Water Meters

Response to California Energy Commission
2013 Pre-Rulemaking Appliance Efficiency
Invitation to Participate

Docket Number: 12-AAER-2C; Water Appliances

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Summary

The information below provides direct response to the California Energy Commission's (CEC) Invitation to Participate (ITP) for the 2013 Appliance Efficiency Pre-Rulemaking, regarding Water Meters, including reference to several primary sources, some of which are attached separately (see References for more details). This document includes all of the questions asked in the ITP, even for those with no response.

In summary, CEC has an excellent opportunity to explore energy efficiency standards for water meters. Water meters with improved measurement accuracy at low flow rates save water, money, and embedded energy. Low-flow leaks that are undetected by meters represent a source of water loss to water purveyors, which, in turn, pass the costs associated with storage, treatment, distribution, and disposal on to all their customers. By allowing water purveyors to charge the subset of customers who are directly responsible for leaks and other low flows that would otherwise be undetected, more accurate meters induce behavioral changes, such as leak repair. Since water meters are primarily owned by water purveyors, (including both public utilities and private companies), water meter regulation by CEC would mirror the regulation of distribution transformers, also owned by utilities, by the U.S. Department of Energy in 2007.

Primary sources of data include an extensive empirical study of water meter accuracy at low flow rates, funded by the U.S. Environmental Protection Agency (EPA) and the Water Research Foundation and conducted by researchers at Utah State University. A useful source data on flow and leakage rate distributions include a statewide study on water use efficiency in single family homes sponsored by the California Department of Water Resources. Another useful reference is an article in the peer-reviewed industry publication *Journal of the American Water Works Association* on methodologies for calculating water loss due to meter inaccuracies at low flow rates.

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1 Basic Information

1.1 Product Definition and Scope

Water meters are devices used to measure and record the volume of water flowing through them. Manufacturers produce a wide variety of meters suitable for agricultural, industrial, commercial, and residential applications. The information contained in this document applies primarily to mechanical meters suitable for measuring cold, potable water.

Meters currently available in the market vary in how accurately they measure at low flow rates (Barfuss 2011), which are characteristic of small leaks like dripping faucets or faulty toilet flappers. Low-flow leaks that are undetected by meters represent a source of water loss to water purveyors. Water purveyors, not individual people or households, are the primary owners and consumers of water meters. In this respect, the regulation of water meters through Title 20 is similar to the regulation of distribution transformers by the U.S. Department of Energy (DOE) in 2007 (DOE 2007). The consumers of distribution transformers are electrical utilities, and DOE assessed the costs and benefits of standards from the perspective of the utilities rather than individuals or households.

Although water purveyors purchase and own water meters, most individual customers would also benefit from greater meter accuracy at low flow rates. Because water purveyors are either public utilities or private companies regulated by the California Public Utilities Commission (CPUC), they pass the costs associated with storage, treatment, distribution, and disposal, including energy costs, on to all their customers. Therefore, the costs of any leakage flows not billed to individual customers are ultimately recovered through the rate-setting process (see also sections 5.1 and 6.2).

By allowing water purveyors to charge the subset of customers who are directly responsible for leaks and other low flows that would otherwise be undetected, more accurate meters induce behavioral changes, such as leak repair. Repairs and other behavioral changes reduce total water use as well as the costs and energy associated with providing that water to customers. As with costs, savings are then be passed on to ratepayers during the rate-setting process. Even without leak repair or behavioral changes, improved low-flow accuracy allows purveyors to more equitably distribute the cost of providing water to those who are actually using it.

Physical Characteristics

Meters vary primarily in size, measurement technology, outer casing material, and registration/encoding element. Water meters used for residential service connections are usually between 5/8 and 2 inches in size (sizes discussed in more detail below) and typically employ one of the following core measurement technologies:

- positive displacement (either nutating disc or oscillating piston);
- single jet;
- multi-jet; or
- fluidic-oscillator.

Residential water meters are manufactured with either bronze or plastic outer casings, but since the outer casing does not particularly affect the meter's low-flow accuracy, this characteristic is not considered further. Figure 1 shows the typical appearance of a water meter suitable for use in detached, single-family homes.

The registration/encoding elements serve to convert the signal generated by the measurement technology into quantitative information that reflects the volume of water that has passed through the meter in a specific standard unit of measure. Virtually all measurement error in modern water meters is associated with the core measurement technology and not with the method of registration. Therefore, while advanced encoders that enable remote reading and other sophisticated functionality may offer significant benefits for water and energy conservation, they do not affect the accuracy of the measurement technology itself, and are not discussed further in the present analysis.

Figure 1: Typical appearance of a water meter suitable for use in detached, single-family homes
Source: Neptune

Size

Water meter size designations refer to the internal diameter of the inlet and outlet apertures on either side of the measurement chamber. In many cases, the size designation is the same as the nominal pipe size of the service pipe. For historical reasons, this correspondence is imperfect, as 5/8" meters are designed for use with 1/2" pipes (AWWA M6). Some meters are manufactured with threads (called "spud threads") that permit connection to a service pipe with an internal diameter different from that meter's nominal inlet and outlet internal diameter. The sizes of such meters are designated with two values, the first corresponding to the inlet and outlet internal diameter and the second to the nominal pipe size to which the spud threads are designed to provide a connection. For example, a 5/8" x 3/4" meter is one with inlet and outlet internal diameters of 5/8" and spud threads allowing a connection to a 3/4" service pipe. In most cases, two fittings must be used to connect the meter to the service pipe: a tailpiece and a pipe coupling. The tailpiece includes a female, internal thread coupling nut on one end that connects to the meter spud thread and a male, external thread on the other end that connects to the pipe coupling. The pipe coupling includes female, internal threads on both ends to unite the tailpiece with the service pipe.

Measurement Technology

Water meters for residential service are typically based on either nutating disc or oscillating piston measurement technologies. Both nutating disc and oscillating piston meters belong to the "positive displacement" category of water meter technologies because they function by coupling the displacement of a known volume of water to the transmission of a signal to the registration element. In a nutating disc meter, water striking the surface of a disc mounted on a spindle causes the disc to wobble, or nutate, as water flows into and out of the measurement chamber (see Figure 2). One complete revolution of the end of the spindle corresponds to the passage of a unit of water equal to the void volume of the measuring chamber. In an oscillating piston meter, water flowing into the measuring chamber pushes a piston element in a circular motion, with the revolution of the piston hub indicating the passage of a unit volume of water (see Figure 3).

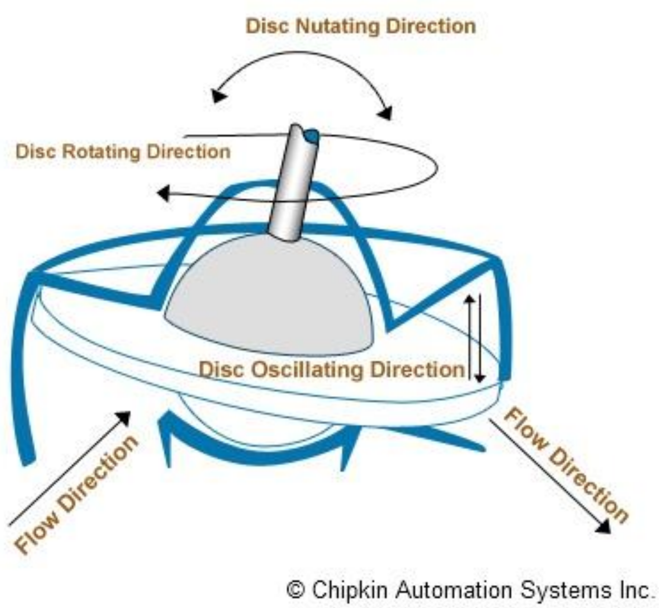

Figure 2: Schematic diagram of nutating disc meter measuring chamber
Source: Chipkin Automation Systems

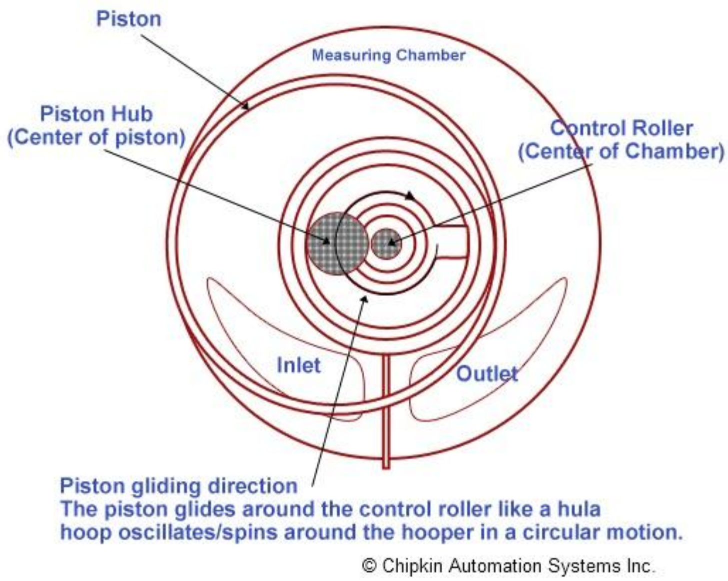

Figure 3: Schematic diagram of oscillating piston meter measuring chamber
Source: Chipkin Automation Systems Inc.

While positive displacement meters are by far the most common in residential and other applications involving meter sizes between 5/8" and 2", single jet and multi-jet meters are occasionally used. Single jet and multi-jet meters belong to the "velocity" category of meter technologies because they measure the water's velocity, from which volumetric flow can then be inferred. Single jet and multi-jet meters function by directing the flow of water against an impeller. The rotation speed of a spindle attached to the center of the impeller provides the signal to the registration element. In single jet meters, a single stream of water strikes the impeller at one location (see Figure 4); in multi-jet meters, water is dispersed and strikes the impeller at multiple locations (see Figure 5).

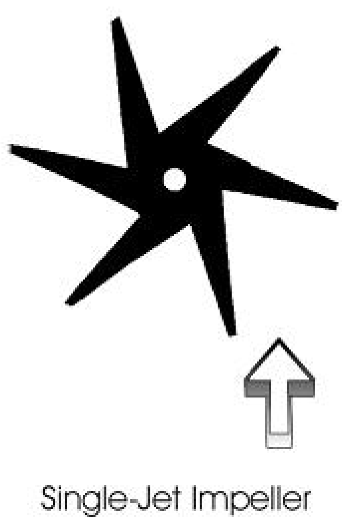

Figure 4: Schematic of single jet meter measuring chamber
Source: Metron-Farnier

Figure 5: Photograph of multi-jet meter measuring chamber
Source: Master Meter

Fluidic oscillator meters are infrequently used in residential and small service applications. Fluidic oscillator meters create a physical oscillation in the direction of the stream of water entering the measuring chamber. The oscillation frequency, which can be detected by electronic sensors within the measuring chamber, is proportional to the velocity of the water, and thus can be used to register flow. Fluidic oscillators are one example of a new class of advanced, "solid-state" or "static" meters that do not include moving parts, but often require a power supply.

1.2 Sources of Test Data

Meter Accuracy

Barfuss, S.L., M.C. Johnson, & M.A. Neilson. 2011. "Accuracy of In-Service Water Meters and High and Low Flow Rates." Denver, CO: Water Research Foundation.

Methodology for Calculating Water Loss Due to Poor Accuracy at Low Flow Rates

Richards, G.L, M.C. Johnson, and S.L. Barfuss. 2010. "Apparent Losses Caused by Water Meter Inaccuracies at Ultralow Flows." *Journal AWWA* 102 (5): 123-132.

Water Leak and Usage Flow Rates

DeOreo, W.B., P.W. Mayer, L. Martien, M. Hayden, A. Funk, M. Kramer-Duffield, R. Davis, J. Henderson, B. Raucher, P. Gleick, M. Hebeberger, F. Sanchez, & A. McNulty. 2011. *California Single-Family Water Use Efficiency Study.* Prepared by AquaCraft Inc. for the California Department of Water Resources and Irvine Ranch Water District.

1.3 Existing Standards and Standards under Development

California Energy Commission

The California Energy Commission (CEC) has a mandate for taking a more aggressive approach to establishing and enforcing standards that will reduce statewide water consumption. Assembly Bill 662 (Ruskin 2007) and Assembly Bill 1560 (Huffman 2007) modified the language of the Warren-Alquist Act to give CEC the authority to set water efficiency appliance standards and required CEC to incorporate water efficiency standards into the existing building efficiency standards (Title 24, Part 6).

Currently, the accuracy of water meters installed by public water utilities is not subject to any legal meter accuracy standards. The accuracy of meters installed by for-profit companies is regulated by the California Public Utility Commission (CPUC) as described below. The accuracy of submeters installed in multifamily housing units is regulated by the California Division of Measurement Standards (CA DMS) as also described below.

A Title 20 standard for water meters established by CEC would apply to any water meter purchased for use in the state of California, including those purchased by public utilities, private water companies, and multifamily housing complex owners. As such, CEC is in a unique position to unify water meter accuracy standards throughout the state while closing a major regulatory gap that potentially subjects millions of homes served by public water utilities to higher costs.

American Water Works Association

The American Water Works Association (AWWA) publishes a series of voluntary water meter standards for different categories of meter types, including bronze-case positive displacement (C700), plastic-case positive displacement (C710), single jet (C712), multi-jet (C708), and fluidic oscillator (C713). Additional standards for emerging, non-mechanical meters are currently under development. The AWWA standards include recommendations for a large number and variety of meter properties, including values for the minimum, normal, and maximum flow rates to be used to test each size and type of meter, as well as the recommended accuracy limits within which meter performance should fall.

http://www.awwa.org/publications/standards.aspx

Natural Resources Defense Council

The National Resources Defense Council (NRDC) has proposed modifications to the AWWA standards to require greater accuracy at low flow rates (NRDC, 2013; NRDC, 2013b).

Proposal: http://docs.nrdc.org/water/files/wat_13032601a.pdf

Press Release: http://www.nrdc.org/media/2013/130326.asp

National Institute for Standards and Technology

The National Institute for Standards and Technology (NIST) standards for residential water meters are almost identical to the AWWA standards. Two exceptions of note are: 1) the AWWA standards require that 1.5 and 2 inch single jet meters meet their minimum accuracy standards at lower flow rates than those required by the NIST standards; and 2) for positive displacement (both nutating disc and oscillating piston) and fluidic oscillator meters, the AWWA standards require a maximum over-registration of 101 percent at the minimum test flow, whereas NIST standards allow a maximum over-registration of 101.5 percent.

http://www.nist.gov/pml/wmd/pubs/h44-13.cfm

California Public Utilities Commission

Through Order 103-A, CPUC requires that all water meters installed within the territories of for-profit water utilities meet AWWA accuracy standards (CPUC 2009).

http://docs.cpuc.ca.gov/PUBLISHED/Graphics/107118.PDF

California Division of Measurement Standards

The California Division of Measurement Standards (CA DMS) requires that all meters used for submetering in multifamily dwellings meet NIST accuracy standards described in Handbook 44, Section 3.36 (NIST 2012). It should be noted that meters installed in multifamily dwellings are subject to two tiers of regulation. Type approval, or approval of the basic model of each meter, is performed by CA DMS' own laboratory. Every individual meter that is actually installed must also pass an inspection by a county lab that is certified by CA DMS.

http://www.cdfa.ca.gov/dms/programs/general/2012FRM.pdf

California Building Standards Commission

The California Building Standards Commission (CA BSC) oversees three codes relevant to water meters: the California Green Building Standards Code (CALGreen), the California Plumbing Code, and the California Fire Code. While CALGreen does not include meter accuracy standards, it does require that multiunit buildings (residential or commercial) greater than 50,000 square feet install submeters on individual units (CA BSC 2010, section 5.303.1.1). CALGreen also requires that any projects or spaces within buildings that are projected to consume more than 1,000 gallons per day also be submetered (CA BSC 2010, section 5.303.1.2). The 2013 edition of CALGreen (effective 2014) does not change these provisions.

The California Plumbing Code does not include requirements for the accuracy of water meters, but does regulate how meters are sized (CA BSC 2010b, section 610). The primary criteria required by the plumbing code for determining meter size are: the pressure available at the meter, the elevation of the highest fixture relative to the elevation of the water source, the length of pipe between the meter and the most remote fixture, and the total number of fixtures served.

The California Fire Code requires that single and two-family homes be equipped with automatic sprinkler systems (CA BSC 2010c, section 903.3.1.3). The recommended best practice for providing water service to automatic sprinkler systems is to use a separate meter, or include a domestic shutoff valve to prevent flow to other fixtures when the sprinkler system is activated (CA SFM 2010). In practice, however, some water purveyors are simply oversizing meters to include possible flows to fire sprinklers (Quinn 2013), reducing average meter accuracy at low flow rates in California (see also section 5.2).Federal Standards

There is no U.S. federal standard for residential service water meter accuracy.

International Standards

The International Organization for Legal Metrology (OIML) publishes the R49 standard, which includes both water meter performance standards and testing procedures (OIML 2006). OIML's R49 standard replaced EN 14154, which replaced ISO 4064. R49 is considered authoritative for virtually all countries outside of North America, but employs a framework very different and completely independent of that provided by AWWA and NIST.

http://www.oiml.org/publications/R/R049-1-e06.pdf

European Union

The European Union's Measuring Instruments Directive (MID) harmonizes the standards for a variety of measurement devices in its 27 member nations, including water meters. The requirements of MID for water meters are equivalent to OIML R49 (Himsley, personal communication).

http://ec.europa.eu/enterprise/policies/european-standards/harmonised-standards/measuring-instruments/

1.4 Product Lifetime

The useful service life of a service water meter is about fifteen years (Satterfield & Bhardwaj, 2004). Manufacturers typically warranty initial accuracy levels only for one year. Maintenance and water quality can both impact the performance of the meter over time, so the average life varies by water purveyor service territory. Water utilities often operate testing programs, that, combined with information about typical customer flows, allow them to replace meters only when accuracy has deteriorated enough to produce losses that financially justify purchasing new equipment.

1.5 Product Development Trends

The basic designs of many of the most widely used measurement technologies have changed very little over time. Patents for positive displacement meters of both the oscillating piston and nutating disc types date back to the late 19th century and some companies that are still manufacturing meters today were first established more than 100 years ago (AWWA M6). Recently, the market for water meters has witnessed the emergence of a variety of innovative, advanced, non-mechanical meter technologies with no internal moving parts (sometimes called static, solid-state, or electronic meters), including fluidic oscillator, ultrasonic, magnetic, and remanent field technologies (Berardinelli, 2012). Some classes of solid-state water meters appear to achieve dramatically greater accuracy at low flow rates than any of the conventional meter technologies (Burns, 2012).

Of the non-mechanical meters, the fluidic oscillator meter has achieved the greatest market penetration, as evidenced by the fact that it is the only non-mechanical meter with its own industry standard (AWWA C713). AWWA standards for other non-mechanical meters are currently under development. Eventually, new meter technologies could challenge the market dominance of positive displacement meters in the residential market, but first costs have thus far inhibited significant penetration.

1.6 Design & Sales Cycle

No response.

2 Energy Saving Technologies, Components, and Features

2.1 What are the technology options or features that allow water meters to save water?

The observed spread in the ability of meters currently available in the market to measure water at low flow rates (see Table 6.1) is probably due to differences in tolerances and quality control procedures used during manufacturing. Some classes of non-mechanical, solid-state (also called static or electronic) water meters appear to achieve dramatically greater accuracy at low flow rates than any of the conventional meter technologies (Burns, 2012), but performance standards have not yet been established for them (other than for fluidic oscillator-type meters).

Meter accuracy can have a significant effect on water and energy consumption by end-users. Extended low flows, such as those created by leaking faucets or faulty toilet flappers, are not detected by lower-accuracy meters. Since water providers cannot directly charge for usage that is not detected by meters, lower-accuracy meters provide end-users with little incentive for making even simple repairs or behavioral changes that would eliminate wasteful leakage. Meters that accurately register low flows provide a better price signal to the end-users responsible for leaks and other low flows. In response to the price signal, end-users act to eliminate leaks and reduce total water consumption. Because energy is required for many processes involved in providing water to consumers, reducing water consumption simultaneously reduces energy consumption. We estimate that the widespread use of more accurate water meters could reduce statewide water and energy consumption by 1 billion gallons of water and 9 gigawatt-hours (GWh) of embedded energy after stock turnover.

2.1.1 How much water does each save?

Based on calculation methodologies published in a peer-reviewed journal (Richards 2010), and data on meter accuracy performance funded by the U.S. Environmental Protection Agency and the nonprofit Water Research Foundation (Barfuss 2011), we estimate that meters with greater low flow accuracy could each save as much as 1,500 gallons per year per meter.

2.1.2 What are the embedded energy savings from the water saved?

Overview of Embedded Energy in California Water

California consumes about 2.9 trillion gallons of water per year for urban uses (Christian-Smith, Heberger and Luch 2012). Urban uses include outdoor and indoor residential water use; water used in commercial, institutional, and industrial applications; and unreported water use, which is primarily attributed to leaks. The 2.9 trillion gallons of water is associated with approximately 26.4 terawatt hours of embedded electricity. Figures 6 and 7 present the estimated urban water use in 2005 and the associated embedded energy use.

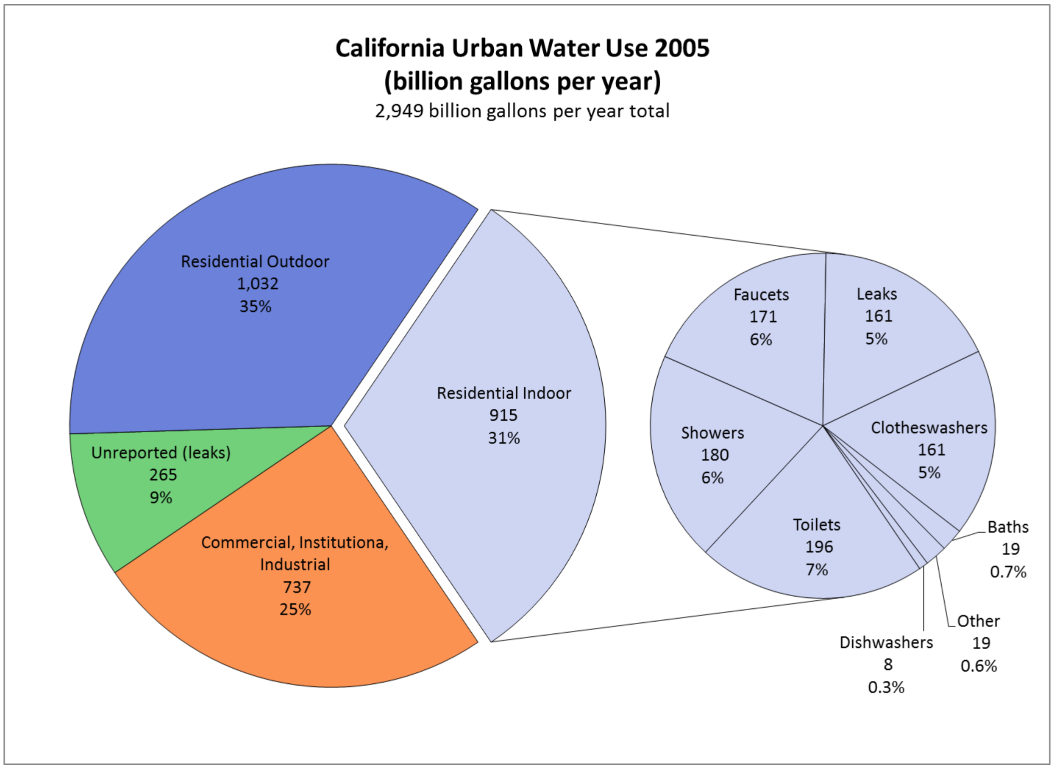

Figure 6: California Urban Water Uses (2005)

Source: Christian-Smith, Heberger, Luch (2012).

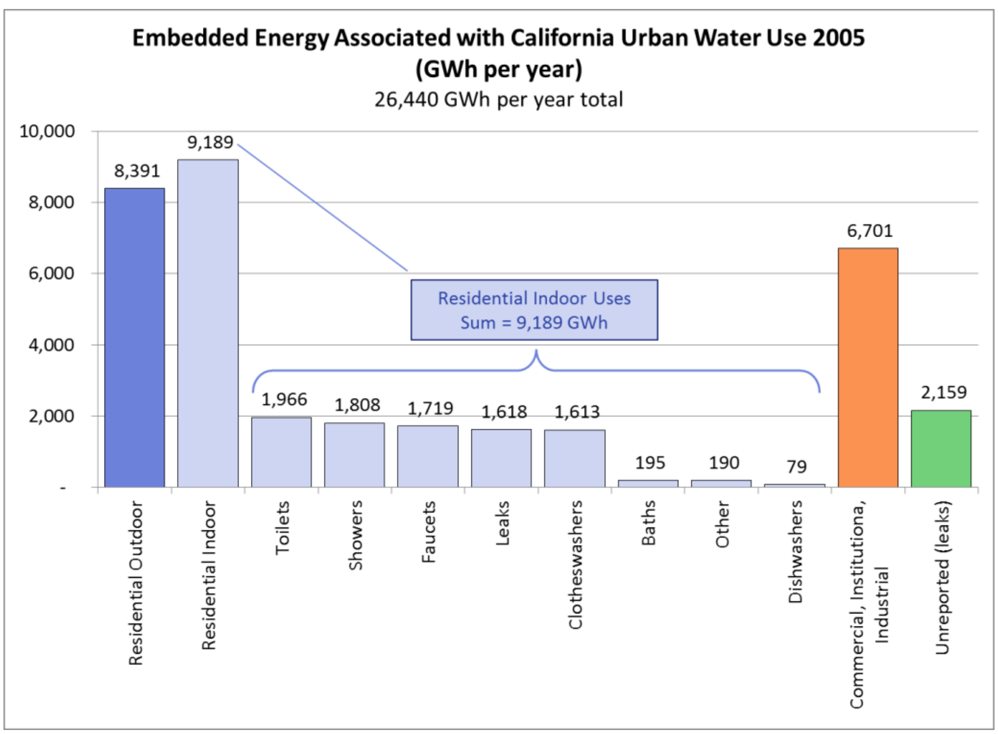

Figure 7: California Urban Water Uses (2005)

Sources: Christian-Smith, Heberger, Luch (2012) Assumptions: Embedded energy factor of 8,134 kWh/MG for residential outdoor water use and unreported (leaks); embedded energy factor of 10,045 kWh/MG for residential indoor; embedded energy factor of 9,090 kWh/MG for commercial, institutional, industrial.

Embedded Energy Factor

Over the past decade, the CEC and the California Public Utilities Commission (CPUC) have made notable progress in understanding the relationship between water and energy in California. However, there is no definitive conclusion on how much water is embedded in California's water, what embedded energy factors should be used for programs that span a wide geographic region, or how water efficiency and water conservation programs might reduce energy used for water supply, conveyance, treatment, distribution, wastewater collect and wastewater treatment. The CEC and CPUC research on embedded energy is referenced below, as is our recommendation on which embedded energy factors should be used for the time being.

In 2005 and 2006 the CEC published reports that explore how much energy is embedded in water (CEC 2005, CEC 2006). Table 1 shows the embedded energy estimates as presented in the CEC's 2006 report.

Table 1: Embedded Energy Estimates

	Indoor Uses		Outdoor Uses	
	Northern California kWh/MG	Southern California kWh/MG	Northern California kWh/MG	Southern California kWh/MG
Water Supply and Conveyance	2,117	9,727	2,117	9,727
Water Treatment	111	111	111	111
Water Distribution	1,272	1,272	1,272	1,272
Wastewater Treatment	1,911	1,911	0	0
Regional Total	5,411	13,022	3,500	11,111

Source: CEC 2006. Table 7.

CPUC's Decision 07-12-050, issued December 20, 2007, authorized the largest electricity utilities to partner with water utilities and administer pilot programs that aimed to save water and energy (CPUC 2011c). The Decision also authorized three studies to validate claims that saving water can save energy and explore whether embedded energy savings associated with water use efficiency are measurable and verifiable. The pilot programs succeed at demonstrating that water conservation measures also result in energy savings.

The CPUC studies were effective at obtaining a more granular understanding of how energy use varies based on a number of factors including supply, (i.e. surface, ground, brackish, or ocean desalination), geography, and treatment technology. The authors found "that the value of energy embedded in water is higher than initially estimated in the CEC's 2005 and 2006 studies."

In March 2013, CPUC released additional information on the relationship between water and energy in California. CPUC's work on the water/energy nexus is available here: http://www.cpuc.ca.gov/PUC/energy/Energy+Efficiency/Water-Energy+Nexus+Programs.htm

Until there is a definitive answer as to which embedded energy factor is most appropriate, we recommend using a population-weighted average of the embedded energy factors for Northern and Southern California presented CEC's 2006 report (see Table 1). We used this methodology to approximate the embedded energy use reported in Figure 7, we weighted the values in Table 1 based on the population in Northern and Southern California in 2011 (U.S. Census Bureau).[1] The population-weighted indoor embedded energy factors were used for residential indoor use categories (toilets, faucets, showers, clothes washers, etc.). The population-weighted outdoor values were used for residential outdoor use and unidentified (leaks) categories. For the commercial, institutional, industrial use category indoor and outdoor water use was assumed to be

2.1.3 How much does each cost a manufacturer to implement on a per product basis?

No response.

3 Market Characteristics

3.1 What are the annual historic and projected sales of water products from 2009-2015 (in CA and nationwide)?

The historic and projected sales of water meters from 2010-2015 in California are presented in Table 2.

[1] Northern and Southern California populations are 39.1% and 60.9% of total California population, respectively.

Table 2: Estimated Water Meter Sales for Single Family Homes 2010-2015

Year	California Population[1]	Single Family Homes (SFH)[2]	Single Family Homes (SFH) Metered3	SFH Metered %	Replacement Meters[3]	Retrofit Meters[4]	New Construction Meters[5]	Total Meter Sales
2010	37,309,382	13,277,360	9,958,020	75%	663,868	92,060	25,526	781,454
2011	37,628,888	13,302,886	10,071,619	76%	663,868	92,060	21,538	777,466
2012	37,951,130	13,324,424	10,190,961	76%	663,868	92,060	27,282	783,210
2013	38,276,131	13,351,706	10,317,771	77%	663,868	92,060	34,749	790,678
2014	38,603,916	13,386,455	10,475,023	78%	663,868	92,060	65,192	821,121
2015	38,934,508	13,451,647	10,640,588	79%	663,868	92,060	73,504	829,432

Source: Water meter annual sales were calculated as the sum of new home installations, replacements of existing meters, and retrofits of homes not previously having meters.

[1] Based on population in 2010 (US Census, 2010) and forecast for 2030 (CA DOF, 2013)

[2] Based the ratio of people to single family homes in California (US Census, 2003), and new construction (see notes 5 and 6).

[3] The meter replacement rate assumes meter lifetime of 15 years and a steady state stock equal to the total number of metered homes in 2010 (will tend to underestimate replacement rate).

[4] The average number of annual retrofits was calculated assuming 75% of homes are metered as of 2010 and 90% will be metered by 2030 in order to comply with AB 2572 (which requires 100% by 2025).

[5] New constructions of single family homes for 2010-2013 estimated based on authorized building permits (CA DOF, 2013b).

[6] New construction for 2013-2015 estimated using projections for total residential units from the California Economic Forecast (CEF 2012), assuming a mix of multi-unit and single family homes equal to that observed in 2010-2012 (CA DOF 2013b).

3.2 What is the market share of water efficient (or accuracy for water meters) products? Provide a brief description of the performance of the units.

The market share meters that are more accurate at low flow rates depends on the meter type, size, and how the accuracy standard is defined. The more stringently the accuracy standard is defined, the fewer the meters on the market that will be able to meet the standard. Test results indicate that reasonable standard more stringent than the current AWWA standard could be established and met by about 33% of meters currently available in the market.

3.3 Is there a difference between units sold to residential and commercial sectors?

No response.

3.4 Estimated percentile annual sales growth (CA and nation).

No response.

3.5 How many small businesses are involved in the manufacture, sale, or installation of these products?

No response.

4 Market Competition for Efficient Products

4.1 Are there any test markets for water efficient units?

Test results from a study funded by the U.S. Environmental Protection Agency and the Water Research (Barfuss 2011) suggest that water meters capable of measure water very accurately at low flow rates are readily available on the market and are probably installed in many places. Unfortunately, the published data do identify which brands perform better than which other brands. This information is known to the researchers, but is kept confidential.

4.2 Breakdown of costs per unit by performance

No response.

4.3 Product duty cycle

Not applicable. Mechanical water meters have one functional mode and are never “off.”

5 Customer Acceptance

5.1 What surveys have been done to gauge consumers' acceptance and performance of more efficient units?

Some water meters currently available on the market and installed in residences measure water more accurately than others at low flow rates (Barfuss, 2011). As described in section 1.1, water meters are typically owned and purchased by water purveyors, making purveyors the primary consumers. Several large utilities have embraced improved accuracy standards for extended low flow rates, including American Water, the largest publicly traded water and wastewater utility company in the country, East Bay Municipal Utility District, New York City Department of Environmental Protection, San Antonio Water System of Texas, and Austin Water Utility (NRDC, 2013; NRDC 2013b).

Although water purveyors are the primary consumers of water meters, purveyors' customers may influence their positions. The vast majority of customers probably do not know the type of meter that is installed, or how it differs from other meters. Customers with large numbers of low-flow leaks would experience an increase in their water bills after meters with better low-flow accuracy are installed. Bill increases would likely be temporary as customers respond to the new charges by repairing low-flow leaks or otherwise limiting low-flow usages that were previously "free" to them (although paid in the form of fees by all customers in that water service territory).

On the other hand, customers without low-flow leaks or other low-flow usages would likely experience lower bills in the long run as a result of the installation of meters with better low-flow accuracy. As other customers repair leaks and/or pay for low flow usages themselves directly, there would be fewer unexplained water losses, and correspondingly lower financial costs, to defray across all service territory customers. See also sections 1.1 and 6.2 for more information.

5.2 Is there any problem due to installation of new units, and whether they perform properly with the current plumbing system and codes?

No. The requirement in the California Building Standards Code requiring that new homes include fire sprinklers (CA BSC 2010c, section 903.3.1.3 or Title 24, CCR, Part 2.5; effective January 1, 2011) is probably driving the average California meter size up (see also section Since larger meters are less accurate at low flow rates, average low flow meter accuracy is probably decreasing. Requiring the installation of meters with greater low flow accuracy would help to counteract that trend.

5.3 Is there a different design duty cycle for the new and existing units? Residential and commercial? What are they?

Not applicable. Water meters have one functional mode and are never "off."

5.4 What is the design life of new and existing units?

Product design life covered in section 1.4 above.

5.5 What test methods were used to test the performance of the appliance?

Water meter accuracy test methods fall into two broad groups corresponding to the standard being applied. In North America, the prevailing accuracy standards and test methods originate with the American Water Works Association (AWWA), an industry group. The AWWA test methods are codified in slightly different forms by the CPUC and the National Institute of Standards and Technology (NIST), but both organizations rely on very similar approaches to meter accuracy testing. In virtually all markets outside of North America, governments and manufacturers use test methods and standards developed by the International Organization for Legal Metrology (OIML). Each of these test methods is described in more detail below.

American Water Works Association

The AWWA M6 manual includes a recommended procedure for testing water meter accuracy (AWWA 2012). The basic approach recommended by the AWWA involves passing a known volume of water (test draft) through the meter at specific flow rates (minimum, normal, and maximum) and comparing the known volume with that registered by the meter. AWWA M6 also includes a recommendation for the minimum volume that should be used as a test draft, to reduce uncertainty associated with the value of the known volume and thus to minimize error in the determination of the meter's accuracy.

AWWA also publishes a series of water meter standards for different categories of meter types, including bronze-case positive displacement (C700), plastic-case positive displacement (C710), single jet (C712), multi-jet (C708), and fluidic oscillator (C713). Additional standards for emerging, non-mechanical meters are currently under development. AWWA standards include recommendations for a large number and variety of meter properties, including values for the minimum, normal, and maximum flow rates to be used to test each size and type of meter, as well as the recommended accuracy limits within which meter performance should fall.

AWWA does not itself perform testing, certify products as meeting its published standards, or certify that laboratories perform testing in accordance with its recommended procedures.

California Public Utilities Commission

In Order 103-A, CPUC prescribes minimum requirements for testing water meters to be used in the service connections of for-profit water utilities (CPUC 2009). Despite minor differences in approach, Order 103-A essentially requires the use of AWWA test methods.

National Institute of Standards and Technology

NIST Handbook 44 includes specifications and test methods for a variety of measuring devices, including water meters (NIST 2012, Chapter 3.36). The test method for determining water meter accuracy prescribed in Handbook 44 are substantively equivalent to the recommendations of AWWA M6 and the individual AWWA meter standards, but presented in a format more consistent with test methods for other devices. The NIST method also includes quantitative requirements for the repeatability of the test results that are not included in AWWA test methods (NIST 2012, Table T.1.1).

The National Conference on Weights and Measures (NCWM) partners with NIST to develop Handbook 44. NCWM also conducts a National Type Evaluation Program (NTEP), which conducts testing of devices according to the standards and test methods prescribed in Handbook 44. There are currently seven laboratories in North America authorized to evaluate devices for compliance with Handbook 44, including the CA DMS. CA DMS' Field Reference Manual describes California's implementation of Handbook 44 pursuant to 4 CCR § 4000.

International Organization for Legal Metrology

OIML publishes the R49 standard, which includes both water meter performance standards and testing procedures (OIML 2006). OIML's R49 standard replaced EN 14154, which replaced ISO 4064. R49 is considered authoritative for virtually all countries outside of North America, but employs a framework very different and completely independent of that provided by AWWA and NIST.

5.6 Was there any difficulty, or issue with the mentioned test methods?

The existing test methods must be extended to allow testing at a new, lower test rate.

5.7 Is there any improvement needed to improve the mentioned test methods?

The current test methods (either AWWA or NIST) are largely sufficient, with three modifications:

1. An additional, lower test flow rate must be used to test any meter type and size combination where a new standard establishes an accuracy limit for a flow rate lower than the minimum flow rate specified in existing standards.
2. The range of accuracy measurements in repeated tests at the CEC Test Flow Rate of the same meter type should fall within a specific limit; and
3. The test volume of water to be used for testing meters at the new, low flow rate must balance the need to minimize total equipment measurement error with keeping testing times and costs as low as possible.

6 Information Request for Water Meters

6.1 Type of water meters and description of their technologies used to achieve the low flow detection and accuracy.

Water meter accuracy at low flow rates is heavily dependent on both meter technology and size. Positive displacement meters tend to be most accurate at low flow rates, while single jet meters tend to be least accurate. Smaller meters are more accurate than larger meters at low flow rates. Notably, some classes of non-mechanical, solid-state (also called static or electronic) water meters appear to achieve dramatically greater accuracy at low flow rates than any of the conventional meter technologies (Burns, 2012), but performance standards have not yet been established for them (other than for fluidic oscillator-type meters).

Since water purveyors have reasons independent of low flow accuracy for choosing meter technology (water quality) and size (anticipated demand to be served by the meter), accuracy standards have historically been created for each combination of meter technology and size, rather than prescribing or proscribing individual types.

Within each meter technology and size class, accuracy performance at low flow rates can vary substantially. Table 3 below shows representative accuracy test results for four different meters types (all 1”), measured at 0.09 gallons per minute (derived from data on new water meters published in Barfuss, 2011).

Table 3: Best and Worst Low-Flow Accuracy Performance in Four Meter Types

Meter Type	Meter Size (inches)	Flow Rate (gallons/min)	Best Accuracy	Worst Accuracy
Displacement Piston	1	0.09	96%	65%
Nutating Disc	1	0.09	95%	89%
Multi-Jet	1	0.09	99%	54%
Single-Jet	1	0.09	95%	85%

(Source: Energy Solutions analysis based on data on new water meters in Barfuss, 2011)

6.2 Who is expected to bear the costs of installing/replacing water meters?

Water meters that measure low flow rates more accurately may not cost more than water meters that do not. Water purveyors (including utilities) typically purchase and own the water meters used to measure water supplied to their customers.

6.3 If the utility providers will bear this cost, can the costs of upgrading the water meters be recovered by avoiding loss of money from leaks?

Water meters that measure low flow rates more accurately may not cost more than water meters that do not. In the event that they do, water purveyors (including utilities) would bear the cost, but would recover it by avoiding water loss associated with low flow leaks.

It should also be noted that costs associated with water loss are ultimately borne by the purveyors’ customers. More accurate meters would help water purveyors recover the costs directly from those most responsible for the leaks. Moreover, by charging for water that was previously not billed, purveyors would recover more revenue from existing rates. As a result, better low-flow accuracy would allow purveyors to postpone rate increases and decrease the frequency of future rate adjustments (see also sections 1.1 and 5.1).

7 Any Other Information Relevant to this Proceeding

No response.

8 References

(References attached separately are highlighted in grey)

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