Arnold Schwarzenegger
Governor

SMART METERS AND CALIFORNIA WATER AGENCIES: OVERVIEW AND STATUS

PIER INTERIM PROJECT REPORT

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Preface

The California Energy Commission's Public Interest Energy Research (PIER) Program supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The PIER Program conducts public interest research, development, and demonstration (RD&D) projects to benefit California.

The PIER Program strives to conduct the most promising public interest energy research by partnering with RD&D entities, including individuals, businesses, utilities, and public or private research institutions.

PIER funding efforts are focused on the following RD&D program areas:

- Buildings End-Use Energy Efficiency
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- Environmentally Preferred Advanced Generation
- Industrial/Agricultural/Water End-Use Energy Efficiency
- Renewable Energy Technologies
- Transportation

SMART METERS AND CALIFORNIA WATER AGENCIES: OVERVIEW AND STATUS is the interim report for the CEC project 500-07-022, which is titled "California Time-of-Use Water Meter Case Study", conducted by Water and Energy Consulting.

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For more information about the PIER Program, please visit the Energy Commission's website at www.energy.ca.gov/research/ or contact the Energy Commission at 916-654-4878.

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Abstract

This report provides an overview of water meter technology and equipment suppliers, and describes the drivers motivating the change from traditional water meters to automatic meter reading (AMR) and advanced metering infrastructure (AMI) systems. The attributes and benefits of AMR and AMI systems are discussed, along with the results of a survey of the expectations and experiences of California water agencies that use these technologies. The project provided an opportunity to demonstrate and monitor the performance of time of use water meter technology at a California water agency as a viable demand-side option for other water agencies in California and elsewhere to reduce on-peak electrical demand by encouraging their customers to shift water use away from peak electrical demand periods. The report also conveys the decision-making process of one California water agency, the Coachella Valley Water Agency, in selecting an AMR system.

Keywords: Public Interest Energy Research (PIER) Program, water, water agencies, water utilities, AMR, automatic meter reading, AMI, advanced metering infrastructure, smartmeter, TOU, time-of-use, water profiles, leak detection

Executive Summary

This report provides an overview of the capabilities, attributes and benefits of automatic meter reading and advanced metering infrastructure systems, and provides the results of a survey of the expectations and experiences of users of these technologies in California. The purpose of this research project under the Energy Commission Public Interest Energy Research (PIER) Program is to demonstrate the technical feasibility and effects of time of use water meters for California water agency customers. In contrast to the current practice of monthly volumetric water delivery tariffs, TOU tariff structures can provide new demand response opportunities. Of specific interest is the relationship between the electrical demand of California water agencies during electric utility peak demand periods, and the potential ability of water agencies to encourage their customers to shift or reduce their on-peak water use. In this situation, the electric utilities would receive the electrical demand reduction associated with the California water agencies' TOU water meters and rate structures.

Automatic meter reading consists of a water meter and a register or index that is capable of generating pulses corresponding to the water consumption, along with an associated time stamp. This provides time-of-use water consumption data. These systems are often called "smart meters." Automatic meter reading automatically collects data from water metering devices and transfers it to a central database for analysis and billing purposes. Advanced metering infrastructure begins with smart meters and adds two-way communication between the meter and the utility, and between the meter and the consumer.

California water utilities have a significantly higher rate of automatic meter reading system installations compared to the national average. More than one-half of California utilities have some automatic meter reading meters installed in their territories, compared with about one-quarter nationally. California water agencies are quite interested in the technology, with 75 percent of them planning on evaluating and/or installing automatic meter reading or advanced meter infrastructure systems in the near future.

There is an eclectic mix of water meter suppliers, with no single manufacturer having more than approximately a one-quarter share of the market. There is little brand loyalty, with almost 70 percent of California water agencies considering automatic meter reading manufacturers other than their current suppliers.

The predominant criterion used by California water agencies in selecting automatic meter reading systems is price, followed closely by dependability, and then customer support and battery life. Water industries, on the other hand, see expected battery life as the primary concern when selecting automatic meter reading systems.

Over 80 percent of automatic meter reading system installations were motivated by the perceived benefits of the technology. This is in contrast to other motivations, such as new California water meter requirements or the natural replacement of aging water meters. Currently, beneficial administrative impacts are cited as the primary reason for the selection of these systems. The foremost administrative benefit expected from automatic meter reading is

the reduced meter reading costs, followed by the more efficient billing process and improved customer service. Following administrative benefits in importance are operational benefits such as increased safety and security for personnel, and the use of automatic meter reading in conservation programs and loss detection. The specific operational benefits of automatic meter reading are expected to change as these systems evolve and as operators become more familiar with the relevant technologies. Changes in tariff design will also influence the operational benefits of automatic meter reading systems. As water conservation becomes increasingly important in California, it is possible that more water utilities will switch from traditionally designed tariffs to water budget tariffs.

The Coachella Valley Water Agency is the host water utility for the smart meter demonstration associated with this project, and their decision making process in selecting the technology is also discussed. The Coachella Valley Water District has been evaluating automatic meter reading technologies for the past five years. The district assessed various manufacturers and technologies for dependability, years of company experience, price, support, warranties, transmitter range, software compatibility, ease of installation, storage of information, sophistication of technology, battery life, and system compatibility with existing conditions. Based on the Coachella Valley Water District's analysis, eight manufacturers were invited to present on their particular products or applications related to automatic meter reading. The Coachella Valley Water District narrowed this group of eight down to four meter vendors. After visiting these manufacturers and their customers, the district decided upon one supplier as having the most reliable and easily adaptable equipment as well as superior service and support for its needs.

Currently at the Coachella Valley Water District, automatic meter reading meters are installed in locations where the task of manually reading traditional meters takes too much time or is hazardous to the meter reader. In new housing developments, the determining factor in the choice of whether to install AMR meters is a combination of the number of water meters and the proximity to existing AMR meter-reading routes. For this project, which is titled "California Time-of-Use Water Meter Case Study," the Coachella Valley Water District will use the same automatic meter reading technology as it uses in the rest of its system.

This report, *Smart Meters and California Water Agencies: Overview and Status*, is the interim report for project 500-07-022, **"**California Time-of-Use Water Meter Case Study**"**. This project addresses the technical feasibility and potential impact of time-of-use meter installations for water agency customers in California. It consists of the following three tasks:

Technical background: This task addresses the technical parameters that are associated with time-of-use water meters. The background report consists of a summary of time of use water meter options, their availability and characteristics, and the decision-making criteria used by water agencies in selecting these meters. This report, *Smart Meters and California Water Agencies: Overview and Status*, is the technical background report for the project.

Time of use water meter installation and operation: This task establishes a representative time-of-use water monitoring program where TOU water meters are installed for a variety of

customer classes. This task also develops the mechanics of obtaining and assessing time of use water meter information.

Impact of customer time of use meters: This task evaluates the effects of time-of-use water meters and incentives on water consumption for the representative members of customer classes during peak demand periods. It also assesses the resultant shift in peak water agency electrical demands.

The project started in May 2008 and is scheduled for completion in March 2010.

1.0 Introduction

Water utilities face a host of issues: droughts and climatic variations that affect water supply, rapidly rising operating costs, demands for increasingly expensive investments in fresh water and wastewater treatment, heightened customer expectations for service and environmental stewardship, increasing energy costs, and the need to replace aging water infrastructure. These issues have spurred interest among water suppliers in managing demand, capturing all revenue, minimizing distribution system and customer water losses, and improving customer support and access to information. Changing the metering systems of water suppliers is a primary tool to accomplish these goals.

The traditional water meter, called a volumetric meter, simply records the volume of water used by a customer. In contrast, automatic meter reading (AMR) is a technology that automatically collects metering data and transmits it to a central database for analysis and billing purposes. AMR is an offshoot of the major meter restructuring occurring in the electric and natural gas industry. These new types of meters are generally called "smart meters." Detailed water usage data can be collected continuously at regular intervals (for example, every 30 minutes) and read remotely via an automated process and then sent to the utility's management and billing system. AMR can consist of a number of methods and technologies. These can range from simple drive-by meters, where a human meter reader cruises down the street and automatically downloads the meter data, to units that are equipped with direct one-way communications with the water utility.

Advanced metering infrastructure (AMI) begins with smart meters and adds two-way communication. These communication links can exist between the meter and the water utility and between the meter and the consumer. Two-way communication allows for several new abilities. In addition to providing water use readings, AMI meters can receive and often act on instructions sent from the utility or from the consumer.

Water utilities realize many benefits when they switch from old, manually read meters to AMR/AMI systems.

These benefits include:

- Increased revenue from previously unaccounted-for water

  As water meters age, particularly the mechanical types, they begin to physically wear out and lose accuracy. Older water meters underestimate water consumption, so one immediate benefit of meter replacement is that water previously not recorded by these inaccurate meters is now captured by the newer meters and billed to the customer.

- Reduced meter reading costs

  Most water utilities still employ human meter readers who walk up to every meter pit, manually read the meter, and record the water use. By deploying AMR systems, water utilities can require fewer meter readers and significantly reduce costs. Even a simple electronic or offsite meter reading system, in which a handheld device equipped with a

radio reads meters from a distance, will save substantial labor. Automation can reduce or eliminate meter reading costs such as salaries, benefits, vehicle costs, cellular phone expenses, obsolete handheld meter reading systems, maintenance, and other general overhead expenses.

- Safety and security benefits

  As more crews are sent on the road, more opportunities for accidents exist. Security for both employees and customers is crucial. For instance, some meter reading routes require a two-person crew due to safety hazards such as unfriendly dogs and physical difficulty in accessing water meters. The deployment of AMR systems can result in fewer employee injuries and can be particularly effective in areas with fenced yards, dogs, intrusive landscaping, and in rural areas with long distances between meters.

- Reduced greenhouse gas emissions

  AMR systems require fewer vehicles in the meter-reading process. This reduces pollutants, dust, and greenhouse gas emissions.

- Help in identifying and pinpointing customer and system losses

  Too often, water leaks are found months after they start. Generally, leaks are found during investigations in response to billing disputes. AMR can allow for much more rapid leak identification on customer premises, by monitoring water consumption once all water systems are turned off, and also in water distribution systems by comparing meter readings at various points in the system.

- Enhanced monitoring of system integrity

  AMR and AMI systems are useful in monitoring the integrity of water distribution systems. For instance, backflow monitoring can indicate a compromise in system integrity. Such problems may require disinfection or orders to customers to boil their water. In a system where large and erratic water flows occur, the ability of a water utility to rapidly detect system events is crucial for an effective response.

- Improved conservation and efficiency

  AMI-based consumption data has a tremendous potential to augment and support water utilities' conservation programs. Consumption data aids in discouraging leaks, responding to short-term droughts and long-term water scarcity, and creating and implementing innovative conservation programs. Interval water usage data, also known as time-of-use (TOU) data, allows a water utility to design sophisticated usage rates. These rates can more closely track TOU costs, such as the increased pumping required during peak periods, and can help encourage conservation. TOU data also enables the creation of customized rates for particular customers.

  Additionally, AMR allows a water utility to monitor compliance with local water restrictions during any time period. These restrictions may involve landscape irrigation,

non-essential water use during daylight hours, or odd/even day outdoor watering requirements.

The ability of AMR systems to collect water consumption data at frequent time intervals significantly aids in water conservation efforts and also allows utilities and customers to access consumption profile data for many purposes. These uses can include education as well as conservation program compliance monitoring and enforcement. AMR systems also have the ability detect continuous flows that often indicate a leak at a customer's premises. Additionally, these systems can provide meter readings at precisely the beginning and end of certain time periods. This ability of AMR can support the creation of seasonal and other TOU pricing structures.

AMR also finds many uses in submetering. Submetering is a technology provides individual metering capability to previously mass-metered locations such as condominiums, apartment buildings, industrial facilities, stores, and offices. It can record the water consumption of individual system subcomponents such as swimming pools, irrigation systems, water-cooled air conditioners, and commercial cooling systems. Submetering systems allow industrial facility owners to monitor individual processes to detect wasteful practices and faulty equipment. The capabilities of submetering and the technology's well-documented efficacy in water conservation make it a particularly powerful application for AMR.

Water utilities are also interested in AMR and AMI systems as a consequence of these systems' ever-decreasing costs. Capabilities such as two-way communication and frequent TOU meter reading can help water utilities to further reduce expenditures, monitor their systems, conserve water, and keep customers informed.

The remaining chapters of this report will provide an overview of water meter technology and its various suppliers. This report will describe the drivers encouraging the change to AMR systems and will illustrate some of the attributes and benefits of the technology. It will also provide the results of a survey of the expectations and experiences of California water utilities that use AMR and AMI systems. Finally, this report will convey the decision-making process of the Coachella Valley Water Agency, the water utility that hosted the smart meter demonstration associated with this project.

2.0 Water Meter Overview

2.1. Types of Water Meters

Several factors influence the selection of water meters. These factors include the flow measurement methods of the meters, the varying types of end users, the required flow rates, the accuracy requirements, and the experience and preferences of the water utility. Three basic types of meter design have been in the mainstream for many years. These types are displacement (volumetric) meters, turbine (inferential) meters, and electromagnetic meters.

Displacement meters are the most common in residential and small commercial applications. These cold water meters are commonly called "positive displacement meters" and can be manufactured from plastic, bronze, or "low lead" brass. They are appropriate for applications that require direct readings of the total volume of water that has passed through the meter. These meters can operate using one of two mechanisms: an oscillating piston, or a nutating (wobbling) disc. Both types require water to move the piston or disc, and each oscillation represents a known volume of water. Thus, a fixed number of oscillations can represent one gallon, one cubic foot, or one cubic meter. Movements of the piston or disc are transferred by a magnetic drive to a direct read register or to an appropriate pulser. Positive displacement meters can be installed in any inclination except upside down. They are generally manufactured in 1⁄2-, 3⁄4- and 1-inch posit sizes, and 1 1⁄2- and 2-inch sizes are less common but also available. This type of meter is typically used in low to moderate flow installations.

Turbine water meters are inferential meters that operate by letting water pass through without changing the direction of flow. Water drives a helix rotor whose speed is directly proportional to the rate of flow through the meter. Turbine water meters are utilized where large volumes of water must be measured accurately. These meters are appropriate for direct read applications. To ensure high quality flow characteristics and minimal turbulence, the American Water Works Association (AWWA) and ISO Installation Procedures recommend that these meters be installed with 10 pipe diameters of straight pipe ahead of the meter and five pipe diameters after the meter. Turbine water meters are available in sizes 1-1⁄2 inches through 12 inches and are manufactured with a bronze or cast iron body with round flat-faced flanged ends.

Electromagnetic water meters have no moving parts and operate according to Faraday's principle of magnetic induction. They are commonly called "magnetic flow meters" or "mag meters." Water moving through the meter's magnetic field induces an electric current proportional to the velocity of the water. Mag meters have many advantages compared to other meter types. Their measurements can be accurate to within 0.25 percent, they can be powered by either AC or batteries, and they have stable long-term calibration. Additionally, they cause low head loss, make no noise, and contain no moving parts. A mag meter can be calibrated in U.S. gallons, cubic feet, or cubic meters and can indicate cumulative flow as well as rate of flow on its display. To ensure high quality flow characteristics and minimal turbulence, these meters require approximately three pipe diameters of straight pipe ahead of the meter and two pipe diameters after the meter. Mag meters are available in sizes ranging from 2 to 24 inches.

2.2. Registers

In addition to the meters themselves, there are several types of registers for water meters. These devices display the volumetric information measured by the water meter.

A standard register typically has a dial, which is similar to a clock face, and a set of odometer wheels. The sweep hand of the register is driven by a magnetic coupling between one magnet, which is attached to the measuring element and inside of the measuring chamber, and another magnet that is attached to the bottom of the register. Gears in the register convert the motion of the measuring element into the movement of the sweep hand, and gears also advance the odometer. Meters with standard registers are read by workers who look at the register and record the position of the sweep hand and the reading of the odometer.

There are also electronic registers that record water use electronically instead of by physical motion. These registers can be manufactured with liquid crystal as well as other types of displays. Typically, electronic registers are pulse registers that send a digital or analog electronic pulse to a recording device.

3.0 Drivers for Installation of New Water Meters

Two principal drivers have traditionally motivated the installation of new water meters. Existing meters naturally wear out and need replacement, and water metering requirements in California change so that previously unmetered customers require water meters.

3.1. Natural Replacement of Water Meters

Water meters and their registers lose accuracy as they age. Therefore, this equipment must be replaced every 15 to 20 years. The length of time that meters retain their accuracy depends on many factors. These factors include the quality of the water passing through the meter, the rate of flow, and the total quantity of water measured. Exact time frames for water meter decay are impossible to formulate because meters are typically exposed to varying ambient temperatures, water chemical compositions, and humidity.

Older meters understate water consumption. Consequently, replacing these meters will capture previously unbilled water and boost water and sewer utilities' revenue without increasing rates. Most studies conclude that residential meters should be repaired or replaced every 15 or 20 years. At this age, their accuracy will have diminished to the point that the cost of replacing a meter is less than loss of revenue associated with its continued use.

3.2. Water Metering Requirements in California

A number of cities in California have built infrastructures without water meters. Regulations now require all previously unmetered systems to eventually install water meters.

Since Jan. 1, 1992, State Water Code Section 525 has mandated water meter installation as a condition of new water service. Existing buildings were exempt from this legislation. The State did not require water meters to be used for billing specifically; it only required that the meters be installed. The Water Code mandated that the cost of the new meters will be paid by the water users. This provision contained several exceptions: It did not apply to systems that served fewer than 15 connections that were used by yearlong residents, to systems that regularly served fewer than 25 yearlong residents, or to single-well systems that served single-family homes.

In September 2004, Governor Schwarzenegger signed AB 2572 (Kehoe, Chapter 884, Statutes of 2004). This bill mandates the installation of water meters on all water connections that were established before 1992 and requires all metered customers to eventually be billed based on the actual volume of water delivered. Beginning January 1, 2010, the state requires water customers who have meters to be billed according to their water consumption. Additionally, the state requires that by 2025 all water users in California must be fully metered and billed based on their water consumption.

The California State Legislature was motivated by the "primary interest" of its constituents to enact the water meter requirements found in Sections 520-529.5 of the California Water Code. Section 520 reads:

> "The Legislature hereby finds and declares that, pursuant to the primary interest of the people of the state to put the limited available supplies of water in this state to beneficial use to the fullest extent of which they are capable, and to prevent waste, unreasonable use, or unreasonable method of use, it is necessary to determine the quantities of water in use throughout the state to the maximum extent that is reasonable to do so."

Section 521 proceeds to stress the necessity of eliminating water waste and unreasonable use and explains how water meters are integral to this effort.

Many California water suppliers receive their water from the Central Valley Project, a federal water project owned and operated by the United States Bureau of Reclamation. The Central Valley Project Improvement Act, signed in 1992[1], is a federal law that requires water metering for suppliers that receive water from this project.

Similarly, Section 526 of the California Water Code mandates that on or before March 1, 2013, urban water suppliers[2] that receive water from the Central Valley Project are to install meters on certain service connections. All connections to residential and nonagricultural commercial buildings that were constructed prior to January 1, 1992, must be metered. This requirement also mandates charging all users for their water consumption on or after March 1, 2013. The costs of the meters and installations are allowed to be recovered through rates, fees, or charges.

Section 527 of the California Water Code addresses urban water suppliers that do not receive water from the Central Valley Project. The section mandates that these water suppliers must install meters on all municipal and industrial service connections on or before January 1, 2025. Additionally, beginning on or before Jan. 1, 2010, these urban water suppliers must charge all customers who already have water meters based on the actual volume of water delivered.

Any water purveyor that becomes an "urban water supplier" on or after Jan. 1, 2005, shall install water meters on all municipal and industrial service connections within 10 years of meeting the definition of an urban water supplier. Within five years of meeting this definition, these purveyors must bill each customer for whom a water meter has been installed based on the actual volume of water delivered. These urban water suppliers may allow their customers to have one annual seasonal cycle of delay prior to being charged for the volume of water consumed.

The last provision under the new law requires that on or after Jan. 1, 2010, any urban water supplier that applies for financial assistance from the state for a wastewater treatment project, for a water use efficiency project, for a drinking water treatment project, or for a new or expanded water supply shall demonstrate that the applicant meets the foregoing requirements.

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1 http://www.usbr.gov/mp/cvpia/title_34/public_law_complete.html

2 Water Code Section 10617 defines an urban water supplier as "a supplier, either publicly or privately owned, providing water for municipal purposes either directly or indirectly to more than 3,000 customers or supplying more than 3,000 acre-feet of water annually."

Additionally, the California Urban Water Conservation Council produced a memorandum of understanding that was signed by 380 California water agencies[3]. In the memorandum, these water agencies pledge to develop and implement 14 comprehensive best management practices (BMPs) for water conservation. The BMP category entitled "Foundational: Utility Operations - Metering" (formerly known as BMP 4) is a list of water metering requirements and specifications. It includes the development of: 1) a census of all meters by size, type, year installed, customer class served, and manufacturer's warranty accuracy when new; 2) a currently approved schedule of meter testing and repair by size, type, and customer class; and 3) a currently approved schedule of meter replacement by size, type, and customer class.

3 http://www.cuwcc.org/mou/exhibit-1-bmp-definitions-schedules-requirements.aspx

The MOU as amended in December 2008 can be found at:
http://www.cuwcc.org/uploadedFiles/Resource_Center/MOU/MOU-08-12-10.pdf

4.0 Automatic Meter Reading (AMR) and Advanced Metering Infrastructure (AMI)

4.1. AMR/AMI Definitions

Automatic meter reading (AMR) is a technology that automatically collects data from metering devices and transfers it to a central database for analysis and billing purposes. This technology gathers data over a wide area from water meters and other devices at customers' premises, and sends it via telecommunications to a remote central location. The technique involves a water meter and a meter register or index that is capable of generating pulses corresponding to the flow of water through the meter. The electronic data stream from the register can contain the meter's current reading as well as additional information such as cumulative water consumption, peak demand, and alarm flags. Meters and registers that produce these data streams are generally called "smart meters." They provide numerous benefits over traditional meters. Detailed energy usage data can be collected continuously at regular intervals (for example, every 30 minutes), and the data can provide a good level of granularity. Below is an illustration of Datamatic's Firefly smart meter system. The system includes a meter reading application, mobile and fixed receivers, and a meter interface unit (MIU) that can be attached to virtually any existing water meter.

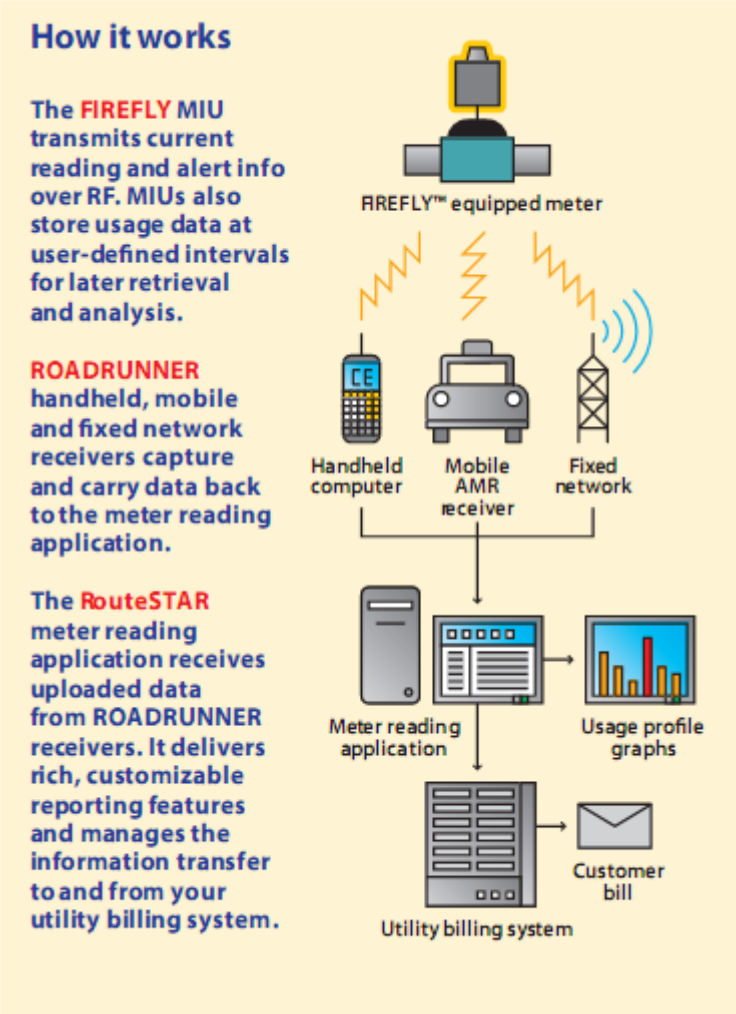

Figure 1. AMR System (Example Using Datamatic's Firefly Technology[4])

AMR can consist of a number of methods and technologies. These can range from simple drive-by meters, where a human meter reader cruises down the street and automatically downloads the meter data, to units that are equipped with direct one-way communications with the water utility. As a meter reader approaches a property that is equipped with a drive-by AMR system, the system uses a radio frequency transmitter to send signals containing the meter identification number and current reading to the employee's handheld device or truck-mounted computer. From here, the information is downloaded to the water utility's computerized billing system. In AMR systems that are equipped with one-way communications, a call or transmission is initiated at the customer's premises and sent directly to the utility.

In contrast, advanced metering infrastructure (AMI) consists of a sophisticated two-way communications system that provides additional capabilities. AMI begins with smart meters and adds the ability of two-way communication between the meter and the water utility, and

4 http://www.datamatic.com/firefly.html MIU = meter interface unit RF = radio frequency

between the meter and the consumer. This means that in addition to providing readings, AMI smart meters can also receive and often act on instructions sent from the utility or from the consumer. Furthermore, AMI smart meters can notify utilities or consumers of problems such as malfunctions, system leaks, or tampering detected in the meter.

AMI systems are composed of several elements. A telemetry interface unit (TIU) is connected to the smart meter to transmit information. A communication system or network is required to transfer data from the TIU to the water utility's offices. A meter data management (MDM) system receives, collects, and manages this data. Software that runs this system also forwards the data to the utility's billing and other information systems. Even a basic MDM system provides a database repository that automates and streamlines the complex process of collecting meter data from multiple points and delivering it, in the appropriate format, to utility billing systems. More comprehensive MDM systems can manage collection system integration, the validation of data, estimation and editing, data storage and retrieval, calculations and aggregation of data, and the exportation and interfacing of data to other parts of the water utility.

The two-way communication ability of AMI meters enables the water utilities to remotely access meter data and actually control the water meter. The benefits of a more costly a AMI system include on-request reads, remote modification of meter functionality, complex rate capability, real-time price signals, full-service connect/disconnect, meter performance and tamper detection, theft protection, and the ability to remotely deactivate a customer's service. AMI systems allow the water utility to send and receive information over the same transmission medium. Although AMI systems tend to be more complex and expensive than one-way AMR systems, their additional capabilities provide considerable benefits.

4.2. Benefits of AMR

The following table provides a summary of benefits for a water utility that are attributed to the installation of an AMR system.

Table 1. Benefits Ascribed to the Installation of an AMR System

- Increased revenue from previously unaccounted-for water
- Reduced meter reading costs, including both regular-cycle reading and special reads
- Safety and security benefits
- Reduced greenhouse gas emissions
- Improved customer service
- Help in identifying and pinpointing customer and system losses
- Help in detecting theft of service
- More efficient billing
- Improved cash flow
- Conservation and efficiency improvements
- Outage detection and management capabilities
- Intangible benefits

These benefits are described in more detail below:

Increased revenue from previously unaccounted-for water

As water meters age, particularly the mechanical types, they begin to physically wear out and lose accuracy. Older water meters underestimate water consumption, so one immediate benefit of meter replacement is that water previously not recorded by these inaccurate meters is now captured by the newer meters and billed to the customer. In one recent test, a city sampled 300 of its meters and found they were only 92% accurate. The author of the test report writes, "So, we were losing about 8%. Assuming that this sample was an accurate picture of water losses, it is estimated that the revenue loss (on a 13,750 water meter system) could be more than $400,000 for a 12 month period. "[5]

Reduced meter reading costs

Most water utilities still need human meter readers who walk up to each meter, manually read it, and log the water use. Costs for manual reading typically range from $.50 to $1.50 per read. Depending on labor costs and the distance between meters, costs can be as high as $3.00 per read. With the implementation of AMR, meter readers no longer have to enter patrons' properties or businesses on a monthly basis to obtain readings. This application of AMR systems can reduce costs substantially.

Other costs associated with manual meter reading that are virtually eliminated with automation include salaries, benefits, vehicle costs, cellular phone expenses, handheld meter reading systems, maintenance, and some general overhead expenses.[6]

On average, manually providing a special meter read can cost a utility from $15 to $30 or more per read. Unscheduled meter reads can cost $50 - $75 per truck roll. Manual reads are done upon the move-in or move-out of a building tenant. Some utilities estimate final reads, but most are required to obtain an actual read within just a few days of the request. On-request reads, such as those that arise from billing disputes, are another type of unscheduled meter read. The savings resulting from this application of AMR can be significant. An Itron technical paper states that "mobile AMR also provides an effective tool for obtaining off-cycle reads and saving significant money through the reduction of service calls and work order processing." [7]

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5 "Upgrading Water Meters Can Pay Off" by Nikki Stiles, *Water Efficiency*, Vol. 3, No. 4, May/June 2008, pg. 32.

6 For example: "With the AMR system complete, Denver Water expects that it will be able to reduce its fleet of 33 meter readers and 33 vehicles to a single meter reader with one vehicle." – A Comparative Study of Urban Water Use Across the Southwest, Western Resource Advocates, pg. 27.

7 "Slashing Off-Cycle Reading Expenses with Mobile Automated Meter Reading," Itron Technical Paper 100669WP-02, December 2006

Safety and security benefits

As more crews are sent on the road, more opportunities for accidents exist. Security for both employees and customers is crucial. For instance, some meter reading routes require a two-person crew because of safety concerns such as unfriendly dogs or physical difficulty in accessing water meters. The deployment of AMR systems will result in fewer employee injuries.

Reduced greenhouse gas emissions

AMR systems require fewer vehicles for the meter reading process. This reduces dust, pollutants, and greenhouse gas emissions.

Improved customer service

Utilities receive numerous calls each month related to a variety of topics. When customers' satisfaction in a utility decreases, the result is an increase in complaint calls. Since water utilities have limited resources available for answering customer calls, a lower level of complaints means that utilities can more effectively address other customer concerns.

Having customer data readily available in electronic forms significantly improves customer service. The ability to provide timely and accurate responses to billing questions can resolve a number of issues. AMR allows utilities to quickly and efficiently provide the kind of service customers expect, along with the ability to answer customer questions about their bills with certainty.

Other customer service benefits associated with AMR are numerous: Billing disputes can be resolved without manual re-reads; initial and final meter readings for opening and closing accounts are readily available; "estimated billing" caused by unavailable meter readings is eliminated, potential high consumption can be spotted before customers receive an expensive bill; and bill investigations can be resolved by showing daily (and more often, hourly) customer usage. See Appendix A for usage profile examples.

"Estimated bills" currently create problems for customers and utilities. If the estimated usage is too high, customers will complain not only about paying early but perhaps also about paying a higher average rate. If the estimated usage is too low, then a following bill based on actual readings will be unexpectedly high. Often in these situations the utility's customer service department gets calls, bill adjustments are made, and customers are unhappy. The ability of AMR to make "estimated bills" virtually disappear is a benefit for all parties involved.

Help in identifying and pinpointing customer and system losses

Too often, water leaks are determined months after they start. Generally, leaks are found due to investigations in response to billing disputes. AMR can allow for very rapid leak identification both on customer premises, by monitoring water consumption when all water systems are turned off, and in water distribution systems by comparing meter readings at various points in the system. In the journal *Water Efficiency*, Peter Hildebrandt writes:

> "Time-synchronized endpoints make a huge difference for utilities who quickly realize they can compare metered consumption with the amount of water actually placed into the system. If the system is fully metered and there is a difference with that time interval, water loss calculations may be done virtually on a daily basis. … This capability, when combined with our other technologies, enables utilities to localize, measure, pinpoint, and correct distribution system leaks more cost-effectively. "[8]

Appendix A provides several examples of using AMR for leak detection.

Help in detecting theft of service

AMR allows for tamper detection and water theft reduction by accurately logging water consumption and identifying where water is being used without being billed. A water utility can use AMR data to focus on inactive accounts and ensure that there is no unauthorized usage on these accounts. This helps the utility determine if services have been illegally restored. Additionally, the existence of automation alone is known to deter theft of service. By simply advertising the automation of water meters and their tamper monitoring features, utilities are able to deter potential theft. Usage data, at utility-selected intervals, can be programmed to assist in locating tampering and leaks.

More efficient billing

Streamlining the billing process, which has traditionally involved manually reading meters and physically transcribing data to the billing system, can greatly reduce employee time as well as errors. By having all meter data read electronically, the read-to-bill turnaround time can be cut drastically.

An AMR solution can significantly reduce the number of estimated reads and the costs associated with re-billing accounts. The exceptional accuracy of AMR systems substantially reduces re-bill costs, especially those associated with expensive re-bills for commercial and industrial customers.

Some utilities provide master or summary billings to customers who own multiple businesses within the service area. Typically, this billing process requires a utility to retain bills until every summary account for a particular month can be read. Some utilities have routed their system to obtain these reads within a short time period. Other utilities are required to wait longer, until all accounts have been read, before issuing the master bill. AMR allows for flexible reading schedules and thereby avoids delays in the summary billing of commercial accounts.

Improved cash flow

The automation of water metering systems offers new opportunities for utilities to increase their cash flow. Utilities that bill on a quarterly or bimonthly basis, often because of the high costs of traditional meter reading, typically have increased accounts receivable issues that are associated

8 "Automatic Water Meter Reading Technology" by Peter Hildebrandt, *Water Efficiency*, Vol. 2, No. 1, January/February 2007.

with larger customer bills. This is in contrast to customers who are billed monthly and receive smaller, more manageable bills.

When any bill is disputed, the long time interval between accurate reads makes it that much more difficult to collect the full amount in arrears. As a consequence of the increased workload associated with disputed bills, some utilities find that they are unable to keep crews on scheduled reading cycles. This causes difficulties in hiring additional personnel. Utilities that are unable to keep crews on scheduled reading cycles may occasionally extend billing cycles to beyond the normal 30 days, which again creates a situation where bills become more difficult to pay.

Policies at some utilities allow some customers to delay their payments pending a re-read for a high or low bill investigation, and this can negatively affect a utility's cash flow. Re-reads are substantially expensive to obtain manually. However, re-reads can be handled very efficiently by utilizing a mobile collector that is enabled with GPS mapping functionality. Using mobile AMR, a water utility can then generate a special read file and obtain these readings quite easily.

Conservation and efficiency improvements

A California Urban Water Agencies report estimates that simply installing meters in water service locations that were previously unmetered typically results in a 15% reduction in water use.[9] Having access to interval usage data gives a utility many options for water conservation. The water utility is able to design much more sophisticated rates that can more closely track costs. This supports the creation of customized rates for large customers and other groups and can also encourage water conservation.

The cost of supplying water can vary seasonally and daily. AMR systems afford utilities the ability to offer time-of-use (TOU) pricing to customers. This encourages usage in off-peak times. Without interval consumption data, a utility cannot offer pricing that encourages these alternative usage patterns.

AMR also allows water utilities to monitor compliance with local water restrictions and mandatory water use cutbacks. It can help to enforce restrictions against outdoor watering, restrictions against non-essential water use during daylight hours, and mandatory odd/even day outdoor watering. Appendix A provides an example of this functionality.

Outage detection and management capabilities

Instead of waiting for customer calls to identify leaks, utilities can use AMR to quickly find where problems are occurring in their water systems. This allows for more efficient outage restoration.[10] For instance, an unexpected drop in water main pressure can be a triggering event that alerts a water utility to a possible line rupture.

Intangible Benefits

9 *Urban Water Conservation Potential - Final Report*, California Urban Water Agencies, August 2001

10"Smart Metering for Water Utilities," Oracle Utilities White Paper, November 2007

AMI improves customer service, increases customer confidence in water invoices, and makes consumption information available to customers and water utilities. These benefits are valuable, yet somewhat unquantifiable. However, over time the availability of consumption information can lead to improved revenue forecasting. Correlating the detailed consumption information with production data, expected billings, and climate variables can powerfully enhance a utility's forecasts. See Appendix A for an example of a detailed customer profile.

4.3. Results of AMR Installations

There have been a host of evaluations of AMR results in water utilities[11]. The following is just one of a multitude of reported results associated with a water utility's installation of an AMR system:

> The new technology gave the board options that they never had before. Initial expectations were far exceeded and the following benefits resulted:
>
> * Leaks are identified in a timely manner because of monthly billing, reducing costs for adjustments and unused water;
>
> * The accuracy of the readings has reduced the number of re-reads, reducing the number of work orders and associated costs in both the maintenance and meter reading departments;
>
> * Monthly billing enabled the board to reduce due dates from 21 to 10 days, increasing cash flows and decreasing bad-debt write-offs;
>
> * Monthly billing reduced the cost of printing and mailing delinquent notices;
>
> * Monthly billing also created a 30% increase in the number of customers signed up for bank draft, reducing mailing costs and guaranteeing cash flows on specific days; and
>
> * Read-times were reduced so dramatically that the board was able to lower its meter reading staff from nine to four employees, enabling them to balance both work flow and cash flow. Some of these meter readers were reassigned (or) retrained to (work in) field service positions and the others took early retirement, resulting in reduced costs in salaries, employee benefits, uniforms and mileage.
>
> The issue of unaccounted-for water was not one of the board's original objectives because they had completed a changeout just four years earlier. As part of this project they replaced meters older than 10 years and lowered unaccounted-for water by 3%.
>
> Source: *Water & Wastes Digest*, Vol. 45 Number 1, January 2005.

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11 For example, "Sum Benefits of AMR" by Don Talend, *Water Efficiency*, Vol 2 No 6, November/December 2007 Additionally, the PennWell series of water magazines Water & Wastewater International, WaterWorld, Industrial WaterWorld, Urban Water Management and Water Utility Management (available at: http://www.pennnet.com/Search/index.cfm?pc=ENL) have thousands of articles detailing AMR installations in water utilities.

4.4. Evaluation of AMR/AMI

The organizational impact of AMR and AMI systems reaches far beyond the savings resulting from avoiding manual meter reads. In order to truly understand all the benefits associated with an automation system, a water utility must determine all the potential operations affected by AMR. Due to the unique nature of each water utility, there is no generic business case to determine whether a utility should deploy a system.[12] However, some important parameters should be evaluated.

The elements of a financial analysis of AMR/AMI should include:

* Capital costs including meters, meter interface units, networks, installation, control computer hardware and software, and project management. It should be noted that many AMR/AMI interface units are compatible with existing meters. This means that meter replacement, aside from that associated with aging equipment, is often optional.

* Labor savings, including the reduction in staff hours for meter reading and related customer service, as well as savings on vehicles and other miscellaneous costs associated with meter reading.

* Operation and maintenance of the system, including telecommunications costs, labor and vehicle costs, repair of system components, and battery replacements.

* Increased revenues resulting from reducing system losses or replacing older, inaccurate meters[13] .

An ongoing Water Research Foundation project entitled *AUTOMATIC METER READING - Best Practices for Selection, Acquisition and Implementation* (Research Project #4000) develops a set of best practices and guidance documents for the purposes of AMR technology assessment, business case development, system procurement, and implementation planning. The project also explores and attempts to quantify the benefits of AMR related to customer service, conservation, and distribution system management. It will gather perspectives from a variety of utilities that already have or are currently undertaking AMR installation, and it will also gather published literature and vendor information. The project involves:

- Detailed case studies of AMR projects.
- A review of current and emerging technologies and applications.
- Pilot tests of AMR-based leak and backflow detectors.
- An assessment of the conservation potential of AMR.
- Developing a "toolkit" for AMR technology assessment.
- Developing a business case template.

12 "Untapped Resources", by Rosalie Leposky, *Water Efficiency*. Elements 2009, Vol. 3, No. 3, 2008.

13 http://www.cognyst.com/amr/

- Identifying critical success factors for AMR implementation.
- Administering workshops to develop and solicit feedback on evaluation and planning tools[14].

4.5. Risks of AMR/AMI

Any event that reduces the expected benefits, increases the anticipated costs, or reduces the expected useful life of an AMR project will have impacts on its cost-effectiveness.

Batteries: Battery life is a critical issue for most water meters that communicate their readings. Unlike some AMR electric meters that already have power for their communications, other water meters are typically remote from a power source. These meters generally rely on batteries. Most AMR units are designed to operate at low power, with short bursts for data transmission. Battery life depends on transmission duration, transmission power, and how often the transmissions occur. Battery life also depends on environmental conditions such as fluctuations in temperature. Most AMR system manufacturers will guarantee a battery life of 15 years or more, but none of these systems have been in place long enough to determine if this is a realistic assumption. Changing out meter batteries is a costly exercise and will reduce the cost savings.

Lack of Standards: The AMR/AMI marketplace is rapidly changing. New systems, vendors, and products are being introduced constantly. No established standards exist yet for AMR. In lieu of standards, many AMR manufacturers have designed their systems to be interoperable with most existing water meters. If a water utility or energy service provider wants an AMR system that supports multiple makes of meters, it must demand interoperability in its Request for Proposals. The lack of standards also means that many meter data management (MDM) tools must be tailored to one specific AMR system and are not flexible enough to include multiple inputs and outputs.

Technological Obsolescence: While AMR meters are often interchangeable, an AMR/AMI system's incorporation of telecommunications and information technologies is generally vendor-specific. As data analysts gain more experience with the increased granularity of water data, water utilities may find additional uses for this detailed data. A water utility's greatest protection from obsolescence is to take into account its future needs as it considers prospective AMR/AMI systems and their specifications, to strive for "open" architecture and interoperability among system components, and to insist on extended support from prospective vendors.

AMR/AMI Vendor Stability: As the next section shows, there are a number of meter and system suppliers that offer water system AMR/AMI services. The AMR/AMI industry is undergoing a period of rapid growth and consolidation. In addition to some of the traditional names in the water meter business, there are a host of new entrants into the market. Some of the current

14 http://www.waterresearchfoundation.org/research/topicsandprojects/ProjectUpdateIndex.aspx?pn=4000

manufacturers and suppliers are not likely to stay in business as the market matures. This situation requires water utilities planning to purchase an AMR/AMI system to exercise caution in their selection process, and to build reasonable safeguards into their contracts.

4.6. Current Status of AMR in Water Utilities

There are about 14,000 water utilities in the United States that have greater than 500 service connections each. In all, about 83 million service connections exist in the United States. The majority of water meters in the US are still read manually; only 28 percent of water systems have AMR installed.[15]

Howard A. Scott, Ph.D., produces the Scott Report[16], which is a series of statistical analyses of the AMR industry. This report states that the conversion to AMR in the drinking water industry lags behind the gas and electricity industries.

However, the report emphasizes that the water industry is rapidly embracing AMR. Of the 10,000 AMR conversion projects now underway in North America, 4,000 projects are for water meters. Dr. Scott predicts that the total number of automated water meters will surpass the number of automated meters in the gas industry within the next three years. In 2007, 5 million AMR units were shipped to North American water utilities, and currently more than 40% of all water meters in North America are being read by AMR technology[17].

15 "The Successful AMI Marriage: When Water AMR and Electric AMI Converge", by Ralph Abbot, *WaterWorld*, May 2008.

16 http://www.thescottreport.com/

17 "Water Utilities Begin the Shift to Advanced Metering Infrastructure", by Don Schlenger, *Waterworld*, August 2008: http://www.waterworld.com/index/display/article-display/337798/s-articles/s-waterworld/s-volume-24/s-issue-8/s-amra/s-water-utilities-begin-the-shift-to-advanced-metering-infrastructure.html

5.0 AMR Meters and System Manufacturers and Suppliers

Most AMR water meter manufacturers also provide AMR/AMI services for electric and gas utilities[18]. Out of the numerous AMR water meter suppliers, relatively few have produced very large volumes of equipment. Only four manufacturers have shipped more than 2 million units. Cumulatively, six manufacturers have shipped more than 1 million units, nine manufacturers have shipped more than 100,000 units, fourteen manufacturers have shipped more than 10,000 units, and nineteen manufacturers have shipped more than 1,000 units.

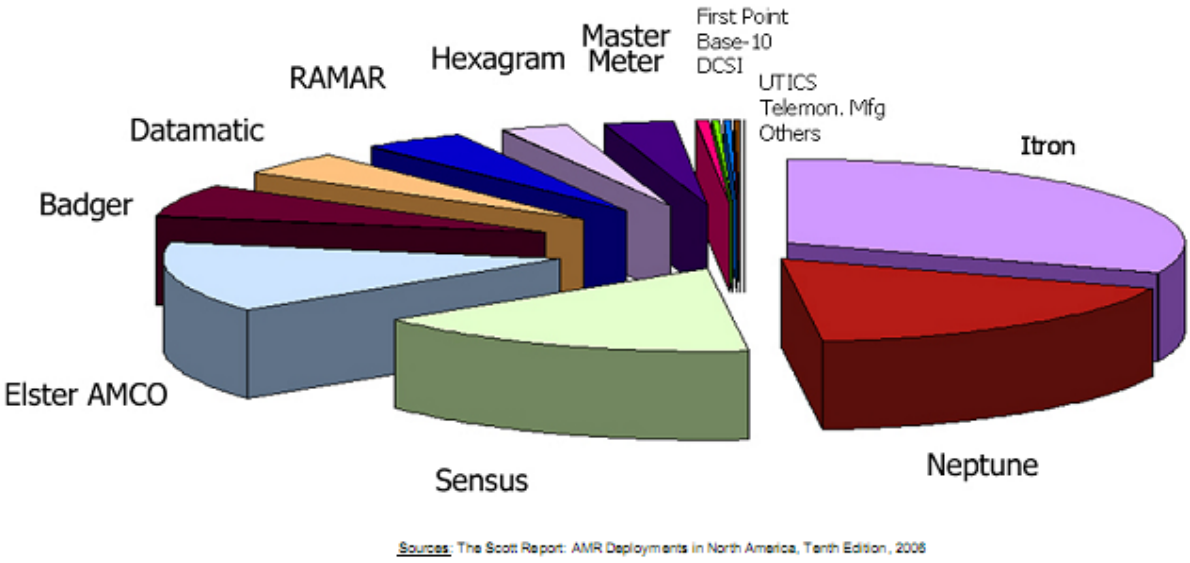


Figure 2. National Market Share of Water Meters

Below is a brief summary of water meter AMR manufacturers and suppliers:

Itron (http://www.itron.com/) provides both flow meters and AMR systems. Itron has two new dual-mode AMR endpoints that are compatible with meters from all leading manufacturers: the 50W ERT module for indoor sets and the 50W-1 module for pit-set meters. The units can operate in either "wake-up" or "bubble-up" mode. In wake-up mode, the ERT receives a radio wake-up signal from an Itron handheld, vehicle-based, or network data collection device before transmitting its water consumption and tamper data.

Sensus (http://www.sensus.com) provides both flow meters and AMR systems. Invensys Metering Systems, formerly Sensus Technologies Inc., is a supplier of automatic meter reading systems. The company's AMR systems include the TouchRead, RadioRead, PhonRead, and SubMetering systems, all of which incorporate absolute-encoder registers. Its Windows-based AutoRead Software is capable of transferring meter-reading data into a utility's billing system.

18 Taken from "Water Meters and Automatic Meter Reading", by Daniel Duff, *Water Efficiency*, Vol 1 No 2, November/December 2006.

Neptune Technology Group (http://www.neptunetg.com/) is a supplier of complete AMR systems to a variety of utilities. Neptune's suite of interrogators (both handheld and mobile) is compatible for use with any utility's R900 metering application. The company's meter reading hardware includes the compact CE 5320X handheld device and the MRX920 Mobile Data Collector, which is a laptop system that collects data via radio frequency and transmits it to the customer information system.

Elser AMCO (http://www.amcowater.com/) manufactures displacement, turbine, and magnetic flow meters. Its Aquamaster electronic water meter is designed to be a replacement for mechanical meters and provides higher-accuracy metering. Bulk metering is performed by AMCO's T3000 and T4000 class turbine meters, and a modified model C3000 provides for a compound metering system.

Badger Meters (http://www.badgermeter.com/) manufactures a wide assortment of meters for almost every industrial and commercial use. The Research Control Mag from Badger Meter is designed for municipal applications requiring extremely low flow metering, such as verifying the outputs of metering pumps. The Recordall Turbo series varies in diameter from 1.5 inches, which measures flows of 2.5 gpm to 200 gpm, to 20 inches which measures flows of 200 gpm to 19,800 gpm.

Datamatic (http://www.datamatic.com/) produces FIREFLY water meter interface units that attach to virtually any commercially available water meter in a matter of minutes. They utilize a unique optic sensor that needs no electronic output registers. This complete compatibility eliminates the meter changeout requirement. The data storage capacity of these meter interface units allows for the storage of 74 days worth of hourly meter readings. The data is managed by Datamatic's ProfilePLUS software system that provides analysis of consumption rates, conservation compliance, and leak detection. Datamatic's MOSAIC forms a self-healing mesh network by linking each meter to its neighbors, thus eliminating the need for a fixed network configuration.

Honeywell (https://buildingsolutions.honeywell.com/) has a Utility Solutions business that offers turnkey deployment services and performance AMR packages for its clients. The goal of performance AMR is to provide a self-funding system that is customized for each application. The upfront cost of installing the system is matched by the subsequent labor cost savings and overall efficiencies. Honeywell follows up with a suite of service offerings including system startup, full program management and administration, data system management, and safety training and practices.

Master Meter (http://www.mastermeter.com/) manufactures all types of flow meters along with compatible AMR systems. Master Meter offers a variety of metering and meter-reading systems, including multi-jet meters for residential applications, turbine meters for high volume utility measurement, and compound meters for utility applications. Its Dialog meter reading systems for utilities include automated electronic on-site reading, automatic telephone and direct-connect (LAN) reading, and fixed network radio frequency systems.

Transparent Technologies (http://www.transparenttech.com/) provides an AMR system that combines GPS with interactive AMR. The software is run on standard laptops, reducing the need for specialized hardware. Its database management software is open-source Microsoft Access. The mobile radio interrogator has enough memory to record the last 16,000 meter the readings. With readings taken hourly, this is equivalent to 21 months of water use data.

Radix International Corp (http://www.radix-intl.com/) has an international customer base and is a leading manufacturer of portable computing equipment for AMR applications. Radix is a manufacturer of equipment and hardware essential to the AMR operations. This includes its FP series of portable printers and printer interfaces as well as its FW series of handheld field computers that utilize PC DOS or Microsoft Windows CE Net operating systems.

Metron Farnier (http://www.metronfarnier.com/) specializes in high-end single-jet velocity flow meters. The Spectrum Single-Jet Meter from Metron Farnier is a single measuring element meter with the widest turndown range of any meter available to U.S. utilities. They have been designed to replace compound type and turbine type meters for commercial services. These meters feature a 1000:1 turndown ratio and superior low flow registration. Metron's newly developed line of handheld reading devices, meter interface units (MIUs), MIU interface software, readers, and AMR interface software are all compatible with its water flow meters. The company's data gathering handhelds are unique in that they rely on standard Palm units but utilize infrared technology for the signaling.

Liquatec (http://www.liquatec.com/) provides a line of flow meters and compatible in-line filters. The company's PMF series wall-mounted flow meters are constructed of durable acrylic and stainless steel. These cost-effective meters are fabricated using injection molding technology and provide metering from 0.2 gpm to 10 gpm.

Hexagram Inc. (http://www.electricnet.com/) specializes in fixed AMR systems. These systems include meter transmission units, data collector units, network control computers, and customer service and metering computers. Hexagram's Star system water meter interface units are compatible with pulse and encoder meters from all manufacturers.

Coronis Systems (http://www.coronis-systems.com/) offers two different solutions for meter reading by fixed networks. The Local Wavenis area network is suitable for local wireless systems utilizing its technology through modules connected to a personal computer, and these networks can have a range of up to several kilometers. Complementing this local network is Coronis' Extended Wavenis area network. This allows networks to perform AMR functions over much greater distances using GSM modems or a server with WAN capabilities. Radio coverage can be extended through repeater modules.

Controlotron (http:// www.controlotron.com/), acquired by Siemens, manufactures several lines of hydrocarbon, industrial, chemical, and residential flow meters. The company uses exclusive Wide Beam transducers that provide accurate flow measures regardless of the type or temperature of the liquid being measured.

BIF (www.bifwater.com/) supplies flow meters for both the water and the wastewater industry. Its universal Venturi tubes are differential flow metering elements. Their dimensions and shape allow for the reliable measurement of flow.

RAMAR (http://www.ramartech.com/) is a designer and supplier of radio-based AMR systems. Since 1995, RAMAR has been providing mobile and fixed radio frequency based AMR systems for water, gas, and electric utilities worldwide. RAMAR systems are based on an "open systems" philosophy. Its products are designed to use standard interfaces and protocols in order to integrate into popular software and hardware platforms.

Firstpoint (http://www.firstpoint.com/) produces TDS-2 and TDS-4M Telemetry Interface Units (TIUs), which are data recording devices designed to deliver interval and time-of-use data as well as current (demand) readings. The low-cost universal 2-port and 4-port TIUs have extensive data logging capability, power outage recovery, and independent port/meter tamper capability. Customers can read any combination of encoded or pulse output meters automatically and at intervals of 5, 10, 15, 30, or 60 minutes, or daily.

Hersey Meters (http://www.herseymeters.com/) now has its Translator™Encoder Register available on the company's entire line of water meters. This register is available in sizes ranging from 5/8 in. to 12 in. The new register is a true absolute encoder. Combined with the TransPondIT™Radio Frequency Meter Interface, the register provides error-free meter reading.

Severn Trent Services (http://www.severntrentservices.com/) has introduced the SmartMeter™, an all-electronic residential water meter with no moving parts. At the heart of the new meter is a fluidic oscillator, which is a non-mechanical flow chamber that is combined with patented sensing technology to provide accuracy over the meter's full dynamic range.

ABB (www.abbwatermeters.com/) offers utilities a choice of meter reading technologies. The company partners with the leading reading systems manufacturers to complement its metering products with state-of-the-art electronic technologies. ABB encoder technology, launched in 1985, enables absolute interrogation of the register by hand-held readers or radio frequency systems. It offers the industry's only true six-digit encoding, with four-digit encoding also available.

Bermad (http://www.bermad.com/) produces the Model 910-P Hydrometer that combines a vertical turbine water meter and a diaphragm-actuated hydraulic control valve in a single valve body. This marriage of hardware measures fluid flow and provides a pulse output for computerized data capture and control, while simultaneously providing the control valve functions of closing, opening, and modulation for pressure control.

NexusData, Inc. (http://www.nexusdata.com/) The WA-TX family of wireless transmitters for water utility applications are the end-point units for the NexusData automated meter reading system. The modules operate in Fixnet™, the company's wireless wide area fixed network. Transmitted messages contain meter reading data, status, and online alerts. Readings can be transmitted in pre-selected intervals, typically daily.

Nertec Inc (http://www.nertec.com/) The TL401 and TL402 Telereadersfrom Nertec are designed for residential, commercial, and industrial water AMR applications. Based on inbound (call-in) telephone technology, the units use the telephone infrastructure as their meter-reading data conduit to the AMR station. They can read a majority of water meters equipped with an encoder, a pulse, or an auto-generator signal device.

Performance Meter (http://www.performancemeter.com/) Performance Encoder Type Retro-fit Registers allow utilities to cost-effectively utilize remote reading technology such as radio frequency AMR, "touch read", or remote registration without having to replace existing water meters.

6.0 California Water Utilities' Experiences With AMR/AMR

6.1. Survey of California Water Agencies' AMR Expectations/Experiences

The Association of California Water Agencies (ACWA) developed a survey on AMR/AMI systems (Appendix C) that was sent out to 450 water agencies in the state. Seventy-three water agencies provided complete responses to the survey.[19]

As Figure 3 shows, there is a considerable diversity of water meter suppliers in the California market, with Badger and Sensus each supplying meters for about one-quarter of the survey respondents. The "other" category of suppliers also accounts for about a quarter of this market. The majority of respondents who chose the "other" category stated that their system used a mix of water meters, and that no single water meter manufacturer was the predominant supplier. The small market share of Datamatic is also somewhat misleading. A number of water agencies are using Datamatic's Firefly technology, which attaches to an existing water meter supplied by a different manufacturer and provides AMR capabilities.

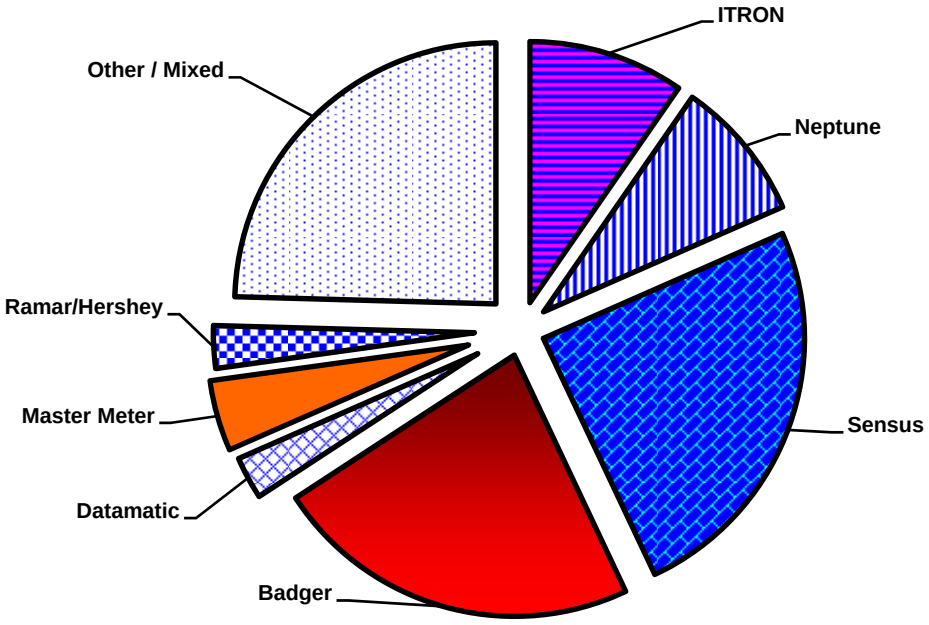


Figure 3. Predominant Water Meter Suppliers in California

Over one-half of the water agencies in California have some amount of AMR capability installed on their systems. Of the water agencies that have some AMR, over 34 percent of them have AMR as the dominant type of water meter in their systems. Another 42 percent of water

19 Appendix B provides a list of California water utilities, and those that have completed the survey are shown in red.

agencies use AMR meters in less than 10 percent of their systems. These utilities generally install the meters in hard-to-read locations, and the agencies may have been performing an evaluation of AMR capabilities at the time of the survey.

There is a significant interest in AMR. Seventy-five percent of the ACWA survey respondents stated that they are considering or already have plans to evaluate or install AMR in their systems.

Figure 4 shows the criteria used by the survey respondents to evaluate AMR meters. The predominant criterion is price, followed closely by dependability and then customer support and battery life. Compatibility with existing system connections and meters, as well as with existing billing software, was also a criterion that was cited by over one-half of the water agencies.

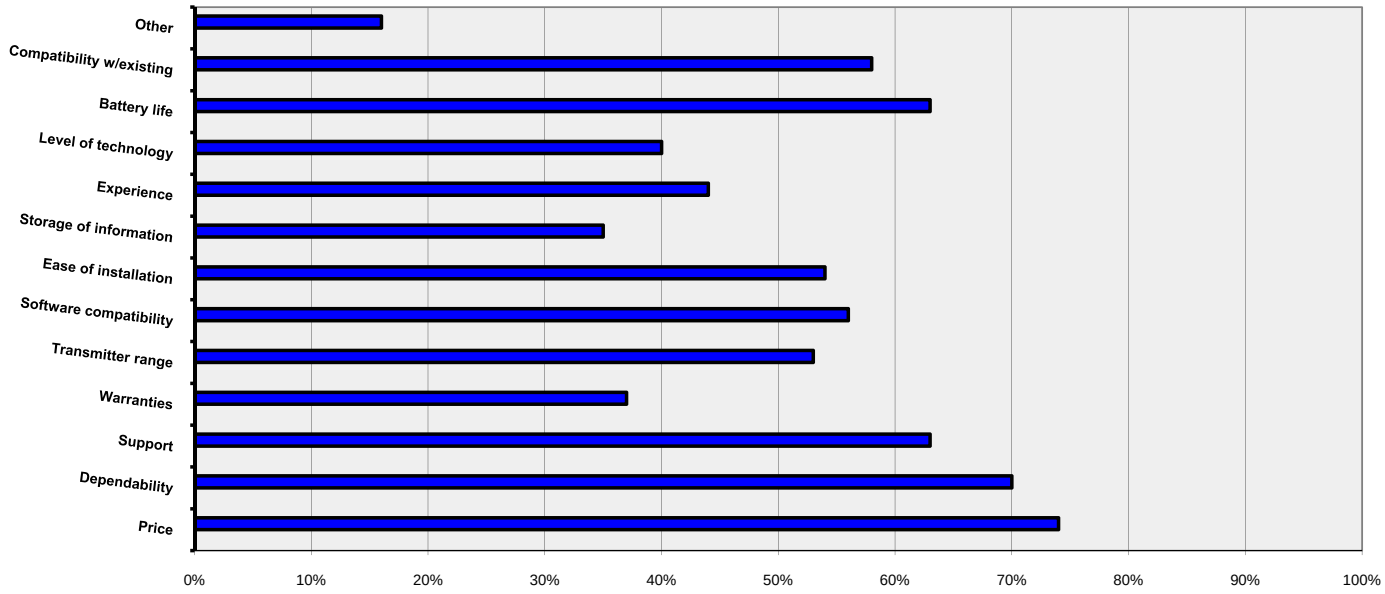


Figure 4. Evaluation Criteria for AMR Selection

There is little brand loyalty within the California water community. In keeping with their eclectic collection of water meter suppliers, 67 percent of the water agencies stated they would consider meter vendors different than the ones they currently use.

Over 80 percent of the AMR system installations were due to the perceived benefits of AMR. This is as opposed to AMR installations resulting from new California water meter requirements or the natural replacement of aging water meters, as discussed in Chapter 3.

Figure 5 shows the benefits expected from AMR. Beneficial administrative impacts were cited as the primary reasons for AMR system selection. The overwhelmingly dominant administrative benefit expected was reduced meter reading costs, followed by more efficient billing and improved customer service. Following administrative benefits in importance were operational benefits such as increased safety and security for personnel, as well as the use of

AMR in conservation programs and loss detection. The operational benefits of AMR are expected to change as these systems evolve and as operators become more familiar with the applicable technologies. Changes in tariff design will also influence this technology's operational benefits. As water conservation becomes increasingly important in California[20], it is possible that more water systems will switch from traditionally designed tariffs to water budget tariffs.[21]

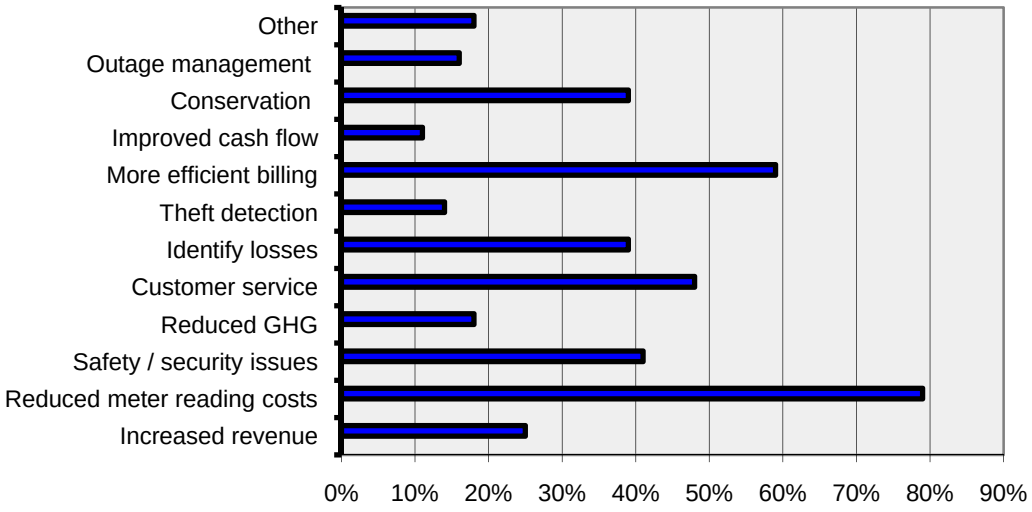


Figure 5. Expected Benefits of AMR

The primary concern about AMR within the California water industry was the expected battery life (Figure 6). Given that the primary benefit expected from AMR is reduced meter reading costs, the premature replacement of meter batteries would negate much of this expected savings. Justifiably, there is a high degree of concern in this area. The next most important concern about AMR was the cost of the systems.

Interestingly, the most common comment in the "other" category was that the water agency had practically no concerns about AMR and is planning to increase the penetration of AMR in their systems.

20 California has announced a policy to achieve a 20% reduction in per capita water use statewide by 2020. The drought in 2008 had forced voluntary and mandatory water conservation programs to be implemented in many parts of the state – particularly along the coast, in the Central Valley, and in Southern California.

21 For example, water budgets establish a water rate for each residential account based upon parameters such as lot size, number of inhabitants, size of landscaping area, and other variables.

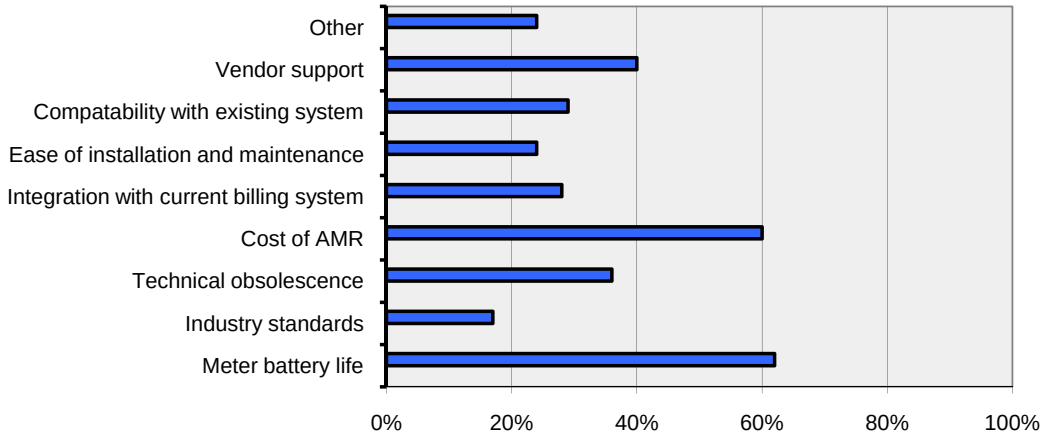


Figure 6. Concerns About AMR

6.2. Coachella Valley Water District (CVWD)

Prior to the board approval of an automatic meter reading (AMR) meter system selection, the Coachella Valley Water District (CVWD) dedicated five years to researching these systems. This included attending conventions, workshops, and seminars related to AMR technology. District staff from various backgrounds and departments formed a committee to evaluate the District's involvement. It was then determined that it would be in the District's best interest to proceed to the next level.

The committee evaluated the water meter manufacturers and technologies on the factors of price, dependability, support, warranties, transmitter range, software compatibility, ease of installation, storage of information, years of company experience, level of technology, meter battery life, and compatibility with existing infrastructure and conditions. The committee found that the benefits to the District of AMR installation included less time to perform each read, more accurate reads, a reduction of human errors in reads, a reduction of injuries due to environmental factors, reduced billing adjustments, and fewer estimated reads.

Eight different manufacturers were invited to make a presentation of their particular products and applications related to AMR. Three different metering methodologies, as well as eight different products with various techniques and warranties, were presented.

The field was narrowed down to four meter manufacturers. The final competitors were Badger, Itron, Master Meter and Ramar/Hershey. Members of the committee visited customers of the selected manufacturers and reported their findings. The committee decided, after careful evaluation of the District's criteria and of each AMR manufacturer, that Master Meter had the most reliable and easily adaptable equipment as well as superior service and support for the District's needs.

A pilot program was proposed for Board of Directors approval in August 2003. Staff recommended that AMR technology be installed for T.D. Developments at La Quinta in the City of La Quinta, California. The Board of Directors authorized the General Manager/ Chief

Engineer to purchase 1,200 radio-read meters from Master Meter. The cost of the meters was funded by the developer. The cost of the reading equipment, which included the software, computer, radio transmitter, and receiver, was funded by the district.

This pilot program was successful, and CVWD staff recommended additional areas for AMR installations. Currently, Master Meter AMR meters are installed in new housing tracts and wherever the task of manually reading takes too much time or is hazardous to the meter reader. The decisive factor in the choice of whether to install AMR systems in a particular area involves several considerations. For new housing developments, the determining factor is a combination of the number of meters and the proximity to existing AMR meter reading routes. The replacement of existing positive displacement meters with AMR meters has already taken place in rural areas such as Cahuilla Hills and Tri-Palms Estates, where the time required to physically read meters has been cut to a faction of the time it previously took. As of July 2008, the number of installed AMR meters stood at 9,529, which was approximately 10 percent of the total number of CVWD meters.

For this project, entitled "California Time-of-Use Water Meter Case Study", the Coachella Valley Water District will utilize the same automatic meter reading technology as it uses in the rest of its system. The use of the Master Meter system will allow complete compatibility with the existing CVWD infrastructure and software. If a problem should arise with a particular meter, the district will have the ability to use a mobile read system to extract information. This is superior to having employees physically walk to each meter to resolve problems.

This report, *Smart Meters and California Water Agencies: Overview and Status*, is the interim report project 500-07-022, **"**California Time-of-Use Water Meter Case Study**."** This study addresses the technical feasibility and potential impact of time-of-use (TOU) meter installations for water agency customers in California. It consists of the following three tasks:

Technical background: This task addresses the technical parameters that are associated with time-of-use water meters. The background report consists of a summary of TOU water meter options, their availability and characteristics, and the decision-making criteria used by water agencies in selecting these meters. This report, *Smart Meters and California Water Agencies: Overview and Status*, is the technical background report.

TOU water meter installation and operation: This task establishes a representative time-of-use water monitoring program, where TOU water meters are installed for a variety of customer classes. This task also develops the mechanics of obtaining and assessing time-of-use water meter information.

Impact of customer TOU meters: This task evaluates the impact of time-of-use water meters and incentives on water consumption for the representative members of customer classes during peak demand periods. It also assesses the resultant shift in peak water agency electrical demands.

The purpose of this research project under the Energy Commission Public Interest Energy Research (PIER) Program is to demonstrate the technical feasibility and impact of TOU water

meters for California water agency customers. This research will assist PIER staff in understanding the value of California water agencies having the ability to implement TOU water delivery tariffs for their customers. In contrast to current practice of monthly volumetric water delivery tariffs, TOU tariff structures can provide new demand response opportunities. Of specific interest is the relationship between the electrical demand of California water agencies during electric utility peak demand periods and the potential ability of water agencies to encourage their customers to shift or reduce their on-peak water use. In this situation, the electric utilities would receive the electrical demand reduction associated with the California water agencies' TOU water meters and rate structures.

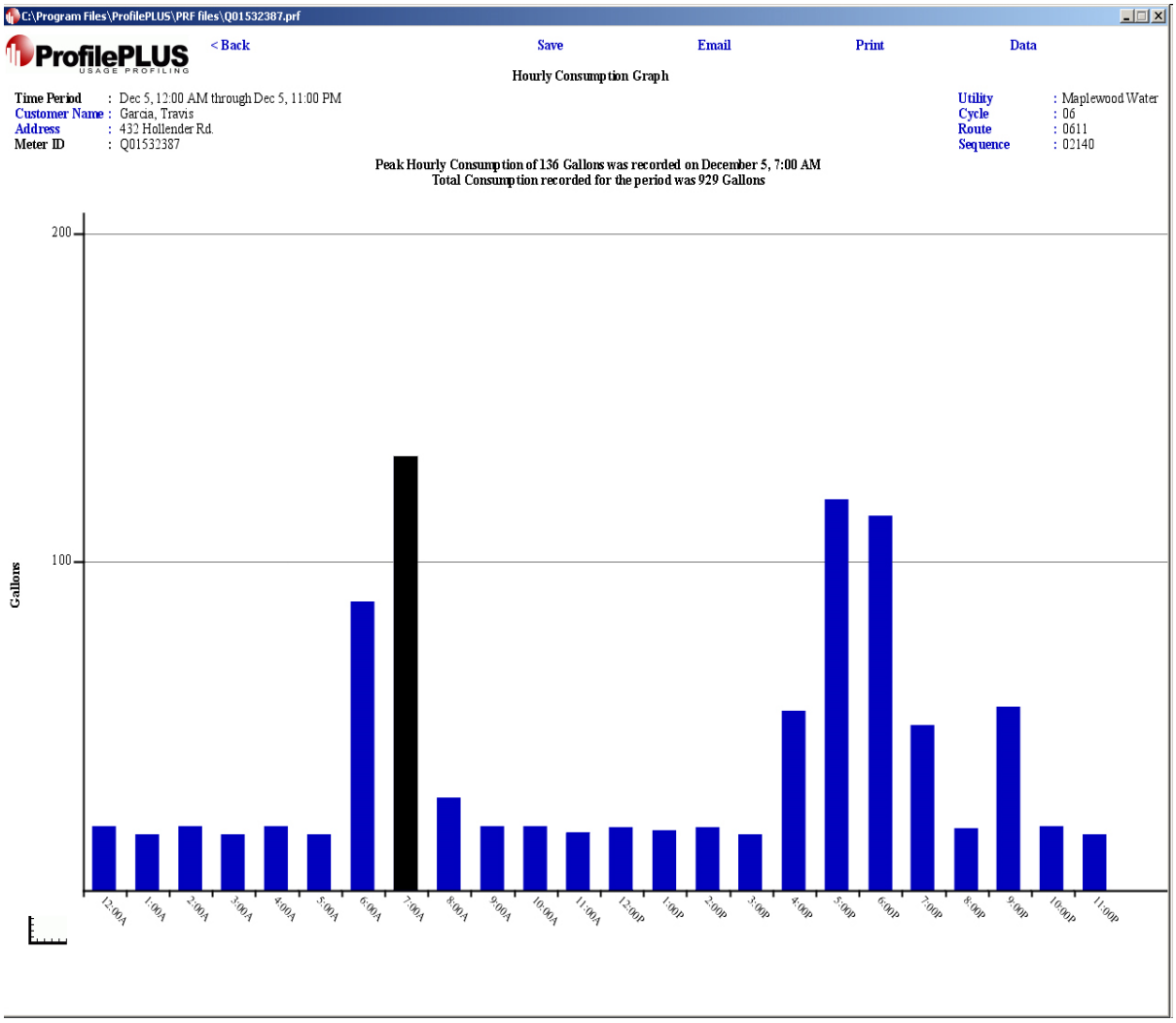
This project will be a test case installation and monitoring demonstration project that will determine whether TOU water meters are a viable demand-side option for water agencies to reduce on-peak electrical demand by encouraging their customers to shift water use away from peak electrical demand periods.

The project started in May of 2008 and is scheduled for completion in March of 2010.

APPENDIX A.

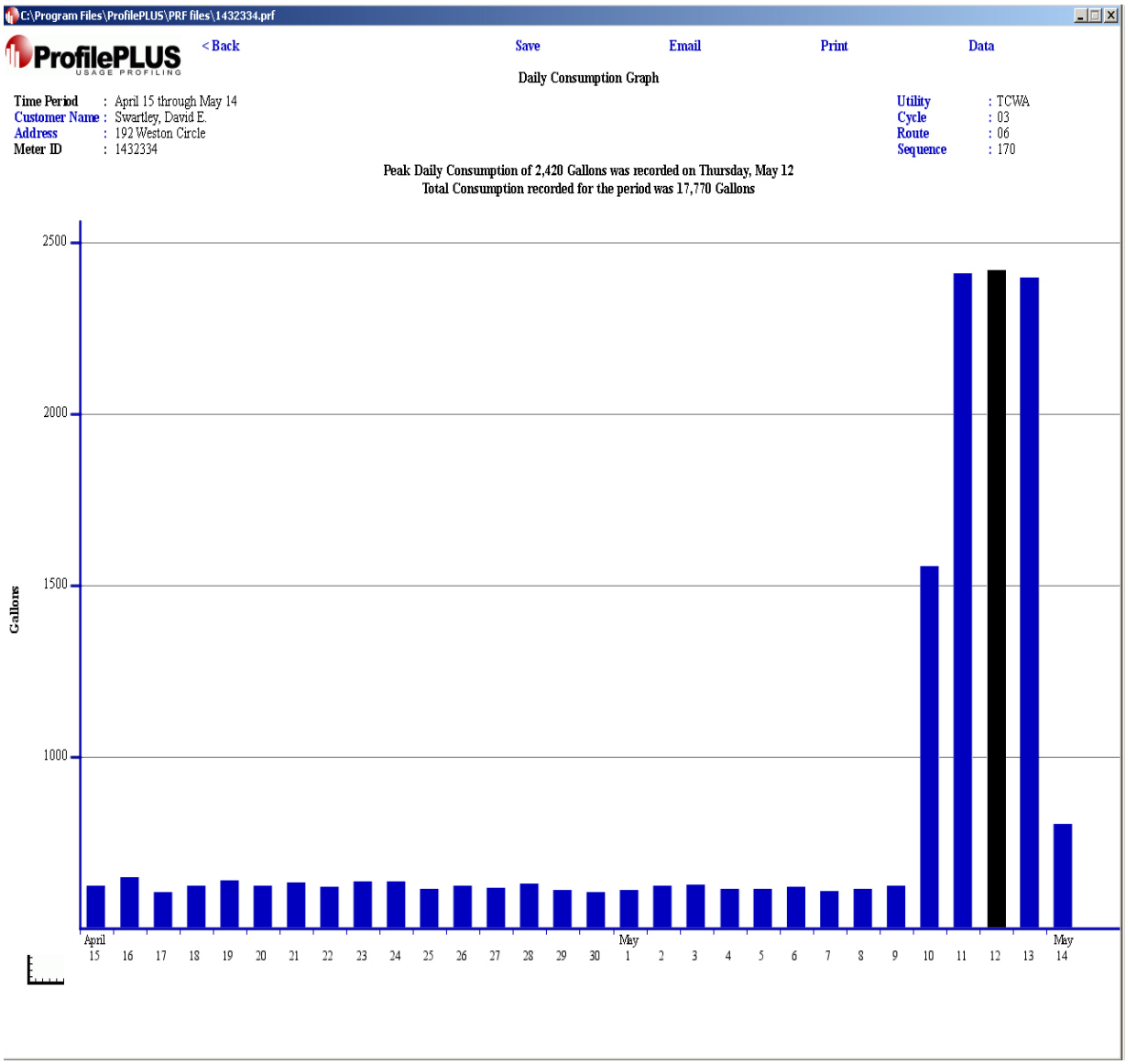
AMR METER INFORMATION EXAMPLES

USE FOR DETERMINING CUSTOMER LEAKS
Leaks are likely to exist if water usage never goes to zero.



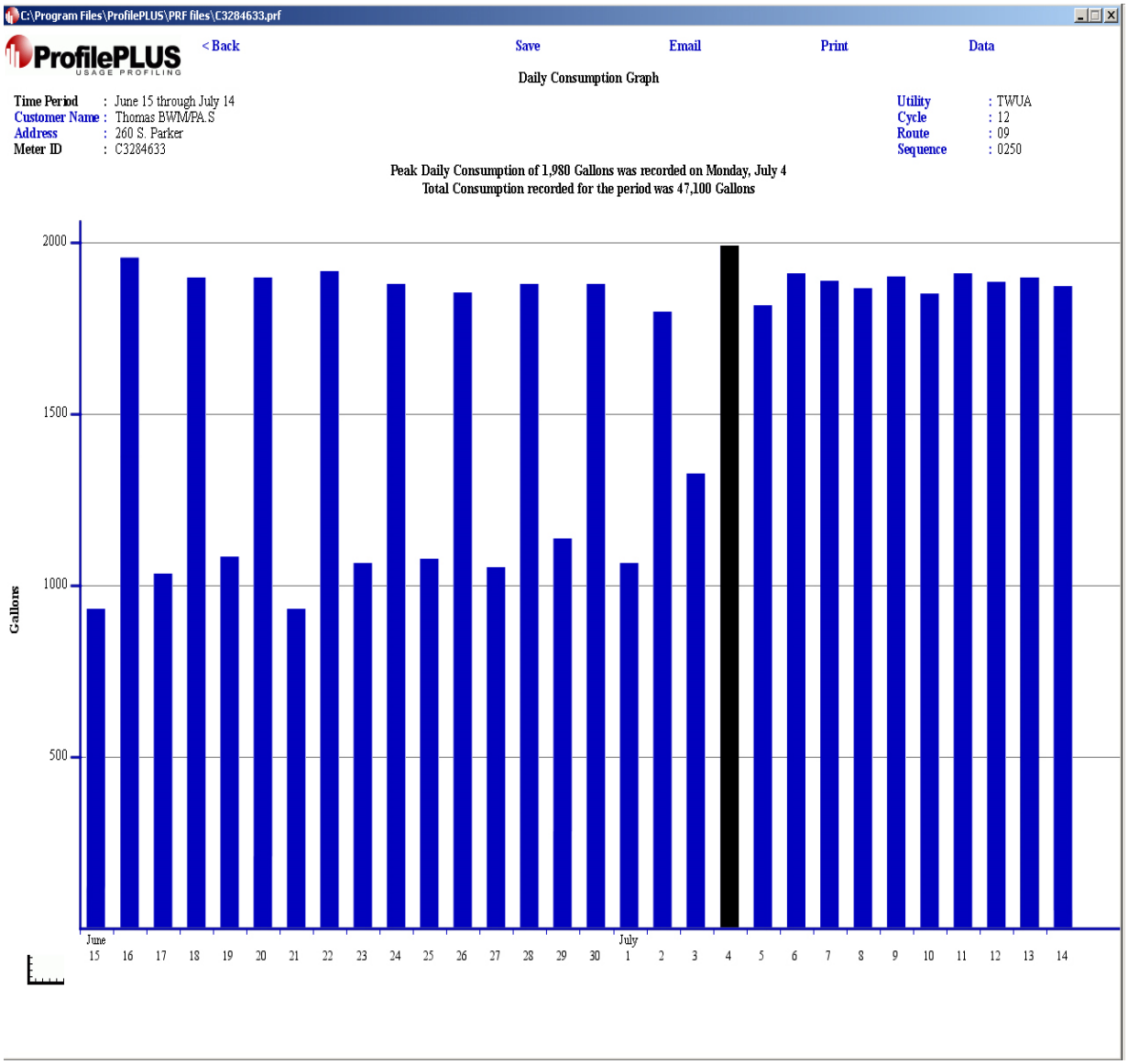
Source: Datamatic

USE FOR CUSTOMER SERVICE- IDENTIFY EXCESS USE OVER A WEEKEND



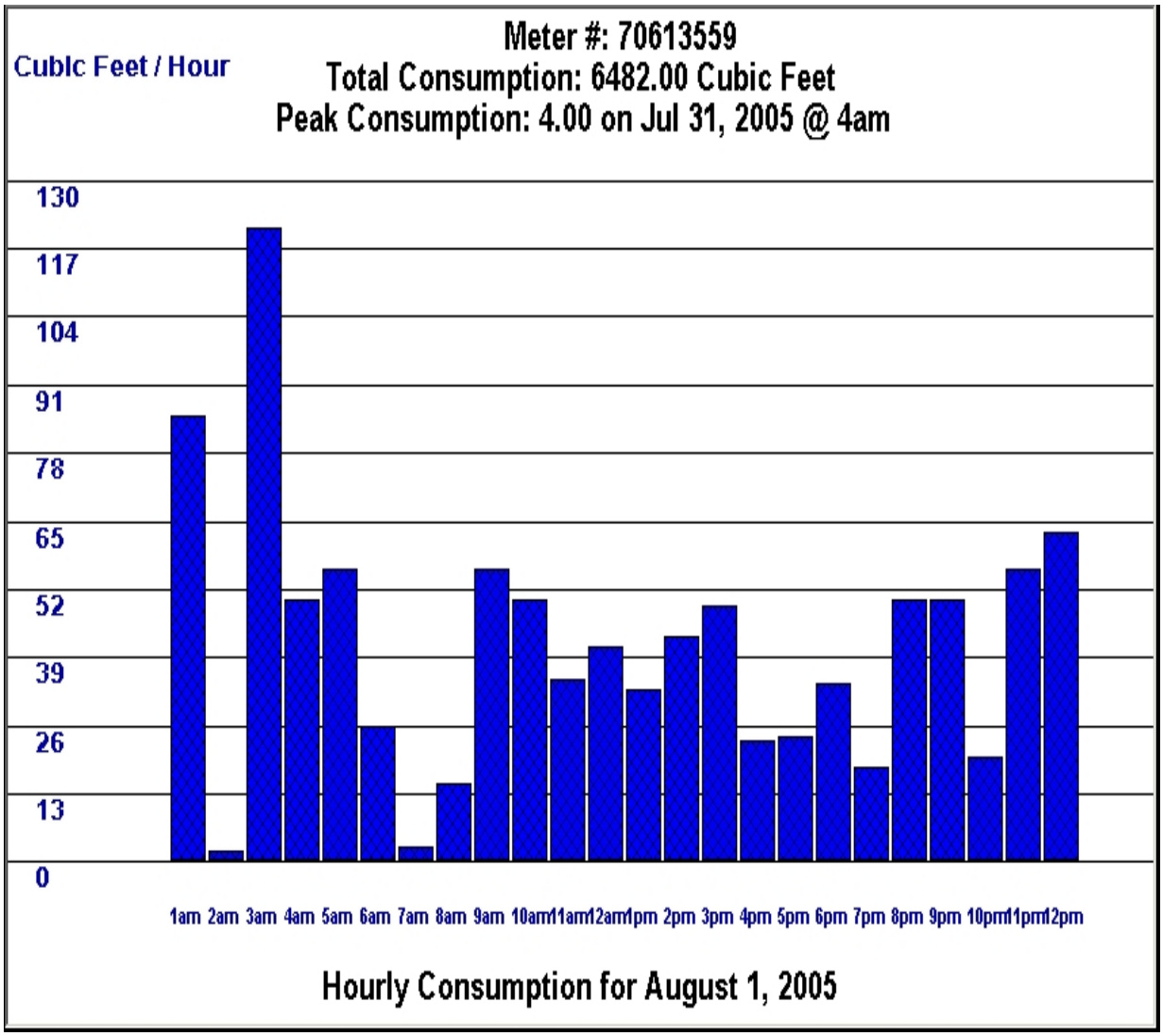
Source: Datamatic

USE IN WATER CONSERVATION PROGRAMS – EVEN/ODD DAY OUTDOOR WATERING VIOLATION



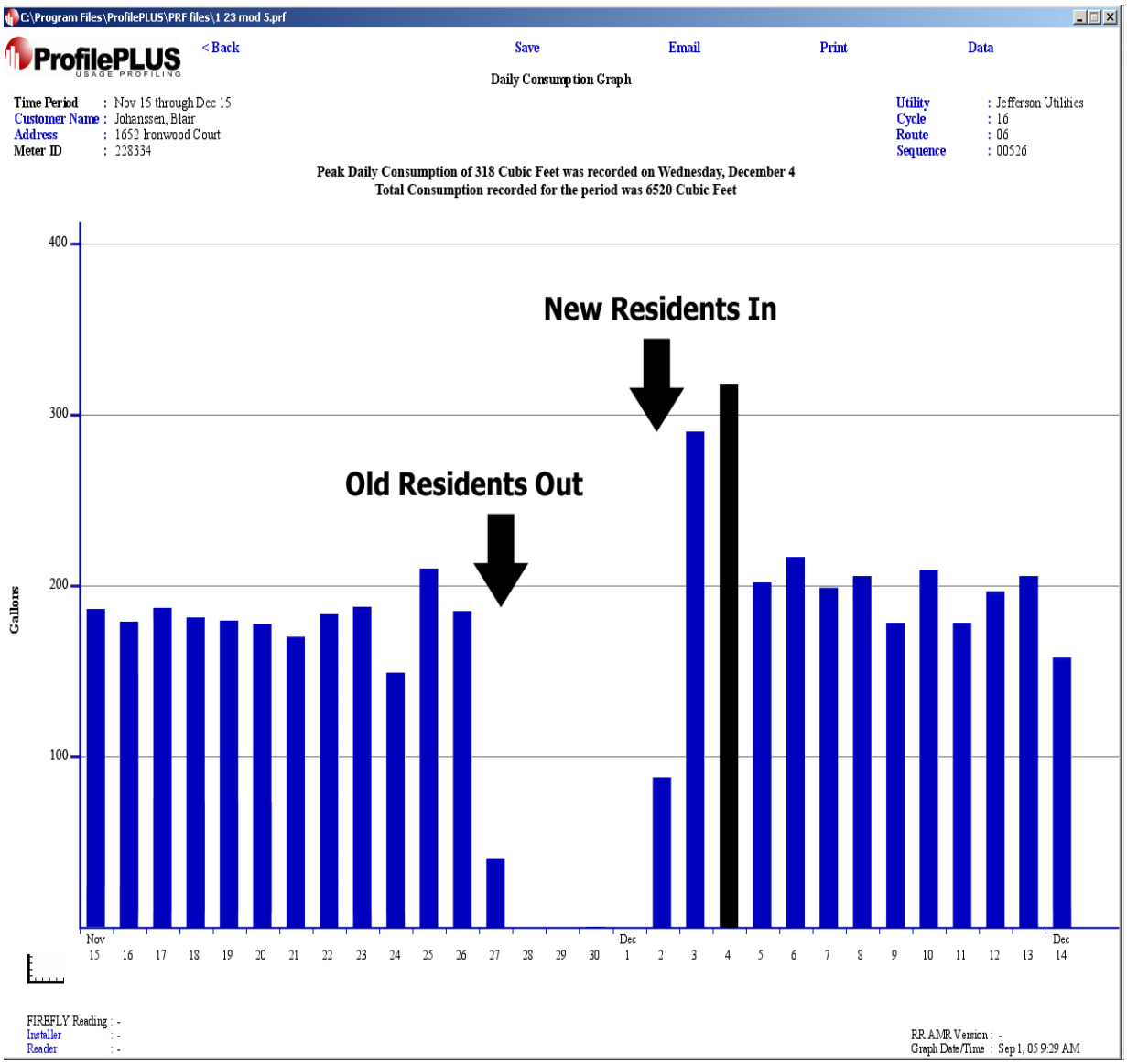
Source: Datamatic

USE FOR DETERMINING CUSTOMER WATER USE PROFILE



Source: Datamatic

Remote (Virtual) Turn Off and Turn On



Source: Datamatic

APPENDIX B.

WATER UTILITIES IN THE STATE OF CALIFORNIA

Note: The water utilities listed in red have responded to the AMR/AMI survey.

- **Alameda County Flood Control and Water Conservation, Zone 7**
- **Alameda County Water District**
- **Alhambra (City of)**
- **Alta Irrigation District**
- **Amador Water Agency**
- **American States Water Company**
- **Anderson-Cottonwood Irrigation District**
- **Antelope Valley-East Kern Water Agency**

- **Bella Vista Water District**
- **Bear Valley Community Services District**
- **Beaumont-Cherry Valley Water District**
- **Berrenda Mesa Water District**
- **Big Bear Area Regional Wastewater Agency**
- **Big Bear City Community Services District**
- **Big Bear Municipal Water District**
- **Bolinas Community Public Utility District**
- **Borrego Water District**
- **Brooktrails Township Community Services District**
- **Buellton (City of)**
- **Byron Bethany Irrigation District**

- **Cachuma Operation and Maintenance Board**
- **Calaveras County Water District**
- **Calaveras Public Utility District**
- **California American Water Company**
- **California Water Service Company (Cal Water)**
- **Callayomi County Water District**
- **Calleguas Municipal Water District**
- **Cambria Community Services District**
- **Cameron Park Community Services District**
- **Camrosa Water District**
- **Carlsbad Metropolitan Water District**
- **Carmichael Water District**
- **Carpinteria Valley Water District**
- **Casitas Municipal Water District**
- **Castaic Lake Water Agency**
- **Central Coast Water Authority**
- **Central Marin Sanitation Agency**

- **Central Municipal Water District**
- **Channel Islands Beach Community Services District**
- **Chino Basin Water Conservation District**
- **Chino Basin Watermaster**
- **Citrus Heights Water District**
- **Clear Creek Community Service District**
- **Coachella Valley Water District**
- **Coastside County Water District**
- **Colusa (City of) Water & Sewer Division**
- **Compton (City of)**
- **Contra Costa Water District**
- **Corona Department of Water and Power**
- **Cotati (City of)**
- **Crescenta Valley Water District**
- **Crestline Village Water District**
- **Cucamonga County Water District**

- **Desert Water Agency**
- **Dublin San Ramon Services District**

- **East Bay Municipal Utility District**
- **East Niles Community Services District**
- **East Orange County Water District**
- **East Valley Water District**
- **Eastern Municipal Water District**
- **Eastside Water District**
- **El Dorado County Water Agency**
- **El Dorado Irrigation District**
- **El Toro Water District**
- **Elsinore Valley Municipal Water District**
- **Escondido (City of) Utilities Division**

- **Fall River Mills CSD**
- **Fair Oaks Water District**
- **Fairfield (City of)**
- **Fallbrook Public Utility District**
- **Firebaugh Canal Water District**
- **Foothill Municipal Water District**
- **Forest Hill Public Utility District**
- **Fresno (City of), Department of Public Utilities**
- **Fresno Irrigation District**
- **Fresno Metropolitan Flood Control District**
- **Friant Water Authority**
- **Friant Water Users Authority**

- **Georgetown Divide PUD**

- **Glendale (City of) Water and Power**
- **Glenn-Colusa Irrigation District**
- **Goleta Water District**
- **Grassland Water District**
- **Green Valley County Water District**
- **Groveland Community Services District**
- **Hamilton (City of) Water and Wastewater**
- **Helix Water District**
- **Hesperia (City of) Water District**
- **Hi-Desert Water District**
- **Hilmar County Water District**
- **Hidden Valley Lake Community Services District**
- **Hollister Water Department**
- **Humboldt Bay Municipal Water District**

- **Inglewood Water Works**
- **Inland Empire Utilities Agency**
- **Inverness Public Utility District**
- **Imperial Irrigation District**
- **Indian Wells Valley Water District**
- **Inyo County Water Department**
- **Irvine Ranch Water District**
- **Joshua Basin Water District**
- **Jurupa Community Services District**

- **Kern County Water Agency**
- **Kern Delta Water District**
- **Kings River Conservation District**
- **Kirkwood Meadows Public Utility District**

- **La Puenta Valley County Water District**
- **Laguna Irrigation District**
- **Lake Arrowhead Community Services District**
- **Lake County Water Resources Division**
- **Lake Elizabeth Mutual Water Co.**
- **Lake Hemet Municipal Water District**
- **Lakeside Water District**
- **Lakewood (City of) Water and Water Quality**
- **Las Virgenes Municipal Water District**
- **Long Beach (City of) Water Department**
- **Los Angeles Department of Water and Power**
- **Lost Hills Water District**
- **Lower Tule Irrigation District**

- **Main San Gabriel Basin Watermaster**
- **Mammoth Community Water District**

- **Marin Municipal Water District**
- **Marina Coast Water District**
- **McKinleyville Community Services District**
- **Merced Irrigation District**
- **Mesa Consolidated Water District**
- **Metropolitan Water District of Southern California**
- **Mid-Peninsula Water District**

- **Midway Heights County Water District**
- **Mission Springs Water District**
- **Modesto Irrigation District**
- **Mojave Water Agency**
- **Monte Vista Water District**
- **Montague Water Conservation District**
- **Montecito Sanitary District**
- **Montecito Water District**
- **Monterey County Water Resources Agency**
- **Monterey Peninsula Water Management District**
- **Moulton Niguel Water District**
- **Municipal Water District of Orange County**
- **Murrieta County Water District**

- **Newhall County Water District**
- **Nevada Irrigation District**
- **North Coast County Water District**
- **North Marin Water District**
- **North of the River Municipal Water District**

- **Oakdale Irrigation District**
- **Oceanside (City of) Water Utilities Department**
- **Olivenhain Municipal Water District**
- **Orange County Water District**
- **Orange Cove Irrigation District**
- **Otay Water District**

- **Padre Dam Municipal Water District**
- **Pajaro Valley Water Management Agency**
- **Palmdale Water District**
- **Paradise Irrigation District**
- **Pasadena Water and Power**
- **Pebble Beach Community Services District**
- **Petaluma (City of) Water Resources and Conservation**
- **Pico Water District**
- **Placer County Water Agency**
- **Poway (City of)**

- **Quartz Hill Water District**

- **Rainbow Municipal Water District**
- **Ramona Municipal Water District**
- **Rancho California Water District**
- **Reclamation District No 106**
- **Reclamation District No. 1000**
- **Redding (City of) Water Utility**
- **Rincon del Diablo Municipal Water District**
- **Riverside (City of)**
- **Riverside County Flood Control and Water Conservation District**
- **Riverview Water District**
- **Rio Alto Water District**
- **Rio Linda-Elverta Community Water District**
- **Rohnert Park (City of)**
- **Rosamond Community Services District**
- **Roseville (City of)**
- **Rowland Water District**

- **Sacramento County Water Agency**
- **Sacramento Suburban Water District**
- **Regional Water Authority - greater Sacramento**
- **San Benito County Water District**
- **San Bernardino (City of) Municipal Water District**
- **San Bernardino Valley Municipal Water District**
- **San Bernardino Valley Water Conservation District**
- **San Diego County Water Authority**
- **San Dieguito Water District**
- **San Francisco Public Utilities Commission**
- **San Gabriel Basin Water Quality Authority**
- **San Gabriel Valley Municipal Water District**
- **San Gabriel Valley Water Association**
- **San Gorgonio Pass Water Agency**
- **San Juan Bautista (City of)**
- **San Juan Capistrano (City of)**
- **San Juan Water District**
- **San Luis & Delta-Mendota Water Authority**
- **Santa Ana Watershed Project Authority**
- **Santa Barbara (City of)**
- **Santa Clara Valley Water District**
- **Santa Cruz City Water Department**
- **Santa Fe Irrigation District**
- **Santa Margarita Water District**
- **Santa Rosa (City of) Utilities Department**
- **Scotts Valley Water District**
- **Semitropic Water Storage District**

- **Shafter-Wasco Irrigation District**
- **Shasta County Water Agency**
- **Sierra Lakes County Water District**
- **Solano County Water Agency**
- **Solano Irrigation District**
- **Sonoma County Water Agency**
- **Soquel Creek Water District**
- **South Coast Water District**
- **South San Joaquin Irrigation District**
- **South Tahoe Public Utility District**
- **Stinson Beach County Water District**
- **Stockton East Water District**
- **Sunnyslope County Water District**
- **Sweetwater Authority**
- **Sweetwater Springs Water District**

- **Tahoe City Public Utility District**
- **Tehama-Colusa Canal Authority**
- **Tehachapi (City of) Water Department**
- **Tehachapi-Cummings County Water District**
- **Three Valleys Municipal Water District**
- **Torrance (City of) Municipal Water District**
- **Trabuco Canyon Water District**
- **Tranquility Irrigation District**
- **Tulare Irrigation District**
- **Tuolumne Utilities District**
- **Turlock Irrigation District**
- **Twentynine Palms Water District**

- **Union Sanitary District**
- **United Water Conservation District**
- **Upper San Gabriel Valley Municipal Water District**

- **Vacaville (City of)**
- **Vallecitos Water District**
- **Valley Center Municipal Water District**
- **Valley County Water District**
- **Vandenberg Village Community Services District**
- **Victor Valley Water District**
- **Ventura River County Water District**
- **Vista Irrigation District**

- **Walnut Valley Water District**
- **Water Replenishment District of Southern California**
- **Weaverville Community Services District**
- **West Side Irrigation District**

- **West Basin Municipal Water District**
- **West Kern Water District**
- **West Patton Village Community Services District**
- **West Stanislaus Irrigation District**
- **Westborough Water District**
- **Westlands Water District**
- **Western Municipal Water District**
- **Wheeler Ridge-Maricopa Water Storage District**

- **Yolo County Flood Control & Water Conservation District**
- **Yorba Linda County Water District**
- **Yuba County Water Agency**
- **Yucaipa Valley Water District**
- **Yuima Municipal Water District**

Note: The water utilities listed in red have responded to the AMR/AMI survey.

APPENDIX C.

SURVEY OF CALIFORNIA WATER AGENCIES' AMR/AMI EXPERIENCES

As part of a research project with the California Energy Commission, we are investigating the use of automated meter reading (AMR) and advanced metering infrastructure (AMI) within the water agencies in California. We are interested in your opinions and experiences. AMR is the use of "smart" water meters to collect water use data and automatically transmit that usage data to the water agency. AMI is the use of two way communications with smart meters to communicate with (and sometimes control) the water meter from a centralized location.

1. Approximately how many water meter connections does your agency have?
73 Responses

2. Do you currently have any AMR meters installed?		
Yes	37	51%
No	35	49%
Total	72	100%

3. What percentage of your current water meters are AMR meters?		
We're doing a demonstration project	4	6%
Under 10%	12	18%
10-50%	9	13%
50-100%	13	19%
Not applicable	31	46%

4. Are you considering or do you have plans to evaluate/install AMR in your agency?		
Yes	36	59%
No	15	25%
Haven't considered it	10	16%

5. What are your reasons for installing AMR?		
Natural replacement of water meters	14	25%
New metering requirements in California	2	4%
New construction	7	12%
Benefits of AMR	44	79%
Other, please specify	15	27%

6. What are some of the benefits you are expecting from AMR?		
Increased revenue	14	25%
Reduced meter reading costs	44	79%
Safety / security issues	23	41%
Reduced GHG	10	18%
Customer service	27	48%
Identify losses	22	39%
Theft detection	8	14%
More efficient billing	33	59%
Improved cash flow	6	11%
Conservation	22	39%
Outage management	9	16%
Other	10	18%

7. What evaluation criteria do you use in selecting AMR (select all that apply)?		
Price	42	74%
Dependability	40	70%
Support	36	63%
Warranties	21	37%
Transmitter range	30	53%
Software compatibility	32	56%
Ease of installation	31	54%
Storage of information	20	35%
Experience	25	44%
Level of technology	23	40%
Battery life	36	63%
Compatibility w/existing	33	58%
Other	9	16%

8. What are your concerns about AMR?		
Meter battery life	36	62%
Industry standards	10	17%
Technical obsolescence	21	36%
Cost of AMR	35	60%
Integration with current billing system	16	28%
Ease of installation and maintenance	14	24%
Compatibility with existing system	17	29%
Vendor support	23	40%
Other	14	24%

9. Who is your predominant current meter vendor?		
ITRON	7	11%
Neptune	6	10%
Sensus	17	28%
Badger	16	26%

Datamatic	2	3%
Master Meter	3	5%
Ramar/Hershey	2	3%
Other / Mixed	17	28%

10. In deciding on AMR meters, will you consider meter vendors other than your current provider?		
Yes	37	67%
No	18	33%
Total	55	100%

11. Do you have any additional comments / suggestions / experiences with AMR/AMI you would like to provide us?
16 Responses