

# ANDY SCHRODER

Estimated weekly domestic hot water (DHW) use

5 person household

Common uses	Number of people (person)	Number of cycles (cycles/person/week)	Total cycles (cycles/week)	Hot water (liters/cycle)	Total hot water (liters/week)	Average hot water (liters/day)	Total energy (kWh/week)	Average energy (kWh/day)
Dishwasher	5.0	1.4	7.0	30.4	212.7	30.4	8.9	1.3
Clothes washer	5.0	1.0	5.0	14.6	73.2	10.5	3.1	0.4
Shower	5.0	7.0	35.0	84.7	2,964.4	423.5	124.2	17.7
Miscellaneous	5.0	7.0	35.0	0.8	28.2	4.0	1.2	0.2
				Total	3,278.5	468.4	137.4	19.6

## Temperature conditions

Description	Value	Units
Cold water from the utility grid	12.8	°C
Hot water from the domestic hot water tank	49.0	°C
Temperature difference	36.2	°C

- Shower flow rate equal to 7 liters/minute for 15 minutes
- Dishwasher based on Whirlpool large capacity model DU850SWP
- Clothes washer based on Whirlpool super capacity model WTW5100S
- Miscellaneous uses might include hand washing, coffee or tea making, cooking, etc.
- Liters/cycle indicates amount of hot water used from the domestic hot water tank
- Total mixed temperature water used (not shown) may be more than hot water used
- Temperature of cold water from the utility grid may vary based on climate and season
- You can modify these calculations to estimate your actual appliances, habits, number of occupants, and climate by starting at the "Temperature" worksheet and working through each proceeding worksheet

## Input water temperature values

1.a) The first step to calculate domestic hot water volume and domestic hot water thermal energy use is to determine the water temperatures from the utility grid and the temperature of your domestic hot water tank. These two values are shown in red text entered into Table 1. To measure cold water from the utility grid, turn on a faucet only opening the cold line, allow temperature to stabilize, and measure the water temperature. Do the same for hot water temperature but instead only open the hot line from the faucet. Input the values respectively into Table 1. If you are unable to make these measurements you should leave this page unchanged. The default values in Table 1 will allow an estimation of your actual use. Another item to consider is that cold water from the utility grid may vary based on geography and/or climate. This means water temperature as well as hot water volume and energy use might increase or decrease depending on the weather. In this case an estimated value or numerous calculations may need to be made in order to better understand actual use across different locations and seasons. The following is done as an average annual scenario.

**Table 1. - Temperature values for domestic water**

Symbol	Description	Value	Units
$T_a$	Cold water from the utility grid	12.8	°C
$T_h$	Hot water from the domestic hot water tank	49.0	°C
$\Delta T$	Temperature difference	36.2	°C

1.b) Note that through the rest of this domestic hot water worksheet  $T_h$  is referred to as hot water from the sun. This represents the assumption that  $T_h$  would match your current domestic hot water tank temperature. Also note, Google provides a quick temperature conversion to Fahrenheit, for example, <http://www.google.com/search?q=48C+in+F>.

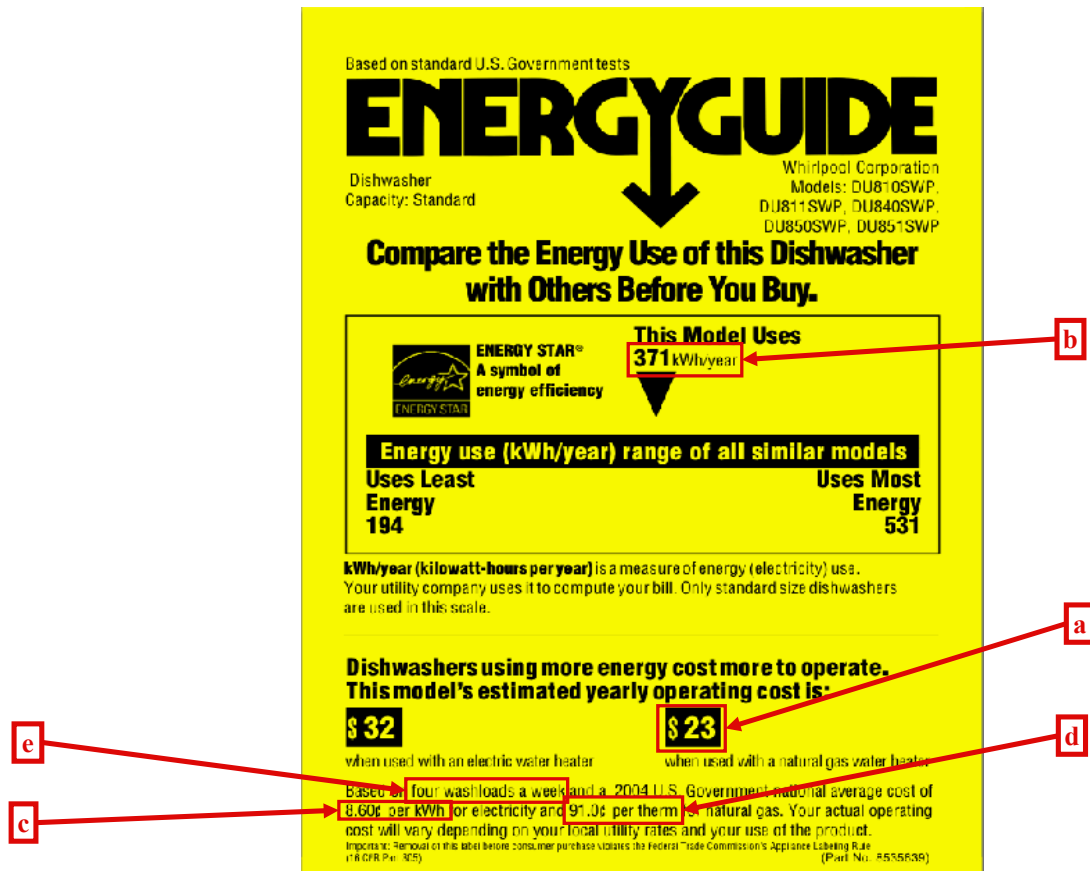
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Yellow background, final calculation for this worksheet

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## Input dishwasher characteristics

2.a) The next step to calculate domestic hot water volume and domestic hot water thermal energy use is to consider actual appliances and their performance. The first appliance considered is a dishwasher. Below is an Energyguide for a large capacity dishwasher. These guides are usually located on the appliance itself or come as supplementary documentation. The red lettered boxes each identify a characteristic of the dishwasher that is needed to calculate hot water volume and energy use per cycle. The values that correlate to each letter are input into Table 2.a.



**Table 2.a – Dishwasher characteristics**

Input	Symbol	Description	Value	Units
<b>a</b>	EAOC <sub>g</sub>	Estimated Annual Energy Cost for Gas Water-Heating	<b>23</b>	\$/year
<b>b</b>	E <sub>ann</sub>	Annual energy consumption	<b>371</b>	kWh/year
<b>c</b>	D <sub>e</sub>	Ave. unit cost of elect. Energy	<b>0.086</b>	\$/kWh
<b>d</b>	D <sub>w</sub>	Ave. unit cost for gas or oil	<b>0.91</b>	\$/Therm
<b>e</b>	N <sub>w</sub>	Number of cycles per week	<b>4</b>	cycles/week

2.b) Please note, values in Table 2.a do not reflect the actual cycles used to calculate your domestic hot water usage. These values indicate the average performance and use based upon Energyguide. They are needed in order to back calculate how your unit performs. The energy calculated in the “Calculations” worksheet will estimate using the actual number of cycles you think you will use per week.

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## Calculated dishwasher hot water use

2.c) "To begin solving for the machine electrical energy consumption and hot water volume consumption, it is necessary to understand basic dishwasher types. The following definitions are used here:

- Type 1 dishwashers – do not heat water internally, hot water connection only
- Type 2 dishwashers – have an electric element internal to the machine for the purpose of providing auxiliary water heating, hot water connection only
- Type 3 dishwashers – have an electric element internal to the machine for the purpose of heating all of the water used to wash the dishes, cold water connection only.

In order to estimate the energy consumption of dishwashers, it is necessary to understand the underlying energy use calculations found in the 10CFR Part 430, Subpt. B, App. C (DOE 1999)."<sup>1</sup>

The following calculation assumes a Type 1 or 2 dishwasher where the washer uses water that is at least the temperature of the domestic hot water tank for the entire load. This means that if you have a Type 2 dishwasher, it might use higher temperature water, but extra energy would be supplied by the washer internally using electricity, not solar hot water energy. Type 1 or 2 dishwasher calculations will not vary according to the method used in this worksheet. If your washer is Type 3 then no solar hot water energy will be supplied to that specific dishwasher and the calculation can be omitted from the total use summary.

Thermal properties of water, density ( $d$ ) and specific heat ( $c$ ), are functions of the average between  $T_h$  and  $T_a$ . In other words, as the temperature of the cold water from the utility grid and solar hot water vary, so too will the properties of the water in the system. These values below have been interpolated automatically using a polynomial fit, and the corresponding temperatures that have been inputted into Table 1.

The values in black text in Table 2.b require no input and will update automatically based upon other inputs in the worksheet. The cell highlighted yellow indicates the hot water use per cycle for the dishwasher. Throughout the rest of this DHW worksheet you will find these yellow cells indicating hot water use per cycle.

**Table 2.b – Hot water use per cycle, dishwasher**

Symbol	Description	Value	Units
$N_m$	Number of cycles per month	16	cycles/month
$N_y$	Number of cycles per year	209	cycles/year
(based on 2008, 366 days per year, 7 days a week)			
$n$	Nominal gas or oil water heater recovery efficiency	0.75	
$W$	Water heating energy used per cycle	1.27	kWh/cycle
$M$	Electrical energy used per cycle	0.82	kWh/cycle
$d$	Density of water	994.5	kg/m <sup>3</sup>
$c$	Specific heat of water	4.19	kJ/(kg-K)
		0.00116	kWh/(l-K)
$V$	Hot water use per cycle	30.4	l/cycle

**Table 2.c – Unit conversions**

1	cm <sup>3</sup> =	0.001	liters =	0.0002642	US gallons
1	Therm =	100000	Btu =	29.3	kWh
1	Joule =	0.0000002778	kWh		

Reference:

(1) Information Bridge: DOE Scientific and Technical Information, 2006 Aug 01, Sponsoring Org: United States Dept. of Energy, Research Org: National Renewable Renewable Energy Laboratory (NREL), Golden, CO, Title: "Method for Evaluating Energy Use of Dishwashers, Clothes Washers, and Clothes Dryers: Preprint", Authors: Eastment, M. and Hendron, R.

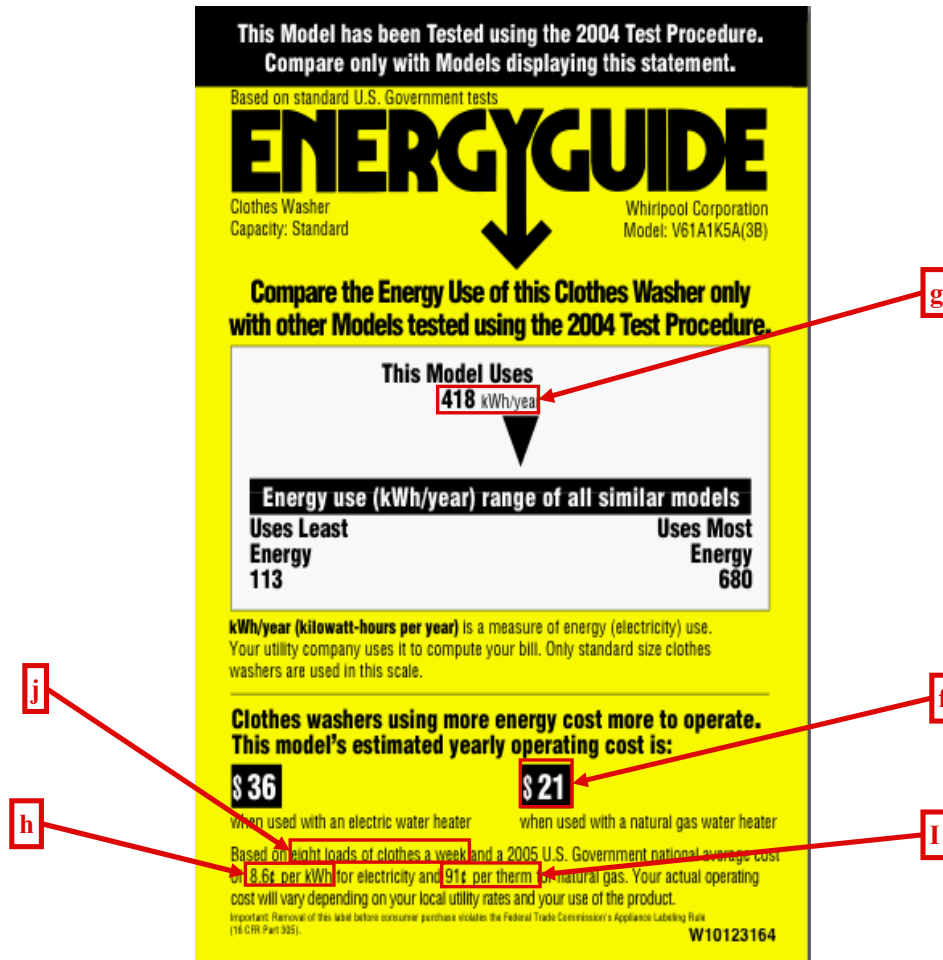
Red text, input optional

Yellow background, final calculation for this worksheet

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## Input clothes washer characteristics

3.a) The third step in calculating domestic hot water volume and domestic hot water thermal energy use is to consider the clothes washer. Below is an Energyguide for a super capacity clothes washer. The method of calculation is the same as in the “Dishwasher” worksheet. The red lettered boxes identify a characteristic that is needed in order to calculate hot water volume and energy use per cycle. The values which correlate to each letter are must be inputted into Table 3.a.



**Table 3.a – Clothes washer characteristics**

Input	Symbol	Description	Value	Units
<b>f</b>	EAOC <sub>g</sub>	Estimated Annual Energy Cost for Gas Water-Heating	<b>21</b>	\$/year
<b>g</b>	E <sub>ann</sub>	Annual energy consumption	<b>418</b>	kWh/year
<b>h</b>	D <sub>e</sub>	Ave. unit cost of elect. Energy	<b>0.086</b>	\$/kWh
<b>I</b>	D <sub>w</sub>	Ave. unit cost for gas or oil	<b>0.91</b>	\$/Therm
<b>j</b>	N <sub>w</sub>	Number of cycles per week	<b>8</b>	cycles/week

3.b) Please note, values in Table 2.a do not reflect the actual cycles used to calculate your domestic hot water usage. These values indicate the average performance and use based upon Energyguide. They are needed in order to back calculate how your unit performs. The energy calculated in the “Calculations” worksheet will estimate using the actual number of cycles you think you will use per week.

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## Calculated clothes washer hot water use

3.c) “To begin solving for the machine electrical energy consumption and hot water volume consumption, it is necessary to understand basic clothes washer types. The following definitions are used here:

- Type 1 clothes washer – does not heat water internally, hot and cold water connections
- Type 2 clothes washer – uses thermostatically controlled water inlet valves to vary the volume of hot and cold water added to the wash load
- Type 3 clothes washer – has an electric element internal to the machine for the purpose of providing auxiliary heating, hot and cold water connections
- Type 4 clothes washer – has an electric element internal to the machine for the purpose of heating all of the water used to wash clothes; cold water connection only.

To estimate the energy consumption of clothes washers, it is necessary to understand energy-use calculations found in 10CFR Part 430, Subpt. B, Appendix J1 (DOE 1999).

Type 2 clothes washers vary the amount of hot water the machine uses in order to achieve a specific wash temperature by opening and closing hot and cold water valves during the fill portion of the cycle that utilizes both hot and cold water. We make the assumption that the mixed water temperature in a Type 2 clothes washer during cycles that draw hot and cold water is 92.5°F [33.6°C] based [on a field test from the U.S. Department of Energy] in Colorado. In order to correct the hot and cold water volumes for this control type, a general derivation of the correction in hot water volume for a Type 2 clothes washer operating with water temperatures that differ from the test conditions is shown below. During machine sub cycles that use both hot and cold water the volume fraction of hot water is defined.

In order to calculate the  $\Delta V$  is known for any combination of hot and cold water inlet temperatures, and the quantity of hot water used by the clothes washer can be estimated under alternate conditions.<sup>11</sup>

The following calculation assumes a Type 2 clothes washer. The energy/hot water consumption will vary if your clothes washer is not Type 2 or the hot water temperature used by the washer is not 33.6°C. If your clothes washer is Type 1 or 3 you can make the assumption that the entering hot water temperature will be the same as the domestic hot water tank. In that case, insert the value for  $T_h$ , solar hot water/hot water from the domestic hot water tank into the red text cell value for  $T_m$  in Table 3.b. This will make the  $\Delta V$ , volume multiplier, equal to 1.00. This means the entire washer cycle would be using hot water at the temperature of the domestic hot water tank. If your clothes washer is Type 4 then no solar hot water will be supplied to that specific clothes washer and the calculation can be omitted from the total summary calculation

**Table 3.b – Determining volume multiplier based on clothes washer type**

Symbol	Description	Value	Units
$T_m$	Mixed water temperature	33.6	°C
$\Delta V$	Change in volume multiplier	0.57	-

3.d) Total hot water volume and thermal energy use per clothes washer cycle can now be calculated using  $\Delta V$ . Hot water use per cycle is multiplied by  $\Delta V$  to calculate the amount of  $T_h$  water is used per cycle since the total volume is a mixture of cold and hot water.

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## Calculate clothes washer hot water use

3.e) In Table 3.c, the thermal properties of water and are exactly the same as in the “Dishwasher” spreadsheet. This is true because the same water temperature is assumed to be taken from the same domestic hot water tank for both dish washing and clothes washing.

**Table 3.c – Hot water use per cycle, clothes washer**

Symbol	Description	Value	Units
$N_m$	Number of cycles per month	32	cycles/month
$N_y$	Number of cycles per year	418	cycles/year
(based on 2008, 366 days per year, 7 days a week)			
n	Nominal gas or oil water heater recovery efficiency	0.75	
W	Water heating energy used per cycle	1.07	kWh/cycle
M	Electrical energy used per cycle	0.20	kWh/cycle
d	Density of water	994.5	kg/m <sup>3</sup>
c	Specific heat of water	4.19	J/(g-K)
		0.00116	kWh/(l-K)
V	Hot water use per cycle	14.6	l/cycle

**Table 3.d – Unit conversions**

1	cm <sup>3</sup> =	0	liters =	0	US gallons
1	Therm =	100000	Btu =	29.3	kWh
1	Joule =	0	kWh		

Reference:

(1) Information Bridge: DOE Scientific and Technical Information, 2006 Aug 01, Sponsoring Org: United States Dept. of Energy, Research Org: National Renewable Renewable Energy Laboratory (NREL), Golden, CO, Title: "Method for Evaluating Energy Use of Dishwashers, Clothes Washers, and Clothes Dryers: Preprint", Authors: Eastment, M. and Hendron, R.

Red text, input optional	Yellow background, final calculation for this worksheet	Black text, white background, no input required
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## Calculate shower and miscellaneous hot water use

4.a) The final step to calculate domestic hot water volume and domestic hot water thermal energy use is to consider shower uses and other miscellaneous hot water uses. The mixed water temperature value,  $T_m$ , on this page is the temperature of water when you are taking a shower. Depending on the person this value may vary. If you take unusually hot or cold showers you may consider changing this value by measuring the water temperature while showering, similar to the method explained in "Temperature" worksheet and inputting the temperature into Table 4.a under the value for  $T_m$ .  $\Delta V$  is then multiplied to the hot water use per cycle calculation in Table 4.a to determine the actual amount of  $T_h$  water used.

The flow rate of your shower may also vary. To measure flow rate, use a bucket to determine how much water flows out of your shower head in one minute and input this value into Table 4.a under the value for  $f$ , flow rate of water out of the shower head.

Last, measure the time you typically spend in the shower. Input the number of minutes into Table 4.a under the value  $t$ , time length of one shower.

If you leave these values unchanged it will still provide an estimated value of hot water use.

**Table 4.a – Hot water use per cycle, shower**

Symbol	Description	Value	Units
$T_m$	Mixed water temperature used in the shower	42.0	°C
$\Delta V$	Change in volume multiplier	0.81	-
$f$	Flow rate of water out of the shower head	7.0	l/min
$t$	Time length of one shower	15.0	min./cycle
$V$	Hot water use per cycle	84.7	l/cycle

4.b) Table 4.b represents miscellaneous domestic hot water use throughout one day for a single person. Miscellaneous uses might include hand washing, coffee or tea making, cooking, etc. where hot water would be used. It is assumed that the hot water would be mixed down to a temperature to that of a hot shower. This means that the  $\Delta V$  value is also multiplied by the hot water use per cycle to get a mixed, cold and hot water combined, water temperature value. This value can be changed higher or lower if you estimate different mixed water temperature use. Inputting a zero for  $T_m$  will make the energy use zero. To change how much miscellaneous water volume is used by one person, change the value for  $m$ , in liters/day. Otherwise these will provide an estimated use.

**Table 4.b – Hot water use per cycle, misc**

Symbol	Description	Value	Units
$T_m$	Mixed water temperature used in the shower	42.0	°C
$\Delta V$	Change in volume multiplier	0.81	-
$m$	Misc. use by one person	1.0	l/day
$V$	Hot water use per cycle	0.8	l/cycle

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## Domestic hot water (DHW) use calculations

5.a) Table 5 summarizes domestic hot water volume and domestic hot water thermal energy use for one week and one average day. Here you can change the number of people and actual number of cycles (red text cells) to reflect your occupants and habits. When determining number of cycles/person/week, remember, this is averaged over 7 days. For example, the default number of dishwasher cycles listed is 1.4. This does not mean that 1 cycle was completed, and then another partial cycle (0.4 cycles) was completed, but rather one dishwasher cycle was completed each day of the week (5 people x 1.4 cycles/person/week = 7.0 cycles/week = 1 cycle/day). After all red values on this page have been inputted, the rest of the hot water and energy values will be automatically calculated and can be viewed on the "Summary" spreadsheet.

Please note that your dishwasher or clothes washer may have the option to choose multiple water temperatures and/or cycle types. This worksheet only calculates the nominal cycle represented in the Energyguides for that specific washer. Since all possible options are not provided in the Energyguide the energy use for those different cycles could not be calculated and prevents its use in this worksheet.

**Table 5 – Domestic hot water use calculations**

Common uses	Number of people (person)	Number of cycles (cycles/person/week)	Total cycles (cycles/week)	Hot water (liters/cycle)	Total hot water (liters/week)	Average hot water (liters/day)	Total energy (kWh/week)	Average energy (kWh/day)
Dishwasher	5	1.40	7.0	30.4	212.7	30.4	8.9	1.3
Clothes washer	5	1.00	5.0	14.6	73.2	10.5	3.1	0.4
Shower	5	7.00	35.0	84.7	2,964.4	423.5	124.2	17.7
Miscellaneous	5	7.00	35.0	0.8	28.2	4.0	1.2	0.2
Total					3,278.5	468.4	137.4	19.6

**GO TO THE SUMMARY WORKSHEET FOR A PRINT OUT**

Red text, input optional

Yellow background, final calculation for this worksheet

Black text, white background, no input required