

# NEWS BULLETIN

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A year and a half long study has just been released on **water and energy savings in residential homes using the Metlund® D'MAND® Hot Water Recirculating System.**

Location – Palo Alto, California

This report summarizes a preliminary study aimed at estimating the potential of saving potable water, (and the electrical energy used to heat it), that is presently lost directly down the drain while occupants wait for hot water to arrive at the faucet (point of use).

Conclusion – “**Water savings** from a single point location fixture to *demand* circulation up to four faucet fixtures on average, would be **3,600 to 12,000 gallons saved per year**”.

“**Energy savings** based on the above varied from 200 to 400 kw-h/year for a single fixture location to over 1200 kw-h/year for up to four fixtures. Depending on the plumbing, only one D'MAND® Pumping System may be necessary”.

An Executive Summary may be requested from Oak Ridge National Laboratory, Dr. Moonis Ally, e-mail: [maq@ornl.gov](mailto:maq@ornl.gov).

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**Water and Energy Savings using Demand Hot Water  
Recirculating Systems in Residential Homes:  
A Case Study of Five Homes in Palo Alto, California**

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## EXECUTIVE SUMMARY

### **Introduction**

This report summarizes a preliminary study aimed at estimating the potential of saving potable water, (and the electrical energy used to heat it), that is presently lost directly to the drain while occupants wait for hot water to arrive at the faucet (point of use). Data were collected from five single-family homes in Palo Alto, California. Despite the small sample size in this study, the results make a compelling case for retrofitting homes with hot water recirculation systems to eliminate unnecessary wastage of water at the point of use. Technical as well as behavioral and attitudinal changes towards water conservation are necessary for a fulfilling and successful conservation effort. This report focuses on the technical issues, but behavioral issues are also noted, which may be factored into future studies involving local and state governments and utility companies.

### **Opportunity for water and energy savings**

When users want hot water, they usually turn on a faucet and let the water run down the sink until water of the desired temperature arrives. All of the water that is wasted was at one time, hot water. Most people leave the faucet running at full flow, draining 1-3 gallons of potable water before warm (or hot) water arrives at the point of use. The amount of water wasted down the drain depends upon the distance between the point of use and the hot water tank, the hot water temperature setting, the location, type, internal diameter, effective length and insulation level of the pipes and other factors such as the consciousness of the user in regulating the flow of water. In a shower the wastage may be more because people who have a long wait generally leave the shower running and return when they know that the temperature will be hot enough. This is often long after the water has attained a comfortably warm temperature. This daily wastage of potable water, endemic in nearly every home, can be eliminated by installing a simple recirculation device, available widely from retail stores or purchased on-line via the internet. Such a device, the Metlund® Hot Water D'MAND® System, was retrofitted in each participating home and offered both convenience as well as water savings.

### **Site characteristics**

The age of the five participating homes varied from 52 years to 92 years old. Water heaters were located in the basement areas or sub-floor areas. Pipes were located in crawl space areas. Most homes had some or all of the original plumbing.

Establishing a baseline level of water and energy consumption is the customary approach taken in comparative studies. However, for the following reasons, an alternative approach was taken to infer water and energy savings from the data gathered following the installation of the Metlund® Hot Water D'MAND® Systems.

- Two of the five homes rented a portion of the house to one or more renters and therefore, the number of occupants varied during the course of this study.
- One home was undergoing renovations, which required intermittent disconnection of the water supply.

- The use of water is behavior dependent and as renters changed, so did the water consumption. In one instance, the renter was not cooperative in using the recirculation system.
- The energy is metered on the whole house and therefore it is impossible to extract the energy consumed by the hot water heater alone without a much bigger investment in instrumentation.
- The daily variability in hot water consumption is larger than any changes to hot water use due to the Metlund® Hot Water D'MAND® System.

### Estimated savings

The water and energy savings involved several subtleties explained in the body of the report and by the calculations shown in Appendix A. It should be noted that the study participants, excluding renters, were very conscientious about conservation in general, and prided themselves in wasting little water or electricity. For example, one of the participants was very active in San Francisco's Bay Area Action Committee and drove an electric vehicle to make his contribution towards air quality. Measurements of water and energy savings from such an environmentally conscientious sample of the population means that our results are expected to be conservative, and represent the **minimum savings** that may be anticipated **at a single point of use of hot water** within a home.

It is important to note that the savings are not the savings per household, but at a single point of use. For each household, typical savings could be four to five times that at each point of use, since overall savings would depend on the number of hot water fixtures in a home that are served by the system. Summary of the savings is tabulated below.

Location in Palo Alto, California	Estimated Water Savings (gallons/year)	Estimated Energy Savings (kW-h/year)	Point(s) of Use	Comments
Washington Avenue	3,042	181	Bathroom sink	
Guinda Street	2,047	67	Kitchen sink	
Josina Avenue	2,618	Undetermined	Guest bath sink	Possible thermocouple problem.
Matadero Avenue	1,232	400	Master bath	
Homer Avenue	893	Undetermined	Bathroom sink (upstairs)	Difficulty in reading digits on display .

These results indicate a significant potential for water savings and a reasonably attractive opportunity for energy savings. The energy savings figures need to be considered in perspective. A new residential 12 cu. ft. refrigerator with a freezer consumes about 400 – 450 kW-h/year. Therefore, the estimated savings in energy in the three cases (where measurements could be made) indicate that the savings can be comparable to the energy consumed by residential refrigerators.

### **Conclusions:**

1. Water usage, and consequently water savings, is behavior-dependent.
2. Water savings for a household of four occupants varied from about 900 gallons to about 3000 gallons per point of use, per year. Point of use is a single location at a home, for example a faucet where hot water is available. Based on these figures, the water savings in a home with four points of use, on the average, would be 3,600 to 12,000 gallons per year.
3. The energy (electricity) savings depend on the hot water temperature setting, and are also behavior-dependent because the use of water is behavior-dependent. Electricity savings for a household of four occupants varied from about 200 kW-h/year to 400 kW-h/year for a single point of use. Extrapolation to a home with at least four points of use would imply electricity savings from 800kW-h/year to 1600kW-h/year.
4. Hot water line insulation in a home is another way of reducing energy consumption, but this was not part of the study and therefore it is only mentioned briefly.
5. Since the ratio of the specific heat of copper to water is 0.092 (~0.1) very little heat is required to heat the bare copper tube to the temperature of the hot water in it. Thus, the copper tube readily heats up and just as readily transmits heat to the environment. Given the high ratio between the mass of copper tube to the mass of water it carries per foot of tube length, a significant amount of heat is temporarily stored in the copper tube that is also quickly dissipated. These thermal losses increase the time it takes the hot water to reach a certain temperature at the fixtures, and they add to the thermal load on the water heater. Other factors that should be taken into account are the influences on second and subsequent users of hot water at the same (or adjacent) fixtures, and how long it might take for the copper pipe to cool to ambient conditions with and without the presence of insulation. Hence, insulating the hot water pipe in a home is an option for improved energy use.
6. A drawback of this study was the reliance on back-calculating important parameters and the use of a floating reference temperature for energy balances and energy savings. The sensitivity of the final figures to small changes in inter-dependent measurements caused difficulty in analyses.

### **Recommendations**

This study shows the potential for saving water and energy by the use of an on demand water recirculation system. This study should be used as a guide for further investigation to quantify and implement a nationwide strategy to encourage, facilitate, and achieve

conservation of potable water and the energy associated with heating it. Depletion of freshwater resources is a national and international issue. Overdrafting of underground aquifers, pollution from agricultural runoffs, industrial pollution, and the increasing demand for freshwater are severely straining the nation's, and the world's freshwater supplies.

The following steps are recommended relative to this study.

1. The sample size of participants should be increased for statistically significant results.
2. Quantify water savings potential in different regions of the country
3. The water savings potential in the urban and suburban areas of these regions also need to be quantified
4. The data acquisition boards should be modified to enable direct measurements of process variables to improve data collection and verification procedures
5. Many homeowners, including those who do not have a technical background want to be involved and every effort should be made to keep them in the project. However, data gathering should be done by the researchers themselves, preferably remotely and if possible, data should be analyzed in real time so that anomalies and equipment malfunction issues can be addressed quickly.
6. Involve professional organizations, utilities, community leaders and city planners in the study. This will help, both with identifying participants for the study, and improve the implementation based on the results.
7. This study only looked at older houses, effectively those built prior to 1950. Over half of the houses in the U.S have been built over the past 30 years and their construction and design are very different from the houses studied here. In particular, water heaters are often located in the garage, and the master bath and kitchen and are typically located over 50 feet from the hot water heater. In addition, a significant number of hot water pipes are located under the slab. In these cases the amount of hot water wasted is likely to be larger than in the homes we studied. Future studies should address homes built in the last 30 years.

## **Acknowledgements**

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# 1. HOT WATER DEMAND SYSTEM EVALUATION

## 1.1 Introduction

The Metlund® Hot Water D'MAND® System (HWDS) shown in Figure 1 offers the prospect of water savings by pumping hot water to a fixture (a water faucet, for example) at the demand of the customer, thus eliminating the need to run water down the drain while waiting for warm or hot water to arrive. Energy savings are likely to be achieved through a combination of two factors. First, the water recirculated to the hot water heater is generally warmer than the temperature of the street supply water coming in to the hot water tank. Second, since the recirculation pump moves the water more quickly than the fixture flow rate, it takes less water to get hot water to the fixture. The City of Palo Alto Utilities (CPAU) was interested in understanding the potential for both water and energy savings and a study was undertaken to evaluate the HWDS concept.

The U.S. Department of Energy's Emerging Technology Program and CPAU teamed together to leverage resources for this project. The Oak Ridge National Laboratory (ORNL) developed and provided customized equipment for gathering data on water and energy consumption based on bi-weekly readings taken by the participant(s). In addition, data were analyzed at ORNL and trends discussed with the project manager at CPAU on a regular basis. The CPAU provided the following items at each participant site:

- Installation of one Metlund® Hot Water D'MAND® System
- Installation of one new energy efficient 40 gallon electric water heater
- Pre and post survey questionnaires

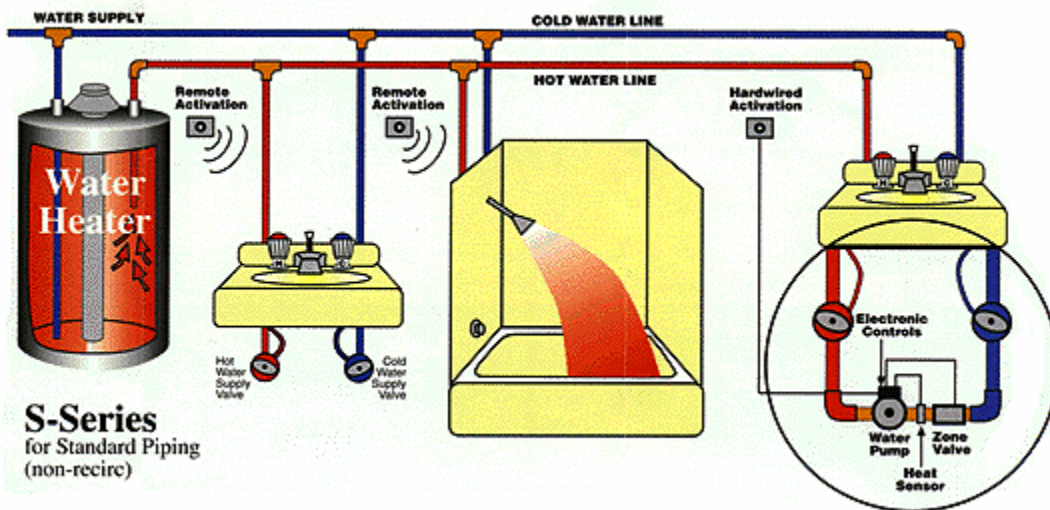


Figure 1. Placement of HWDS under sink (on right) provides hot water to the customer in a manner that eliminates running water to the drain while waiting for hot water to arrive at the hot water faucet. Please note that in the configuration shown, the HWDS serves multiple fixtures.

## **2. METLUND® HOT WATER D'MAND® SYSTEM (HWDS)**

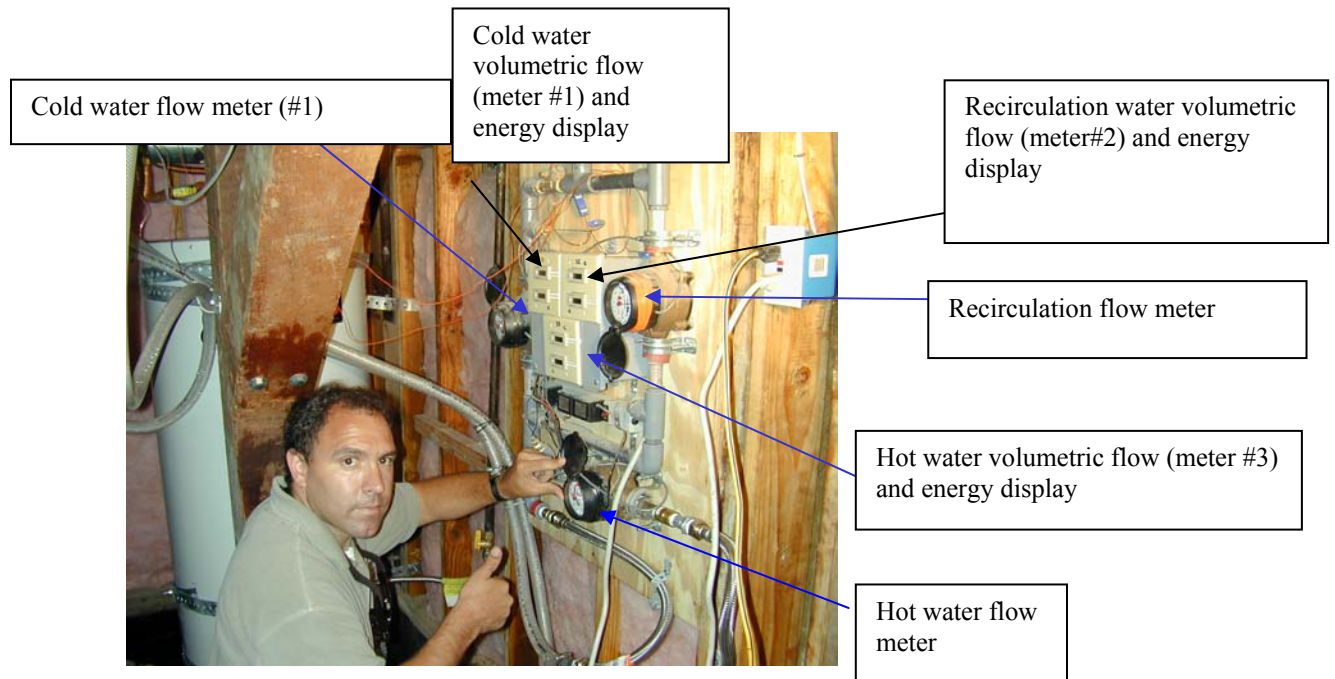
The HWDS is an electric water pumping system that quickly (typically within 30 seconds) brings hot water to the fixture by drawing water from the hot water tank and returning ambient house temperature water back to the hot water tank where it is heated. The HWDS is usually installed under the sink farthest from the water heater. At the push of a button, it circulates the ambient house temperature water normally discarded down the drain, back to the water heater through the cold water line. At the same time, the HWDS pumps hot water rapidly from the hot water heater to the fixture. When a predetermined set point temperature (usually 5°F above room temperature) in the line near the fixture is reached the pump stops automatically and hot water is subsequently available at the faucet. The pump may be operated by a switch placed next to the fixture, or by a remote control. In our study, participants were given both options, although the use of the remote is more convenient. When a person wakes up in the morning and activates the pump via the remote, hot water is available by the time the person gets to the bathroom fixture (if installed in the bathroom). Additional details about the system may be obtained from <http://www.gothotwater.com>

### **2.1 Instrument Panel**

The instrument panel was designed, built and calibrated at ORNL and shipped to CPAU. The panel consists of three water meters modified to interface with the electronic circuit boards that meter and display the volumetric flow rates of water and its energy content (enthalpy) relative to the temperature of the cold water in the pipe that feeds the hot water tank. This reference temperature is usually above the temperature of the street water supply. Seasonal or daily fluctuation in the reference temperature is immaterial to the measurements because the energy content of the water is always measured on a relative basis with respect to the same reference temperature. A photograph of an installed panel in the basement of one of the homes in Palo Alto, California is shown below.

### **2.2 Instrumentation Panel Calibration**

Each home owner was requested to fill in the meter readings on the data sheet depicted in Figure 3 which shows the boxes corresponding to the display meters from where readings are to be recorded. The data sheet is dated and sent to Oak Ridge National Laboratory in self-addressed, stamped envelopes provided to each participant. The flow displays (Figure 3) for meters 1, 2 and 3 indicate a number (called Flow Counts) proportional to the volumetric flow of water registered through the meter which is connected to it. The relationship between Flow Counts and the actual volumetric flow (e.g. pounds or gallons) of water was established gravimetrically, as part of the calibration process. Water was flowed through each meter, collected, and weighed and the reading on the display (Flow Counts) noted. A series of measurements yielded a relationship between Flow Counts and volumetric (or gravimetric) water flow. This process was carried out for each of three meters on each panel.



**Figure 2. Installed instrument panel connected to household supply line, hot water heater and recirculation pump (not shown).** Person in foreground is Brian Ward, Manager, CPAU.

Another display adjacent to the Flow Count display indicates a number (called the BTU Count) which is proportional to the energy content of the water with respect to the reference temperature (mentioned above) that flows through the particular meter. The relationship between BTU Count (at a specified temperature) and the volume of water flowed through the meter was also determined by calibration. To do this, a reference temperature thermocouple (TC) was immersed in an ice bath and the hot water TC was immersed in a constant temperature bath to simulate the temperature of the hot water. For calibration, the difference between the hot water temperature and the reference temperature was utilized. This temperature difference was varied from 10°F to approximately 73°F. This upper bound is close to what occurs in a typical household, where the difference between the street water (55°F) and the hot water temperature (130°F) is roughly 75°F.