Evaluation of
Potential Best Management Practices
-
Residential Dishwashers

Prepared for

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IV. Residential dishwashers

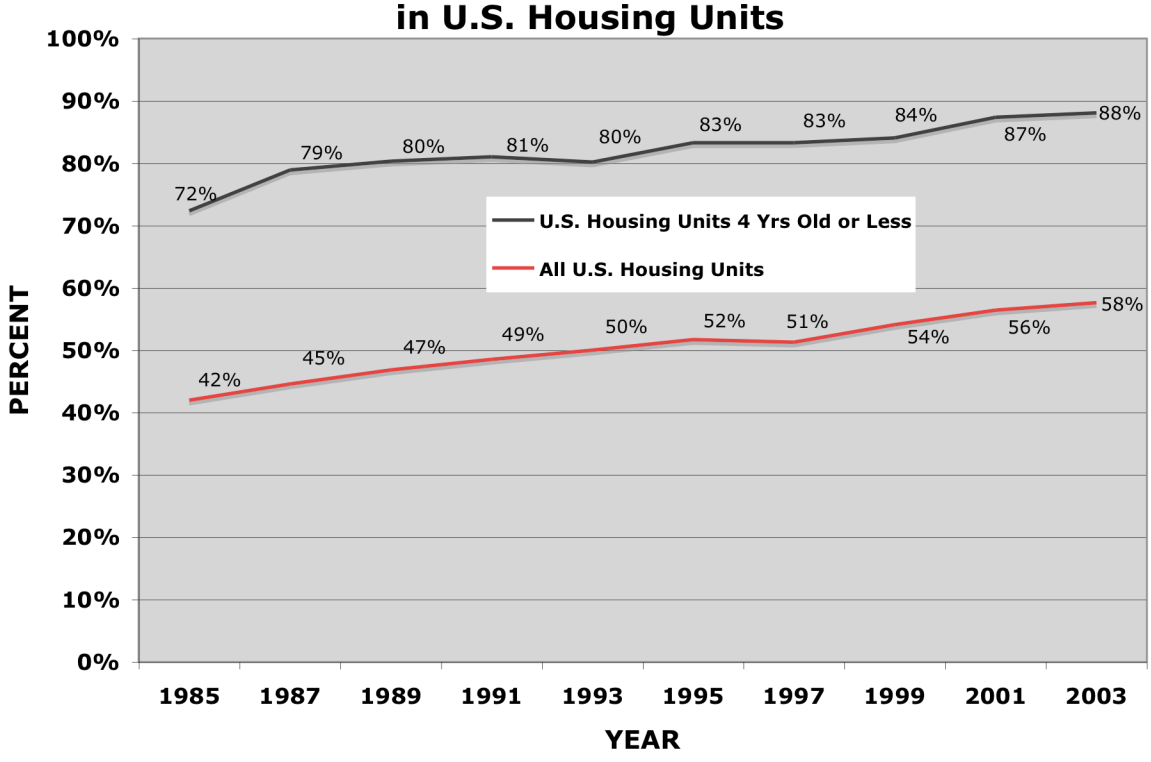
1. Background

History

The first hand-operated dishwashing machine was patented in 1850. However, a powered dishwasher with permanent plumbing hookups was not developed until 1920, according to the Whirlpool Corporation[1]. In 1947, household dishwashers went into production and soon became a feature in the American home[2]. Numerous technological advances since then have significantly improved the cleaning, energy, and water efficiency of residential dishwashers in the North American marketplace.

Over the past 20 years, the percentage of all U.S. housing units with automatic dishwashers has grown steadily, from only 42 percent in 1985 to nearly 58 percent by 2003. Of special note is the fact that about 88 percent of all new housing units constructed in the period from 2000 to 2003 were equipped with builder-installed automatic dishwashers.[3] Figure 1 displays annual data on installed product in the U.S. for the 1985 to 2003 period.

Figure 1. Percentage of Dishwashers in U.S. Housing Units



[1] Whirlpool Corporation, 1993. *How to make a home run with clean-up appliances.*
[2] Lindsay, F.D., 1980. *Dishwashers: A look at the past while pondering the present with an eye to the future.* Proceedings of the Detergents in Depth 1980 Symposium.
[3] U.S. Departments of Commerce and Housing and Urban Development, various dates. *American Housing Survey for the United States* (Multiple reports: 1985 through 2003)

Efficiency Standards

In 1987, the U.S. Congress passed the National Appliance Energy Conservation Act (NAECA). The NAECA led, in 1988, to the first Federal residential dishwasher standard, which required these appliances to provide the option to dry without heat. In 1994, the first Federal standard and test procedure was adopted that was based on an Energy Factor (EF)[4,5].

In 1997, the voluntary Energy Star program was expanded to include residential dishwashers. Under the direction of the U.S. Department of Energy (DOE), dishwasher energy use criteria are developed and maintained for the Energy Star program.

Within these two areas, the minimum EFs for residential dishwashers have been established as follows:

Federal standard (NAECA)[6] - mandatory:	0.46 and 0.62[7]
Energy Star (DOE)[8] – voluntary:	0.52 (1997 to 2000) 0.58 (2001 to today) 0.65 and 0.88[9] (beginning 2007)

None of the above efficiency standards contain any requirements directly related to water use by the dishwasher. During the DOE's deliberative and comment process for the proposed increases in the EF, comments from water utilities and from the Steering Committee for Water Efficient Products[10] clearly advocated for the addition of a water factor (WF) within the Energy Star criteria. While some appliance manufacturers argued that energy use is well-correlated with water use and, thus, a WF is unnecessary, others representing water utilities argued that such is not necessarily the case. Therefore, they concluded, a measure of water use is meaningful and necessary in order to promote the most water-efficient products. At this point, however, there is no indication that a WF, or some equivalent measure or threshold, will be included by the DOE.

While a WF is absent in the standards, water use data from the Energy Star work is gathered, made available, and used by a few water utilities operating water efficiency programs. The State of Oregon's Department of Energy Residential Tax Credit Program provides credits of up to $50 for energy-efficient residential dishwashers with a EF of at least 0.61 and WF of no more than

[4] Karney, Richard H., 2005a. *Energy Star Criteria for Dishwashers*, U.S. Department of Energy, July 13 (powerpoint presentation)
[5] For dishwashers, the energy factor is defined as the number of cycles per kWh of input power.
[6] McNary, Bill, 2005. *Energy Star Criteria for Dishwashers, Market Impact Analysis*, D&R International, July 13 (powerpoint presentation)
[7] Requirement is a 0.46 EF for standard dishwasher models and 0.62 for compact models.
[8] Karney, Richard H., 2005b. Letter to Energy Star Partners and Stakeholders, U.S. Department of Energy, December 20.
[9] Final version of requirements (dated March 2, 2006) calls for a 0.65 EF for standard dishwasher models and 0.88 for compact models.
[10] The Steering Committee and its constituent membership is comprised of representatives from the water utility industry, appliance manufacturers, and other interested parties. This ad hoc organization represents the interests of water efficiency before both the DOE and the U.S. Environmental Protection Agency (EPA), as well as other stakeholder groups.

6.5 gallons of water use per cycle. Qualifying washers (as of April 2006) are listed on the department's website, which is frequently updated:

http://oregon.gov/ENERGY/CONS/RES/tax/appdish.shtml

Natural Resources Canada (NRC) provides energy and water use[11] data for all residential dishwashers qualified for Energy Star. NRC's website permits the viewer to sort machines by water use per cycle as well as by energy use. The website is frequently updated and may be accessed at:

http://oee.nrcan.gc.ca/energystar/english/consumers/dishwashers-search.cfm

Both sites provide valuable and usable information for those organizations developing residential green building programs and water-efficiency subsidy (rebate) programs for dishwashers.

Market

The U.S. market for new dishwashers is currently supplied by 17 different manufacturers that produce a total of 565 dishwasher models under 47 different brand names. Of those models, 486 are Energy Star-compliant, or 86 percent of the total.[12] This indicates that while Energy Star has very successfully influenced the marketplace by encouraging the development of efficient product, the distinctiveness of the label for dishwashers has largely disappeared. As such, the actions being taken by the DOE to "raise the bar" on efficiency are necessary and welcome.

According to DOE data, and consistent with the marketplace inventory of Energy Star models cited above, nearly 86 percent of all dishwashers sold in the last quarter of 2004 met Energy Star qualifications.

Of the 486 Energy Star-qualified dishwasher models, 346 meet the requirements of the State of Oregon (a maximum WF of 6.5 gallons per cycle) and thereby qualify for their $50 tax credit.[13]

Dishwasher Use

Two important factors are worthy of note when considering the potential for a Best Management Practice related to residential dishwashers:

a) The household use of automatic dishwashers is declining.

   Energy Star and DOE have reduced the number of cycles of dishwasher use per year from 322 to 264 in 2002, then subsequently to 215 as the current estimate.[14] Oregon uses

[11] Residential dishwashers are connected only to the hot water side of the plumbing in a typical installation. As such, the "hot water" use shown for each machine on the NRC website constitutes the total water consumption. All water and energy consumption data is provided by the manufacturers of the machines.

[12] _____2005. *Market Impact Analysis on the Potential Revision of the Energy Star Criteria for Dishwashers*, June 10 (author unidentified)

[13] Oregon Department of Energy, 2006a. Qualifying Dishwashers, Apr 06. As viewable at: http://oregon.gov/ENERGY/CONS/RES/tax/appdish.shtml Note: Oregon sets the EF at a minimum of 0.61, which is below that that will be required by Energy Star beginning in 2007. As such, some of the models currently qualifying under the Oregon program would not be Energy Star-qualified after January 1, 2007.

[14] McNary, 2005.

215 cycles per year as well for their measure of water use.[15] This phenomena of reduced activity is attributed by many experts to the strong trend to dining outside the home (particularly in California, which leads the nation in restaurants per capita). It can also be attributed, in part, to the downward trend in household size (of those households that have dishwashers), which leads to a reduced use of dishware.

b) The pre-rinsing of dishes prior to loading the dishwasher is an unknown behavioral issue.

Most automatic dishwasher manufacturers today recommend that the consumer load their machine without pre-rinsing. However, a certain (unidentified) number of people not only remove large food scraps but also rinse their dishware under the faucet or in the sink unnecessarily before loading. Of course, this is a behavioral issue that is largely unrelated to the water use in the automatic dishwasher and, as such, is not addressed in this paper. Authoritative studies on consumer habits related to pre-rinsing are necessary to establish the extent to which this frequently unnecessary practice is consuming water.

2. California Installations

Existing inventory

The only reliable, publicly available data[16] that exists regarding the installed base of automatic dishwashers is that provided through the Census data in the American Housing Surveys. This national data must be applied to California housing data on a percentage basis to arrive at an estimate for the state.

As of January 1, 2006, California's housing inventory amounted to 13.139 million units. Growth since 2000 has been as follows[17]:

Table 1. Housing Unit Inventory

January 1 of….	Housing Unit Inventory[18] (millions)	Inventory Growth in prior year (millions)
2000	12.215	
2001	12.307	.092
2002	12.448	.141
2003	12.599	.151
2004	12.758	.159
2005	12.942	.184
2006	13.139[19]	.197

[15] Oregon Department of Energy, 2006b. Qualifying Dishwashers as of March 1, 2006.
[16] It is very likely that individual appliance manufacturers and/or the Association of Home Appliance Manufacturers (AHAM) have substantial data on the installed base of residential dishwashers in the state, as well as current information on sales into the replacement and new construction markets. This information, however, is deemed proprietary and is not generally made available to water utilities or other "outsiders".
[17] California Department of Finance (DOF), 2006. *Report E-5a.xls, 1/1/2006*, May 1.
[18] Includes all types of housing units: occupied, unoccupied, single family, multi-family, group quarters, and mobile homes.
[19] California DOF reports population as of January 1, 2006 at 37.172 million, or 2.83 persons per total dwelling unit.

Using figures from the 2003 American Housing Survey[20], we estimate that approximately 7.4 million automatic dishwashers are currently installed in California derived as follows:

Pre-2000 housing: 12.215 housing units x 54.1 percent =	6.608 million dishwashers
2000 to 2005: 0.925 housing units x 88.1 percent =	0.815 million dishwashers
Total installed base =	7.423 million dishwashers

According to estimates by various authorities, the older units (greater than 6 years old) are likely functioning within the range of 7.0 to 12.0 gallons per cycle[21], with an average we estimate at about 9.5 gallons.[22] The newer units (installations from 2000 through 2005) are functioning at an estimated 7.5 gallons per cycle. At these levels of efficiency, and with a use of 215 cycles per year, annual water use in California currently approximates 45,500 acre-feet (exclusive of any pre-rinsing by hand).

Annual additions to the inventory

Annual additions of housing units to the California inventory during the 6-year period of 2000 to 2005 averaged 154,000 units.[23] While this figure will vary significantly as the economic and housing cycles occur, it is fairly consistent with the projected housing unit additions through 2040.

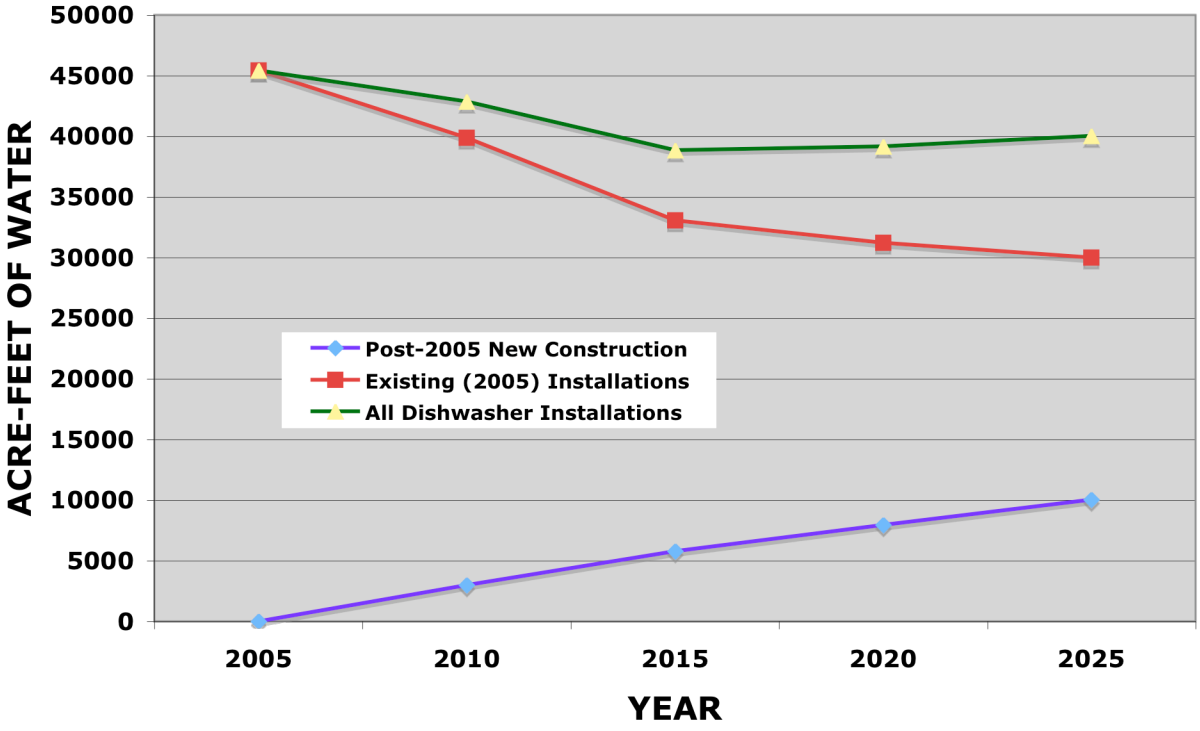
The California DOF estimates that state population will reach 51.5 million persons by 2040.[24] At the current persons per housing unit ratio, such an increase would indicate that an additional 5.1 million housing units will be required by that date. Data from the 2003 American Housing Survey reveals automatic dishwasher installations were found in 88.1 percent of the new residential housing units (4 years old or less – see Figure 1). Using this data, we can project that about 4.4 million new dishwashers will be installed in new construction during the 34-year period from 2006 to 2040, or a average of about 130,000 annually. By 2040, the number of installed dishwashers will have grown from 7.4 million to nearly 12 million.[25]

The addition of 130,000 new dishwashers to the inventory each year will add about 600 acre-feet to the water demand. At the same time, existing dishwashers will be replaced with units of higher efficiency. (The normal physical life of a residential dishwasher is about 10 years.) As water factors decline and units are replaced, the overall demand for water is expected to decline as well. By 2025, water demand is predicted at slightly over 40,000 acre-feet per year, a reduction of 5,500 acre-feet of demand based solely on natural replacement with more efficient machines.

[20] U.S. Departments of Commerce and Housing and Urban Development, 2003. *American Housing Survey for the United States: 2003.*
[21] Vickers, Amy, 2001. Handbook of Water Use and Conservation, p131. WaterPlow Press, May.
[22] McNary (2005) estimates that the new non-efficient models are using 10 gallons per cycle. Vickers estimates that the older models (1990 to 1995 and 1995 to present) function at 7.0 to 12.0 gallons per cycle.
[23] 925,000 new housing units over 6 years = 154,000 units per year.
[24] California DOF, 2005. *P-1 Tables.xls*, November 7.
[25] This assumes that the installation rate of 88.1 percent prevails through the entire period.

Figure 2 illustrates the demand profile for the period from 2005 to 2025. It should be noted that while demand has declined over the 20-year period, it is beginning to rise again by 2020. No projections beyond 2025 were attempted due to our inability to predict the marketplace WF for these appliances.

Figure 2. Projected Annual Water Use by Residential Dishwashers - California



3. Water Savings Estimates

Water savings through the implementation of a BMP for residential dishwashers will be achieved entirely through reductions in the WF. Because WFs appear to already be on a general decline due to energy efficiency initiatives by the DOE and the Energy Star program, water use will naturally decline as older machines are replaced. For the purpose of developing Figure 2, WFs were assumed as follows:

Table 2. Projected Water Factors for Dishwashers

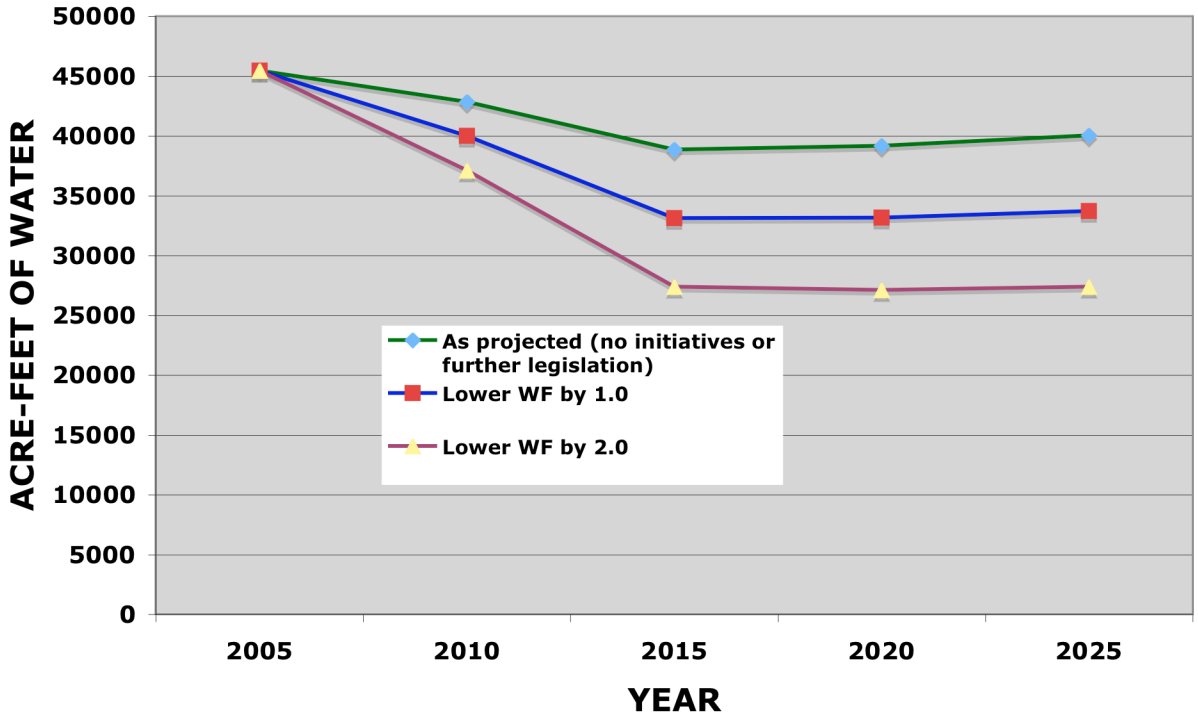
Dishwashers delivered to market in…	Assumed Average Water Factor
2006-2010	7.00
2011-2015	6.50
2016-2020	6.25
2021-2025	6.00

A reduction in the maximum WF through legislation (mandatory) to something less than these figures would yield savings in 2025 estimated as follows:

- Reduction in the average WF by 1.0 – reduction of 6,300 AFY
- Reduction in the average WF by 2.0 – reduction of 12,700 AFY

Figure 3 illustrates the water demand by dishwashers at the projected efficiency without any mandated changes, as well as the demand that would result with the above reductions in the WF.

Figure 3. Projected Annual Water Use With Reduced Water Factors



Those who might advocate the elimination of automatic dishwashers as a means to save water would, in fact, probably be encouraging an increase in household water use, since at least one such study indicated that the "water factor" for hand washing is as high as 18![26] The study found that to clean 12 place settings of dishes, an average of 27 gallons of water was used. (Converting this to the 8-place setting criteria of the DOE, for example, would mean that the water use was 18 gallons per "cycle".)

4. Cost Effectiveness

The cost of implementing a mandatory WF through legislation is difficult to estimate. If such an initiative were undertaken and legislation approved today with an implementation date 10 years hence (when overall water demand from dishwashers begins to increase), costs might be negligible. If, on the other hand, appliance manufacturers were pressed through legislation to comply with an aggressive WF within 2-4 years, the costs would probably escalate as industry resisted.

[26] Home Energy Magazine, 2004. *Is a machine more efficient than the hand?* by Rainer Stamminger, University of Bonn, May/June 2004.

Because of the minimal water use of residential dishwashers (only 1.4 percent of water use in a single family home is attributed to dishwashing[27]), the short 10-year physical life, and the improving efficiencies of these machines, it is not recommended that the water providers attempt to develop rebate structures directed at today's installed base of machines. Figure 4 displays what subsidy (rebate or other financial incentive) could be "justified" at various values of water and with three different WF reduction thresholds.

Figure 4. Justifiable Financial Subsidy (Rebate) at Various Reductions in the Dishwasher WF

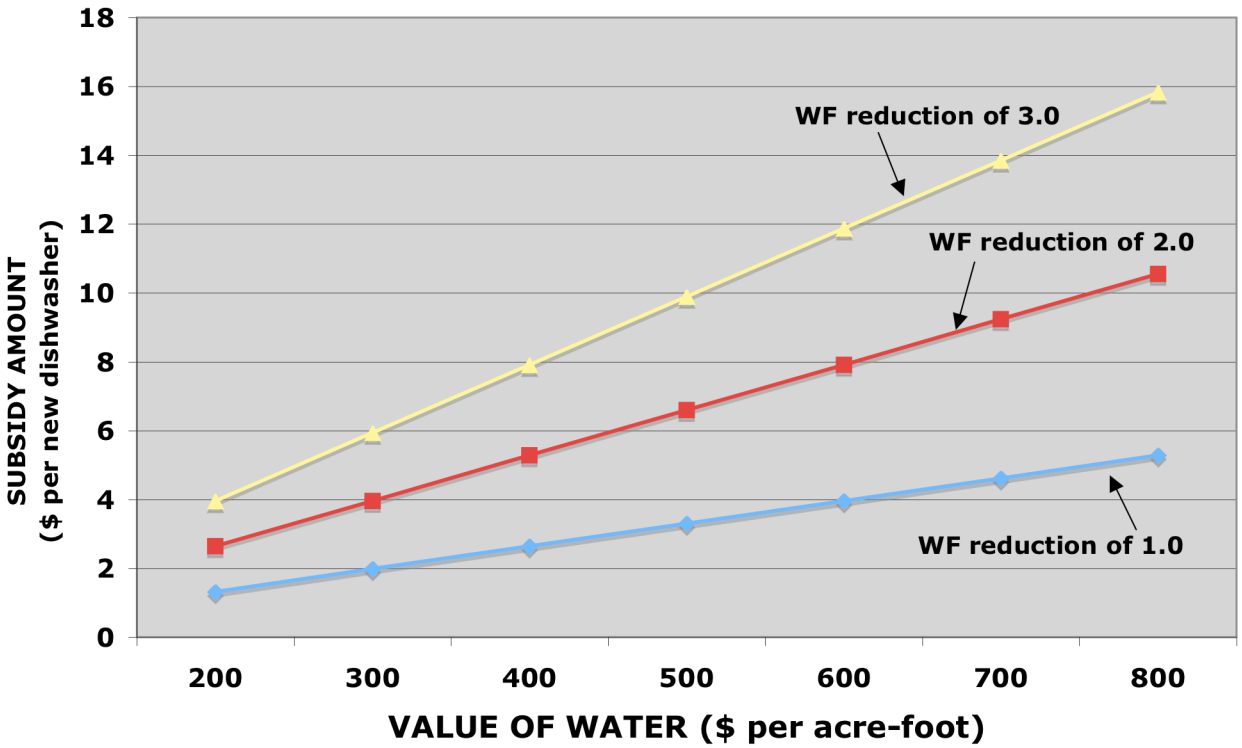


Figure 4 illustrates that even with an aggressive WF reduction of 3.0, the subsidy by the water utility would not exceed $16 per dishwasher replacement where the value of the water is $800 per acre foot. This small subsidy is probably insufficient to even market and administer a program, much less provide a financial incentive to a customer. Furthermore, it is likely that such a rebate would be largely consumed by freeriders, although there is no data to indicate that such is the case with energy rebates for dishwashers.

The only area where a Potential BMP appears feasible in the short-term is through the green building approach, directed at new construction. Here, the water providers have the opportunity to influence the various national and regional green building programs to incorporate a WF into

[27] Mayer, P. et al., 1999. *Residential End Uses of Water Study*, American Water Works Research Foundation, Denver, Colorado

their guidelines and criteria. The costs to do so are negligible, inasmuch as the water interests are already working with these programs and organizations to incorporate water efficiencies in other areas of new homes. Including residential dishwashers with a WF of 6.5 or less, for example, would be relatively easy to implement for most of the programs in existence today.

5. California Potential

The additional initiatives on dishwashers that might be taken through or because of a BMP will probably not yield the savings that BMPs associated with other indoor appliances and fixtures might. Therefore, while the magnitude of potential savings (as noted above and in Figure 3) appears to be meaningful and worthwhile to pursue, the other areas in the residential sector probably deserve more attention than dishwashers.

Overall, the water savings potential for California that might be achieved with more resource-efficient residential dishwashers is estimated at between 6,000 and 12,000 AFY if legislation mandating aggressive WFs is implemented. On a voluntary basis (through green building programs[28]), we project that less than 20 percent of this potential could be captured. However, in both cases, the cost to the water providers to seek out either or both of these avenues for increased efficiencies would be minimal and, in most cases, would be encompassed within existing advocacy programs directed toward legislation and green building.

[28] A few new home green building programs are beginning to incorporate WFs for residential dishwashers into their guidelines or standards, although it is not yet a widespread practice. The usual focus by these programs is instead upon the higher water-using elements of the new home, such as landscape and plumbing.