Recommended DHW Use in Multifamily and Other Commercial Applications

Guidance on hot water use, water temperature, and other assumptions for energy savings calculations for Category 6 of the NY Clean Heat Program

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Overview

Accurate estimates of domestic hot water (DHW) use are essential for determining thermal loads and accurate energy savings in both single family and central DHW systems. This paper recommends appropriate DHW water use in gallons per day (GPD) for several building types based on field data as well as commonly used defaults from the NY Technical Resource Manual (NY TRM) and ASHRAE. Hot water use GPD recommendations are given for various applications. Recommendations are also given for thermal loop losses and appropriate inlet and outlet water temperatures.

NY TRM Recommendations for Hot Water Use

The NY TRM recommendations are summarized below.

Basic Recommendation: 17.2 gallons per day (GPD) per person
45.4 GPD per single family household

NY TRM Footnotes

Water Research Foundation: Residential End Uses of Water, Version 2, April 2016, pg. 5; 17.2 GPD equated from the report findings indicating an average 2.65 people per household and 45.5 GPD per household. Implicit in these GPD recommendations is a hot water delivery temperature of 125°F.

Table 1 below summarizes the basic recommendations for various commercial DHW applications from the NY TRM. Most are consistent with the basic recommendations above.

Table 1. Hot Water Use Recommendations for Various Building Application from the NY TRM V10

Building Type	GPD	Rate	Notes/Assumptions	Source
Assembly	239	7.02 GPD per 1,000 SF	Assumes 10% hot water, 34,000 SF	EIA[890]: Public Assembly
Auto Repair	25	4.89 GPD per 1,000 SF	Assumes 10% hot water, 5,150 SF	EIA: Other
Big Box Retail	448	3.43 GPD per 1,000 SF	Assumes 10% hot water, 130,500 SF	EIA: Mercantile
Community College	1,520	1.9 GPD per person	Assumes 800 students	NREL[891]: School with Showers
Dormitory	8,600	17.2 GPD per resident	Assumes 500 residents	Water Research Foundation[892]
Elementary School	250	0.5 GPD per student	Assumes 500 students	NREL: School
Fast Food Restaurant	500	500 GPD per restaurant		FSTC[893]: Quick Service
Full-Service Restaurant	2,500	2,500 GPD per restaurant		FSTC: Full Service
Grocery	172	3.43 GPD per 1,000 SF	Assumes 10% hot water, 50,000 SF	EIA: Mercantile
High School	1,520	1.9 GPD per person	Assumes 800 students	NREL: School with Showers
Hospital	16,938	54.42 GPD per 1,000 SF	Assumes 40% hot water, 250,000 SF	EIA: Health Care, Inpatient
Hotel	9,104	45.52 GPD per 1,000 SF	Assumes 40% hot water, 200,000 SF	EIA: Lodging
Large Office	550	1.1 GPD per person	Assumes 500 people	NREL: Office
Large Retail	446	3.43 GPD per 1,000 SF	Assumes 10% hot water, 130,000 SF	EIA: Mercantile
Light Industrial	489	4.89 GPD per 1,000 SF	Assumes 10% hot water, 100,000 SF	EIA: Other
Motel	1,366	45.52 GPD per 1,000 SF	Assumes 40% hot water, 30,000 SF	EIA: Lodging
Multifamily High-Rise	4,600	46 GPD per unit	Assumes 100 units	Water Research Foundation
Multifamily Low-Rise	552	46 GPD per unit	Assumes 12 units	Water Research Foundation
Refrigerated Warehouse	86	0.93 GPD per 1,000 SF	Assumes 10% hot water, 92,000 SF	EIA: Warehouse and Storage
Religious	77	7.02 GPD per 1,000 SF	Assumes 10% hot water, 11,000 SF	EIA: Public Assembly
Small Office	110	1.1 GPD per person	Assumes 100 people	NREL: Office
Small Retail	27	3.43 GPD per 1,000 SF	Assumes 10% hot water, 8,000 SF	EIA: Mercantile
University	1,000	0.5 GPD per student	Assumes 2,000 students	NREL: School
Warehouse	465	0.93 GPD per 1,000 SF	Assumes 10% hot water, 500,000 SF	EIA: Warehouse and Storage
Other	Calculate	4.89 GPD per 1,000 SF	Assumes 10% hot water	EIA: Other

NY TRM Table footnotes

890 U.S. Energy Information Administration, 2012 Commercial Buildings Energy Consumption Survey: Water Consumption in Large Buildings, Table WD1. Daily water consumption in large commercial buildings, 2012.

[891] National Renewable Energy Laboratory, Saving Energy in Commercial Buildings: Domestic Hot Water Assessment Guidelines, Table 1. Hot Water Use By Building Type, June 2011. [892] Water Research Foundation: Residential End Uses of Water, Version 2, April 2016.
[893] Improving Commercial Kitchen Hot Water System Performance, Design Guide – Energy Efficient Heating, Delivery and Use, Table 1. Typical hot water system cost for restaurants, March 2010.
[894] Burch, Jay and Christensen, Craig, "Towards Development of an Algorithm for Mains Water Temperature." National Renewable Energy Laboratory.

Measured Data from Residential Studies

The NYSERDA / Syracuse COE Study (Henderson et al, 2015) measured hot water use in 18 single-family homes they found:

- median hot water use was 45 GPD (closely aligned with other national studies and NY TRM).
- median two-person household used 39 GPD
- median 4-person household used 66 GPD.

The hot water use for two people implies about 20 GPD per person while the marginal use to go from 2 people to 4 people implies 13.5 GPD per person. The average of these is about 17 GPD per person

Measured Data from Multifamily

Data from NYSERDA and DOE/Building America study by Dentz et al. (2016) for two LMI buildings are shown below in Table 2. The usage per person is higher, perhaps implying higher occupancy in public housing multifamily buildings.

Table 2. Building Characteristics and Hot Water Use for two Low and Moderate Income (LMI) Buildings from Dentz et al (2016)

Site	Building A	Building B
Location	East New York, Brooklyn	East New York, Brooklyn
Collection Period	August 2013–April 2014	August 2013–March 2014
DHW System	Dedicated boiler and storage tank	Dedicated boiler and storage tank
Number of Floors	3	3
No of Apartments/Bedrooms	54 / 81	48 / 72
Average HW Tank Temperature	159°F	131°F
Average DHW Use		
GPD/Bedroom	38	41
GPD/Apartment	57	62

In 2020, a NYSERDA-funded team that included Sundog Solar, E2G Solar, and Owahgena Consulting assembled a portable data logger system that could be temporarily installed at building to measure hot water (HW) flows as well as various temperatures. The datalogging systems was built around a Flexim ultrasonic flow meter that could be strapped on the outside of HW piping to measure flows. This effort measured DHW use in five multifamily buildings in 2020 and 2021. At each facility a few weeks of data were collected at one-minute intervals.

Table 3 below summarizes the measured DHW use at these five facilities. DHW use was around 15 GPD per apartment for Senior living facilities – perhaps reflecting lower occupancy of about one person per

apartment in these units. In market and LMI apartments the usage of 30 GPD per apartment implies closer to 2 occupants per unit.

Zero Place, another newly-built multifamily building with some retail spaces, has been monitored since early 2022 as part of a NYSERDA-sponsored field demonstration. This building uses geothermal heat pumps for both space conditioning and domestic water heating. The results from that field test are shown at the bottom of Table 3. Usage in Zero Place came out to be about 17 GPD per bedroom or 27.8 GPD per apartment.

Table 3. Measured Hot Water Use from Several NY Multifamily Buildings (measured in 2020-2021) and Zero Place (2022-2023)

Site	City	No. of Apts	Occ. Type	Est Occ. per Apt	Hot Water Use (GPD per apt)	HW Delivery Temp (°F)	Recirc Losses (MBtu/ day-apt)	Recirc Losses (%)
Meadows E	New Hartford	35	Senior	1	15.4	125-135	14.6	62
Colonial	Rome	83	Senior	1	14.3	125-130	4.3	42
Solara	Rotterdam	24	Market	1.5	33.0	110		
Ohav Shalom (before changes)	Albany	210	Senior	1	13.8	125-150	3.3	35
Ohav Shalom (after changes)	Albany	210	Senior	1	15.4	lower	1.9	21
Kingsboro	Gloversville	50	LMI	1.5	29.2	140	6.8	30
Zero Place (2022)	New Paltz	46	Market	1.5	27.8	120	7.2	30

Note: the % recirculation losses = [Recirc Losses] / ([Hot Water Energy] + [Recirc Losses])

The test instrumentation also allowed for the team to calculate the recirculation losses at most sites, which is shown in the last column of Table 3 above. At most sites we found that 30% of the total heat input went to recirculation losses. At Meadows E the percentage was even higher at 62% -- perhaps due the relatively low use in that facility. At Ohav Shalom changes were made to the recirculation system and storage tanks that reduced recirculation losses from 35% to 21%.

The Ecosizer tool from Ecotope (https://ecosizer.ecotope.com/sizer/) uses a default of 100 Watts per apartment for the combined thermal losses in DHW systems. This equates to 8.1 MBtu/day per apt and is equivalent to about 13 GPD per apt of additional DHW use. The 2020-2021 field tests of the five multifamily buildings ranged from 1.9 to 14.6 MBtu/day per apt with an average of 6.2 MBtu/day per apt. Similarly, the average recirculation losses at Zero Place was 7.2 MBtu/day per apt. Since the Ecosizer default is for all thermal losses, these measurements and model defaults are in good agreement.

Energystar Tool for Multifamily

EPA's Energystar Multifamily High Rise Performance Path Calculator Tool (EPA 2015) includes assumptions for DHW use based on the demographic factors listed in the table below (from the "3 - Multifamiliy Details" sheet, Table 3.6). The data given in Table 4 is labeled as GPD per person; however, the descriptions in table, and how the formulas use these values in the XLS, imply the actual units are

GPD per bedroom (not per person). The footnote in table states the assumption is one person per bedroom, we apply that assumption to the low use case and then determine the inferred occupancy for medium and high use cases.

Table 4. Classifications of Hot Water Use in Multifamily Buildings from EPA Energystar Performance Path Calculator

EPA Classification	EPA Description	Baseline GPD per bedroom	Implied occupancy per bedroom
Low	Demographics such as all occupants working, seniors, middle income, and higher population density.	12	1
Medium	Demographics such as mixture of working / non-working occupants, mixture of age groups, medium population densities.	25	2.1
High (use for affordable housing only)	Demographics such high percentages of children, low income, public assistance, or no occupants working.	44	3.7

Note: Baseline use is without appliances. EPA states that the dishwasher adds another 3.5 GPD per apartment, and clothes washers add 7.5 GPD for Energystar and 16 GPD for non-Energystar appliances.

The assumed DHW use for appliances in the table footnote above appears to be more applicable to per appliance numbers in shared laundry facilities – as opposed to apartments with their own washing machine. In shared laundry facilities in multifamily buildings, there are usually about 10 apartments per washing machine. Therefore, the per apartment use value is closer to 1-2 GPD with a washing machine inside the apartment.

Therefore, adding in the water use for appliances increases the water use for a one bedroom apartment with one occupant to be a 12 + 3.5 +1.5 = 17 GPD, which is in line with the NY TRM recommendations.

The high use case shows 44 GPD per bedroom is 3 to 4 times higher than the low use case. This high usage is consistent with the field measurements from Dentz et al (2016) for an LMI building in NYC. It appears to be related to the higher occupancy in public housing and perhaps because the tenants do not directly pay for utilities related to DHW use. The newest version of the EPA tool provides guidance that the high use case only applies in public housing.

Table 7 of the ASHRAE Applications Handbook (2019) provides even higher guidance for the Low, Medium and Hugh use cases in multifamily, at 14, 30 and 54 GPD per person, respectively.

Other Commercial DHW Applications

Measured Data for High Schools

Dinse, Henderson and Richardson (2004) measured DHW use in high school in Tennessee. Measured DHW use was about 0.9 GPD per student. This is about half the value recommended by ASHRAE (1.8 GPD/student) and in the NY TRM table above (1.9 GPD/student)

Comparing the NY TRM to ASHRAE Applications Handbook

Table 5 compares the NY TRM hot water use values for commercial applications to ASHRAE 2019 Applications Handbook. There are generally only minor differences between these two sources. Some of the ASHRAE values assume lower per unit use in larger buildings which would also seem to be counter intuitive.

One building application where the ASHRAE value may be more appropriate than NY TRM recommendation is for Dormitories. The ASHRAE recommendation of 12-13 GPD per resident makes more sense in applications where laundry and food service are not in the building. The ASHRAE values are also consistent with the EPA base recommendations without appliances.

Table 5. Comparing NY TRM Recommendations to the ASHRAE Applications HandBook

Building Type	NY TRM	ASHRAE Applications Chapter 51, Table 6	ASHRAE differences
Assembly	7.02 GPD per 1,000 SF		
Auto Repair	4.89 GPD per 1,000 SF		
Big Box Retail	3.43 GPD per 1,000 SF		
Community College	1.9 GPD per person		
Dormitory	17.2 GPD per resident	13.1 GPD men, 12.3 women	Like the EPA GPD value, seem not to include laundry or dishwasher
Elementary School	0.5 GPD per student	0.6 GPD per student	
Fast Food Restaurant	500 GPD per restaurant	0.7 GPD per meal	Different basis, but may be compatible
Full-Service Restaurant	2,500 GPD per restaurant	2.4 GPD per meal	
Grocery	3.43 GPD per 1,000 SF		
High School	1.9 GPD per person	1.8 GPD per student	
Hospital	54.42 GPD per 1,000 SF		
Hotel and Motel	45.52 GPD per 1,000 SF	20 GPD per unit, under 20 units 14 GPD per unit, 20 to 60 units	Different basis, but may be compatible; implies bigger buildings have less GPD use
Large Office	1.1 GPD per person		
Large Retail	3.43 GPD per 1,000 SF		
Light Industrial	4.89 GPD per 1,000 SF		
Multifamily High-Rise	46 GPD per unit	35 GPD per apt (200 units)	Implies bigger buildings have less GPD use
Multifamily Low-Rise	46 GPD per unit	42 GPD per apt (20 units)	
Nursing Homes		18.4 GPD per bed	
Refrigerated Warehouse	0.93 GPD per 1,000 SF		
Religious	7.02 GPD per 1,000 SF		
Small Office	1.1 GPD per person	1.0 GPD per person	
Small Retail	3.43 GPD per 1,000 SF		
University	0.5 GPD per student		
Warehouse	0.93 GPD per 1,000 SF		
Other	4.89 GPD per 1,000 SF		

Inlet (Cold) Water Temperature from City Mains

Inlet (or cold) water temperatures from the city mains from an urban water system vary according to climate and are approximately equal to the annual average outdoor temperature plus 6°F according to Burch and Christensen (2007). The city main temperatures (T_{main}) based on the annual outdoor temperature from the NY TRM are shown below in Table 6.

Table 6. TRM-Recommended Temperatures for City Main Temperatures (T_{main}) in Various NY Cities

City	T_{main} (˚F)
Albany	54.3
Binghamton	52.3
Buffalo	54.3
Massena	49.5
NYC	61.4
Poughkeepsie	55.8
Syracuse	54.3

Burch and Christensen (2007) also observed that the amplitude of the main temperature swings across the year could be approximated as 40% of average annual value. From Kusudah and Achenbach (1965) we know that the minimum temperature occurs about 38 days after the beginning of the year for Upstate cities and 37 days for NYC. Using Kusudah equations with the time shift, we determined daily temperatures across the year and therefore the monthly averages, which are given in Table 7 below.

Table 7. Recommended Monthly Temperatures for City Main Temperatures (T_{main}) in Various NY Cities

	Albany	Binghamton	Buffalo	Massena	NYC	Poughkeepsie	Syracuse
January	39.6	38.1	39.6	35.7	45.3	41.1	39.6
February	39.0	37.4	39.0	35.1	44.6	40.5	39.0
March	40.9	39.3	40.9	36.9	47.0	42.4	40.9
April	44.7	42.9	44.7	40.3	51.4	46.2	44.7
May	49.6	47.5	49.6	44.7	57.1	51.1	49.6
June	54.0	51.7	54.0	48.6	62.2	55.5	54.0
July	57.0	54.5	57.0	51.3	65.5	58.5	57.0
August	57.6	55.1	57.6	51.8	66.1	59.1	57.6
September	55.7	53.4	55.7	50.2	63.9	57.2	55.7
October	51.8	49.6	51.8	46.6	59.3	53.3	51.8
November	47.1	45.1	47.1	42.4	53.8	48.6	47.1
December	42.5	40.8	42.5	38.3	48.6	44.0	42.5
Annual AVG	54.3	52.3	54.3	49.5	61.4	55.8	54.3

These monthly values can be useful in more detailed DHW analysis that considers seasonal changes in city main temperatures.

Delivered Hot Water Temperatures

The hot water delivery or supply temperature is typically 120-130°F for single family homes (the NY TRM says to use 125°F). In central DHW systems with recirculation loops, the delivery temperature ($T_{delivered}$) is often controlled by mixing valve to be in the range of 110-125°F to protect against scalding at end use fixtures. New York City housing regulations require that hot water in multifamily buildings be delivered

at a minimum of 120°F (https://www.nyc.gov/site/hpd/services-and-information/heat-and-hot-water-information.page). The hot water generation plant (or fuel-fired tank) in central DHW systems can often operate at much higher temperatures (e.g., 140 to 160°F) to either reduce storage requirements or to control the growth of legionella bacteria. However, this higher plant or tank temperature is not the delivery temperature and should not be used in the energy calculations with GPD values. Higher plant temperatures and poor mixing valve performance often lead to unnecessarily high recirculation loop flow rates, which greatly increase thermal losses in the DHW system.

Recommendations

Recommended DHW Use

The assumed value of 17.2 GPD per person from the NY TRM is corroborated by various field measurements in residential applications. The variation in the assumed occupancy for different buildings explains most of the differences in the NY TRM table based on single family homes or apartments. Field studies often do not know that exact occupancy of buildings but generally concur with the general TRM values (Table 1) when assumptions are applied.

Table 8 below uses the baseline 17 GPD per person values and applies occupancy assumptions (per bedroom and per apartment) to come up with appropriate values per household or per bedroom. In other situations, we recommend using the NY TRM values from Table 1 above.

Table 8. Recommended Occupancy Rates for Various Residential Applications

	Assumed Occupancy	**DHW Use (GPD)**
Single Family		Per house
average	2.7 per house[1]	45
2-person household	2 per house[2]	34
4-person household	4 per house[2]	68
Mulifamily		Per apartment
Senior Apartments	1 per apt, 1 per bedroom[3]	17
Market Rate or General	1.7 per apt, 1.2 per bedroom[4]	29
Urban Public Housing	3.5 per apt, 2.4 per bedroom[5]	65
Schools		Per student
with Showers		1.9
without showers		0.9
Dormitories		Per resident
without laundry		12
with laundry		13.5

Notes: 1 – from the NY TRM
2 – Using 17 GPD per person; generally agrees with Henderson et al (2015)
3 – from 2020 field tests and consistent with “Low Use” for Energystar tool
4 – from 2020 field tests; consistent with than “Medium Use” for Energystar tool
4 – from Dentz et al (2014); slightly less than “High Use” for Energystar tool implies

Accounting for Thermal Losses in Central DHW Systems

Central DHW systems have thermal losses that are primarily driven by recirculation losses. Estimates from simulation tools and field measurements imply thermal losses from recirculation loops can be in the range of 20 to 60% of the total heat input, or 2 to 15 MBtu per day per apartment. Typical thermal recirculation losses are 30% of total heat input, or 6 MBtu/day per apartment. We recommend that losses be assumed to be slightly less than average when estimating loads for determining incentives for DHW systems under Category 6 of the Clean Heat Program. Therefore, we recommend thermal losses of 5 MBtu/day per apartment or 25% of the total heat input.

[Total DHW MBtu/day] = [No. Apartments] x [HW Usage MBtu/day-apt] / (1 – 0.25)

OR

[Total DHW MBtu/day] = [No. Apartments] x { [HW Usage MBtu/day-apt] + [5 MBtu/day-apt] }

Where:

[HW Usage MBtu/day-apt] = GPD x 8.33 x $(T_{delivered} - T_{main})/1000$

References

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