

Final Report
Invoice Details & Project Deliverables for:
Best Practices for Water Meter Retrofit Projects Financed by State Performance
Contracts in Colorado

Name of Grantee - Western Resource Advocates (WRA)
Contract or purchase order number - POGG1,PDAA,201900000020

Invoice Details

We have completed all five tasks and have included our final invoice with the completion of this project. All matching commitments have been fulfilled during the execution of this grant. In sum, we met all the deliverables of the project within our budget. As described in our previous invoice, Task 3 was completed more quickly (and at lower cost) than originally projected. To complete Task 5, WRA used more hours to help successfully launch an additional pilot project in Colorado. Also included as part of our invoice for Task 5 are the expenses associated with our contractor from Pacific Northwest National Laboratories (PNNL).

Project Deliverables

The objective of this project was to develop robust, peer-reviewed Best Practices for Water Meter Replacement projects through performance contracting, and help to launch a pilot water meter replacement project. All tasks are complete. Tasks 1-4 are complete and were fully reported on in our previous progress reports, and we provide a brief summary here. Task 5 is complete and is described in more detail below.

Tasks 1-4 Summary:

Peer Exchange/Lessons Learned Webinars –WRA convened two Peer Exchange/Lessons Learned webinars with key stakeholders to inform the Best Practices. One webinar was with staff from State performance contracting programs that already cover water meter replacement projects (Washington and New Mexico), the other was with water providers that have done water meter retrofit projects via performance contracts (Martinsville, VA; Roswell, NM; Sanger, CA).

WRA facilitated three meetings with the Colorado Energy Office and the project consultants (PNNL) to scope out the project and ensure that the Best Practices address priority needs of Colorado's State Performance Contracting Program. WRA worked closely with the Colorado State Performance Contracting Program and project consultants to develop the Water Meter Best Practices draft. We each reviewed the draft before it was released for stakeholder input.

WRA convened two Peer Exchange/Lessons Learned webinars with key stakeholders to inform the Best Practices. One webinar was with staff from State performance contracting programs that already cover water meter replacement projects (Washington and New Mexico), the other was with water providers that have done water meter retrofit projects via performance contracts (Martinsville, VA; Roswell, NM; Sanger, CA).

Description of Task 5: WRA facilitates and coordinates a process with prospective pilot project partners, resulting in a commitment to conduct a pilot project in 2019. Project will implement the Water Meter Best Practices in a water meter retrofit project that uses a performance contract.

Task 5 Deliverable: Pilot Project MOU document describing 2019 pilot project.

Progress on Task 5:

The City of Trinidad is Colorado's first community to undertake a water meter replacement project through performance contracting using the Water Meter Replacement Best Practices WRA developed with the Pacific Northwest National Laboratory, thanks to the support of CWCB's grant. The installation of new water meters in Trinidad is about 50% complete. Following the installation of all meters, the energy service company (ESCO, or performance contractor) will use the Water Meter Replacement Best Practices to initiate the monitoring and verification process. Trinidad has reported already seeing improvements in water reading and data management from the new meters installed to date. The City also reports that the Best Practices were paramount in persuading City decision-makers to proceed with this project and in securing additional funds to support the project from the Colorado Department of Public Health and Environment.

In addition, according to the Colorado Energy Office (CEO), there is currently one other community pursuing a meter installation project through performance contracting, and two other water utilities considering it. If these projects move forward, their identity can be made public. This is a very encouraging development, given that the protocols have only been available for one year.

Because the CEO officially adopted the Water Meter Replacement Best Practices with the expectation (and strong encouragement) that any projects involving water meter replacements will use Best Practices, WRA's assistance to facilitate or coordinate the execution of any meter replacement project was not necessary as originally anticipated. This is a very strong outcome as it is highly likely that most, if not all, performance contracts will use the Best Practices for any meter replacement projects. Accordingly, WRA redirected its efforts toward increasing awareness about performance contracting so that more water utilities might consider using this pathway. Since our last report, WRA and our partners have promoted performance contracting and the Best Practices through:

- A presentation at the 8th Annual Market Transformations Conference in August 2019, which is the largest conference dedicated to performance contracting. This conference featured two sessions focused on water efficiency and water infrastructure, in large part due to our engagement on this issue through our work with Colorado Energy Services Coalition chapter.
- A presentation at the Special District Association annual conference in Keystone in September 2019. This presentation was received with great interest based on the audience's level of engagement, as special districts are often looking for novel funding mechanisms to execute costly projects. In addition, an ESCO representative was in the audience, and he was able to answer many questions after the presentation session.
- Direct communication with half a dozen water utilities that expressed interest in learning more about performance contracting, often directly as a result of one of our conference presentations as well as the webinar we conducted in April 2019.
- Mass email to approximately 200 of our professional contacts in the water and performance contracting industries explaining and linking to the Best Practices
- Promotion and requests for further distribution of the Best Practices to ten national and international industry associations (e.g., National Association of Energy Service Companies, National Society of Professional Engineers, and International Water Association).
- Continued outreach by the CEO to water utilities and ESCOs. The CEO and ESCOs are using resources that WRA developed, such as powerpoint slides and pamphlets.

Obstacles Encountered/Lessons Learned:

The process of launching the meter replacement pilot project differed somewhat from our original vision. We had not anticipated so much interest so quickly for this kind of project, which was generated in large part due to WRA's and the CEO's outreach efforts. This meant that WRA's technical assistance wasn't needed to help initiate and advance the project, nor was an MOU necessary as originally envisioned, because Trinidad committed to an investment grade audit which is a superior indicator of committing to a performance contract. This allowed WRA to accelerate our outreach efforts to increase awareness of the value of performance contracting among water utilities as a financial tool to accomplish water meter replacement projects.

The adoption of the Best Practices by the CEO was clearly an essential component of this work, and a leverage point for having the Best Practices be used more widely in future projects. This significant milestone was achieved by WRA working in partnership with the CEO at every step in the development of the Best Practices. In addition, a robust group of stakeholders, including leaders in this field and industry experts from state agencies, utilities, ESCOs and consulting professionals, reviewed drafts of the document resulting in a significant level of buy-in from the State and ESCOs and their willingness to use

the Best Practices. We learned through this that the significant efforts we made to engage with a variety of stakeholders was a valuable investment of our time.

Impacts of this Work

- It is clear that through the development of the Best Practices, we have changed the conversation about water efficiency in performance contracts, and embedded new practices in performance contracting throughout Colorado. We expect that many utilities will realize water savings through water meter replacement projects that would otherwise not have been possible. The Best Practices increase the confidence of future clients (public entities) and energy service companies that through improved meter accuracy, these projects will have a measurable return on their investment.
- Based on the analyses conducted by McKinstry and WRA in the report [Tapping the Power of the Market](#) (2015), we anticipate that the application of the Best Practices could result in an increase in \$36,000,000 in utility revenue in total across Colorado (assuming a 40% adoption rate among utilities and 10% increase in billable water), and a savings of 2,050 acre-feet of water each year due to end user savings (assuming a 0.5% reduction in water use).
- The value of these Best Practices extends beyond performance contracting. WRA has promoted these Best Practices to water efficiency engineers and practitioners to enable them to achieve higher levels of confidence in the efficacy of their meter replacement projects, and a more rigorous cost-benefit calculation. The fact they have been officially adopted in Colorado, and recognized as valuable in Nevada and New Mexico, indicates that virtually any state can adopt these protocols. As such, we will work to continue to promote these protocols through a variety of venues, including state energy offices.

WRA will continue to promote performance contracting as a pathway for realizing water meter replacement projects in Colorado, and beyond. We very much appreciate the support of the CWCB, and we are grateful for having had the opportunity to conduct this important work.

How EPC Works

- STEP
1

Government entities or water providers/ utilities/districts sign-up for CEO's EPC program and begin benefiting from free engineering support
- STEP
2

Program participants contract with a pre-qualified Energy Service Company (ESCO) to analyze current water use and loss
- STEP
3

An investment grade audit (IGA) determines facility improvements/ replacements to deliver potential water cost savings, which are guaranteed by the ESCO
- STEP
4

Once the proposal is approved, an EPC contract is signed, financing is secured, and construction begins
- STEP
5

Guaranteed water cost savings are measured and verified [During the EPC performance period, water cost savings pay for the improvements; after the performance period, all water cost savings accrue to the program participant]



GET STARTED TODAY

Interested?

Contact the Colorado Energy Office EPC Team
303.866.3464 | CEO_EPC@state.co.us

COLORADO EPC PROGRAM ESCO PARTNERS



Energy Performance Contracting (EPC) for Water Efficiency & Water Meter Replacement



COLORADO
Energy Office



Why EPC for Water Efficiency?

- While the Energy Performance Contract (EPC) program is best known for energy savings benefits, water efficiency can be a major source of financial savings too
- Building owners can save water and money through water fixture replacements, cooling tower retrofits and landscape improvements
- Water providers can reduce water losses and increase revenue through water meter replacement/upgrade projects

Colorado Water Savings Potential Snapshot

Statewide potential savings from water efficiency improvements in public buildings	
Acre-feet/year	\$/year
6,840	\$8,400,000

Statewide potential water loss reductions and revenue increases through water meter replacement projects by providers	
Water loss reductions (acre-feet/year)	Increases in revenue (\$/year)
38,950	\$34,000,000

Water Efficiency in Public Buildings

EPC for water efficiency in public buildings typically includes indoor water fixture replacements—toilets, sinks, showerheads—though often the largest water-savings comes from cooling tower retrofits, landscape/turf conversions and outdoor irrigation improvements.

What are the benefits?

Cooling Tower Retrofit

- System efficiency improvements optimize cooling tower performance
- Conductivity control upgrades better manage cycles of concentration
- Advanced control platforms better monitor and manage system performance

Landscape/Turf Conversion

- Converting turfgrass and other water-intensive plantings and practices to water-wise, local landscapes significantly reduces water use

Outdoor Irrigation

- Irrigation system efficiency improvements minimizes water waste
- Advanced irrigation system controls manage landscape water application
- Real-time sensors monitor landscape and environment conditions

Water Meter Replacement for Water Providers

EPC for water providers can finance water meter replacement/upgrade projects that include Automatic Meter Reading (AMR) and Advanced Metering Infrastructure (AMI).

What are the benefits?

- Increase revenue by reducing water losses that are not billed
- Reduce meter-reading costs by eliminating meter reads at each customer premises
- Facilitate rapid and accurate leak detection throughout the system
- Significantly improve billing process and customer service
- Provide detailed data on water use to significantly enhance water conservation programs





Water Meter Measurement and Verification Best Practice

August 2018

K McMordie Stoughton R Rosenkilde

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for the

UNITED STATES DEPARTMENT OF ENERGY

under Contract DE-AC05-76RL01830

Printed in the United States of America

Available to DOE and DOE contractors from the

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Water Meter Measurement and Verification Best Practice

K McMordie Stoughton
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August 2018

Prepared for
Western Resource Advocates as model guidelines for the State
Performance Contracting Program of Colorado.

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Acknowledgments

The authors would like to thank all of the experts who participated in the stakeholder review process. We are grateful for their invaluable time and generous support. We also genuinely appreciate, and are fortunate for, the excellent and gracious guidance of the Colorado Energy Office and expertise provided by Will Jernigan of Cavanaugh.

This work was funded through a grant from the Rosin Fund — Environment Program.

Acronyms, Abbreviations, and Definitions

AWWA	American Water Works Association
AMI	Advanced metering infrastructure
AMR	Automatic meter reading
commissioning	The process whereby the measure improvements made to the equipment and/or the control system have been verified to comply with the approved plan, and visually inspected and evaluated for proper operation.
ESCO	Energy service company (performance contractor)
IGA	Investment grade audit. The purpose of the IGA is to develop a scope of work to be implemented by the ESCO, establish guaranteed savings, develop an agreed-upon plan to measure and verify the guaranteed savings, and ensure that the agreed-upon project meets statute requirements.
IPMVP	International Performance Measurement and Verification Protocol
measurement frequency	The number of measurements that will be collected over the measurement period to determine water use savings.
measurement period	The timeframe during which the performance metric is monitored
M&V	Measurement and verification
O&M	Operations and maintenance
PRL	Potential recoverable leakage. Potential recoverable real losses are the amount of potential apparent water losses that can be captured through a leak detection and repair program.
study period	The total timeframe that water use will be monitored per the contractual arrangement for the baseline and post-installation periods.
WRF	Water Research Foundation

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1.0 Introduction

This measurement and verification (M&V) best practice provides recommended procedures for energy service companies (ESCOs) to validate the performance of water metering projects that are executed with water providers under energy performance contracts. This document covers metering projects such as advanced metering infrastructure (AMI) and automatic meter reading (AMR) technology. The term “advanced metering system” is used in this document to represent the type of systems that are implemented for these types of performance contracts.

This best practice outlines the basic components of the M&V plan, provides potential performance metrics to consider for metering systems, and describes the procedures to use to verify project performance.

The procedures presented in this best practice are performance based. This best practice does not prescribe the types of metering systems that are required to be implemented. The specific advanced metering system will be determined as a result of the ESCO’s investment grade audit (IGA). (See Section 4.1 for more information.) Instead, this document outlines the steps that an ESCO can take to measure and verify that a metering system is meeting the performance requirements. Figure 1 provides the basic steps involved in M&V for advanced metering systems, which are covered in this document.

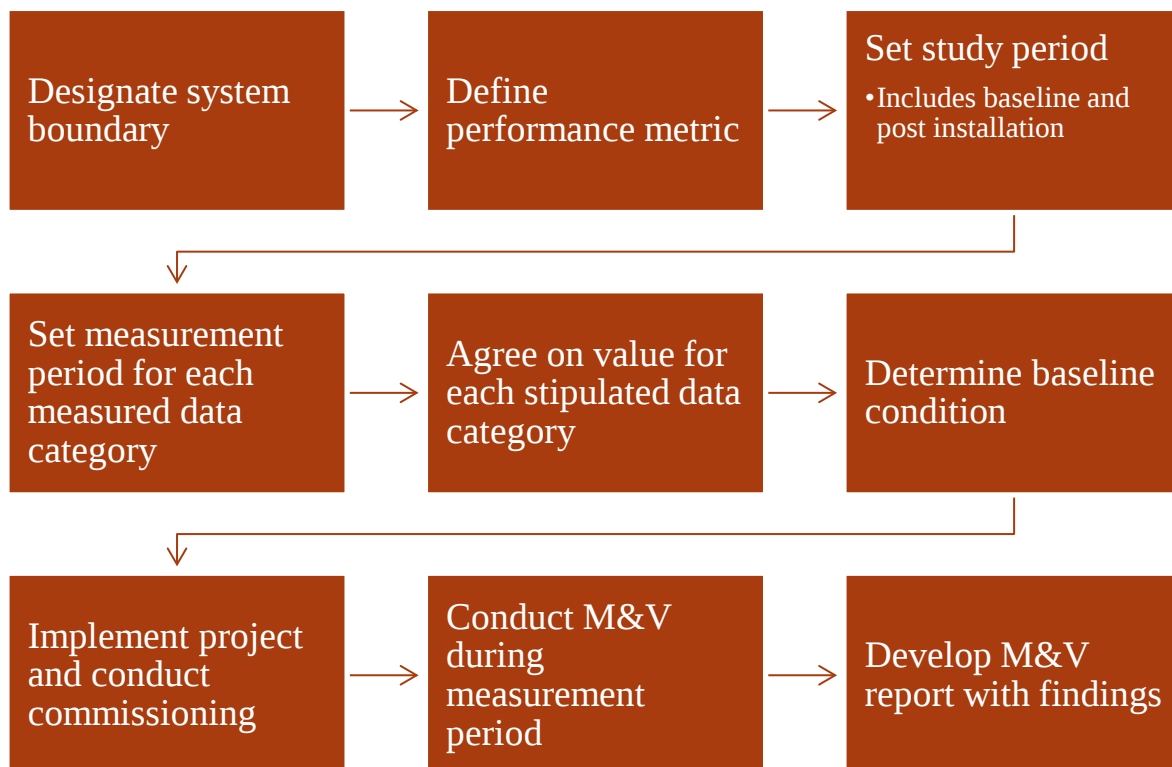


Figure 1. Primary M&V Steps

2.0 Measurement and Verification Plan Elements

This section provides the basic structure of the M&V plan. Each subsection describes a critical element of a comprehensive M&V plan, which should be developed by an ESCO and agreed upon by the water provider. This section is intended to serve as a template that an ESCO can follow in developing their M&V plan.

2.1 Project Description and Measurement Boundary

The M&V plan should describe the specific metering system that will be implemented in the performance contract, identified during the IGA. In addition, the plan should clearly define the measurement boundary of the project. The measurement boundary defines precisely what will be monitored as part of the performance contract. For example, the measurement boundary may be the specific geographic regions where the metering system will be installed or the specific meter accounts (e.g., commercial, residential) that will be covered by the metering system. The M&V plan should provide a detailed list of all accounts that will be covered in the metering system.

2.2 M&V Method

The M&V plan should specify the method that will be used to measure and verify the performance metric. The International Performance Measurement and Verification Protocol (IPMVP) has four options (A, B, C, and D) that can be used to verify the savings of measures. For water metering systems, the most appropriate IPMVP option to verify the performance metrics is Option A, “Retrofit Isolation: Key Parameter Measurement”. The objective of this option is to measure key performance parameters to determine the system performance. This option also allows for stipulation of other parameters that cannot be readily measured. The M&V plan should clearly specify the parameters that will be measured and the measurement methods that will be used. The M&V plan should also detail the parameters that will be stipulated and the agreed upon stipulated value.

2.3 Project Performance Metrics

The M&V plan should specify the performance metrics that will be measured and verified per the performance contract. There are three primary options for performance metrics with water metering projects that are covered in this section: water meter accuracy improvement; water loss reduction; and operations and maintenance (O&M) cost reduction.¹ This section describes the performance metrics and the data categories that the ESCO should collect for each option. Information on the methods to determine the baseline conditions and post-installation conditions can be found in Section 4 of this document.

¹ Performance metrics for metering projects are specified in Colorado Energy Performance Contracting Office. *Colorado Statutes Regarding Energy Performance Contracts for Local Government*. Title 29 Government – Local: Energy Conservation Article 12.5 Energy Conservation Measures C.R.S. 29-12.5-101 (2017).

2.3.1 Water Meter Accuracy Improvement

This performance metric is the increase in meter accuracy as a result of the direct replacement of inaccurate meters. It is common for water utilities to have an aging meter population with no ongoing meter testing or replacement program, which causes loss of revenue due to under-registration of customers' true usage. Properly installed and specified water meter technology accurately measures the water flow across the appropriate range of flow rates for a given customer. This results in more accurately recorded water consumption, thereby reducing lost revenue for the water provider. This M&V best practice only focuses on the procedures used to measure and verify meter accuracy. Appendix A of this document provides information on determining revenue increases due to increased meter accuracy. (This revenue increases should be tied to the increase in meter accuracy and not an increase in the water provider's rate that is charged customers.)

Data Categories – The following data categories should be collected by the ESCO for this performance metric and specified in the M&V plan for each measurement period (see Section 3.5). The M&V plan should also state which data categories are measured and stipulated. (See Section 4.2.1 for more information on these data categories.)

- Meter groupings: Meters should be grouped into specific categories such as:
 - Meter account types such as small, intermediate, and large (e.g., residential, commercial, industrial)
 - Meter sizes (e.g., ¾", 1", 1½", 2")
 - Meter types (e.g., positive displacement, velocity, electronic)
- Flow rates: Water meters will be tested at low, intermediate, and high flow rates relevant to customer usage profile, which is required to determine meter accuracy. ESCOs should consider third party testing of meters by independent and certified meter testing laboratories.
- Flow weighting (also known as percent volume): The proportion of water used within each flow rate range compared to the total volume should be determined.
- Average weighted meter accuracy: This is the final performance metric, which is the mean meter accuracy across a sampling of meters for a range flow rates, taking into account the flow volumetric weighting of each flow rate.

This data is typically collected from the water provider's electronic billing system via digital extraction. Digital extraction is the process used to collect a water provider's billing database through a query such as a structured query language (SQL). The ESCO should work closely with the water provider's point of contact who is familiar with the digital extraction process from the billing software. If the water provider does not have this capability, the ESCO will need to provide it. The extracted database should be constructed from a unique meter identification number field, and should typically include identification fields for meter specifications, customer, service type, consumption, and revenue. Customer accounts and meter databases are discussed in the American Water Works Association (AWWA) Manual 36 (M36), *Water Audits and Loss Control Programs* Chapter 3, Task 2 and Task 3.²

² American Water Works Association Manual 36. *Water Audits and Loss Control Programs*. Fourth Edition. 2016. Denver, CO.

2.3.2 Water Loss Reduction

This performance metric is the reduction in water losses that are potentially recoverable from the water provider's distribution system. These losses are typically reduced through an active leak detection and repair program identified in the IGA. For example, an AMI system provides real-time data that can be processed through data analytics to identify potential indications of water leaks, which greatly improve the water provider's time for leak awareness, location, and repair. The M&V plan should document the responsible party for repairing leaks identified via the advanced metering system, which will typically be the water provider. The M&V plan should also include a reasonable response time for repairing leaks. The volume of potentially recoverable water loss is determined through a leakage component analysis, which is detailed in the AWWA M36 and Water Research Foundation (WRF) Project 4372A, *Real Loss Component Analysis: A Tool for Economic Water Loss Control*.³ These reference documents contain additional information on the data requirements and method for this analysis. See Section 4.2.2 for more information on a leakage component analysis.

2.3.3 O&M Cost Reduction

This performance metric is the reduction in O&M costs as a result of increased efficiencies provided by an advanced metering system. Advanced metering systems such as AMI systems commonly have automatic meter reading capability that reduces the number of manual meter reads and associated vehicle use. Advanced metering systems can also allow water providers to remotely turn-on or shut-off accounts, which reduces labor hours and associated vehicle usage, thereby reducing costs. In addition, advanced metering systems provide easy access to data that reduces the time needed to resolve customer complaints for being overcharged (referred to as "high-bill" complaints), which reduces administrative costs and the total amount refunded to the customer.

However, it should be noted that at the onset of the advanced metering system installation, there may be an increase in labor costs due to "false-positive" readings that indicate false leaks. If the advanced metering system is not properly commissioned, it may record high water readings that prompt staff to follow up with customers unnecessarily. These "false-positive" readings can be reduced by fine-tuning the thresholds so that they are properly set in the system to alert the water provider of leaks. A provision could be added to the M&V plan that allows for proper commissioning of the system to reduce these "false-positive" readings.

Data Categories – The following data categories should be collected by the ESCO for this performance metric and specified in the M&V plan for each measurement period (see Section 3.5). These data categories are typically stipulated values, provided by the water provider.

- Meter reading cost savings:
 - Number of meter reads
 - Number of meter "re-reads" to reconfirm original meter reads
 - Average cost per manual meter read (not including vehicle savings – see below)

³ Water Research Foundation. Water Audits and Real Loss Component Analysis. Project #4372a. Denver, CO. <http://www.waterrf.org/Pages/Projects.aspx?PID=4372>.

- Vehicle cost savings:
 - Number of vehicles assigned for meter reading
 - Operating hours for each vehicle
 - Average operation cost per hour for each vehicle
- Meter turn-on/shut-off cost savings:
 - Number of account shut-offs
 - Average cost per manual shut-off
- Customer billing resolution for high-bill complaints cost savings:
 - Number of high-bill complaints
 - Average cost per high-bill complaint
 - Funds that are attributed to refunds from customer high-bill complaints

2.4 Study Period

The study period should be clearly specified in the M&V plan, which will cover the total timeframe of the project, including the baseline, project execution, and post-installation M&V. The study period defines the timeframe during which the performance metrics will be monitored per the contractual arrangement for the baseline and post-installation periods, identified in the IGA. The study period should follow the established M&V requirements of the State Performance Contracting Program.⁴

The plan should define the baseline study period. The baseline study period should be determined, preferably over a 2-year timeframe or at a minimum of 1 year. Using an average of multiple years for the baseline study period is preferable because it helps to minimize anomalies caused by changes such as population fluctuations.

The plan should also define the study period for the post-installation water use measurement. For example, the State of Colorado requires ESCOs to provide a written savings guarantee for the first 3 years of the contract period.⁵ At the agency's discretion, the performance guarantee can be extended beyond the legislatively required time period. At the end of each performance year, the ESCO is required to submit an annual M&V report to demonstrate that the performance has been met.

2.5 Measurement Period

The M&V plan should specify the measurement period, which defines the frequency at which the performance metrics are measured and verified. For stipulated data, the water provider and ESCO need to

⁴ See, for example, the State of Colorado's M&V Guidelines for Energy Savings Performance Contracts. Nexant. *Measurement and Verification (M&V) Guidelines for Energy Saving Performance Contracts in State of Colorado Facilities*. 2008. Boulder, CO. June.

⁵ Colorado Energy Performance Contracting Office. *Colorado Statutes Regarding Energy Performance Contracts for Local Government*. Title 29 Government – Local: Energy Conservation Article 12.5 Energy Conservation Measures C.R.S. 29-12.5-101. 2017.

agree upon the values and the appropriate adjustments that may need to be taken to normalize the data (see Section 4).

3.0 Performance Monitoring Methods

This section describes the procedures that can be considered when measuring and verifying the performance metrics of advanced metering systems. The methods included in this section are considered best practices that will help to ensure that the water provider is receiving the guaranteed savings specified in the contract.

3.1 American Water Works Association Water Audit Method

The AWWA developed a standard water audit method in their manual M36, *Water Audits and Loss Control Programs*.⁶ This water audit method provides a best practice approach to calculate a water provider's water distribution system efficiency. This method can be used by an ESCO to determine the baseline water loss condition for a water metering performance contract and an estimate of the savings that may result from a new metering system. This section provides a brief overview of this method.

AWWA M36 provides a “top-down” water audit approach that produces a water balance. A water balance accounts for all of the water that moves through the provider's system, quantifying water consumption and losses. A water balance determines authorized consumption through billing data and records, including estimation of authorized unmetered consumption. A water balance also determines water losses categorized as apparent losses (e.g., billing data errors and meter inaccuracies) and real losses (e.g., physical escape of water through leaks). Figure 2 provides an overview of the AWWA M36 water balance. A key result of the water balance is the determination of “non-revenue water,” which is the sum of unbilled consumption and apparent and real losses.

⁶ American Water Works Association Manual 36. *Water Audits and Loss Control Programs*. Fourth Edition. 2016. Denver, CO.

Volume From Own Sources (corrected for known errors)	System Input Volume	Water Exported (corrected for known errors)	Billed Water Exported				Revenue Water
		Authorized Consumption	Billed Authorized Consumption	Billed Metered Consumption		Revenue Water	
				Billed Unmetered Consumption		Non-Revenue Water	
			Unbilled Authorized Consumption	Unbilled Metered Consumption			
				Unbilled Unmetered Consumption			
		Water Losses	Apparent Losses	Customer Metering Inaccuracies			
				Unauthorized Consumption			
				Systematic Data Handling Errors			
			Real Losses	Leakage on Transmission and Distribution Mains			
				Leakage and Overflows at Utility's Storage Tanks			
Water Imported (corrected for known errors)				Leakage on Service Connections up to the Point of Customer Metering			

Figure 2. AWWA M36 Water Balance⁷

A comprehensive description of how to perform this method can be found in AWWA M36, Chapter 3.

Note that an AWWA M36 water audit may be required prior to or during the ESCO's IGA to determine and document the inaccuracies of the system, as it can help target the metering system to mitigate issues found and to identify the most appropriate metric for the performance contract. Figure 3 provides an overview of how the water audit process can be used to determine the cost benefit of specific interventions such as a leak management program or revenue protection program.

⁷ American Water Works Association Manual 36. *Water Audits and Loss Control Programs*. Fourth Edition. 2016. Figure 3-1. Denver, CO.

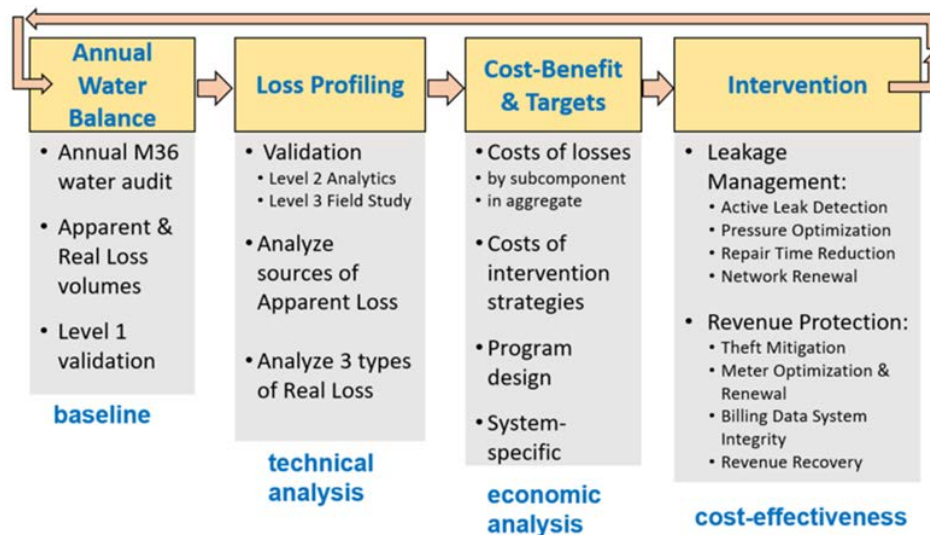


Figure 3. AWWA M36 Methodology – Conceptual Illustration⁸

3.2 Baseline and Post-Installation Performance Determination

The following section provides an overview of the procedures that can be used to determine the baseline condition of the provider's water system prior to the installation of the metering system and post-installation performance of the metering system. These two elements are necessary in measuring and verifying the system performance. The general equation to determine the system performance is:

$$\text{Performance} = (\text{Baseline Condition} - \text{Post Installation Condition}) \pm \text{Adjustments}$$

where:

Baseline Condition = Performance prior to the installation of the metering system

Post Installation Performance = Performance after installation of the metering system

Adjustments = Factor applied to normalize the metric when appropriate

This section provides best practice procedures for three performance metrics: water meter accuracy improvement, water loss reduction, and O&M cost reduction.

3.2.1 Water Meter Accuracy Improvement

This performance metric is defined by the average weighted meter accuracy. Meter accuracy is determined by comparing a known volume of water passing through the meter to the volume that is recorded by the meter. The average weighted meter accuracy is the mean meter accuracy across a sampling of meters for a range flow rates, taking into account the volumetric weighting of each flow rate. The measurement of average weighted meter accuracy should be determined to define baseline condition of the existing meters and the post-installation M&V phase of the project.

The following section provides the elements that need to be collected to calculate the average weighted water meter accuracy of the baseline and post-installation conditions. This procedure is from AWWA

⁸ Graphic provided by Will Jernigan of Cavanaugh, April 11, 2018.

Manual 6 (M6) *Water Meters – Selection, Installation, Testing, and Maintenance*.⁹ Chapter 5 of AWWA M6 details this procedure. The M&V plan should clearly state values that are measured and those that are stipulated.

Meter Grouping: Meters should be grouped by size and type for accuracy testing, which should be specified in the M&V plan.

Sample Size: The M&V plan should specify the number of existing meters that will be tested to determine the baseline accuracy by meter grouping. The sample size of meters should be determined using the AWWA M6 statistical sampling procedures found in Chapter 5.¹⁰ The M&V plan should specify the confidence and interval levels as agreed upon by the water provider.

Flow Rate Testing: Water meters should be tested at low, intermediate, and high flow rates at an AWWA-certified water meter testing facility and in accordance with AWWA guidelines for meters pulled from service as specified in AWWA M6 manual. It is recommended that the flow rates of specific meter types provided in Table 5-3 of AWWA M6 be used. The M&V plan should specify the methods used to test the flow rate by meter grouping. It is suggested that testing be performed by an independent third party for validation.

Meter Accuracy: The meter accuracy is calculated by dividing the meter indicated flow rate by the actual flow rate as follows:

$$\text{Accuracy (\%)} = \frac{\text{meter indicated flow rate}}{\text{actual flow rate}} \times 100$$

Flow Weighting (aka Percent Volume): To determine the weighted average meter accuracy, the flow weighting needs to be determined for each meter grouping. This is the proportion of water used at the range of flow rates compared to the total volume. AWWA M36, Chapters 3 and 5 provide information on this weighting factor. The M&V plan should specify the flow weighting for each meter grouping and the source of the data that was used to determine these values.

Average Weighted Meter Accuracy: To determine the overall weighted accuracy of the tested meters by meter group, the meter tested accuracy for each flow rate range (low, intermediate, and high) by meter grouping is prorated by the flow weighting. For an example of this method, see AWWA M36, Table 3-13. The results of accuracy testing determine the baseline average weighted meter accuracy, which should be included in the M&V report that is provided to the water provider.

Post-Installation Average Weighted Meter Accuracy: The performance contract should specify the guaranteed meter accuracy of the new system and the basis for this guarantee (such as the meter warranty). The same procedures that are used to determine the baseline average weighted meter accuracy (as described above) should also be used to determine the post-installation average weighted meter accuracy over each measurement period. The results should be documented in the M&V report to show if the guaranteed performance has been met over the study period. The M&V plan should state the measurement frequency that the average weighted meter accuracy is measured.

⁹ American Water Works Association Manual 6. *Water Meters – Selection, Installation, Testing, and Maintenance*. Fifth Edition. 2012. Denver, CO.

¹⁰ An example of this meter testing sampling size exercise is available within AWWA M6, Chapter 5, page 70.

Appendix A of this document provides information on determining revenue increases due to increased meter accuracy.

3.2.2 Water Loss Reduction

This performance metric is the reduction in water losses that are potentially recoverable from the water provider's distribution system. This value is determined through a leakage component analysis that is a part of the AWWA M36 water audit method. A leakage component analysis is described by AWWA as: "A means to analyze real losses and their causes by quantity and type. The goal is to identify volumes of water loss, the cause of the water loss, and the value of the water loss for each component."¹¹ A detailed description of the leakage component analysis is in AWWA M36, Chapter 7.

This methodology can be considered the preferred method to validate the performance for this metric. A leakage component analysis model was developed by the WRF Project 4372A, *Real Loss Component Analysis: A Tool for Economic Water Loss Control*.¹² This model is freely available and can be used to conduct a leakage component analysis.

The general elements of the leakage component analysis are as follows:

Current Annual Real Losses: Total real losses determined in the top-down AWWA water balance.

Current Reported Leakage: The total volume of leakage that has surfaced on its own, estimated from leak repair records over a given timeframe (e.g., annually). The ESCO will have to work closely with the water provider to gather the required data to determine this value if it is unknown.

Current Unreported Leakage: The total volume of leakage discovered and assessed via proactive leak detection. If no proactive leak detection is in place, this volume will be zero.

Unavoidable Annual Real Losses: Reference value for the minimum water leakage of a system given its physical parameters. These leaks are highly dependent on water system pressure.

Potential Recoverable Leakage (PRL): This forms the basis for the performance metric, which is the amount of potential real water losses that can be captured through a leak detection and repair program.

The baseline PRL of the water provider's distribution system should be determined prior to the installation of the advanced metering system. The ESCO should clearly document the procedures and the data inputs that were used to determine the PRL, following the AWWA M36 and WRF 4372A methodology.

The ESCO and water provider should review the PRL results to develop a goal for reasonable and obtainable water loss recovery and to formulate the appropriate leak detection and repair program. The ESCO and water provider should also agree on a reasonable timeframe for the water provider to repair

¹¹ American Water Works Association Manual 6. *Water Meters – Selection, Installation, Testing, and Maintenance*. Fifth Edition. 2012. Denver, CO. page 17.

¹² Water Research Foundation. Water Audits and Real Loss Component Analysis. Project #4372a. Denver, CO. <http://www.waterrf.org/Pages/Projects.aspx?PID=4372>.

leaks. It will be critical that the water provider leverages data from the advanced metering system to quickly identify and repair leaks.

Once the leak detection and repair program has been developed, the ESCO and water provider should agree on a level of water loss reduction that can be achieved to set the amount of guaranteed water savings. This can be represented as a percentage reduction in baseline water loss volume, based on the results of the PRL determination. It is recommended that water loss reduction not be represented as a reduction in water loss as percent of system input volume. For each measurement period of the contract, the same procedures should be performed to determine the revised post-installation PRL that will document if this performance metric has been met.

3.2.3 O&M Cost Reduction

This performance metric is the reduction in O&M cost as a result of increased efficiencies of the advanced metering system. The following information provides the basic procedures to determine the cost reductions and potential parameters that can be used to normalize the savings. It is recommended that costs are escalated for each measurement period based on the water provider's escalation rate or inflation rate. **Meter Reading Cost Savings:** The basic calculation to determine the baseline and post-installation meter reading cost over the measurement period is as follows:

$$\text{Meter Reading Cost} = \text{Number of Meter Reads} \times \text{Average Cost per Meter Read}$$

This cost is associated with labor reduction and not vehicle savings (see below). The cost per meter read should be provided by the water provider. The total number of meter reads over the measurement period can also include the number of meter "re-reads" that are typically required to confirm original meter reads. Subtracting the baseline meter reading cost from the post-installation cost produces the amount of cost savings. This cost savings value can be normalized for each measurement period based on the number of total meter reads, stipulated by the water provider.

Vehicle Savings: The basic calculation to determine the baseline and post-installation vehicle cost over the measurement period is as follows:

$$\text{Vehicle Cost} = \text{Number of Vehicles} \times \text{Number of Vehicle Hours} \times \text{Average Cost per Hour to Operate Vehicle}$$

These parameters should be provided by the water provider. The cost per hour to operate the meter reading vehicles should include fuel and vehicle maintenance costs. Subtracting the baseline vehicle cost from the post-installation cost produces the amount of cost savings. This cost savings value can be normalized for each measurement period based on the number of total vehicle hours, stipulated by the water provider.

Meter Turn-on/Shut-off Cost Savings: The basic calculation to determine the costs associated with manual turn-on and shut-off of meter accounts over the measurement period is as follows:

$$\text{Meter Turn-On/Shut-Off Cost} = \text{Number of Account Turn-On/Shut-off} \times \text{Average Cost per Account Turn-On/Shut-Off}$$

These parameters should be provided by the water provider. The cost per account turn-on/shut-off should be informed by the labor and vehicle costs associated with manually turning on or shutting off accounts. Subtracting the baseline vehicle cost from the post-installation cost produces the amount of cost savings. This cost savings value can be normalized for each measurement period based on the number of accounts turned off or shut off over the measurement period, stipulated by the water provider.

Customer Billing Resolution Cost Savings: The basic calculation to determine the costs associated with customer billing resolution for high-bill complaints over the measurement period is as follows:

$$\text{Customer Billing Resolution Cost} = \text{Number of Complaints} \times \text{Average Cost per Complaint} + \text{Total Refunded Amount}$$

These parameters should be provided by the water provider. The cost per complaint should be informed by the average time for staff to resolve a complaint and associated labor cost. Subtracting the baseline customer billing resolution cost from the post-installation cost produces the amount of cost savings. This cost savings value can be normalized for each measurement period based on the number of customer complaints over the measurement period, stipulated by the water provider.

An increase in labor costs may be experienced due to “false-positive” leaks if the advanced metering system is not properly commissioned, which prompt staff to follow up with customers unnecessarily. These “false-positive” readings can be reduced by fine-tuning the thresholds to alert the water provider of operational issues. Other Considerations

The M&V plan should state any potential issues that may significantly impact the performance metrics, as the baseline and post-installation performance metrics may need to be adjusted. The ESCO should follow the established dispute resolution steps identified in the State Performance Contracting Program, which should be reviewed and agreed upon between the ESCO and the water provider. Such issues may include:

- Unauthorized consumption, which includes meter tampering, illegal connections, and misuse of fire hydrants;
- Detected leaks that are not repaired;
- Systematic data handling errors with customer billing systems, including miscoding in billing software of multipliers for conversion of reading units to billing units;
- Drought management (and other types of) watering restrictions imposed by the water provider, or local or state government entities that may reduce water use;
- Water providers’ escalation rates that may impact revenue; and
- Water use reduction as a result of advanced metering system providing data to customers that help to reduce water consumption, thereby lowering the water provider’s revenue.

The annual M&V report should provide a detailed description of any significant issue that was experienced, the subsequent impact on water use, and adjustments made to the baseline estimate as a result of the issues.

4.0 Commissioning

Commissioning is an important step to ensure the advanced metering system will achieve the guaranteed savings specified in the performance contract. Commissioning is the process whereby the system is verified to comply with the approved plan and inspected and evaluated for proper operation. Commissioning ensures system components are functioning optimally per the design and data analytics are programmed per the performance contract. The following information provides a general overview of meter commissioning with the key elements that should be included in a commissioning plan.

4.1 Meter Commissioning

The ESCO should establish a commissioning plan that outlines the specific steps that will be performed. AWWA M6, Chapter 4, provides guidance on proper meter installation that can inform the commissioning plan. The following list provides the primary requirements that should be checked during the commissioning process to ensure proper installation.¹³ These elements should be considered in the planning and design phase as well as the post-installation inspection.

- Meter installation – the meters should be installed with the following considerations:
 - Horizontally installed for optimum function
 - Water-tight connections
 - Installed within the correct number of pipe diameter lengths upstream and downstream of the meter (per the meter’s specifications)
- Meter location – the meters should be located to ensure the following items:
 - Accessible for maintenance and repair and proper reading
 - Protected from freezing and other adverse conditions (such as flooding) that could potentially cause damage
- Meter components – the meters should have the following components:
 - Inlet shut-off valve that is easily accessible and allows the meter to be taken offline for maintenance
 - Permanent electrical grounding to prevent accidental shock
 - Back-flow prevention

It should be noted that large commercial/industrial meters require detailed planning and preparation to ensure proper installation, which can typically be more rigorous than small residential meters.

¹³ American Water Works Association Manual 6. *Water Meters – Selection, Installation, Testing, and Maintenance*. Fifth Edition. Chapter 4. 2012. Denver, CO.

4.2 Data System Commissioning

The data management system of an advanced metering system should also be commissioned. The commissioning process should include training for the water provider to ensure access to required data for billing, leak detection, and other important management features. The following list provides the main elements that should be included in commissioning the data management system:

- Communications network connectivity and data transmission – system has been tested to:
 - Ensure system network connection is communicating with the advanced meters
 - Ensure data is accurately transmitting at the designated intervals
 - Alert the system if meters are not sending data to the network
 - Ensure cyber-security measures are in place to protect the system
- Software integration - software has been properly programmed to:
 - Collect the desired interval data
 - Generate automated billing
 - Set thresholds that alert of high water use, which can inform the water provider of leaks and other operational issues. These set-points should be reviewed and adjusted over the first measurement period to reduce the number of “false-positive” readings.
 - Generate the necessary reports for meter data management (e.g., leak detection, high-use alerts)

After the commissioning has been performed, the contractor should provide a report that outlines the findings. It is recommended that the water provider (or consultant) witness commissioning activities, review the commissioning report, provide comments to the ESCO, and have comments resolved to the water provider’s satisfaction prior to approving the project. The report should include the results of all tests performed, state if the system is functioning per the design, and list necessary corrections.

Appendix A

Revenue Increase

The following steps provides the basic procedure that can be used to determine the amount of revenue increase as a result improved meter accuracy from an advanced metering project. This revenue is specifically tied to the increase in the meter accuracy and not an increase in the water provider's rate that is charged customers.

These procedures can be performed for each meter grouping identified in the M&V plan.

Baseline Metered Consumption: The first step is to determine the baseline volume of water that was recorded by the water provider's meters before the installation of the advanced metered system taking into account the baseline meter accuracy, calculated as follows:

$$\text{Baseline Metered Consumption} = \frac{\text{Total Baseline Billed Water Use}}{\text{Baseline Average Weighted Meter Accuracy (\%)}}$$

Adjusted Metered Consumption: The next step is to determine the water volume that would have been captured with improved meter accuracy as a result of the advanced metering system, calculated as follows:

$$\text{Adjusted Metered Consumption} = \text{Baseline Metered Consumption} \times \text{Post-Installation Average Weighted Meter Accuracy (\%)}$$

Net Consumption Increase: Subtracting the baseline from the adjusted metered consumption reveals the amount of water consumption that was not accounted for with the old meters, represented as follows:

$$\text{Net Consumption Increase} = \text{Adjusted Metered Consumption} - \text{Baseline Metered Consumption}$$

Revenue Increase: The increase in the water provider's revenue that is a result of the net volume of water recorded by the new metering system is calculated by multiplying the net consumption increase by the provider's weighted average volumetric water rate (e.g., \$ per thousand gallons). The weighted average volumetric water rate is equivalent to the Customer Retail Unit Cost determined in the AWWA M36 water audit, which is described in AWWA M36, Chapter 3, Steps 5-6. The M&V plan should carefully document the volumetric water rates for each customer class corresponding with the meter groupings, which should account for the potential change in rates over the study period. An acceptable alternate water rate can be the lowest individual volumetric water rate, which is a conservative estimate of the customers' water rate. The ESCO and water provider should agree upon the method selected and document the water rate in the M&V plan.

The calculation to determine the revenue increase is as follows:

Revenue Increase (\$)

$$= \text{Net Consumption Increase} \times \text{Weighted Average Volumetric Water Rate} \left(\frac{\$}{\text{unit volume}} \right)$$

Normalization: The baseline metered consumption and adjusted metered consumption can be normalized to account for potential changes in water consumption patterns. The most common parameters to normalize this water consumption is water use per meter connection over each measurement period.

This report prepared in partnership with Western Resource Advocates



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Prepared for the U.S. Environmental Protection Agency
under a Government Order with the U.S. Department of Energy
CONTRACT DE-AC05-76RL01830

U.S. DEPARTMENT OF
ENERGY