BMP COSTS & SAVINGS STUDY

A Guide to Data and Methods for Cost-Effectiveness Analysis of Urban Water Conservation Best Management Practices

July 2000

Prepared for

The California Urban Water Conservation Council

455 Capitol Mall, Suite 703
Sacramento, CA 95814
(916) 552-5885

By

A & N Technical Services, Inc.

2450 20th St, Suite F
Santa Monica, CA 90405
(310) 581-4025

839 2nd St, Suite 5
Encinitas, CA 92024
(760) 942-5149

Acknowledgements

This project was supported by and prepared for the California Urban Water Conservation Council. CUWCC signatories that contributed to the project fund include:

Alameda County Water District
City of Santa Monica
Contra Costa Water District
East Bay Municipal Utility District
Kern County Water Agency
Los Angeles Department of Water and Power
Metropolitan Water District of Southern California
San Diego County Water Authority
Santa Clara Valley Water District

CUWCC and A & N Technical Services appreciate the time and energy contributed by the Project Advisory Committee of the Measurement and Evaluation Committee:

Conner Everts, P.O.W.E.R.
David Czamanske, Sierra Club
Dick Bennett, East Bay Municipal Utility District
Eric Cartwright, Alameda County Water District
Mary Lou Cotton, Kern County Water Agency
Mary Ann Dickinson, California Urban Water Conservation Council
David Fullerton, National Heritage Institute
Michael Hollis, Metropolitan Water District of Southern California
David Mitchell, M.Cubed
Susan Munves, City of Santa Monica
Tom Panella, PCL
Marsha Prillwitz, United States Bureau of Reclamation
Greg Smith, California Department of Water Resources
Meena Westford, United States Bureau of Reclamation

Much of the savings and cost information in this document has been published previously in other sources. Though we are grateful to build on this previous work, the errors that remain are our own.

Contents

1 Introduction

1.1 Purpose and Caveats

The California Urban Water Conservation Council (CUWCC) is charged with implementing The Memorandum of Understanding Regarding Urban Water Conservation in California (MOU). To this aim, CUWCC developed and published its "Guidelines to Conduct Cost-Effectiveness Analysis of Urban Water Conservation Best Management Practices," in 1996, which we hereafter refer to as the "CEA Guidelines".[1] CUWCC's Measurement and Evaluation Committee commissioned this report to extend the previous efforts at developing methods and data to enact the economic analysis provisions of the MOU.

What this document attempts to do:

- Supplement CUWCC's existing *CEA Guidelines* by explicitly linking conservation program costs and water savings to the MOU's set of Best Management Practices (BMPs).
- Identify and summarize the best available information about program costs and water savings.
- Assess the reliability and generalizability of information currently available for quantifying and valuing conservation activity and for preparing cost-effectiveness exemption claims.
- Identify the absence of, and note critical deficiencies in, cost and savings estimates needed to quantify and to gauge the cost-effectiveness of specific BMPs.

What this document does not do:

- Provide or endorse the use of single, uniform estimates of programs costs and water savings. Differences in each agency's service area characteristics preclude a 'cookbook' approach to calculating the costs and the effectiveness of conservation programs.
- Pretend to provide definitive or complete estimates. Indeed, a conscious effort has been made to highlight the limitations of currently available estimates of program costs and water savings.[2]
- Repeat material already covered in the companion *CEA Guidelines*.

[1] See "Guidelines to Conduct Cost-Effectiveness Analysis of Urban Water Conservation Best Management Practices," prepared by A&N Technical Services for CUWCC, September 1996.

[2] The Measurement & Evaluation Committee strongly recommends that the CUWCC consider ways of remedying these deficiencies and that the information in this document be reviewed and updated on an annual basis.

Caveat: Generalizability[3]

The conservation savings estimates summarized in this document are drawn from a variety of studies conducted using different methods (e.g., engineering estimates developed in laboratory settings versus measuring changes in actual household water use following a ULFT retrofit); at different times (e.g., during versus after a drought episode, or during the earlier versus later stages of market saturation); in different geographic regions; and for different customer groups (e.g. owners versus renters; residential versus non-residential sectors). Careful thought should always be given to factors that may limit the applicability or generalizability of the cost and savings estimates developed by the studies summarized in this document. In some cases, it may be necessary to use service area specific information or professional judgment to adjust the estimates reported in this document to more meaningfully fit the distinctive characteristics and circumstances of different service territories. When making such applications and judgments, one must bear the burden of showing that they are warranted, reasonable and appropriate.

Caveat: Economic Terminology

Often, the cost-effectiveness of conservation is expressed in dollars per unit (for example, $/AF). Note also that conservation activities are often referred to as "cost-effective" if they have dollar valued benefits that exceed costs (for example, positive net present value, NPV). This mix of usage has led to some confusion regarding the distinction between "cost-effectiveness analysis" and "cost-benefit analysis." The MOU, for example, defines a BMP as "cost-effective" when the present value of its benefits exceeds the present value of its costs—that is, when NPV is positive. The CEA Guidelines closely follow the original MOU nomenclature. In contrast, this document employs nomenclature intended to more formally, and more properly, distinguish between cost-benefit analysis and cost-effectiveness analysis. We also seek to clarify the distinction with definitions (below) and the example presented in Appendix A.

Caveat: Common Errors in the use of Conservation Savings Estimates

The following list of common errors is important to remember at the outset of an analysis of conservation savings:

- Not accounting for ongoing savings due to natural replacement;
- Not identifying whether savings are "net" of other possible causes aside from the conservation program under consideration; and
- Not accounting for the decay in conservation savings, should such decay exist.

[3] In addition to the issue of generalizability, studies of conservation savings and costs need to be concerned with threats to reliability and validity. Has random measurement error contributed to incorrect statistical conclusions? Has an event occurred in the test period that could influence the outcome of a study? We urge the careful consideration of such questions when drawing on the results summarized in this document to analyze water savings of BMP conservation practices. This document only begins the discussion of reliability, validity, and generalizability of savings and cost results; future research is needed to address these issues rigorously. See also Hollis, M., A. Bamezai, and D. Pekelney, " The Reliability and Validity of Conservation Measures," Proceedings of the American Water Works Annual Conference (1998).

1.2 Definitions of Key Concepts Used in this Report

This section seeks to standardize the language used to discuss and describe conservation BMPs and their analysis. Thereby, we hope to minimize ambiguous communication and to move toward standardized BMP cost-effectiveness reporting:

A conservation **device** is a piece of equipment or hardware used to conserve water. Low-flow showerheads, ultra-low-flush toilets (ULFTs), and cooling tower controllers are examples of conservation devices.

A conservation **activity** is an action performed to conserve water. Water audits and surveys, irrigation timer adjustments, leak detection, public service announcements, and school education programs are conservation activities. Some, but not all, conservation activities may involve the installation of conservation devices (for example, residential surveys that include installation of showerheads).

A conservation **program** is a means by which devices are installed and activities are performed. Examples of programs include ULFT rebate programs to promote installation of low flow toilets and commercial, industrial, and institutional (CII) survey programs to promote more effective adjustment of cooling tower controllers. When considering costs, it is important to address the administrative time and overhead related to the delivery of devices and activities. Likewise, when considering savings, it is important to distinguish between program delivery mechanisms if these differences result in different amounts of water saved.

Important **perspectives of analysis** include the total society perspective, the supplier perspective, the supplier perspective with cost sharing, and the customer perspective. The total society perspective concerns itself with summing all of the costs and benefits to society. The supplier perspective is concerned with summing the cost and benefits to the supplier, with and without cost sharing with other agencies such as waste water agencies. Likewise, the customer perspective sums the costs and benefits to customers—both those participating in the program and those not participating. Chapter 1 of the *CEA Guidelines* describes the perspectives of analysis most central to the MOU's exemption process, including the **total society perspective**, the **supplier perspective**, and the **supplier perspective with cost sharing**. In this document we seek to assemble data for the supplier and total society perspectives.

Perspective of analysis is one of several key factors that influence the estimation of costs and water savings of water conservation programs. Other key factors include the natural replacement rate of conservation devices and the existence of uniform plumbing standards. In what follows, this section defines these factors and describes ways to account for them when analyzing the costs and benefits of BMPs.

The benefits of water conservation programs include all of the positive results of program efforts to increase water use efficiency. Benefits are determined first by measuring water savings, which are quantified in physical units (e.g., gpd) by comparing water consumption with and without conservation devices or activities. When conducting cost-benefit analysis, water savings are expressed in dollar terms. The dollar value of water savings is determined by assessing factors such as the avoided costs of water supply and the avoided costs wastewater treatment. Benefits also include environmental benefits; we refer the reader to the *CEA Guidelines* for an introduction to environmental benefits valuation.

When determining conservation savings, it is important to identify **incremental savings** that the program produces—that is, water savings that would not have resulted without the program. **Active conservation** refers to incremental savings resulting from supplier-assisted conservation programs. **Passive conservation** refers to water savings resulting from customer actions and activities which do not involve, or depend on, direct assistance from supplier-assisted conservation programs. The additional increment of active conservation above passive conservation is the savings needed for cost-effectiveness calculations of suppliers' programs. Consider, for example, the water savings resulting from replacing an older toilet with a new water efficient model. If the replacement would not occur otherwise, but is motivated by a utility-sponsored rebate program, the resulting water savings should be counted as active conservation. But if the customer replaces a broken toilet that needs to be replaced immediately even without the rebate program, the savings should be counted as passive conservation.[4] The difference between active and passive savings has a direct bearing on program cost-effectiveness.

Customers who participate in a rebate program, but who would have conserved without the program, are known as **free riders.** When assessing program cost-effectiveness, water savings accruing as the result of program participation by free riders should not be credited to the program. In other words, savings from installation of conservation devices by free riders does not represent an additional increment of savings *due to the program*. For this reason, free riders reduce the cost-effectiveness of utility-sponsored conservation programs.

If there is no water efficiency plumbing code or other standards, then there may be competing technologies for water consuming appliances such as washing machines, and not all of the competing technologies may be water efficient. In this circumstance, rebate programs may influence not only the customer's decision of *when* to replace an appliance (acceleration of savings), but also the decision of *what* to purchase. Incremental savings are thus the sum of savings due to acceleration of replacement and savings due to the choice of high efficiency technologies (for example, a high efficiency washer).[5]

Where possible, this report relies on **field studies** and impact evaluations. The important distinction between field studies and **mechanical/engineering estimates** is that field studies measure conservation savings in actual use rather than in the lab or on the design table. Field studies are designed to account for variable human behavior, physical performance decay, and other factors encountered in the field.

There are at least three factors intervening between potential savings estimated by engineering/mechanical calculations and actual (or realized) savings measured in field studies:

[4] Plumbing codes, city ordinances and discretionary behaviors influenced by a personal "conservation ethic" are the most common factors responsible for passive conservation savings.
[5] See Appendix A for a discussion of how accelerated savings affect cost-effectiveness calculations.

- Whether the measure is actually implemented--something that can only be know with certainty through independent, on-site verification;
- Validity issues—for example, ANSI sanctioned tests used to measure ULFT flushing performance may not validly capture the dynamics of in-home use; and
- Discretionary behavior—for example, increasing shower time after retrofitting a shower with a low-flow showerhead.

These and other factors can instrumentally effect the amount of water actually saved by a water efficient device. Where field studies are not available, engineering estimates and assumptions are used. Where neither field nor engineering studies are available, the estimates used in this report are based on **professional judgment**.

The difference between field studies and mechanical/engineering estimates makes it important to distinguish between **savings potential** and **actual savings** achieved. For example, CII surveys often yield a set of recommendations for conservation devices and activities, which—if fully implemented—would yield a certain level of water savings. But to know if these potential savings are actually realized, it is necessary to know if all of the recommended measures are actually implemented. Failure to properly account for the difference between potential and actual savings can cause program-related water savings to be over-estimated.

Another important factor in correctly estimating conservation savings involves the **persistence** of savings over time. Savings may decay over time due to lack of maintenance, physical deterioration, and decline in behavioral compliance with conservation activities. As an example of savings decay, large landscape savings often rely on a combination of conservation devices, such as timers, leak repair and sprinkler adjustment, and seasonal timer adjustments. However, if there is a change in landscape contractors, the behavioral component of these measures may be lost without additional training. An example of high persistence is high efficiency washers, which do not require additional maintenance or adjustment over time to keep conserving water.

The amount of potential water savings available to a utility-sponsored conservation program depends, in part, on program timing and scale. Incremental savings are measured relative to a “no program” alternative—that is, the case where the active conservation program is not implemented. If the background saturation rate of conserving devices is increasing over time due to passive conservation (for example, plumbing code and natural replacement), then active conservation programs will yield diminishing incremental savings. The expected savings from the installation of a conserving device is less as time goes on because on average there will be fewer and fewer low efficiency devices left in the customer population, and thus a lower chance of the active conservation program resulting in the replacement of a low efficiency device. This same background saturation rate may account for declining savings over time after the device is installed. The important implication is that declining savings from active conservation means declining program cost-effectiveness. Conversely, implementing a program sooner rather than later and increasing the scale of the program may under certain circumstances increase cost-effectiveness.

The **costs** of conservation programs include costs to customers, capital and O&M expenditures for conservation programs, program administration and implementation costs, and environmental costs. The *CEA Guidelines* provide categories of costs that should be included for various perspectives of analysis. For example, for the total society perspective, valid cost categories include participant program costs, supplier program costs, and external costs. Program costs can include staff salaries and overhead; vehicle costs; administrative cost to develop, administer, and monitor the program; material costs; and marketing.

Program costs and savings may differ according to program design or "delivery mechanism." For example, CII surveys may be carefully targeted, which increases both their costs and presumably their potential for conservation savings compared to less carefully targeted programs.

It is important to identify the **incremental costs** of the conservation device or activity. For example, when determining the labor costs associated with a conservation program or activity, it is important to include overhead. But only that share of overhead associated hours actually spent working on the conservation activity should be counted. If standard overhead multipliers include cross-subsidies to unrelated functions, they should be corrected, to the extent practical.

Cost-effectiveness analysis (CEA) is the comparison of costs of a conservation device or activity, measured in dollars, with its benefits, expressed in physical units (for example, $Costs per AF of savings). **Cost-benefit analysis** (CBA) is the comparison of costs of a conservation device or activity, measured in dollars, with its benefits, expressed in dollar terms (for example, $Net Benefits = $Benefits - $Costs). The most meaningful measure for purposes of cost-benefit analysis is **net present value** (i.e., NPV = $PresentValueBenefits – $PresentValueCosts). NPV compares costs and benefits that occur at different periods of time by discounting to determine their present value. The *CEA Guidelines* discuss these calculations in greater detail.

Sometimes it is not clear whether to represent a particular item as a cost or a benefit. For example, from the customer's perspective, energy savings that result from some conservation devices--such as high efficiency washing machines--imply a reduction in energy costs compared to the no program alternative. Should these energy savings be counted as a reduction in costs or as an increase in benefits? When calculating NPV, it does not matter because, whether characterized as a "negative cost" or a "positive benefit" it still will be part of the NPV calculation. However, for cost-effectiveness calculations (i.e., cost per AF), we need to decide whether to subtract the energy savings from the costs of the conservation program. The *CEA Guidelines* would characterize the energy savings as a benefit, not a cost; for this document, we extend this convention.

1.3 Devices and Activities Potentially Applicable to BMPs

Table 1 shows categories of conservation devices and activities and indicates how they may be related to the BMPs contained in the MOU. Note that some activities and devices relate to more than one BMP. "X" indicates that the device/activity is widely understood to be associated with the BMP or PBMP and "O" indicates potential association.[6]

Table 1 also illustrates the organization of this report. The report consists of separate sections that contain savings and cost estimates for each device/activity category for which we currently have quantified water savings. Within each section, there is a range of relevant activities and devices. Note that some of the device/activity categories do not have sections in this report because they do not currently have water savings quantified. Rather than obscure the limitations of currently available information, this report purposely highlights existing deficiencies in an attempt to help the CUWCC identify areas where additional, or better, information is needed. The report format leaves room to "fill in the blanks" as additional BMP savings are quantified in the future, and as savings and cost estimates are improved. Indeed, it is strongly recommended that the program cost and water savings estimates contained in this report be reviewed and updated annually.

For each conservation device/activity category, the report includes:

- **Device/Activity Description**
- **Applicable BMPs**
- **Available Water Savings Estimates**
  - Summary of Savings Estimates
  - Persistence
  - Limitations
  - Confidence in Estimates
- **Program and Device/Activity Cost Estimates**
  - Program Costs
  - Limitations
  - Confidence in Estimates
- **Water Savings Calculation Formula(s)**
  - Calculations
  - Factors to Consider in Applying the Formula
- **Example Calculations**
- **Questions to Ask**
- **Sources**

The "Confidence in Estimates" sections designate levels of high, medium, or low confidence in the reliability and accuracy of specific estimates. These designations are subjective judgments that are meant to indicate the strength of the evidence for savings and cost estimates relative to one another. The "Questions to Ask" sections suggest items to help identify important variables to consider when determining BMP costs and savings.

[6] Table 1 is not intended to be proscriptive, authoritative, or limiting to the creativity of future ways to better implement BMPs.

1.4 Example of CBA and CEA

Appendix A provides numerical examples of CBA and CEA that illustrates their differences and the mechanics of their calculation in a spreadsheet. The examples address the following topics described so far, among others:

- Perspectives of analysis;
- Presence or absence of plumbing code (low efficiency alternatives); and
- Incremental savings and costs.

1.5 Known Areas Where Future Research is Needed

The following is a list of areas that require additional future research:

- Savings decay over time
- Free riders
- Discount rates
- Natural replacement rates
- Device saturation rates
- The affects of key program design variables like timing, scale, and targeting
- The types and amounts of costs utilities avoid by implementing conservation programs
- Expressing program benefits in dollar terms

Table 1 - Devices and Activities Potentially Applicable to BMPs*

Device/Activity Category	BMPs: 1 Residential Water Surveys	2 Residential Plumbing Retrofits	3 System Water Audits, Leak Detection	4 Metering and Commodity Rates	5 Large Landscape	6 High Efficiency Washing Machines	7 Public Information	8 School Education	9 Commercial, Industrial, Institutional	10 Wholesale Agency Assistance**	11 Conservation Pricing	12 Conservation Coordinator	13 Water Waste Prohibition	14 Residential ULFT Replacements
Educational Events and Materials	X				X		X	X	X					
High Efficiency Washing Machines		O				X			O					
Metering				X	O						X			
Pricing				X							X			
Residential Plumbing Retrofit Devices	X	X												
Residential Surveys	X	X												
Ultra Low Flush Toilets (Residential)														X
CII Surveys					X				X					
Self-Closing Faucets		O							X					
Ultra Low Flush Toilets (CII)									X					
Urinals									X					
Large Landscape Devices					X				X					
System Audits and Leak Detection			X											
Graywater Systems		O			O				O					
Hot Water Demand Units		O							O					

Key: X indicates that the device/activity is widely understood to be associated with the BMP or PBMP; **O** indicates potential association.

Notes: * This table is not intended to be proscriptive, authoritative, or limiting to the creativity of future ways to better implement BMPs.

** This table does not directly apply to wholesale agencies. Wholesale agencies, under BMP 10 of the MOU, are required to provide financial incentives and/or technical assistance for cost-effective BMPs. Hence, any of the above BMPs/measures may or may not be required to be supported by a wholesale agency depending soley on the cost-effectiveness of that BMP or measure.

2 Savings and Costs

This section contains descriptions for each of the following categories of water conservation devices and activities, grouped by sector:

Residential Sector

- High Efficiency Washing Machines
- Metering
- Pricing [Place holder for upcoming CUWCC report and results]
- Residential Plumbing Retrofit Devices
- Residential Surveys
- Ultra Low Flush Toilets (Residential)

Commercial, Industrial, and Institutional Sector

- CII Surveys
- Self-Closing Faucets
- Ultra Low Flush Toilets (CII)
- Urinals

Landscape Sector

- Large Landscape Devices

Distribution System

- System Audits and Leak Detection

Potential Best Management Practices (PBMPs)

- Graywater Systems
- Hot Water Demand Units

2.1 High Efficiency Washing Machines

2.1.1 Device/Activity Description

High efficiency washing machines are those designed to save energy and water. The estimates below refer to currently available high efficiency machines, which have not been fully optimized for *water* savings. When the fully optimized machines have been tested, these savings estimates should be updated.

2.1.2 Applicable BMPs

BMP 6 – High-Efficiency Washing Machine Rebate Programs calls for the CUWCC to develop reliable water savings estimates. In addition, one of the criteria to determine implementation status is to offer "cost-effective" financial incentives. To make this determination, water savings needs to be quantified.

2.1.3 Available Water Savings Estimates

Summary of Individual Studies

Early studies found that some users tended to fill front-loading washers to less than full capacity, highlighting the difference between savings potential and actual savings. The field studies below measure actual savings.

The *THELMA* project (The High Efficiency Laundry Metering & Marketing Analysis) lab testing is complete and the field testing is in progress. The Field testing is at 26 locations (26 machines) in the Pacific Northwest and California. Currently available machines are being tested, and "new generation" machines will be tested when they are available. The project also includes focus groups which were conducted in Bellevue, Washington and Concord California in February 1995. Table 1 shows savings estimates with confidence intervals derived from THELMA (1997).

Oak Ridge National Laboratory conducted a field study of high efficiency washers for the U.S. Department of Energy (Oak Ridge National Lab 1998). More than one hundred participants in a town of 200 population (Bern, Kansas) cleaned over 20,000 loads of laundry over a five month period. The study considered energy and water consumption, customer habits and perceptions, and community-wide water and waste water system impacts. Savings were estimated to be 37.8 percent.

The *Consortium for Energy Efficiency* (CEE 1995) has implemented a High-Efficiency Clothes Washer Initiative in an effort to promote water and energy conservation. CEE approves efficient washers, which are then promoted by utilities. CEE studies have reported 37.5 gallons per load, on average, for conventional machines in use and 24.2 gallons per load for high efficiency machines.

Table 1 - Estimated Water Savings (gallons/unit of time)

Time Period	Per Week	Per Year
Mean Savings	97.8	5,085.6
90% C.I. Range	87.7 - 107.9	4,560.4 - 5,610.8
95% C.I. Range	85.7 - 109.9	4,456.4 - 5,714.8

Source: Mitchell (1998) derived from THELMA (1997) data.

Persistence

We have not found a study that considers the persistence of savings from high-efficiency washers.

Limitations

Savings estimates do not consider that some customers will purchase high efficiency machines even without the existence of an active conservation program. As the market for these machines matures and if the price comes down as expected, this free rider impact may grow.

Confidence in Estimates

High for estimates based on the recent field evaluations such as the THELMA project.

2.1.4 Program and Device/Activity Cost Estimates

Program Costs

Participant program costs may include:

- Difference in cost for high efficiency machine, less rebate if it exists.
- Installation cost if higher or accelerated compared to no program alternative.

Supplier program costs may include:

- Staff time to develop rebate program
- Rebate costs, if they exist
- Administration
- Contractors
- Marketing

THELMA (1997) reports the incremental cost of high efficiency washers is $400 more than comparable conventional washers. The study reports that a typical customer would save between $43 and $106 per year in energy, water, and waste water costs. (Note that energy and wastewater savings are *benefits* of the high efficiency washers and should not be included in as “net costs” when calculating cost per AF, given the convention established in the *CEA*

Table 2 - Washing Machine Costs

Type	Retail Price Range $1998
Front Loading	$700-1600
Top Loading	$300-600

Source: Consumer Reports (1998)

Guidelines and this document.) These figures assume:

- 6.7 loads per week
- 60 percent of loads using warm or hot water
- $0.0835 per kWh
- $0.002011 per gallon of water
- $0.002362 per gallon of waste water

Another potential cost savings is detergent. Although high efficiency machines use less detergent, special detergent is necessary for some models (although the special detergent may be more expensive per unit).

Consumer Reports (1998) collected retail price data on the major front-loading and top-loading models of washing machines available in the U.S. (Table 2). Rebates would reduce the cost to the customer and increase the cost to the supplier. The incremental costs of a high-efficiency washing machine program is the difference between their cost and the costs that would be incurred without the program (e.g., the difference between front- and top-loading machines for natural replacements).

It is important to note that, like other devices and activities, the costs of the high efficiency washers may be different for the different perspectives of analysis. From the total society perspective, the cost is as described above—the difference between conventional washers and the high efficiency counterparts. For the customer, however, the costs might be less because of a purchasing rebate program. Likewise, the cost from the agency perspective is the cost of the rebate, which may not be the entire difference in costs—something less than $400 for example for each washer.

Limitations

As the market for high efficiency washers develops, the price difference between high efficiency and conventional machines is expected to decrease, so washer prices should be monitored by CUWCC to keep current.

Confidence in Estimates

High for estimates based on current market data. Less so for projections of future costs, although, costs are expected to decrease as production scale increases.

Table 3 - High-Efficiency Clothes Washers

Supplier	SF_PPH	MF_PPH	SF_Savings gpd/machine	MF_Savings gpd/machine*
Supplier A	2.00	1.50	14.4	53.8
Supplier B	3.00	2.25	21.5	80.7
Supplier C	4.00	3.00	28.7	107.7

*Assuming 5 households per machine.

2.1.5 Water Savings Calculation Formula(s)

Calculations

S = Savings_per_Load * Water_Use_per_Load * Loads_per_Person * PPH

where:
- S is savings (gpd/machine)
- PPH is persons per household.

Factors to Consider in Applying the Formula

Loads per person may vary among demographic segments of the population, so a demographic distribution assessment could improve savings calculations.

2.1.6 Example Calculations

Savings estimates from this numerical example are summarized in Table 3. When washing machines are shared, savings per machine can be estimated by multiplying savings times the number of households per machine (e.g., number of apartments per machine in an apartment building). In this example, we assume multi-family buildings have 5 households per machine. For coin-operated laundries, multiply the number of loads per machine (calculated by dividing the revenue from a machine by the price) times (Savings_per_Load * Water_Use_per_Load). Savings and water use will vary for large commercial machines (double and triple loaders). The following assumptions were used in the example:

- Savings_per_Load is 25% for maximum fill, 10% for minimum (THELMA). Oak Ridge National Laboratory (1998) reports 37.8% savings.
- Water_Use_per_Load is 48.5 gallons per load (mean of HUD values reported in Waterplan 1988).
- Loads_per_Person is .3 loads per capita per day (HUD value reported in Waterplan 1988) to .45 loads per day (calculated from data reported in Oak Ridge National Laboratory 1998).

2.1.7 Questions to Ask

- Does the energy provider(s) and/or waste water agency(ies) covering your water service area offer incentives for the purchase of these machines?

- Are there other agencies that you can partner with to make your program more cost effective?
- Does your agency have access to grant or other partnership type funding?
- Which models are included?
- Are savings estimates associated with models you have selected?
- Will utilization be tracked (e.g., housing density)?

2.1.8 Sources

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2.2 Metering

2.2.1 Device/Activity Description

Metering for conservation consists of installing meters in existing customer sites where they do not currently exist, and requiring that new construction sites install water meters. Meters can also be added to individual units in a multi-family building; so called "sub-metering" allows separate household-level water usage measurement in buildings where there was previously only a master meter. Metering can also be used to separately measure indoor from outdoor use. Another aspect of metering is their service and rate of replacement; in terms of conservation, such activity may "true up" the price signal sent to customers. It is important to note that meters are instrumental to number of conservation efforts because they provide information on use to consumers.

2.2.2 Applicable BMPs

- BMP 4 – Metering with Commodity Rates.
- Metering is a necessary condition for implementing BMP 11 – Pricing.

2.2.3 Available Water Savings Estimates

Summary of Individual Studies

Speedwell (1994) analyses data from a sample of 590 multi-family buildings in New York City and a sample of 676 multi-family buildings in Jamaica, New York. The Jamaica service area is metered and the New York City buildings were not metered. A statistical model was developed, regressing housing density, median income in the census tract, building size water use, and a dummy variable for Jamaica service area on water use. Controlling for these independent variables, metered billing resulted in a 36 percent decrease in water use, which the authors attribute to metered water consumption.

Bishop and Weber (1995) report the results of a statistical analysis of Denver's universal metering program. The average annual water savings is reported as 28 percent, with a summer peak seasonal reduction of 38.4 percent in 1991. The authors cite landscape irrigation as the reason for the large summer savings with metering. The authors report that controlling for season, weather, and the effect of metering and conservation practices that 98 percent of the monthly variation is explained in the model. However, savings estimated in the statistical model cannot be separated from savings from concurrent programs to promote the installation of conservation devices, such as bathroom retrofits. The savings effect is also not separated from the effect of newly metered accounts that may have systematic differences in lot size, income, or housing density.

Leblanc (1997) notes that the Residential Water Metering Study in Greater Vancouver assumed that "residential water meters, an appropriate rate structure and bimonthly billing would result in a 20 percent reduction in single family residential consumption, “based on the experience in other areas.”

Lovett (1992) reports water savings from the addition of universal metering has been in the range of 25 to 40 percent where it has been implemented in several Canadian locations.

Koch and Oulton (1990) report that single family dwellings that have been converted to individual meters save on average 20 to 30 percent .

Persistence

We have not found a study that considers the persistence of savings from water metering.

Limitations

None of the studies have fully controlled for all possible and reasonable explanitory variables. In particular, other conservation programs may have been concurrent with the metering program evaluations.

Confidence in Estimates

Low. Future efforts should include empirical measurement of water savings considering an appropriate range of explanatory variables. It is important to consider the interactive effect of metering along with other conservation programs; savings from metering and other conservation programs may not be additive. Savings also may be considerably different depending on the amount of outdoor use.

2.2.4 Program and Device/Activity Cost Estimates

Program Costs

Participant program costs may include:

- Meter installation cost, if not paid by the supplier.

Supplier program costs may include:

- Staff time to develop meter program and new rates structure
- Meter and installation costs, if the supplier pays.
- Administration
- Contractors
- Marketing

Denver Water Department (1993) reports the average cost per meter setting to be $425, including purchase, installation, repair if deteriorating lines, and public education.
Bishop and Weber (1995) report costs in the range of $250 to $750 per meter for purchase and installation. The cost to install a meter in a new construction residence is cited as $175.

Table 1 - Savings from Meters (gpd)

	Percent Savings		
Water Use (gpd)	**20%**	**30%**	**40%**
20	4	6	8
40	8	12	16
60	12	18	24
80	16	24	32
100	20	30	40
120	24	36	48

Leblanc (1997) reports that the cost of meter purchase and installation is $210 for indoor installation and $450 for outdoor installation. [We assume Canadian dollars, although it is not specified in the article].

Westerling and Hart (1995) develop a cost minimization model to determine the optimal period of time between meter replacements. Their sample calculations indicate a range between 7 and 14 years.

Limitations

Payments conventions may vary from supplier to supplier. For example, where new development takes place, metering cost may be incurred by the developer and new owners, not by the supplier. Alternatively, retrofit costs may be incurred by the supplier.

Confidence in Estimates

Low.

2.2.5 Water Savings Calculation Formula(s)

S = Household_Water_Consumption * Savings_Percent

where :

- Household_Water_Consumption is the pre-metering consumption
- Savings_Percent is the percent savings assumed to result from metering

Factors to Consider in Applying the Formula

Household water consumption may variable considerably by socioeconomic status, climate, and landscape variation.

2.2.6 Example Calculation(s)

Savings have been reported in the range of 20 to 40 percent; however these estimates have not been made with rigorous models. With the available information, savings can be calculated by taking a service area water use and testing percentage savings for sensitivity. Table 1 shows sample calculations for different levels of water use.

2.2.7 Questions to Ask

- Are there other agencies that you can partner with to make your program more cost effective?
- Does your agency have access to grant or other partnership type funding?
- Are current unmetered connections in easements behind the residences or out in front in public property? (1)
- If in easements behind the residences, does your agency maintain leak histories, which would indicate the need to replace the easement mains? (1)
- Are there currently shutoff valves with spacers (for future meter installations) inside meter boxes for your unmetered connections? (1)
- If service line shutoff valves are not already in place, are the locations of your agencies service lines known where meter boxes, shut off valves and meters are to be installed? (1)
- What is the typical distance from main to meter? (1)
- Based on the meter manufacturer your agency has selected for use, what is the availability and cost of remote (radio frequency) reading? (1)
- What is the cost of meters in bulk? (1)
- Would your agency install meters with its own personnel or contract the installations with contractors? (1)
- Can your agency bill metered customers prior to completing your meter program for all customers?
- Will your agency meter all customers within the shortest cost effective period, or spread implementation over the 10 years allowed by the BMP? (1)
- Would your agency read meters on a monthly or bimonthly basis? (2)
- Does your agency currently have a metered billing system, or would such a system have to be designed an/or purchased? (2)
- Is the water bill designed to communicate water consumption and compare like months or periods for current and past years? (2)
- What is the age of the housing stock (opportunity for leak detection?)
- How often is meter accuracy checked?

(1) Your metering cost will vary substantially based on the responses you obtain for these questions. Hint - your operations department should be able to provide this information or direct you to those within your agency who can.
(2) Your operational cost will vary depending your responses to these questions. Hint - your accounting and/or your information systems department(s) should be able to provide you with these responses.

2.2.8 Sources

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2.3 Pricing

This section is a place holder for the forthcoming CUWCC Pricing Study.

2.4 Residential Plumbing Retrofits:
Low Flow Showerheads And Other Devices (Excluding ULFTs)

2.4.1 Device/Activity Description

Low flow (LF) showerheads are showerheads designed to provide water at lower rates of water flow. Flow is typically measured in gallons per minute and low flow showerheads are rated at 2.5 gallons per minute (gpm) or less (at pressure levels up to 80 psi). California state law currently requires that all showerheads sold in the state meet the 2.5 gpm standard. Toilet displacement devices come in a variety of designs that all displace some water volume in the toilet tank. Since less water is needed to refill the tank, less water is used per flush. Toilet leak detection is typically performed with dye tablets. Faucet aerators reduce flow from faucets.

2.4.2 Applicable BMPs

- BMP 1 – Residential Water Surveys. Residential surveys may involve plumbing retrofits.
- BMP 2 – Residential Plumbing Retrofit.

2.4.3 Available Water Savings Estimates

Summary of Individual Studies

The savings estimates presented below are based on a series of rigorous field studies that examined the change in metered water consumption of more than 27,000 households and customers in the Cities of Irvine, Los Angeles, San Diego, and Santa Monica. Because the exact number and type of devices contained in a retrofit kit can and has varied significantly, device-level estimates assist the comparison across studies.

<u>Showerheads</u>

The water savings estimates below represent a statistical estimate of the mean change in water use observed over a large number of residential households. We present a subset of estimates from these field studies that: (1) are based on a large sample size, (2) represent a multiple year period, and (3) have statistically controlled for non-plumbing related factors and ongoing conservation. It is desirable to have a large sample size so as to increase the precision of the estimate. A multiple year period is needed to examine patterns over time. Careful control for biasing effects is required to ensure the estimates represent *net* water savings, not *gross* water savings—that is, savings from conservation programs, not from other factors such as household characteristics. Table 1 provides a summary of these estimates.

The probability of a showerhead actually being replace can vary widely. The probability of replacement depends in part on the method of distribution (e.g., “hang and pray”). Field studies of retrofit kit distributions in Irvine (Source 5) and Los Angeles (Source 7) have found initial installation probabilities that range from 49 percent to 59 percent. Not all showerheads that are replaced are retained. Since both estimates reflect self-reports, they may overstate the true installation probability. The same two field studies found that 7-9 percent of installed LF

Table 1 - Statistical Estimates of Low Flow Showerhead Savings

Estimates	Margin	Time Period	Sample Size	Source
5.5 gpd/LFSH Single Family	+/- 1.5 gpd	1990-92	~2,900 SF Dwellings	(3)
5.8 gpd/LFSH Single Family	+/- 2.6 gpd	1990-93	~3,000 SF Dwellings	(4)
5.2 gpd/LFSH Multi-Family	+/- 1.1 gpd	1990-92	~2,300 MF Complexes (9.5 Units/Complex)	(3)

Table 2 - Statistical Estimates of Savings from Other Retrofit Devices

Retrofit Device	Savings (gpd/device)	Error Margin
Toilet Dams	4.2 gpd	+/- 2.6 gpd
Faucet Aerators	1.5 gpd	+/- 2.6 gpd
Leak Detection Tablets	8 gpd	+/- 2.6 gpd

Source: (4)

Table 3 - Flow Rate of Existing Showerheads

Home Survey Location	Flow Rate of Existing Showerheads	Time Period	Sample Size	Source
Los Angeles	3 gpm	Summer 1993	5,502 SF Residences	(10)
San Diego	3.08 gpm	FY 1994-95	3,666 SF Residences and 489 MF	(11)

showerheads were later removed. Direct install programs allow a direct count of the number of installed showerheads; only the probability of removal then needs to be estimated.

<u>Other Devices</u>

Table 2 shows water savings estimates for the other plumbing retrofit devices from a field study in Los Angeles (Source 4). Even with the large sample size of this study, these estimates of the expected change in metered household water consumption are less precise than the showerhead estimates. In the two field studies of plumbing retrofit programs mentioned above (Sources 5 and 7), toilet dams exhibited somewhat higher self-reported installation rates *and* higher removal rates. Estimates of the installation rate for faucet aerators also come from self-reported data and, as such, should also be considered speculative. The field study in Irvine Ranch found that 13 percent of respondents reported the use of leak detection tablets. Estimates of the rate of toilet leakage derive from Sources 1, 4, 7, and 11.

Persistence

Showerhead savings estimates have been measured in recent programs. Since these field studies examined water use over a multi-year period, the estimates reflect the multi-year period average and they embed any retention and decay effects. There is some evidence that future programs may yield less water savings due to the increasing saturation of LF showerheads in most service areas. State plumbing code requiring sale of LF showerheads tends to increase the saturation of low flow showerheads over time. Direct evidence of background saturation rates can be derived from data collected during home water surveys. Table 3 shows flow rates of *existing* showerheads as measured in recent residential surveys in Los Angeles and San Diego.

Limitations

Since conserving showerheads are required in plumbing code, background saturation rates are likely to be higher now than during the study periods referred to above.

Confidence in Estimates

Medium to High. Considerable empirical research has been conducted regarding the savings of low flow showerheads. Important areas for future research include background saturation rates and persistence of savings over time.

2.4.4 Program and Device/Activity Cost Estimates

Program Costs

Participant program costs may include:

- Cost of retrofit kit if not fully subsidized
- Installation cost if not fully subsidized

Supplier program costs may include:

- Staff time to contact building departments, developers, and plumbing supply outlets
- Retrofit kits: showerheads, toilet displacement devices, and installation costs
- Administration
- Contractors
- Marketing

The following are professional judgments of costs by conservation program coordinators and managers, as reported in A&N Technical Services (1995):

- Low flow showerheads, kit: $2
- Low flow showerheads, direct install: $10-15

Limitations

Cost estimates vary with the scale of the program.

Table 4 - Retrofit Device Savings

		Method 1	Method 2
Device	**Initial Savings (gpd per device)**	**Device Life Span**	**Device Decay Rate per Year**
Low Flow Showerheads	5.5 gpd	3-7 years	20-30 percent
Toilet Displacement Devices	4 gpd	2-5 years	40-60 percent
Faucet Aerators	1.5 gpd	1-3 years	40-60 percent
Toilet Leak Detection	.64 gpd (8 gpd per repaired leaking toilet; 8 percent of toilets leak)	7-10 years	1-2 percent
Other Household Leak Check	.5 gpd (12.4 gpd per household repair; 4 percent of households with leaks)	7-10 years	1-2 percent
Turf Audit	12.2	4 years	40-60 percent
Turf Audit with Timer	25.9 gpd (12.2 gpd for turf audit plus 13.7 if timer)	4 years	40-60 percent
Source	Field Studies	Judgment	Judgment

2.4.5 Confidence in Estimates

Medium.

2.4.6 Water Savings Calculation Formula(s)

Calculations

Water Savings = Device_Savings * Number_of_Devices * Probability_of_Installation * Lifespan

Factors to Consider in Applying the Formula

Per device water savings from field studies embed behavioral responses (longer showering times) and mechanical/engineering estimates do not. Water savings decay can be very site specific. Water supplies with high mineral content can degrade showerheads relatively quickly. This affects the background saturation rate, degradation of new showerheads, and ongoing device replacement rates. The probability of installation/retention is both site-specific and uncertain.

Example Calculations

Table 4 summarizes savings rates, life spans and decay rates for low flow showerheads and other retrofit devices. Method 1 is a method to account for savings decay by accounting for the savings over a number of years representing the device life span. Method 2 is an alternative method, whereby the savings are reduced by the indicated percent over the period of analysis (percent year over year, exponential) or until savings approach zero.

2.4.7 Questions to Ask

- Are there other agencies that you can partner with to make your program more cost effective?
- Does your agency have access to grant or other partnership type funding?
- Are devices to be provided on “hang and pray” or “directly installed” basis?
- Will the selected method be accomplished with agency’s own personnel or using a contractor?
- Does your agency allow your agency personnel or contractor personnel to enter the customer’s home?
- What marketing technique will be used to accomplish the selected method?
- What devices and actions are included?
- Will your personnel or the contractor’s personnel install the devices? If not, how will installations be verified?
- Do you have estimated or comparative cost for device components and method selected to implement the program?
- Are you going to design and maintain a database covering program results?
- What is the age of the housing stock?
- Can you influence how the cost of this program is accounted for? If capitalized, the cost impact will be spread over “x” number of years and reduce the rate impact. If expensed, will the cost of your program have to be recovered in one year?

2.4.8 Sources

(1) Bamezai, A. and T.W. Chesnutt, *Residential Water Audit Program: Evaluation of Program Outcomes and Water Savings*, A report for the Metropolitan Water District of Southern California, December 1994.

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(3) Pekelney, D.M., and T.W. Chesnutt, “Reference Document: Program Design Tool and Savings Estimates,” A&N Technical Services (1995), for MWDSC.

2.5 Residential Surveys

2.5.1 Device/Activity Description

Residential home surveys target both indoor and outdoor water use. In practice, home surveys usually imply a site visit by trained staff who (1) solicit information on current water use practices and (2) make recommendations for improvements in those practices. Sometimes indoor plumbing retrofit devices are directly installed when appropriate. The outdoor portion of the survey can vary widely, ranging from an intensive outdoor water efficiency study (turf audit, catch can test, and written recommendations for irrigation scheduling or landscape changes) to provision of a brochure on outdoor watering practices.

2.5.2 Applicable BMPs

- BMP 1 – Residential Water Surveys.
- BMP 2 – Residential Plumbing Retrofit. Residential surveys may involve plumbing retrofits.
- BMP 6 – High Efficiency Washing Machines. Residential surveys may result in washing machine replacement.
- BMP 10 – Wholesale Agency Assistance. Surveys are applicable to wholesale assistance and incentive programs.
- BMP 14 – Residential ULFT. Residential surveys may result in ULFT replacement.

2.5.3 Available Water Savings Estimates

Summary of Individual Studies

The Contra Costa County Water District conducted a residential water audit evaluation that was designed to determine the water savings from a program that was implemented from 1989 to 1993 (Source 4). Of the 4,390 audits CCWD conducted, 2,216 audits were selected for the evaluation study because the customers: (1) had complete audits (indoor and outdoor), (2) had only one audit, and (3) stayed in the same home for the five-year study period. After statistically controlling for indoor and outdoor household characteristics, the study determined that audit savings were between 6 and 24 percent with an average of 16 percent. The study found that water savings were higher in the summer and that homes with irrigation timers used more water than homes without timers.

We provide two methods of estimating savings from residential home surveys. The first estimates one total number for survey savings and the second estimates a number for each of the components of the survey. Both sets of figures are derived from statistical analyses of data collected in field studies. The second method allows design of the survey using different components.

<u>Total Survey Savings Method</u>

Table 1 - Component Savings

		Method 1	Method 2
Survey Component Device	**Initial Savings (gpd per device)**	**Device Life Span**	**Device Decay Rate per Year**
Low Flow Showerheads	5.5 gpd	3-7 years	20-30 percent
Toilet Displacement Devices	4 gpd	2-5 years	40-60 percent
Faucet Aerators	1.5 gpd	1-3 years	40-60 percent
Toilet Leak Detection	.64 gpd (8 gpd per repaired leaking toilet; 8 percent of toilets leak)	7-10 years	1-2 percent
Other Household Leak Check	.5 gpd (12.4 gpd per household repair; 4 percent of households with leaks)	7-10 years	1-2 percent
Turf Audit	12.2	4 years	40-60 percent
Turf Audit with Timer	25.9 gpd (12.2 gpd for turf audit plus 13.7 if timer)	4 years	40-60 percent
Source	Field Studies	Judgment	Judgment

Savings from Intensive Home Surveys Targeted to High Water Users:
- 32.2 gpd per single family household (weighted average of targeted surveys in Sources 1 and 2).

Savings from Untargeted Intensive Home Surveys:
- 21 gpd per household (1/3 the above amount, observed ratio in Source 1).

<u>Survey Components Method</u>

The savings estimates in Table 1 indicate the device savings from various survey components. One can estimate savings from different design surveys by choosing the component savings from the table. Method 1 is a method to account for savings decay by accounting for the savings over a number of years representing the device life span. Method 2 is an alternative method, whereby the savings are reduced by the indicated percent over the period of analysis or until savings approach zero.

Persistence

The persistence of water savings is one of the central issues to estimating the cost-effectiveness of residential home surveys. This issue is rarely addressed in empirical impact evaluations because of the expense and intrinsic difficulty of providing a multiple-year measure of impact. One such example was based on data from a field study in Los Angeles (2). Examining early participants and four years of post-intervention water use data, the following graph was developed.

Figure 1 plots the average annual net water savings for each year following the initial home survey. The net water savings hold up surprisingly well during the first three years. The fourth year appears to give some evidence of a decline in water savings, but some caveats are in

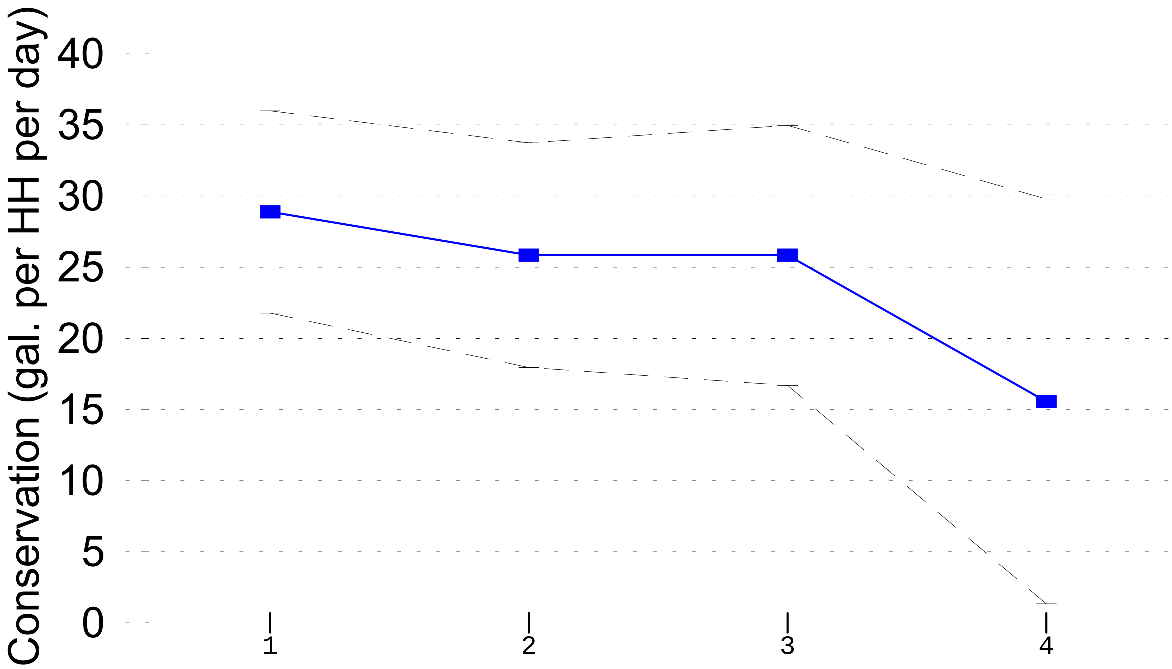

Figure 1 - Years after Home Survey

order. First, there is a greater amount of uncertainty surrounding the savings in the fourth year. This is due to the smaller sample size of Phase I participants that possessed four years of post-intervention water use. The broader bands of uncertainty surrounding the fourth year of water use make it more difficult to discern any decline in water savings. Second, the estimated level of water savings in the fourth year may also reflect characteristics of the smaller sample of early participants that does not reflect later participants. The authors caution against drawing too much inference about the magnitude of decay in water savings from this early evidence and recommended more long-term follow-up of conservation program results.

The CCWD (1994) study calculated water savings persistence in three time periods subsequent to audit implementation: "Savings over the first year, second year, and beyond average 17 percent, 16 percent, and 13 percent respectively."

Limitations

The persistence of water savings from residential surveys remains a difficult quantity to predict.

Confidence in Estimates

Low.

2.5.4 Program and Device/Activity Cost Estimates

Program Costs

Participant program costs may include:

- Cost of survey devices/materials if not fully subsidized
- Installation cost if not fully subsidized

Supplier program costs may include:

- Staff time to develop survey materials, target sites, and conduct survey (if not contracted out)
- Survey equipment and devices
- Administration
- Contractors
- Marketing

CCWD (Source 4) estimated their program costs as they were incurred in their 1993 program implementation.

The following are professional judgments of costs by conservation program coordinators and managers, as reported in A&N Technical Services (1995):

- Survey, targeted indoor/outdoor: $200
- Survey, untargeted indoor: $40
- Low flow showerheads, kit: $2
- Moisture sensor, residential: $125
- Irrigation timer, residential: $230
- Swimming pool/spa covers: $5-150
- Low flow showerheads, direct install: $10-15

Limitations

Costs vary with scale of the program and the weather—hot and dry periods make for easier marketing to many residential customers.

Table 2 - Cost of Residential Audit

Action	Hours	Costs
Labor		
Audit	1.25@ $15.43/Hour	$19.28
Administrative Costs		$ 5.86
Labor Subtotal		$ 25.14
Equipment		
Showerhead	0.61@ $2.49	$ 1.52
Toilet dam	1.54@ $1.20	$ 1.85
Bucket (1993 only)		$ 1.80
Faucet aerator		$ 1.19
Information material		$ 3.50
Hose nozzel		$ 0.99
Milage	17 mi.@ $.28/mi.	$ 4.76
Equipment Subtotal		$ 15.61
Total		$ 40.75

Reproduced from CCWD 1994.

Confidence in Estimates

Low-Medium. Achieved conservation from residential home water surveys can vary widely depending upon: (1) the content of the survey, (2) the targeted marketing, and (3) the water and wastewater rate structures in place.

2.5.5 Water Savings Calculation Formula(s)

Calculations

Water Savings = Survey_Savings * Number_of_Surveys

Factors to Consider in Applying the Formula

Survey savings can vary greatly depending on weather, water rates, and follow-up. Multiplying by “Number_of_Surveys” as shown above allows the calculation of program savings, not just from a single survey, assuming constant savings by scale. Survey_Savings is an average over the years of estimation, with decay imbedded.

Example Calculation

Water Savings = Survey_Savings * Number_of_Surveys

11,000 gpd per 1000 Surveys = (5.5gpd + 4gpd + 1.5gpd) * 1000 Surveys

2.5.6 Questions to Ask

- Are there other agencies that you can develop partnerships with to make your program more cost effective?
- Does your agency have access to grant or other partnership type funding?
- Is the survey targeted, and to whom?
- What marketing technique(s) will be used to enlist customer participation and will the selected technique(s) include incentives?
- How many times are customers contacted?
- What are climatic conditions, and do you have the ETo for determining the right application of water?
- Are the landscape areas generally small or large and overall, are most watered by hand or by automatic sprinkler system?
- Do you intend to conduct the surveys with agency personnel or contract with others?
- Does your agency allow your personnel or contractor personnel to enter the customer's home?
- What are the elements of the survey (devices, actions, etc.?)
- Do you have estimated or comparative costs for survey/device components and method selected to implement the program?
- If you intend to provide devices (BMP 2) or ULFTs (BMP 14) with your survey program, will your personnel or the contractor's personnel install the devices and/or ULFTs. If not, how will installations be verified?
- How will you use the survey results and will results be tied to a customer specific database (customer conservation screen?)
- Are you going to design and maintain a database covering all participants and program results?
- Can you influence how the cost of this program is accounted for? If capitalized, the cost impact will be spread over "x" number of years and reduce the rate impact. If expensed, will the cost of your program have to be recovered in one year?

2.5.7 Sources

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2.6 Ultra Low Flush Toilets (Residential)

2.6.1 Device/Activity Description

“Ultra-low-flush” (ULF) toilets are low-water-using toilets. Specifically, ULF toilets must use no more than 1.6 gallons per flush.

2.6.2 Applicable BMPs

- BMP 1 – Residential Water Surveys. Complete residential surveys may result in ULFT replacement.
- BMP 2 – Residential Plumbing Retrofit. Concerns toilet retrofit devices rather that ULFT replacements.
- BMP 13 – Wholesale Agency Assistance. ULFT replacements are applicable to wholesale assistance and incentive programs.
- BMP 14 – Residential ULFT Replacement. Fully applicable for the residential sector.

2.6.3 Available Water Savings Estimates

Summary of Individual Studies

The most rigorous savings estimates to date are based on a series of field studies that examined the change in metered water consumption of more than 23,000 residential households and customers in Los Angeles, San Diego, and Santa Monica. Based on these field studies we present a primary method for estimating ULF toilet savings that adjusts the per toilet saving estimate for household density--number persons per household. Separate extrapolation equations are provided for both single family and multiple family sectors. Statistical models were estimated from the field study data to examine the relationship between savings and household density.

We also present a secondary method for estimating toilet savings based upon the number of first toilets replaced, second toilets replaced, and third toilets replaced. One of the findings from field studies was the declining marginal effectiveness of ULF toilets--two toilets do not save twice as much as one toilet. When information on the number of replaced toilets per household is available to conservation planners, this secondary method can yield more accurate estimates of ULF toilet conservation potential.

Per capita extrapolation assumes that the number of persons per household among participants is precisely equal to that of the service area in question. This relationship may not hold true depending upon how the ULF toilet programs are marketed. For example, many of the single family toilet rebate program participants exhibit, on average, a lower household density than the service area average. Several possible explanations for the difficulty of reaching high density households exist. Because density and income are inversely related, low income households may face tighter cash flow constraints. Conservation planners should give careful thought to the assumption of persons per household that drives per capita estimates of ULF toilet water conservation potential.

The number of persons per dwelling is often used as the primary adjustment factor in mechanical estimates of conservation potential. To illustrate, consider an often used reduction factor of 15.6 gpcd (gallons per capita per day).[7] A short list of the most important problems with this method to estimate savings for ULF toilets includes:[8]

(1) It assumes a **constant per capita effect** for both single family and multiple family households. There are many reasons why multiple family savings should differ from that experienced in the single family sector. Existing multiple family toilets tend to be older, less well maintained, and less likely to be retrofitted with a toilet displacement device. Further, one cannot rule out the possibility of fundamental differences in toilet use habits. In sum, we would be much more surprised by an equivalence in ULF toilet saving potential than by differences[9].

(2) It assumes strict **linearity in savings.** The assumption of perfect proportionality (four persons save four times as much as one) also runs afoul of findings from field studies. The water savings per household do not increase in a one-to-one fashion with the number of inhabitants. As documented in A&N Technical Services (1992a, Appendix B) functions were estimated from field data to fit observed conservation from ULF toilet replacement. Separate functions were estimated for single family households and for multiple family households. Both functions tested for and rejected the hypothesis of a linear per capita effect at high levels of confidence. The estimated functions were referred to as conservation "mappings" because they map from household characteristics (persons per household and ULF toilets replaced per household) to expected household water savings.

(3) It provides no guidance for situations of **less than complete ULF toilet replacement.**

(4) It requires **knowledge of the number of persons per household**.

Field studies show that the first two assumptions do not exist in real world conservation programs. Problem (1) can be addressed by separately estimating extrapolation equations for single family and multiple family sectors. Problem (2) can be addressed by permitting the estimated equation to take on a nonlinear form. The primary method of estimating expected savings involves estimation of separate single family and multiple family equations (see below).

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[7]This is based on 4 flushes per day and 3.9 gallons per flush savings. The source is Brown and Caldwell, *Residential Water Conservation Projects, Summary Report*, U.S. Department of Housing and Urban Development, June 1984, also known as "The HUD Study". This was an important early empirical study of residential water conservation. Its quick adoption and wide use for extrapolation in the water industry attests to its groundbreaking nature. We cite the report both because it is widely used and because extrapolations citing the report are often poorly implemented.

[8]Additional problems not addressed here are more technical in nature. Even if the functional form were accurate, a gpcd extrapolation yields a "biased" estimate and produces no estimate of uncertainty. Both of these issues are documented in A&N Technical Services (1992c) pp. 12-13.

[9]The oft-cited "HUD Study" (op. cit.) only includes single-family households and therefore cannot offer any empirical weight to bear on questions of multiple family water savings differences.

Table 1 - Program Costs ($/ULFT)

Sector	Toilet Cost [1]	Installation [2]	Rebate [3]	Other Costs [4]	Participant Costs [5]	Supplier Costs [6]	Total Society Costs [7]
Single Family Rebate	$120	$70	$75	$40	$115	$115	$230
Single Family Direct	$60	$65		$40	$35	$130	$165
Multi-Family Direct	$60	$55		$40	$35	$120	$155

Source: *CUWCC Guidelines*
All costs are dollars per ULF toilet
[4] “Other Costs” includes contract inspections and processing, advertising, workshops, and toilet recycling.
[5] = [1]+[2] - [3] for Rebate and $35 Copayment for Direct Installation
[6] = [3]+[4] for Rebate and [1]+[2]+[4] - [3] for Direct Installation
[7] = [1]+[2]+[4]

Persistence

The most recent field study tested for, and could not detect, any downward trend in the level of water savings amongst early participants in ULF toilet programs in Los Angeles and Santa Monica. It had been hypothesized that much of the water savings initially observed from ULF toilet replacement came from the removal of previously leaking toilets. If this were the case, one might expect to see a distinct decline in the level of water savings over time; as ULF toilets age, they too would eventually become as leaky as the toilets they replaced. Results from the first three years of ULF toilet programs cannot discern any such downward trend in water savings. Data from single family survey programs in Los Angeles and San Diego also suggest that the magnitude of leaking toilet problem may be overstated. Leakage rates among toilets tested were 4-5.6 percent among participants in the City of San Diego Water Conservation residential surveys and 7 percent among participants in the City of Los Angeles Home Survey Program. Another hypothesis for savings decay is that background saturation levels of ULFTs is increasing, cutting into incremental savings.

Limitations

More research needs to be done on the persistence of savings and savings at different levels of background saturation. Saturation rates may have changed since the studies were conducted.

Confidence in the Estimates

High. These estimates are based on rigorous field studies.

2.6.4 Program and Device/Activity Cost Estimates

Program Costs

Participant program costs may include:

- Cost of ULF toilet and installation not reimbursed by rebate

Supplier program costs may include:

- Staff time to administer rebate program
- Rebate incentive
- Administration
- Contractors
- Marketing

City of Santa Monica planning documents for their BAYSAVER Phase I and II Programs estimate cost of ULF toilets in different sectors (Santa Monica 1989 and 1992). A&N Technical Services (1995) also examine the cost of ULF toilets in its study of toilet savings. As demonstrated in the CUWCC *Cost-Effectiveness Guidelines*, these figures can be used to show that costs vary not only by sector but by delivery mechanism—rebate or direct install programs.

The ULFT Study reports retail toilet purchase costs of $130 and the BAYSAVER Phase II Proposal reports that ULF toilet prices are falling and are available for as low as $100. Bulk purchases were made at approximately $60 per toilet. The purchase cost estimate comes from the direct installation program in the City of Santa Monica.

A key determinant of cost of the BAYSAVER Program is the delivery mechanism for the ULF toilets. About half of the single family ULF toilets were delivered with the “rebate” option and half were directly installed. In contrast, the majority of multi-family and commercial ULF toilets were directly installed. With the rebate, the participant purchases and installs the toilet, after which the City provides a rebate check ($75 in BAYSAVER Phase II). With direct installation, the City purchases and installs the toilet and the customer provides a copayment ($35 in BAYSAVER Phase II).

With the rebate, customers purchase the ULF toilet at retail prices; with direct installation, the City purchases the toilets in bulk at wholesale prices. Although single family installation costs are approximately $70, they are considerably less when negotiated in large number by the City for direct installation and for multiple family sites where economies of scale become apparent ($50 and $40 respectively). Other costs of the program include rebate processing, advertising, and workshops.

With the rebate, from the participating customer perspective, costs include the acceleration in toilet replacement costs, including installation, less the rebate. Table 1 shows the costs to replace a new toilet. With direct installation, from the participating customer perspective, costs include only the $35 co-payment—again, this should be the acceleration in costs. From the total society perspective, costs include the acceleration in the costs of the toilet, its installation, and other costs. From the supplier perspective, costs include of the direct installation program including the toilet, its installation, and other costs, less the customer co-payment.

Limitations

Costs will depend importantly on program design. Rebate programs, direct installation, and other programs need to be clearly defined. Cost estimates should be viewed in light of the time that has elapsed since the above figures were reported and with respect to the scale of the

Table 2 - Residential ULFT Savings Sample Calculation

Supplier	Single Family Persons per Household	Multi- Family Persons per Household	Single Family Savings gpd/ULFT	Multi-Family Savings gpd/ULFT
Supplier A	2.50	2.00	21.2	36.7
Supplier B	3.50	3.00	24.8	51.1
Supplier C	4.50	4.00	27.2	63.7

program under consideration (volume purchases). Finally, some of the early toilet replacement programs faced the problem that installed ULFTs did not work well and suppliers faced unforeseen costs of replacements.

Confidence in Estimates

Medium.

2.6.5 Water Savings Calculation Formula(s)

Calculations

<u>Savings Calculation Primary Method: Toilet Savings Adjusted for Household Density</u>

These equations assume that only household density information is available and savings estimates are desired on a per ULF toilet basis. (If information on both persons per household and toilets per household were available, the conservation mappings could be directly used to produce predicted household water saving. See Appendix B of A&N Technical Services 1992a). The resulting prediction of conservation from ULF toilets forms the dependent variable for the extrapolation equations. Estimates of the parameters of the equations are obtained through the following regression models:

$S^{SF} = 6.693 * \text{Persons\_Dwelling} - 0.529 * (\text{Persons\_Dwelling})^2 + 7.826$

$S^{MF} = 19.138 * \text{Persons\_Unit} - 0.942 * (\text{Persons\_Unit})^2 + 2.181$

<u>Savings Calculation Secondary Method: Toilet Savings Adjusting for Completeness of Retrofit</u>

The primary method of estimating toilet savings does not address problems (3) and (4). The secondary method addresses both problems--it corrects for the declining marginal effectiveness of ULF toilet replacements and requires no knowledge of the expected household density among program participants. It only requires knowledge of number of toilets replaced per household.

$S^{SF} =$ 29.9 * Number of First Toilets Replaced +
20.6 * Number of Second Toilets Replaced +
19.1 * Number of (Third or higher) Toilets Replaced

$S^{MF} =$ 44 * Number of First Toilets Replaced +
34 * Number of Additional Toilets Replaced

Source: A&N Technical Services (1995) Table III-3 and III-4.

Factors to Consider in Applying the Formula

Additional secondary adjustments can also be made. Information on the distribution of 3.5 gallon per flush and 5 to 7 gallon per flush toilets can be incorporated using methods documented in the CUWCC *Memorandum of Understanding*, Exhibit 6, Section II, amended March 9, 1994. Few conservation planners, however, have access to accurate information on the mix of pre-existing toilets.

Example Calculation

Table 2 shows results from calculations of water savings for three hypothetical suppliers with different housing density. The calculations are based on the primary savings calculation method described above. Examples of the complete cost-benefit analysis and cost-effectiveness analysis are illustrated in the *CEA Guidelines*, Chapter 4.

2.6.6 Questions to Ask

- Are there other agencies that you can partner with to make your program more cost effective?
- Does your agency have access to grant or other partnership type funding?
- What is the age of the housing stock in the relevant service area (pre or post code?)
- Is the program targeted, and to which sector (SF, MF, low income, other)
- Is your water service area metered or unmetered? (Marketing and incentives will definitely vary based on your response to this question.)
- Will your program be a free distribution; co-pay (customer and agency share in the cost); direct install (when use, often limited to low income and elderly); or rebate?
- Will your program be conducted using agency personnel or contracted to others?
- Will your agency limit the approved models to those toilets that have been tested for long term water savings and customer satisfaction?
- Are installations verified?
- Will results be tied to a customer specific data base (customer conservation screen?)
- Are you going to design and maintain a data base covering all participants and program results?
- Is this program in combination with other measures (showerheads, surveys, public education, price changes?)
- Can you influence how the cost of this program is accounted for? If capitalized, the cost impact will be spread over “x” number of years and reduce the rate impact. If expensed, the cost of your program will have to be recovered in one year?
- When applying an existing savings estimate, how similar is the service area in terms of socioeconomic characteristics and conditions?

2.6.7 Sources

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2.7 CII Surveys

2.7.1 Device/Activity Description

Commercial, Institutional, and Industrial (CII) surveys can range from short "walkthroughs" to sophisticated water efficiency studies. Customers are targeted with a marketing strategy and incentives. Recommendations are made to reduce water consumption at the facility. The recommended actions then may be implemented by the site managers.

Recommended measures include sanitation, irrigation, kitchen, industrial, cooling, laundry, wastewater cooling, and others. Savings and cost data for faucets, urinals, ULF toilets, and landscape irrigation are examined in other sections of this document. This section focuses on cooling towers and industrial process savings.

Two broad categories of water loss in cooling towers include bleed-off (draining cooling water) and uncontrolled losses (drift loss from mist and leaks). In some parts of California nearly all cooling towers are recirculating systems (as opposed to single pass systems) and many of these have conductivity controllers to automatically manage total dissolved solids by adjusting bleed-off and make-up. Water savings potential for multi-pass systems are related to (1) better tuned conductivity controllers and (2) adding conductivity controllers if one is not present.

Industrial process savings are a large category of potential savings, but they are as diverse in nature as the industrial base. Industrial processes may include: metal plating, electronics fabrication, photographic processing, product water and rinses, in-plant cleaning, sterilizers, container cleaning, kitchens and water treatment and regeneration.

Note that the CUWCC CII Subcommittee is in the process of preparing a guidebook to CII savings that will have additional information relevant to CII surveys.

2.7.2 Applicable BMPs

BMP 9 – Conservation Programs for Commercial, Industrial, and Institutional Accounts. Implementation of this BMP includes:

a) identifying and ranking CII customers according to use,
b) establishing targets for ULFT replacements in the CII sector, and *EITHER*
c) implementing water-use surveys and incentives to 10 percent of CII customers within 10 years, *OR*
d) achieving water use reductions equal to or exceeding 10 percent over 10 years.

2.7.3 Available Water Savings Estimates

Summary of Individual Studies

Western Policy Research (1996) has analyzed data for the Metropolitan Water District of Southern California on its CII survey program. Three types of CII surveys have been conducted--analyst surveys, consultant surveys, and water efficiency studies--depending on the size of the site.

Table 1 - CII Survey Potential Savings

	n	Median Reduction Factor	Mean Reduction Factor	Median Savings Potential (AF/yr)	Mean Savings Potential (AF/yr)
Analyst Surveys	145	20.3%	17.9%	1.9	3.3
Consultant Surveys	22	18.0%	11.0%	8.4	7.4
Water Efficiency Studies	12	17.8%	29.2%	15.6	72.1

Source: WPR (1996)

Table 2 - Percentage Breakdown of Water Use and Potential Savings By Broad End Use

	Analyst Surveys		Consultant Surveys		Wat. Eff. Studies	
End Use	**Water Use**	**Pot.Savings**	**Water Use**	**Pot.Savings**	**Water Use**	**Pot.Savings**
Sanitary	33.3	50	9.3	24.6	4.8	5.1
Cooling	14.9	14	10.8	14.2	6	1
Irrigation	23.6	18.5	15.7	22.5	5.4	6.1
Other	28.2	17.5	64.2	38.7	83.8	87.8
TOTAL	100	100	100	100	100	100

Source: WPR (1996)

Table 1 shows potential water savings from the three types of surveys. Total potential savings shown in the table are based on implementing the full range of conservation recommendations. Table 2 shows the breakdown of potential savings by type of conservation measure. Note that cooling savings, although sizable for analyst surveys and consulting surveys, are a small proportion of savings from water efficiency studies (the largest sites).

Sweeten and Chaput (1997) report analyses of CII surveys at a broad range of sites, ranging from large industrial facilities to smaller commercial and institutional sites (source data for the WPR study cited above). Overall, the surveys identified a potential savings of 29 percent, 30 percent of which was reported to be implemented in follow-up telephone calls. The study further reports that large industrial sites have the greatest potential savings, but technical complexity makes achieving those savings challenging. Successful savings at large industrial facilities would be facilitated by working with performance-based contractors or manufacturer’s representatives with an interest in the efficient operation of process equipment.

Ploeser, Pike, and Kobrick (1992) present estimates of use and savings potential for cooling towers for different types of CII sites. The savings programs may have included conductivity controllers, cooling water management (sulfuric acid, filtration, etc.), addition of recirculation system, or air cooling systems. The study only makes gross savings potential estimates so we cannot distinguish between these conservation methods.

Table 3 - CII Survey Costs of Full Implementation

	Median Cost	Mean Cost
Analyst Surveys	$ 1,014	$ 3,598
Consultant Surveys	$ 6,828	$ 12,387
Water Efficiency Studies	$ 30,035	$ 97,527

Source: WPR (1996)

EPA/CADWR (1997) conducted a national study that included 13 cities across the country to determine the savings potential from commercial water users. A total of 22 categories of water users were considered. Aside from toilets and landscape, water uses included laundries, kitchens, process water, and cooling towers. Average water savings potential ranged from 9 percent to 31 percent.

Additional sources of information that are relevant to CII surveys can be found in the source list below.

Persistence

We have not found a study that considers the persistence of savings from CII survey programs.

Limitations

The savings figures reported here are *potential* savings based on full implementation of survey recommendations. Indeed, actual savings achieved may be considerably different due to partial implementation or different than expected effectiveness. Because of CII site heterogeneity and limitations of the study sample, extrapolation of findings to CII sites outside the sample should be done with caution and qualifications.

Confidence in Estimates

Low when generalized outside the study sample. Future efforts should include empirical measurement of water savings considering behavior (maintenance, etc.); the interaction of multiple conservation technologies (water maintenance, filtration, etc.); the diversity of such CII sites and savings technologies; the persistence of savings, and the relationship between recommended conservation actions and those actually implemented.

2.7.4 Program and Device/Activity Cost Estimates

Program Costs

Participant program costs may include:

- Costs of additional water savings equipment or processes that would not have been utilized without the audit.

Table 4 - Cost-Effectiveness of CII Surveys

	Analyst Survey	Consultant Survey	Water Efficiency Study
Average Survey Cost	$600	$1,484	$8,121
Average Potential Savings/Yr.	3.3 AF	8.4 AF	35.9 AF
	Cost of Saved Water ($/AF)		
100% of average potential	$ 43	$ 42	$ 54
80% of average potential	$ 54	$ 52	$ 67
60% of average potential	$ 72	$ 70	$ 89
40% of average potential	$ 108	$ 105	$ 134
20% of average potential	$ 216	$ 210	$ 268

Source: WPR (1996)

Supplier program costs may include:

- Staff time to audit water users and make recommendations, if not contracted out.
- Administration
- Contractors
- Marketing

Table 3 shows the costs of full implementation of the recommendations from each of the three different types of CII surveys in the WPR study. Rebates or financial incentives are not subtracted from these figures. Table 4 shows the costs of the surveys. Total costs are the sum of customer costs to implement the recommendations and survey costs.

Limitations

Program costs will vary widely depending on the industry type and survey type. Note that program costs reported here are for full implementation of survey recommendations.

Confidence in the Estimates

Low-Medium.

2.7.5 Water Savings Calculation Formula(s)

Calculations

Although CII savings are heterogeneous and one equation overly simplifies such calculations, we can generally consider savings as the product of water use, savings potential in percentage terms, and savings implementation in percentage savings terms:

S = Use * SavingsPotential * ImplemenationPercentage

Table 5 - Cooling Tower Savings (gpd/site)

	n	Site Total Mean Savings (AF/yr)	Site Total Mean Savings (gpd)	Percent from Cooling	Cooling Savings (gpd/site)
Analyst Surveys	145	3.3	2,944	14.0%	412
Consultant Surveys	22	7.4	6,603	14.2%	938
Water Efficiency Studies	12	72.1	64,332	1.0%	643

Source: WPR (1996) and author's calculations.

where:
- S is savings in gpd per site from cooling towers.
- Use is water consumption in gpd.
- SavingsPotential is the technical potential for water savings identified by the water survey (percent savings from pre-program use).
- ImplementationPercentage is the percent of the savings potential that is implemented.

Factors to Consider in Applying the Formula

This formula simple formulation is useful only to the extent that the savings estimates are applied to the appropriate sites.

Example Calculation

Table 5 shows calculated savings. Table 4 shows the cost-effectiveness calculations presented in the WPR study. The calculations assumed a 6% discount rate, a five year life span, and constant savings over time. The table shows how the cost-effectiveness varies considerably depending on how much of the savings potential is achieved in practice, on average.

2.7.6 Questions to Ask

- Are there other agencies that you can partner with to make your program more cost effective?
- Can you now identify your CII customers by class?
- What are the elements of the survey?
- Will you do interior and exterior components at the same time?
- Does your agency have internal expertise to perform the more involved surveys?
- Does your agency have access to grant or other partnership type funding?
- Will your agency offer incentives to promote implementation?
- Has your agency considered utilizing the services of a “pay-for-performance” contractor?
- What sub-sectors/technologies are targeted?
- Are recommendations implemented and verified?
- Are savings determined with engineering estimates or measured savings from field studies?

- Can you influence how the cost of this program is accounted for? If capitalized, the cost impact will be spread over "x" number of years and reduce the rate impact. If expensed, will the cost of your program have to be recovered in one year?
- Is operator training included in implementation of the program?

2.7.7 Sources

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2.8 Self-Closing Faucets

2.8.1 Device/Activity Description

Self-closing faucets are based on one of two technologies. The first involves a spring loaded faucet lever that closes the faucet in a prescribed period of time after it is opened. The second technology involves an infrared (IR) sensor which turns on the water only as long as it detects hands are under the faucet. Both faucets save water compared to conventional low flow faucets by reducing the average length of time the faucet is opened ("self-closing savings effect"). Since both types are made to meet low flow standards, the faucets save more water when they replace old high flow faucets ("low flow savings effect"). Spring loaded self-closing faucets are less expensive, although the IR technology is thought to save more water. Self-closing faucets are targeted primarily at CII sites, such as airports, schools, movie theaters, and restaurants.

2.8.2 Applicable BMPs

BMP 9 – Conservation Programs for Commercial, Industrial, and Institutional Accounts. In addition to activity-based criteria to determine implementation status, BMP 9 also calls for water-savings performance targets. An agency is considered "on schedule" if their CII accounts show reduction of 10% of baseline within 10 years. BMP 9 estimates the reduction in gallons per employee per day in the Year 2000 to be 12% for commercial and 15 % for industrial water use (from 1980 to 2000).

2.8.3 Available Water Savings Estimates

Summary of Individual Studies

Behling and Bartilucci 1992 analyze the impact of water-efficient fixtures on office water consumption. The study considers common water using fixtures in an office setting, including toilets, urinals, sinks. Other water consuming activities are factored out in the water savings estimation, including irrigation and cooling water. The study estimates the water use per wash for old (pre-1980 high flow) faucets based on 3 gallons per minute flow for 10 seconds.

McCuen 1975, as reported in Waterplan 1988, determines that self-closing faucets reduce water consumption by "up to 50 percent" compared to conventional low flow faucets. Waterplan 1988 uses a "conservative" estimate of 25 percent water savings.

NOTES: Since all faucets sold currently are low flow faucets, the incremental active conservation for <u>new</u> faucet installations is the difference between low flow and low flow self closing faucets--the self-closing savings effect. For replacement of <u>old</u> (high flow) faucets, the incremental active conservation savings is the self-closing savings effect plus any increase in the rate of replacement induced by the active program.

Persistence

We have not found a study that considers the persistence of savings from self-closing faucets. Possible sources of savings decay might include increased number of malfunctions of self-closing devices over time.

Limitations

Future efforts should include a search for existing estimates and/or empirical estimation the number of washes per day per fixture and water use per wash for high and low flow fixtures, and for self-closing faucets. Persistence of savings should also be assessed.

Confidence in Estimates

Low.

2.8.4 Program and Device/Activity Cost Estimates

Program Costs

Participant program costs may include:

- Cost of purchase and installation of the faucet if not fully subsidized

Supplier program costs may include:

- Faucet and purchase of faucets if supplier shares costs
- Administration
- Contractors
- Marketing

The following are professional judgments of costs by conservation program coordinators and managers, as reported in A&N Technical Services (1995):

- Infrared: $200
- Spring valve: $50

Note that these costs are the full cost of the fixture. The incremental cost is difference between the self-closing and the conventional low flow faucet because code requires low flow faucets.

Limitations

In addition to updating with recent vendor cost estimates, these figures do not reflect differences in maintenance costs, if there are such differences.

Confidence in Estimates

Low.

2.8.5 Water Savings Calculation Formula(s)

Calculations

Savings is calculated by multiplying washes per day by water savings, estimated as the difference between the self-closing faucet and what would have been installed otherwise. For example, for replacement of an old high flow faucet with an IR self-closing faucet, the equation is:

$S^{High\_to\_IRLow}$ = Washes_per_Day * (GP_Wash_High_Flow_Faucet - (GP_Wash_IRSelfClosing_Faucet)

where:

- $S^{High\_to\_IRLow}$ is savings per day from replacing high with an IR self-closing faucet.
- Washes_per_Day is the average washes per day at a faucet during a working day.
- Gallons_per_Wash is in units of gpd per self closing faucet

For sample installations, savings are calculated based on the above table plus the number of working days per year and the percent of the self-closing faucets that are replacing otherwise low-flow faucets:

S^{Sample} = ((Percent_Low * $S^{Low\_to\_IRLow}$) + ((1 - Percent_Low) * $S^{High\_to\_IRLow}$)) * Working_Days_per_Year / 365

where:

- Working_Days_per_Year are the days of operation for a typical faucet. For example, faucets in office buildings are assumed to operate 260 days per year.
- Percent_Low is the percent of self-closing faucets that replace low flow faucets, including new installations and replacements of existing low flow faucets.

Factors to Consider in Applying the Formula

As with other mechanical/engineering estimates, these figures do not fully reflect behavior that may impact actual savings. For example, if spring loaded faucets run longer than needed for brief hand washes, actual savings may not be what is anticipated.

Example Calculation

Table 1 - Savings by Washes per Day is calculated with the following assumptions:

Gallons_per_Wash is (in units of gpd per self closing faucet) for <u>old high flow faucets</u> .5gpd (Behling and Bartilucci 1992); for <u>new faucets</u> .33gpd (Behling and Bartilucci 1992), for <u>new faucets with IR self closing</u> .2gpd (Based on McCuen 1975; Waterplan 1988 and judgment), and for <u>new faucets with spring self closing</u> .25gpd (McCuen 1975 and Waterplan 1988).

Tables 2 and 3 - Sample Installations are calculated for a range of assumptions using the second formula presented above.

Table 1 - Savings (gpd/faucet) by Washes per Day

Washes per Day	Infrared Install/Replace Low Flow	Infrared Replace High Flow	Spring Loaded Install/Replace Low Flow	Spring Loaded Replace High Flow
10	1.3	3.0	0.8	2.5
20	2.6	6.0	1.6	5.0
30	3.9	9.0	2.4	7.5
40	5.2	12.0	3.2	10.0
50	6.5	15.0	4.0	12.5
60	7.8	18.0	4.8	15.0
70	9.1	21.0	5.6	17.5
80	10.4	24.0	6.4	20.0
90	11.7	27.0	7.2	22.5
100	13.0	30.0	8.0	25.0
110	14.3	33.0	8.8	27.5
120	15.6	36.0	9.6	30.0
130	16.9	39.0	10.4	32.5
140	18.2	42.0	11.2	35.0
150	19.5	45.0	12.0	37.5

Table 2 - Savings for Sample Installations of IR Self-Closing Faucets

	Washes per Working Day	Working Days/YR	Percent Install/Replace Low Flow	Savings (gpd/faucet)
Airport	100	365.25	80%	16.4
Movie Theater	100	365.25	80%	16.4
Shopping Mall	80	365.25	90%	11.8
School	50	260.00	10%	10.3
Office Building	30	260.00	70%	10.9
Restaurant	30	365.25	70%	12.7

Table 3 - Savings for Sample Installations of Spring Self-Closing Faucets

	Washes per Working Day	Working Days/YR	Percent Install/Replace Low Flow	Savings (gpd/faucet)
Airport	100	365.25	80%	11.40
Movie Theater	100	365.25	80%	11.40
Shopping Mall	80	365.25	90%	7.76
School	50	260	10%	8.41
Office Building	30	260	70%	7.66
Restaurant	30	365.25	70%	9.17

2.8.6 Questions to Ask

- Are savings estimates for the particular model self-closing faucets installed?

2.8.7 Sources

A&N Technical Services (1995) Pekelney, D.M., and T.W. Chesnutt, "Reference Document: Program Design Tool and Savings Estimates," prepared for the Metropolitan Water District of Southern California.

Behling, P.J., and N.J. Bartilucci, "Potential Impact of Water-Efficient Plumbing Fixtures on Office Water Consumption," *Journal of the American Water Works Association*, October 1992.

McCuen, R.H., R. C. Sutherland, and J.R. Kim, "Forecasting Urban Water Use: Software for Water Management Planning," prepared for California Department of Water Resources, November 1988.

Waterplan (1988) Synergic Resources Corporation, "Waterplan Benefit/Cost Analysis Software for Water Management Planning," prepared for California Department of Water Resources, November.

2.9 Ultra Low Flush Toilets (CII)

2.9.1 Device/Activity Description

"Ultra-low-flush" (ULF) toilets are low-water-using toilets. Specifically, ULF toilets must use no more than 1.6 gallons per flush.

2.9.2 Applicable BMPs

- BMP 10 – Commercial, Industrial, Institutional.

2.9.3 Available Water Savings Estimates

Summary of Individual Studies

CUWCC commissioned a study of CII ULF toilet savings that estimated gallons per day savings in a number of different market segments (Hagler Bailly 1997). These results of statistical analysis of 1,320 CII sites in ten agencies in Northern, Central and Southern California are summarized in Table 1.

Persistence

We have not found a study that estimates the persistence of conservation savings from CII ULFTs.

Limitations

This fundamentally sound methodology yields results that are limited in their ability to be generalized to the extend industry categories do not map well to those in this study. For example, the wide range of wholesale savings estimates indicates the wide variability in ULFT use profiles within this sector.

Confidence in Estimates

Good.

2.9.4 Program and Device/Activity Cost Estimates

Program Costs

Participant program costs may include:

- Cost of ULF toilet and installation not reimbursed by rebate

Table 1 - Savings per CII ULFT Installed

Market Segment	Estimated Savings (gpd)	90% Confidence Interval
Wholesale	57	19-94
Food Store	48	37-59
Restaurant	47	36-58
Retail	37	33-42
Automotive	36	22-50
Multiple Use	29	14-45
Religious	28	20-37
Manufacturing	23	15-32
Health Care	21	13-28
Office	20	17-23
Miscellaneous	17	11-23
Hotel/Motel	16	11-20

Source: Hagler Bailly (1997)

Supplier program costs may include:

- Staff time to administer rebate program
- Rebate incentive
- Administration
- Contractors
- Marketing

A&N Technical Services (1995) reports that commercial ULF toilets retail for $150 to $170. The purchase cost estimate comes from the direct installation program in the City of Santa Monica (1989, 1992) and assumes that all installed commercial ULF toilets were flushometer valve-type. Since both flushometer-valve and gravity-fed toilets are used in commercial applications, the $170 purchase cost estimate represents an upper bound. Gravity-fed commercial ULF toilet costs are about the same as multi-family residential toilets.

Limitations

Limitations include generalizations about volume purchases and discounts, rates of growth in new facilities and old fixture retrofits (natural replacement), and background saturation (free riders) that are not consistent with those in the study areas.

Confidence in the Estimates

High, although more research needs to be done on the persistence of savings and savings at different levels of background saturation.

2.9.5 Water Savings Calculation Formula(s)

Calculations

The general core variables among the market segmented models included in CUWCC sponsored study (Hagler Bailly 1997) are included the following function:

Monthly_Water_Use (ccf) = f(Number_of_Retrofits_Installed, Net_Irrigation_Requirements, Region, Season, Time_Trend)

Additional explanatory variables in one or more market segment models include:

- change in facility operating hours
- change in number of visitors at facility
- change in total number of employees
- change in gender composition of employees
- change in production process
- extended interruptions in water service
- occurrence of major water leaks
- change in number of faucet aerators or showerheads in facility
- change in efficiency level of urinals
- changes to size or type of irrigation system
- other changes at facility that could affect water use

Factors to Consider in Applying the Formula

This formula is meant to be used in the context of statistical estimation of conservation savings. Separate models should be constructed for market segments to account for the great heterogeneity.

Example Calculation

Table 1 shows how the equations have been used in a statistical analysis of CII ULFT savings.

2.9.6 Questions to Ask

- Are there other agencies that you can partner with to make your program more cost effective?
- Does your agency have access to grant or other partnership type funding?
- What is the age of the building stock in the relevant service area (pre or post code?)
- Will your program be a free distribution; co-pay (customer and agency share in the cost); direct install; or rebate?
- Will your program be conducted using agency personnel or contracted to others?
- Will your agency limit the approved models to those toilets that have been tested for long term water savings and customer satisfaction?
- Are installations verified?

- Will results be tied to a customer specific data base (customer conservation screen?)
- Are you going to design and maintain a database covering all participants and program results?
- Is this program in combination with other measures (e.g., CII surveys, pricing?)
- Can you influence how the cost of this program is accounted for? If capitalized, the cost impact will be spread over "x" number of years and reduce the rate impact. If expensed, will the cost of your program have to be recovered in one year?
- When applying an existing savings estimate, how similar is the service area in terms of socioeconomic characteristics and conditions?

2.9.7 Sources

A&N Technical Services (1995) Chesnutt, T.W., C.N. McSpadden, and A. Bamezai, *Ultra Low Flush Toilet Programs: Evaluation of Program Outcomes and Water Savings*, A report for the Metropolitan Water District of Southern California, July.

Hagler Bailly Services (1997), *The CII ULFT Savings Study*, sponsored by the California Urban Water Conservation Council, August.

Santa Monica (1989), "Recommendation to Approve the Residential Plumbing Fixture Rebate Program," Proposal to the Mayor and City Council from City Staff, City of Santa Monica, July 25.

Santa Monica (1992), "Recommendation to Approve Phase II of the BAYSAVER Plumbing Fixture Rebate Program," Proposal to the Mayor and City Council from City Staff, City of Santa Monica, February 11.

2.10 Urinals

2.10.1 Device/Activity Description

Two water saving urinals technologies are (1) low flow valves that utilize less water than conventional valves and (2) waterless urinals.

2.10.2 Applicable BMPs

In addition to activity-based criteria to determine implementation status, BMP 9-Commercial, Industrial, and Institutional Accounts also calls for water-savings performance targets. An agency is considered "on schedule" if their CII accounts show reduction of 10% of baseline within 10 years. BMP 9 estimates the reduction in gallons per employee per day in the Year 2000 to be 12% for commercial and 15 % for industrial water use (from 1980 to 2000).

2.10.3 Available Water Savings Estimates

Summary of Individual Studies

Behling and Bartilucci (1992) analyze the impact of water-efficient fixtures on office water consumption. The study considers common water using fixtures in an office setting, including toilets, urinals, sinks. Other water consuming activities are factored out in the water savings estimation, including irrigation and cooling water. The study reports the water use per flush for old (pre-1980 high flow) urinals as 1.5 to 3.0 gallons per flush and new water efficient urinals as 1.0 gallons per flush.

The City of Bellevue (1992a and 1992b) analysis considered the replacement of 28 urinal flush valves. The old valves ranged between 1.5 and 2.0 gallons per flush and the new valves used 1 gallon per flush. The setting was a city office building and the analysis was conducted in 1993. The analysis measured building water savings by comparing water use before and after installation of the water saving devices. As reported in PMCL (1994), there is no indication that water use was measured at the individual fixture level or that water savings at the building level was controlled for other explanatory variables such as work force mix and employment.

Persistence

We have not found a study that considers the persistence of savings from low flow urinal valves or waterless urinals.

Limitations

Future efforts should include a search for existing estimates and/or empirical estimation the number of flushes per day per fixture and water use per wash for high and low flow fixtures. Persistence of savings should also be assessed.

Confidence in Estimates

Low.

2.10.4 Program and Device/Activity Cost Estimates

Program Costs

Participant program costs may include:

- Cost of purchase and installation of the faucet if not fully subsidized

Supplier program costs may include:

- Faucet and purchase of faucets if supplier shares costs
- Administration
- Contractors
- Marketing

The following are professional judgments of costs by conservation program coordinators and managers, as reported in A&N Technical Services (1995):

- Low flow valve: $20
- Waterless urinal: $100-$400

Limitations

The long term maintenance costs and life span of this new class of fixtures has yet to be assessed.

Confidence in Estimates

Medium-Low.

2.10.5 Water Savings Calculation Formula(s)

Calculations

Savings is calculated by multiplying flushes per day by water savings, estimated as the difference between the low flow valve (or waterless urinal) and what would have been installed otherwise. For example, for replacement of an old high flow urinal with low-flow valve, the equation is:

$$S^{High\_to\_Low} = Flushes\_per\_Day * (GP\_Flush\_High\_Flow\_Urinal - GP\_Flush\_Low\_Flow\_Urinal)$$

Table 1 - Savings by Flushes per Day

Flushes per Day	LF Valve Replace High Flow	Waterless Urinal Replace Low Flow	Waterless Urinal Replace High Flow
5	3.8	5.0	8.8
10	7.5	10.0	17.5
15	11.3	15.0	26.3
20	15.0	20.0	35.0
25	18.8	25.0	43.8
30	22.5	30.0	52.5
35	26.3	35.0	61.3
40	30.0	40.0	70.0
45	33.8	45.0	78.8
50	37.5	50.0	87.5
55	41.3	55.0	96.3
60	45.0	60.0	105.0
65	48.8	65.0	113.8
70	52.5	70.0	122.5
75	56.3	75.0	131.3

For replacing a low flow valve with a waterless urinal, the equation is:

$S^{Low\_to\_No}$ = Flushes_per_Day * (GP_Flush_Low_Flow_Urinal - 0)

Savings from replacing a high flow valve with a low flow valve are calculated based on Table 1 and the number of working days per year. Since low flow valves are required in California Code, new construction valve installations are not considered active conservation. Since waterless urinals save more water than low flow valves, savings depend on the percent of waterless urinals that are replacing otherwise low-flow urinals, rather than high flow urinals:

S^{Sample} = ((Percent_Low * $S^{Low\_to\_No}$) + ((1 - Percent_Low) * $S^{High\_to\_No}$)) * Working_Days_per_Year / 365.25

where:

- Flushes_per_Day is the average number of flushes per urinal during a working day.
- Working_Days_per_Year are the days of operation for a typical urinal.
- Percent_Low is the percent of waterless urinals that replace low flow urinals, including new installations that would have been low flow, and replacements of existing low flow urinals.

Factors to Consider in Applying the Formula

As with other mechanical/engineering estimates, these figures do not fully reflect behavior that may impact actual savings, such as double flushing.

Table 2 - Savings for Sample Installations of Low Flow Urinal Valves

	Flushes per Working Day	Working Days/yr	Savings (gpd/urinal)
Airport	50	365.25	37.50
Movie Theater	50	365.25	37.50
Shopping Mall	40	365.25	30.00
School	25	260.00	13.35
Office Building	15	260.00	8.01
Restaurant	15	365.25	11.25

Table 3 - Savings for Sample Installations of Waterless Urinals

	Flushes per Working Day	Working Days/yr	Percent Replace Low Flow	Savings (gpd/urinal)
Airport	50	365.3	80%	57.50
Movie Theater	50	365.3	80%	57.50
Shopping Mall	40	365.3	90%	43.00
School	25	260.0	10%	30.53
Office Building	15	260.0	70%	16.11
Restaurant	15	365.3	70%	18.38

Example Calculation

For Table 1 - Savings by Flushes per Day and for Tables 2 and 3 - Sample Installations, the following assumptions are used:

- Flushes_per_Day, Working_Days_per_Year, and Percent_Low urinals are judgment estimates in this hypothetical example.
- Gallons_per_Flush is for high flow urinal valve 1.5 to 2.0 gallons per flush (Bellevue 1992a and 1932b; Behling and Bartilucci 1992); for low flow urinal valve 1 gallon per flush (Bellevue 1992a and 1932b; Behling and Bartilucci 1992); and for waterless urinal 0 gallons per flush.
- Working_Days_per_Year are assumed to operate 260 days per year.
- Percent_Low is the percent of waterless urinals that replace low flow urinals, including new installations that would have been low flow urinals and replacements of existing low flow urinals.

2.10.6 Questions to Ask

- Are there other agencies that you can partner with to make your program more cost effective?
- Does your agency have access to grant or other partnership type funding?
- Will your program be a free distribution; co-pay (customer and agency share in the cost); direct install; or rebate?
- Will your program be conducted using agency personnel or contracted to others?
- Will your agency limit the approved models to those that have been tested for long term water savings and customer satisfaction?

- Are installations verified?
- Will results be tied to a customer specific data base (customer conservation screen?)
- Are you going to design and maintain a database covering all participants and program results?
- Is this program in combination with other measures (e.g., CII surveys, pricing?)
- Can you influence how the cost of this program is accounted for? If capitalized, the cost impact will be spread over “x” number of years and reduce the rate impact. If expensed, will the cost of your program have to be recovered in one year?
- When applying an existing savings estimate, how similar is the service area in terms of socioeconomic characteristics and conditions?

2.10.7 Sources

Behling, P.J., and N.J. Bartilucci (1992), “Potential Impact of Water-Efficient Plumbing Fixtures on Office Water Consumption,” *Journal of the American Water Works Association*, October 1992.

Bellevue (1992a) Public Works Department--Utility Services and Property Services Division, “City Building Toilet and Urinal Valve Retrofit Benefit-Cost Analysis,” Bellevue, WA.

Bellevue (1992b) Public works Department--Utility Services and Property Services Division, “City Building Retrofit Project,” Bellevue, WA.

PMCL (1994) Planning and Management Consultants, “Urban Water Conservation Programs Volume I: Annotated Bibliography,” September 1994. Sponsored by U.S. Army Corps of Engineers, U.S.G.S., MWD of Southern California, Southern Nevada Water Authority, CUWA, Phoenix Water Services Department, AWWA.

A&N Technical Services (1995) Pekelney, D.M., and T.W. Chesnutt, “Reference Document: Program Design Tool and Savings Estimates,” prepared for the Metropolitan Water District of Southern California.

2.11 Large Landscape Devices

2.11.1 Device/Activity Description

Large landscape conservation programs target outdoor water use. In practice, “large” is often taken to mean a land parcel greater than 2 or 3 acres with significant landscaping. Sometimes the large landscapes are metered separately from non-landscape water consumption. Large landscape programs can take on many forms and involve site visits, training, device adjustment, upgrading, or water budgets. Devices and activities include centralized computer control, moisture sensors (akin to a water “thermostat” placed in the soil), rain shut-off switches (precipitation causes a switch to interrupt automatic irrigation schedules), telephone connections to CIMIS information, and numerous other technologies to improve the efficiency of landscape water use. Some large landscape programs include budget-based rates and/or other economic incentives such as equipment rebates.

California Irrigation Management Information System (CIMIS) data can be used in several different types of large landscape conservation programs. One type of program includes a water audit to determine where mechanical improvements and irrigation scheduling can reduce water consumption. The audit may include “catch cone” tests and distribution uniformity tests. CIMIS data may be accessed periodically and utilized in a computer program to determine the appropriate adjustments to irrigation scheduling. Another type of program involves irrigation management training only, without a comprehensive water audit. A workshop or training session is held where instruction is presented on how to access and use information on an irrigation “hot line,” along with lookup tables, to determine irrigation levels.

CUWCC has recently published its “Handbook: A Guide to Implementing Large Landscape Conservation Programs,” which provides additional information regarding BMP 5 and its implementation (CUWCC 1999).

2.11.2 Applicable BMPs

BMP 5 – Large Landscape Water Audits and Incentives calls for suppliers to implement conservation methods that are at least as effective as a set of actions that include identifying, contacting, and auditing all large landscape sites, and incentives, follow-up audits, and multilingual training (in summary). To make the case that a large landscape conservation program fulfills BMP 5, one would have to either a) implement the same provisions listed in the BMP, or b) calculate savings and determine whether they are equivalent to the savings from the BMP 5 listed measures. The intervention and device savings described in this section could be useful information to calculate savings for the purpose of determining whether a supplier’s large landscape program fulfills BMP5. Note that there are separate requirements for dedicated accounts and mixed-use accounts.

Table 1 - Capistrano Valley Water District Savings

Analytic Approach	Percent Water Use Reduction
Simple Model: All Landscape Customers	35%
Simple Water Use Model: Long Term Customers	23%
Models Controlling for Climate	22%
Structural Intervention Model	19%

2.11.3 Available Water Savings Estimates

Summary of Individual Studies

Water-Budget Based Rate Structures, Outreach, Incentives

A&N Technical Services (1997) conducted a study of four large landscape conservation programs in Southern California that each involved a water budget based rate structure. The study included a water use analysis based on empirical data collected in cooperation with participating suppliers. Using historical account level water use records and multiple CIMIS climatic measures, climate-adjusted estimates of water savings were developed.

The water use analysis was conducted in three steps, where steps 2 and 3 involved developing increasingly refined regression model specifications: (1) raw water use comparison, (2) comparison correcting for customer characteristics and climate, and (3) structural models of the conservation program interventions. The raw water use analysis required careful data analysis to assure the validity of the water consumption measures. Otay Water District experienced a 20 percent decline in water applied to landscapes, Irvine Ranch experienced a 37 percent decline, and Capistrano Valley experienced a 35 percent decline between the pre- and post-program periods (Table 1). Changes in customer characteristics can make important differences in the estimated savings rates. For example, long-term customers showed a smaller decline in mean water use, about 25 percent; newer customers tended to come on line with lower application rates. Simple models to control for climate reduced the estimated change in raw water use from approximately 25 percent to 22 percent.

The estimates from the structural model suggest that the combined intervention of water-budget based rate structures and customer outreach programs in Capistrano Valley had the following effects on the pattern of water demand:

- Average water demand was reduced by 18.6 percent (Table 1);
- The seasonal peak demand was also reduced, though to a lesser degree than average daily demand;
- Customer demand became more responsive to information about evapotranspiration; and
- Customer demand became less responsive to rainfall.

Central Irrigation Systems

An analysis was conducted of the water consumption reduction due to the use of a centralized irrigation system installed in the community of Aliso Viejo in Orange County (Western Policy Research 1996). Controlling for climate and landscape size, water consumption was reduced by 34 percent overall compared to the period before the retrofit. Most of the savings is attributed to the sloped areas, which account for 75 percent of the study area. Sloped areas were shown to have a 45 percent reduction in water use compared to no significant reduction in the turf grass areas. Due to the diversity of plant material on sloped areas, the author concludes that it is difficult to optimize irrigation for sloped areas without a central system.

Landscape Audits

CCWD 1994a and 1994b measured savings from a landscape audit program that involved visits to irrigated sites by irrigation management experts who made recommendations for conservation change. Among other important findings, the study concluded:

- The degree of excess irrigation is large in the fall season;
- Contract landscapers are less efficient in terms of water consumption and irrigation practices;
- Smaller sites (e.g., less than 2 acres) have the potential for a greater *percentage* water savings because they are not as well managed as large sites.
- Savings from water audits decline rapidly over time.

Water savings were estimated to be 20.6 percent in the first year, 7.7 percent in the second year, and 6.5 percent in the third year.

Combined Landscape Management Practices

Western Policy Research (1997) reports the results of a statistical analysis of the water saving effects of combinations of landscape management practices. The three categories of landscape management practices include evapotranspiration-based irrigation scheduling, improved system maintenance, and advanced turf grass horticultural practices. The study included 16 sites in similar climate conditions with cool-season turf.

Outcomes of the study were measured in terms of conservation savings, turf quality, and root depth. Overall, water consumption was cut in half by the programs, even after controlling for climate. Tiered rates and outreach programs were implemented just prior to the study of conservation practices. For example, the study attributed 30 inches of water savings per year to the inclining block rates and outreach programs. An additional 21.9 inches is attributed to the advanced practices. It is important to note that appearance of turf grass was also evaluated over time by a team of judges, who concluded that appearance actually improved over time.

CIMIS Hot Lines

Two programs were conducted by the Marin County Water District, as described in Bourg 1993 and Nelson 1989. The "Irrigation Management Program" contacted the largest irrigation customers, of which 63 agreed to participate in water conservation workshops. Look-up tables were developed by conducting a study to calibrate the reference evapotranspiration to the local vegetation. The workshops were attended by turf managers, who were instructed on how to use the Hot Line and look-up tables to determine the appropriate irrigation level. A water auditor monitored irrigation.

The other program involved an on-site audit of commercial/government customers with greater than 100HCF/YR water use to determine opportunities for water conservation. The audits involved an initial audit to determine low-cost savings opportunities, and then a comprehensive audit with water distribution uniformity and catch cone tests. Turf managers were then trained in how to access CIMIS data periodically and utilized in a computer program to determine the appropriate adjustments to irrigation scheduling.

The following summarizes some of the available savings estimates from Bourg 1993 and Nelson 1989:

CIMIS Hot Line with Water Audits for Parks and Playing Fields (Customers >400 HCF/YR):
- 16% reduction in expected water usage (government parks)
- 7.7% reduction in expected water usage (private park)

CIMIS and Irrigation Management Training for Large Irrigation Customers:
- 10.9% reduction in peak month demand (with Hot Line and training)
- 3.6% reduction in peak month demand (with Hot Line, but no training)

Although these water use per acre values are specific to an agency, the savings studies were conducted in Marin County, which has significantly different climate and landscape characteristics than many parts of California; the differences in climate, vegetation, and ET_o, limit the generalizability of these results.

Persistence

More research needs to be conducted to develop generalizable estimates of persistence. One study indicates that savings from large landscape audit programs drop off quickly (CCWD 1994). Savings in the same year were 20.6 percent, savings in one season later were only 7.7 percent, and savings two seasons later were 6.5 percent.

Limitations

One important limitation is the difficulty of distinguishing the savings achieved from the water-budget-based rate structures from the outreach and incentives programs. Since these programs have been implemented concurrently, a more detailed statistical analysis would be needed to determine how much each of the program components contribute to water savings.

Confidence in Estimates

Medium-Low. The difficulty of generalizing landscape savings is apparent when considering the great diversity in climate among the regions throughout the state.

2.11.4 Program and Device/Activity Cost Estimates

Program Costs

Participant program costs may include:

- Cost of purchase and installation of landscape efficiency equipment, including controllers moisture sensors, one-way valves, sprinkler heads, etc., to the extent they are not financially supported by the water supplier.

Supplier program costs may include:

- Landscape measurement
- Financial incentives.
- Administration
- Contractors
- Marketing

CUWCC (1999) includes example cost estimates for a water budget program (Table 2) and a water survey program (Table 3). Cost estimates for the water budget program range between $50 and $300 per site, according to the report. Water survey costs range between $500 and $1500 per site.

Table 2 - Example Costs of Water Budget Program

Task	Fixed Costs	Cost per Site	Notes
Inventory of dedicated irrigation meters	$ 1,800		30 hours x $60/hour = $1,800
Landscape measurement		$ 100	Assumes field measurement method used
Budget calculation	$ 1,200		20 hours x $60/hour
Budget distribution		$ 12	$1 per site per monthly billing period
Monitoring and tracking		$ 30	0.5 hours x $60/hour
Total	$ 3,000	$ 142	

Reproduced from CUWCC 1999.

Table 3 - Example Costs of Water Survey Program

Task	Fixed Costs	Cost per Site	Notes
Inventory of CII Mixed Use Accounts	$ 2,400		40 hours x $60/hour
Targeting	$ 2,400		40 hours x $60/hour
Marketing	$ 2,400	$ 25	40 hours x $60/hour plus direct costs
Survey Implementation		$ 720	12 hours x $60/hour
Follow-Up Activities			Not Included
Monitoring and Tracking	$ 6,000	$ 10	100 hours x $60/hour which includes 1 basic analysis
Total	$ 13,200	$ 755	

Reproduced from CUWCC 1999.

Table 4 - Mean Reported Costs of Conservation

	Per Customer		Per Acre	
Action	**Initial**	**Ongoing**	**Initial**	**Ongoing**
Adjusted Timers	$ 482	$ 247	$ 137	$ 77
Upgrade Equipment	$ 2,571	$ 1,540	$ 953	$ 54
Repaired Irrigation System	$ 793	$ 2,571	$ 560	$ 399
External Audit	$ 45	$ 126	$ 43	$ 46
Other	$ 185	$ 77	$ 141	$ 80

A&N Technical Services (1997) also reports the results of a survey of large landscape customers subject to water-budget based rate structures. A mail survey was sent to all separately metered irrigation customers in four Southern California service areas. The inference that can be drawn from the subset of returned surveys to the population is limited by the potential for response bias; inference to other agencies is limited further by the degree to which site characteristics and other conditions are similar to the study. Table 4 shows the results of the customer self-reported estimates of costs of conservation actions: Supplier costs might include computer programming to set up a new rate structure, program design and setup, area measurement, operation, education and outreach, and equipment rebates.

CCWD (1994) reports that auditing a site of up to one acre costs $310, and $84 for each additional acre at the same site. A detailed breakdown of audit costs in Appendix B of the study is reproduced in Table 5.

Limitations

Program costs will vary considerably depending on the design of the program.

Confidence in Estimates

Medium.

2.11.5 Water Savings Calculation Formula(s)

Calculations

Water_Savings = Savings_Per_Acre * Acres_Per_Site * Number_of_Sites

Factors to Consider in Applying the Formula

Statistical models, such as those used in A&N Technical Services (1997) are more complex that the simple equation above; however they require extensive data and modeling efforts.

Table 5 - Cost of Audit for Site with 1 Acre of Turfgrass

Action	Hours	Costs
Labor		$28/hr.
Audit	6	
Report/Schedule	3	
Subtotal	9	$ 252.00
Administrative Costs		$ 36.00
Labor Subtotal		$ 288.00
Equipment		
Computer	$3200/500 audits	$ 6.40
Catch Cans, Soil Probe, Pressure Guage, Flags, Wheel, Walkie-Talkie	$750/250 audits	$ 3.00
Milage	30 mi.@ $.28/mi.	$ 8.40
Mailings		$ 4.00
Equipment Subtotal		$ 21.80
Total		$ 309.80

Example Calculations

We provide three sample calculations. The first is based on an empirical study of water budget based landscape conservation programs. This study demonstrates a data- and model-driven method for calculating conservation savings from programs that combine water budget based rate structures with auxiliary program types (rebates, education, etc.), subject to appropriate caveats. The latter two examples are speculative efforts at quantifying conservation savings of a single program element, such as moisture sensor program. We then summarize evidence for CIMIS hotline programs.

<u>Example 1: Empirical Estimation with a Statistical Model</u>

Table 1 shows the savings result of the structural model from Capistrano Valley Water District. This model estimates the conservation effect of an "intervention," composed of a water budget based rate structure combined with outreach. Since, in this case, both the rate structure and the outreach programs occur together, the statistical analysis cannot identify separate effects of each element of the intervention.

<u>Example 2: Rough Estimation of a Savings Parameter, Separately Metered Sites</u>

The next two examples show how savings figures can be used in "back of the envelope" calculations to develop rough savings estimates. The examples illustrate how savings estimates can be developed for different definitions of a conservation activity. In the first example the activity is a "site" audit, and in the second example the activity is an "acre" audit. As explained below, the activity is defined differently in these two examples because of the available data: in the first case separate meter data are available and in the second case they are not.

A large landscape program is targeted toward 250 separately metered irrigation accounts. Consumption histories from the billing system provide an estimate of average consumption among these sites--approximately 120 hundred cubic feet per monthly billing period. If the savings parameter needs to be expressed in gallons per day, average use per day in HCF/Month is converted to GPD. If the program saves 15 percent of this use, the expected *savings per site* will be (2,967 X .15 =) 445 GPD.

$$\text{Calculate Use per Site :}$$
$$1\text{HCF} = 748\text{Gl.}$$
$$1\text{MONTH} = 30.25\text{DAYS}$$
$$\Rightarrow\ 120\frac{\text{HCF}}{\text{MONTH}} = 120 \bullet \frac{748\text{Gl.}}{30.25\text{DAYS}} \approx 2{,}967\frac{\text{Gl.}}{\text{DAY}}$$
$$\text{Calculate Savings per Site :}$$
$$.15 \text{ x } 2967\frac{\text{Gl.}}{\text{DAY}} = 445\frac{\text{Gl.}}{\text{DAY}}$$

<u>Example 3: Rough Estimation of a Savings Parameter, Separately Metered Sites</u>

A large landscape program is targeted toward 250 multi-family complexes whose outdoor water use is not separately metered. Hence, consumption summaries from the billing system represent both indoor and outdoor water use. The complexes each have about 2 acres of irrigated landscape area.

On-site audits have shown irrigation of 60 or more inches of water per acre in areas where ET_o is only 48 inches per year. This savings potential is 12 inches per acre. Taking a conservative 6 inches per acre savings in practice, we calculate the savings per acre in gallons per day for the audit program:

$$\text{Calculate Savings per Acre :}$$
$$1\ \text{AF} = 325{,}851\ \text{Gl.}$$
$$1\text{YEAR} = 365\text{DAYS}$$
$$\Rightarrow\ .5\frac{\text{FEET}}{\text{YEAR}} = .5 \bullet \frac{325{,}851\text{Gl.}}{365\text{DAYS}} \approx 446\frac{\text{Gl.}}{\text{DAY}}$$

2.11.6 Questions to Ask

- Are there other agencies that you can partner with to make your program more cost effective?
- Are landscape areas on dedicated irrigation meters identified?
- Are CII accounts with mixed-use meters and like accounts without meters identified?

- What are the climatic conditions, and do you have the ETo for determining the right application of water?
- Does your agency have a separate irrigation rate/tariff?
- Does your agency already have an establish billing system that will accommodate the use of water budgets?
- Will your agency conduct these audits with its own personnel or with an outside contractor?
- What type of water is used: potable or reclaimed?
- Is follow-up training and tracking part of the program?

2.11.7 Sources

A&N Technical Services (1997), "Landscape Water Conservation Programs: Evaluation of Water Budget Based Rate Structures," prepared for the Metropolitan Water District of Southern California, September.

CCWD (1994a), Contra Costa Water District, "Landscape Water Audit Evaluation," August 1994.

CCWD (1994b), Contra Costa Water District, "Weather Normalized Evaluation," August 1994.

CUWCC (1999), "Handbook: A Guide to Implementing Large Landscape Conservation Programs."

Nelson, J.O. (1989), "Irrigation Management Program," North Marin Water District, Novato, CA. As reported in PMCL (1994).

Bourg, J.D., and J.O. Nelson (1993), "Results of Irrigation Audits/Scheduling of the Parks and Playing Fields of Novato California," *Proceedings of CONSERV93: The New Water Agenda*, Denver: American Water Works Association, pp. 1019-1024. As reported in PMCL (1994).

PMCL (1994), "Urban Water Conservation Programs Volume I: Annotated Bibliography," Planning and Management Consultants, Inc., September.

Western Policy Research (1997), "Efficient Turf grass Management: Findings from the Irvine Spectrum Water Conservation Study: Statistical Analysis," prepared for the Metropolitan Water District of Southern California.

Western Policy Research (1996), "Do Centrally Controlled Irrigation Systems Use Less Water? The Aliso Viejo Experience," prepared for the Metropolitan Water District of Southern California.

2.12 System Audits and Leak Detection

2.12.1 Device/Activity Description

This conservation activity consists of three possible components:

- System audits
- Leak detection
- Leak repair

System audits include quantifying all produced and sold water, and may include testing meters, verifying records and maps, and field checking distribution controls and operating procedures (AWWA 1990). The objective is to determine the amount of water that is lost and unaccounted for in the system. System audits may identify losses from:

- Accounting procedure errors
- Illegal connections and theft
- Malfunction distribution-system controls
- Reservoir seepage, leakage, and overflow
- Evaporation, and
- Detected and undetected leaks.

Leak detection is the process of searching for and finding leaks in the system with sonic, visual, or other indicators. Reviewers have noted that sonic and acoustic leak detection equipment is more accurate for smaller systems than for larger systems. Audits and detection programs incur costs whether or not repairs are made; thus, audits and detection alone do not save water. Conversely, leaks are sometimes discovered without organized audit and detection programs. Finally, reviewers have noted that "leak prevention" would also be part of these programs, including corrosion control, quality control on materials and installations, and backflow device testing.

2.12.2 Applicable BMPs

BMP 3 – System Water Audits, Leak Detection and Repair calls for prescreening audits, full-scale audits when indicated, and repairs.

2.12.3 Available Water Savings Estimates

Summary of Individual Studies

The incremental savings of system audits and leak detection are the additional savings from repairs that: a) would not have taken place without the program or b) would have taken place at a later time and perhaps more severely. Moyer (1985) makes the rough assumption that leaks are detected one year earlier than they would have been without the program.

Table 1 - Cost of Leak Detection Equipment

Type	Price (1988 $)
Sonic	$334-3270
Acoustic	$15-260
Correlator	$27,000-43,000

Source: AWWA 1990.

Persistence

We have not found a study that considers the persistence of savings from leak detection.

Limitations

The assumptions regarding how much earlier leaks are detected with a program than without a program are not well supported.

Confidence in Estimates

Low. To obtain reliable estimates of water conservation from leak repair, one needs to measure rates and how they may over time.

2.12.4 Program and Device/Activity Cost Estimates

Program Costs

Supplier program costs may include:

- System audits.
- Leak detection equipment and labor.
- Contractors

AWWA (1990) concludes that the cost of water audits vary widely depending on factors such as the completeness of the audit, the size of the service area, and quality of utility records. Testing large meters was reported to cost between $150 to $500 and testing residential meters is reported to range from $25 to $50. In addition to meter testing, the major component of cost is labor by utility staff or consultants.

Reviewers have commented that the AWWA figures are outdated and too low. For 12” to 15” meters, reviews reported audit cost from $500-$2,500. A 1994 calibration of a 30” meter cost $600. California water system costs tend to run higher than the national averages reported by AWWA, according to the reviewers.

Note that AWWA (1990) is being updated and revised; the new edition is expected to be published in 2000.
AWWA (1990) also reports that leak detection costs between $75 and $300 per mile of water main, or $150 to $500 per mile if consultants are utilized. The cost of equipment needed to

perform leak detection is summarized in Table 1. AWWA (1990) also states that leak repair costs are not a direct cost of leak detection because the leaks would be repaired any how sometime in the future. However, since some leaks will be discovered and repaired that would not be discovered otherwise, there may be incremental costs of repair. Also, some leaks will be detected sooner and may have lower repair costs (less severe leak), again suggesting that the costs of leak repair should be examined carefully.

Reviewers have commented that the AWWA figures for leak detection equipment are outdated. "Pigging" equipment should also be added to the list of detection equipment for larger systems ($20,000 to $50,000 cost range).

Reviewers also noted that leak prevention activities cost about $150 per test. Materials cost in the range of $500 to $2,000—for example—for installation of back flow devices.

Limitations

Leak detection equipment is evolving rapidly and cost data need to updated periodically.

Confidence in Estimates

Medium-Low.

2.12.5 Water Savings Calculation Formula(s)

Calculations

Estimating the water lost from a leak can be performed with one of three methods: 1) bucket and stopwatch, 2) hose and meter, or 3) calculation using Greeley's formula (AWWA 1990):

$$Q = (43{,}767/1440) * A * \mathrm{sqrt}(P)$$

where:

- Q is flow in gallons per minute
- A is the cross-sectional area of the leak in square inches (or $3.14 * r^2$ if circular hole)
- P is pressure in pounds per square inch
- 43,767 is calculated with an orifice coefficient of .80

The orifice coefficient of .8 is used to calculate 54709*.80/1440 = 30.39. The orifice coefficient for joints and cracks used in Table 3 is .6, which yields 54709*.60/1440 = 22.79 as it appears in Table 4-4 of AWWA 1990.

Factors to Consider in Applying the Formula

The formula provides only a rough approximation, not a source of measured data.

Table 2 - Leak Losses for Circular Holes Under Different Pressures (gpm)

Diameter of Hole (in.)	Area of Hole (in.^{2})	20 psi	100 psi	200 psi
0.1	0.01	1.1	2.4	3.4
0.5	0.20	26.7	59.7	84.4
0.9	0.64	86.5	193.4	273.4
1.3	1.33	180.4	403.4	570.5
1.7	2.27	308.5	689.9	975.6
2.0	3.14	427.0	954.8	1350.4

Source: AWWA 1990. Orifice coefficient is .80.

Table 3 - Leak Losses for Joints and Cracks Under Different Pressures (gpm)

Length of Crack (in.)	Width of Crack (in.)	20 psi	100 psi	200 psi
1.0	0.03	3.2	9.5	13.4
1.0	0.06	6.4	14.2	20.1
1.0	0.13	12.7	28.5	40.3
1.0	0.25	25.5	57.0	80.6

Source: AWWA 1990. Orifice coefficient is .60.

Example Calculation

Table 2 contains results of savings calculations using Greeley's formula for circular holes. Table 3 contains results for leaks in joints and cracks (reproduced from AWWA 1990).

2.12.6 Questions to Ask

- Do you know who to ask to obtain your "unaccounted for" percentage? (Hint - operations and billing departments are sources for produced and sold water, which can be used to calculate a cursory estimate of unaccounted for water. However, a thorough audit process is needed for a fully substantiated estimate of unaccounted for water.)

2.12.7 Sources

Moyer, E.E. (1985), "The Economics of Leak Detection: A Case Study Approach," American Water Works Association.

California Department of Water Resources (1986), "Water Audit and Leak Detection Guidebook," with the American Water Works Association California – Nevada Section.

AWWA (1990), American Water Works Association, " Water Audits and Leak Detection: Manual of Water Supply Practices M 36."

Greeley, D.S. (1981), "Leak Detection Productivity," Reference Number 1981, Water/Emergency & Management, Des Plaines, p. 111 (as noted in AWWA 1990).

2.13 Graywater

2.13.1 Device/Activity Description

Developed pursuant to the *Graywater Systems for Single Family Residences Act of 1992* (AB 3518), the State of California now has graywater system standards in the State Plumbing Code (DWR 1994). "Graywater is untreated household waste water which has not come into contact with toilet waste." Graywater, "Includes: used water from bathtubs, showers, bathroom wash basins, and water from clothes washing machines and laundry tubs." Graywater, "Does not include: waste water from kitchen sinks, dishwashers, or laundry water from soiled diapers." (California Graywater Standards; Title 24, Part 5 of the California Administrative Code). A typical graywater system includes a plumbing system, a surge tank, a filter, a pump and an irrigation system (DWR 1994).

2.13.2 Applicable BMPs

Although graywater is not mentioned in BMP 1 – Residential Water Surveys, other means of conserving landscape irrigation water are included. Graywater recommendations or evaluations could be included as part of the residential surveys; however, the BMP does not have provision for gaining credit towards BMP compliance for doing so. It does not appear that graywater could be used toward compliance with BMP 2.

2.13.3 Available Water Savings Estimates

Summary of Individual Studies

Whitney et al. (1999) estimate the savings from a graywater system to be 446,200 gallons over a 15 year life span. The per capital annual average discharge to the landscape site was 20.4 gallons per day.

The California Department of Water Resources *Graywater Guide* (1994) estimates daily graywater flows for each occupant in a single family residence. Graywater flow per day per occupant is the sum of flow from showers, bathtubs, wash basins, and clothes washers. Water savings is estimated as the amount of graywater flow that displaces landscape water use that would occur otherwise.

A direct method of estimating savings per household in a specific service area is to multiply graywater flow per person by the average number of persons per household in the agency service area. Presumably the graywater displaces fresh irrigation water only for the part of the year that landscape is irrigated. Note that usable yield depends on gray water storage capacity and the irrigation requirements at the site, which under current health codes, can be met using graywater.

Table 1 - Equipment Costs of Typical Graywater System ($1994)

Plumbing Parts	$	121.00
Tank Parts	$	233.00
Pump	$	150.00
Drip Parts (or)	$	253.00
Leachfield Parts	$	230.00
Total Drip	$	757.00
Total Leachfield	$	734.00

Source: DWR *Graywater Guide*

Persistence

We have not found a study that considers the persistence of savings from household graywater systems.

Limitations

Savings estimates are situation specific and need to account for slope of landscape, vegetation, climate, level of maintenance and other factors.

Confidence in Estimates

Medium-Low. Future efforts should include empirical measurement of water savings considering behavior (e.g., maintenance), the presence of other low flow devices (e.g., low flow showerheads, faucet aerators, and washing machines), and persistence of savings. Savings estimates may be confounded if wastewater were to be recycled (potential overestimate) or if water percolates to the groundwater basin rather than lost to the sewer (potential underestimate).

2.13.4 Program and Device/Activity Cost Estimates

Program Costs

Whitney et al. (1999) estimate the costs of equipment and installation for a graywater system fulfilling all legal requirements. Capital costs are estimated to be $5,400 per site, including $1,250 for equipment and $4,150 for labor. Over a 15 year life span, the cost of energy for the pump is estimated to be $100, and back-wash water cost is $20.

DWR's *Graywater Guide* (1994) also estimates the equipment costs of installing a typical graywater system. The costs depend on whether the system uses drip or leachfield design. Table 1 summarizes these costs, without labor.

Limitations

Often it is complex to get legal permits for graywater systems. Costs depend greatly on the housing construction—whether it is slab foundation, whether it is two story, and/or whether it is

Table 2 - Potential Graywater Savings Calculation

Example Agency (irrigation season)	Single Family Persons/Household	Single Family Savings (gpd/system)
Water Agency A (4 months irrigation)	2.00	26.7
Water Agency A (4 months irrigation)	3.00	40.0
Water Agency A (4 months irrigation)	4.00	53.3
Water Agency B (6 months irrigation)	2.00	40.0
Water Agency B (6 months irrigation)	3.00	60.0
Water Agency B (6 months irrigation)	4.00	80.0
Water Agency C (8.5 months irrigation)	2.00	56.7
Water Agency C (8.5 months irrigation)	3.00	85.0
Water Agency C (8.5 months irrigation)	4.00	113.3

new or retrofit construction.

Confidence in Estimates

Medium-Low. Better cost data is also needed to account for differences in housing construction types (slab foundation, two story, retrofit, etc.).

2.13.5 Water Savings Calculation Formula(s)

Calculations

The potential graywater savings is calculated by multiplying persons per household times graywater flow per person per day times the percent of irrigation that is saved. Note that the graywater per person per day includes a clothes washer; this figure would be less at sites without clothes washers.

S = PPH * Graywater_PPH_Day * Percent_Irrigation_Saved

where:

- S is Savings (gpd per household system)
- PPH is persons per household
- Graywater_PPH_Day is the sum of: (1) showers, bathtubs and wash basins 25 gal. per day/occupant (DWR 1994) and (2) clothes washers 15 gal. per day/occupant (DWR 1994)
- Percent_Irrigation_Saved is the percent of irrigation days saved (depends on the service area; suggested range of 4 to 8.5 months per year irrigation saved in the example)

Factors to Consider in Applying the Formula

Savings estimates should account for site characteristics.

Example Calculation

The following assumptions were used in the sample calculations:

- Graywater_PPH_Day is the sum of: (1) showers, bathtubs and wash basins 25 gal. per day/occupant (DWR 1994) and (2) clothes washers 15 gal. per day/occupant (DWR 1994)
- Percent_Irrigation_Saved is the suggested range of 4 to 8.5 months per year irrigation

Table 2 summarizes estimates for three hypothetical agencies in three climate zones in California, each with a different number of irrigation days that are potentially replaced with graywater.

2.13.6 Questions to Ask

- Is the graywater system installed at the time of construction of is it a later retrofit?
- What is slope of the yard and what type of soil is present?
- What is the configuration of the graywater sources relative to the irrigation site (closse or far, in basement or first floor)?
- What are the irrigation needs of the local climate and particular landscape?
- What are the permit requirements?

2.13.7 Sources

DWR (1994) California Department of Water Resources, "Using Graywater in Your Home Landscape: Graywater Guide," December.

Whitney et al. (1999) [A. Whitney, R. Bennett, C.A. Carvajal, and M. Prillwitz], “Monitoring Graywater Use: Three Case Studies in California,” (undated, assume 1999).

2.14 Hot Water Demand Unit

2.14.1 Device/Activity Description

Hot water demand units deliver hot water to a faucet or shower without having to drain the cold water sitting in the pipes between the water heater and the fixture. Using a valve and a pump, the device temporarily opens a loop between the hot and cold water lines and pumps the cold water sitting in the hot water pipe into the cold water pipe and back into the hot water heater tank. When the hot water in the hot water pipe arrives at the unit and the water temperature rises, pumping stops, the loop closes, and the plumbing system is returned to conventional functioning--now with the hot water. The system can be enacted with buttons or with a “TV-like” remote control.

2.14.2 Applicable BMPs

Although hot water demand systems are not mentioned in BMP 1 – Residential Water Surveys, recommendations or evaluations could include these systems. BMP 1 does not appear to have provisions for gaining credit towards BMP compliance by promoting hot water demand units. Similarly, hot water demand units are related to BMP 2 – Residential Plumbing Retrofits; although not mentioned in the BMP, the units are a type of plumbing retrofit. It does not appear that hot water demand units could be used toward compliance with BMP 2.

2.14.3 Available Water Savings Estimates

Summary of Individual Studies

Advanced Conservation Technology Metlund Inc. has conducted a small scale survey of households that have been retrofitted with hot water demand units. A four page survey was sent to 30 randomly selected households. Respondents self reported by following directions on the survey on how to measure water loss (e.g., respondents measured length of wait time for water to get hot, and flow rate of device by measuring with a quart container). A total of 26 out of the 30 households responded.

The California Energy Commission (CEC) is in the middle of a case study analysis of the water and energy savings from a hot water demand unit in a single family residential setting (Klein 1995). The CEC analysis has included bucket measurements of lost water and stopwatch measurements of warm up time.

Water savings depend on the number of "cold start" hot water runs from the water heater to the faucet or shower. Water is saved only when water in pipe is cold, not when water is already hot. Furthermore, although runs per day will clearly be higher in households with more persons per household, it is not clear that "cold-start" runs will increase in proportion to household residents; the greater the frequency of use of a fixture, the more likely that it is already hot. In most cases, uninsulated pipes cool down in about 10 minutes.

Water savings is not simply the volume in the pipe between the water heater and the faucet. The CEC measurements indicate that approximately twice the pipe volume is needed to warm up the water at the faucet because of the need to warm up the pipes along the way.
Not all of the houses in a region will be able to realize the full savings from the hot water demand system because of the design of their plumbing system.

Persistence

We have not found a study that considers the persistence of savings from hot water demand units.

Limitations

An important limitation is data regarding the number and type of sites with plumbing that is configured in a way that can take advantage of the hot water demand system.

Confidence in Estimates

Medium. More evidence needs to be developed regarding the number existing plumbing configurations that would effectively save water if retrofitted with hot water demand systems, the number of cold-start runs per person per day, how the number of cold-start runs scales as more people live in the same household (scaling factor), and the mean and distribution of savings per run that can be expected under different circumstances.

2.14.4 Program and Device/Activity Cost Estimates

Program Costs

One estimate of costs of hot water demand units is $500 per unit installed (Stranz 1996). These cost figures are derived from information supplied by the manufacturer. ACT Metlund indicates that the latest model reduces installation labor time by 50 percent compared to previous models, and that its cost is $208 for the parts without labor (www.chilipeperapp.com 1999).

Limitations

(1) The savings figures are for retrofits. If the house is plumbed to take full advantage of the hot water demand unit, then greater savings are likely to occur. One important savings factor is the distance between the fixture (e.g., shower or sink) and the trunk water line from the water heater--that is, the length of the branches from the trunk. Short branches are better. Only one demand unit is needed if the fixtures are arrayed in series along the trunk line (the unit is installed at the furthest point from the water heater). If a radial design is used, then a unit is needed at the end of each branch, which would be costly. Other factors that influence savings include the distance between the water heater and the fixtures (most houses in California have water heaters in the garage, rather than at the center of the house), and pipe location and insulation (pipes are often uninsulated and in attics or basements). (2) Most of these devices are going into the single family residential sector, although the multi-family sector has potential.

Table 1 - Hot Water Demand Unit (savings gpd/unit)

Supplier	SF PPH	Cold-Start Hot Water Runs (runs/day/unit)	Savings g/day/unit
Supplier A*	2.0	7.7	23.0
Supplier B*	3.0	9.2	27.6
Supplier C*	4.0	9.8	29.5
Supplier A**	2.0	8.0	6.0
Supplier B**	3.0	12.0	9.0
Supplier C**	4.0	16.0	12.0

*saving per run: 4 gal; runs per person per day 6; scale factor .8; plumbing factor .75
**saving per run: 1 gal; runs per person per day 4; scale factor 1; plumbing factor .75

(3) Some new houses are built with recirculating hot water systems similar to those used in the commercial sector. In these houses, the demand unit technology would not save additional water if hot water is circulated continuously back through the dedicated hot water return line, but could be used to save energy by operating the recirculating system on-demand rather than continuously.

Confidence in Estimates

Medium-Low. Costs will depend on plumbing layout.

2.14.5 Water Savings Calculation Formula(s)

Calculations

S = Cold_Start_Hot_Water_Runs * Savings_per_Run * Plumbing_Factor

where:

- S is savings (gpd/hot water demand unit)
- Cold_Start_Hot_Water_Runs = PPH * Hot_Water_Runs * $\text{Scale\_Factor}^{\text{PPH}}$
- Savings_per_Run is the water savings per hot water run.
- Hot_Water_Runs is the number of times the water is heated up at the faucet.
- Scale_Factor is the degree to which hot water runs are reduced as persons per household increases, because the likelihood of water already being hot is higher (judgement; CEC 1995).
- PPH is persons per household.
- Plumbing_Factor is represents the ability house to realize savings because of the configuration of the plumbing system and its ability to take advantage of the hot water demand unit (e.g., 1/2 get 50 percent savings, the other half get 100%, so together the plumbing factor is .75).

Factors to Consider when Applying the Formula

Additional data would allow stratification that could be used to develop separate models for different site types.

Example Calculations

The following assumptions were used in the sample calculations:

- Savings_per_Run is a mean of 4.0 gallons per hot water run; with a range of 2-12 gallons per run (ACT Metlund 1995; CEC 1995).
- Hot_Water_Runs has a mean of 6 hot water runs per day per person and a range of 2-10 (based on ACT Metlund 1995; CEC 1995; Davis Energy Group 1988).
- Scale_Factor is .8 is the degree to which hot water runs are reduced as persons per household increases, because the likelihood of water already being hot is higher (judgement; CEC 1995).
- Plumbing_Factor is .75.

Table 1 shows the results of using these assumptions, and using another plausible set of assumptions. Table 1 demonstrates the need for better data; savings estimates can be widely different under different conditions.

2.14.6 Questions to Ask

- Is the hot water demand unit installed at the time of construction or retrofit?
- Is the plumbing configuration closer to an "in-line" or "hub-and-spoke" layout?
- How many pump and controller units would be needed to use the system at the most important sinks (bathroom and kitchen sink)?

2.14.7 Sources

Acker, Larry (1995), ACT Metlund Systems, Telephone interview, 21 December.

ACT Metlund Systems (1995), "Home Test Audit Report," Metlund Hot Water Demand Systems, July 18.

Davis Energy Group (1988), "Residential Water Heating Study: Technical Report," Use Pattern Assumptions in Appendix F, Table F-2, prepared for the California Energy Commission, Contract Number 400-88-003 (1988 contract), as reported by Klein (1995).

Klein, G. (1995), California Energy Commission Staff, Telephone interview, 25 December.

Stranz, Blake (1996), "Hot Shot: Innovative Hot Water System Saves Money, Energy and Time," *America How-To*, March/April.

www.chilipeperapp.com (1999), Chilipepper Hot Water Appliance.

Appendix A

Example Cost-Benefit and Cost-Effectiveness Calculations

By

David L. Mitchell, M.Cubed

Introduction

This appendix presents several examples of how water savings and cost data in this report can be used to develop cost-benefit (CB) and cost-effectiveness (CE) estimates for BMPs. Through these examples, we discuss several important issues that confront the analyst preparing these estimates. These include:

- How CB and CE estimates change depending on whether one views them from a total societal or supplier perspective
- Calculation of water savings and costs in the presence or absence of uniform efficiency standards
- Impact of free-riders on water savings and costs
- The effect of program scale on CB and CE estimates

While we draw much of the data used to construct the following examples from empirical estimates and seek to employ assumptions consistent with actual supplier experience, keep in mind that the examples are hypothetical. In particular, data on program benefits, which are not directly addressed by this report, are hypothetical and only for illustration. These examples are presented to (1) demonstrate how data contained in this report can be harnessed, (2) provide an expanded discussion of key issues affecting the "bottom lines" of CB and CE estimates, and (3) illustrate how various methods can be used to analyze a variety of program design issues.

This appendix assumes a basic familiarity with CB and CE methods. Readers not possessing a basic understanding of these methods will find it useful to review the CUWCC's "Guidelines for Preparing Cost-Effectiveness Analyses of Urban Water Conservation Best Management Practices" (CE Guidelines) prior to reading this appendix. The CE Guidelines also contain several more fully developed examples of cost-effectiveness calculations that the reader may wish to review.

Common Assumptions

We use the following assumptions in each example, unless specifically noted:

Constant Dollars

The examples remove inflationary effects on costs and benefits. All monetary time series are expressed as constant dollars. Therefore, if a unit price of a commodity (e.g. the cost of new supply) changes through time, it means we are assuming its real cost (i.e., its cost relative to all other goods and services) is changing. This might occur, for example, if we expect water supply development to become increasingly expensive, or if we think program costs for a given conservation effort (e.g., the cost of locating and recruiting eligible program participants) will rise through time as the level of market saturation increases.

Similarly, discount rates are expressed in real terms, net of inflation premiums. One can approximate a real discount rate by subtracting the expected rate of inflation from its corresponding nominal discount rate using OMB's six-year inflation forecast.[1]

Discount Rates

To facilitate comparison of how other variables (such as rate of natural replacement or avoided cost) affect estimates depending on the analysis perspective, we use the same discount rate for both perspectives. In an actual analysis, the two would likely differ. We use the following discount rate to convert future costs and benefits to present values:

Perspective	Discount Rate
Total Society	4.0%
Supplier	4.0%

Program Benefits

We assume program benefits come in two forms: avoided costs of supply and avoided costs of wastewater treatment.[2] We use the avoided cost assumptions used for the ULFT illustrative example contained in the CUWCC's Guidelines. These are as follows:

Total Society Perspective[3]

- Avoided cost of water: $600/AF, escalated by 1.5%/year
- Avoided cost of wastewater: $700/AF

Supplier Perspective[4]

- Avoided cost of water: $480/AF, escalated by 1.5%/year

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[1] Note that the precise conversion from nominal to real is somewhat more complicated. As shown in the CUWCC's guidelines, if d is the real discount rate, r is the nominal discount rate, and i is the expected rate of inflation, then $d = (r - i) \div (1 + i)$. This is approximately equal to $r - i$. OMB's long-term forecast is 2.3% per annum. We carry this forecast forward when analyzing devices or activities with savings extending beyond six years.

[2] These examples focus on problem formulation and methods. To keep things from getting overly complicated the examples do not address the full range of potential avoided costs. For instance, they do not address potential avoided environmental costs and other potential non-market benefits. The CE Guidelines contains a discussion of potential avoided environmental costs and how to address them in CE and CB analyses.

[3] Readers uncertain what is meant by the Total Society and Water Supplier perspectives of analysis should refer to the CUWCC CE Guidelines for further explanation.

[4] Unlike the examples in the CE Guidelines, these examples assume the supplier does not own, operate, or directly pay for the wastewater facility. This allows us to construct an example involving cost sharing with other program beneficiaries. Of course, an actual supplier may have different or additional avoided costs than those used in this example.

While we use these assumptions in the examples, it is important to stress that we are greatly oversimplifying avoided cost calculations. Actual avoided cost of supply will depend on each supplier's circumstances. In some cases, conservation investments may help displace or defer investments in supply, transmission, and treatment capacity. In other cases, where existing capacities have yet to be fully utilized, they may only help to avoid variable operating and maintenance costs in one or more of these areas. We certainly are not suggesting that avoided costs are broadly the same for utilities across California or even of the same magnitude as we assume here for the sake of example.

A Quick Review of Some Key Formulas

The examples that follow rely on basic discounting formulas for converting future costs and benefits into their present value equivalents. In particular, the following formulas are extensively used throughout the ULFT examples. Bear in mind that you can use a spreadsheet to quickly calculate present values using these formulas. In some cases, the spreadsheet will have predefined functions based on the formula.

Suppose you will receive a payment of A_t dollars in year t. You will receive these payments every year for 20 years and you want to know their present value equivalent. If r is the discount rate, then the present value of these payments can be computed as

$$PV = \sum_{t=1}^{20} \frac{A_t}{(1+r)^t}$$

If the annual payment is the same in each year, then a shortcut formula can be used to calculate the present value. When the payment A is the same in each year the present value is

$$PV = A \times \frac{(1+r)^{20} - 1}{r \cdot (1+r)^{20}}$$

This is the formula your spreadsheet uses to calculate the present value of a series of constant payments.

Suppose you won't receive the payment A every year. Rather you will receive it every 10 years. That is, 10 years hence you will receive A, 20 years hence you will receive A, 30 years hence you will receive A, and so on. If these payments will be made indefinitely, then the present value of these payments is

$$PV = \frac{A}{(1+r)^{10} - 1}$$

Suppose you have a rich uncle who has set up a trust fund for you. You are only 5 years old and the trust will not be turned over to you until you are 20 years old. When the trust is turned over to you, you will receive a payment of A dollars, and every 10 years thereafter you will receive a payment of A dollars. You are hoping to use this future income to secure a loan from the bank so you can play the market, which is all the vogue among 5-year-olds. You want to go to the bank and negotiate the loan but first you want to know the present value of your trust so the bank does not swindle you. Since you have just read this section of the report you have all the information you need to determine the present value. You receive your first payment in 15 years. Its present value is therefore

$$\text{PV of first payment} = \frac{A}{(1+r)^{15}}$$

You get your next payment when you are 30 years old, and then every 10 years thereafter. When you are 20 years old the present value of all these payments is

$$\text{PV of subsequent payments when you are 20 years old} = \frac{A}{(1+r)^{10}-1}$$

But you need to know their present value today, when you are 5 years old. So you discount these payments to the present as follows

$$\text{PV of subsequent payments when you are 5 years old} = \frac{\dfrac{A}{(1+r)^{10}-1}}{(1+r)^{15}}$$

You are now ready to go to the bank and negotiate your loan.

Example 1A:

High-Efficiency Washing Machine Rebate Program – Evaluating a Rebate

We use the example of a high-efficiency (tumble action) washing machine rebate program to illustrate CE and CB calculations in the absence of a uniform efficiency standard. This is the situation for which consumer rebates were originally developed.

Consumers have choices regarding efficiency-price tradeoffs for clothes washing machines. Market dominant models are lower cost but also less efficient than newer horizontal-axis models. Price conscious consumers may choose to forgo future (and potentially uncertain) savings associated with newer high-efficiency models for the immediate (and certain) price savings associated with market dominant low-efficiency models. The purpose of the rebate is to tilt the consumer's choice in favor of the high-efficiency model. In this example, we show how to calculate CE and CB estimates for a *given level of rebate*. In the following example, we show how spreadsheet models can be used to determine the appropriate level of rebate and to test the sensitivity of program net benefits to various program parameters and data. For the sake of brevity, we only discuss the supplier's perspective in these examples. The ULFT program examples that follow discuss both the supplier and the total society perspectives.

The Rebate Program

We assume the supplier is offering rebates of $150 for the purchase of high-efficiency washing machines. The administrative cost is assumed to be $40 per rebate (we use the same administrative cost assumption for this and the ULFT examples). Total program cost from the perspective of the supplier is therefore $190 per rebate.

Annual Expected Program Water Savings

Expected program water savings can be estimated using the data provided in Section 2.1 (High Efficiency Washing Machines) of the report. There are three different ways one could calculate expected savings using this data.

1. The CUWCC's interim savings estimates shown in Table 1 (page 2-3) could be used. This table summarizes data from the THELMA study on water savings. For example, it shows mean savings ranging between 4,560 and 5,611 gallons/machine/year at a 90% confidence level.

2. The Consortium for Energy Efficiency reports average water use of 37.5 gallons per load for conventional machines and 24.2 gallons per load for high-efficiency machines, yielding a savings of 13.3 gallons per load. The Oak Ridge National Laboratory's Bern, Kansas study (which replaced all the washing machines in Bern, Kansas with high-efficiency machines) estimated 0.45 loads per capita per day while the HUD study reports 0.3 loads per day. Multiplying these estimates by savings per load yields mean savings ranging between 1,456 and 2,185 gallons/machine/capita/year. A supplier could then multiply by service area persons-per-household to estimate a likely range of savings per machine per year. For example, if persons-per-household is 2.5 the range would be 3,640 to 5,463 gallons/machine/year.

3. The Oak Ridge National Laboratory's study estimated water savings of 37.8%. If a conventional machine uses 37.5 gallons per load and the number of loads are thought to range between 0.3 and 0.45 per capita per day, then estimated savings per machine per year range between 3,880 gallons and 5,821 gallons, assuming persons-per-household is 2.5.

For this example, we'll use the CUWCC's mean savings estimate ranging between 4,560 and 5,611 gallons/machine/year at a 90% confidence level. This is equivalent to 0.014 to 0.017 AF/machine/year.

Cumulative Program Water Savings

Washing machines are generally rated to last 10 to 20 years. For this example we assume an average life of 15 years. Cumulative water savings would then range between 68,400 and 84,165 gallons over the average life of the washer.

Cost-Effectiveness

Given these assumptions and data the program has an estimated cost per acre-foot of saved water ranging between $736 and $905 (program cost of $190/rebate divided by the range of expected cumulative water savings expressed in acre-feet).

Present Value Net Benefit of Rebates

Given our assumptions about avoided cost, the benefit of the program to the supplier is the avoided cost of water supply times the amount of avoided water supply. In this example, the avoided cost is initially $480/AF and is expected to increase at a rate of 1.5% per year. Applying the standard discounting formula to these values the present value benefit is

$$\sum_{t=1}^{15} \frac{\text{Initial Avoided Supply Cost} \times (1 + \text{Cost Escalation Rate})^t}{(1 + \text{Discount Rate})^t} \times \text{Annual Water Savings (AF/YR)}$$

Substituting values yields:

$$\sum_{t=1}^{15} \frac{\$480 \times (1.015)^t}{(1.04)^t} \times 0.014 \text{ AF/YR} \quad \text{(Lower Bound)}$$

$$\sum_{t=1}^{15} \frac{\$480 \times (1.015)^t}{(1.04)^t} \times 0.017 \text{ AF/YR} \quad \text{(Upper Bound)}$$

These amounts equal $83/Rebate and $101/Rebate, respectively. The net benefit of the program ranges between -$107 and -$89 (this is calculated by subtracting the program cost per rebate from the present value benefit per rebate).

Under the present assumptions about program costs and benefits, the rebate program has a negative net present value. This is not to suggest that this would be a typical outcome for most suppliers. The results will depend on each supplier's avoided cost of supply, program costs, and rebate levels. It is a relatively simple exercise the set up a spreadsheet to (1) examine CE and CB estimates for various avoided cost levels and (2) use the model to calculate the economically justifiable rebate for a given avoided cost. The next example shows how.

Example 1B:

High-Efficiency Washing Machine Rebate Program – Determining the Rebate

Table A1 shows a simple spreadsheet model that provides an example of how an analyst could set up a problem to calculate the maximum affordable rebate for a given program avoided cost. It can also be used to calculate the avoided cost level necessary to make a program cost-effective for a given rebate level. Either way, it is an effective way to examine how different program assumptions and parameter estimates affect bottom line results.

Table A1. Simple Spreadsheet Model to Calculate Rebate Level

	Lower	Upper	Cell Description
Annual Savings (AF/YR)	0.014	0.017	Estimated using reported data
Years of Savings	15	15	Assumption based on rated life of typical washers
Starting Annual Benefit ($/AF)	480	480	Example Assumption
Benefit Escalation Rate (%)	0.0150	0.0150	Example Assumption
Discount Rate (%)	0.0400	0.0400	Example Assumption
Effective Discount Rate (%)	0.0246	0.0246	Calculated using formula in footnote 1, assuming real water costs escalating at 1.5% per year.
Present Value Benefit	$83.43	$101.31	Calculated using spreadsheet's PV formula
Rebate Cost	$150.00	$150.00	Example Assumption
Program Admin Cost	$40.00	$40.00	Example Assumption
Present Value Net Benefit	($106.57)	($88.69)	

Goal Seeking to Determine the Affordable Rebate Level
Most spreadsheet programs have built-in tools that allow a user to solve "what-if" problems and to easily project model results for a range of possible parameter values. Excel, for instance, has a Goal Seek command that allows a user to find a specific value for a particular cell by adjusting the value of another related cell. The great thing about built-in commands like Goal Seek is the computer does all the tedious calculation work allowing the analyst to focus on problem formulation.

For example, we could use the Goal Seek command to determine what rebate level results in the present value of net benefits equaling zero given our assumptions about program administrative cost, expected savings, years of savings, and program benefits. Table A2 shows the result of this exercise (note: it took the computer less than one second to find the answer).

Table A2. Using Goal Seek to Determine Affordable Rebate for Given Program Savings, Costs and Benefits

	Value	Lower	Upper	Cell Description
Annual Savings (AF/YR)		0.014	0.017	Estimated using reported data
Years of Savings	15			Assumption based on rated life of typical washers
Starting Annual Benefit ($/AF)	480			Example Assumption
Benefit Escalation Rate (%)	0.0150			Example Assumption
Discount Rate (%)	0.0400			Example Assumption
Effective Discount Rate (%)	0.0246			Calculated using formula in footnote 1.
Present Value Benefit		$83.43	$101.31	Calculated using spreadsheet's PV formula
Rebate Cost		***$43.43***	***$61.31***	**Goal Seek Result**
Program Admin Cost		$40.00	$40.00	Example Assumption
Present Value Net Benefit		$0.00	$0.00	**Goal set by analyst**

Alternatively, we could use the goal seek command to determine what level of program benefits is required to justify a given rebate, say a rebate of $150. Table A3 shows the result of this experiment.

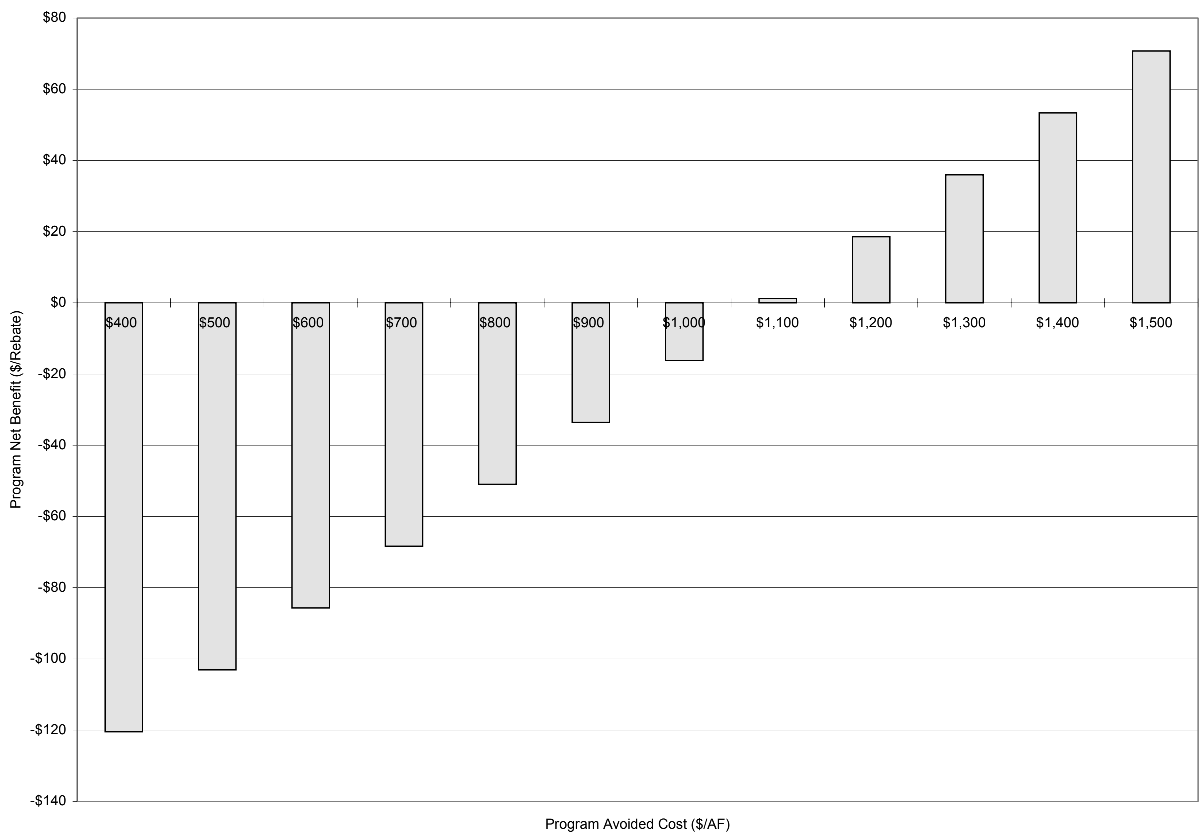
Table A3. Using Goal Seek to Determine Necessary Avoided Cost for Given Program Savings and Rebate

	Lower	Upper	Cell Description
Annual Savings (AF/YR)	0.014	0.017	Estimated using reported data
Years of Savings	15	15	Assumption based on rated life of typical washers
Starting Annual Benefit ($/AF)	***1093.139***	***900.2324***	**Goal Seek Result**
Benefit Escalation Rate (%)	0.0150	0.0150	Example Assumption
Discount Rate (%)	0.0400	0.0400	Example Assumption
Effective Discount Rate (%)	0.0246	0.0246	Calculated using formula in footnote 1.
Present Value Benefit	$190.00	$190.00	Calculated using spreadsheet's PV formula
Rebate Cost	$150.00	$150.00	Example Assumption
Program Admin Cost	$40.00	$40.00	Example Assumption
Present Value Net Benefit	$0.00	($0.00)	**Goal set by analyst**

Finding Results for Several Possible Parameter Values

Another useful tool available in most spreadsheet applications is a command that allows the user to calculate results for a specified formula given a range of possible values for one or two formula parameters. In Excel this is done using the Table command. For example, we could use the Table command to calculate the net present value for a rebate of $150 and avoided cost ranging between $400/AF and $1500/AF, as shown in Figure A1.

Figure A1. Using a Spreadsheet to Calculate the Net Present Value for a Range of Avoided Costs Given Program Cost and Benefit Assumptions Listed in Table A3.



The sensitivity of model results to any other model parameter could be tested in the same way. Becoming familiar with these tools can greatly ease and speed up the task of examining program costs and benefits under a variety of program assumptions.[5]

[5] Note that these tools allow the analyst to test at most two variables at a time. To evaluate interactions across more than two variables requires more sophisticated simulation modeling.

Example 1C:

High-Efficiency Washing Machine Rebate Program – Examining Free Rider Affects

Some consumers may be planning to replace an old or broken washer with a new high-efficiency washer regardless of the rebate. It seems reasonable to expect that these consumers will take advantage of the rebate if they are aware of it. Consumers fitting these circumstances are commonly called program free riders. Water savings resulting from their purchases of high-efficiency machines cannot properly be attributed to a rebate program since the savings would have occurred regardless of the program. The effect of free riders is to reduce overall savings attributable to the program thereby raising per acre-foot program costs.

The spreadsheet model in Examples 1A and 1B can quickly be extended to examine how different levels of free-ridership affect program net benefits. For this example, we assume the supplier wants to set the rebate at $100 and that it expects program benefits of $1000/AF, escalating at 1.5% per annum. Given these assumptions the program has a positive net present value at both the upper and lower water savings estimates.

What happens to net benefits if free riders are present? Since the effect of free riders is to reduce water savings attributable to the program we need to adjust program water savings according to the percent of program free riders.[6] (If 10% of rebates go to free riders, then program water savings decrease by 10%.) Table A4 shows the adjusted model.

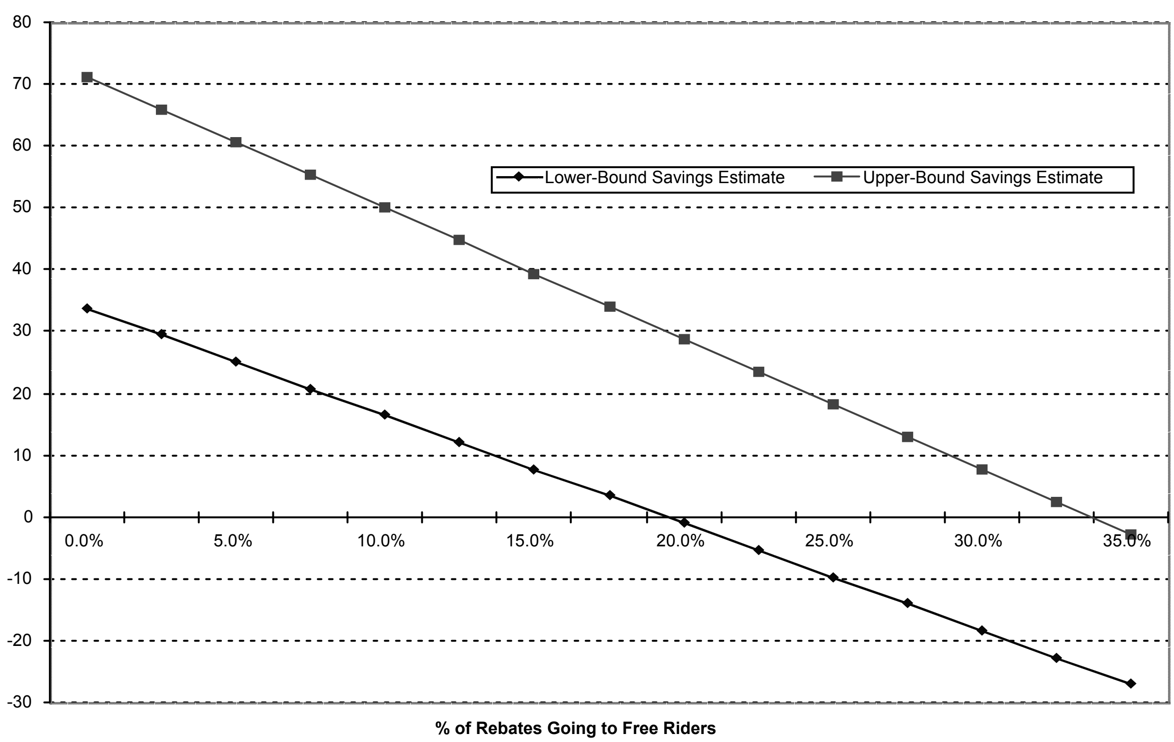
With this extension to the model we can use the Goal Seek or Table commands to determine how the level of free ridership affects bottom line results. For example, we could use the Goal Seek command to determine what percentage of free riders would result in the program having zero net benefit. We would then know that if free ridership exceeds this level, the program would not be cost-effective given our set of other assumptions. Alternatively, we could use the Table command to examine how net benefits change for different levels of free ridership, as shown in Figure A2.

[6] The extent of free-ridership is an empirical question. Unfortunately it is a question for which there is very little data to provide an answer. It is an area where additional empirical research is needed.

Table A4. Extension of Rebate Model to allow for Free Rider Effects

	Lower	Upper	Cell Description
Annual Savings (AF/YR)	0.014	0.017	Estimated using reported data
Free Rider Rebates (% of total)	10%	10%	Example Assumption
Effective Annual Savings (AF/YR)	0.0126	0.0153	(1-%Free Riders)*Annual Savings
Years of Savings	15	15	Assumption based on rated life of typical washers
Starting Annual Benefit ($/AF)	1000	1000	Example Assumption
Benefit Escalation Rate (%)	0.0150	0.0150	Example Assumption
Discount Rate (%)	0.0400	0.0400	Example Assumption
Effective Discount Rate (%)	0.0246	0.0246	Calculated using formula in footnote 1.
Present Value Benefit	$156.43	$189.95	Calculated using spreadsheet's PV formula
Rebate Cost	$100.00	$100.00	Example Assumption
Program Admin Cost	$40.00	$40.00	Example Assumption
Present Value Net Benefit	$16.43	$49.95	

Figure A2. Using a Spreadsheet to Calculate the Net Present Value for a Range of Free Ridership Given Program Cost and Benefit Assumptions Listed in Table A4.



Example 2A:

ULFT Replacement Program With Known Savings Acceleration

We use the example of a ULFT replacement program to discuss CB and CE calculations in the presence of a uniform efficiency standard. The issues discussed in this example also apply to other plumbing device programs subject to uniform efficiency standards, such as showerheads and faucets.

<u>In the presence of a uniform efficiency standard new high-efficiency toilets will eventually replace low efficiency toilets as a matter of course. The best active conservation can do is to accelerate when replacement occurs.</u> The benefits and costs of this active conservation therefore depend directly on the rate of acceleration. The benefits and costs of replacing a toilet today that would have been naturally replaced one year from today will obviously differ from the benefits and costs of replacing a toilet today that would have been naturally replaced ten years from today.

Let's suppose the program replaces a toilet today that would have been replaced ten years from today. Further suppose that new and old toilets have average lives of 25 years.[7] The *water savings* attributable to accelerating replacement by ten years are easy to understand. They are simply the savings that accrue over the ten years in which replacement is accelerated.

The *cost* of accelerating replacement is a bit more complicated and depends on the perspective used to analyze the program.

Total Society Perspective

From the total society perspective the cost of the program is not simply the present day cost of replacing the toilet. With or without the program, society will incur the cost of replacing the toilet. The question is whether it incurs the cost today or ten years from today. If it chooses to replace the toilet today, then it can expect to incur costs of replacement today, 25 years from today, 50 years from today, 75 years from today, and so on.[8] If it chooses to replace the toilet ten years from today, then it can expect to incur costs of replacement 10 years from today, 35 years from today, 60 years from today, 85 years from today, and so on. The cost to society is therefore the present value difference between these two payment streams.

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[7] This would be consistent with an annual replacement rate of 4%, the default replacement rate used in Exhibit 6 of the MOU.

[8] Remember the average life is 25 years. On average, society will spend resources to replace the toilet every 25 years.

We can compare this cost to the water savings that accrue over the 10 years of accelerated replacement to calculate the cost per acre-foot of savings. Similarly, we can compare this cost to the benefits attributable to the savings to calculate the net present value of replacing the toilet via the program.

We do this now using the cost and savings data from report section 2.7. "Ultra Low Flush Toilets (Residential)." We assume a rebate program targeted primarily at single-family residences. Under this program, participants purchase and install a new toilet and receive a rebate check from the supplier. We use the following costs from Table 1, page 2-27:

- Toilet Cost (TC): $120
- Installation Cost (IC): $70
- Rebate Cost (RC): $75
- Program Administrative Cost: (PC): $40

If the program replaces the old low efficiency toilet, the cost to society is $230 (TC + IC + PC).[9] If the customer replaces it, the cost to society is $190 (TC + IC). By having the customer replace the toilet, society avoids the program administrative costs associated with having the program replace the toilet. We assume the program only replaces a toilet once. Costs of all future replacements are borne by the owner of the toilet. Future replacements therefore do not incur the Program Administrative Cost (PC). The costs are shown in Table A5.[10] The net cost to society of accelerating replacement ten years is $139 (= $344 - $205).[11]

Note that if we had assumed the cost is equal to the present day cost of replacing the toilet ($230) we would have overstated costs by 65%, given our cost assumptions.

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[9] RC, the rebate cost, is not a net cost to society. It is a transfer payment from supplier to program participant. The gain by the participant exactly equals the cost to the supplier. The net societal cost is therefore zero.

[10] We can get the same result by using the formula for the present value of a perpetual periodic annuity. If payment A is made N years in the future, and then every N years thereafter, then the present value of these payments is $\frac{A}{(1+r)^N - 1}$, r is the discount rate. Using this formula, the net cost is

$$\left(\$230 + \frac{\$190}{(1.04)^{25} - 1}\right) - \left(\frac{\$190 + \frac{\$190}{(1.04)^{25} - 1}}{(1.04)^{10}}\right)$$

Note this formula only works with a constant periodic payment. If costs are changing through time, we can use a spreadsheet model to perform the calculations.

[11] We sum over a very long period (210 years) to show the effect of discounting on future costs. As shown in the table, future costs decline rapidly after 30 to 40 years. The higher the discount rate the more rapidly future costs and benefits approach zero and vice versa. This is why the discount rate plays such a critical role in CB analysis.

To estimate savings, we use the ULFT water savings equation on page 2-7-5. For the sake of example, we assume the average household density of single-family program participants is 3.0. The estimate of savings is:

$$S^{SF} = 6.693 \times 3 - 0.529 \times 3^2 + 7.826 = 32.67 \text{ gallons / day}$$
$$\text{or } 365 \text{ days/year} \times 32.67 \text{ gallons/day} \div 325{,}900 \text{ gallons/AF} = 0.0367 \text{ AF/year}$$

These savings accrue to the supplier program for ten years, yielding cumulative savings of 0.367 AF. The total society cost per acre-foot saved is approximately $380/AF.

The program produces societal benefits both in terms of avoided water supply costs and avoided wastewater treatment costs. The present value of these benefits over ten years is:[12]

$$PV_B = \sum_{t=1}^{10} \frac{\left[\text{Supply Avoided Cost} \times (1 + \text{Cost Escalation Rate})^t + \text{Wastewater Avoided Cost}\right] \times \text{Annual Water Savings}}{(1 + \text{Discount Rate})^t}$$

Substituting values yields:

$$PV_B = \sum_{t=1}^{10} \frac{\left[\$600 \times (1.015)^t + \$700\right] \times 0.0367}{(1.04)^t} \approx \$400$$

The net benefit to society of accelerating replacement by 10 years is therefore approximately $260 (= $400 - $139). Again note that if we had assumed the cost of the program to society was equal to the present day cost of replacing the toilet ($230) we would have calculated a net present value of $170 (= $400 - $230), 35% lower than the actual net benefit, given our cost assumptions.

Supplier Perspective

From the perspective of the supplier, the cost of the program is what it has to pay today to accelerate toilet replacement. Unlike society at large, in the absence of the program, the supplier incurs no cost of replacement. In this example, the supplier also does not incur the cost of the toilet or installation. It only incurs rebate and administrative costs. Without program cost sharing, the cost to the supplier is $115 (RC + PC). The cost per acre-foot saved is $313.[13]

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[12] A spreadsheet can be used to perform these calculations.

[13] $115/ULFT ÷ (0.0367 AF/YR/ULFT * 10 YR) = $313.35/AF

Table A5. Cost to Society to Accelerate Toilet Replacement 10 Years

Net Resource Cost		**$139**	**Cost/AF**	**$378**
Year	Replacement Cost w/ Program	Present Value	Replacement Cost w/o Program	Present Value
0	$230	$230.00		
5				
10			$190	$128.36
15				
20				
25	$190	$71.27		
30				
35			$190	$48.15
40				
45				
50	$190	$26.74		
55				
60			$190	$18.06
65				
70				
75	$190	$10.03		
80				
85			$190	$6.78
90				
95				
100	$190	$3.76		
105				
110			$190	$2.54
115				
120				
125	$190	$1.41		
130				
135			$190	$0.95
140				
145				
150	$190	$0.53		
155				
160			$190	$0.36
165				
170				
175	$190	$0.20		
180				
185			$190	$0.13
190				
195				
200	$190	$0.07		
205				
210			$190	$0.05
Totals	$1,750	$344	$1,710	$205

The benefit of the program to the supplier in year t is equal to the amount of water saved by the program in year t times the avoided cost of the saved water. (Remember that this example assumes this avoided cost is escalating at 1.5% per year.) The present value of the sum of these annual benefits is:

$$PV_B = \sum_{t=1}^{10} \frac{\text{Supply Avoided Cost} \times (1 + \text{Cost Escalation Rate})^t}{(1 + \text{Discount Rate})^t} \times \text{Annual Water Savings}$$

Substituting values yields :

$$PV_B = \sum_{t=1}^{10} \frac{\$480 \times (1.015)^t}{(1.04)^t} \times 0.0367 \approx \$150$$

The present value net benefit to the supplier is $35 (= $150 - $115).

The Affect of Perspective

Perspective obviously can have a big impact on CE and CB estimates. The cost data will often be different. For example, while the cost of the rebate is the primary cost from the perspective of the supplier, it is not even considered a cost from the perspective of society. Different perspectives can also result in different discount rates, time horizons, and avoided costs.

Bottom line results also are likely to be quite different. From the societal perspective, this example yielded a net benefit of about $260 per toilet. When we shift perspective to that of the supplier, program net benefit falls to $35 per toilet. When societal and supplier perspectives yield significantly different results substantial cost sharing opportunities are likely to exist. In the case of this example, these external benefits accrue to the wastewater service provider, and opportunities to cost share between the water supplier and the wastewater service provider are likely to exist.

The Affect of Acceleration

We can also use this example to see how acceleration of replacement affects the CE and CB estimates. Assume the program accelerates replacement by only five years rather than ten. In this case the cost of the program to the supplier remains unchanged ($115), but the cumulative savings attributable to the program fall by 50% to 0.1835 AF. The cost per acre-foot doubles to $626. Net present value turns negative. Without cost sharing the program is no longer cost-effective from the perspective of the supplier.

From the perspective of society, the cost *per acre-foot saved* rises to about $510. Although the present value of benefits falls from $400 to about $220, net present value remains positive. The program continues to be cost-effective. Note how different the affect of halving the acceleration of replacement is from the society's perspective compared to the supplier's perspective. The following figures illustrate these differences graphically.

Figure A3. Affect of Acceleration of Replacement on Cost Per AF

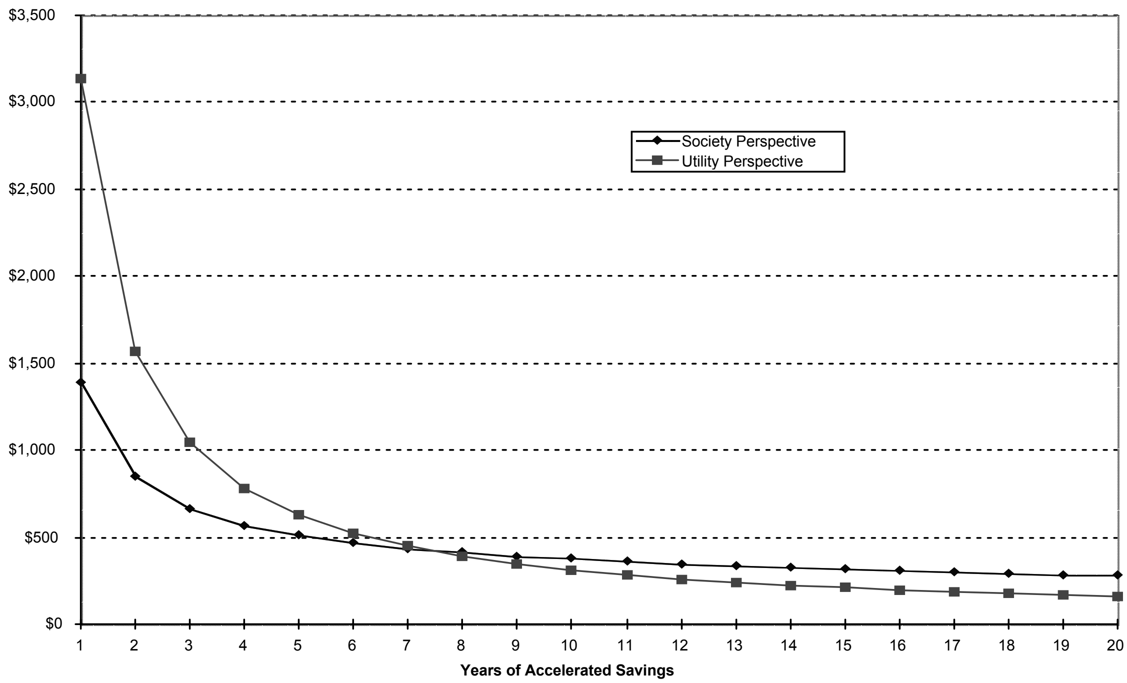
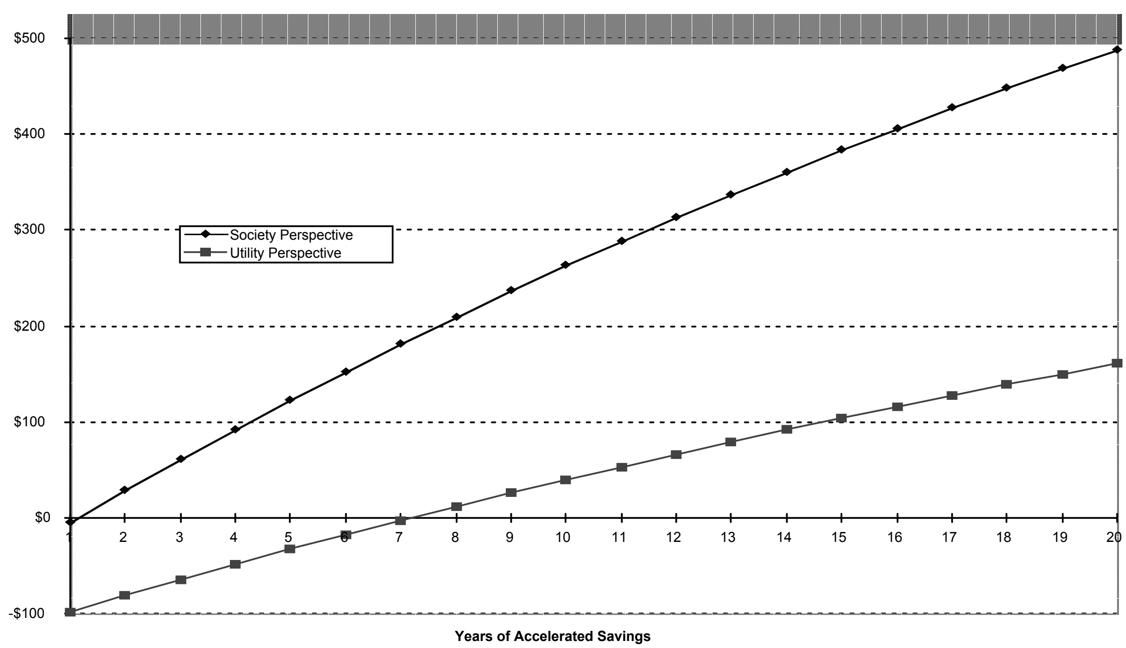


Figure A4. Affect of Acceleration of Replacement on Net Present Value



Example 2B:

ULFT Replacement Program With Expected Savings Acceleration

In the preceding example we assumed we knew by how many years replacement would be accelerated. In most cases, suppliers will not know with certainty how much acceleration their program is achieving. The best they can do is to analyze how different rates of acceleration affect CE and CB estimates, and design their programs to target participants whom they expect to have lower than average rates of natural replacement. In this example, we show how CE and CB estimates can be developed when the rate of acceleration is not known with certainty.

Exhibit 6 of the MOU addresses this issue by estimating a natural rate of replacement and then removing savings attributable to natural replacement from the estimate of savings attributable to a replacement program. It assumes a natural replacement rate – i.e. device failures plus replacement due to remodeling -- of 4% per year.[14] This means that Exhibit 6 assumes the initial stock of old low-efficiency toilets is decaying at a rate of 4% each year.[15]

Expected Savings

The first question to ask is what are the expected water savings if the rebate program randomly selects an old low-efficiency toilet for replacement? We answer this question by reasoning as follows:

1. In year one there is a 4% chance the toilet would have been replaced through natural replacement (remember our assumption is the toilet was randomly selected from the population) and a 96% chance that the toilet would not have been replaced.

2. If the toilet would not have been replaced through natural replacement the program realizes savings of 0.0367 AF in the first year. If the toilet would have been replaced through natural replacement the program does not realize any savings in the first year.

[14] This estimate of the rate of natural replacement was developed in consultation with MWD planning staff and is derived from bathroom remodeling data as well as other sources of information. While the rate of natural replacement is crucial to the effectiveness of ULFT programs, there is currently only limited data on the subject.

[15] Exhibit 6 assumes exponential decay. If X is the initial stock of old toilets, then in year one the remaining stock is X(1-0.04), in year two its X(1-0.04)(1-0.04), in year three its X(1-0.04)(1-0.04)(1-0.04), and so on. With exponential decay, the initial stock approaches but never reaches zero. With 4% exponential decay, the expected life of a toilet would be 25 years. An alternative assumption would be linear decay. With linear decay, in year one the remaining stock is X(1-0.04), in year two its X(1-2*0.04), in year three its X(1-3*0.04), and so on. With linear decay the initial stock reaches zero in 25 years and the expected life of a toilet would only be 13 years given a 4% replacement rate. Assumptions about natural replacement rates will be large impacts on CE and CB bottom-line results.

(The savings still occur, but they are not attributable to the program.) Therefore the expected savings in year one is 0.96*0.0367 + 0.04*0.0 = 0.0352 AF.

3. In year two there is a 7.84% chance the toilet would have been replaced (4% in year 1 + 4%*0.96 in year 2) and a 92.16% chance it would not have been replaced, yielding an expected savings in year two of 0.0338 AF.
4. The general formula for the probability the toilet would not have been replaced by year t, given a 4% rate of replacement, is $(1-0.04)^t$. Using this formula, we can calculate expected savings for all future years. Summing the results we get expected cumulative savings of 0.88 AF.[16]

Note that our assumption about natural replacement determines expected savings. The higher the rate of natural replacement the lower the expected savings and vice versa. Table A6 shows how different assumptions about natural replacement affect expected savings. Doubling the rate of natural replacement from 4% to 8% results in slightly less than half the expected savings. This is why assumptions about natural replacement are crucial to CE and CB estimates of toilet rebate/replacement programs.

Table A6. Affect of Natural Replacement on Expected Savings

	Natural Replacement Rate				
	4%	5%	6%	7%	8%
Expected Savings (AF)	0.88	0.70	0.57	0.49	0.42

Expected Costs: Total Society Perspective

What is the expected cost to society of replacing the toilet today? Remember that this cost is equal to the difference between replacing the toilet today versus the present value cost of replacing it some year in the future. In this case we don't know what year in the future it will be replaced. We only have an estimate of the probability it will be replaced in any given year, given our assumption about the natural replacement rate. For example, under the 4% exponential decay assumption, we can figure out the probability the toilet is replaced *in any given* year as follows:

1. In year 1 we know the probability is 4%.
2. Using the same reasoning we used to calculate expected savings, we know there is a 7.84% chance the toilet would have been replaced *by year 2*.[17] We also know there is a 4% probability that replacement will occur *in year 1.* Therefore, the probability that replacement would have occurred *in year 2* is 3.84% (= 7.84% - 4%)

[16] The easiest way to do this is to use a computer spreadsheet to estimate expected savings over some long period (until the probability approaches zero).

[17] Note that saying the toilet would have been replaced *by* year 2 is not the same as saying it would have been replaced *in* year 2. If we say it would have been replaced *by* year 2 this means the toilet could have been replaced either in year 1 or year 2.

3. Similarly, there is an 11.53% chance the toilet would have been replaced *by year 3*. We also know there is a 4% probability that replacement would have occurred *in year 1* and a 3.84% probability replacement would have occurred *in year 2*. Therefore, the probability that replacement will occur *in year 3* is 3.69% (= 11.53% - 4% - 3.84%).

4. Using this logic, we can use a spreadsheet to quickly calculate the probability the toilet is replaced in any given year t. In the following formula, we call this probability $prob_t$.

Given knowledge of the probability of replacement in any given year, the expected cost can be calculated using the following formula:

$$\left[\mathrm{TC}+\mathrm{IC}+\mathrm{PC}+\frac{\mathrm{TC}+\mathrm{IC}}{(1+0.04)^{25}-1}\right]-\left[\sum_{t}\left(\frac{\mathrm{TC}+\mathrm{IC}}{(1.04)^{t}}+\frac{\frac{\mathrm{TC}+\mathrm{IC}}{(1.04)^{25}-1}}{(1.04)^{t}}\right)\times \mathrm{prob}_{t}\right]$$

[Cost to Replace Toilet by Program] - [Cost to Replace Toilet Naturally]

This is a large and scary formula. To understand what it is doing, it is best to take it term by term.

1. The set of terms in the left-hand brackets calculates the present value cost to society of replacing the toilet via the program. This is the same calculation as was done in Example 2A (see footnote 6). It calculates the cost of replacing the toilet via the program plus (using the formula for the present value of a perpetual periodic payment) the present value cost to society of having to replace the toilet every 25 years thereafter.

2. The set of terms in the right-hand brackets calculates the expected present value cost to society of waiting for natural replacement. It is an expected value because unlike Example 1A, we assume we don't know when the toilet would have been naturally replaced. (In Example 2A we assumed we knew the toilet would have been replaced in year 10.)

3. To calculate this expected cost we calculate the cost of replacing the toilet through natural replacement in year t plus the present value cost (in year t) of having to replace the toilet every 25 years thereafter. We then discount these costs to the present and multiply by the probability of occurrence. Summing these values yields the expected cost of natural replacement.[18]

4. The expected present value net cost of the program is the difference between the expected cost to society of replacing the toilet today via the program and the expected cost to society of waiting for the toilet to be replaced naturally.

Once the formula is understood these calculations can be done easily using a spreadsheet. Using the cost data from example 1A, the expected present value net cost to society of

[18] If this is confusing you, go back and review the example of our 5-year-old calculating the present value of his trust fund. Exactly the same formulas are being used.

replacing the toilet via the program is \$195. The expected program savings are 0.88 AF. The expected cost per acre-foot is therefore roughly \$220.

Expected Benefits: Total Society Perspective

Expected program benefits from the perspective of society are equal to the avoided cost of supply and wastewater treatment times the expected savings in each year.

1. For any given year t, the avoided cost of an acre-foot of supply is $\$600 \times 1.015^t$ (remembering that we are assuming avoided supply costs are escalating by 1.5% per year).

2. The avoided cost of an acre-foot of wastewater disposal in year t is \$700.

3. Water savings attributable to the program in year t equal estimated savings per toilet multiplied by the probability the toilet *would not have been replaced naturally* by year t. As shown previously, the probability the toilet would not have been replaced naturally by year t equals $(1-0.04)^t$.

Therefore, the present value of expected program benefits is:

$$PV_B = \sum_t \left[\frac{\$600 \times (1.015)^t + \$700}{(1.04)^t} \times 0.0367 \cdot (1-.04)^t \right] \approx \$635$$

The present value of expected net benefits from society's perspective is therefore \$440 (= \$635 - \$195).

Expected Costs: Supplier Perspective

From the perspective of the supplier, the cost of replacing the toilet today is the same as in example 1A, \$115 (the rebate cost plus the administrative cost). The expected program yield is the same as for the total society perspective, 0.88 AF. The expected cost per acre-foot is therefore approximately \$130.

Expected Benefits: Supplier Perspective

Expected program benefits are equal to the avoided cost of supply times the expected savings in each year. The formula is the same as for the societal perspective, though the cost terms differ. It is

$$PV_B = \sum_{t=1} \left[\frac{\$480 \times (1.015)^t}{(1.04)^t} \times 0.0367 \cdot (1-.04)^t \right] \approx \$260$$

The expected net present value of the program from the supplier's perspective is therefore \$145 (= \$260 - \$115).

The Importance of the Rate of Natural Replacement

Example 1B uses Exhibit 6's default estimate of the rate of natural replacement. What would happen to the CE and CB estimates if we use a different assumption? For example, what if the natural replacement rate was 8% rather than 4%, would we get significantly different results? Would NPV become negative? We can use a spreadsheet model to calculate CE and CB values and then vary the underlying assumptions to see how the results change. Figures A5 and A6 show how the estimates change if we vary natural replacement between 4% and 8%.

As can be seen from the figures, the natural replacement rate can significantly affect CE and CB estimates. Doubling the natural rate of replacement from 4% to 8% more than doubles the expected cost per acre-foot, and reduces net present value by more than two-thirds from the supplier's perspective. Assumptions about natural replacement are important to bottom line results when a uniform efficiency standard is present.

Figure A5. Affect of Natural Replacement Rate on CE and CB Estimates: Total Society Perspective

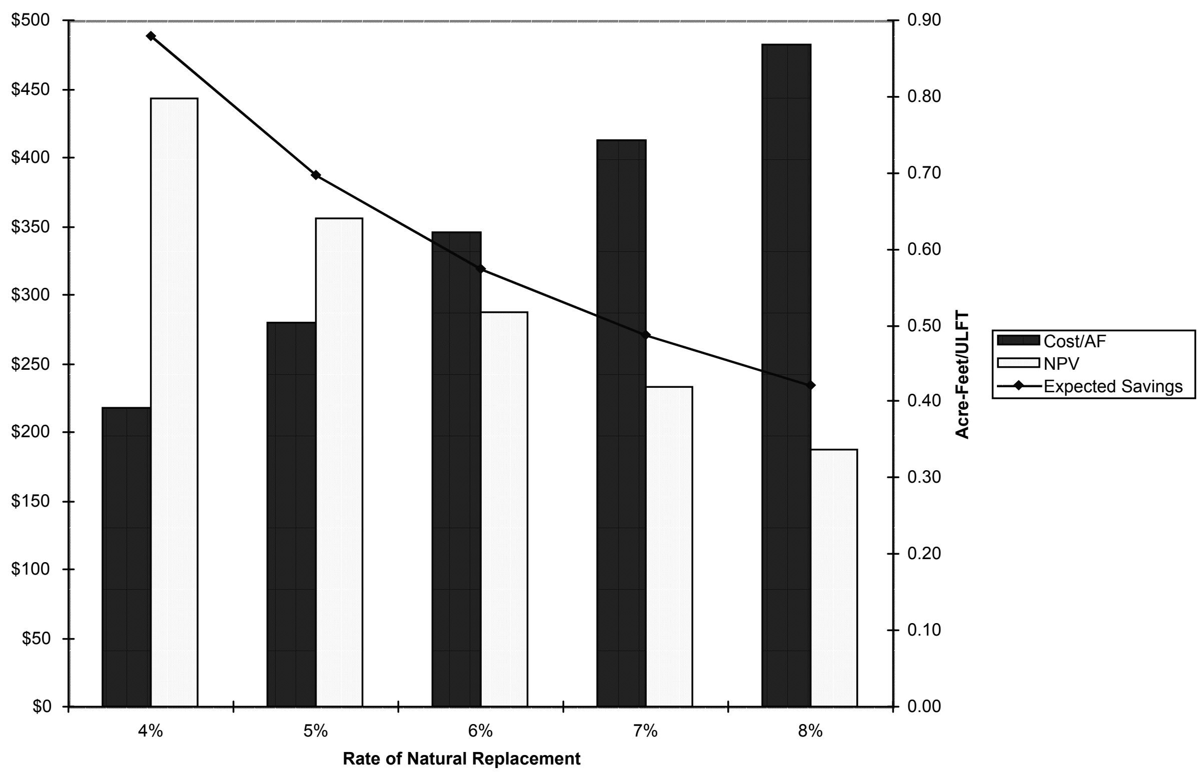
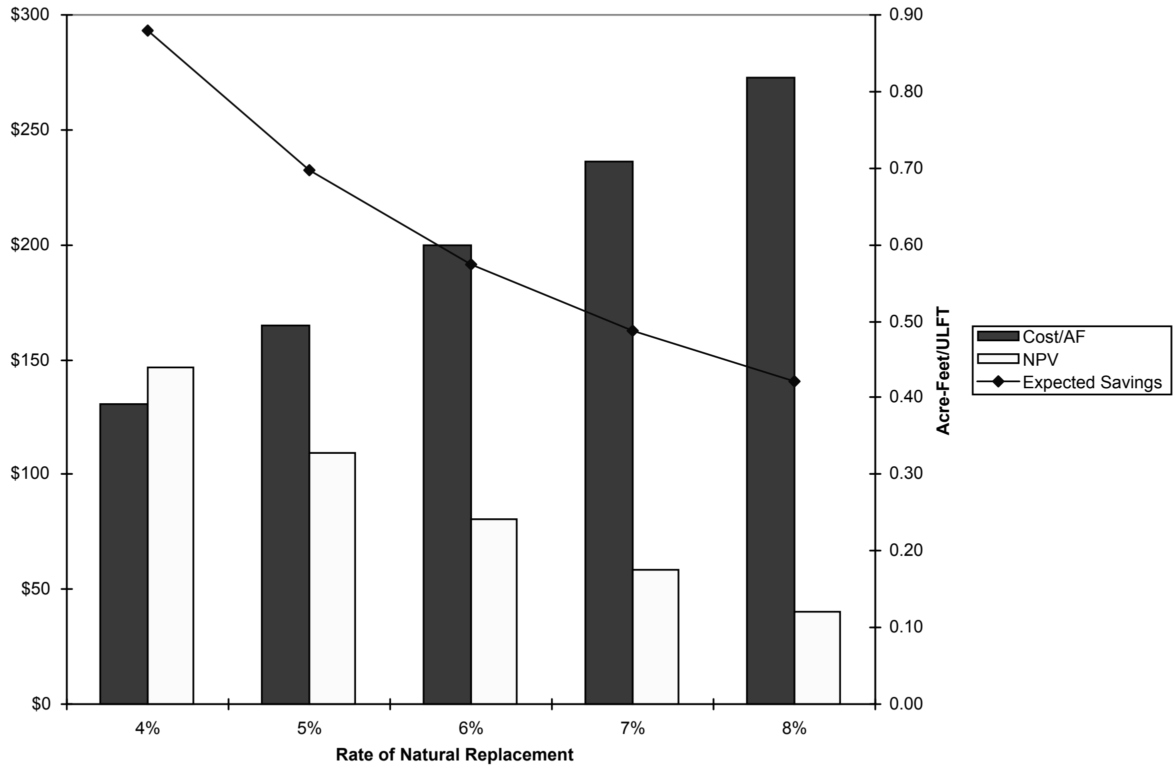


Figure A6. Affect of Natural Replacement Rate on CE and CB Estimates: Supplier Perspective



Example 2C:

ULFT Replacement Program With Free Riders

Rebate programs in the presence of a uniform efficiency standard seem particularly vulnerable to free rider affects. Most rebate programs were originally developed to make high-efficiency appliances cost-competitive with their low-efficiency counterparts. They were intended to influence *what* consumers purchased. With a uniform efficiency standard the "*what*" question is no longer relevant. As far as efficiency is concerned, we know what consumers are going to purchase. There is but one choice.

It seems reasonable to expect that people replacing toilets today because of toilet failure or bathroom remodeling will take advantage of a rebate if they are aware of it. Further, it seems reasonable to presume these people will replace their toilet with or without the rebate, at least in the case of toilet failure, since very few of us consider living without a toilet an option. These people are likely program free riders.

From the perspective of the supplier, free riders reduce program benefits and increase program costs per acre-foot of saved water. There are two basic ways a supplier can combat free riders:

(1) target replacements to avoid them (such as by pursuing targeted direct installations instead of mass rebates); and (2) increase the scale of the program to dilute their effect on program benefits and costs.[19] This example examines both of these strategies using the simple spreadsheet model shown in Table A7.

Our example assumes a starting population of 100,000 low-efficiency toilets. The supplier is planning to replace some percent (say 5%) of these toilets annually with a rebate program. Using the spreadsheet we can then examine what happens to CE and CB estimates if the supplier scales up or scales down its program.

We assume the rate of natural replacement is 4%, meaning 4,000 toilets will fail, be removed for remodeling, or be replaced for some other reason regardless of the program in the first year. Let's assume 80% of these replacements will take advantage of the rebate offer.[20] Using the spreadsheet we can then examine how increasing or decreasing the percent of natural replacements affects our CE and CB estimates.

Estimates of program savings, costs, and benefits use the same assumptions as were used in the previous examples.[21] With our starting values for program scale and free rider participation the net present value of the program is negative ($-17/ULFT), as shown in Table A7.

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[19] There are potential cost consequences to both strategies that the supplier needs to be aware of. Targeting replacements may involve additional administrative, material, and installation costs (particularly if done through direct installation). Targeting replacements may also have equity implications that merit careful consideration. Increasing program scale may allow the supplier to reduce unit costs in some areas (e.g., bulk purchases of toilets) but may increase administrative costs in others. These potential costs need to be compared to the cost of free riders to determine which approach has the highest expected net present value.

[20] This example is completely hypothetical. There is no empirical basis for the 80% freerider assumption.

[21] To calculate expected savings for rebates for toilets that would not have been replaced in the first year, we note that savings in the first year equal 0.0367. In the following year, there is a 96% chance the toilet will not have been replaced, so savings in the second year equal 0.0367*0.96. In the year after that, there is a 92% chance the toilet will not have been replaced, so savings in the third year equal 0.0367*0.92. The general formula is

$$\sum_{t} 0.0367 \times (1 - 0.04)^{t-1}$$

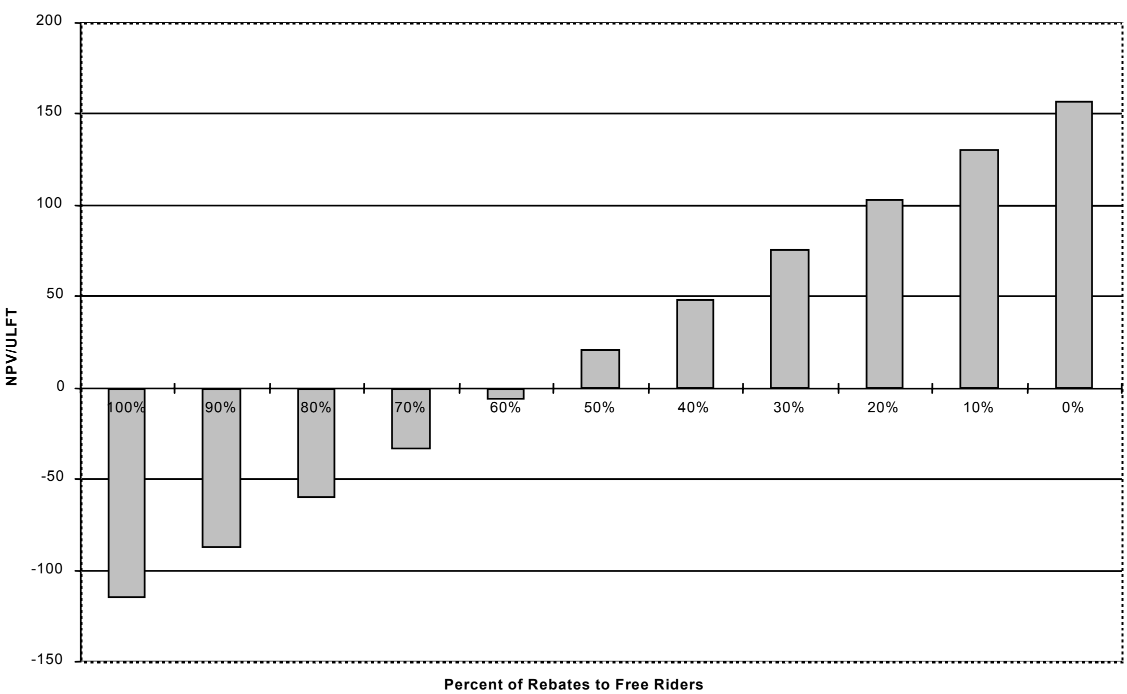
Program savings equal this value multiplied by (1 - % of rebates going to free riders).

Table A7. Simple spreadsheet model to examine affects of free riders on CE and CB estimates

Row No.	Row Description	Row Value
1	Starting population of low efficiency toilets	100,000
2	Percent of toilets targeted for replacement by utility during program year	5%
3	Number of rebates offered by utility	5,000
4	Program outlay: (75+40)*5000	$575,000
5	Number that will be naturally replaced during program year	4,000
6	Percent of natural replacements participating in program	80%
7	Percent of rebates going to free-riders	64%
8	Expected savings attributable to program (AF)	1,651
9	Expected benefits ($)	$490,615
10	NPV ($/ULFT)	-$17
11	Cost Effectiveness ($/AF)	$348

Figure A7 shows how the net benefit of the program depends on the extent of free-ridership. In this example, if the percent of rebates given to free-riders approaches 60%, the program is no longer cost-effective.

Figure A7. Affect of Free Riders on Program NPV Given Program Assumptions in Table A7.



The Importance of Program Scale

One way to combat free-ridership is to increase the scale of the program. To see why this can work imagine a situation in which you know 100 toilets will be replaced naturally and your utility is planning to offer rebates for 100 toilets. Under worse case conditions, free riders could comprise 100% of your program participants. If you double the size of your program to 200 rebates, under worse case conditions free riders could comprise only 50% of your program participants. This is basically following the engineer's adage: the solution to pollution is dilution. If free-riders are pollution, then one way to dilute them is to scale up the program.

Using the spreadsheet model in Table A7, what happens if the supplier doubles the size of the program? Instead of offering 5,000 rebates it offers 10,000. Table A8 shows the change in results. The percent of rebates going to free riders falls from 64% to 32%, water savings increase from 1,650 AF to about 6,240 AF, and net present value increases from -$17 to +$70.[22] Figure A8 shows how program scale affects net benefits when free riders are present.

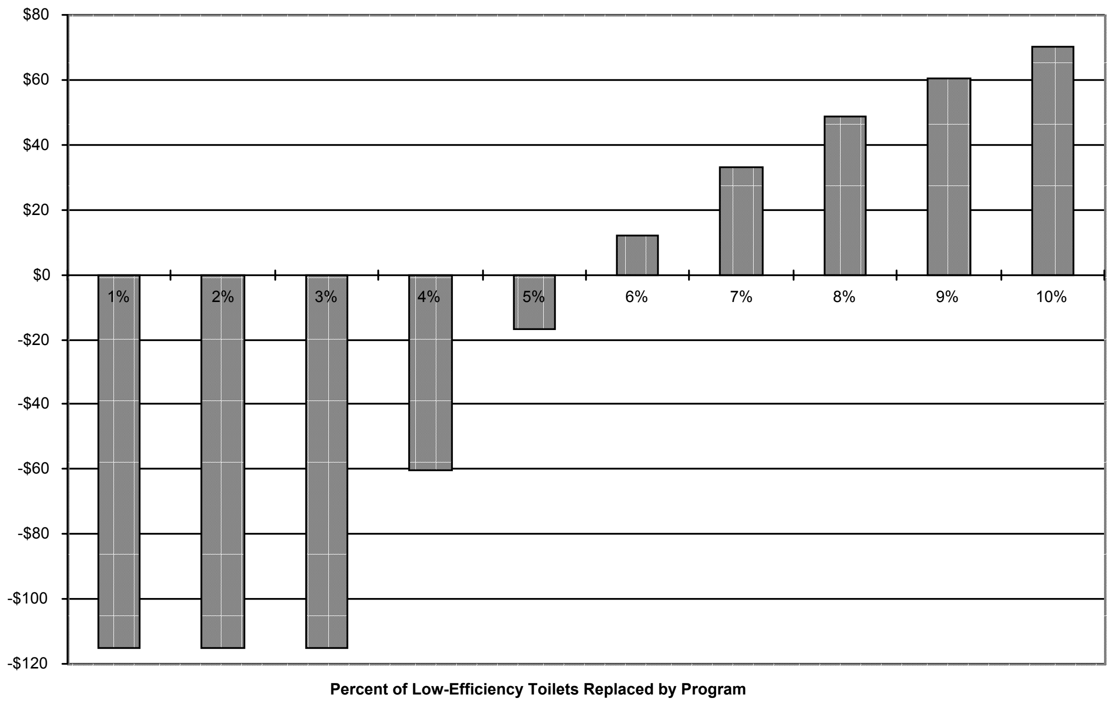
We use this example is to show that program scale is important to CE and CB estimates and should be given serious consideration during program design, particularly if free riders are a concern.

Table A8. Effect of doubling program size in the presence of program free riders.

Row No.	Row Description	Row Value
1	Starting population of low efficiency toilets	100,000
2	Percent of toilets targeted for replacement by utility during program year	10%
3	Number of rebates offered by utility	10,000
4	Program outlay: (75+40)*10000	$1,150,000
5	Number that will be naturally replaced during program year	4,000
6	Percent of natural replacements participating in program	80%
7	Percent of rebates going to free-riders	32%
8	Expected savings attributable to program (AF)	6,237
9	Expected benefits ($)	$1,853,435
10	NPV ($/ULFT)	$70
11	Cost Effectiveness ($/AF)	$184

[22] Note that the example assumed administrative costs per toilet remained unchanged. The model could easily be extended to examine how changes in costs due to changes in program scale affect the CE and CB estimates. For example, if we assume administrative costs double, then NPV increases from -$17 to +$30.

Figure A8. Affect of Program Scale on Program NPV Given Program Assumptions in Table A8



The Importance of Targeting Replacements

Let's suppose increasing the scale of the program is not an option for the supplier. What happens to the CE and CB estimates if the supplier selectively targets replacements? For example, what happens to the estimates if the supplier is able to reduce the percent of natural replacements participating in the program from 80% to 40%? Let's suppose it does this by scrapping the rebate program and implementing a direct install program. We use the cost data for direct install programs for single-family residences on page 2-27. Through bulk purchases, the program obtains toilets for $60 each. The cost of direct installation is $50 per toilet. We assume the cost of program administration remains unchanged at $40 per toilet. The total cost to the supplier to replace a toilet through direct installation is $150. Table A9 shows the results.

Table A9. Effect of combating free riders through targeted replacements

Row No.	Row Description	Row Value
1	Starting population of low efficiency toilets	100,000
2	Percent of toilets targeted for replacement by utility during program year	5%
3	Number of ULFT direct installations offered by utility	5,000
4	Program outlay: ($60 + $50 + $40)*5,000	$750,000
5	Number that will be naturally replaced during program year	4,000
6	Percent of natural replacements participating in program	40%
7	Percent of replacements going to free-riders	32%
8	Expected savings attributable to program (AF)	3,119
9	Expected benefits ($)	$926,718
10	NPV ($/ULFT)	$35
11	Cost Effectiveness ($/AF)	$240

In this example, the supplier is able to reduce the percentage of natural replacements participating in the program from 80% to 40% through targeted installations. Reconfiguring the program increases program costs by 30%, but results in program water savings increasing by almost 90% and net benefit increasing from -$17/ULFT to +$35/ULFT.

As with program scale, this example serves to show that program targeting is likely to have strong influence on bottom line results, and should be given careful consideration during program design.