



SAFER, SMARTER, GREENER

DEER Water Heater Calculator Documentation

v5.0 for the DEER2023 Update

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1 DEER Water Heater Calculator

1.1 General background

The DEER Water Heater Calculator (DWHC) was initially developed for DEER2015 water heater measures. The tool utilizes representative water heater “technologies”, hourly hot water loads (in gallons per minute, by DEER building type) and ambient conditions (incoming “mains” water temperature, ambient space dry- and wet-bulb temperature) to estimate hourly energy use of each modeled water heater.

The previous Ex Ante Review team considered building energy models (e.g., eQUEST®) to be excessive and time-consuming for most water-heating measures. This was a primary motivator for creating an Excel-based calculator to estimate water heating measures. The DWHC was also expanded to handle simple modeling requirements of heat pump water heaters (HPWHs) and to provide a relatively easy method to add new measures and technologies based on program administrator (PA) requirements.

With the advancement of HPWH technology and the importance of modeling interactive and time-based (e.g., load shifting) effects of HPWHs on other building loads and equipment, version 5.0 of the DWHC will begin a transition back to modeling some DEER water heating measures using building energy modeling software. PAs also continue to develop water heating measures using modeling software like OpenStudio® (which uses the EnergyPlus® engine).

The DWHC utilizes a calculation methodology that accounts for the water heater’s recovery or thermal efficiency (i.e., effectiveness of converting fuel energy into hot water) and other supplemental energy uses (tank loss, auxiliary ventilation, pilot-light gas, supplemental/backup electric resistance heat) to estimate the water heater’s total energy use. The ambient air temperature of the water heater tank and/or heat pump (HP) evaporator is used to determine the heat loss from the tank as well as the hourly coefficient of performance (COP) of a HPWH.

Throughout this document, it is implied that version 5.0 of the DWHC—intended for use for the DEER2023 Update—is being discussed unless otherwise indicated.

Version 5.0 of the calculator accounts for the following:

- Incoming cold-water temperature (“mains” temperature), by climate zone and day of year¹
- Hourly hot water load: total building hot water demand (gallons of water) for a given hour²
- Tank loss (if applicable): stored hot water energy lost to the ambient air where the storage tank is assumed to be located
- Auxiliary load: energy consumed by pilot lights, fans, etc.

¹ Using CZ2022 weather files and equations from 2019 Title 24 ACM Reference Appendix B

² Water temperature is assumed to be 135 °F for all building types.

- HPWH COP and capacity adjustments due to ambient air temperature and tank temperature set point.
- HPWH compressor cut-off temperatures i.e., minimum and maximum ambient temperatures at which the compressor will be disabled and only the electric resistance element will heat water
- HPWH supplemental electric resistance load when hot water load exceeds water heater's maximum hourly heating flowrate, in gallons/hour (gph)³

There are notable limitations to the calculator. It *does not* account for:

- Interactive effects between the water heater and the HVAC system serving the corresponding conditioned space
- Split-system heat pump water heaters; tank and HPWH evaporator are assumed to be in same thermal zone
- Variable hot-water temperature set points
- Hourly changes in fractional, supplemental electric-resistance heating supplied by HP water heaters: if the hourly hot-water load (in gallons) exceeds what can be supplied by the HP compressor alone, a fraction (assumed to be 10%) of heating for that hourly load is provided by the backup electric resistance heater. This assumed fraction does not change regardless of the estimated excess hourly hot-water load.
- Heat pump defrost-cycle energy

The calculator determines how much energy is required to meet hot-water loads using water heater performance characteristics derived from Air Conditioning, Heating, & Refrigeration Institute (AHRI), U.S. Department of Energy (DOE), ENERGY STAR[®], and/or the California Energy Commission (CEC) databases. These characteristics that are commonly found in the databases are listed as follows:

- Water heater type
- Recovery efficiency (%), for residential water heaters
- Thermal efficiency (%), for commercial water heaters
- Standby loss (Btu/hr or %/hour), for commercial water heaters
- Rated input capacity (kBtu/hr or kW)
- Rated storage volume (gallons)
- Uniform Energy Factor (UEF), for residential water heaters (used to determine COP for residential HPWH)
- Usage or draw pattern bin, for residential water heaters
- First-hour rating (FHR), for residential water heaters
- Coefficient of Performance (COP), for commercial HPWH

³ Electric resistance load is assumed by all HPWHs to be 10% for hours where hourly HW demand exceeds maximum hourly flowrate of HPWH. Derived from NREL study at <https://www.nrel.gov/docs/fy16osti/64904.pdf>.

1.2 Hot water load profiles

The calculator contains 8,760-hour hot water load profiles (in gallons of hot water) for 23 commercial and 3 residential DEER building types. The commercial load profiles were extracted from DEER DOE2 building prototypes and remain unchanged from the previous DWHC version. The university and hotel prototypes use the dorm room and guest room space profiles, respectively.

1.3 Ambient air temperature profiles

Hourly ambient air temperature profiles of the hot water tank and heat pump evaporator is used to determine the heat loss from the tank and the adjusted COP/capacity of a HPWH. The ambient temperature profiles were extracted from DEER DOE prototypes for seven space types and for each climate zone. See Table 1-1 for each building type's designated ambient temperature space type. HPWH COP/capacity adjustment due to ambient air temperature is discussed in Section 1.7.1.

Table 1-1. Water heater ambient space type by building type

Building Type	Water heater ambient space type
Assembly	Conditioned Interior space
Primary School	Conditioned Storage space
Secondary School	Conditioned Storage space
Community College	Conditioned Storage space
University	Conditioned Storage space
University Dormitory	Conditioned Storage space
Relocatable Classroom	Interior Hallway
Grocery	Conditioned Storage space
Hospital	Conditioned Interior space
Nursing Home	Conditioned Interior space
Hotel	Conditioned Interior space
Hotel Guest Room	Interior Hallway
Motel	Interior Hallway
Bio/Tech Manufacturing	Conditioned Interior space
Light Industrial Manufacturing	Conditioned Storage space
Large Office	Conditioned Interior space
Small Office	Conditioned Interior space
Sit-Down Restaurant	Conditioned Storage space
Fast-Food Restaurant	Conditioned Storage space
Department Store	Conditioned Storage space
Big Box Retail	Conditioned Storage space
Small Retail	Conditioned Storage space
Conditioned Storage	Conditioned Storage space
Unconditioned Storage	Unconditioned Storage space
Refrigerated Warehouse	Conditioned Interior space
Single Family Home	Attached Garage
Multifamily Home	Interior Hallway
Mobile Home	Outdoor Cabinet

1.4 Temperatures of water mains

The calculator also accounts for variation in incoming (“mains”) water temperature. Ground water temperature is calculated using weather data and equations defined in the 2019 ACM Reference Manual Appendix B⁴. The water mains temperature is listed by day of year and climate zone.

1.5 Water heater load

Water heater measures historically have used DOE performance metrics including Energy Factor (EF), Uniform Energy Factor (UEF), thermal efficiency (TE), first-hour rating (FHR), or standby loss as criteria for measure qualification. EF and UEF represent the efficiency of the equipment’s water-heating components and tank losses under a specific 24-hour test procedure. While EF used a single draw pattern for the 24-hour test procedure, UEF uses different draw patterns (very small, low, medium, high) for the test procedure.

The water heater calculator does not directly use UEF—or Energy Factor (EF)—to calculate water heating energy usage. UEF and EF values are used as a comparison metric among water heater types. The derivation of the UEF/EF metric relies on specific hot water draw patterns that are not used by the calculator (the calculator uses hot water load profiles as mentioned in Section 1.2). The calculator uses recovery efficiency (RE), thermal efficiency, COP, and tank UA (i.e., tank heat loss) as key efficiency parameters.

The calculator categorizes three separate loads water heaters must satisfy as described in the sub-sections that follow.

1.5.1 Hot water load

Hot water load is the calculated hourly hot water load in Btu/hr due to hot water use. This load uses the building-specific hot water load profiles (in gallons of water), assumed main water temperature, and assumed tank temperature as shown in Equation 1-1.

Equation 1-1. Hourly hot water load

$$HW_{load} = HW_{gal} \times (T_{tank} - T_{mains}) \times 8.2$$

where,

HW_{load} = hourly hot water load in Btu/hr

HW_{gal} = hourly hot water volume, in gallons

T_{tank} = water heater temperature, 135 °F

T_{mains} = water mains (ground water) temperature

8.2 = specific heat and density conversion factor for water

1.5.2 Tank loss load

Tank loss represents the hourly hot water load in Btu/hr due to heat lost through the tank walls/insulation. This load is calculated using the water heaters tank loss factor (tank UA) and is described in greater detail in Section 1.6.

⁴ <https://energycodeace.com/site/custom/public/reference-ace-2019/index.html#!Documents/b4hourlyadjustedrecoveryload.htm>

1.5.3 Auxiliary load

Auxiliary load represents the hourly hot water load due to pilot light heating the water tank.⁵ Gas storage water heaters are assumed to have a constant hourly load; instantaneous gas heaters are assumed to only use pilot light energy while the heater is operating.

1.6 Tank losses (Tank UA)

Standby losses are not reported in AHRI for residential water heaters. The calculator uses Equation 1-2 to estimate standby losses (Btu/hr-°F) for storage water heaters that are not HPWHs. Instantaneous water heaters are assumed to have no tank losses.

Equation 1-2. Tank UA of residential (storage) water heaters⁶

$$UA_{tank} = \frac{\left(\frac{RE}{UEF} - 1\right)}{\left(\frac{24}{Btu/hr_{daily}} - \frac{1}{(UEF \times Cap \times 1,000)}\right)} \times 67.5$$

where,

- UA_{tank} = tank heat losses to ambient air, Btu/hr-°F
- RE = recovery efficiency, %
- UEF = uniform energy factor or energy factor
- Cap = input capacity of water heater, in kBtu/hr
- Btu/hr_{daily} = water heating energy for the 24-hour draw volume (depends on draw pattern)

Commercial water heaters have published standby losses in Btu/hr or %/hr (% of input capacity). The TechID tank UA values (Btu/hr-°F) for commercial water heaters are calculated using Equation 1-3.

Equation 1-3. Tank UA of commercial (storage) water heaters

$$UA_{tank} = \frac{LOSS_{standby}}{70}$$

where,

- UA_{tank} = tank heat losses to ambient air, Btu/hr-°F
- $LOSS_{standby}$ = published (AHRI, CEC) standby loss in Btu/hr
- 70 = assumed temperature difference between tank and ambient air, °F

Tank loss rates of HPWHs are discussed in Section 1.7.2.

⁵ Assumed to be 350 Btu/hr and 67% efficient

⁶ The equation is based on the estimate of water heater energy consumption proposed in WHAM: A Simplified Energy Consumption Equation for Water Heaters (Lutz, 1998). The WHAM model is also utilized in the DOE UEF conversion procedure

1.7 HPWH performance

The HPWHs utilize EF values to estimate corresponding COP values.⁷ The COP values are used in the calculator to estimate water heating energy usage and are utilized in the calculator like RE and TE. This EF-COP correlation is based on an NREL study⁸ that investigated heat pump water heater performance.

1.7.1 HPWH COP

The nominal HPWH COP is estimated as a fraction of the rated EF for a tank temperature range between 120 and 135 °F. The COP is also adjusted as a function of ambient temperature. The water heater calculator uses the same assumptions and equations that estimate nominal HPWH COP as previous calculator versions. The equation for nominal HPWH COP is shown in Equation 1-4.

Equation 1-4. HPWH COP as a function of EF and tank temperature

$$COP = EF \times (2.6 - 0.0133 \times T_{tank})$$

where,

COP = coefficient of performance

EF = energy factor

T_{tank} = tank temperature, °F

The HPWH COP and heating capacity are further adjusted as function of wet bulb temperature and tank temperature. These adjustments are described further in Section 3.5.

1.7.2 HPWH tank loss (Tank UA) rate

Standby losses are not published for HPWHs and are dependent on characteristics that differ from traditional storage water heaters. The Deemed Ex Ante Review team decided to use a value of 4.37 Btu/hr-°F for all HPWHs.⁹

2 Using the DWHC

2.1 General function of the DWHC

The calculator estimates the annual energy usage of each “TechID”. TechIDs represent types of water heaters on the market or pre-existing water heaters that are currently installed in buildings. The “Technologies” worksheet contains all the combinations of water heaters offered in DEER measures. The worksheet can be amended to offer new types of water heaters. There are currently three water heater technology types:

- Storage (“Stor”). This type represents storage-type water heaters that are not heat pumps. These storage type water heaters generally have storage volumes greater than 20 gallons and have an input rating of less than 4,000 Btu per hour of input per gallon of storage.

⁷ The calculator converts the published UEF values into EF values (using DOE conversion formulae), then uses EF values to estimate COP values.

⁸ <https://www.nrel.gov/docs/fy16osti/64904.pdf>

⁹ Field Performance of HPWH in the Northeast, February 2016, C. Shapiro; S. Puttagunta

- Instantaneous (“Inst”). This type represents instantaneous water heaters that, in general, have a storage volume less than 2 gallons and an input rating of more than 4,000 Btu/hr of input per gallon of storage. Hot water supply boilers are also represented using this technology type
- Packaged heat pump water heaters (“PkHP”). This type represents *packaged* heat pump water heaters.

Storage and instantaneous water heaters use recovery efficiency or thermal efficiency as the primary efficiency metric for calculating how much energy (gas or electric) is required to heat incoming cold water to the hot water temperature. Heat pump water heaters use COP.¹⁰ The calculator accounts for two fuel types: electricity and natural gas.

DEER measures (MeasureIDs) are the comparison of two TechIDs. One TechID represents the base case and one TechID represents the measure case. These comparisons, the MeasureIDs, are defined on the “Measure” sheet. The measure entries on this sheet specify the measure technology, the standard/code-compliant technology and the pre-existing technology. It also specifies the building sector (residential or commercial) and the measure’s savings unit (“Each” or “Cap-kBtuh”).

The general procedure for adding new measures to the water heater calculator involve the following steps:

1. Add TechIDs to the Technologies worksheet
2. Add Measure IDs to the Measure worksheet
3. Execute “Calculate All Results” button macro on the TechCalc worksheet. This generates all the TechID permutations (building type, climate zone, and technology ID)
4. Execute “Create All Impacts” button macro on the EnImpacts-Res and EnImpacts-Com worksheets. This compares TechIDs against each other to create savings values.
5. Execute “Export” button macro on the EnergyImpact worksheet.

The following sections describe in more detail how to add new TechIDs on the “Technologies” worksheet, add new MeasureIDs on the “Measure” worksheet, and execute the macros.

2.2 Adding TechIDs to the DWHC

This section describes how to use version 5.0 of the water heater calculator.

2.2.1 TechID naming conventions

This update attempted to follow precedent established from previous versions of the water heater calculator. The Deemed Ex Ante Review team wanted to make clear some specific conventions for the TechID name and input parameter values (e.g., UEF, RE, input capacity, etc.) of those TechIDs.

- Efficiency value in pre-existing TechID names match the efficiency input parameter value
- Efficiency value in standard/code TechID names match the corresponding minimum code value; however, the efficiency input parameter value of the TechID can be the same or higher than what is in the name. This is because of the average binning method discussed in Section 2.2.5.

¹⁰ COP values are estimated using EF or UEF values and the tank temperature

- Efficiency values in measure TechID names match measure package efficiency tier efficiency values; however, the efficiency input parameter value of the TechID can be the same or higher than what is in the name. This is because of the averaging method discussed in the Section 2.2.5.

2.2.2 Pre-existing TechIDs

TechIDs that are used to simulate vintage water heaters did not have their TechID input parameters or descriptions converted in to UEF. Part of the reason not to convert the name was to distinguish pre-existing TechIDs from standard/code-level or measure-level TechIDs. Standard/code-level and measure-level TechIDs all use UEF or TE in their names, but pre-existing TechIDs do not.¹¹

2.2.3 Standard/code TechIDs

The TechIDs that represent standard/code base case water heaters were developed using a combination of minimum efficiency standards defined in the U.S. Code of Federal Regulations and percentage ranges above the minimums.¹² This method is intended to approximate typical entry-level water heaters on the market that are usually slightly above code. There are UEF standards for residential consumer (and residential-duty commercial) products and TE standards for commercial products. The minimum efficiency values used by the binning workbook are shown in the figures that follow (Figure 2-1, Figure 2-2, and Figure 2-3).

¹¹ Exceptions are made for the commercial sector where pre-existing TechIDs did not previously exist for 80, 100, and 120-gallon water heaters. Future updates of the calculator may include a research component that incorporates more findings from commercial building stock studies (e.g., California Commercial End-Use Survey).

¹² Residential consumer products: [Title 10 → Chapter II → Subchapter D → Part 430 → Subpart C → § 430.32](#); commercial products: [Title 10 → Chapter II → Subchapter D → Part 431 → Subpart G → § 431.110](#).

Figure 2-1. UEF minimum efficiency standards for residential consumer water heater products

Product class	Rated storage volume and input rating (if applicable)	Draw pattern	Uniform energy factor
Gas-fired Storage Water Heater	≥20 gal and ≤55 gal	Very Small	$0.3456 - (0.0020 \times V_r)$
		Low	$0.5982 - (0.0019 \times V_r)$
		Medium	$0.6483 - (0.0017 \times V_r)$
		High	$0.6920 - (0.0013 \times V_r)$
	>55 gal and ≤100 gal	Very Small	$0.6470 - (0.0006 \times V_r)$
		Low	$0.7689 - (0.0005 \times V_r)$
		Medium	$0.7897 - (0.0004 \times V_r)$
		High	$0.8072 - (0.0003 \times V_r)$
Oil-fired Storage Water Heater	≤50 gal	Very Small	$0.2509 - (0.0012 \times V_r)$
		Low	$0.5330 - (0.0016 \times V_r)$
		Medium	$0.6078 - (0.0016 \times V_r)$
		High	$0.6815 - (0.0014 \times V_r)$
Electric Storage Water Heaters	≥20 gal and ≤55 gal	Very Small	$0.8808 - (0.0008 \times V_r)$
		Low	$0.9254 - (0.0003 \times V_r)$
		Medium	$0.9307 - (0.0002 \times V_r)$
		High	$0.9349 - (0.0001 \times V_r)$
	>55 gal and ≤120 gal	Very Small	$1.9236 - (0.0011 \times V_r)$
		Low	$2.0440 - (0.0011 \times V_r)$
		Medium	$2.1171 - (0.0011 \times V_r)$
		High	$2.2418 - (0.0011 \times V_r)$
Tabletop Water Heater	≥20 gal and ≤120 gal	Very Small	$0.6323 - (0.0058 \times V_r)$
		Low	$0.9188 - (0.0031 \times V_r)$
		Medium	$0.9577 - (0.0023 \times V_r)$
		High	$0.9884 - (0.0016 \times V_r)$
Instantaneous Gas-fired Water Heater	<2 gal and >50,000 Btu/h	Very Small	0.80
		Low	0.81
		Medium	0.81
		High	0.81
Instantaneous Electric Water Heater	<2 gal	Very Small	0.91
		Low	0.91
		Medium	0.91
		High	0.92
Grid-Enabled Water Heater	>75 gal	Very Small	$1.0136 - (0.0028 \times V_r)$
		Low	$0.9984 - (0.0014 \times V_r)$
		Medium	$0.9853 - (0.0010 \times V_r)$
		High	$0.9720 - (0.0007 \times V_r)$

* V_r is the Rated Storage Volume (in gallons), as determined pursuant to 10 CFR 429.17.

Figure 2-2. UEF minimum efficiency standards for residential-duty commercial water heaters

Product class	Specifications ^a	Draw pattern	Uniform energy factor ^b
Gas-fired Storage	>75 kBtu/hr and ≤105 kBtu/hr and ≤120 gal	Very Small	0.2674 – (0.0009 × Vr)
		Low	0.5362 – (0.0012 × Vr)
		Medium	0.6002 – (0.0011 × Vr)
Oil-fired Storage	>105 kBtu/hr and ≤140 kBtu/hr and ≤120 gal	High	0.6597 – (0.0009 × Vr)
		Very Small	0.2932 – (0.0015 × Vr)
		Low	0.5596 – (0.0018 × Vr)
Electric Instantaneous	>12 kW and ≤58.6 kW and ≤2 gal	Medium	0.6194 – (0.0016 × Vr)
		High	0.6740 – (0.0013 × Vr)
		Very Small	0.80
		Low	0.80
		Medium	0.80
		High	0.80

^aAdditionally, to be classified as a residential-duty commercial water heater, a commercial water heater must meet the following conditions: (1) if the water heater requires electricity, it must use a single-phase external power supply; and (2) the water heater must not be designed to heat water to temperatures greater than 180 °F.

^bVr is the rated storage volume (in gallons), as determined pursuant to 10 CFR 429.44.

Figure 2-3. TE minimum efficiency standards for commercial water heater products¹³

Equipment category	Size	Energy conservation standard ^a		
		Maximum standby loss ^c (equipment manufactured on and after October 29, 2003) ^b	Minimum thermal efficiency (equipment manufactured on and after October 29, 2003 and before October 9, 2015) ^b (%)	Minimum thermal efficiency (equipment manufactured on and after October 9, 2015) ^b (%)
Electric storage water heaters	All	0.30 + 27/Vm (%/hr)	N/A	N/A
Gas-fired storage water heaters	≤155,000 Btu/hr	Q/800 + 110(Vr) ½ (Btu/hr)	80	80
	>155,000 Btu/hr	Q/800 + 110(Vr) ½ (Btu/hr)	80	80
Oil-fired storage water heaters	≤155,000 Btu/hr	Q/800 + 110(Vr) ½ (Btu/hr)	78	80
	>155,000 Btu/hr	Q/800 + 110(Vr) ½ (Btu/hr)	78	80
Gas-fired instantaneous water heaters and hot water supply boilers	<10 gal	N/A	80	80
	≥10 gal	Q/800 + 110(Vr) ½ (Btu/hr)	80	80
Oil-fired instantaneous water heaters and hot water supply boilers	<10 gal	N/A	80	80
	≥10 gal	Q/800 + 110(Vr) ½ (Btu/hr)	78	78
Equipment category		Size	Minimum thermal insulation	
Unfired hot water storage tank	All		R-12.5	

^aVm is the measured storage volume (in gallons), and Vr is the rated volume (in gallons). Q is the nameplate input rate in Btu/hr.

As with the code/standard TechIDs of previous versions of the calculator, this update defines the code/standard TechID minimum efficiency as a range equal to and a percentage above the code minimum requirement. For example, the TechID that represents a gas-fueled 50-gallon storage water heater with a medium draw pattern would have a minimum code UEF of 0.56 (see Figure 2-1; 0.6483-0.0017*50). However, a 5.0% tolerance above the minimum code requirement is added so the range of water heaters in the database representing this TechID have an allowable UEF from 0.56 to 0.59. The representative UEF for this code-level TechID (Stor_UEF-Gas-050gal-MD-0.56UEF) turned out to be 0.57. Based on the UEF range (code level + some % above code), the TechID input capacity and RE are also averaged using the binning workbook.

¹³ See 3.4 for hot water supply boilers federal code thermal efficiency value going into effect for boilers manufactured in January 2023.

2.2.3.1 Heat pump water heaters

There are no specific code requirements for (residential/consumer) HPWHs; they are technically covered under electric storage water heaters. All HPWHs on the market significantly exceed the electric storage water heater UEF code requirements; therefore, UEF values (see Table 2-1) were selected by the Deemed Ex Ante Team to match the SWWH014 workpaper minimum standard efficiency for HPWHs, based on storage volume. The values represent standard/code UEF values when the HPWH is defined in the measure as the base case water heater.

Table 2-1. Standard TechID UEF requirement for HPWHs

Volume (gallons)	UEF
65	2.91
80	3.00

2.2.4 Measure TechIDs

TechIDs that represent measure-level water heaters are developed similarly to code/standard TechIDs except that the qualifying criteria (e.g., UEF, standby loss) are, generally speaking, modified to meet or exceed ENERGY STAR® requirements. There are some TechIDs where the qualifying criteria do not exceed ENERGY STAR.

The residential ENERGY STAR criteria (version 5.0, enacted January 5, 2022) give qualification pathways for UEF ratings only. Commercial ENERGY STAR criteria (enacted October 2018) give qualification pathways for TE, COP, and standby loss. ENERGY STAR criteria are shown in Table 2-2 and Table 2-3 that follow.

Table 2-2. ENERGY STAR criteria for residential water heaters¹⁴

Residential water heater type	Capacity, ≤55 gallons	Capacity, >55 gallons	All
Integrated HPWH (UEF)	—	—	3.30
Integrated HPWH 120 V / 15 A circuit	—	—	2.20
Split-system HPWH	—	—	2.20
Gas storage, medium draw (UEF)	0.64	0.78	—
Gas storage, high draw (UEF)	0.68	0.80	—
Gas instantaneous (UEF)	—	—	0.87
Residential-duty gas storage (UEF)	—	—	0.80

Table 2-3. ENERGY STAR criteria for commercial water heaters

Commercial water heater type	Thermal efficiency	Standby loss (Btu/h)	COP
Gas storage	0.94	$0.84 \times [(\text{Input rate} / 800) + 110 \times (\text{Volume})^{1/2}]$	—
Gas storage-type instantaneous	0.94	$0.84 \times [(\text{Input rate} / 800) + 110 \times (\text{Volume})^{1/2}]$	—

¹⁴ All HPWH require a first hour rating (FHR) of greater than or equal to 45 gallons per hour; gas storage require a FHR of greater than or equal to 51 gallons per hour; instantaneous water heaters require max GPM more than or equal to 2.8 gallons per minute

Commercial water heater type	Thermal efficiency	Standby loss (Btu/h)	COP
Gas instantaneous	0.94	0.80	—
Electric heat pump	—	—	3.0

Unlike the code/standard binning range discussed above and UEF percentage range outlined in Section 2.2.5, the input parameter values for the measure TechIDs are developed using a pivot table averaging method in order to accommodate for multiple efficiency tier levels. This method allows specific efficiency ranges to be included in the category (e.g., 40-gallon storage gas with medium draw pattern) average. From this pivot table method, category averages are calculated for key input parameters like input capacity, UEF, RE, TE, and storage volume. The pivot table(s) used for developing input parameters for the measure TechIDs are included in the binning workbook. Cell notes are also included in the water heater calculator on the “Technologies” worksheet. Some of these notes explain exceptions made for some measure TechIDs, mostly due to a lack of water heaters in specific categories.

2.2.4.1 Heat pump water heaters

The qualifying measure efficiencies for HPWHs are shown in Table 2-4.

Table 2-4. Measure TechID UEF requirement for HPWHs

Volume (gallons)	Tier 1 UEF	Tier 2 UEF	Tier 3 UEF
All	3.30	3.50	3.75

2.2.5 Using the companion “binning workbook”

Adding TechIDs should generally be performed using the AHRI binning workbooks (referenced hereafter as the binning workbook). There is a commercial binning workbook and a residential binning workbook. The binning workbooks contain the latest consumer water heater databases released by the AHRI and ENERGY STAR. They also define baseline and measure tier criteria, and average input parameter values for use in the DWHC. There are examples of TechIDs that do not follow exactly the binning workbooks; the primary reasons being lack of data in the AHRI database or lack of efficiency standards by which to bin database entries by. For those TechIDs, addition into the calculator should include documentation on how the TechID parameters were generated. Documentation could be a separate workbook showing how input parameters were arrived to, or cell comments explaining how the parameters were generated. The binning workbooks categorize the database entries by:

- Residential or nonresidential/commercial
- Residential water heater types
 - Heat pump
 - Gas instantaneous
 - Gas storage
 - Residential-duty gas storage

- Nonresidential water heater types
 - Commercial Heat pump (COP-rated)
 - Commercial Gas instantaneous (TE-rated)
 - Gas hot water boiler (TE rated)
 - Storage type gas instantaneous (TE rated)
 - Commercial Gas storage (TE rated)
- Draw pattern (residential only) – very small, low, medium, high
- Storage volume – 2, 30, 40, 50, 55, 60, 75, 80, 100, and 120 gallons
- Meets code requirements (Yes or no)¹⁵
- Meets measure tier requirements (Yes or no)¹⁶

The binning workbooks function and have the average binned input parameter values applied to Technology IDs similar to the workbook delivered in the version 4.2 DWHC release. However, they have been updated to include multiple measure tiers and sub-categories of the water heater types mentioned above.

2.2.6 Final notes for adding TechIDs

Each TechID row must be completed for the workbook's lookup equations to function correctly. It is not necessary to remove TechIDs from the Technologies worksheet; rather, add new TechIDs at the bottom of the list, filling down existing column equations. Column W ("Update") is set to TRUE or FALSE to signal the calculator to perform the calculation process when the macro "Calculate All Results" is executed on the "TechCalc" worksheet.

2.3 Adding Measure IDs

Measure IDs are entered and defined on the "Measure" spreadsheet. The general procedure and rules for adding new measures are as listed below:

- Fill down the index on column C
- Designate "Res" or "Com" sector on column E
- Adjust the "Res" and "Com" upper and lower bounds (Cells J2:K3) according to the measure list entries. These upper and lower bounds can be sub-sets of the total list, the "Create Impacts" macros on the "EnImpacts-Res" and "EnImpacts-Com" use these bounds to determine which measures to create.
- For "Res" measures, NumUnits = 1, NormUnit = Each
- For "Com" measures, NumUnits = N/A, NormUnit = Cap-kBtuh
- Column H "Code/Standard" is the baseline TechID for the Measure ID. Column I "Measure" is the measure TechID for the Measure ID

¹⁵ Different code requirements for residential and nonresidential are defined in the binning workbook

¹⁶ Different measure requirements for residential and nonresidential are defined in the binning workbook

- Columns M through S are informational and use lookup equations to populate the cells

2.4 Executing the DWHC macros

Once new TechIDs and Measure IDs have been entered, macros must be executed to generate results.

2.4.1 TechCalc “Calculate All Results” macro

This macro cycles through all TechIDs with column W = TRUE and calculates annual results for that water heater by every building type and climate zone. The macro copies annual results (located in cells J14:Z14) from the TechCalc worksheet into the TechResults worksheet.

Notes on the macro:

- The TechResults worksheet should have only one unique combination of TechID + building type + climate zone. In other words, once a TechID is calculated using the macro, its UPDATE cell can be changed to FALSE. If the TechID parameters are for some reason updated (but the TechID name remains the same), the rows of the previous TechID run should be removed from the TechResults sheet before running the macro again. (Otherwise, there will be two copies of the same TechID on the TechResults sheet.)
- The macro is very time intensive; allow at least 10 minutes per TechID.

2.4.2 TechCalc “8760” macro

This macro cycles through TechIDs much like the “Calculate All Results” macro but it instead copies the 8760 columns for kWh and therms (columns Y and Z) to the “8760” worksheet. Column AA (“8760 Flag”, TRUE or FALSE) designates whether the TechID is processed or not. Once the TechID is processed, it copies all the 8760 columns (for all building type and climate zones combinations for that TechID) to a separate csv file named by the TechID name. The csv files are located in a subfolder “8760” under where the DWHC file is located.

- This is also a time-intensive macro; expect at least 10 minutes per TechID.
- It is also space intensive since there are hundreds of 8760 columns per TechID. Each TechID csv can be between 40 and 70 Mbytes.

2.4.3 EnImpacts-Res and EnImpacts-Com “Create Impacts” macros

These macros cycle through all the measureIDs included in the bounds defined on the Measure worksheet. The pre-defined cells on the EnImpacts-Res and EnImpacts-Com worksheets are updated based on which Measure ID is selected and the results are copied over to the EnergyImpact worksheet.

2.4.4 Notes on the macros

Here are some cautionary notes from our experience with the calculator:

- The EnImpacts macros perform their operations quickly. Allow 1-2 minutes per macro.
- The EnergyImpacts worksheet should only have one unique combination of MeasureID + PA (Any, PGE, SCE, SCG, SDG) + building type + building vintage + climate zone. If the EnImpacts-Res and EnImpacts-Com macros are executed again, it may create duplicate entries on the EnergyImpacts sheet. You may remove entries on the EnergyImpacts worksheet by deleting rows

- There may be enterprise- or company-level safety-related restrictions for executing macros within workbooks. The calculator workbook may need to be added to a set of “Trusted Documents” or the calculator user may need to request assistance from their IT department in order to enable and execute macros.

3 DEER2023 updates in v5.0

In 2021, the Deemed Ex Ante Review team was assigned with updating the domestic water heater calculator. Specific tasks included:

1. Update water heating sizing method.
2. Update residential hot water load profiles
3. Update assumed tank temperature
4. Update input parameters for Technology IDs
5. Update HPWH performance profiles
6. Update temperature data (ambient air and inlet water temperature)
7. Add 8,760 Profile ID macro

3.1 Update water heating sizing method

DWHC Version 4.2 defines single water heater unit specifications (e.g., 50-gallon gas storage, 40 kBtu/h input capacity, 0.60 UEF, etc.) and compares the capacity to the building’s total hot water load to “size” the energy simulation i.e., determines how many water heaters would be necessary to satisfy the whole building’s hot water load. Normalized unit energy savings (UES) is then reported in “Each” (per water heater) or “Cap-kBtu/hr” (per kBtu/hr input capacity of the installed water heater).

This approach is adequate for most building types and water heater combinations because of the relative equivalence and magnitude of hot water load and/or water heater capacity. However, this sizing method introduced errors with larger capacity commercial water heaters. In Equation 3-1 that follows, the DWHC v.4.2 method for calculating normalized Cap-kBtu/h UES is shown. With larger commercial heaters, the difference between NumUnits_{base} and NumUnits_{measure} could be large because the inputs representing the water heaters could vary significantly. The large variance brought about unreasonable unit-level savings.

Equation 3-1. DWHC v.4.2 Cap-kBtu/hr savings

$$savings_{Cap-kBtu/hr} = \frac{(usage_{unit,base} \times NumUnits_{base} - usage_{unit,measure} \times NumUnits_{measure})}{(NumUnits_{measure} \times Cap_{measure})}$$

where,

$usage_{unit,base}$ = unit energy consumption of base case water heater

$usage_{unit,measure}$ = unit energy consumption of measure water heater

$NumUnits_{base}$ = number of base case heaters required to satisfy building HW load

$NumUnits_{measure}$ = number of measure heaters required to satisfy building WH load

$Cap_{measure}$ = input capacity of unit measure water heater

The sizing method that is used in the version 5.0 release does not use the Technology ID input capacity values; instead it uses the building's hot water load in Btu/hr (multiplied by a 1.2 sizing factor) to "size" both the baseline and measure case water heaters. Sizing relative to the building load allows an equivalent comparison across different water heaters and technologies.

Equation 3-2. DWHC v.5.0 Cap-kBtu/hr savings

$$savings_{Cap-kBtu/hr} = \frac{(usage_{base} - usage_{measure})}{(Cap_{bldg})}$$

where,

$usage_{base}$ = total building energy usage with base case water heater

$usage_{measure}$ = total building energy usage with measure water heater

Cap_{bldg} = required output capacity to meet peak building hot water load (Calculated as:
peak gal/hr x 100 °F x 8.2 Btu/gal-°F x 1.2)

Per Equation 3-2, the normalizing unit is technically represented by the *output* capacity; however, given the use of the 1.2 sizing factor, the Deemed Ex Ante Review team considered it a reasonable method to employ in the calculator. For the purposes of reporting claims, however, the NormUnit Cap-kBtu/h should still represent the *input* capacity of the water heater in kBtu/hr.

3.2 Update residential hot water load profiles

The hot water profiles for single family, single dwelling unit multifamily, and mobile home building types were updated from the DEER2014 hot water profiles to profiles that were derived from CBECC-Res 2019/2021. The CBECC-Res water draw profiles were developed using actual draw data from a California residential water study and analyzed to generate representative sets of daily profiles for different occupancy levels.¹⁷ The Deemed Ex Ante Review team weighted and combined these daily draw profiles according to 2019 RASS data to develop one 8,760 hourly profile representative of each residential building type. The RASS data determined an average number of bedrooms and average occupancy for each building type.

The CBECC-Res draw profiles are in a "draw event" format (indicates water fixture type, time of day, duration of event, and flow rate of event) and is different than what is used in the DWHC. The profiles needed to be aggregated and converted in to 8,760 hourly sets.

The update also removed the "normalized NREL event schedule" profiles that were used to estimate peak electric demand for residential building types. The new profiles derived from CBECC-Res are considered adequate for annual energy and peak demand estimates. Table 3-1 shows the difference between DWHC versions for the average number of hot water gallons per day estimated for each building type.

¹⁷ http://www.ibpsa.org/proceedings/BS2017/BS2017_237.pdf

Table 3-1. Comparison of average gallons hot water per day

DWHC Version	SFm	MFm	DMo
Version 4.2	45	38	38
Version 5.0	43	39	36

3.3 Update assumed tank temperature

2019 RASS data was reviewed to determine the average tank temperature reported by the survey respondents. The survey question asked for a ranged response where low = below 130 °F, medium = 130 to 150 °F, and high = above 150 °F. The responses corroborated well with the current assumed tank temperature of 135 °F; therefore, the tank temperature was not adjusted for residential buildings. The assumed tank temperature for all commercial buildings remains at 135 °F.

3.4 Update input parameters for Technology IDs

The input parameters (e.g., UEF, RE, TE, input capacity, etc.) were updated using new AHRI entries. New efficiency tiers were also developed along with a separate boiler technology and measure ID designation. Commercial packaged boilers will have new federal standards in 2023, effectively changing the code thermal efficiency from 80% to 84%.¹⁸ Previously, instantaneous water heaters and boilers shared the same technology and measure IDs.

3.4.1 Gas storage water heaters

Table 3-2. Gas storage water heaters

Measure ID	Tier	Code/Std	Pre
RG-WtrHt-SmlStrg-Gas-lte75kBtuh-30G-MD-0p64UEF	1	Storage	Storage
RG-WtrHt-SmlStrg-Gas-lte75kBtuh-40G-MD-0p64UEF	1	Storage	Storage
RG-WtrHt-SmlStrg-Gas-lte75kBtuh-50G-MD-0p64UEF	1	Storage	Storage
RG-WtrHt-SmlStrg-Gas-lte75kBtuh-30G-HI-0p68UEF	1	Storage	Storage
RG-WtrHt-SmlStrg-Gas-lte75kBtuh-40G-HI-0p68UEF	1	Storage	Storage
RG-WtrHt-SmlStrg-Gas-lte75kBtuh-50G-HI-0p68UEF	1	Storage	Storage
RG-WtrHt-SmlStrg-Gas-lte75kBtuh-30G-HI-0p78UEF	2	Storage	Storage
RG-WtrHt-SmlStrg-Gas-lte75kBtuh-40G-HI-0p78UEF	2	Storage	Storage
RG-WtrHt-SmlStrg-Gas-lte75kBtuh-50G-HI-0p78UEF	2	Storage	Storage
RG-WtrHt-SmlStrg-Gas-lte75kBtuh-30G-HI-0p88UEF	3	Storage	Storage
RG-WtrHt-SmlStrg-Gas-lte75kBtuh-40G-HI-0p88UEF	3	Storage	Storage
RG-WtrHt-SmlStrg-Gas-lte75kBtuh-50G-HI-0p88UEF	3	Storage	Storage
NG-WtrHt-SmlStrg-Gas-lte75kBtuh-30G-MD-0p64UEF	1	Storage	Storage
NG-WtrHt-SmlStrg-Gas-lte75kBtuh-40G-MD-0p64UEF	1	Storage	Storage

¹⁸ <https://www.govinfo.gov/content/pkg/FR-2020-01-10/pdf/2019-26356.pdf>

Measure ID	Tier	Code/Std	Pre
NG-WtrHt-SmlStrg-Gas-lte75kBtuh-50G-MD-0p64UEF	1	Storage	Storage
NG-WtrHt-SmlStrg-Gas-lte75kBtuh-30G-HI-0p68UEF	1	Storage	Storage
NG-WtrHt-SmlStrg-Gas-lte75kBtuh-40G-HI-0p68UEF	1	Storage	Storage
NG-WtrHt-SmlStrg-Gas-lte75kBtuh-50G-HI-0p68UEF	1	Storage	Storage
NG-WtrHt-SmlStrg-Gas-lte75kBtuh-30G-HI-0p78UEF	2	Storage	Storage
NG-WtrHt-SmlStrg-Gas-lte75kBtuh-40G-HI-0p78UEF	2	Storage	Storage
NG-WtrHt-SmlStrg-Gas-lte75kBtuh-50G-HI-0p78UEF	2	Storage	Storage
NG-WtrHt-SmlStrg-Gas-lte75kBtuh-30G-HI-0p88UEF	3	Storage	Storage
NG-WtrHt-SmlStrg-Gas-lte75kBtuh-40G-HI-0p88UEF	3	Storage	Storage
NG-WtrHt-SmlStrg-Gas-lte75kBtuh-50G-HI-0p88UEF	3	Storage	Storage

3.4.2 Gas instantaneous water heaters

Table 3-3. Gas instantaneous water heaters

Measure ID	Tier	Code/Std	Pre
RG-WtrHt-SmlInst-Gas-lt200kBtuh-lt2G-rep40G-MD-0p81UEF	1	Storage	Storage
RG-WtrHt-SmlInst-Gas-lt200kBtuh-lt2G-rep40G-HI-0p81UEF	1	Storage	Storage
RG-WtrHt-SmlInst-Gas-lt200kBtuh-lt2G-rep40G-MD-0p87UEF	2	Storage	Storage
RG-WtrHt-SmlInst-Gas-lt200kBtuh-lt2G-rep40G-HI-0p87UEF	2	Storage	Storage
RG-WtrHt-SmlInst-Gas-lt200kBtuh-lt2G-rep40G-HI-0p92UEF	3	Storage	Storage
RG-WtrHt-SmlInst-Gas-lt200kBtuh-lt2G-rep40G-HI-0p96UEF	4	Storage	Storage
RG-WtrHt-SmlInst-Gas-lt200kBtuh-lt2G-HI-0p87UEF	1	Inst	Storage
RG-WtrHt-SmlInst-Gas-lt200kBtuh-lt2G-HI-0p92UEF	2	Inst	Storage
RG-WtrHt-SmlInst-Gas-lt200kBtuh-lt2G-HI-0p96UEF	3	Inst	Storage
NG-WtrHt-SmlInst-Gas-lt200kBtuh-lt2G-rep40G-MD-0p87UEF	2	Storage	Storage
NG-WtrHt-SmlInst-Gas-lt200kBtuh-lt2G-rep40G-HI-0p87UEF	2	Storage	Storage
NG-WtrHt-SmlInst-Gas-lt200kBtuh-lt2G-rep40G-MD-0p81UEF	1	Storage	Storage
NG-WtrHt-SmlInst-Gas-lt200kBtuh-lt2G-rep40G-HI-0p81UEF	1	Storage	Storage
NG-WtrHt-SmlInst-Gas-lt200kBtuh-lt2G-rep40G-HI-0p92UEF	3	Storage	Storage
NG-WtrHt-SmlInst-Gas-lt200kBtuh-lt2G-rep40G-HI-0p96UEF	4	Storage	Storage
NG-WtrHt-SmlInst-Gas-lt200kBtuh-lt2G-HI-0p87UEF	1	Inst	Storage
NG-WtrHt-SmlInst-Gas-lt200kBtuh-lt2G-HI-0p92UEF	2	Inst	Storage
NG-WtrHt-SmlInst-Gas-lt200kBtuh-lt2G-HI-0p96UEF	3	Inst	Storage
NG-WtrHt-LrgInst-Gas-gte200kBtuh-lt2G-0p84Et	1	Storage	Storage
NG-WtrHt-LrgInst-Gas-gte200kBtuh-lt2G-0p90Et	2	Storage	Storage

Measure ID	Tier	Code/Std	Pre
NG-WtrHt-LrgInst-Gas-gte200kBtuh-lt2G-0p96Et	3	Storage	Storage
NG-WtrHt-SmlInst-Gas-lt200kBtuh-lt2G-0p84Et	1	Storage	Storage
NG-WtrHt-SmlInst-Gas-lt200kBtuh-lt2G-0p90Et	2	Storage	Storage
NG-WtrHt-SmlInst-Gas-lt200kBtuh-lt2G-0p96Et	3	Storage	Storage

3.4.3 Gas hot water supply boilers

Table 3-4. Gas hot water boilers

Measure ID	Tier	Code/Std	Pre
NG-WtrHt-LrgBoiler-Gas-gte300kBtuh-0p90Et	1	Boiler	Storage
NG-WtrHt-LrgBoiler-Gas-gte300kBtuh-0p96Et	2	Boiler	Storage

3.4.4 Electric storage water heaters

Table 3-5. Electric storage water heaters

Measure ID	Tier	Fuel	Code/Std	Pre
RE-WtrHt-FuelSub-SmlStrg-HP-lte6kW-rep30G-3p30UEF-50g	1	Switch	Storage	Storage
RE-WtrHt-FuelSub-SmlStrg-HP-lte6kW-rep40G-3p30UEF-50g	1	Switch	Storage	Storage
RE-WtrHt-FuelSub-SmlStrg-HP-lte6kW-rep50G-3p30UEF-50g	1	Switch	Storage	Storage
RE-WtrHt-FuelSub-SmlStrg-HP-lte6kW-rep30G-3p50UEF-50g	2	Switch	Storage	Storage
RE-WtrHt-FuelSub-SmlStrg-HP-lte6kW-rep40G-3p50UEF-50g	2	Switch	Storage	Storage
RE-WtrHt-FuelSub-SmlStrg-HP-lte6kW-rep50G-3p50UEF-50g	2	Switch	Storage	Storage
RE-WtrHt-FuelSub-SmlStrg-HP-lte6kW-rep30G-3p75UEF-50g	3	Switch	Storage	Storage
RE-WtrHt-FuelSub-SmlStrg-HP-lte6kW-rep40G-3p75UEF-50g	3	Switch	Storage	Storage
RE-WtrHt-FuelSub-SmlStrg-HP-lte6kW-rep50G-3p75UEF-50g	3	Switch	Storage	Storage
RE-WtrHt-FuelSub-SmlStrg-HP-lte6kW-rep60G-3p30UEF-65g	1	Switch	Storage	Storage
RE-WtrHt-FuelSub-SmlStrg-HP-lte6kW-rep75G-3p30UEF-80g	1	Switch	Storage	Storage
RE-WtrHt-FuelSub-SmlStrg-HP-lte6kW-rep60G-3p50UEF-65g	2	Switch	Storage	Storage
RE-WtrHt-FuelSub-SmlStrg-HP-lte6kW-rep75G-3p50UEF-80g	2	Switch	Storage	Storage
RE-WtrHt-FuelSub-SmlStrg-HP-lte6kW-rep60G-3p75UEF-65g	3	Switch	Storage	Storage
RE-WtrHt-FuelSub-SmlStrg-HP-lte6kW-rep75G-3p75UEF-80g	3	Switch	Storage	Storage
RE-WtrHt-SmlStrg-HP-lte6kW-rep30G-3p30UEF-50g	1	Electric	Storage	Storage
RE-WtrHt-SmlStrg-HP-lte6kW-rep40G-3p30UEF-50g	1	Electric	Storage	Storage
RE-WtrHt-SmlStrg-HP-lte6kW-rep50G-3p30UEF-50g	1	Electric	Storage	Storage
RE-WtrHt-SmlStrg-HP-lte6kW-rep30G-3p50UEF-50g	2	Electric	Storage	Storage
RE-WtrHt-SmlStrg-HP-lte6kW-rep40G-3p50UEF-50g	2	Electric	Storage	Storage

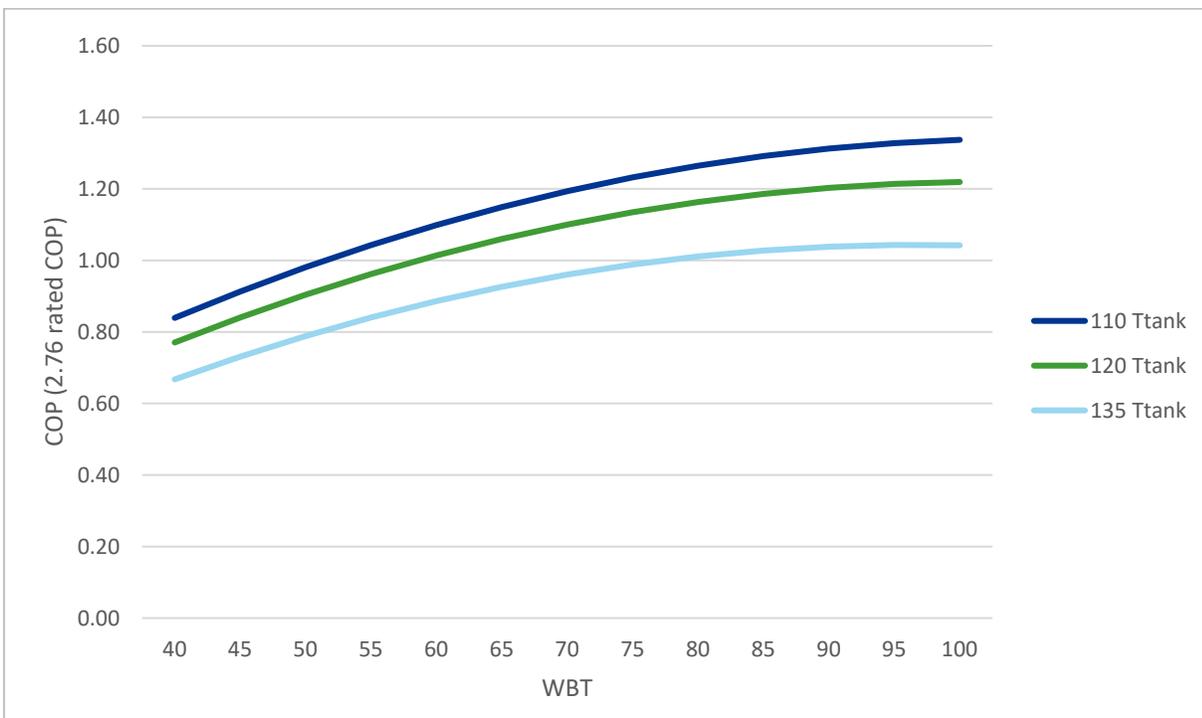
Measure ID	Tier	Fuel	Code/Std	Pre
RE-WtrHt-SmlStrg-HP-lte6kW-rep50G-3p50UEF-50g	2	Electric	Storage	Storage
RE-WtrHt-SmlStrg-HP-lte6kW-rep30G-3p75UEF-50g	3	Electric	Storage	Storage
RE-WtrHt-SmlStrg-HP-lte6kW-rep40G-3p75UEF-50g	3	Electric	Storage	Storage
RE-WtrHt-SmlStrg-HP-lte6kW-rep50G-3p75UEF-50g	3	Electric	Storage	Storage
RE-WtrHt-SmlStrg-HP-lte6kW-rep60G-3p30UEF-65g	1	Electric	HPWH	Storage
RE-WtrHt-SmlStrg-HP-lte6kW-rep75G-3p30UEF-80g	1	Electric	HPWH	Storage
RE-WtrHt-SmlStrg-HP-lte6kW-rep60G-3p50UEF-65g	2	Electric	HPWH	Storage
RE-WtrHt-SmlStrg-HP-lte6kW-rep75G-3p50UEF-80g	2	Electric	HPWH	Storage
RE-WtrHt-SmlStrg-HP-lte6kW-rep60G-3p75UEF-65g	3	Electric	HPWH	Storage
RE-WtrHt-SmlStrg-HP-lte6kW-rep75G-3p75UEF-80g	3	Electric	HPWH	Storage
NE-WtrHt-FuelSub-SmlStrg-HP-lte6kW-rep30G-3.30UEF-50g	1	Switch	Storage	Storage
NE-WtrHt-FuelSub-SmlStrg-HP-lte6kW-rep40G-3.30UEF-50g	1	Switch	Storage	Storage
NE-WtrHt-FuelSub-SmlStrg-HP-lte6kW-rep50G-3.30UEF-50g	1	Switch	Storage	Storage
NE-WtrHt-FuelSub-SmlStrg-HP-lte6kW-rep30G-3.50UEF-50g	2	Switch	Storage	Storage
NE-WtrHt-FuelSub-SmlStrg-HP-lte6kW-rep40G-3.50UEF-50g	2	Switch	Storage	Storage
NE-WtrHt-FuelSub-SmlStrg-HP-lte6kW-rep50G-3.50UEF-50g	2	Switch	Storage	Storage
NE-WtrHt-FuelSub-SmlStrg-HP-lte6kW-rep30G-3.75UEF-50g	3	Switch	Storage	Storage
NE-WtrHt-FuelSub-SmlStrg-HP-lte6kW-rep40G-3.75UEF-50g	3	Switch	Storage	Storage
NE-WtrHt-FuelSub-SmlStrg-HP-lte6kW-rep50G-3.75UEF-50g	3	Switch	Storage	Storage
NE-WtrHt-FuelSub-SmlStrg-HP-lte6kW-rep60G-3.30UEF-65g	1	Switch	Storage	Storage
NE-WtrHt-FuelSub-SmlStrg-HP-lte6kW-rep75G-3.30UEF-80g	1	Switch	Storage	Storage
NE-WtrHt-FuelSub-SmlStrg-HP-lte6kW-rep60G-3.50UEF-65g	2	Switch	Storage	Storage
NE-WtrHt-FuelSub-SmlStrg-HP-lte6kW-rep75G-3.50UEF-80g	2	Switch	Storage	Storage
NE-WtrHt-FuelSub-SmlStrg-HP-lte6kW-rep60G-3.75UEF-65g	3	Switch	Storage	Storage
NE-WtrHt-FuelSub-SmlStrg-HP-lte6kW-rep75G-3.75UEF-80g	3	Switch	Storage	Storage
NE-WtrHt-FuelSub-LrgStrg-HP-gt6kW-120G-4p30COP	1	Switch	Storage	Storage
NE-WtrHt-SmlStrg-HP-lte6kW-rep30G-3p30UEF-50g	1	Electric	Storage	Storage
NE-WtrHt-SmlStrg-HP-lte6kW-rep40G-3p30UEF-50g	1	Electric	Storage	Storage
NE-WtrHt-SmlStrg-HP-lte6kW-rep50G-3p30UEF-50g	1	Electric	Storage	Storage
NE-WtrHt-SmlStrg-HP-lte6kW-rep30G-3p50UEF-50g	2	Electric	Storage	Storage
NE-WtrHt-SmlStrg-HP-lte6kW-rep40G-3p50UEF-50g	2	Electric	Storage	Storage
NE-WtrHt-SmlStrg-HP-lte6kW-rep50G-3p50UEF-50g	2	Electric	Storage	Storage
NE-WtrHt-SmlStrg-HP-lte6kW-rep30G-3p75UEF-50g	3	Electric	Storage	Storage
NE-WtrHt-SmlStrg-HP-lte6kW-rep40G-3p75UEF-50g	3	Electric	Storage	Storage
NE-WtrHt-SmlStrg-HP-lte6kW-rep50G-3p75UEF-50g	3	Electric	Storage	Storage

Measure ID	Tier	Fuel	Code/Std	Pre
NE-WtrHt-SmlStrg-HP-lte6kW-rep60G-3p30UEF-65g	1	Electric	HPWH	Storage
NE-WtrHt-SmlStrg-HP-lte6kW-rep75G-3p30UEF-80g	1	Electric	HPWH	Storage
NE-WtrHt-SmlStrg-HP-lte6kW-rep60G-3p50UEF-65g	2	Electric	HPWH	Storage
NE-WtrHt-SmlStrg-HP-lte6kW-rep75G-3p50UEF-80g	2	Electric	HPWH	Storage
NE-WtrHt-SmlStrg-HP-lte6kW-rep60G-3p75UEF-65g	3	Electric	HPWH	Storage
NE-WtrHt-SmlStrg-HP-lte6kW-rep75G-3p75UEF-80g	3	Electric	HPWH	Storage

3.5 Update HPWH performance profiles

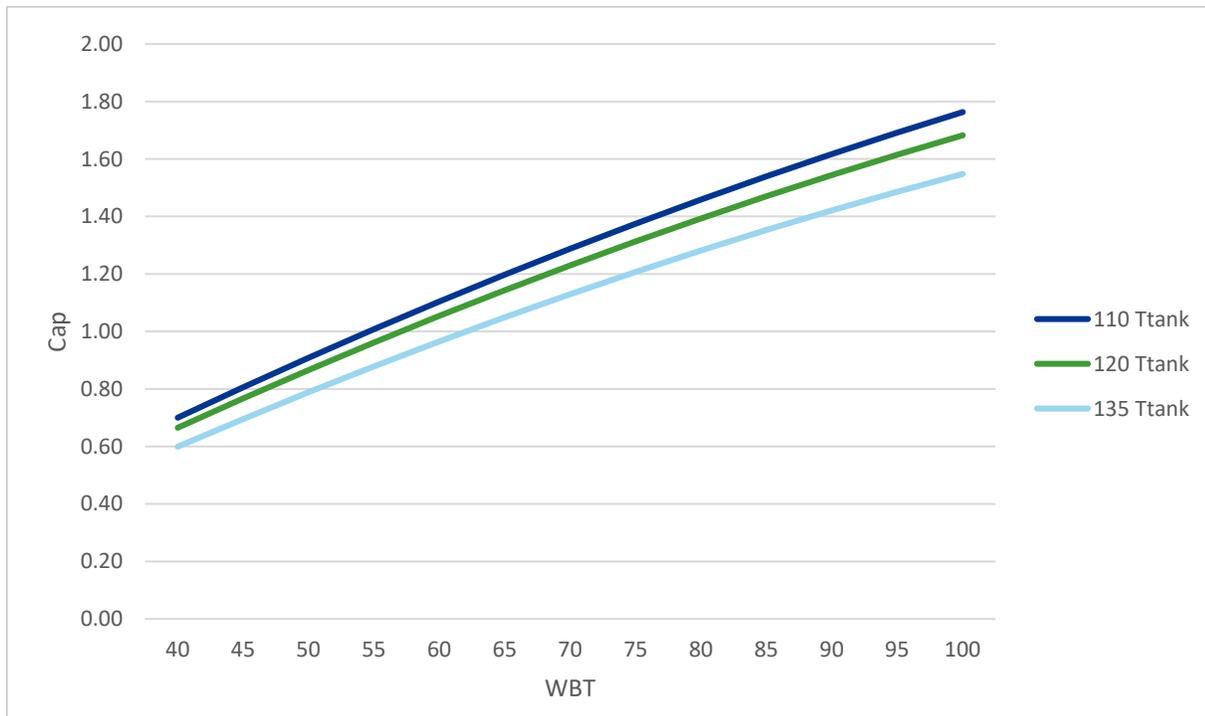
HPWH performance profiles were updated using field performance data from a 2016 NREL study (Shapiro, Puttagunta, 2016).¹⁹ The assumed nominal COP and capacity are adjusted according to the curves shown in Figure 3-1 and Figure 3-2.

Figure 3-1. HPWH adjusted COP (function of tank temperature and inlet wet bulb temperature)



¹⁹ <https://www.nrel.gov/docs/fy16osti/64904.pdf>

Figure 3-2. HPWH adjusted capacity (function of tank temperature and inlet wet bulb temperature)



3.6 Update temperatures due to weather update

The temperature data that is used to estimate ambient space temperature and mains water temperature were updated from DEER2014 (which used CZ2010) to CZ2022 weather data. The mains water temperature represents the incoming cold-water temperature that the water heater heats up to the tank temperature set point. The mains water temperature is estimated using equations referenced from the 2019 ACM Reference Manual Appendix B.²⁰

3.7 Added 8,760 Profile ID macro

A macro was added to the “TechCalc” sheet that copies the 8,760 hourly outputs of the Technology IDs and aggregates them in workbooks external to the calculator. The 8,760 outputs represent water heater load shape profiles. These are raw profiles output from the calculator; they must be further processed to represent the technology load shapes entered into the DEER database.

3.8 Future considerations

The Deemed Ex Ante Review team, with input from DEER stakeholders, acknowledges limitations that the spreadsheet-based calculator has on water heating measures with higher complexity. Load shifting, schedule changes, HPWH control strategies, and other advanced measures are better handled in building simulation tools. While the DWHC may still be used for certain types of water heating measures, the Deemed Ex Ante

²⁰ <https://energycodeace.com/site/custom/public/reference-ace-2019/index.html#!Documents/b4hourlyadjustedrecoveryload.htm>



Review Team anticipates gradually migrating away from the DWHC and developing heat pump water heating measures using building simulation tools (e.g., EnergyPlus™, California Simulation Engine, etc.). This will enable future updates to accommodate for advanced measure interactions and controls like:

- Interactive effects, specifically for HPWH
- Simulating multiple locations for HPWHs
- Simulating different HPWH configurations
- Variable tank temperature (e.g., dual set point controllers)
- Load shifting and 8,760-hour load shapes
- Higher resolution (e.g., 1-minute) or draw event DHW profiles
- Tank loss changes from ambient and tank temperature
- Improved modeling of HPWH operating sequences