efficiency at which the service is being delivered. In the lighting case, for example, the coefficients α and ß will be smaller in the treated case because less energy will be required to obtain the same level of service.

The "reference case" is the energy use and set of designated levels of services from which the savings are measured. The energy use associated with the reference service levels is called the service-adjusted energy use, $SAEU_{ref}$. By definition, the reference case consists of the untreated group's energy use adjusted to service levels from the treated group (with exceptions described below):

$$SAEU_{ref} = f_{unt}\,(S_{ref})$$

This differs from many definitions of reference cases, where the untreated (pre-retrofit) energy use and service levels establish the reference case. In this protocol, service levels from the treated case were chosen as the reference because service levels often change as a result of the retrofit and are more likely to prevail for the subsequent years. For example, a building exit light retrofit will probably include retrofitting lights that were not operating (i.e., burned out) in the first place. In the course of HVAC retrofits, ventilation rates are often raised to meet code requirements. In both cases, the post-retrofit conditions are a more appropriate baseline from which to measure the savings.

Weather Adjustments

The severity of the heating and cooling seasons fluctuates considerably from year to year. Similarly, other meteorological factors, such as wind speed and insolation, have long-term, average conditions that may differ from the period of measurement. Using the measurement periods to project subsequent-year savings can lead to obvious errors. Fortunately, long-run average data for these services are available and should be used for the reference case. The appropriate reference service levels for space heating would be the long-term average number of degree days rather than those for the treated year.

The difference between the conditions during measurement and the average means that the reference case must contain some levels of services that differ from the treated period. As a result, both the untreated and treated groups will need service adjustments. A new set of services must be defined such that:

$$SAEU_{ref} = f_{unt}\,(S_{avg})$$

where S_{avg} becomes the S_{ref}.

Energy use often depends on a combination of service levels determined by the user and the weather. For example, a building air conditioning system's energy use might be determined by the building's operating hours and the cooling degree-days experienced:

$$E_i = \alpha + \beta H_i + \eta DD_i$$

In this case, $SAEU_{ref}$ will contain service levels from both the treated and average conditions:

$$SAEU_{ref} = f_{unt}\,(S_{treat}, S_{avg})$$

The $SAEU_{treat}$ requires a similar adjustment:

$$SAEU_{treat} = f_{treat}\,(S_{treat}, S_{avg})$$

As a result, the service-adjusted energy use will reflect a combination of service levels derived from the measurement periods and long-term average values.

Calculation of Service-Adjusted Savings

The "service-adjusted savings" (SAS) is the difference between the SAEUs:

$$SAS = SAEU_{ref} - SAEU_{treat}$$
$$= f_{unt}\,(S_{ref}) - f_{treat}\,(S_{ref})$$

These SAS must satisfy the 75% confidence hypothesis test (discussed later) so that SAS will always be less than or equal to the difference in SAEUs:

$$SAS \leq SAEU_{ref} - SAEU_{treat}$$

In most cases, the service levels will change in the untreated and treated groups. For the lighting retrofit example, the lights may have operated 3000 hours before the retrofit and 4000 after the retrofit. The reference level of service is thus 4000 hours. So the $SAEU_{ref}$ is an estimate of the energy use of the original inefficient lights operating at the higher number of hours occurring after the retrofit:

$$SAEU_{ref} = f_{unt}\,(4000)$$

The SAS for this situation is:

$$SAS = SAEU_{ref} - SAEU_{treat}$$

$$= f_{unt}\,(4000) - f_{treat}\,(4000)$$

Note that this assumes no other changes of service level occurred in the treated case. If the lighting retrofits also included adjusting illumination levels, this factor should be included in f_{unt} and f_{treat}. A possible relationship would be:

$$E_i = \alpha + \beta L_i H_i$$

where L_i is the average level of illumination, in lumens, as determined by a series of representative spot measurements. The $SAEU_{ref}$ and $SAEU_{treat}$ are similarly calculated.

Aggregation

The above procedure for calculating the service-adjusted savings can also be applied to a group of sites by aggregating the individual results or pooling data and performing a single analysis on the aggregate data. The pooled approach may be necessary when level-of-service information (such as that derived from surveys) is not available for individual sites.

Sampling and Hypothesis Test

In all cases, the verified savings must satisfy a 75% confidence hypothesis, that is, the utility must have 75% confidence that the actual savings equal or exceed the requested amount. As indicated above:

$$SAS \leq SAEU_{ref} - SAEU_{treat}$$

The SAS must be lowered until the 75% confidence in the difference $SAEU_{ref} - SAEU_{treat}$ actually occurs. The precise technique to evaluate the 75% confidence hypothesis will depend on the sampling procedure and experiment design.

Ideally, all participants in the treated and untreated groups should be included in the verification. Here, simple tests for confidence in the savings can be applied. (Note that uncertainty in results exists even when 100% of the population is evaluated.)

The high cost of monitoring, surveys, and data management will often prevent evaluation of 100% of the participants. If comprehensive evaluation is not possible, then a statistically representative sample of participants is acceptable.

If a sample of n installations is monitored, out of a population of N, then

$$\overline{SAS}_{sample} = \frac{1}{n} \sum_{i=1}^{n} SAS_i ,$$

where $\overline{SAS}_{sample}$ is the average SAS for the sampled installations. In this case, a hypothesis test must be used to determine the population mean, $\overline{SAS}_{population}$, that can be extrapolated to have occurred within a certainty of 75%.

A variety of hypothesis tests may be used.[1] A calculation using a one-tailed t-test is presented here as an example. The $\overline{SAS}_{population}$ is calculated as follows:

$$\overline{SAS}_{population} = \overline{SAS}_{sample} - t_{0.25} \frac{S_{SAS}}{\sqrt{n}}$$

where S_{SAS} is the sample standard deviation of SAS, and $t_{0.25}$ is the critical value of the t-statistic for a one-tailed hypothesis test at the 75% confidence level for $n - 1$ degrees of freedom (determined from a table). A table of critical values of the t-statistic is included as Appendix C. The total service adjusted savings that may be claimed for the population is then $N \times \overline{SAS}_{population}$.

Stepwise Procedure

The following steps summarize the procedure for calculating the Service-Adjusted Savings:

1. Identify reference case and levels of service determining energy use. This usually happens after the pre-retrofit phase of metering is completed.
2. Identify levels of service requiring average conditions (usually weather-related).
3. Quantify relationship between service levels and energy use based on energy data, manufacturing data, surveys, etc.
4. Calculate $SAEU_{ref}$ and $SAEU_{treat}$.
5. Calculate SAS at 75% confidence level.

[1] P.W. John, *Statistical Methods in Engineering and Quality Assurance*. New York: John Wiley & Sons, 1990.

Appendix C

T-Statistics for 75% Confidence One-Tailed Hypothesis Testing

n-1	$t_{0.25}$	n-1	$t_{0.25}$
1	1.000	18	.688
2	.816	19	.688
3	.765	20	.687
4	.741	21	.686
5	.727	22	.686
6	.718	23	.685
7	.711	24	.685
8	.706	25	.684
9	.703	26	.684
10	.700	27	.684
11	.697	28	.683
12	.695	29	.683
13	.694	30	.683
14	.692	40	.681
15	.691	60	.679
16	.690	120	.677
17	.689	∞	.674

Appendix D

Stipulated Savings, Procedures, Lifetimes, and Conversion Factors

Engineering Estimates of Energy Savings

Technology Description

In certain circumstances, an engineering estimate of energy savings will be acceptable in lieu of measurements. An engineering estimate typically requires use of recognized calculation procedures and technical specifications of materials or equipment.[1] Estimated savings often differ from measured savings because of incorrect assumptions, especially regarding baseline conditions. Therefore, when measurement is not used, greater care must be placed on verification of actual measure installation and correct operation.

Engineering calculations may be used in any one of the following situations:

- Measurement costs would exceed 10% of program cost.
- Program-wide energy savings are expected to 5000 MWh/year or less (1-10 allowances) and no customer accounts for more than 20% of total savings.
- Energy savings are expected to be less than 5% of use of the smallest isolatable circuit. For example, energy savings from residential lighting efficiency improvements will appear on many different circuits. In this case, the smallest isolatable circuit is the whole house.

If energy savings from the improvements are expected to be less than 5% of total household electricity use, then engineering estimates are acceptable.

Verification Requirements

The following requirements must be satisfied in order for the stipulated savings to qualify as verified:

- Each submittal must include a brief description of the technologies employed in the conservation program, and the assumptions and procedures used to estimate energy savings.
- The utility must employ quality control measures in lieu of direct verification of energy savings, i.e., short-term measurements, inspections, interviews, etc. Such inspections must include a representative sample of installations.
- All estimates of energy savings must be calibrated to measured consumption. If program-specific data from that utility are not available, then other data from other utility programs are acceptable.

[1] Electric Power Research Institute, *Engineering Methods for Estimating the Impacts of Demand-Side Management Programs, Volume 1: Fundamentals of Engineering Simulations for Residential and Commercial End Uses*, EPRI TR-100984, Palo Alto, CA, July 1992, Prepared by Architectural Energy Corporation.

Higher Efficiency Motors for Constant Load Applications Operating Continuously

Technology Description

The measure consists of replacing or upgrading inefficient motors being used to power a constant load for at least 8500 hours per year. The retrofit will typically be undertaken in factories or buildings with constant operation (such as hospitals) for fans and pumps.[2]

Energy Savings Calculations

The energy savings are determined by calculating the difference in power consumption between the old and new motors and multiplying by 8500 hours. Annual savings (in kWh/year) for a single retrofit are calculated as follows:

Annual Energy Savings = 8500 x (P_{old} - P_{new})

where:

- Annual Energy Savings = stipulated energy savings (in kWh/year) for the measure.
- 8500 = number of operating hours per year (which assumes 3% average downtime for maintenance).
- P_{old} = power consumption of motor (in kW).
- P_{new} = power consumption of replacement motor (in kW).

True power measurements of P_{old} and P_{new} must be performed during typical operation.

Verification Requirements

The following requirements must be satisfied in order for the stipulated savings to qualify as verified:

- The name and address of the building in which the retrofit occurred must be recorded (but not submitted).
- The motor application must be recorded (but not submitted).
- The measured power of the original and replacement (or upgraded) motors must be recorded (but not submitted).

[2]S.M. Nadel, M. Shepard, S. Greenberg, G. Katz, and A.T. de Almeida, *Energy-Efficient Motor Systems: A Handbook on Technology, Programs, and Policy Opportunities (Series on Energy Conservation and Energy Policy,* Carl Blumstein, ed.), American Council for an Energy-Efficient Economy, Washington, D.C., 1991.

Exit Sign Light Replacements

Technology Description

Illuminated exit signs are required by law in almost all non-residential and many multifamily residential buildings. They are required to operate 24 hours/day in most situations.[3] This measure involves replacing existing lights in exit signs (which are mostly incandescent) with fluorescent lights or light-emitting diodes.[4]

Energy Savings Calculations

The energy savings for each fixture replacement are determined by calculating the difference in power consumption between the old and new fixtures and multiplying by the number of hours of operation. Annual savings (in kWh/year) for a single fixture retrofit are calculated as follows:

Annual Energy Savings **= 8760 x** $(P_{old} - P_{new})$

where:

- Annual Energy Savings = stipulated energy savings (in kWh/year) for the measure.
- 8760 = number of hours per year.
- P_{old} = power consumption of original exit light (in kW).
- P_{new} = power consumption of replacement exit light (in kW).

The power consumption of the original exit light may be assumed to be 0.03 kW. A larger value for P_{old} may be used if verified by inspection or measurement of each model replaced.

Verification Requirements

The following requirements must be satisfied in order for the stipulated savings to qualify as verified:

- The number of replaced signs must be recorded (but not submitted) for each address.
- The original exit sign must be functioning and illuminated at the time of replacement. If only one lamp is illuminated, the default is 0.015 kW.
- Rated power for the replacement must include the entire system, that is, fluorescent light and ballast.

[3] International Conference of Building Officials, *Uniform Fire Code*, International Conference of Building Officials, Whittier, CA, May 1991.
[4] A.B. Lovins and R. Sardinisky, *The State of the Art: Lighting (Competitek)*, Rocky Mountain Institute, Snowmass, CO, March 1988.

Amorphous Metal Distribution Transformers

Technology Description

Amorphous metal-core transformers reduce no-load losses by 60 to 70% over those in conventional silicon-steel transformers. No-load losses are the power required to energize the transformer and are constant regardless of the load. These are dominated by core losses. There are also load losses, which vary depending on the load, and are dominated by winding losses. For some transformers replaced energy savings from decreased no-load losses may be partly offset by increased load losses, while in other cases load losses will also decrease. On average, such offsets will not be significant. No credit is given for decreases in load losses (although qualified savings can be earned when verified through monitoring). Energy savings accruing from the reduction of no-load losses through this measure will occur 8760 hours each year.

Energy Savings Calculations

The energy savings are determined by multiplying the 3/4 power of the replaced transformer's rated capacity by a factor representing the decrease in no-load losses per unit of capacity (to the 3/4 power) and multiplying by 8760 hours. Annual energy savings (in kWh/year) for a single transformer are calculated as follows:

$$\textit{Annual Energy Savings} = C^{0.75} \times 3.1 \times 10^{-3} \times 8760$$

where:

- Annual Energy Savings = stipulated energy savings (in kWh/year) for the measure.
- C = rated capacity of replaced transformer (kVA).
- 3.1×10^{-3} = decrease in no-load losses per unit capacity$^{3/4}$ (kW/kVA$^{3/4}$).
- 8760 = number of operating hours per year.

Verification Requirements

The following requirements must be satisfied in order for the stipulated savings to qualify as verified:

- The transformer must be used instead of a silicon steel or silicon iron transformer.
- The rated capacity and the location must be collected. (This information need not be submitted.)

Optional testing of no-load and load losses (ANSI C57.12.90-1987; IEEE C57.120 Draft 16-91) may be done for the new and old transformers, to obtain greater than the stipulated savings.

Higher Efficiency Lights in Office Buildings

Technology Description

This measure involves replacing lights with higher efficiency units in offices. It only applies to office buildings and usually consists of replacing incandescent or old fluorescent fixtures with high-efficiency fluorescent lamps, improved fixtures, and electronic ballasts. A retrofit consists of identical lights replaced on a single circuit.[5] No credit is given for improved switches, occupancy sensors, or daylight controls in this measure (although qualified savings from these measures can be earned when verified through monitoring).

Energy Savings Calculations

Energy savings from commercial lighting retrofits will depend on the number of operating hours and the energy intensities of the original and new lighting systems.[6,7] In addition, lighting levels are often adjusted during the retrofit. The exact values for these variables are difficult to determine without monitoring. Monitored savings have varied depending on the conditions outlined above.[8,9,10,11] The stipulated savings listed below put caps on the variables that are most likely to be overestimated. As a result, use of these values will, in some cases, lead to underestimates of actual energy savings.

The energy savings are determined by calculating the difference in power consumption between the old and new fixtures and multiplying by the number of hours of operation and number of fixtures replaced. Annual savings (in kWh/year) for a single retrofit are calculated as follows:

$$\textit{Annual Energy Savings} = H \times L \times (P_{old} - P_{new})$$

where:

- Annual Energy Savings = stipulated energy savings (in kWh/year) for the measure.
- H = number of operating hours in the year following the retrofit.
- L = number of identical fixtures in building on same circuit operating prior to retrofit.
- P_{old} = power consumption of original light fixture (in kW) that was operating prior to the retrofit.
- P_{new} = power consumption of replacement light fixture (in kW).

The number of hours, H, must be less than or equal to 3300.[12] The difference (P_{old} P_{new}) for fluorescent lights may not exceed the values given in the following table:

Original Fluorescent Lamp Type	Maxium Allowable Difference*
2 Lamp fixture	0.025
3-lamp fixture	0.037
4-lamp fixture	0.050

*(P_{old} - P_{new}) (in kW)

[5] A lighting circuit is the electrical service to a group of lights serviced by its own circuit breaker or panel. In large buildings, lighting circuits are often 277 Volts; in smaller buildings 120 Volts is more common. In complex buildings, the lighting circuit is the combination of circuits servicing the lights for a distinct area, such as one or more floors.

[6] A.B. Lovins and R. Sardinsky, *The State of the Art: Lighting (Competitek)*, Rocky Mountain Institute, Snowmass, CO, March 1988.

[7] Rochester Gas & Electric Co., "Basis for Compensation," *Document Reference # III.H.8* (RG&E DSM #1503), RG&E, Rochester, NY, March 11, 1991.

[8] S.M. Nadel and K.M. Keating, "Engineering Estimates vs. Impact Evaluation Results: How do They Compare and Why?", *Proceedings of the 1991 International Energy Program Evaluation Conference*, Evanston, IL, 1991, pp. 24-33.

[9] M.A. Piette et al., "Technology Assessment: Energy-Efficient Commercial Lighting," *LBL-27032*, Lawrence Berkeley Laboratory, Berkeley, CA, 1989.

[10] Xenergy, Inc., *Impact Evaluation of Commercial Lighting Rebate Program*, Vol. 1992, Integrated Least-Cost Resource Plan, Prepared for Potomac Electric Power Co., Washington, D.C., 1992.

[11] The Results Center, *Sacramento Municipal Utility District: Commercial Lighting Installation Program*, IRT Environment, Inc., Aspen, CO, 1992.

[12] Pacific Gas and Electric Co., *Commercial, Industrial and Agricultural Direct Rebate Programs Hours of Operation Study*, PG&E, Measurement and Evaluation Planning Section, San Francisco, CA, August 1992.

It is technically possible to achieve energy savings approximately double those given in the above table, in cases where state-of-the-art fluorescent lamps, ballasts, and fixtures replace very inefficient (but fully functioning) ones. Many utilities will want to monitor a sample of their commercial lighting retrofits, which could lead to these larger savings.

Verification Requirements

The following requirements must be satisfied in order for the stipulated savings to qualify as verified:

- The name and address of the building in which the retrofit occurred must be recorded (but not submitted).
- The number, type, and power rating of replaced lights must be recorded for each building (but not submitted).
- The number of non-functioning (removed or broken) lights must be recorded for each retrofit (but not submitted). Retrofits replacing broken or missing lights cannot be counted for credit with this stipulated measure.
- Rated power for the replacement must include the entire system, that is, the fluorescent light and ballast.

High Efficiency Refrigerator Replacement

Technology Description

This measure involves replacing an existing refrigerator-freezer with a higher efficiency unit. It applies to all new residential refrigerator-freezers sold with Energy Guide labels.

Energy Savings Calculations

The field energy use of a refrigerator has been shown to correlate well with the labeled energy use.[13] Net energy savings are the difference between the labeled energy use of the purchased unit and a comparable new unit meeting the applicable efficiency standard. A single stock-wide value, based on 1991 AHAM data[14], is provided to avoid determining the labeled energy use of each comparable unit.

$$\textit{Annual Energy Savings} = \sum_{i=1}^{\textit{all refrigerators}} (\bar{e}_n - e_i)$$

where:

- Annual Energy Savings = program-wide energy savings due to refrigerator replacements occurring in year n (in kWh/year).
- i = each new refrigerator.
- All refrigerators = all new refrigerators participating in the program.
- e_i = labeled energy use of each purchased refrigerator unit (in kWh/year).

Year replacement took place (n)	$\bar{e}_n$ (kWh/year)
1985-1989	1200
1990-1992	950
1993-1996	750

Verification Requirements

The following requirements must be satisfied in order for the stipulated savings to qualify as verified:

- The name and address of each participating customer, date of delivery of rebate check, and the manufacturer and model number of the associated refrigerator, must be recorded (but not submitted).
- An older unit must be taken from the customer's premises for each new unit supplied.

[13] A.K. Meier and R. Jansky, "Field Performance of Residential Refrigerators: A Comparison with the Laboratory Test," LBL-31785, Lawrence Berkeley Laboratory, Berkeley, CA, 1991.

[14] Association of Home Appliance Manufacturers, *Energy Efficiency Trends*, AHAM, Chicago, IL, June 20, 1991. An average 18 cubic foot model refrigerator-freezer is assumed here to represent the entire stock. The 1993-1996 value accounts for the sale in 1993 of a small number of units carried over from the 1992 stock, and reflects consumers' growing preference toward purchase of larger refrigerator-freezers.

Higher Efficiency Street Lights

Technology Description

This measure involves replacing existing street lights with higher efficiency units.

Energy Savings Calculations

The energy savings are determined by calculating the difference in power consumption between the old and new fixtures and multiplying by the number of hours of operation. Annual savings (in kWh/year) for a single retrofit are calculated as follows:

$$\textit{Annual Energy Savings} = 4000 \times (P_{old} - P_{new})$$

where:

- Annual Energy Savings = stipulated energy savings (in kWh/year) for the measure.
- 4000 = number of operating hours per year.
- P_{old} = power consumption of original street light (in kW).
- P_{new} = power consumption of replacement street light (in kW).

Verification Requirements

The following requirements must be satisfied in order for the stipulated savings to qualify as verified:

- The number, type, and power rating of replaced street lights must be recorded (but not submitted) for each community.
- The street light must be functioning and in use prior to the retrofit; otherwise each such retrofit cannot be counted for credit with this stipulated measure.
- Rated power for the replacement must include the entire system, that is, high-intensity discharge (HID) light and ballast, etc.
- The street light must be controlled by a functioning photocell.

Water Heater Insulation Blankets

Technology Description

This measure involves reducing the standby losses of residential water heater storage tanks through insulation blankets and anti-convection valves.

Energy Savings Calculations

Energy savings from insulation blankets depend primarily on the temperature of the hot water being stored, the ambient air temperature, and the amount of insulation already around the tank. Savings from individual units will vary somewhat but average energy savings from retrofits of many units are reliable and more consistent.[15,16,17] Actual savings from individual units may, in some cases, be greater than the stipulated savings if the savings are monitored.

If the utility choses to use the stipulated value, annual savings (in kWh/year) for a single retrofit are calculated as follows:

Annual Energy Savings = Expected Savings

where:

- Annual Energy Savings = stipulated energy savings (in kWh/year) for the measure.
- Expected Savings = typical savings for a carefully installed measure, as determined from the table below:

Measure	Expected Electricity Savings (kWh/year)
Insulation blanket around tank	400
Anti-convection valves	200
Pipe insulation	200

Verification Requirement

The following requirements must be satisfied in order for the stipulated savings to qualify as verified:

- Each installation must be inspected by a utility representative.
- The name and address of each participating customer and date of inspection must be recorded (but not submitted).
- Insulation blankets must have a thermal resistance of at least R-7.
- Anti-convection valves must be installed on both the incoming cold water and outgoing hot water pipes.
- Insulation must cover the first three feet from the water heater for both hot and cold pipes.

[15] A. Usibelli, "Monitored Energy Use of Residential Water Heaters," *Proceedings of the ACEEE 1984 Summer Study on Energy Efficiency in Buildings*, American Council for an Energy-Efficient Economy, Santa Cruz, CA, 1984.
[16] D.H. Sumi and B. Coates, "Persistence of Energy Savings in Seattle City Light's Residential Weatherization Program," *Proceedings of the 1989 International Energy Program Evaluation Conference*, Evanston, IL, 1989, pp. 311-16.
[17] M.A. Brown et al., *Impact of the Hood River Conservation Project on Electricity Use for Residential Water Heating*, Oak Ridge National Laboratory, Oak Ridge, TN, 1987.

Stipulated Lifetimes for Common Conservation Measures

Technology Description

The effective lifetime of conservation measures is crucial in determining the cumulative impact and cost-effectiveness of conservation measures and programs. There remains considerable uncertainty regarding lifetimes and research continues to improve estimates.[18,19,20]

Energy Savings Calculations

The stipulated median lifetimes are given in the following two tables. They are adapted from the consensus[21] reached by the California utilities, regulatory commissions and other interested parties but are based on work by many groups across the country. These lifetimes may be used for calculations of savings as described in the Protocols.

Verification Requirements

The following requirement must be satisfied in order for the stipulated lifetimes to qualify as verified:

- The conservation measure in the submittal must closely resemble that described in the list.

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[18] L.A. Skumatz, K.M. Lorberau, R.J. Moe, R.D. Bordner, and R.D. Chandler, "Bonneville Measure Life Study: Effect of Commercial Building Changes on Energy Using Equipment," SRC No. 7619-R2, Synergic Resources Corporation, Seattle, WA, December 1991.

[19] Synergic Resources Corporation, "Effective Measure Life and Other Persistence Issues in DSM Programs," Interim Report #1.2, *R7729 1R1*, SRC, Oakland, CA, February 1992.

[20] Northeast Utilities, *A Survey of Other Utilities for Measure-Life and Persistence-of-Savings Issues*, Northeast Utilities, Conservation & Load Management Department, Hartford, CT, March 1992.

[21] Measurement Subcommittee, *Measurement Protocols for DSM Programs Eligible for Shareholder Incentives (An Energy Efficiency Blueprint for California: Report of the Statewide Collaborative Process)*, State of California, January 1990, Appendix A.

Useful Lives of Residential Energy Conservation Measures

Measure	Lifetime (Years)	Measure	Lifetime (Years)
Caulking	10	High-efficiency A/C	18
Weatherstripping	10	Central heat pump	18
Ceiling Insulation	25	Evaporative coolers	15
Wall insulation	25	Clock thermostat	15
Low-flow showerheads	10	High-efficiency refrigerator	20
Water faucet aerators	10	High-efficiency central furnace	20
Duct wrap/insulation	15	Whole house fan	15
Water heater blanket	10	Double glazing	25
Fluorescent bulbs	10	Storm windows	10
Window shade awnings	10	Furnace retrofit	15
		Efficient gas water heater	13

Useful Lives of Commercial and Industrial Energy Conservation Measures

Equipment Type & Description	Lifetime (Years)
LIGHTING	
Energy-efficient fluorescent lamp	5
Same as above with build-in ballast	2
Energy-efficient ballast	11
Electronic ballast	10
Metal halide lamp	10
Low-pressure sodium lamp	5
High-pressure sodium lamp	5
Parabolic fixture	20
Dimming systems	20
On-off switching	7
Motion sensor	10
HVAC	
Economizer	11
Chiller strainer cycle system	15
Air-to-air packaged heat pump	10
Water-to-air packaged heat pump	15
Ice thermal energy storage	19
Water thermal energy storage	20
Plate type heat pipe recovery system	14
Rotary type heat recovery system	11
Heat recovery from refrigerator condenser	11
Low leakage damper	9
Variable air volume, inlet vane controls	11
Variable pitch fan for cooling power	13
Make-up air unit for exhaust hood	10
Air de-stratification fan-paddle type	10
Air de-stratification fan—high inlet/ low discharge	15
Air curtain	10
Deadband thermostat	13
Spot radiant heat	10
CONTROLS	
Computer logic energy-management systems	13
Electronic controls	11
Time clocks	10
MOTORS, DRIVES, & TRANSFORMERS	
Standard electric motor	15
High-efficiency electric motor	17
Variable-speed DC motor	18
Variable-speed drive—solid type	15
Variable-speed drive—belt type	10
Efficient AC electric transformer	15
DOMESTIC HOT WATER	
Heat pump water heater	10
Point-of-use water heater	12
Solar water heater	15
Change electric to gas booster	—
REFRIGERATION	
Unequal parallel refrigeration	14
Condenser float head pressure control	10
Auto cleaning system for condenser tubes	15
Hot gas bypass defrost	10
Polyethylene strip curtain	3
Refrigeration case cover	11
BUILDING ENVELOPE	
Double glazing	20
Heat mirror	18
Low-emissivity coating	14
Solar shade film (retrofit)	7
Tinted & reflective coating	14

Stipulated Gross-To-Net Factors for Stipulated Measures

Description

Conversion factors in the following list can be used to convert the gross annual savings calculated in the stipulated measures to net, first-year savings. These values should be used when utilities cannot provide estimates based on their own programs or market research. Factors that affect the net impacts of conservation programs such as free riders vary widely by the type of conservation program and market conditions.[22] Utilities may conclude that their conservation programs have larger net energy savings when they conduct their own analyses rather than rely on the default factors given below. Several recent studies have found, for example, free-rider rates of 10% or less.

Net savings are calculated with the following formula:

Net Savings = Annual Energy Savings x GNCF

where:

GNCF = "Gross-To-Net-Conversion Factor" listed in the table below:

Conservation Measure	Gross-To-Net Conversion Factor
Engineering estimates of energy savings	0.6
Exit sign light replacements	0.6
Higher efficiency motors for constant load applications operating continuously	0.6
Higher efficiency lights in office buildings	0.6
Amorphous metal distribution transformers	1.0
High efficiency refrigerator replacement	0.9
Higher efficiency street lights	0.9
Water heater insulation blankets	0.6

[22] W. Saxonis, "Free Riders and Other Factors that Affect Net Program Impacts," in E. Hirst and J. Reed, eds., *Handbook of Evaluation of Utility DSM Programs*, ORNL/CON-336, Oak Ridge National Laboratory, Oak Ridge, TN, December 1991, pp. 119-34.

Appendix E

U.S. Environmental Protection Agency
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Subcommittee on Conservation Verification

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