→Research GAHP Screening Criteria and Design

Project Number ET23SWG0012

GAS EMERGING TECHOLOGIES (GET) PROGRAM
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Abbreviations and Acronyms

Abbreviation	Meaning
ACEEE	American Council for an Energy-Efficient Economy
ASHRAE	American Society of Heating, Refrigeration and Air-Conditioning Engineers
ASPE	American Society of Plumbing Engineers
CPC	California Plumbing Code
COP	Coefficient of Performance
CV	Coefficient of Variation
C	Contractors
DWHC	DEER Water Heater Calculator
DOE	Department of Energy
DHW	Domestic Hot Water
EHPWH	Electric Heat Pump Water Heater
EE	Energy Efficiency
GAHP	Gas Absorption Heat Pump
GET	Gas Emerging Technology
GHPWH	Gas Heat Pump Water Heater
GPM	Gallons Per Minute
HPWH	Heat Pump Water Heater
HVAC	Heating, Ventilation, and Air Conditioning
IST	Indirect Storage Tank
IAPMO	International Association of Plumbing and Mechanical Officials
ICC	International Code Council
IECC	International Energy Conservation Code
IPC	International Plumbing Code
MFG	Manufacturer
M&V	Measurement and Verification
REUW	Residential End Uses of Water
SME	Subject Matter Experts
TE	Technical Experts
UPC	Uniform Plumbing Code

Executive Summary

Evidence suggests that domestic hot water (DHW) systems in multifamily buildings are frequently oversized, despite revised sizing standards from organizations like the American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE). At the outset of this study, it was unknown how sites can be screened for gas absorption heat pump (GAHP) implementation and what, if any, existing DHW sizing tools could be used to screen or design GAHP systems. This hinders market adoption because customers and installers do not know what criteria makes an ideal GAHP site. This Gas Emerging Technology (GET) Project focused on addressing these challenges by examining available DHW sizing methods, interviewing DHW subject matter experts (SMEs), comparing DHW sizing methods with actual site data, and providing basic site screening criteria and design considerations for GAHPs. The study identified several areas where more research is needed for site screening of GAHP systems.

Project Goal: The goal of this study was to research and develop/update site screening criteria and sizing methods for GAHP in DHW systems after analyzing currently available sizing tools and expert insights. This includes addressing the challenges of oversizing in current DHW systems and providing contractors with the tools needed for GAHP system design and installation.

Key Project Findings:

- The DHW sizing tools examined in this study sized DHW systems anywhere from 57% undersized to 252% oversized compared to the actual maximum DHW demand, using site data. In other words, they were very inconsistent.
- ASHRAE is the closest to the actual maximum DHW demand (without undersizing the system) at three out of six sites, which is more consistent than the other tools.
- The number of occupants and heat rate are consistently identified by SMEs as the most important factors for accurate DHW sizing.
- Existing DHW sizing tools cannot be used to screen sites for GAHPs because they size for the peak DHW load, which happens in winter when many people are using hot water. Conversely, a GAHP screening tool needs to know what the minimum DHW load is, which happens during the summer when few people are using hot water. This is an entirely new way of thinking about DHW sizing and there is no tool that can do it, at this point.
- Designers and installers should calculate minimum required flow rates for the GAHP to run continuously. If the minimum flow rate is not met at a site, they should use an indirect storage tank (IST) and determine the minimum number of cycles per day.

- The minimum number of cycles per day and the IST size are affected by the following factors:
    - GAHP run time
    - Target GAHP COP
    - Cost of natural gas
    - Cost of the GAHP retrofit
    - Value of CO_2 emissions reductions (if any)
- GAHP units can be effectively integrated with traditional boilers, with GAHPs managing base hot water load and boilers addressing peak load.
- Operational adjustments for the site-specific factors such as available space, flow rate, and temperature requirements are critical for ensuring optimal performance in hybrid GAHP-boiler systems.

Project Recommendations: The Study Team offers the following recommendations based on the findings:

- **Refine Summer Minimum Load Measurement:** The best way to determine summer minimum DHW load is to measure it, but more research is needed to refine this method. Even if it is refined, installers may not want to measure it, so a tool should be created in the future.
- **Generate GAHP COP as a Function of GAHP Run time:** The Study Team and other GET Team members are gathering information that can generate this data.
- **Develop a GAHP Site Screening Tool:** More research is needed to screen sites for GAHP installation when the cost of natural gas, targeted GAHP COP, cost of the GAHP retrofit, and CO_2 emissions value are considered. Ultimately, a screening tool that takes these variables into account should be created to screen sites for GAHP implementation.

Introduction

This Gas Emerging Technology (GET) Project includes research into site screening criteria and sizing methods for gas absorption heat pump (GAHP) water heaters. GAHPs have been around for many years, but the application of this technology to domestic hot water (DHW) systems is novel and presents several challenges. Legacy DHW heaters are often sized for the maximum expected DHW load and can easily turn down output during lower demand. GAHPs, on the other hand, require a minimum DHW load to function optimally with a fixed baseline load and are recommended to be sized to 40–60% of the maximum DHW load. There is evidence that the DHW heater/boiler sizing methods currently in use overestimate DHW load, which becomes a problem when the GAHP requires a minimum load to function properly. Further complicating matters is the fact that many DHW retrofit projects in the multifamily segment are completed by contracting companies who do not have engineering staff to run DHW sizing calculations or come up with new designs for each retrofit project. Contractors generally rely on outside engineers or manufacturers to provide them with recommended DHW heater/boiler capacities and designs. Additionally, contractors need to have rough ideas of project costs up front to sell a project to a multifamily property. In order for the GAHP to be successful as an energy efficiency (EE) measure in the California multifamily market, the contractor community must be provided with appropriate tools to quickly screen sites for GAHP retrofits and determine the recommended size/quantity of GAHPs. This project seeks to bridge that gap by investigating current DHW sizing methods, researching what site information contractors can typically collect, and providing recommendations for site screening criteria and GAHP sizing and design.

Background

There is evidence that DHW systems in commercial and multifamily buildings are often oversized [1]. Consequently, the ASHRAE standards were updated in 1995 to introduce "Low/Medium/High" user classifications based on building demographics and different peak period hot water usage lengths. In addition, the Energy Policy Act has mandated flow rate limits for faucets and showerheads along with improvement in the water use efficiency of washing machines and dishwashers over the past three decades. These changes have resulted in a decrease in hot water consumption [2]. Although no recent studies have compared actual DHW loads to DHW sizing since the 1994 ACEEE study, the oversizing problem seems to persist. For example, the Department of Energy (DOE) proposed a rule for energy conservation standards for commercial water heating equipment for which there were comments that the manufacturing guidelines tend to oversize equipment. The DOE agreed that "manufacturing guidelines are likely to result in oversizing hot water equipment in many applications." An International Association of Plumbing and Mechanical Officials (IAPMO) Study for a Water Demand Calculator states that "the plumbing industry has long recognized that building potable water systems in today's buildings are oversized." This

IAPMO study considered the size of both the pipes and the water heater [3]. Lastly, a study conducted in Poland that compared the forecasted and actual DHW demand in multifamily buildings, demonstrated oversizing of 7% to 45% depending on the sizing method used [4].

Oversizing a DHW boiler raises concerns for various reasons. It is particularly worrisome for new/emerging gas water heating technologies given that an oversized GAHP will not function as intended thereby reducing or eliminating the GAHP's energy savings potential. GAHPs use an absorption cycle that extracts heat from the air and transfers it to hot water resulting in greater than 1.0 coefficient of performance (COP) during the majority of the outdoor conditions. Although these systems are more expensive than traditional DHW boilers on a per unit of heat output basis and still not yet well-known, they are promising emerging EE technology. However, unlike incumbent DHW boilers, these systems only come in a few heat output sizes, with only some units having turn down capabilities, and in most cases require a minimum heating load. If that minimum load is not met, the unit may experience excessive cycling, which puts wear and tear on the machine and reduces its designed COP. Furthermore, an oversized GAHP increases the initial system cost, thereby negatively impacting project economics and hindering market adoption. This issue is similar to the challenges encountered with electric heat pump water heaters (EHPWHs), for which sizing and education tools have been developed. Like EHPWHs, GAHPs could also benefit from additional potable hot water storage to reduce cycling and lower the unit size. However, unlike EHPWHs, this approach has not yet been studied for GAHPs, as it remains a novel concept for these systems.

Additionally, the deemed savings measure package (SWWH033) on California's electronic Technical Resource Manual (eTRM) for GAHPs targets multifamily building types, and two other GET projects seeking to expand the available field data to hotel/motel building types (ET23SWG0002 and ET24SWG0006). The contractors who work in these markets typically do not have in-house technical staff who can assist with site screening and DHW design. Contractors bridge this gap in the following ways:

- Perform like-for-like DHW heater/boiler replacements eliminating the need for new DHW sizing or design.
- Provide DHW boiler/heater manufacturers with site data and receive recommended DHW size from the manufacturer.
- For more complex DHW systems (e.g., solar thermal water heaters or EHPWHs), outside tools are used to determine DHW size and outside engineering services are procured for design. The design used is a boiler plate design that can be adjusted based on site conditions to save on design costs.

As contractors gain experience with DHW systems, their ability to screen, size, and design improves, and they develop an intuitive understanding of what constitutes a good site and the expected cost magnitude. However, since the GAHP systems are a novel application for DHW end-use, contractors do not currently have this intrinsic knowledge and there are currently no resources to support them or their contracted engineers. This lack of resources will likely limit adoption of GAHPs, so this project seeks to overcome gaps and provide the necessary resources.

Assessment Objectives

The goal of this study as listed below is to investigate existing methods of DHW system sizing; research what site information is typically available to installation contractors; and provide recommendations for site screening criteria and GAHP sizing and design.

1) Investigate the most-commonly used DHW sizing and design methods in multifamily and hotel buildings in California.

2) Evaluate if these methods can reliably calculate site specific minimum DHW loads from available data.

3) Analyze if these methods are applicable for sizing and designing GAHP DHW systems and provide recommendations if they are not suitable in their current form.

4) Provide recommendations for site screening, GAHP sizing calculation, and system design tailored for a contractor audience.

The expected project outcomes are listed below.

1) Identification of the most frequently used DHW system sizing methods in multifamily and hotel/motel buildings in California.

2) Comparison of the expected DHW loads using the most common sizing methods to actual natural gas billing data and actual DHW loads and identify gaps between sizing methods and actual site data.

3) Recommendations for site/operation data points needed to screen sites for GAHPs, size GAHPs, and design new GAHP systems.

DHW Sizing Methods

Common DHW Sizing Methods

The three most commonly used sources for DHW sizing tools are as follows:

- ASPE (American Society of Plumbing Engineers)
- ASHRAE Handbook HVAC Applications
- Manufacturer (MFG) sizing tools: (referred as MFG Tool 1, MFG Tool 2, and MFG Tool 3)

The Study Team also reviewed the following resources but did not use any of them as sizing methods, as they lacked relevant information for sizing DHW systems:

- California Plumbing Code (CPC) (Chapter 5 of Title 24) the basis of which is the IAPMO Uniform Plumbing Code (UPC)
- International Plumbing Code (IPC)
- International Energy Conservation Code (IECC)

This research included a comprehensive literature review and several meetings with a leading industry SME with expertise in hot water heating, who helped guide the study and reviewed its findings.

Preliminary Research for Water Heater Sizing Methods

This section summarizes the findings from the reviewed water heater handbooks, codes, and standards related to water heater sizing methods. The following sections will analyze the selected DHW sizing tool sources and explain why some sources were excluded from this study.

ASPE and ASHRAE [5], [6]

Both ASPE and ASHRAE have DHW sizing guidelines for different types of commercial buildings including schools, dormitories, nursing homes, motels, office buildings, and multifamily buildings. Both include different types of water heaters, source fuels, and sizes. Fuels include oil, gas, and electric and equipment types are tankless or instantaneous and storage. ASPE's sizing guidelines for multifamily buildings are in the "Plumbing Engineering and Design Handbook" in the section titled "Multifamily Buildings" [5]. ASHRAE's sizing guidelines are in "HVAC Applications Handbook" in Chapter 50.12 "Hot-Water Load and Equipment Sizing" [6]. Both methods use similar inputs, outputs, and calculation methodology. The basic inputs to both methods for a multifamily building are as follows:

- User demand profile: Total and average water demand depends upon the type of user. Both ASPE and ASHRAE split these consumption profiles into “Low,” “Medium,” and “High” categories based upon the occupant demographics.
- Peak period: The maximum water heater capacity [Btu/h] depends on the peak hot water demand duration. Both methods use peak periods ranging from 5 minutes to 180 minutes.

Figure 1 and 2 below show the Low, Medium, and High consumption profile occupant demographics as well as the hot water demands for each of these consumption profiles based on different peak periods. The consumption occupant demographics and hot water demands are the same for both ASPE and ASHRAE. The ASHRAE information is shown in Figure 3 and 4 below.

Some design considerations that ASHRAE tool provides under various steps are summarized below [6]:

Step 1: Choose high-performance equipment or processes that use less hot water or eliminate the need for it.

Step 2: Optimize plumbing layout for efficient hot water delivery, considering distributed generation or point-of-use heating for distant sinks.

Step 3: Select high-efficiency water heaters compatible with the system and fixtures.

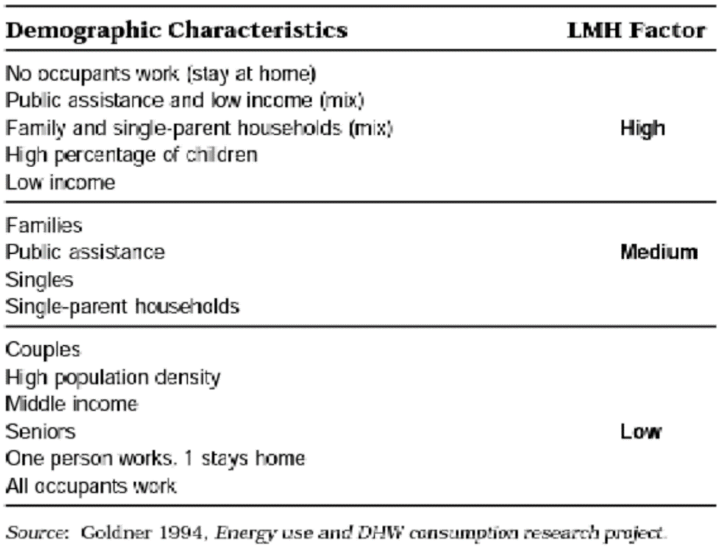
Step 4: Explore pre-heating technologies (e.g., heat recovery or solar) before finalizing system design.

Step 5: Ensure proper system installation and consider monitoring equipment for commissioning and maintenance.

Step 6: Use hot-water recirculation loops sparingly to maintain hot pipes but be aware of potential energy use increases. Alternatively, employ multiple separate water heating systems to reduce or eliminate the need for recirculation loops.

Based on discussions with SMEs, we found that while recirculation and tank losses are typically accounted for, they were not a critical factor in this analysis. Since the sizing focuses on the system's performance during peak hours when losses are minimal compared to the user demand, they were acknowledged but not explicitly incorporated into the system design considerations.

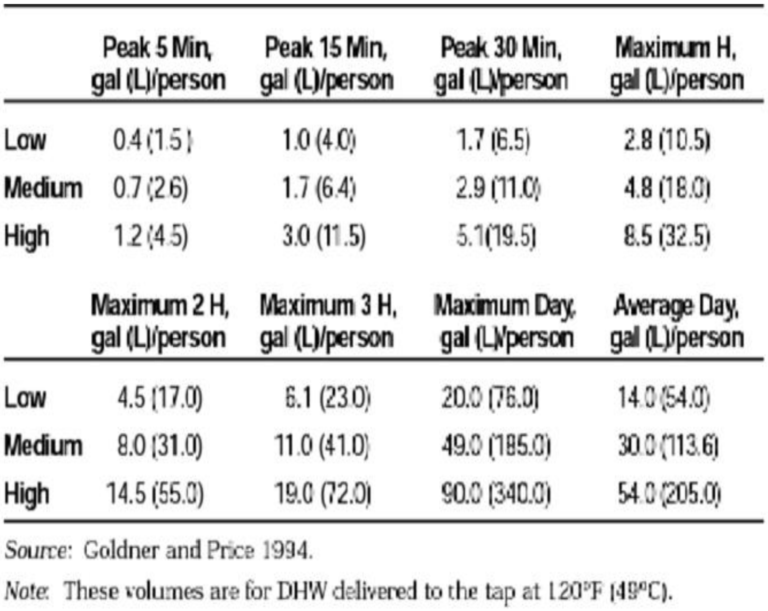
Figure 1: ASPE Hot Water Demands Based on Demographic LMH (Low, Medium, High) Factor [5]



Demographic Characteristics	LMH Factor
No occupants work (stay at home) Public assistance and low income (mix) Family and single-parent households (mix) High percentage of children Low income	High
Families Public assistance Singles Single-parent households	Medium
Couples High population density Middle income Seniors One person works, 1 stays home All occupants work	Low

Source: Goldner 1994, *Energy use and DHW consumption research project.*

Figure 2: ASPE Hot Water Demands (gallons) Based on Figure 1 [5]



	Peak 5 Min, gal (L)/person	Peak 15 Min, gal (L)/person	Peak 30 Min, gal (L)/person	Maximum H, gal (L)/person
Low	0.4 (1.5)	1.0 (4.0)	1.7 (6.5)	2.8 (10.5)
Medium	0.7 (2.6)	1.7 (6.4)	2.9 (11.0)	4.8 (18.0)
High	1.2 (4.5)	3.0 (11.5)	5.1(19.5)	8.5 (32.5)

	Maximum 2 H, gal (L)/person	Maximum 3 H, gal (L)/person	Maximum Day, gal (L)/person	Average Day, gal (L)/person
Low	4.5 (17.0)	6.1 (23.0)	20.0 (76.0)	14.0 (54.0)
Medium	8.0 (31.0)	11.0 (41.0)	49.0 (185.0)	30.0 (113.6)
High	14.5 (55.0)	19.0 (72.0)	90.0 (340.0)	54.0 (205.0)

Source: Goldner and Price 1994.

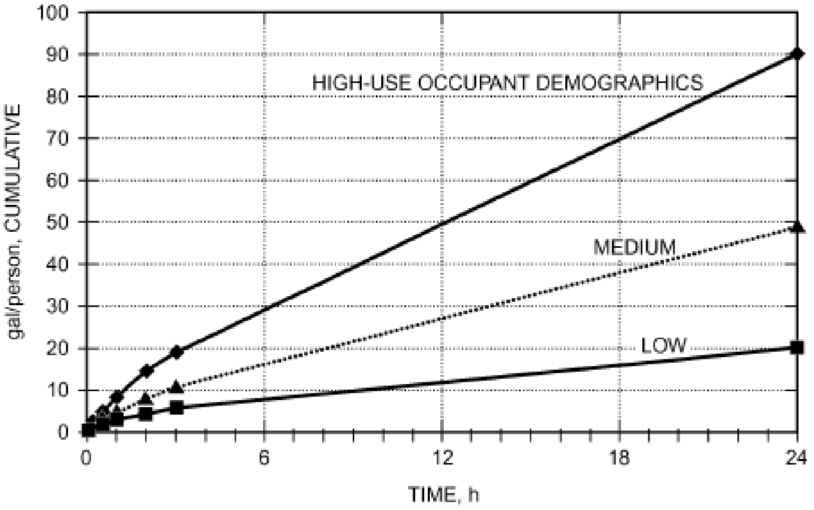
Note: These volumes are for DHW delivered to the tap at 120°F (49°C).

Figure 3: ASHRAE Hot Water Demands (gallons) [6]

(Gallons per Person at 120°F Delivered to Fixtures)

	Peak Minutes						Maximum Daily	Average Daily
Guideline	5	15	30	60	120	180		
Low	0.4	1.0	1.7	2.8	4.5	6.1	20	14
Medium	0.7	1.7	2.9	4.8	8.0	11.0	49	30
High	1.2	3.0	5.1	8.5	14.5	19.0	90	54

Figure 4: ASHRAE Hot Water Demand based on Demographics and Values from Figure 3 [6]



In the most basic form of this sizing method, the following equations are used.

Equation 1: Total Daily Hot Water Gallons Required Based on Consumption Profile, Peak Period, and Number of People

$v_{pp} = v_{cp,pp} * ppl$ (In the most basic form of this sizing method, the following equations are used.

Equation 1)

Where:

v_{pp} = *total* daily hot water gallons required based on consumption profile, peak period, and number of people.

$v_{cp,pp}$= the daily volume of hot water required *per person* based on consumption profile and peak period.

ppl = the total number of people in the building

Equation 2: Volumetric Hot Water Flowrate of Water Based on Consumption Profile and Peak Period

$$\dot{v}_{pp}\left[\frac{Gallons}{Minute}\right] = \frac{v_{pp}[Gallons]}{t_{pp}\ [Minute]} \qquad \text{Equation 2)}$$

Where:

$\dot{v}_{pp}$= *volumetric* flowrate of hot water based on the consumption profile and peak period (gal/min)

t_{pp} = the peak period time in minutes.

Equation 3: Heat Rate Formula:

$$\dot{Q} = (\dot{v}_{pp} * \ \rho * \ C_p * \ \Delta T * 60)/\ \eta \qquad \text{Equation 3)}$$

Where:

$\dot{Q}$= *Heat Rate (Btuh)*
ρ= *density of water (lbm/gal)*
C_p = Specific heat of water (Btu / *lbm- °F)*
ΔT=Temperature difference (°F)
η = *Water Heater/Boiler Efficiency*

Equation 4: Storage Tank Volume Formula:

$$V = \frac{v_{pp}}{UC} \qquad \text{Equation 4)}$$

Where:

V= Storage Tank Volume
UC= Usable Tank Capacity, on average 70% [6]

Example ASHRAE/ASPE Sizing Calculation

This is an example sizing calculation for 100 people in a middle-income apartment building. Assume that the incoming cold-water temperature is 40°F and the desired hot water temperature is 120°F. The efficiency of the water heater/boiler is planned to be 80%.

Based on Figure 1, the consumption profile is "Low."

Equation 1 gives the total daily volume of hot water based on the peak period, consumption profile and number of people. The total gallons per person at a 5-minute peak for a Low consumption profile user is 0.4 gallons/person-day. To get total daily hot water volume, use Equation 1

$$v_{pp} = 0.4 \left[\frac{Gallons}{person - day}\right] * 100\ [People]$$

$$v_{pp} = 40 \left[\frac{gallons}{day}\right]$$

Using Equation 2, the volumetric flow rate is found at a peak period of 5 minutes.

$$\dot{v}_{pp} = \frac{40 \left[\frac{gallons}{day}\right]}{5\ [Minutes]}$$

$$\dot{v}_{pp} = 8 \left[\frac{Gallons}{min}\right]$$

Using Equation 3, the heat rate (or water heater capacity is found)

$$\dot{Q} = \frac{\left(8 \left[\frac{Gallons}{minute}\right] * 8.4 \left[\frac{lbm}{gallon}\right] * 1 \left[\frac{Btu}{lbm - \text{°F}}\right] * (120\text{°F} - 40\text{°F}) * 60 \left[\frac{Minutes}{hr}\right]\right)}{80\%}$$

$$\dot{Q} = 6{,}720\ Btu/hr$$

At a 5-minute peak period, the total required heating rate is 6,720 Btu/hour.

Equation 4 gives the total required storage tank volume at a 5-minute peak period.

$$V\ [gallons] = \frac{40\ [gallons]}{70\%}$$

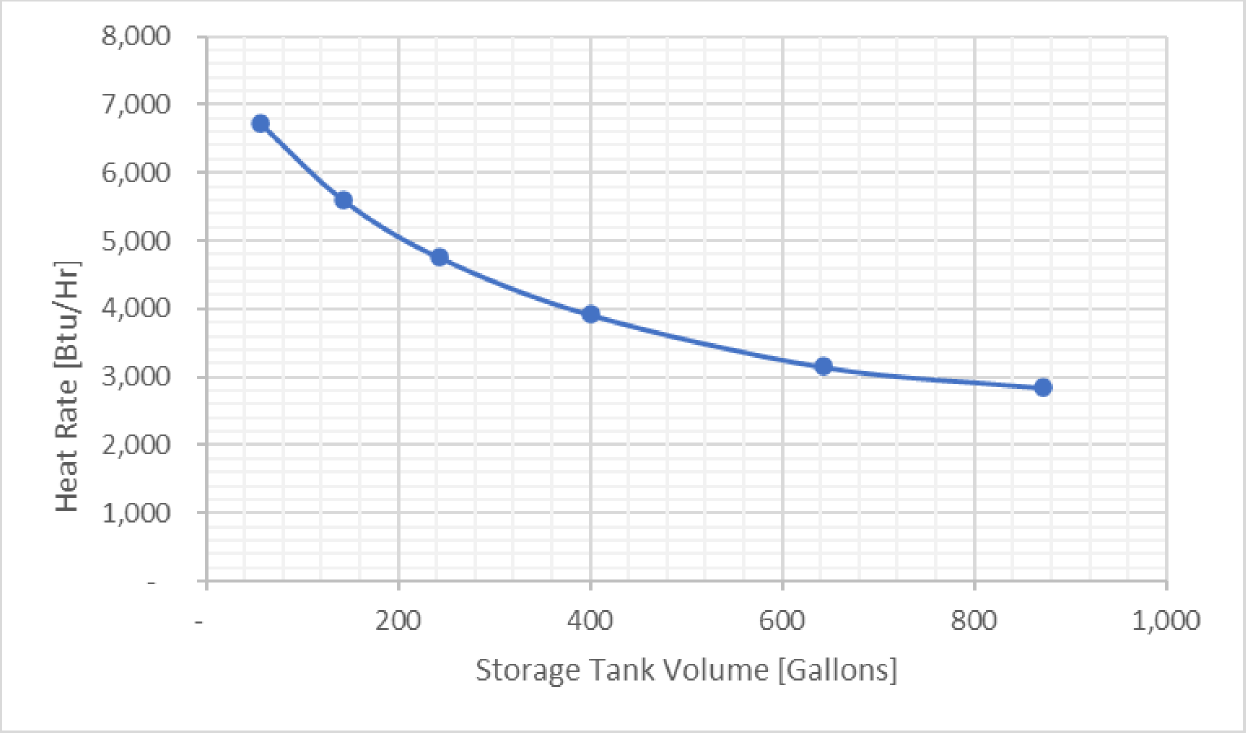
$$V = 57\ Gallons$$

This same calculation is done at 15-minute, 30-minute, 60-minute, 120-minute, and 180-minute time intervals. This gives a range of heat rates and storage tank capacities to satisfy the water heating load. Table 1 shows the outputs of Equations 1 – 4 at the other peak periods.

Table 1: Example Heat Rate and Storage Tank Volumes for a 100-person, Middle-Income Multifamily Building with an 80% Efficient Water Heater

Peak Min	5	15	30	60	120	180
Gal/Person/Day	0.4	1	1.7	2.8	4.5	6.1
Gal/Day	40	100	170	280	450	610
Gal/Min	8	7	6	5	4	3
Heat Rate [Btu/hr]	6,720	5,600	4,760	3,920	3,150	2,847
Storage Tank Vol [Gallons]	57	143	243	400	643	871

Figure 5: Example Heat Rate and Storage Tank Volumes for a 100-Person, Middle-Income Multifamily Building with an 80% Efficient Water Heater



ASHRAE and ASPE Differences

While ASHRAE and ASPE tools are quite similar, they utilize slightly different design considerations. This section discusses the *differences* between the two methods.

- The ASPE method does not consider the incoming water temperature, and instead assumes a set temperature rise in the boiler. Whereas ASHRAE requires users to input the design incoming water temperature and specify the desired hot water temperature which can range from 120°F to 140°F.
- The ASPE method takes the following additional nuances into consideration which are not part of the ASHRAE tool:
    - Who pays for water: When individuals pay for their hot water usage, it tends to reduce usage by 20-30%.
    - Peak demand may vary over different seasons and times of the day: Excess storage capacity required may vary depending upon the time of the day. Different peak times may show varying demand splits, so carefully analyze this data. It's advisable to use numbers from the winter season as it represents the true maximum demand for hot water.
    - Laundry needs: ASPE considers whether the DHW system will be providing hot water for clothes washers and adjusts for this additional water need.
    - Kitchen needs: ASPE considers how many fixtures are in the kitchen and whether there is a dishwasher and adjusts for the dishwasher water need.
    - Laws about flow restrictions: ASPE reminds the designer to pay attention to local and state regulations regarding fixture flow restrictions to refine volumetric flow rates.
- The method outlined in Equations 1-4 is the “Simplified” method in ASHRAE. It assumes that there is no existing hot water in the storage tank to satisfy the water heating needs. ASHRAE also has a “More Accurate Method” that accounts for the existing stored hot water available to satisfy the demand. This method uses the local slopes of the hot water use curve to calculate a more accurate heating rate.

IAPMO

IAPMO is an organization dedicated to ensuring the safety and efficiency of plumbing and mechanical systems. IAPMO’s “2021 Uniform Plumbing Code” serves as a comprehensive reference detailing various aspects of plumbing design, installation, and maintenance, offering guidance on codes, standards, and best practices in the plumbing industry [7]. Guidelines on water system requirements are listed in Chapter 5, Appendix A and Appendix M in the 2021 Uniform Plumbing Code.

UPC Chapter 5: Water Heater Requirements

In this chapter, IAPMO outlines specific requirements for water heater installation, including heater location and safety requirements. While the provided information is valuable for water heater installation, it is not relevant to the sizing of water heater capacity and tank volume.

UPC Appendix A: Recommended Rules for Sizing the Water Supply System

Appendix A of the 2021 Uniform Plumbing Code provides a comprehensive set of rules for sizing the water supply system. It begins with preliminary information, such as minimum daily service pressure, water meter specifications, and pipe types. The document then delves into the concept of demand load, emphasizing the importance of understanding the supply needed in gallons per minute based on the number of fixtures in the building. It introduces the notion of permissible friction loss, which aims to maintain desirable minimum residual pressure at the highest fixture in the supply system, accounting for factors like elevation above street level.

The sizing of the building supply is a critical aspect discussed in this appendix. It involves determining the diameter of the pipe based on total demand and permissible friction loss. Special attention is given to copper and alloy piping, noting their potential impact on hydraulic pressure and considerations for hard water supply. Additionally, the document covers the sizing of principal branches and risers, outlining the required sizes to meet the demand load while considering permissible friction loss. In cases where branches to the building supply are sized for the same friction loss as branches and risers to the highest level in the building, measures such as size adjustments, throttling using valves, or increasing the size of the building supply are suggested.

Appendix M: Peak Water Demand Calculator

Appendix M covers how to calculate peak water demand for multifamily dwellings while accounting for water conserving plumbing fixtures, fixture fittings, and appliances. It accounts for different fixtures, flowrate, pipe sizing and probability of use. This gives important information on how to calculate the peak demand but does not explicitly state how to apply this to calculate water heater capacity or storage tank volume.

IAPMO Summary

IAPMO's 2021 Uniform Plumbing Code offers a comprehensive overview of regulations and requirements for water heater systems, but it lacks information on water heater capacity and storage tank sizing. IAPMO does provide hot water GPM output data but does not provide a method to use it to size the water heater capacity and/or storage tank. Therefore, IAPMO tool was not considered for further analysis in this study.

ICC: 2021 International Energy Conservation Code (IECC):

Section C404 Service Water Heating

The International Code Council (ICC) is an organization that develops building codes and standards for the construction industry. The 2021 International Energy Conservation Code (IECC) is one of the codes established by the ICC and focuses on energy efficiency in building design and construction [8]. Section C404 of the IECC covers the following regarding service water heaters:

- Type of equipment: Instantaneous or Storage water heaters.
- Fuel Types: Oil, gas electric, or combination.
- Based on the type of equipment, there are options for input, rating condition storage tank, performance required and test procedure.
- Charts that provide information dependent on pipe sizes, volume, and material

The IECC offers valuable insights into sizing water heaters based on different equipment types and fuel options. However, it lacks methodology for translating this information into specific water heater capacity and storage tank volume for various occupational demands. Consequently, the section in the IECC that addresses water heater sizing was not included as one of the sizing methods considered in this study.

ICC: 2021 International Plumbing Code (IPC)

Chapter 5 Water Heaters

- The IPC stands for the International Plumbing Code. It is a set of plumbing codes and standards also developed by the ICC. The IPC provides regulations and guidelines for the design, installation, and inspection of plumbing systems in buildings, ensuring the safety and functionality of plumbing systems [9]. Chapter 5 of the IPC is on water heaters and includes the following: Regulations concerning the safety of water heating units and hot water storage tanks.
- Heated portable water needs and associated fixtures.
- Temperature and pressure controls for hot water storage tanks.
- Access requirements to water heaters and hot water storage tanks to allow for the maintenance and replacement of equipment.

Similar to the aforementioned IECC, the IPC has valuable insights concerning the regulation, use and maintenance of hot water heaters, but not any relevant information regarding system sizing. Therefore, the IPC was not included as one of the sizing methods in this study.

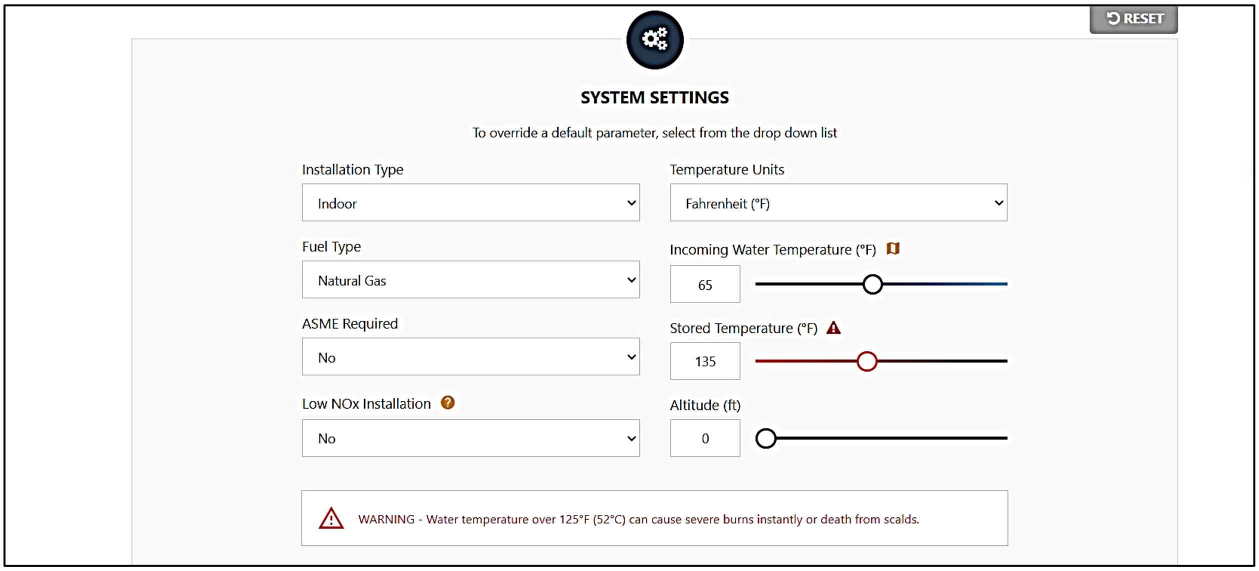
Manufacturers' Water Heater Sizing Tools

Three manufacturer-specific tools were examined in this section: MFG Tool 1, MFG Tool 2, and MFG TOOL 3[1]. The inputs to the three manufacturer sizing tools are similar with some variations. The common inputs for the manufacturer sizing tool inputs are as follows:

- Fuel Type
- Number of apartment units
- No. of bedrooms/bathrooms
- Occupancy per unit
- Design incoming water temperature
- Desired hot water temperature
- Peak period

These inputs are very similar to the inputs to ASHRAE and ASPE tools. Some tools give the option to specify numerous different floor plans with flow rates for fixtures in bathrooms and kitchens for each floor plan. Examples of inputs and outputs for each tool with the same temperature and demand requirements are presented in the figures below.

Figure 6: MFG Tool 1 Inputs 1



SYSTEM SETTINGS

To override a default parameter, select from the drop down list

Installation Type: Indoor

Temperature Units: Fahrenheit (°F)

Fuel Type: Natural Gas

Incoming Water Temperature (°F): 65

ASME Required: No

Stored Temperature (°F): 135

Low NOx Installation: No

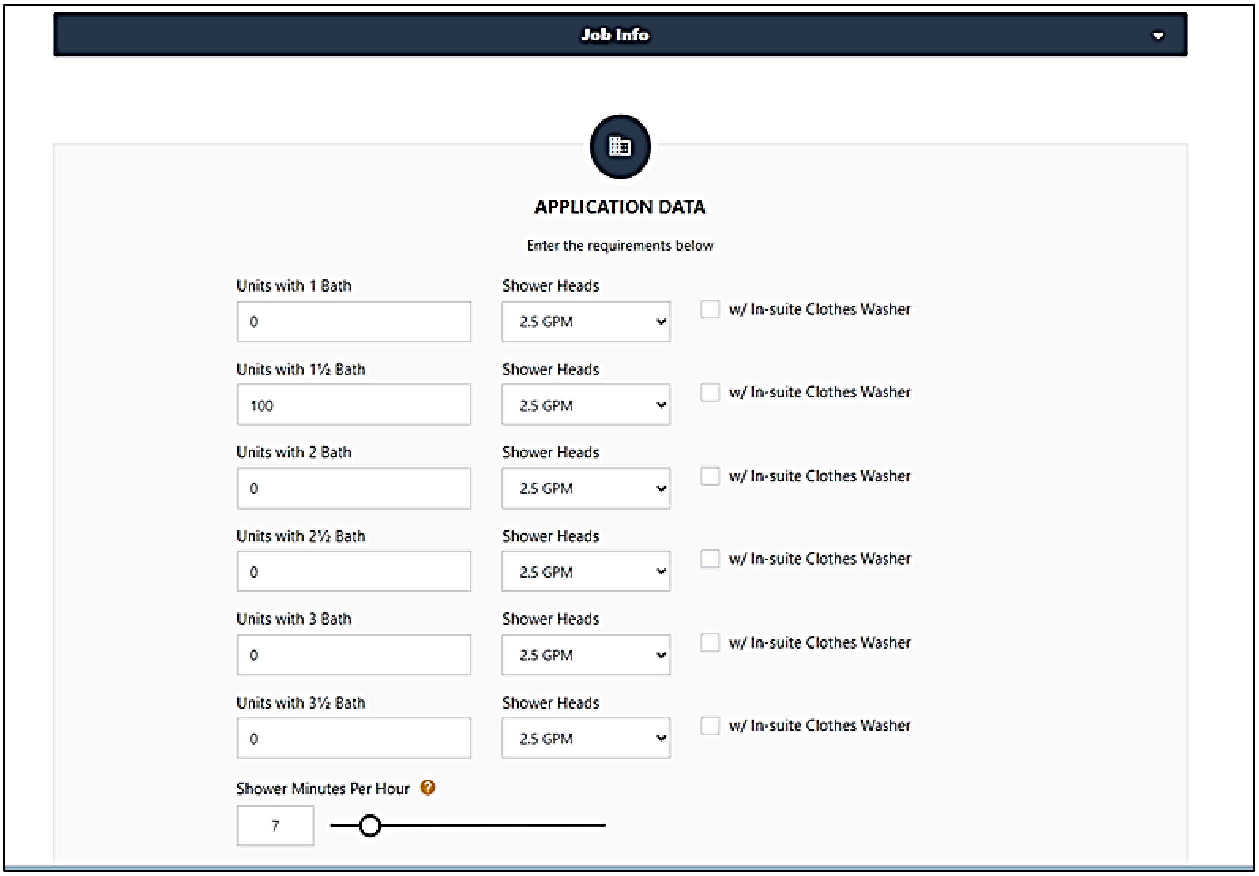
Altitude (ft): 0

WARNING - Water temperature over 125°F (52°C) can cause severe burns instantly or death from scalds.

---

[1] Manufacturer/tool names were anonymized for this report

Figure 7: MFG Tool 1 Inputs 2



APPLICATION DATA

Enter the requirements below

Units with 1 Bath: 0 | Shower Heads: 2.5 GPM | ☐ w/ In-suite Clothes Washer

Units with 1½ Bath: 100 | Shower Heads: 2.5 GPM | ☐ w/ In-suite Clothes Washer

Units with 2 Bath: 0 | Shower Heads: 2.5 GPM | ☐ w/ In-suite Clothes Washer

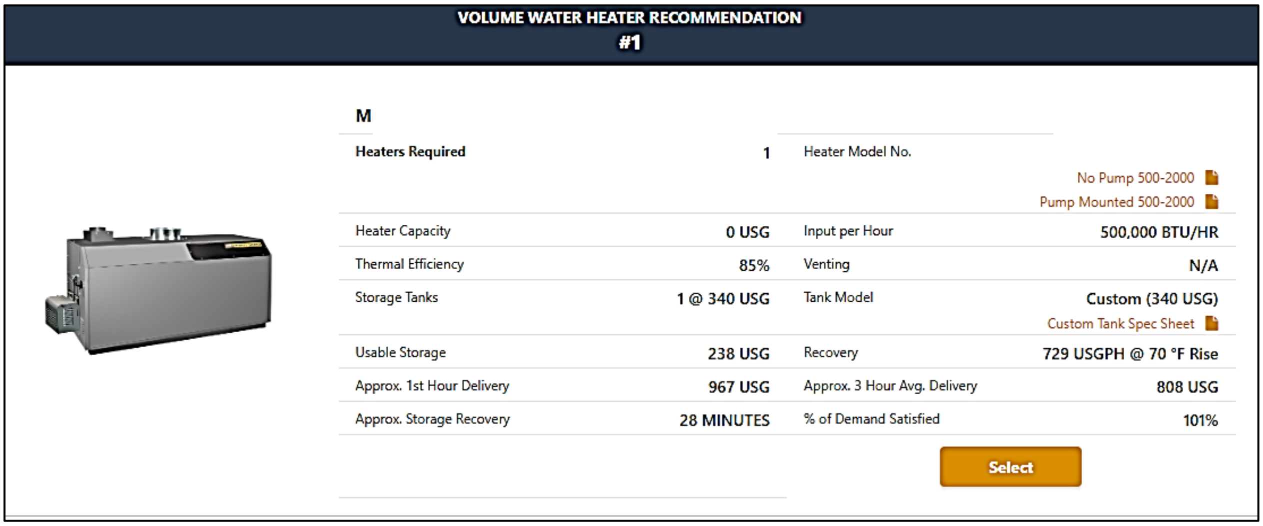
Units with 2½ Bath: 0 | Shower Heads: 2.5 GPM | ☐ w/ In-suite Clothes Washer

Units with 3 Bath: 0 | Shower Heads: 2.5 GPM | ☐ w/ In-suite Clothes Washer

Units with 3½ Bath: 0 | Shower Heads: 2.5 GPM | ☐ w/ In-suite Clothes Washer

Shower Minutes Per Hour: 7

Figure 8: MFG Tool 1 Outputs

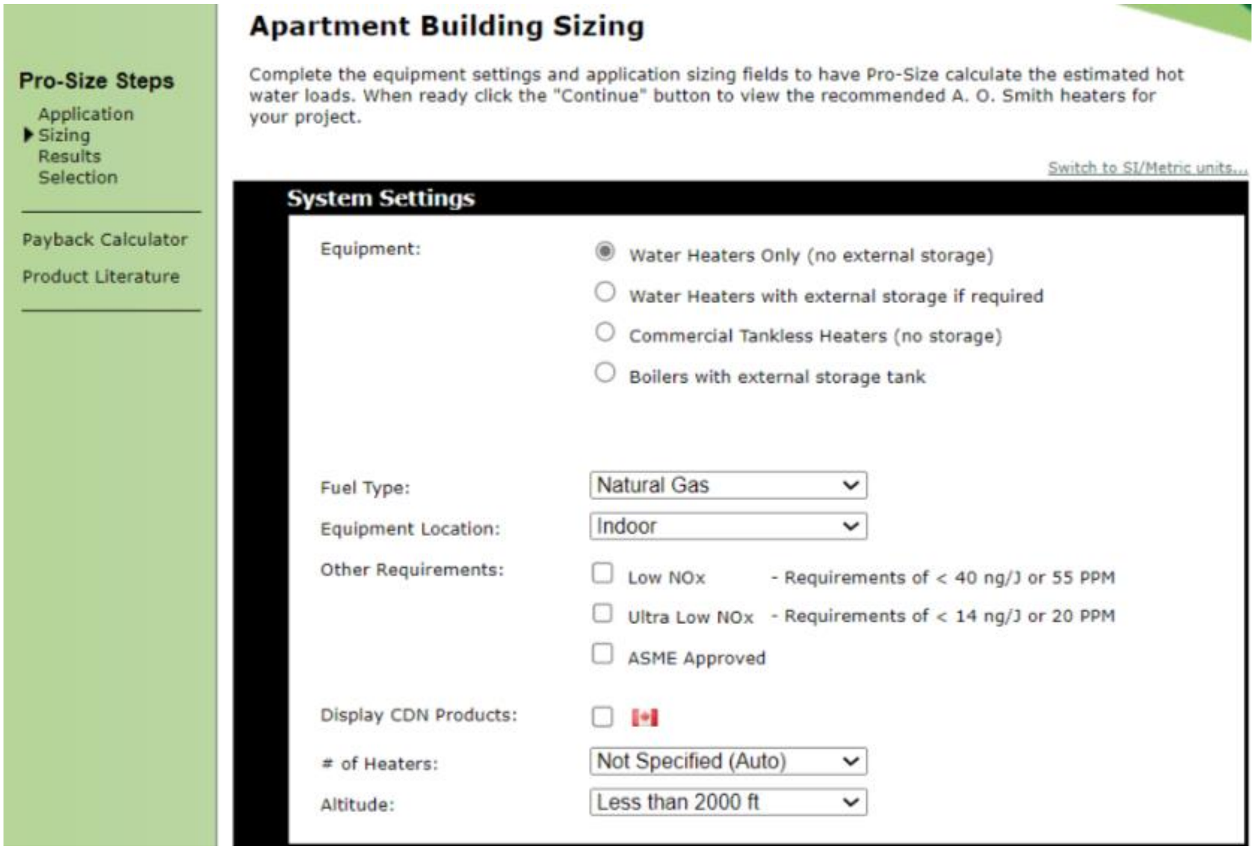


VOLUME WATER HEATER RECOMMENDATION
#1

M

Heaters Required	1	Heater Model No.	No Pump 500-2000 Pump Mounted 500-2000
Heater Capacity	0 USG	Input per Hour	500,000 BTU/HR
Thermal Efficiency	85%	Venting	N/A
Storage Tanks	1 @ 340 USG	Tank Model	Custom (340 USG) Custom Tank Spec Sheet
Usable Storage	238 USG	Recovery	729 USGPH @ 70 °F Rise
Approx. 1st Hour Delivery	967 USG	Approx. 3 Hour Avg. Delivery	808 USG
Approx. Storage Recovery	28 MINUTES	% of Demand Satisfied	101%

Figure 9: MFG Sizing Tool 2 Inputs 1



Pro-Size Steps

- Application
- ▶ Sizing
- Results
- Selection

Payback Calculator

Product Literature

Apartment Building Sizing

Complete the equipment settings and application sizing fields to have Pro-Size calculate the estimated hot water loads. When ready click the "Continue" button to view the recommended A. O. Smith heaters for your project.

Switch to SI/Metric units...

System Settings

Equipment:
- ● Water Heaters Only (no external storage)
- ○ Water Heaters with external storage if required
- ○ Commercial Tankless Heaters (no storage)
- ○ Boilers with external storage tank

Fuel Type: Natural Gas

Equipment Location: Indoor

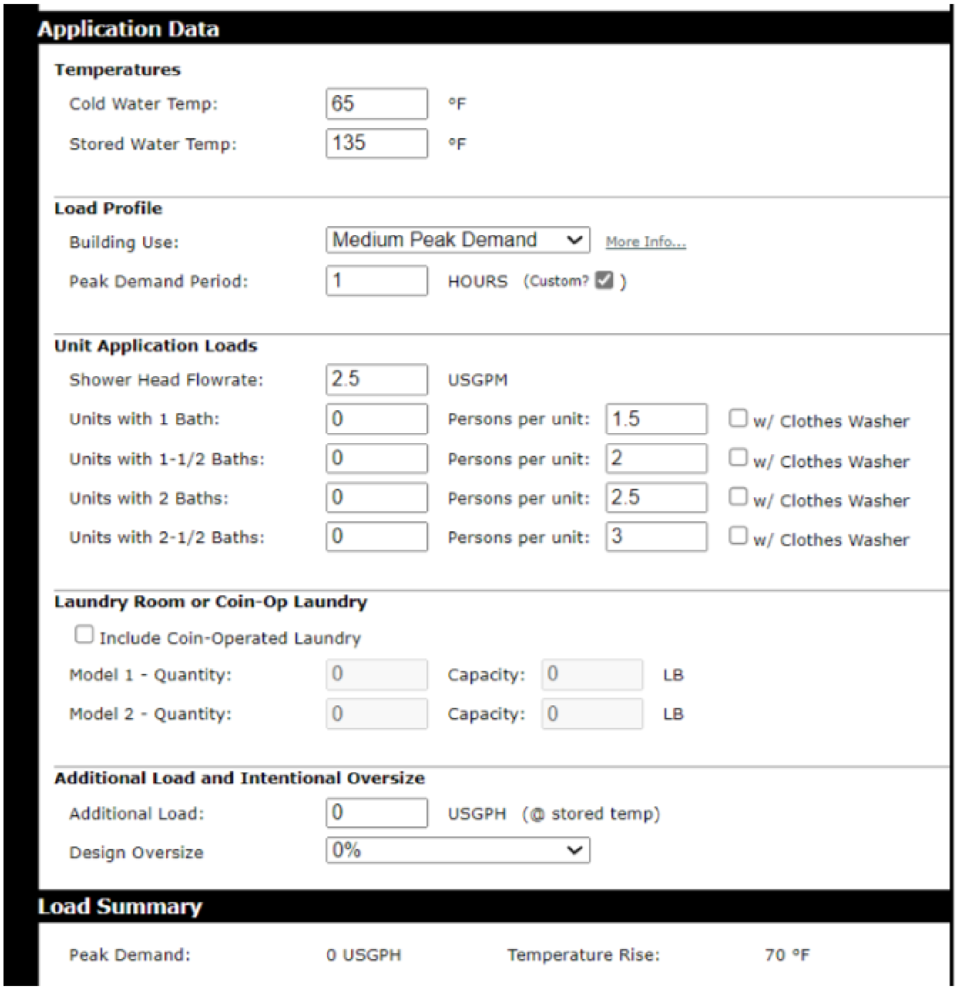
Other Requirements:
- ☐ Low NOx - Requirements of < 40 ng/J or 55 PPM
- ☐ Ultra Low NOx - Requirements of < 14 ng/J or 20 PPM
- ☐ ASME Approved

Display CDN Products: ☐

# of Heaters: Not Specified (Auto)

Altitude: Less than 2000 ft

Figure 10: MFG Sizing Tool 2 Inputs 2



Application Data

Temperatures

Cold Water Temp: 65 °F

Stored Water Temp: 135 °F

Load Profile

Building Use: Medium Peak Demand More Info...

Peak Demand Period: 1 HOURS (Custom? ☑)

Unit Application Loads

Shower Head Flowrate: 2.5 USGPM

Units with 1 Bath: 0 Persons per unit: 1.5 ☐ w/ Clothes Washer

Units with 1-1/2 Baths: 0 Persons per unit: 2 ☐ w/ Clothes Washer

Units with 2 Baths: 0 Persons per unit: 2.5 ☐ w/ Clothes Washer

Units with 2-1/2 Baths: 0 Persons per unit: 3 ☐ w/ Clothes Washer

Laundry Room or Coin-Op Laundry

☐ Include Coin-Operated Laundry

Model 1 - Quantity: 0 Capacity: 0 LB

Model 2 - Quantity: 0 Capacity: 0 LB

Additional Load and Intentional Oversize

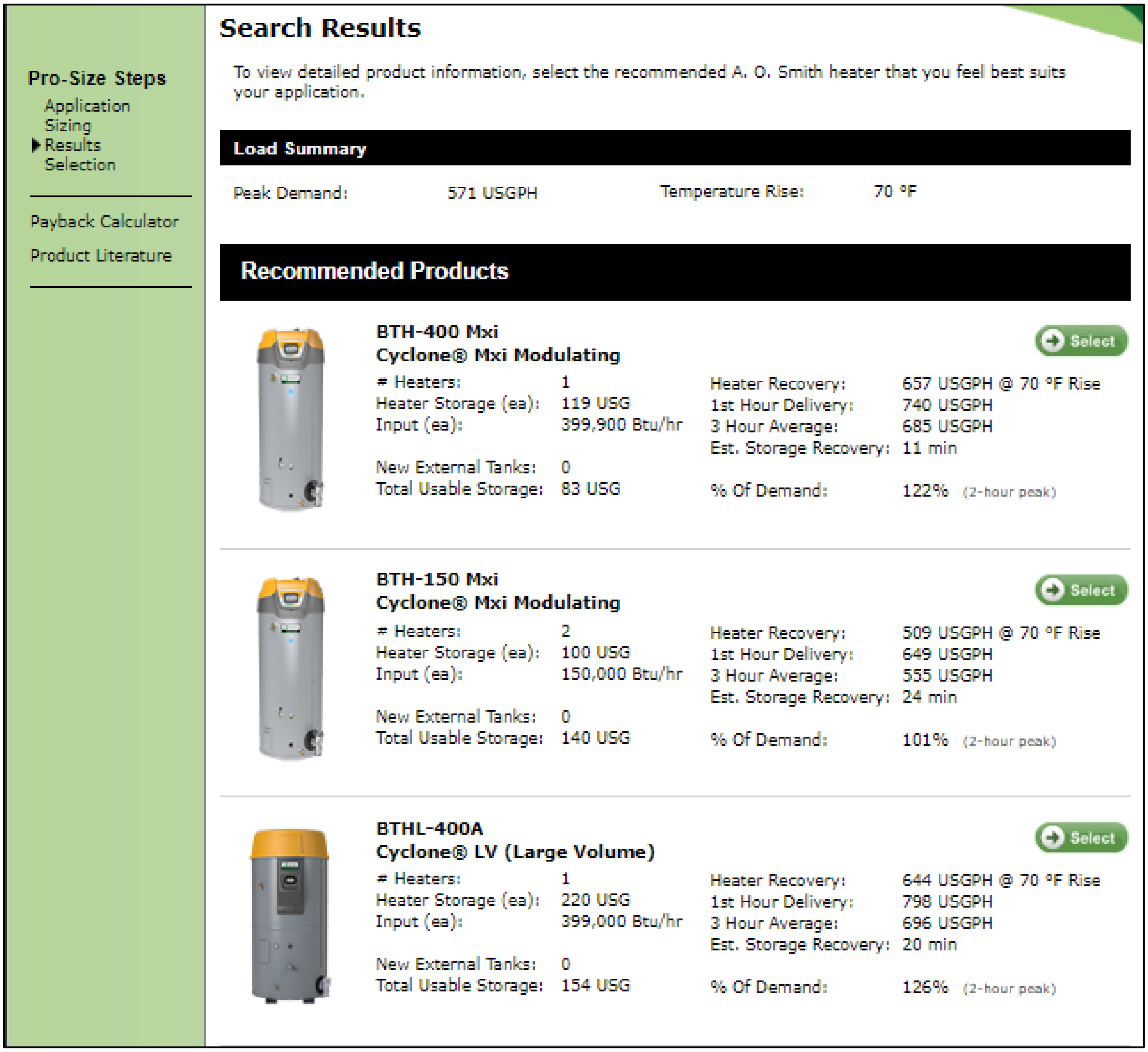
Additional Load: 0 USGPH (@ stored temp)

Design Oversize 0%

Load Summary

Peak Demand: 0 USGPH Temperature Rise: 70 °F

Figure 11: MFG Sizing Tool 2 Outputs



Search Results

To view detailed product information, select the recommended A. O. Smith heater that you feel best suits your application.

Load Summary

Peak Demand:	571 USGPH	Temperature Rise:	70 °F

Recommended Products

BTH-400 Mxi
Cyclone® Mxi Modulating

# Heaters:	1	Heater Recovery:	657 USGPH @ 70 °F Rise
Heater Storage (ea):	119 USG	1st Hour Delivery:	740 USGPH
Input (ea):	399,900 Btu/hr	3 Hour Average:	685 USGPH
		Est. Storage Recovery:	11 min
New External Tanks:	0		
Total Usable Storage:	83 USG	% Of Demand:	122% (2-hour peak)

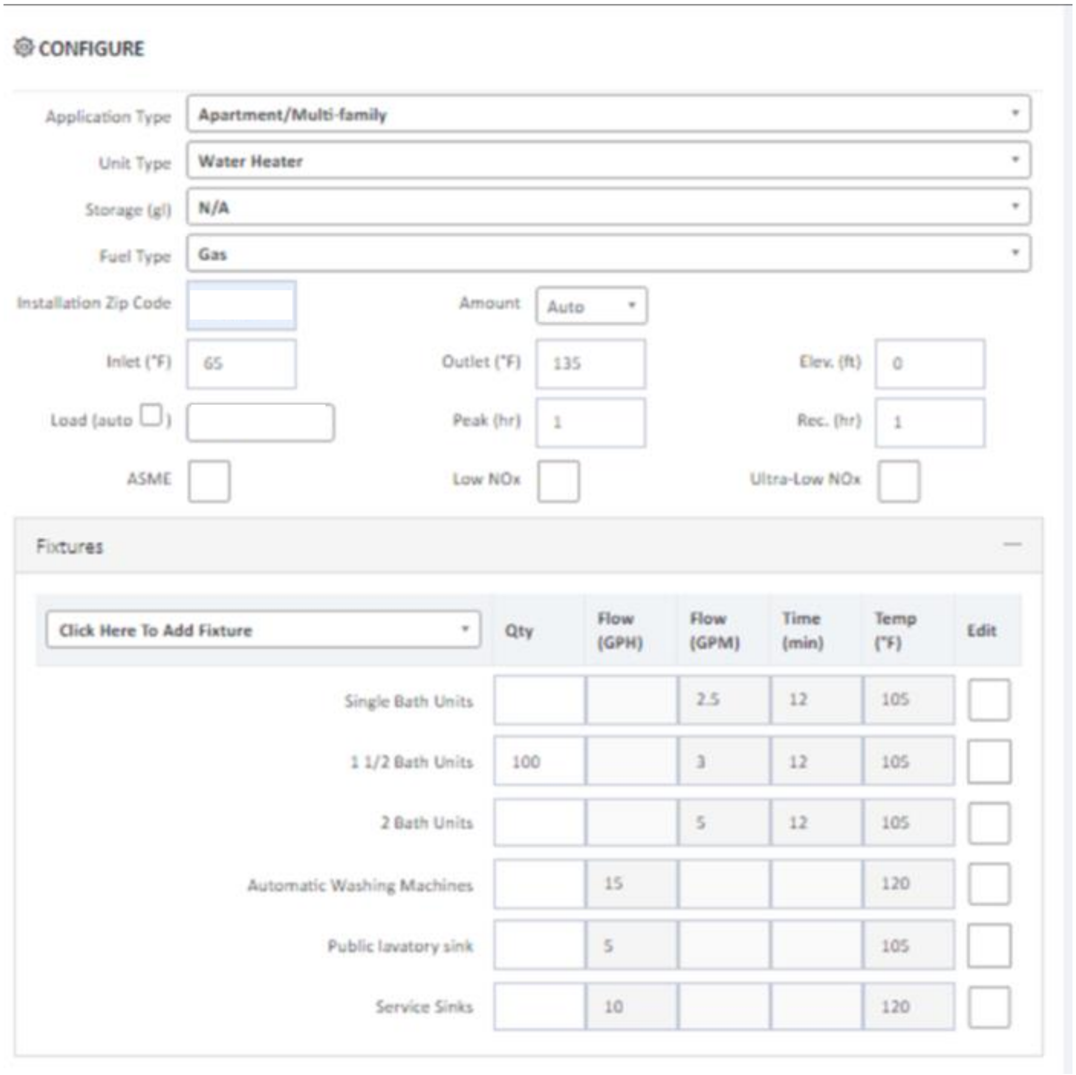
BTH-150 Mxi
Cyclone® Mxi Modulating

# Heaters:	2	Heater Recovery:	509 USGPH @ 70 °F Rise
Heater Storage (ea):	100 USG	1st Hour Delivery:	649 USGPH
Input (ea):	150,000 Btu/hr	3 Hour Average:	555 USGPH
		Est. Storage Recovery:	24 min
New External Tanks:	0		
Total Usable Storage:	140 USG	% Of Demand:	101% (2-hour peak)

BTHL-400A
Cyclone® LV (Large Volume)

# Heaters:	1	Heater Recovery:	644 USGPH @ 70 °F Rise
Heater Storage (ea):	220 USG	1st Hour Delivery:	798 USGPH
Input (ea):	399,000 Btu/hr	3 Hour Average:	696 USGPH
		Est. Storage Recovery:	20 min
New External Tanks:	0		
Total Usable Storage:	154 USG	% Of Demand:	126% (2-hour peak)

Figure 12: MFG Tool 3 Inputs



CONFIGURE

Application Type: Apartment/Multi-family

Unit Type: Water Heater

Storage (gl): N/A

Fuel Type: Gas

Installation Zip Code:

Amount: Auto

Inlet (°F): 65

Outlet (°F): 135

Elev. (ft): 0

Load (auto ☐)

Peak (hr): 1

Rec. (hr): 1

ASME ☐

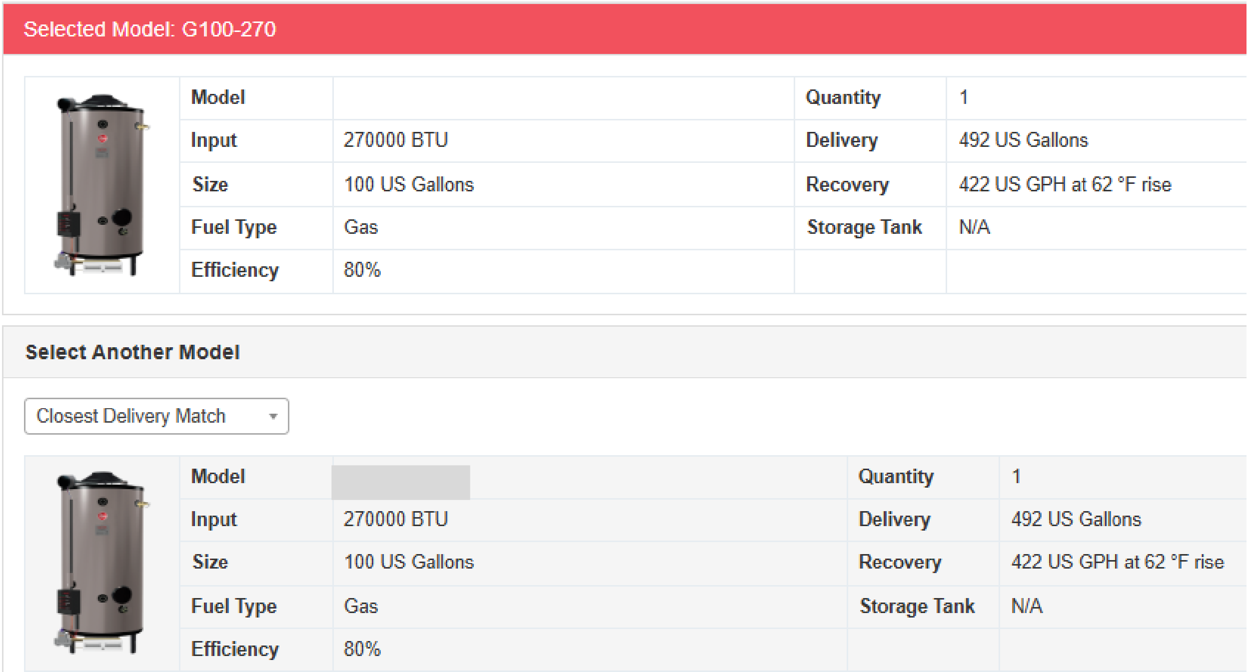
Low NOx ☐

Ultra-Low NOx ☐

Fixtures

Click Here To Add Fixture	Qty	Flow (GPH)	Flow (GPM)	Time (min)	Temp (°F)	Edit
Single Bath Units			2.5	12	105	☐
1 1/2 Bath Units	100		3	12	105	☐
2 Bath Units			5	12	105	☐
Automatic Washing Machines		15			120	☐
Public lavatory sink		5			105	☐
Service Sinks		10			120	☐

Figure 13: MFG Tool 3 Outputs



Selected Model: G100-270

Model		**Quantity**	1
Input	270000 BTU	**Delivery**	492 US Gallons
Size	100 US Gallons	**Recovery**	422 US GPH at 62 °F rise
Fuel Type	Gas	**Storage Tank**	N/A
Efficiency	80%		

Select Another Model

Closest Delivery Match ▾

Model	[redacted]	**Quantity**	1
Input	270000 BTU	**Delivery**	492 US Gallons
Size	100 US Gallons	**Recovery**	422 US GPH at 62 °F rise
Fuel Type	Gas	**Storage Tank**	N/A
Efficiency	80%		

Summary of Sizing Methodology Inputs/Outputs

In summary, all water heater sizing methods investigated in this study use a similar set of system inputs to calculate water heater capacity and storage tank volume as shown in Figure 14 below. The methods used for sizing water heaters are ASPE, ASHRAE, and manufacturer sizing tools. The specific inputs and outputs for these tools are summarized below in Table 2, Table 3, and Figure 14.

Figure 14: Water Heater Capacity and Storage Tank Sizing Method

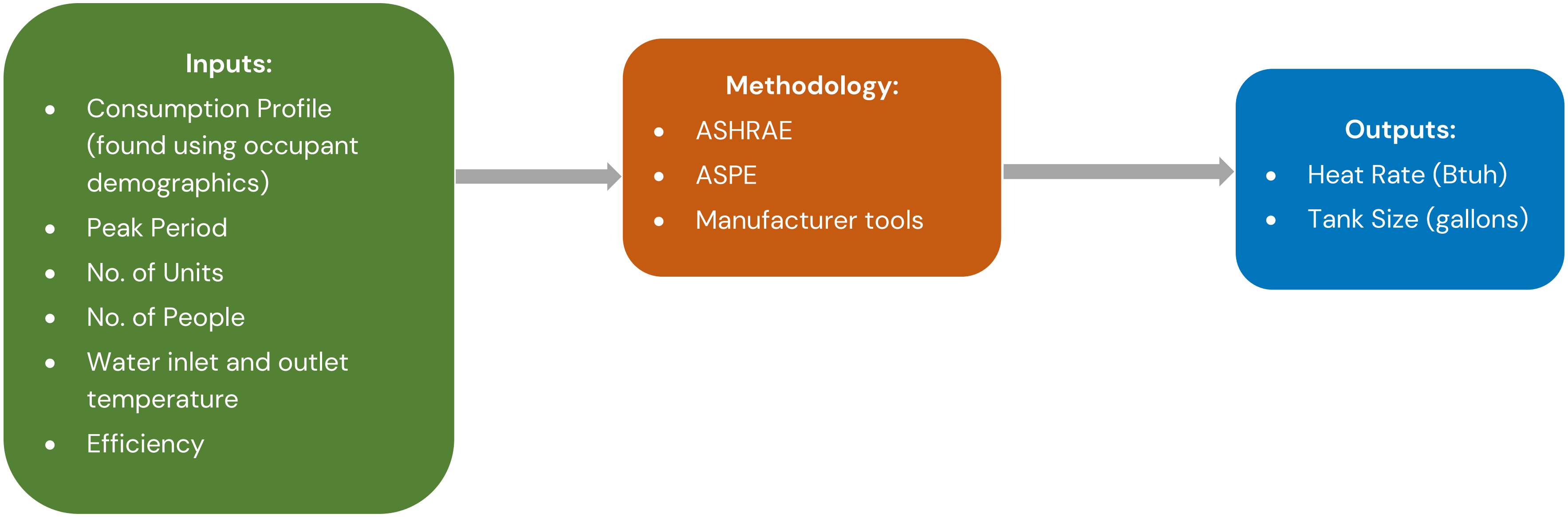
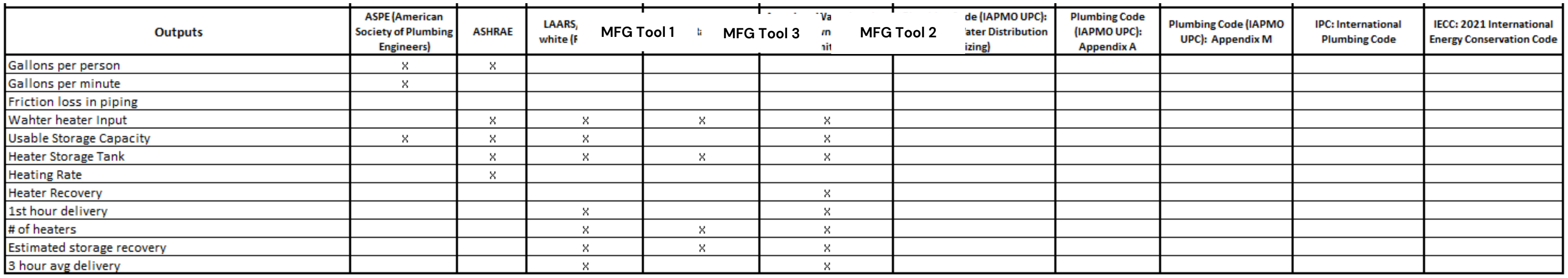


Table 2: Inputs Needed for Different Sizing Methods

			Manufacturer Tools			California Codes *for reference only, not used for water heater sizing*			International Codes *for reference only, not used for water heater sizing*	
Inputs	**ASPE (American Society of Plumbing Engineers)**	**ASHRAE**	**LAARS white (MFG Tool 1**	**R MFG Tool 3**	**American Water heating MFG Tool 2**	**Plumbing Code (IAPMO UPC): ater Distribution izing)**	**Plumbing Code (IAPMO UPC): Appendix A**	**Plumbing Code (IAPMO UPC): Appendix M**	**ICC: International Plumbing Code**	**IECC: 2021 International Energy Conservation Code**
Installation Type (indoor/ outdoor)			X	X	X	X	X	X	X	
Fuel Type						X	X			X
Gallons per person	X	X								
Season Changes to Gallons per person	X									
ASME required (Y/N)			X	X	X	X	X			
Incoming water Temp		X	X	X	X			X	X	
Stored Water Temp		X		X	X	X	X		X	
Building use (High,Med,Low) & Peak demand use time	X	X		X	X	X	X			
# of Units	X	X	X	X	X	X	X	X		
# of Units with 1/1.5/2/2.5 baths	X	X	X	X	X	X	X	X		
Number of Bathroom Fixtures (Bathtub, Bidet, Bath/shower combo, Faucet, Shower, water closet)			X			X	X		X	X
Shower head GPM			X		X		X			
Shower Minutes Per Hour			X							
Bathroom Flow (GPM), time (min), and Temp (F)				X			X			
Persons per Unit		X			X			X		
Heating Device Efficiency (%)		X								X
Peak Minutes	X	X		X	X		X			
Include Laundry? (Y/N)		X	X	X	X					
(If laundry) Quantity, Capacity, Temperature required	X	X	X	X	X					
Number of laundry fixtures (Washing machine, Faucet)	X					X				
Include Food Service / Restaurant? (Y/N)	X	X	X	X						
(If Food Service) # of sinks and sizes & temperatures	X	X	X	X						
Number of Kitchen Fixtures (Dishwasher, Faucet/kitchen sink)	X					X		X	X	
Number/ type of other fixtures						X		X	X	
Laws about flow restrictions or temp	X									X
Flowrate of all fixtures						X				
Pipe Diameter							X	X	X	X
Pipe Length							X	X		X
Pipe Material							X	X		X
Pipe Insulation										
Pipe velocity								X		
Altitude			X	X	X		X		X	
Low Nox (Y/N)			X	X	X					
Diversity Factor			X							
Additional Load (GPH)					X					
Length of Service							X			
Design oversize					X					
Recirculation Loop			X							
Recirculation Tank temp			x		X		X			

Table 3: Outputs from Different Sizing Methods



Outputs	ASPE (American Society of Plumbing Engineers)	ASHRAE	LAARS, white (F MFG Tool 1	ti MFG Tool 3	Va vn nit MFG Tool 2	de (IAPMO UPC): ater Distribution izing)	Plumbing Code (IAPMO UPC): Appendix A	Plumbing Code (IAPMO UPC): Appendix M	IPC: International Plumbing Code	IECC: 2021 International Energy Conservation Code
Gallons per person	x	x								
Gallons per minute	x									
Friction loss in piping										
Wahter heater Input		x	x	x	x					
Usable Storage Capacity	x	x	x		x					
Heater Storage Tank		x	x	x	x					
Heating Rate		x								
Heater Recovery					x					
1st hour delivery			x		x					
# of heaters			x	x	x					
Estimated storage recovery			x	x	x					
3 hour avg delivery			x		x					

Analysis of Methods

ASHRAE and ASPE

ASPE and ASHRAE provide clear assumptions and calculations that can be used to properly size a water heater. They share a similar approach to sizing a DHW system and use the same underlying data. Both consider Low, Medium, and High consumption profiles and different peak periods to calculate the heat rate and storage tank volume required to meet the hot water demand during specific peak periods. Both ASHRAE and ASPE provide water consumption profiles based on data collected approximately 30-40 years ago (1994), as illustrated in the captions from the ASPE Handbook shown in Figure 1 [5].

Since the ASHRAE and ASPE consumption profile data was collected over 30 years ago, the Study Team gathered hot water usage data from a more recent study by The Water Research Foundation, "Residential End Uses of Water, Version 2 Executive Report" [10] (REUW) and compared it to the ASHRAE and ASPE data. According to this source, the current per-person hot water consumption averages are lower compared to ASHRAE and ASPE. This is attributed to the increased use of water-efficient fixtures and appliances since the ASHRAE/ASPE data was gathered. The actual gallons per household per day (GHPD) hot water consumption in the REUW report is split into different categories shown in Table 4 and includes the impacts of leaks.

Table 4: Average Daily Hot Water use per Household REUW [10]

Shower	39.1%	**17.8 gphd**
Faucet	33.8%	**15.4 gphd**
Clothes washer	9.7%	**4.4 gphd**
Bath	5.7%	**2.6 gphd**
Dishwasher	4.8%	**2.2 gphd**
Leak	4.6%	**2.1 gphd**
Other	2.0%	**0.9 gphd**
Toilet	0%	**0.0 gphd**
Total		**45.5 gphd**

The Study Team determined that leaks should not be included in calculating the total daily hot water use per household, making the total *43.4 gallons per household per day*. Assuming the number of people per household to be 2.6[2], the calculated daily average per capita hot water use is about 16.6 gallons [10]. This average is lower than the "Low" consumption profile provided by ASPE/ASHRAE. Since an average can include values below/above the average number, actual water usage in some residences can be even lower than 16.6 gallons/person-day. After consulting with an industry SME, a "Very Low" consumption value of 10 gallons per person per day was used to compare to the ASPE/ASHRAE values. This consumption would correspond to the same occupant demographics of ASHRAE/ASPE's "Low" consumption profile [5]. The ratio of the ASHRAE/ASPE and "Very Low" consumption value was used to determine the "Very Low" consumption per person per day at different peaks, as shown in Table 5.

Table 5 also shows that ASHRAE/ASPE methods is oversizing water heater heat consumption and storage tank volume because the more recent water consumption data is significantly less than the data in the "Low" consumption profile. This is consistent with anecdotal evidence of oversized water heaters in California.

Table 5: Hot water demand as a function of consumption profile and peak minutes (gallons per person per day)

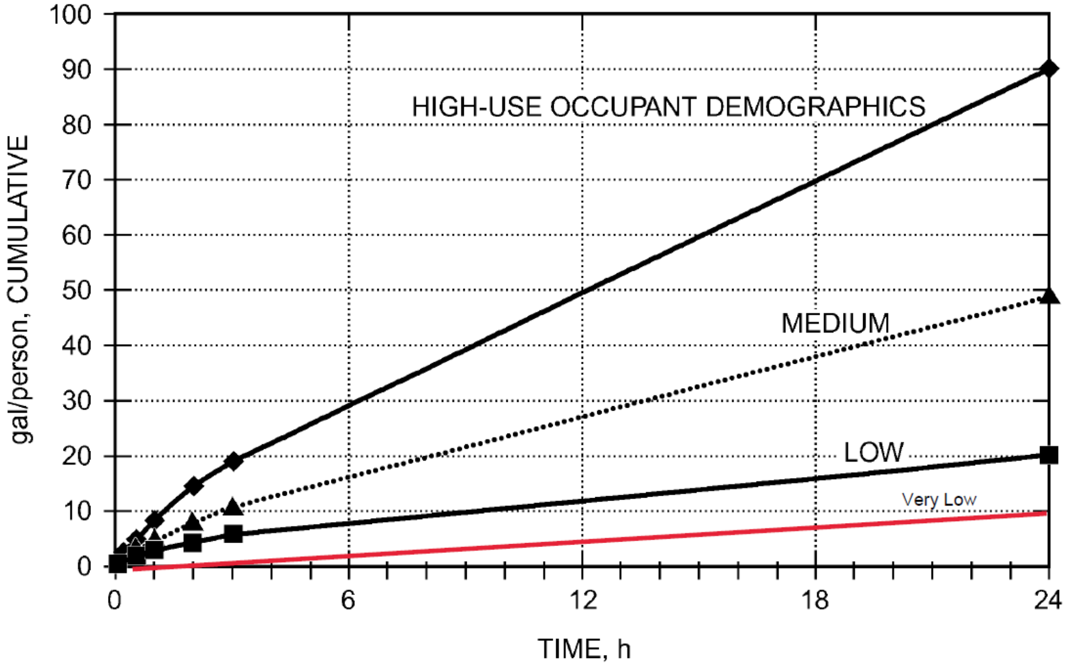
Consumption Profile	**Peak Minutes (gallons/person)**						**Max Daily (gallons/day)**
	5	**15**	**30**	**60**	**120**	**180**	
Very Low	0.2	0.6	1.0	1.6	2.5	3.4	10
Low [5]	0.4	1	1.7	2.8	4.5	6.1	20
Medium [5]	0.7	1.7	2.9	4.8	8	11	49
High [5]	1.2	3	5.1	8.5	14.5	19	90

Figure 15 shows graphical representation of the "Very Low" consumption profile.

---

[2] This value from the REUW Report

Figure 15: Updated ASHRAE Hot Water Demand Profile



The next section in the report includes a comparative analysis between actual site DHW usage data with ASHRAE/ASPE and REUW data.

Analysis of ASHRAE/ASPE vs. Manufacturer tools:

The Study Team compared the manufacturer sizing tool outputs to the ASHRAE/ASPE outputs using the same set of inputs. The inputs to the manufacturer tools and ASHRAE/ASPE are shown in Table 6 below. If the manufacturer tool had additional inputs, the default values were used. Multiple iterations of manufacturer tool and ASHRAE/ASPE calculations are conducted starting with the assumption of 100 apartment units and increasing by 20-unit increments up to 240 units. This was done to understand how sizing changes with increasing hot water demand. Each of the manufacturer's tool allowed modification of the inputs listed in Table 6. The tools also contained some default settings, such as flow rate, temperature at fixture, which were not modified.

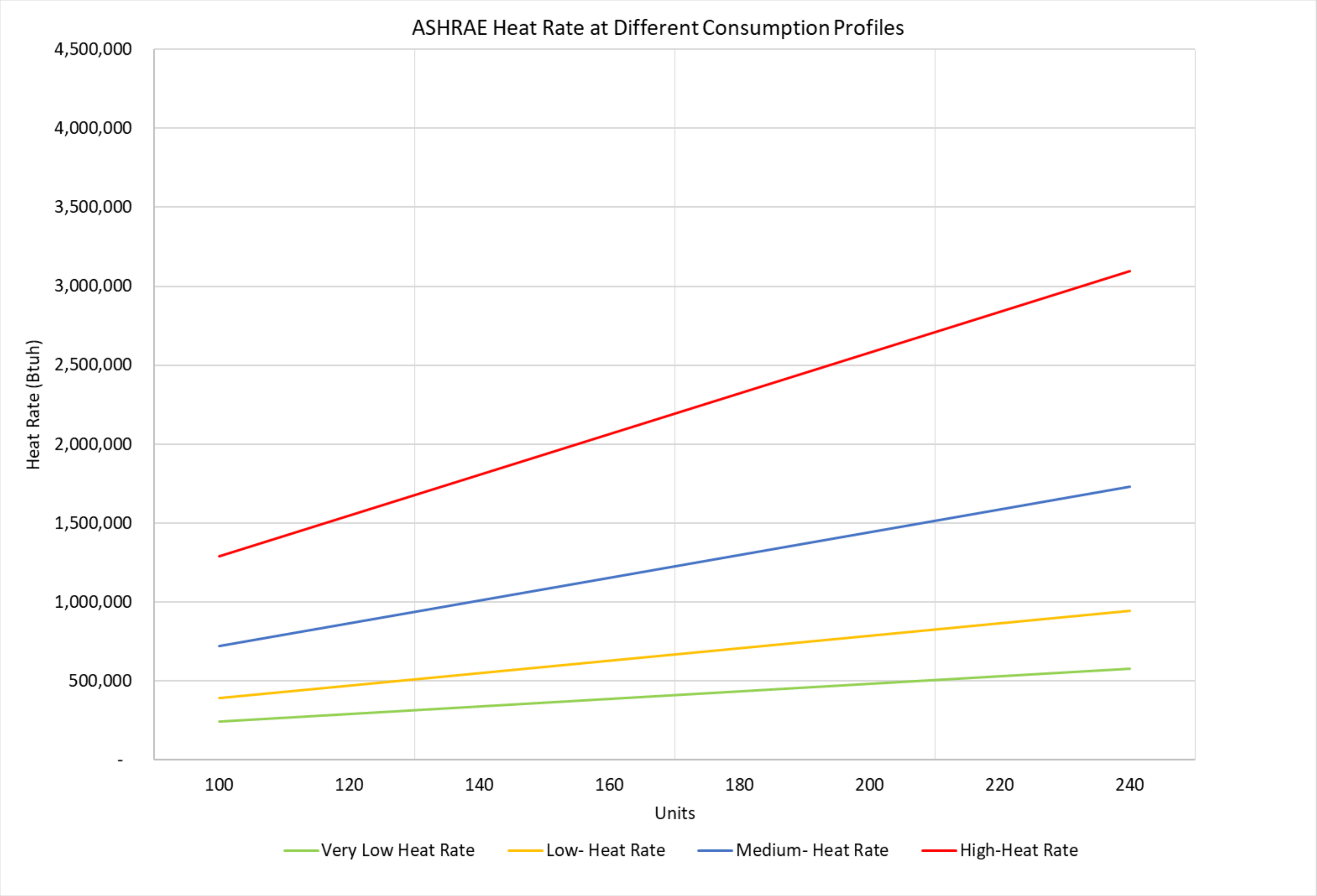
Table 6: Key Assumption used in manufacturing tools to size water heater

Input	Value
Units	100-240
Type of unit	1 bed/ 1.5 bath
People per unit	2.6 [10]
Temperature in	65°F
Temperature Out	135°F
Peak Time	60 minutes

The ASHRAE/ASPE method was used to calculate heat rate and storage tank volume for each peak period. MFG Tool 2 and MFG Tool 3 have an option to input the peak period while the MFG Tool 1 does not. After several iterations of the MFG Tool 1, it was determined that these tools most likely use a 60-minute peak period. Therefore, a 60-minute peak period was used in all tools for consistency.

Error! Reference source not found. shows the ASHRAE heat rate for different consumption profiles as the number of dwellings (and therefore the number of people) increases. Figure 17-19 illustrates that peak hot water demand has a greater impact on the recommended water heater capacity in manufacturer tools relative to the ASHRAE approach. This underscores the need to accurately predict the hot water demand when sizing water heaters.

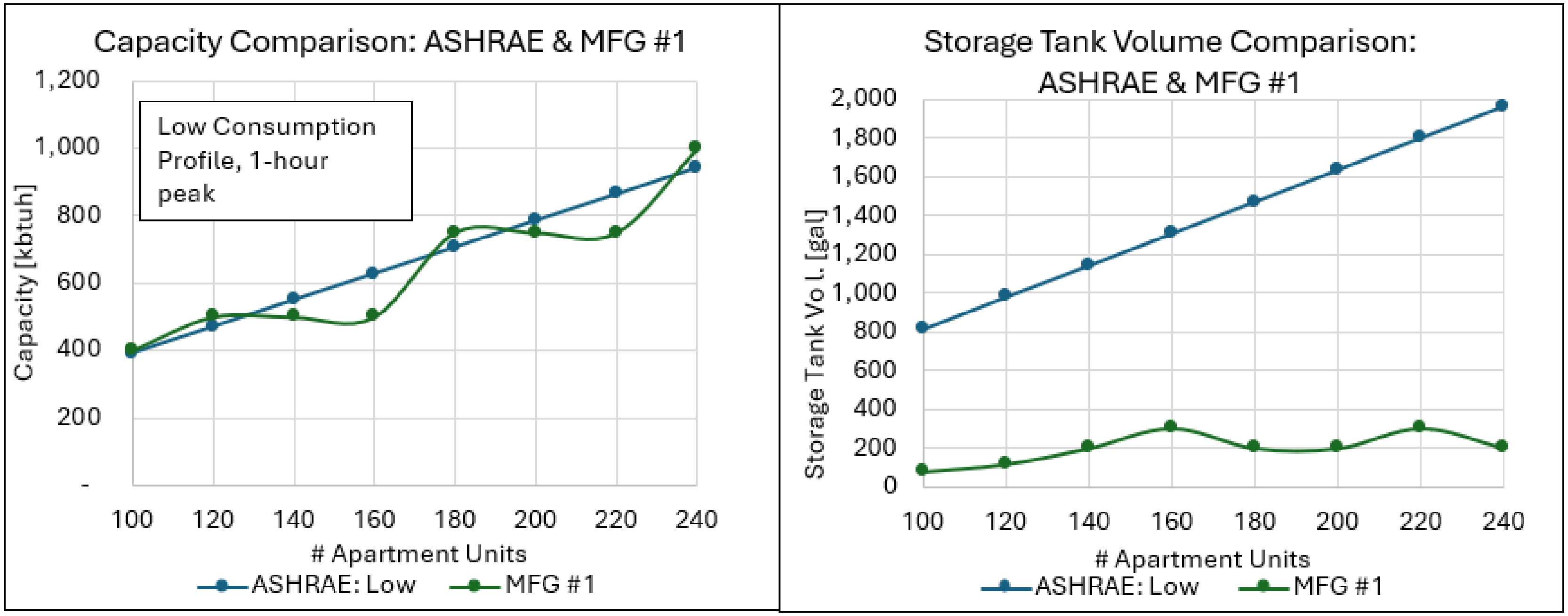
Figure 16: ASHRAE/ASPE Calculated Heat Rate Based at Different Consumption Profiles



ASHRAE vs MFG Tool 1:

Below is the predicted water heater heat rate and storage tank volume using the MFG Tool 1 sizing tool as a function of apartment units. Each heating unit has an efficiency of 85%.

Figure 17: ASHRAE vs MFG Tool 1 Recommended Water Heater Sizes as a function of Units in a Multifamily Building



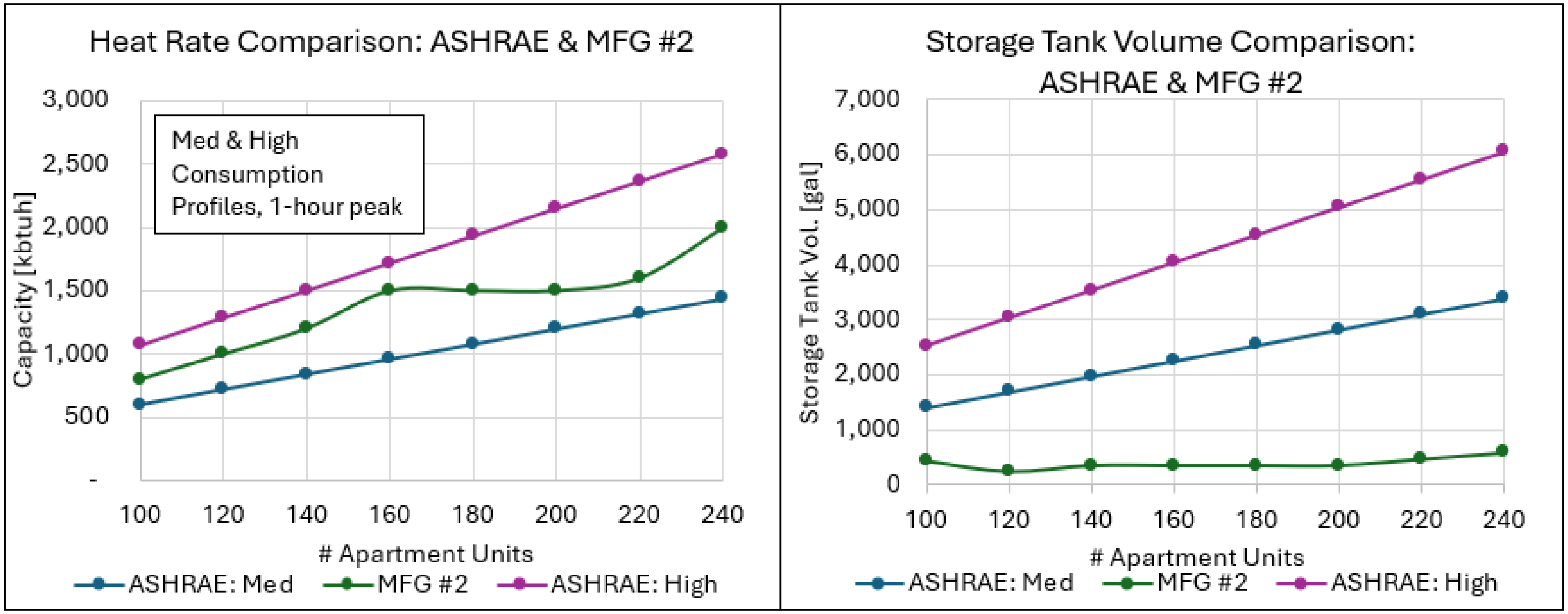
The ASHRAE method shows a steady increase in both the capacity and the storage volume as the number of apartments increases from 100-240. The capacity values at 100 and 240 apartments are similar for both Manufacturer #1 and ASHRAE. Between the two endpoints, ASHRAE capacities rise steadily. Capacity recommendations from Manufacturer #1 do not follow a straight line because the manufacturer does not produce "made-to-order" equipment, and the tool recommends actual manufacturer-produced units. ASHRAE's recommended storage tank volume increases steadily with increased demand, but the recommendations from Manufacturer #1 are much, much lower. Comparing heat rate output with the ASHRAE method, it was concluded that the MFG Tool 1 is likely assuming a water use profile that is similar to ASHRAE's "Low".

There was less correlation between storage tank volumes, as the ASHRAE tool showed a steeper increase in tank size with increasing demand compared to the MFG Tool 1 which barely increases as the number of apartments goes up.

ASHRAE vs MFG Tool 2:

Below, in Figure 18, is the predicted water heater heat rate and storage tank volume using the MFG Tool 2 as a function of apartment units. Each heating unit has an efficiency of 96%.

Figure 18: ASHRAE vs MFG Tool 2 Recommended Water Heater Sizes as a function of Units in a Multifamily Building



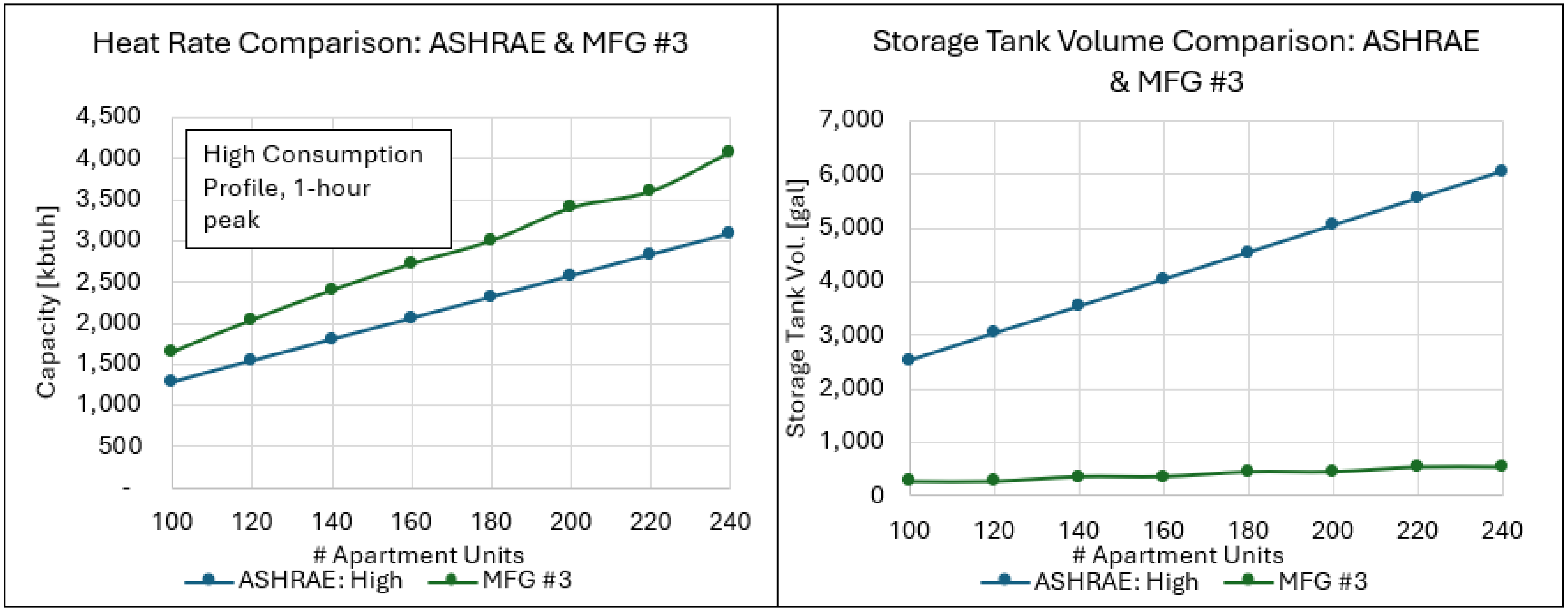
Similar to the comparison with MFG Tool 1, the heat rates increase as the number of apartments goes up. MFG Tool 2 offers the flexibility to select a consumption profile, and in this case, "Medium" was chosen. However, the consumption profile seems to fall in between ASHRAE's "Medium" and "High" consumption profiles.

Again, the heat rate appears to be increasing as a function of demand, whereas storage tank volume does n

ASHRAE vs MFG Tool 3:

The final manufacturer tool under consideration was MFG 3's sizing tool. See the comparison between MFG Tool 3 and ASHRAE in Figure 19 below.

Figure 19: ASHRAE vs MFG Tool 3 Recommended Water Heater Sizes as a function of Units in a Multifamily Building



As with the two previous tools, it was observed that as demand increases, the required heat rate also increases. In this case, MFG Tool 3 uses a consumption profile which is higher than ASHRAE's "High" consumption profile. Again, the actual storage tanks recommended by MFG Tool 3 are considerably smaller than ASHRAE.

Sizing Method Findings

The Study Team conducted a comprehensive analysis of various water heating system sizing methods/tools. Below are the significant findings from this research:

- Energy and plumbing codes do not offer helpful information for sizing water heaters. While IAPMO provides hot water design flow data, it lacks guidance on how to use it for sizing. Similarly, IECC provides information on different fuel types and pipe sizing information but lacks information on how to calculate heat rate and storage tank volume. The IPC provides regulations and guidelines for plumbing system design, installation, and inspection, including safety measures for water heaters, but it does not offer information on water heater sizing, making it irrelevant for this study.
- ASHRAE and ASPE provide equations for and clear guidance for sizing water heaters and storage tanks in multifamily properties.
- The underlying data used to determine water consumption profile in ASHRAE/ASPE is dated and has high consumption values compared to the more recent data from the Residential End Uses of Water report.
- It's likely that manufacturer tools use the same basic methodology as ASHRAE and ASPE for heat rate calculations. The heat output rates in manufacturer tools matched closely with ASHRAE/ASPE values. However, manufacturer tools recommend much smaller storage tanks than ASHRAE/ASPE. This may be due to additional code requirements for larger storage tanks.
- A key difference was identified in the approach between ASHRAE and the manufacturer tools: ASHRAE seemed to offer a choice between a storage tank capable of providing hot water for peak periods or larger water heaters, while manufacturers calculated a water heater size that balances both heat rate and storage volume. ASHRAE lacked a method to combine these two factors into one equation, unlike the manufacturer tools.
- If manufacturer tools are using the same underlying data and method as ASHRAE/ASPE, it is possible that all methods oversize water heaters and storage tanks. This possibility is further investigated in later sections using actual site data and comparing against ASHRAE/ASPE and manufacturer tool recommendations.

Subject Matter Expert Interviews

The findings of the previous section determined that there are various resources used in the industry to size DHW systems. The resources are usually similar but have distinct differences leading to a lack of uniformity within the industry. The major DHW sizing resources considered were:

- American Society of Heating, Refrigerating and Air-Conditioning Engineers Handbook
- American Society of Plumbing Engineers Plumbing Engineering Design Handbook
- Manufacturer tools
- International/Uniform Plumbing Codes
- Electric Heat Pump Water Heater Tool

Therefore, SMEs in water heating for multifamily buildings were surveyed to understand:

- Issues associated with DHW sizing
- Key components considered when sizing DHW systems
- Most utilized sizing resources
- Key components considered when selecting DHW systems
- Approaches for anticipating future demand changes

Survey Participants

SMEs were recruited from various stakeholders. These included water heating manufacturers (MFG), technical experts (TE), and Contractors (C) involved in the gas-fired domestic water heating industry.

Survey Questionnaire

The survey questionnaire consisted of two sections: one with open-ended questions focused on DHW sizing and replacement, and another featuring multiple choices to be ranked. The questions were designed to collect insights from various stakeholders, i.e., technical expert, manufacturer, or contractor. The survey questionnaire is presented below.

Section 1: Open ended questions:

- Question 1: Why do you replace a water heater? (failure, age, capacity, technology)
- Question 2: Do you see any issues with how water heating system sizing is happening currently?

Section 2: Ranking Questions:

Table 7: SME Survey Question 3

Question 3	**Here are some key components needed for the sizing of a water heating system. Are there any additional components? Please rank order the top five. Please explain your rankings.**			
		L/M/H (Low, Medium, High)	**Rank**	**Explanation**
A	Number of occupants			
B	Number of apartments			
C	Demographics of the occupancy (senior, affordable, families, etc.)			
D	Number of bathrooms			
E	Type of fixtures			
F	Age of the plumbing fixtures			
G	Number of washing machines			
H	Location of washing machines (in apartments, shared)			
I	Time of day the peak uses occur			
J	Duration of the peak periods			
K	Gallons per person per day			
L	Type of temperature maintenance system (do you prefer circulation, heat trace, etc.)			
M	If circulation, the method of balancing the riser			
N	Hot water piping material			
O	Length of the hot water piping			
P	Diameter and volume of the hot water distribution network			
Q	Configuration of the hot water distribution network			
R	Insulation on the hot water piping			
S	Effectiveness of the pipe insulation installation			

Table 8: SME Survey Question 4

Question 4	**Here are some resources used to size water heating systems. Are there any other resources that you use? Please rank order the top five. Please explain your rankings.**			
		LMH (Low, Medium, High)	**Rank**	**Explanation**
A	ASHRAE			
B	ASPE			
C	IPC (International Plumbing Code)			
D	IAPMO/ UPC (Uniform Plumbing Code)			
E	Manufacturer's method			
F	EHPWH Tool			
G	Measured data from the site or from a similar occupancy			
	Other method			
	Other method			
	Other method			

Table 9: SME Survey Question 5

Question 5	Here are some features that may be used to select a water heater. Are there any other features that are important. Please rank order the top five. Please explain your rankings.			
		LMH (Low, Medium, High)	Rank	Explanation
A	Water heater efficiency			
B	Cost			
C	Location where the water heater will be installed			
D	Incoming cold-water temperature			
E	Hot water temperature			
F	Master mixing valve temperature			
G	First hour rating			
H	Recovery efficiency			
I	Heat rate (capacity)			
J	Location where the storage tank(s) will be installed			
K	Volume of storage (one large tank or a number of smaller ones. ASME tanks?)			
L	Size of storage tanks (volume, dimensions, ASME tanks?)			
M	Heat losses of the circulation loop			
N	Brand			
O	Is water heater sizing adjusted based on the presence of preheat sources (Solar, etc.)			
P	Gallons per hour (recovery rate)			
	Other			

Table 10: SME Survey Question 6

Question 6	Here are some ways to account for future increases in demand when selecting a water heater. Are there any others that you use? Please rank order the top five. Please explain your rankings.			
		LMH (Low, Medium, High)	Rank	Explanation
A	Provide space for additional water heaters			
B	Provide space for additional storage tanks			
C	Install larger storage as part of initial design			
D	Install additional storage tanks as part of initial design			
E	Install heater with larger heating capacity as part of initial design			
F	Provide additional capacity in the gas line or in the electrical panel			
	Others			
	Others			

SME Responses

The surveys were conducted through 1-hour recorded video calls with each SME. First, open-ended questions were asked to identify patterns within SME responses. In the second section, experts were asked to assign importance levels (Low, Medium, High) to each sizing element. The responses initially assigned as “High” were further ranked from 1 -5 to provide quantifiable answers for statistical analysis. The scaling system is based on the importance of the specific element being questioned, where 1 is the rank given to the most important element, 2 as the second most important, and so on. An example of a response to question 3 is shown in Table 11 to show the “Low,” “Medium,” and “High” categories and scores associated with the sizing elements that ranked “High”. All SME responses are presented in Appendix 1. The survey questions were standardized across all experts to ensure consistency, and the ranking process aimed to quantify the results. To quantify the importance of each element in the ranking questions, each ranking was assigned a score. The most important ranking of “1” was given a score of 5, “2” was given a score of 4, and so on. Components that were not categorized as “High” automatically received a score of 0. This was done to ensure that the most important sizing element received the highest score. Table 12-Table 19 summarize the responses from all SMEs interviewed with values of the scores quantified based on their rankings. Figure 20-Figure 23 present the results in pie charts to show which elements had the highest score and were ranked of highest importance.

Table 11: SME #12 Question 3 Responses

Question 3	Here are some key components needed for the sizing of a water heating system. Are there any additional components? Please rank order the top five. Please explain your rankings.			
		LMH (Low, Medium, High)	Rank	Explanation
A	Number of occupants	H	2	Establishes demand
B	Number of apartments	L		
C	Demographics of the occupancy (senior, affordable, families, etc.)	H	3	Correlated with how much usage per person
D	Number of bathrooms	L		
E	Type of fixtures	H	4	Fixture efficiency/ capability affects demand
F	Age of the plumbing fixtures	H	5	Fixture efficiency/ capability affects demand
G	Number of washing machines	M		
H	Location of washing machines (in apartments, shared)	M		
I	Time of day the peak uses occur	L		
J	Duration of the peak periods	L		
K	Gallons per person per day	H	1	Derivate the other 4 Highs
L	Type of temperature maintenance system (do you prefer circulation, heat trace, etc.)	L		
M	If circulation, the method of balancing the riser	L		
N	Hot water piping material	L		
O	Length of the hot water piping	L		
P	Diameter and volume of the hot water distribution network	L		
Q	Configuration of the hot water distribution network	L		
R	Insulation on the hot water piping	L		
S	Effectiveness of the pipe insulation installation	L		

DHW System Sizing Issues and Causes for Replacement

During the interviews, each SME was asked about the primary reason for replacing a water heater. Around 85% of the interviewed SMEs highlighted that the most common cause for DHW system replacement is failure. Less frequent reasons included replacements due to age, incentives, newer technologies, or capacity. Contractors, tasked with replacements after DHW failure, operate with a swift turnaround time, given the substantial impact of a failed water heater on residents. When a water heater has failed, contractors often opt for a 'like-for-like' replacement, essentially upgrading to a newer version of the same-sized system. However, when sizing new DHW systems or replacements not due to failure, contractors often defer to manufacturers to recommend DHW systems which are sized based on manufacturer tools. According to SME #8 and SME #29, who are contractors, it is advantageous to use manufacturer tools to size DHW systems in these cases because manufacturers provide a guarantee that their sizing predictions will be sufficient. If their calculations are insufficient, the manufacturers commit to supplying all additional equipment at no additional cost. Technical experts, usually contacted early in the designing of a building, are tasked with sizing a DHW system based on certain design considerations and demand requirements without the presence of an existing system. Since there are different end goals and time constraints regarding DHW system sizing for each type of SME, there is often a divergence in sizing approaches between technical experts, manufacturers and contractors. When replacing failed systems, contractors and building managers typically choose the same size already in place, leading to different sizing methodologies for new constructions, non-failure replacements, and failure replacements.

When asked about the main issue with DHW system sizing, 72% of SMEs agreed that systems were often oversized, citing a lack of uniformity in sizing tools. Less discussed issues included the use of outdated data in DHW sizing resources, which no longer aligns with modern, energy-efficient fixtures. Furthermore, the presence of uncertainty in real-world data underscores the need for improved modeling techniques. While many SMEs agree oversizing is an issue, SME #9 emphasized that 'oversizing is not a dirty word.' Instead, it can be viewed as a positive design approach aimed at mitigating the likelihood that users will run out of hot water, thereby reducing the maintenance calls. In traditional gas boiler water heaters, the initial cost per Btuh is small so oversizing generally has a minimal impact on upfront capital cost. However, it's essential to recognize that the industry is moving towards heat pump water heaters due to their energy efficiency, environmental benefits, and growing consumer preference. These systems do come with a higher upfront cost per Btuh, which underscores the importance of right sizing to reduce costs and improve market adoption. Additionally, as the industry transitions to heat pumps, there are not yet as many readily available resources on sizing heat pump water heaters, which is causing a gap in proper sizing practices.

Key Parameters for DHW System Sizing

In Question 3, each SME was presented with several parameters affecting DHW sizing and was asked to categorize each as “High”, “Medium” or “Low” importance and then number rank the “High” importance parameters. Then a score was assigned to each parameter based on its rank with higher scores being more important variables. The most important DHW sizing component was found to be "Number of Occupants" with a total score of 108 as shown in Figure 20. According to the interviewees, having an accurate count of occupants in a multifamily building is crucial in establishing the hot water demand. The components that received the next highest scores were “Gallons per Person per Day” with a score of 73, "Number of Apartments” with a score of 62, “Duration of the Peak” with a score of 52, and “Demographics of the occupancy” with a score of 35. These five (5) highest scorings components are all used in ASHRAE sizing tool. This indicates agreement between ASHRAE’s sizing methodologies and the survey findings. Table 7Table 10 and Figure 20Figure 23 show the scored responses by the SMEs.

Table 12: Key Components for DHW System Sizing SME Responses Summary

Q3	DHW System Sizing Component	Total Score	Mean	Standard Deviation	CV
A	number of occupants	108	3.72	1.98	0.53
B	number of apartments	62	2.14	2.06	0.97
C	demographics of the occupancy	35	1.21	1.54	1.28
D	number of bathrooms	28	0.97	1.77	1.83
E	type of fixtures	21	0.72	1.51	2.08
F	age of the plumbing fixtures	1	0.03	0.18	5.29
G	number of washing machines	14	0.48	0.97	2.01
H	location of washing machines (in apartments, shared)	8	0.28	0.64	2.31
I	time of day the peak uses occur	13	0.45	0.97	2.16
J	duration of the peak periods	52	1.79	1.67	0.93
K	gallons per person per day	73	2.52	1.94	0.77
L	type of temperature maintenance system (do you prefer circulation, heat trace, etc.)	21	0.72	1.17	1.62
M	If circulation, the method of balancing the riser	5	0.17	0.59	3.43
N	length of the hot water piping	2	0.07	0.36	5.29
O	diameter and volume of the hot water distribution network	5	0.17	0.46	2.67
P	configuration of the hot water distribution network	5	0.17	0.53	3.07

Table 13: Key Components for DHW System Sizing SME Responses Part 1

Q3	A	B	C	D	E	F	G	H
	number of occupants	number of apartments	demographics of the occupancy	number of bathrooms	type of fixtures	age of the plumbing fixtures	number of washing machines	location of washing machines (in apartments, shared)
Total Score	108	62	35	28	21	1	14	8
Mean	3.72	2.14	1.21	0.97	0.72	0.03	0.48	0.28
Standard Deviation	1.98	2.06	1.54	1.77	1.51	0.18	0.97	0.64
Coefficient of Variation	0.53	0.97	1.28	1.83	2.08	5.29	2.01	2.31
SME 1	0	2	0	4	5	0	3	0
SME 2	4	1	0	0	0	0	0	0
SME 3	5	3	0	0	0	0	0	0
SME 4	3	5	1	0	0	0	0	0
SME 5	5	3	0	0	0	0	2	0
SME 6	4	0	2	0	0	0	0	0
SME 7	5	5	0	2	1	0	0	0
SME 8	5	0	0	4	0	0	0	0
SME 9	0	0	0	0	0	0	0	0
SME 10	0	5	4	0	0	0	0	1
SME 11	4	0	3	0	2	1	0	0
SME 12	5	2	4	0	0	0	0	0
SME 13	5	0	4	0	0	0	0	0
SME 14	5	0	4	0	0	0	0	0
SME 15	5	5	3	0	0	0	0	0

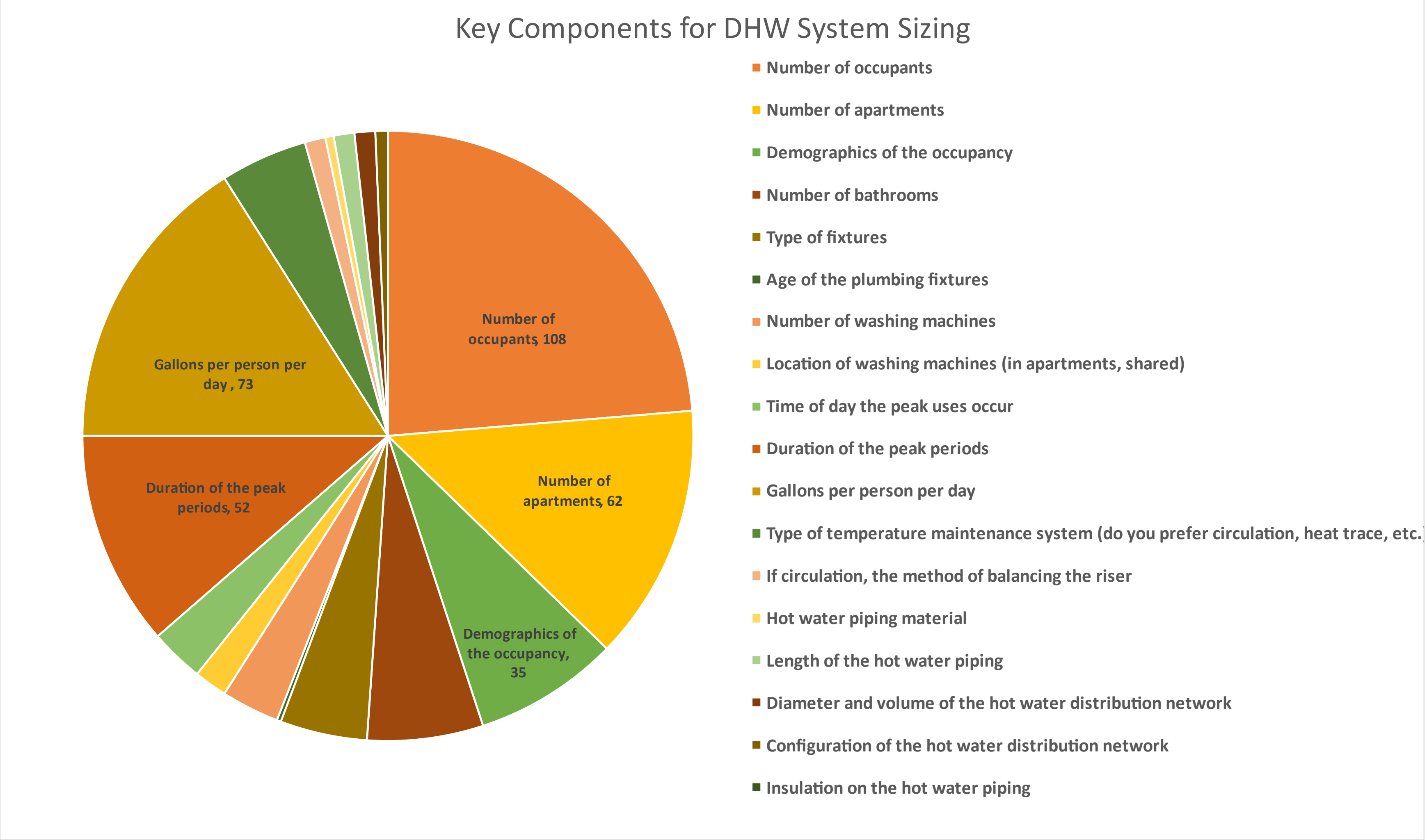
Q3	A number of occupants	B number of apartments	C demographics of the occupancy	D number of bathrooms	E type of fixtures	F age of the plumbing fixtures	G number of washing machines	H location of washing machines (in apartments, shared)
SME 16	0	0	0	0	0	0	0	0
SME 17	5	5	1	0	0	0	0	0
SME 18	5	5	1	0	0	0	0	0
SME 19	5	0	0	0	0	0	0	0
SME 20	5	1	0	0	0	0	0	2
SME 21	5	1	0	0	0	0	0	2
SME 22	5	4	3	0	5	0	0	0
SME 23	5	0	0	0	0	0	0	0
SME 24	5	5	0	4	0	0	2	0
SME 25	5	2	2	0	1	0	0	0
SME 26	3	0	0	0	4	0	0	0
SME 27	0	4	3	5	0	0	2	1
SME 28	5	0	0	4	3	0	2	0
SME 29	0	4	0	5	0	0	3	2

Table 14: Key Components for Water Heater Sizing SME Responses Part 2

	I	J	K	L	M	N	O	P
Q3	time of day the peak uses occur	duration of the peak periods	gallons per person per day	type of temperature maintenance system (do you prefer circulation, heat trace, etc.)	If circulation, the method of balancing the riser	length of the hot water piping	diameter and volume of the hot water distributio n network	configuration of the hot water distribution network
Total	**13**	**52**	**73**	**21**	**5**	**2**	**5**	**5**
Mean	**0.45**	**1.79**	**2.52**	**0.72**	**0.17**	**0.07**	**0.17**	**0.17**
Standard Deviation	**0.97**	**1.67**	**1.94**	**1.17**	**0.59**	**0.36**	**0.46**	**0.53**
Coefficient of Variation	**2.16**	**0.93**	**0.77**	**1.62**	**3.43**	**5.29**	**2.67**	**3.07**
SME 1	0	1	0	0	0	0	0	0
SME 2	3	2	5	0	0	0	0	0
SME 3	0	4	0	0	0	0	0	0
SME 4	0	2	0	0	0	0	0	0
SME 5	0	1	4	0	0	0	0	0
SME 6	0	5	3	2	0	2	2	2
SME 7	0	3	4	0	0	0	0	0
SME 8	0	2	3	0	1	0	0	0
SME 9	0	0	0	0	0	0	0	0
SME 10	2	3	0	0	0	0	0	0
SME 11	0	0	5	0	0	0	0	0
SME 12	1	1	4	3	0	0	0	0

	I	J	K	L	M	N	O	P
Q3	time of day the peak uses occur	duration of the peak periods	gallons per person per day	type of temperature maintenance system (do you prefer circulation, heat trace, etc.)	If circulation, the method of balancing the riser	length of the hot water piping	diameter and volume of the hot water distributio n network	configuration of the hot water distribution network
SME 13	0	0	3	2	0	0	1	0
SME 14	0	3	0	0	0	0	0	0
SME 15	3	3	4	1	0	0	1	1
SME 16	0	0	5	4	0	0	0	0
SME 17	0	4	3	2	0	0	0	0
SME 18	0	4	3	2	0	0	0	0
SME 19	1	1	4	3	3	0	0	0
SME 20	0	4	3	0	0	0	0	0
SME 21	0	4	3	0	0	0	0	0
SME 22	0	0	0	0	0	0	0	0
SME 23	0	0	4	2	0	0	1	0
SME 24	0	1	3	0	0	0	0	0
SME 25	3	4	5	0	0	0	0	0
SME 26	0	0	5	0	0	0	0	2
SME 27	0	0	0	0	0	0	0	0
SME 28	0	0	0	0	1	0	0	0
SME 29	0	0	0	0	0	0	0	0

Figure 20: Key Components for DHW System Sizing SME Responses Summary



System Sizing Resources

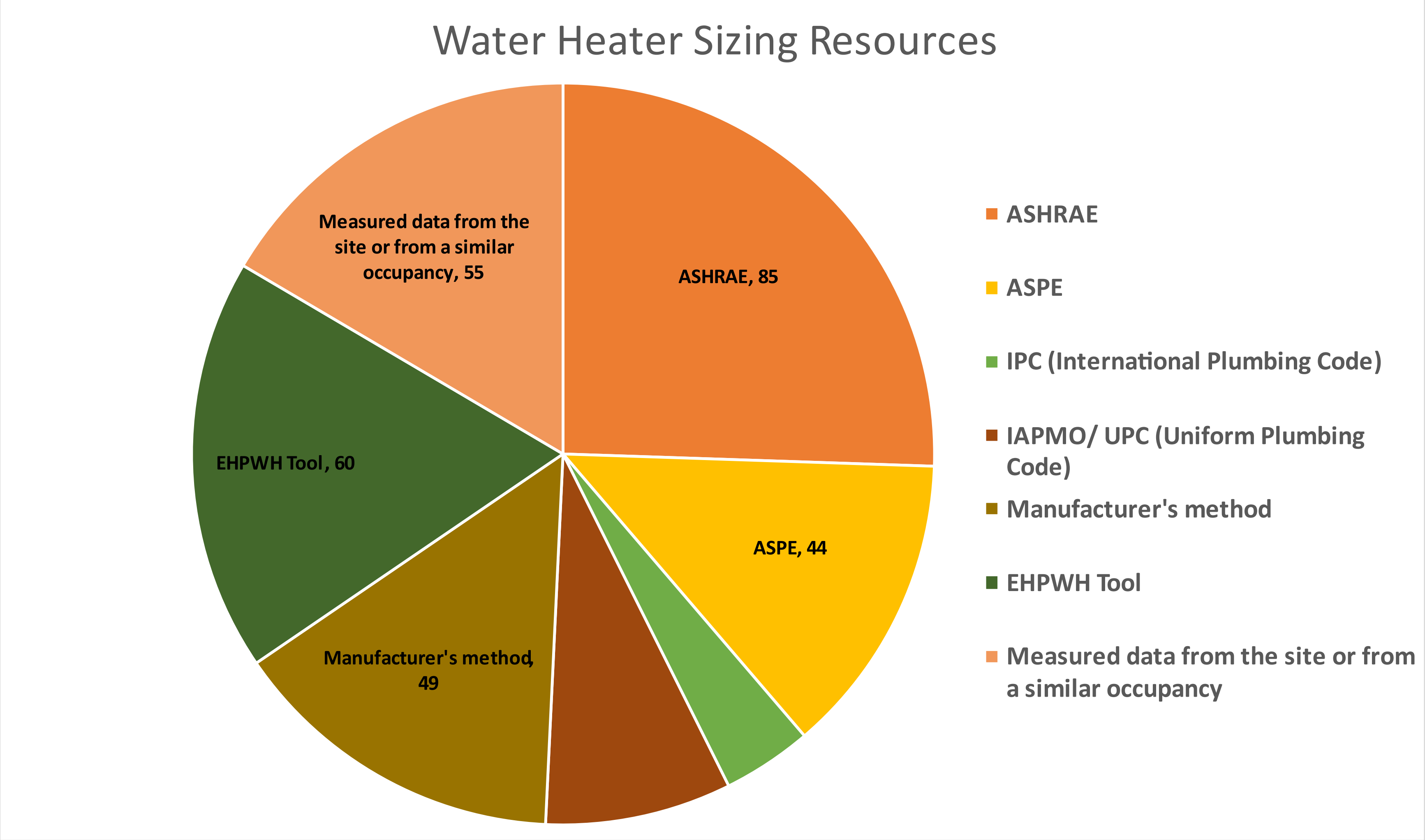
The subject matter experts were presented with a variety of sizing resources and asked to categorize and rank their preferred resources. ASHRAE's handbook emerged as the most preferred resource with a score of 85. The second most preferred resource is the EHPWH Tool with a score of 60, which incorporates calculations often derived from the ASHRAE Handbook. SME #19, who specializes in non-failure DHW system replacement projects, mentioned that they prefer using the EHPWH Tool as their sizing resource because it is regularly updated with current data. Measured data from the site or sites with similar occupancy characteristics was the third preferred resource with a score of 55. The top scoring resource, ASHRAE's handbook, requires time consuming calculations. So, even though it is the most preferred resource, it is often not used in the case of failure because it is not always feasible to conduct exhaustive sizing calculations under such time constraints. As discussed before, replacement due to failure is usually done by 'like-for-like' replacement. However, 'like-for-like' replacement is not a sizing resource and was not included in this section of the survey. Therefore, in these cases, experts resort to readily available measured data from similar occupancy profiles or easily accessible manufacturer tools. SME #11, who prioritized measured data from similar occupancy profiles as their top choice, emphasized that this data holds a significant advantage. It is favored because it provides insight into an already functioning system, offering a practical reference point for sizing DHW systems. Table 15 and Figure 21 below show a summary of the SME responses.

Table 15: Water Heater Sizing Resources SME Responses

Q4	A	B	C	D	E	F	G
	ASHRAE	ASPE	IPC (International Plumbing Code)	IAPMO/ UPC (Uniform Plumbing Code)	Manufacturer's method	EHPWH Tool	Measured data from the site or from a similar occupancy
Total Score	**85**	**44**	**13**	**27**	**49**	**60**	**55**
Mean	**2.93**	**1.52**	**0.45**	**0.93**	**1.69**	**2.07**	**1.90**
Standard Deviation	**1.89**	**1.89**	**1.07**	**1.51**	**2.07**	**2.21**	**1.97**
Coefficient of Variation	**0.65**	**1.24**	**2.39**	**1.62**	**1.22**	**1.07**	**1.04**
SME 1	3	4	2	5	0	0	0
SME 2	4	2	0	0	0	5	3
SME 3	5	0	3	2	4	0	0
SME 4	0	0	0	0	0	3	4
SME 5	5	4	0	0	3	0	0
SME 6	2	1	0	3	0	4	5
SME 7	5	2	3	4	0	0	0
SME 8	4	3	1	2	5	0	0
SME 9	5	0	0	0	0	0	0
SME 10	5	5	0	0	3	4	2
SME 11	3	0	0	2	0	4	5
SME 12	2	2	0	0	3	5	4
SME 13	0	0	0	0	0	0	0
SME 14	5	4	0	0	0	0	0

	A	B	C	D	E	F	G
Q4	ASHRAE	ASPE	IPC (International Plumbing Code)	IAPMO/ UPC (Uniform Plumbing Code)	Manufacturer's method	EHPWH Tool	Measured data from the site or from a similar occupancy
SME 15	2	0	0	0	1	5	3
SME 16	0	0	0	0	0	0	0
SME 17	4	5	0	0	0	3	0
SME 18	4	5	0	0	0	3	0
SME 19	4	0	0	2	0	5	3
SME 20	3	0	0	0	5	0	4
SME 21	3	0	0	0	5	0	4
SME 22	5	0	4	3	0	0	0
SME 23	3	0	0	0	0	4	5
SME 24	0	0	0	0	0	0	0
SME 25	4	3	0	0	5	5	5
SME 26	5	4	0	0	2	5	3
SME 27	0	0	0	4	5	0	3
SME 28	0	0	0	0	3	5	2
SME 29	0	0	0	0	5	0	0

Figure 21: Water Heater Sizing Resources SME Responses Summary



Key Parameters for DHW System Selection

In the process of selecting DHW systems, SMEs often face the task of choosing between multiple manufacturers, brand makes, and models of DHW Heaters/Boilers after completing the sizing process. The SMEs were asked which components are considered when selecting their preferred water heater. The most highly ranked component for system selection, with a score of 93, was "Heat Rate (Capacity)" followed by "Size of Storage Tanks" with a score of 58. These findings align with those from the previous section, which affirm that these are the most crucial features when selecting DHW systems. Many readily available sizing tools often output the capacity of the water heater in Btuh, and the size of the water heater tanks in gallons when recommending DHW systems. The SMEs' responses to this question are presented in Table 16 and Figure 22. According to SME #13, the key determinant when selecting a DHW system is its capacity, as it often determines the system's ability to fulfill demand.

The parameters that shared the third rank, with a score of 57, were "Cost" and “Gallons per hour (recovery rate). Many SMEs highlighted that cost plays a significant role in determining whether the customer can afford the system. "Recovery Rate” emerged as a top consideration due to its ability to ensure a consistent supply of hot water during peak periods. Although not a high-scoring parameter, many contractors emphasized the importance of the "Brand" in their selection criteria, citing brand loyalty and a preference for recommending products with positive past experiences. This section sheds light on the considerations involved in the selection of DHW systems, ranging from technical specifications to cost and brand reputation.

Table 16: Key Components for DHW System Selection SME Responses Summary

Q5	DHW System Selection Component	Total	Mean	Standard Deviation	CV
A	Water heater efficiency	48	1.66	1.58	0.96
B	Cost	57	1.97	1.87	0.95
C	Location where the water heater will be installed	35	1.21	1.54	1.28
D	Incoming cold water temperature	5	0.17	0.59	3.43
E	Hot water temperature	13	0.45	1.16	2.59
F	Master mixing valve temperature	6	0.21	0.92	4.47
G	First hour rating	43	1.48	2.09	1.41
H	Recovery efficiency	27	0.93	1.51	1.62
I	Heat rate (capacity)	93	3.21	1.88	0.59
J	Location where the storage tank(s) will be installed	4	0.14	0.57	4.14
K	Volume of storage (one large tank or a number of smaller ones. ASME tanks?)	21	0.72	1.53	2.11
L	Size of storage tanks (volume, dimensions, ASME tanks?)	58	2.00	2.05	1.03
M	Heat losses of the circulation loop	2	0.07	0.36	5.29
N	Brand	21	0.72	1.46	2.02
O	Is water heater sizing adjusted based on the presence of preheat sources (Solar, etc.)	6	0.21	0.66	3.21
P	Gallons per hour (recovery rate)	57	1.97	2.19	1.11

Table 17: Features in Selecting Water Heaters SME Responses Part 1

	A	B	C	D	E	F	G	H	I
Q5	**Water heater efficiency**	**Cost**	**Location where the water heater will be installed**	**Incoming cold-water temperature**	**Hot water temperature**	**Master mixing valve temperature**	**First hour rating**	**Recovery efficiency**	**Heat rate (capacity)**
Total	**48**	**57**	**35**	**5**	**13**	**6**	**43**	**27**	**93**
Mean	**1.66**	**1.97**	**1.21**	**0.17**	**0.45**	**0.21**	**1.48**	**0.93**	**3.21**
Standard Deviation	**1.58**	**1.87**	**1.54**	**0.59**	**1.16**	**0.92**	**2.09**	**1.51**	**1.88**
Coefficient of Variation	**0.96**	**0.95**	**1.28**	**3.43**	**2.59**	**4.47**	**1.41**	**1.62**	**0.59**
SME 1	0	0	0	0	4	5	0	0	2
SME 2	0	2	3	0	0	1	5	4	0
SME 3	0	5	0	0	0	0	4	0	1
SME 4	5	3	2	0	4	0	0	0	0
SME 5	3	2	0	0	0	0	0	0	5
SME 6	5	0	0	0	0	0	3	2	1
SME 7	1	0	0	0	0	0	5	0	2
SME 8	2	1	0	0	0	0	5	0	3
SME 9	1	2	0	0	0	0	4	0	3
SME 10	0	2	0	0	0	0	5	4	3
SME 11	0	5	0	0	0	0	0	0	4
SME 12	3	4	2	0	0	0	5	0	5
SME 13	3	1	0	0	0	0	0	0	5
SME 14	3	4	0	0	0	0	0	0	5

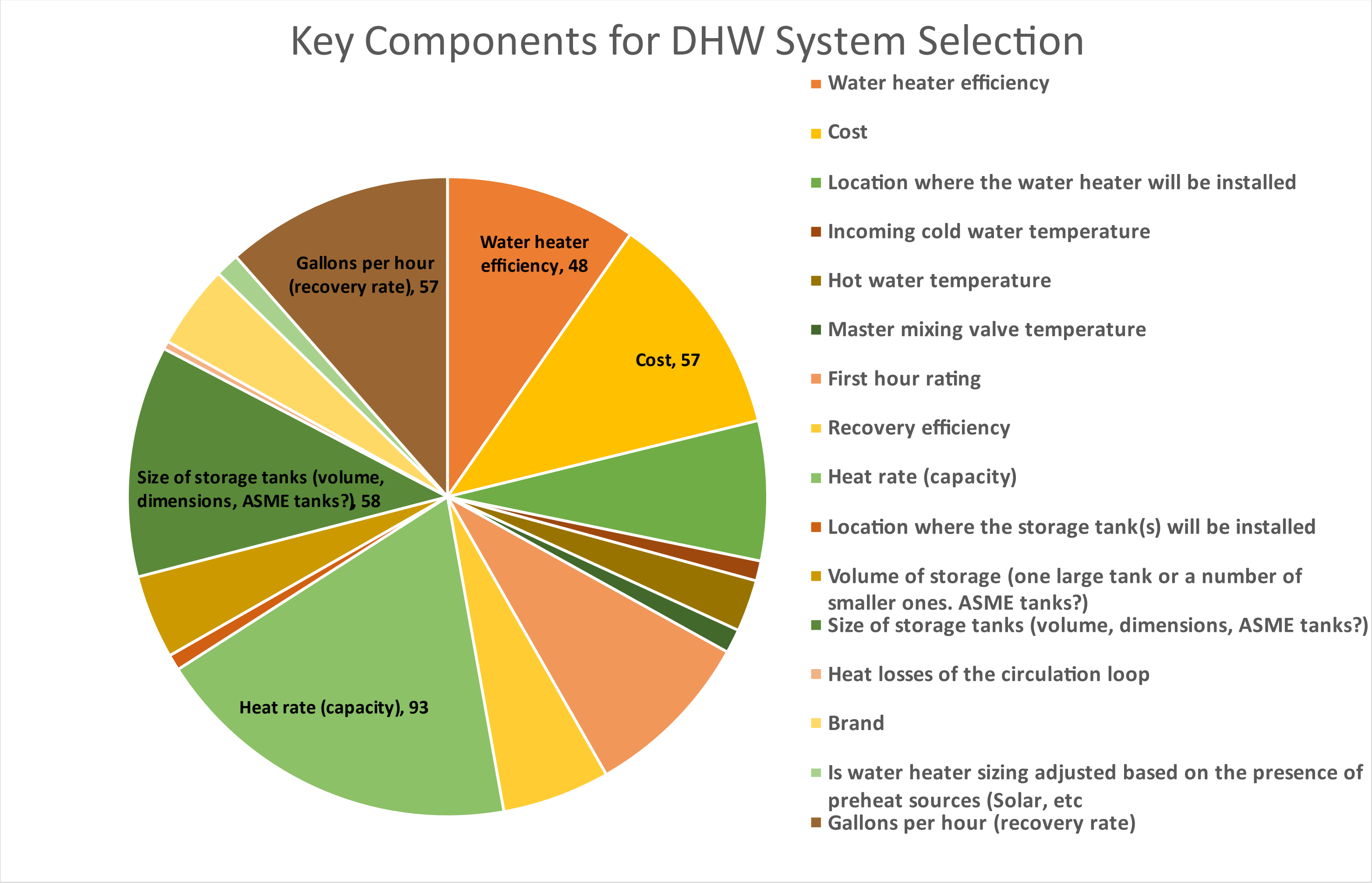
	A	B	C	D	E	F	G	H	I
Q5	Water heater efficiency	Cost	Location where the water heater will be installed	Incoming cold-water temperature	Hot water temperature	Master mixing valve temperature	First hour rating	Recovery efficiency	Heat rate (capacity)
SME 15	1	5	2	3	0	0	0	0	4
SME 16	3	0	0	0	0	0	0	5	4
SME 17	0	0	2	0	0	0	0	3	5
SME 18	0	0	2	0	0	0	0	3	5
SME 19	2	0	4	0	0	0	0	0	5
SME 20	3	4	1	0	0	0	0	2	5
SME 21	3	4	1	0	0	0	0	2	5
SME 22	0	0	1	0	0	0	4	2	3
SME 23	2	0	0	0	3	0	0	0	5
SME 24	2	3	5	0	0	0	0	0	4
SME 25	4	3	0	1	2	0	0	0	0
SME 26	2	3	5	0	0	0	0	0	4
SME 27	0	4	2	1	0	0	0	0	0
SME 28	0	2	3	0	0	0	0	0	5
SME 29	0	5	0	0	0	0	3	0	0

Table 18: Features in Selecting Water Heaters SME Responses Part 2

	J	K	L	M	N	O	P
Q5	**Location where the storage tank(s) will be installed**	**Volume of storage (one large tank or several smaller ones. ASME tanks?)**	**Size of storage tanks (volume, dimensions , ASME tanks?)**	**Heat losses of the circulation loop**	**Brand**	**Is water heater sizing adjusted based on the presence of preheat sources (Solar, etc.**	**Gallons per hour (recovery rate)**
Total	**4**	**21**	**58**	**2**	**21**	**6**	**57**
Mean	**0.14**	**0.72**	**2.00**	**0.07**	**0.72**	**0.21**	**1.97**
Standard Deviation	**0.57**	**1.53**	**2.05**	**0.36**	**1.46**	**0.66**	**2.19**
Coefficient of Variation	**4.14**	**2.11**	**1.03**	**5.29**	**2.02**	**3.21**	**1.11**
SME 1	0	3	1	0	0	0	0
SME 2	0	0	0	0	0	0	0
SME 3	0	0	3	0	2	0	0
SME 4	0	0	0	0	1	0	0
SME 5	0	0	4	0	0	0	0
SME 6	0	4	0	0	0	0	0
SME 7	0	4	3	0	0	0	0
SME 8	0	0	0	0	4	0	0
SME 9	0	0	0	0	0	0	5
SME 10	0	0	0	0	0	0	0
SME 11	3	0	0	0	0	0	4
SME 12	0	0	0	0	1	0	5

	J	K	L	M	N	O	P
Q5	Location where the storage tank(s) will be installed	Volume of storage (one large tank or several smaller ones. ASME tanks?)	Size of storage tanks (volume, dimensions , ASME tanks?)	Heat losses of the circulation loop	Brand	Is water heater sizing adjusted based on the presence of preheat sources (Solar, etc.	Gallons per hour (recovery rate)
SME 13	0	4	0	0	0	2	0
SME 14	0	0	2	0	0	0	2
SME 15	0	0	0	0	0	3	0
SME 16	0	0	1	2	0	0	5
SME 17	0	0	4	0	0	0	5
SME 18	0	0	4	0	0	0	5
SME 19	0	0	5	0	0	0	0
SME 20	0	0	5	0	5	0	5
SME 21	0	0	5	0	5	0	5
SME 22	0	0	0	0	0	0	5
SME 23	0	0	4	0	1	0	0
SME 24	0	5	5	0	0	1	4
SME 25	0	0	5	0	0	0	5
SME 26	0	1	0	0	0	0	0
SME 27	0	0	3	0	0	0	5
SME 28	1	0	4	0	0	0	0
SME 29	0	0	0	0	2	0	4

Figure 22: Key Components for DHW System Selection SME Responses Summary



Accounting for Demand Increase in DHW System Sizing

When sizing DHW systems, SMEs were prompted to consider the factors necessary to accommodate future increases in demand. According to survey results, the highest ranked way to plan for increased demand, with a score of 83, is to provide space for additional storage tanks during the initial sizing of the system and mechanical room/mechanical enclosure. SME #22 indicated that storage tanks are not only more economical but also easier to install as demand grows compared to additional water heaters or the initial oversizing of the system. Respondents tend to assert that allocating additional storage tank space is the most convenient approach for accommodating future demand. The summarized SME responses are presented in Table 19 and Figure 23.

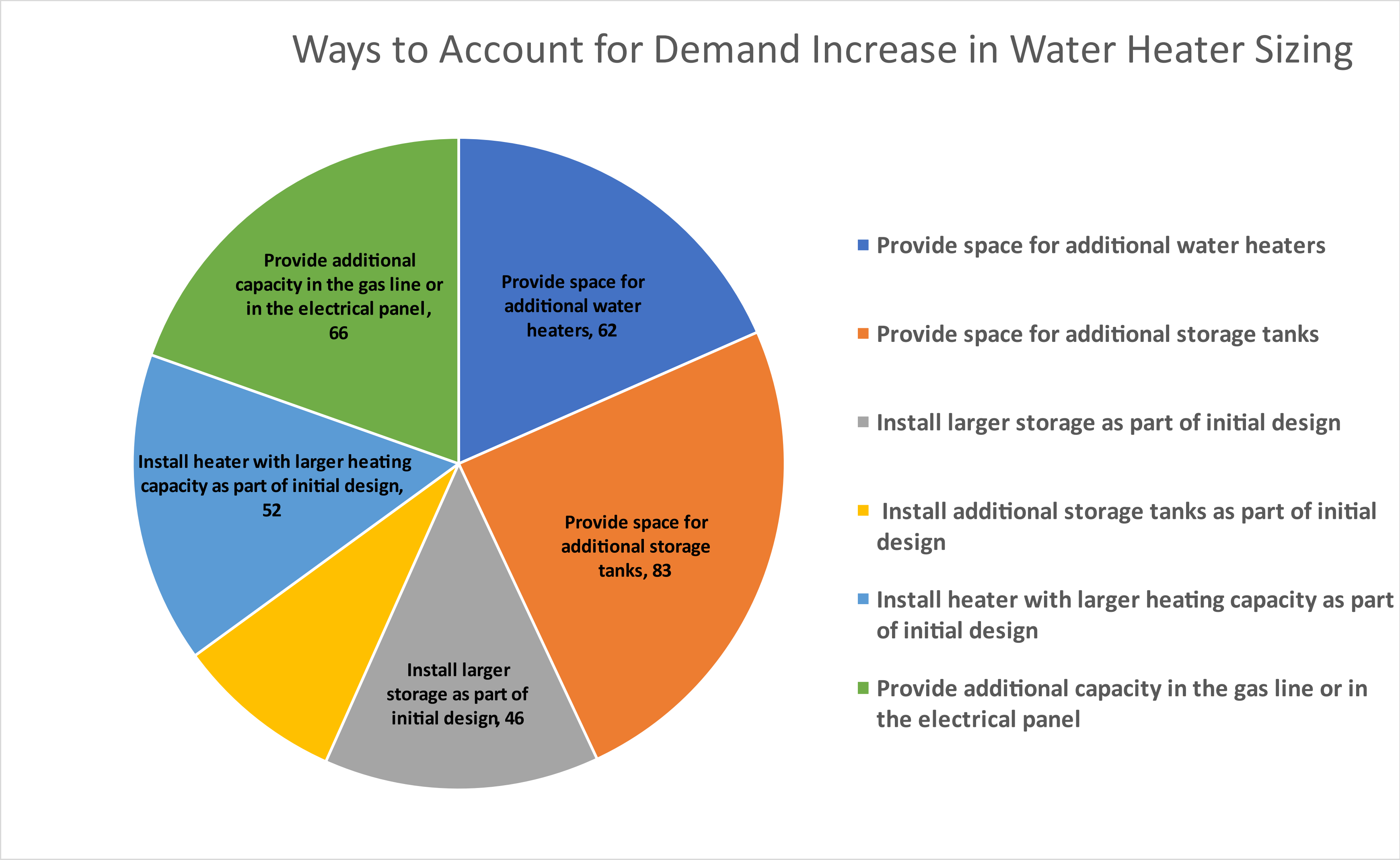
The second-highest ranking method of addressing demand increase, with a score of 66, is the need to provide additional capacity in the gas line or electrical panel. This is important as it addresses the crucial issue of ensuring that gas lines or electrical panels are appropriately sized in advance to accommodate increased demand. The difficulty and cost of resizing the power system after the fact underscores the significance of this approach.

Table 19 : Ways to Account for Demand Increase in Water Heater Sizing SME Responses

Q6	A	B	C	D	E	F
	Provide space for additional water heaters	Provide space for additional storage tanks	Install larger storage as part of initial design	Install additional storage tanks as part of initial design	Install heater with larger heating capacity as part of initial design	Provide additional capacity in the gas line or in the electrical panel
Total	**62**	**83**	**46**	**28**	**52**	**66**
Mean	**2.14**	**2.86**	**1.59**	**0.97**	**1.79**	**2.28**
Standard Deviation	**1.81**	**1.96**	**1.92**	**1.59**	**2.14**	**2.13**
Coefficient of Variation	**0.85**	**0.68**	**1.21**	**1.64**	**1.19**	**0.94**
SME 1	5	0	0	0	4	3
SME 2	3	4	0	0	0	5
SME 3	0	0	4	3	5	0
SME 4	0	0	4	3	0	0
SME 5	0	0	0	0	0	0
SME 6	3	2	0	0	0	5
SME 7	4	4	5	2	3	0
SME 8	2	5	3	4	0	1
SME 9	0	0	0	0	0	0
SME 10	0	0	3	2	5	4
SME 11	4	3	0	0	0	5
SME 12	4	4	0	0	0	5
SME 13	0	5	0	0	0	4

Q6	A	B	C	D	E	F
	Provide space for additional water heaters	Provide space for additional storage tanks	Install larger storage as part of initial design	Install additional storage tanks as part of initial design	Install heater with larger heating capacity as part of initial design	Provide additional capacity in the gas line or in the electrical panel
SME 14	0	4	0	0	5	0
SME 15	3	4	1	1	3	2
SME 16	0	0	3	0	4	5
SME 17	4	5	0	0	0	3
SME 18	4	5	0	0	0	3
SME 19	4	4	2	0	0	5
SME 20	3	4	0	0	5	0
SME 21	3	4	0	0	4	0
SME 22	0	5	0	0	0	0
SME 23	4	5	0	0	0	3
SME 24	0	0	4	0	5	3
SME 25	3	4	5	5	0	5
SME 26	1	2	5	4	3	0
SME 27	0	5	4	4	0	0
SME 28	4	3	0	0	1	5
SME 29	4	2	3	0	5	0

Figure 23: Ways to Account for Demand Increase in Water Heater Sizing SME Responses Summary



Survey Response Variation

The variation in responses is measured by the coefficient of variation (CV), calculated for questions 3-6 on the survey. These were the only questions where CV was applied since they were the only ones with quantifiable results. The lowest CV value indicates the highest level of agreement among surveyors. In question 3, where SMEs were asked about the key components needed to size DHW systems, the lowest CV of 0.53 and the highest score of 108 revealed that "Number of occupants" was the most agreed-upon factor. Moving on to question 4, regarding DHW sizing resources, the SMEs predominantly agreed that ASHRAE was the most preferred sizing resource with the highest score of 85 and the lowest CV of 0.65. For question 5, addressing the selection of DHW systems, the SMEs were aligned in considering "Heat Rate (Capacity)" with a score of 93, as the top factor which was underscored by the lowest CV value of 0.59. Lastly, in question 6, which asked SMEs to suggest adjustments to DHW systems to account for increased demand, there was a majority agreement that the optimal way, with the lowest CV of 0.68 and highest score of 83, is by providing space for additional water heaters.

SME Findings

This section identified inconsistencies in central DHW system sizing resources and methodologies for multifamily buildings. A total of (29) Subject Matter Experts were interviewed to gain more insight into the inconsistencies, preferred sizing methods, important sizing factors and gaps. Below are the main conclusions from these interviews:

- The primary reason for water heater replacement is often due to failure.
- Oversizing of water heaters is identified as a common issue.
- The findings also bring to light disparities in DHW system sizing between new construction, replacements due to failure, and replacements not due to failure.
- There are variations among contractors, technical experts, and manufacturers in their recommended sizing practices.
- The most important component for sizing DHW systems is the "Number of Occupants".
- There is a strong preference among SMEs for traditional sizing tools like ASHRAE’s handbook, making it the most used resource.
- Newer tools like the EHPWH Tool and the practical use of measured data from similar sites are also favored because they are regularly updated with current data.
- "Heat Rate (Capacity)" is identified as the most important factor when selecting DHW equipment.

- The selection of DHW equipment involves considering various manufacturers and models after sizing calculations. Among contractors, brand loyalty is an important factor when selecting DHW equipment.
- SMEs find that providing space for additional storage tanks during initial sizing is the most cost-effective and convenient approach for addressing future demand increases.
- Another important design consideration is ensuring that gas lines and electrical panels have enough capacity for demand increase.

The previous section highlighted a lack of consistency in manufacturer sizing tools, potentially attributed to different sizing methodologies, although confirmation is hindered by intellectual property constraints. Unfortunately, this research was not able to add any additional insights regarding the inconsistencies between various sizing methodologies. Furthermore, as the industry transitions to heat pumps, a notable knowledge gap in proper sizing practices is observed.

In summary, this section provided insight into the preferred sizing resources, key factors considered and highlighted the divergence in sizing approaches between technical experts, manufacturers, and contractors. This study was essential in understanding the perspectives of SMEs in the DHW system sizing industry and lays the foundation for further investigation in the next section, where sizing methodologies will be compared to real-site data.

Compare Sizing Methods with Actual Site Data

The findings from the previous sections discussed various resources used to size DHW systems as well as how SMEs ranked the different sizing resources. In this section, different sizing methods are compared with actual site data. This comparison aimed to identify gaps in the commonly utilized sizing methods and provide recommendations to bridge these gaps. The DHW loads at six (6) sites were determined using hourly gas bill data or hourly monitored DHW system data and compared with the recommended DHW capacities and storage tank volumes from the following commonly used sizing methods:

- ASHRAE/ASPE
- EHPWH Tool
- Manufacturer Tools (MFG Tool 1, MFG Tool 3, MFG Tool 2)

Site Data

Site data for six multifamily sites were collected and are shown in Table 20 below. The occupant demographics for each site are shown in Table 21. For each site, the occupant demographics constitute an ASHRAE "Medium" consumption profile as explained in **Figure 1**.

Table 20: Site Data

Inputs	Incoming cold water temp (F)	Supply hot water temp (F)	Units	Existing DHW system input capacity (Btuh)	Existing storage tank volume (gal)	Nominal Efficiency of existing DHW system
Site 1	65	130	(72) 2 bed/ 1 bath	System 1: 750,000 Btuh System 2: 650,000 Btuh **Total: 1,400,000 Btuh**	System 1: 119 gal System 2: 119 gal **Total: 238 gal**	82%
Site 2	58	120	(18) Total: (12) 1 bed/ 1 bath, (6) studio	System 1: **263,000 Btuh**	**Total: 119 gal**	80%
Site 3	65	135	(16) 2 bed/2 bath	System 1: **200,000 Btuh** System 2: **199,999 Btuh** **Total: 399,999 Btuh**	System 1: 99 gal System 2: 100 gal **Total: 199 gal**	80%
Site 4	65	140	(62) Studios	System 1: **500,000 Btuh**	System 1: **115 gal**	84%
Site 5	65	140	(49) Total: (12) 3 bed/ 2bath , (36) 2 bed/2 bath, (1) studio	System 1: 399,000 Btuh System 2: 399,000 Btuh **Total: 798,000 Btuh**	System 1: 400 gal System 2: 400 gal **Total: 800 gal**	82%
Site 6	66	130	(101) Total (1) 2 bed/ 1bath, (100) 1 bed/ 1 bath	System 1: 1.: 270,000 Btuh 2., 199,999 Btuh	System 1: 1. 100 gal 2. 100 gal	82%

Inputs	Incoming cold water temp (F)	Supply hot water temp (F)	Units	Existing DHW system input capacity (Btuh)	Existing storage tank volume (gal)	Nominal Efficiency of existing DHW system
				System 2: 1. 270,000 Btuh 2. 199,000 System 3: 1. 270,000 Btuh 2. 270,000 Btuh System 4: 1. 199,000 Btuh 2. 199,900 Btuh **Total: 1,876,999 Btuh**	System 2: 1. 100 gal 2. 100 gal System 3: 1. 100 gal 2. 100 gal System 4: 1. 100 gal 2. 100 gal **Total: 800 gal**	

Table 21: Site Occupant Demographics

Site	Occupant Demographics
Site #1	Mostly working age families No housing assistance
Site #2	Working age people
Site #3	Luxury apartments for working singles, couples and families
Site #4	50% on housing assistance 50% working-age and senior adults
Site #5	Families and working age adults 20% on housing assistance
Site #6	Working age adults 30% on housing assistance

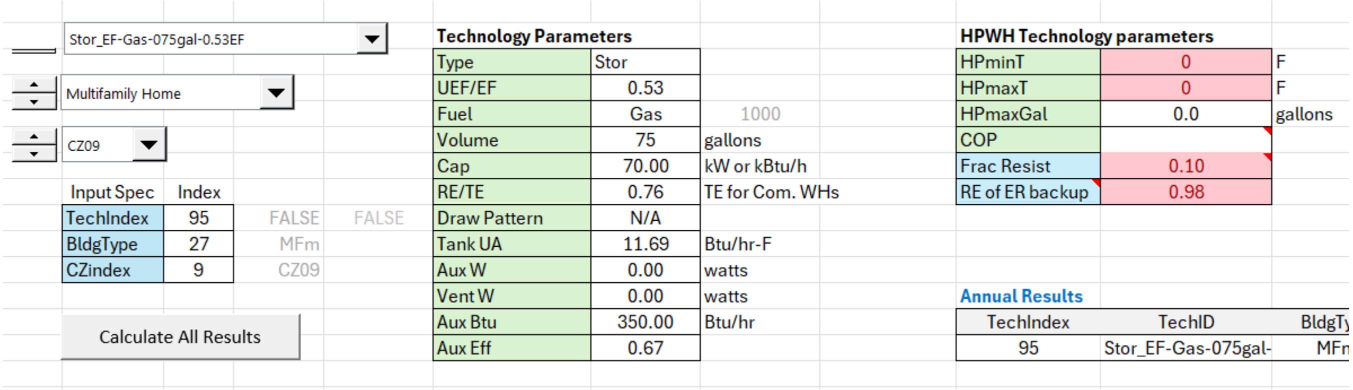
Sizing Analysis

Winter Projected Load

Property management from Sites 1, 3, 4, 5, and 6 shared hourly gas bill data for a 5-year period. The Study Team used monitored DHW data from another project (ET23SWG0001) for Site 2. The monthly gas bill data was categorized into two seasons: 'Summer' and 'Winter'. For this study, the summer months are assumed to be June, July, and August and all other months are considered winter months. According to the 2019 Residential Appliance Saturation Study (RASS) study, domestic hot water consumption emerges as the most significant gas consumption end-use during the summer months [8]. In contrast, winter months include additional gas end-uses such as space heating, contributing to variations in overall gas usage. Due to the absence of end-use level gas consumption data for sites 3-6, the study team relied on the summer gas bill data to isolate DHW consumption. This data was then scaled to predict the winter DHW load. Since site 1 provided gas bill data exclusively for DHW load, the study team utilized site 1's summer-to-winter DHW load as a reference to verify the proposed “Summer to Winter Scale Factor” for sites 4-6. Occupancy was unknown but assumed to be relatively high.

The DEER water heater calculator (DWHC) version 5.1 [11] was used to project the DHW load during the winter months and also used to determine the summer to winter scale factor. The DHWC provides hourly hot water load in Btuh for all 12 months. The inputs used in the “TechCalc” sheet of the DWHC are presented in Figure 24 below. Once the major inputs, “Building Type” and “Climate Zone,” are entered, the tool has a “Calculate All Results” button which outputs the projected hourly DHW load for a full year.

Figure 24: DEER water heater calculator v5.1 inputs part 1



Stor_EF-Gas-075gal-0.53EF

Multifamily Home

CZ09

Input Spec	Index		
TechIndex	95	FALSE	FALSE
BldgType	27	MFm	
CZindex	9	CZ09	

Technology Parameters

Type	Stor	
UEF/EF	0.53	
Fuel	Gas	1000
Volume	75	gallons
Cap	70.00	kW or kBtu/h
RE/TE	0.76	TE for Com. WHs
Draw Pattern	N/A	
Tank UA	11.69	Btu/hr-F
Aux W	0.00	watts
Vent W	0.00	watts
Aux Btu	350.00	Btu/hr
Aux Eff	0.67	

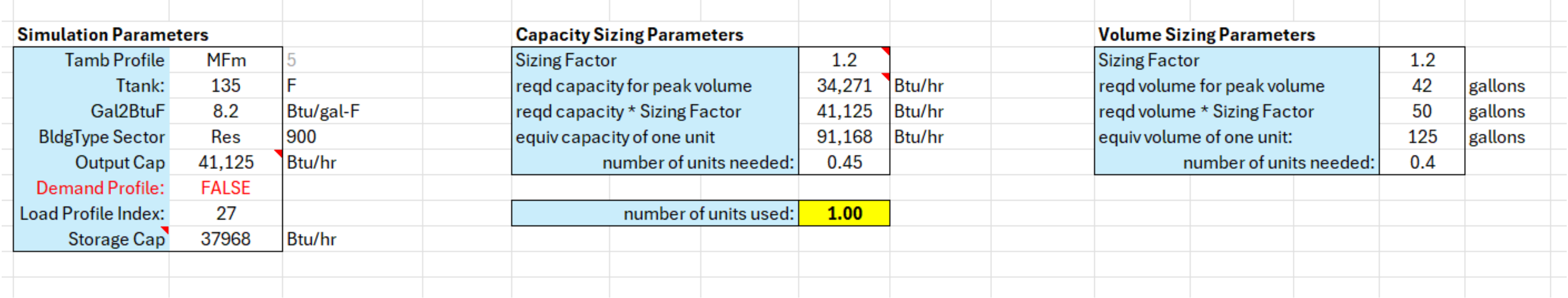
HPWH Technology parameters

HPminT	0	F
HPmaxT	0	F
HPmaxGal	0.0	gallons
COP		
Frac Resist	0.10	
RE of ER backup	0.98	

Annual Results

TechIndex	TechID	BldgTy
95	Stor_EF-Gas-075gal-	MF

Figure 25: DEER water heater calculator v5.1 inputs part 2



Simulation Parameters

Tamb Profile	MFm	5
Ttank:	135	F
Gal2BtuF	8.2	Btu/gal-F
BldgType Sector	Res	900
Output Cap	41,125	Btu/hr
Demand Profile:	FALSE	
Load Profile Index:	27	
Storage Cap	37968	Btu/hr

Capacity Sizing Parameters

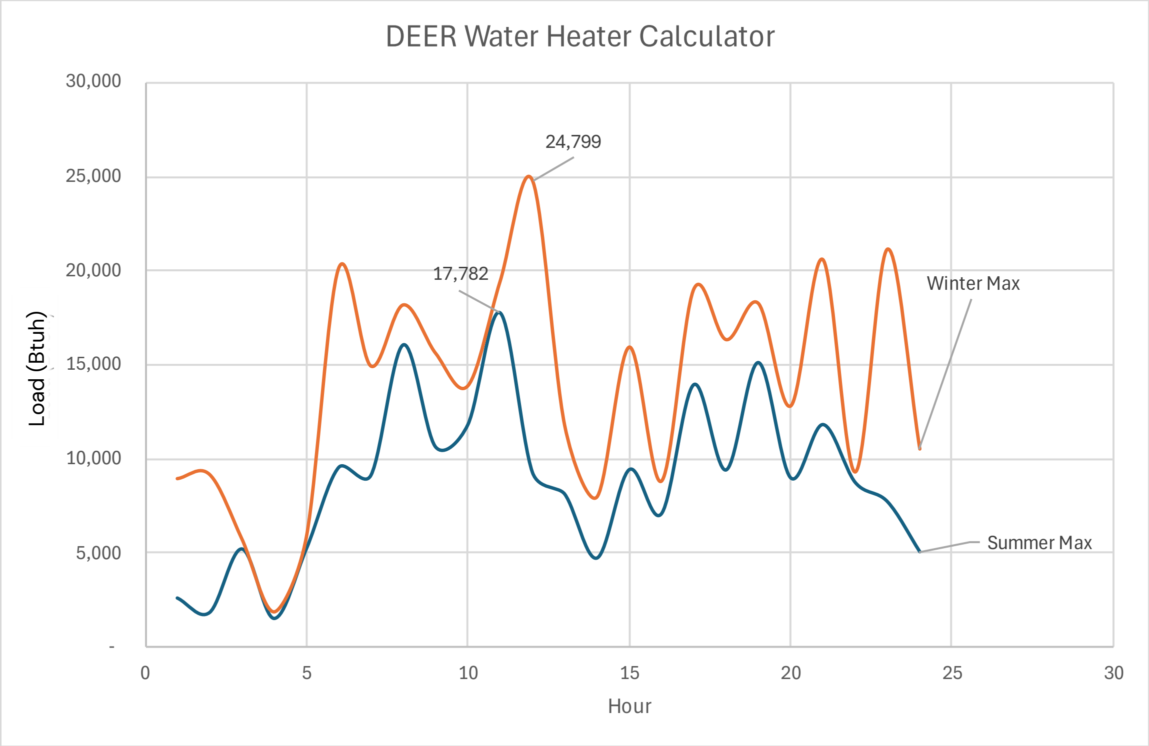
Sizing Factor	1.2	
reqd capacity for peak volume	34,271	Btu/hr
reqd capacity * Sizing Factor	41,125	Btu/hr
equiv capacity of one unit	91,168	Btu/hr
number of units needed:	0.45	
number of units used:	1.00	

Volume Sizing Parameters

Sizing Factor	1.2	
reqd volume for peak volume	42	gallons
reqd volume * Sizing Factor	50	gallons
equiv volume of one unit:	125	gallons
number of units needed:	0.4	

After the tool was run, the maximum hot water load for each hour during the summer months and winter months were compiled. The maximum hourly values for each season were then plotted in Figure 26 below.

Figure 26: DEER Water Heater Calculator Summer to Winter Scaling Factor



The summer to winter scale factor is 1.39 and was calculated using equation 5 below:

Equation 5: DHW Summer to Winter Scale Factor

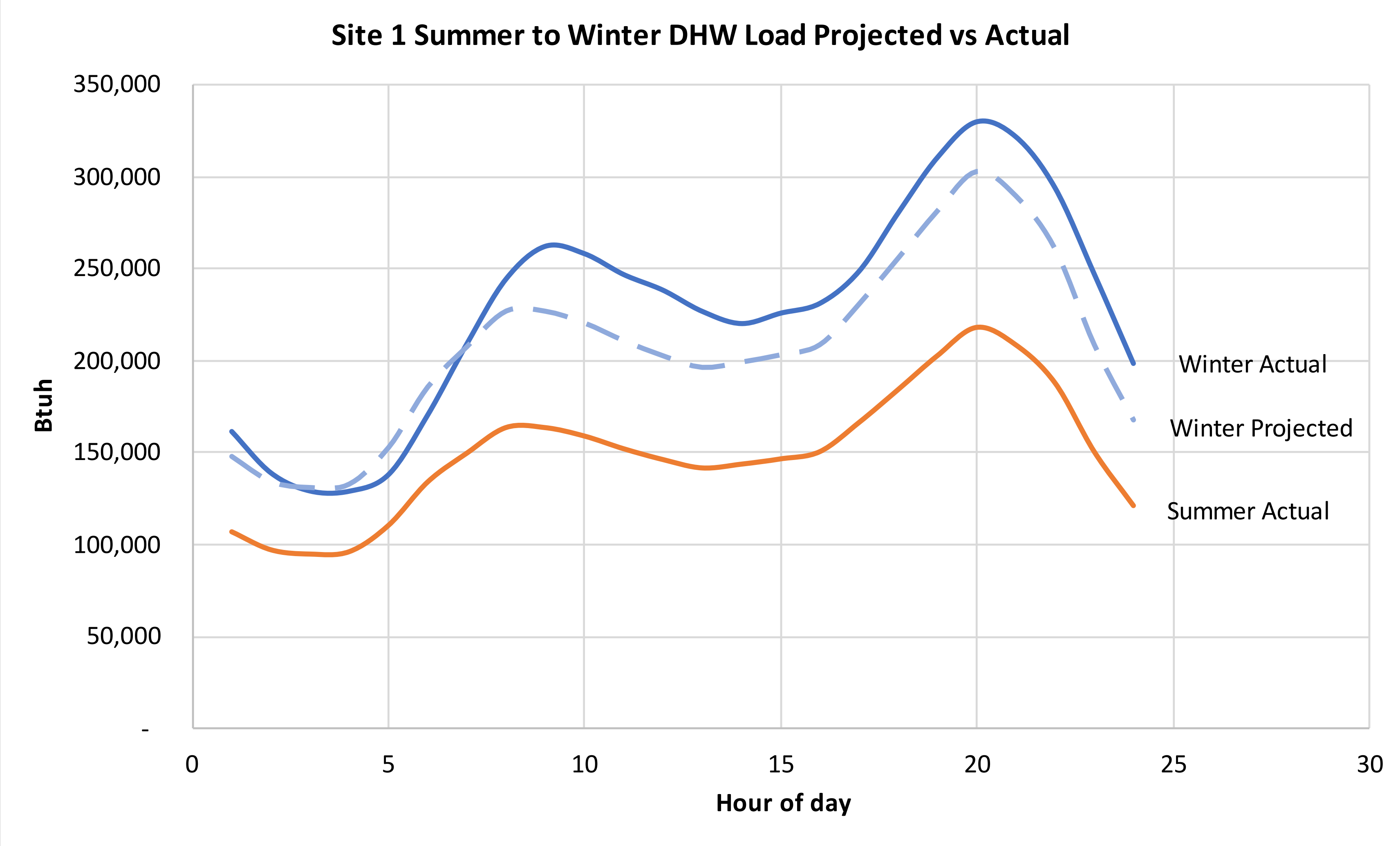
$$\boldsymbol{DHW_{Winter:Summer} = \frac{Max\ Hot\ Water\ Load_{Winter}}{Max\ Hot\ Water\ Load_{summer}}} \quad (5)$$

$$Max\ Hot\ Water\ Load_{Winter} = 24{,}799\ BTUh$$
$$Max\ Hot\ Water\ Load_{Summer} = 17{,}781\ BTUh$$

$$DHW_{Summer:Winter} = 1.39$$

The scaling methodology was validated using data from site 1 because it had gas bill data that solely reflected DHW load during both summer and winter periods. Figure 27 below illustrates the comparison between the actual winter hot water load and the winter projected load using the summer to winter scale factor of 1.39 at site 1.

Figure 27: Summer to Winter DHW load projection vs actual comparison



The data showed an average 10% difference between the 'Winter Actual' and the 'Winter Projected' data, indicating a good approximation. Table 22 below breaks down gas end-uses for each site. In cases where the data was not solely DHW load, the team calculated the winter projected load based on the summer data using the winter to summer scaling factor from Equation 5.

Table 22: Site-Specific Gas bill end-uses

Site	Gas Bill Data End-Uses
Site 1	DHW only
Site 2	DHW only
Site 3	DHW only
Site 4	DHW Space Heating Other miscellaneous end-uses
Site 5	DHW Space Heating Other miscellaneous end-uses
Site 6	DHW Space Heating Other miscellaneous end-uses

Recirculation Loads

Recirculation loads can vary widely. ASHRAE does not provide a concrete way to size DHW capacity for recirculation loads. The EHPWH sizing tool does account for recirculation, and there is no way to know if the manufacturer tools account for recirculation loads or not. The DHW loads from the gas bills include recirculation. The recommended water heaters for all sizing methods must provide heating for recirculation, so the Study Team did not try to disaggregate recirculation loads from the maximum loads.

Comparisons of Sizing Tools to Site Data

The Study Team input the information from Table 20 into ASHRAE sizing tool, the manufacturer sizing tools, and the EHPWH sizing tool. The tools provide recommended DHW heating capacity and storage tank volume. The Study Team combined the DHW heating capacity and the energy in the stored hot water to develop a metric called the “Equivalent Peak Capacity”. Equivalent peak capacity is found by adding the available capacity from the water heater with the available capacity from the stored hot water. Available capacity from the water heater is simply the heat rate of the burner multiplied times the efficiency. The stored hot water capacity is the tank size multiplied by 70% [6], the density of water

(8.33 lbm/gal) and the temperature difference (delta-T) between make-up and supply water temperature shown in Table 20. All values in Figures 28 through 33 and Tables 33-28 were **normalized by the total number of apartments** so the values could be easily compared between sites. Comparisons are difficult between sites without normalization because the DHW loads at the sites range widely because of the varying number of apartments at each site.

The Study Team compared the equivalent peak capacities recommended by each tool to the 75th percentile of DHW demand and to the 100Th percentile. The 100th percentile is the maximum DHW demand at the site, and if tools do not size for this demand, they risk recommending a system that could run out of hot water. However, the 75th percentile is shown and compared to because the DHW systems operate at this demand many more hours of the year.

In Figures 24 through 33

- The “AOS” bar stands for “Available on Site” and represents the Equivalent Peak Capacity (Btuh) of all DHW systems present at the site. Total capacity and storage tank volume for each site can be found in Table 20.
- The bars labeled “MFG # 1,” “MFG # 2,” and “MFG # 3” represent the recommended Equivalent Peak Capacity (Btuh) corresponding to each manufacturer’s tool. For specific manufacturer recommendations pertaining to Site 1, refer to Appendix 2.
- The “ASHRAE” bar represents the Equivalent Peak Capacity (Btuh) calculated using the ASHRAE sizing method utilizing the inputs from Table 20.
- The “EHPWH Tool” bar illustrates the EHPWH Tool’s recommended Equivalent Peak Capacity (Btuh) based on the inputs from Table 20, which are building type, incoming and outgoing water temperature, and demographic.
- The four percentile lines were created using the gas billing data. These were used to see how the DHW sizing tools compare to the DHW gas consumption at each site. Since the sizing methods do not explain if they are aiming for a 99th percentile design (as is common for space heating systems) or for a 100th percentile design, the Study Team used the gas bill data to calculate both metrics and display them. The lines for the 75th and 50th percentiles from the gas bills are also included to assess how hot water usage looks outside of the limited peak periods.

Site 1

Figure 28 illustrates the DHW capacity estimated by each sizing method in comparison to the DHW loads recorded in Site 1's gas bills during the peak winter season. Table 23 shows the sizing tool outputs, equivalent peak capacity, and comparison of outputs to actual DHW loads.

Figure 28: Site 1 Comparison (Per Apartment Unit)

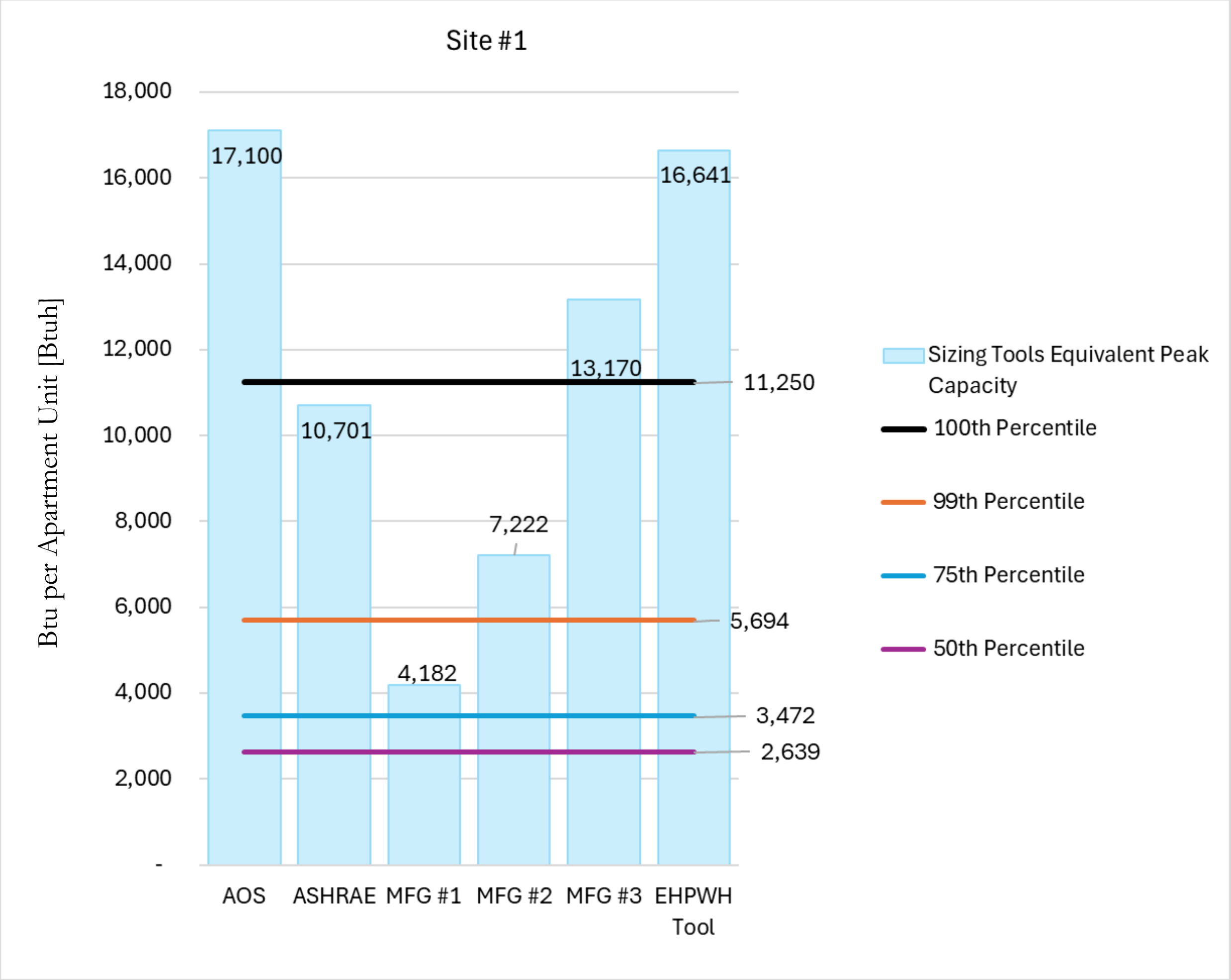


Table 23: Site 1 DHW Comparison (Per Apartment Unit)

Tool	Actual/ Recommended Capacity (Btuh)	Efficiency	Available Capacity (Btuh)	Actual/ Recommended Storge Tank Size (gal)	Stored Hot Water Capacity (Btuh)	Equivalent Peak Capacity (Btuh)	% Difference of Equivalent Peak Capacity (Btuh) to 75th Percentile	% Difference of Equivalent Peak Capacity (Btuh) to 100th percentile (Maximum DHW Load)
Available on Site[3]	19,444	82%	15,847	3.3	1,253	17,100	392%	52%
ASHRAE	,566	82%	5,351	14.1	5,350	10,701	208%	-5%
MFG Tool 1	3,958	95%	3,760	1.1	421	4,182	20%	-63%
MFG Tool 2	6,943	95%	6,596	1.7	626	7,222	108%	-36%
MFG Tool 3	15,278	80%	12,222	2.5	948	13,170	279%	17%
EHPWH Tool	4,065	100%	4,065	33.2	12,576	16,641	64%	48%

---

[3] From Table 20

Site 1 Conclusions and comparisons

At Site 1, the onsite DHW system is oversized compared to the 75th and 100th percentile DHW demand. The onsite unit is 392% oversized compared to the 75th percentile and 57% oversized compared to the 100th percentile.

All manufacturer tools oversized compared to the 75th percentile and only one oversized compared to the 100th percentile. MFG Tool 3 oversized by 17% compared to the 100th percentile while MFG Tool 1 undersized by 63% and MFG Tool 2 undersized by 36%. MFG Tool 2 only under sizes compared to the 100th percentile at Site 1 and Site 6.

The recommended equivalent peak capacity using the ASHRAE method was oversized by 208% compared to the 75th percentile and was under sized by 5% compared to the 100th percentile. ASHRAE only under sizes the DHW system compared to the 100th percentile at this site and Site 4. The EHPWH Tool recommended an equivalent peak capacity that was oversized by 64% compared to the 75th percentile and by 49% compared to the 100th percentile.

The manufacturer tools recommend the smallest storage tank volume, followed by ASHRAE, followed by the EHPWH Tool.

MFG Tool 3 is the closest to the actual 100th percentile without under sizing.

Site 2

Figure 29 illustrates the DHW capacity estimated by each sizing method in comparison to the projected DHW loads during the peak winter season. Site #2 used monitored DHW data from another project (ET23SWG0001) and the data came from the summer months. Table 24 shows the sizing tool outputs, equivalent peak capacity, and comparison of outputs to actual DHW loads.

Figure 29: Site 2 DHW Comparison (Per Apartment Unit)

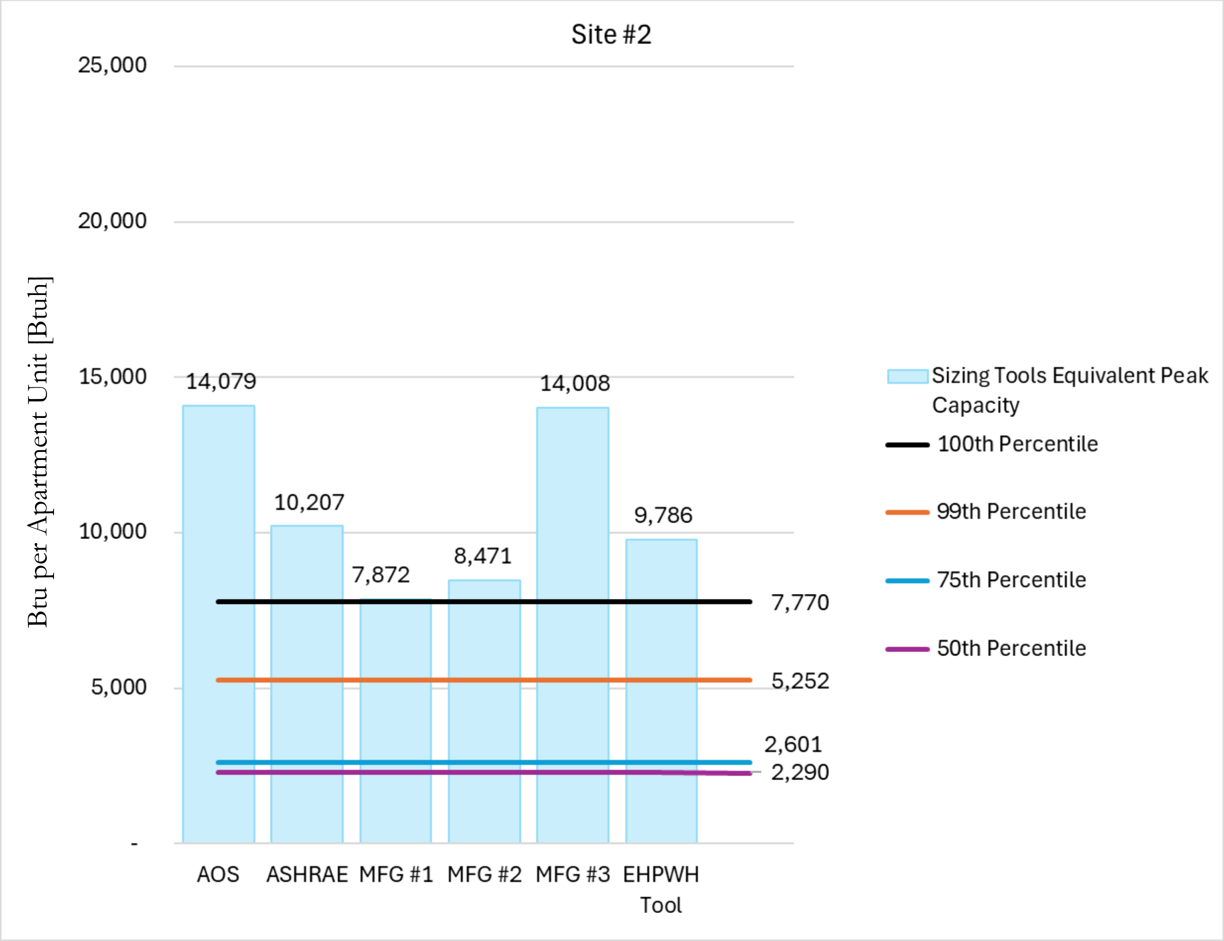


Table 24: Site 2 DHW Comparison (Per Apartment Unit)

Tool	Actual/ Recommended Capacity (Btuh)	Efficiency	Available Capacity (Btuh)	Actual/ Recommended Storge Tank Size (gal)	Stored Hot Water Capacity (Btuh)	Equivalent Peak Capacity (Btuh)	% Difference of Equivalent Peak Capacity (Btuh) to 75th Percentile	% Difference of Equivalent Peak Capacity (Btuh) to 100th percentile (Maximum DHW Load)
Available on Site	14,611	80%	11,689	7	2,390	14,079	441%	81%
ASHRAE	6,381	80%	5,104	14	5,103	10,207	292%	31%
MFG Tool 1	6,944	96%	6,667	3	1,205	7,872	203%	1%
MFG Tool 2	8,556	80%	6,844	5	1,627	8,471	226%	9%
MFG Tool 3	15,000	80%	12,000	6	2,008	14,008	439%	80%
EHPWH Tool	2,394	100%	2,394	20	7,391	9,786	276%	26%

Site 2 Conclusions and comparisons

At Site 12 the onsite DHW system is oversized compared to the 75th and 100th percentile DHW demand. The onsite unit is 441% oversized compared to the 75th percentile and 81% oversized compared to the 100th percentile.

All manufacturer tools oversized compared to the 75th percentile and the 100th percentile. MFG Tool 3 oversized by 80% compared to the 100th percentile, MFG Tool 2 oversized by 9% and MFG Tool 1 undersized by only 1%. This is the only site where MFG Tool 1 meets the 100th percentile. MFG Tool 1 could be meeting the 100th percentile here because this site has only 18 apartments. Even the smallest units built by MGF 2 may be sufficient for the maximum DHW load for 18 apartments.

The recommended equivalent peak capacity using the ASHRAE method was oversized by 292% compared to the 75th percentile and by 31% compared to the 100th percentile. The EHPWH Tool recommended an equivalent peak capacity that was oversized by 276% compared to the 75th percentile and by 26% compared to the 100th percentile.

The manufacturer tools recommend the smallest storage tank volume, followed by ASHRAE, followed by the EHPWH Tool.

MFG Tool 2 was the closest to the actual 100th percentile without under sizing. At this site, all of the tool recommendations were able to meet the 75th percentile and the 100th percentile DHW demands. ASHRAE might over predict the maximum DHW load at this site because 2.6 people per apartment was used for all sites, but there are six and (12) 1 bedroom/1 bathroom units so a better approximation of people per unit would be 1.5.

Site 3

Figure 30 illustrates the DHW capacity estimated by each sizing method in comparison to the DHW loads recorded in Site 3's gas bills during the peak winter season. Table 25 shows the sizing tool outputs, equivalent peak capacity, and comparison of outputs to actual DHW loads. The inputs utilized for each of the sizing tools to recommend DHW units for site 3 are in Table 20. For EHPWH Tool and manufacturer tool recommendations specific to Site 3 refer to Appendix 2.

Figure 30: Site 3 DHW Comparison (Per Apartment Unit)

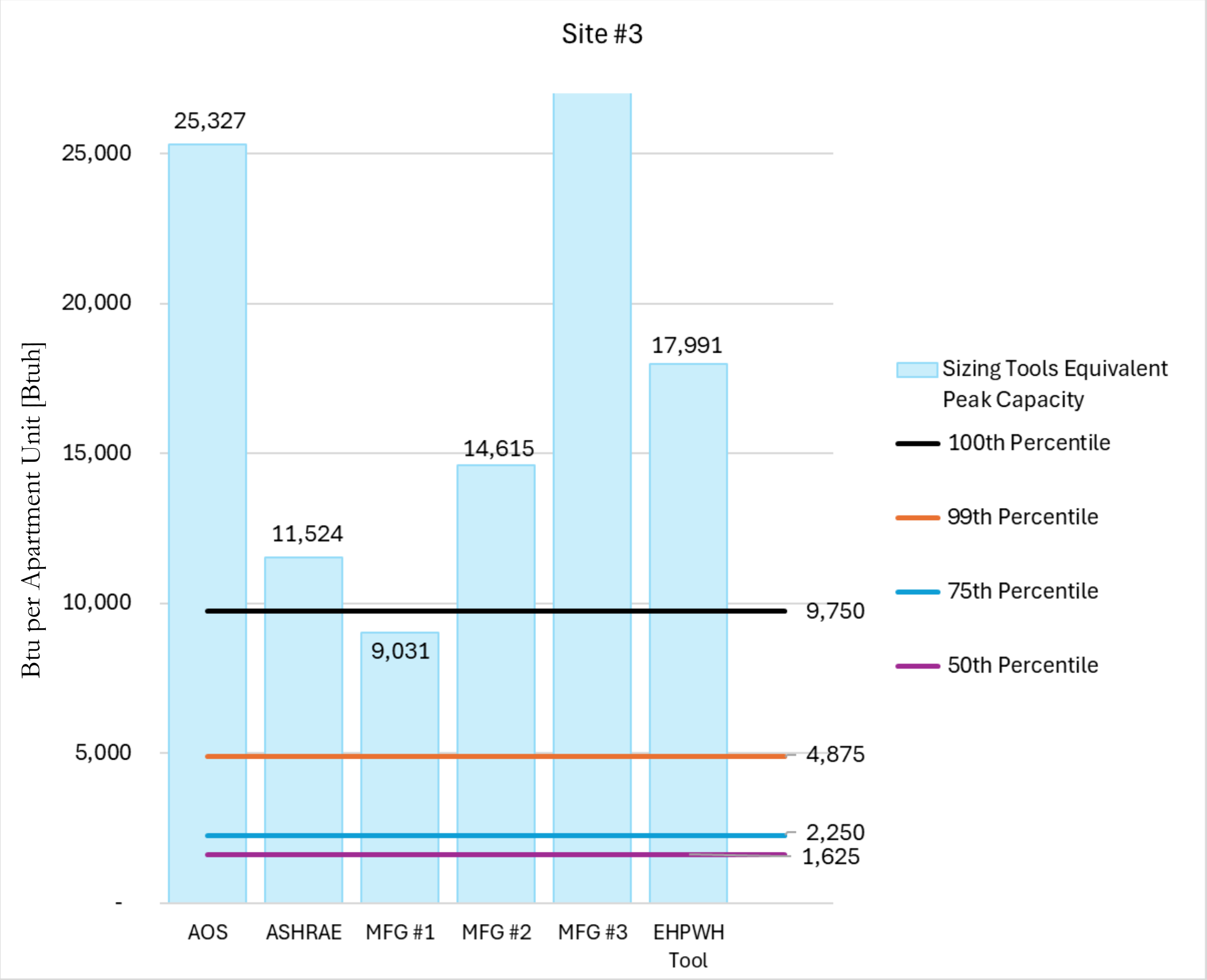


Table 25: Site 3 DHW Comparison (Per Apartment Unit)

Tool	Actual/ Recommended Capacity (Btuh)	Efficiency	Available Capacity (Btuh)	Actual/ Recommended Storge Tank Size (gal)	Stored Hot Water Capacity (Btuh)	Equivalent Peak Capacity (Btuh)	% Difference of Equivalent Peak Capacity (Btuh) to 75th Percentile	% Difference of Equivalent Peak Capacity (Btuh) to 100th percentile (Maximum DHW Load)
Available on Site	25,000	81.0%	20,250	12	5,077	23,327	1026%	160%
ASHRAE	7,115	81.0%	5,763	14	5,761	11,524	412%	18%
MFG Tool 1	7,813	96.0%	7,500	4	1,531	9,031	301%	-7%
MFG Tool 2	12,438	97.0%	12,064	6	2,551	14,615	550%	50%
MFG Tool 3	40,000	80.0%	32,000	6	2,296	34,296	1424%	252%
EHPWH Tool	4,394	100.0%	4,394	33	13,597	17,991	700%	85%

Site 3 Conclusions and comparisons

The onsite DHW system is oversized compared to the 75th and 100th percentile DHW demand. The onsite unit is 1,026% oversized compared to the 75th percentile and 160% oversized compared to the 100th percentile.

All manufacturer tools oversized compared to the 75th percentile, two tools oversized compared to the 100th percentile, and one tool under sized. MFG Tool 3 was oversized by 252% and MFG Tool 1 was oversized by 50% compared to the 100th percentile. However, MFG Tool 3 was undersized by 7%.

The recommended equivalent peak capacity using ASHRAE's methodology was oversized by 412% compared to the 75th percentile by and was oversized by 18% compared to the 100th percentile. The EHPWH Tool recommended a DHW system that was oversized by 700% compared to the 75th percentile and by 85% compared to the 100th percentile.

The manufacturer tools recommend the smallest storage tank volume, followed by ASHRAE, followed by the EHPWH Tool.

ASHRAE is the closest to the actual 100th percentile without under sizing.

Site 4

Figure 31 illustrates the DHW capacity estimated by each sizing method in comparison to the DHW loads recorded in Site 4's gas bills during the peak winter season. Table 26 shows the sizing tool outputs, equivalent peak capacity, and comparison of outputs to actual DHW loads. The inputs utilized for each of the sizing tools to recommend DHW units for site 4 are in Table 20. For EHPWH Tool and manufacturer tool recommendations specific to Site 3 refer to Appendix 2.

Figure 31: Site 4 DHW Comparison (Per Apartment Unit)

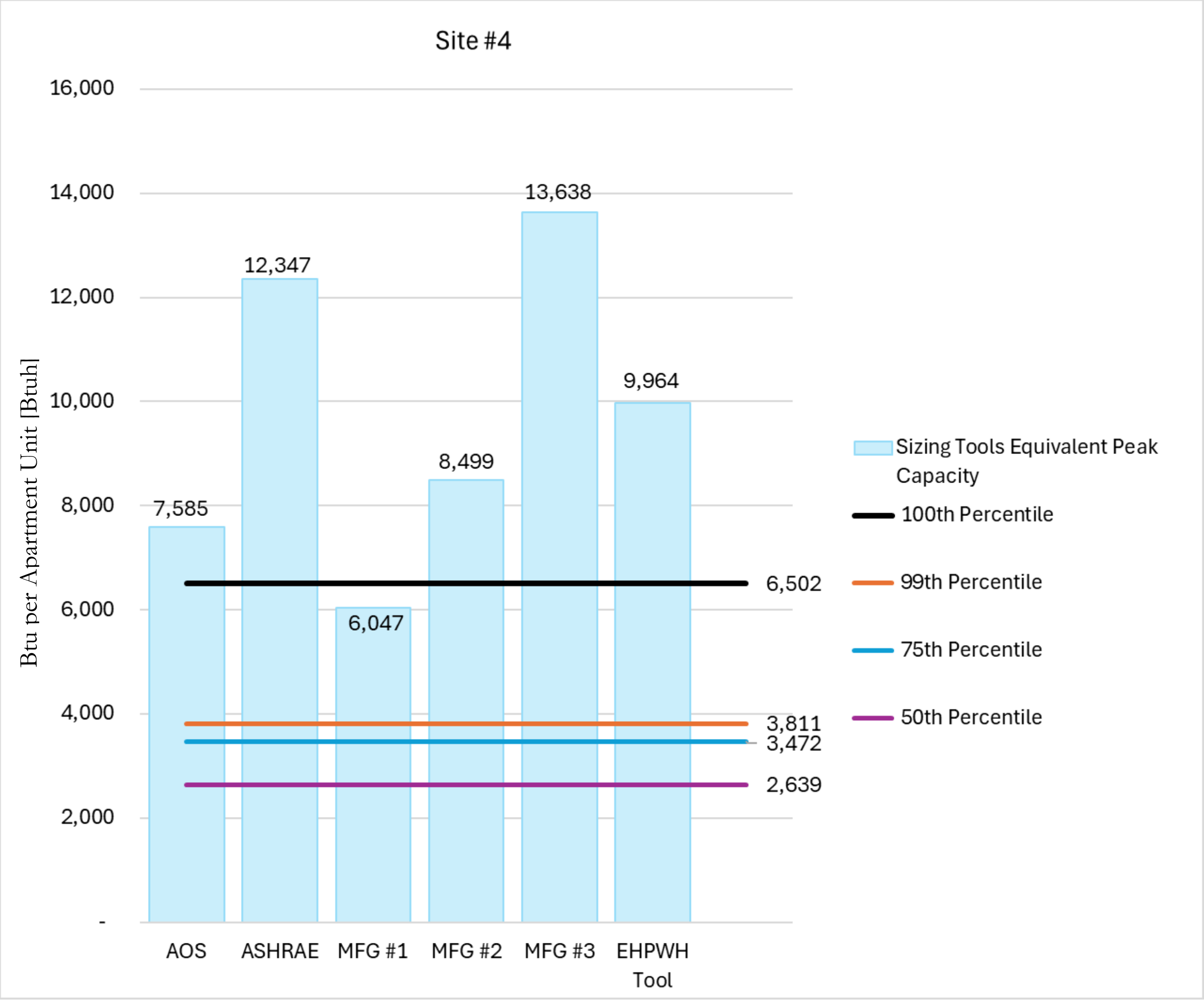


Table 26: Site 4 DHW Comparison (Per Apartment Unit)

Tool	Actual/ Recommended Capacity (Btuh)	Efficiency	Available Capacity (Btuh)	Actual/ Recommended Storge Tank Size (gal)	Stored Hot Water Capacity (Btuh)	Equivalent Peak Capacity (Btuh)	% Difference of Equivalent Peak Capacity (Btuh) to 75th Percentile	% Difference of Equivalent Peak Capacity (Btuh) to 100th percentile (Maximum DHW Load)
Available on Site	8,065	84%	6,774	2	811	7,585	238%	17%
ASHRAE	7,351	84%	6,175	14	6,173	12,347	451%	90%
MFG Tool 1	6,450	85%	5,483	1	564	6,047	170%	-7%
MFG Tool 2	8,063	95%	7,660	2	839	8,499	279%	31%
MFG Tool 3	12,871	95%	12,227	3	1,411	13,638	508%	110%
EHPWH Tool	2,466	100%	2,466	17	7,498	9,964	344%	53%

Site 4 Conclusions and comparisons

At Site 4 the onsite DHW system was oversized compared to 75th and 100th percentile DHW demands. The onsite unit is 238% oversized compared to the 75th percentile, but it was only 17% oversized compared to the 100th percentile. At all other sites, the onsite system is at least 52% oversized (Site 1).

The manufacturer tools recommended units that were oversized compared to the 75th percentile, but only MFG Tool 2 and MFG Tool 3 were oversized compared to the 100th percentile. MFG Tool 2 was oversized by 31% and MFG Tool 3 was oversized by 110% compared to the 100th percentile. MFG Tool 1 was undersized by 36% compared to the 100th percentile.

The recommended equivalent peak capacity using the ASHRAE method was oversized by 451% compared to the 75th percentile and by 90% compared to the 100th percentile. The EHPWH Tool recommended a DHW system that was oversized by 53% compared to the absolute maximum load but was oversized by 344% compared to the 75th percentile.

The manufacturer tools recommend the smallest storage tank volume, followed by ASHRAE, followed by the EHPWH Tool.

At site 4, the onsite unit was the closest to the 100th percentile without under sizing (17% oversized) and MFG 2 was the next closest at 31% oversized. ASHRAE might over predict the maximum DHW load at this site because 2.6 people per apartment was used for all sites, but all the apartments in site 4 are studios so a better approximation of people per unit would be 1.5. Since ASHRAE was predicting the demand for more people, it makes sense that it overshot the 100th percentile prediction more than in other sites.

Site 5

Figure 32 illustrates the DHW capacity estimated by each sizing method in comparison to the DHW loads recorded in Site 1's gas bills during the peak winter season. Table 27 shows the sizing tool outputs, equivalent peak capacity, and comparison of outputs to actual DHW loads.

Figure 32: Site 5 DHW Comparison (Per Apartment Unit)

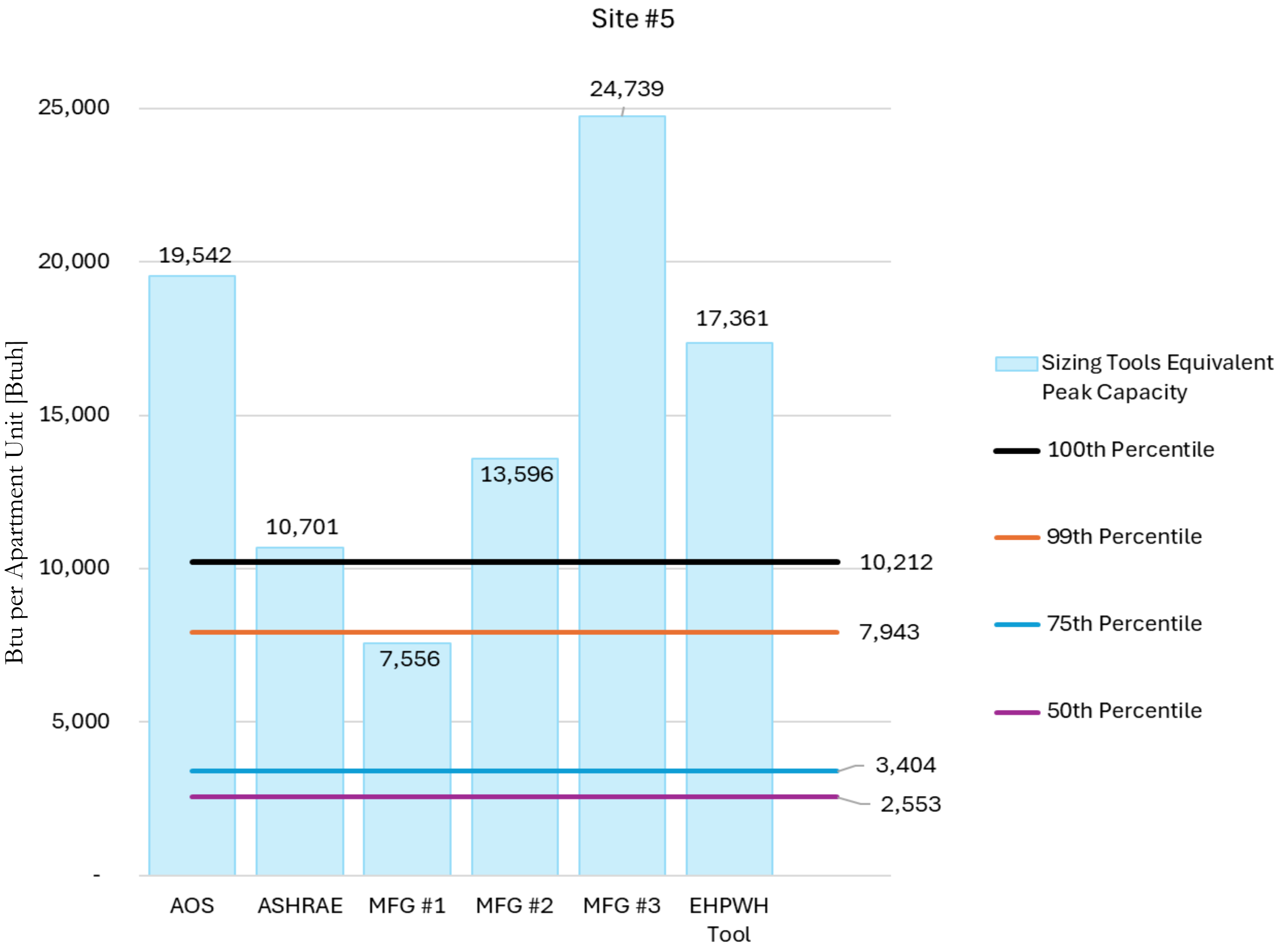


Table 27: Site 5 DHW Comparison (Per Apartment Unit)

Tool	Actual/ Recommended Capacity (Btuh)	Efficiency	Available Capacity (Btuh)	Actual/ Recommended Storge Tank Size (gal)	Stored Hot Water Capacity (Btuh)	Equivalent Peak Capacity (Btuh)	% Difference of Equivalent Peak Capacity (Btuh) to 75th Percentile	% Difference of Equivalent Peak Capacity (Btuh) to 100th percentile (Maximum DHW Load)
Available on Site	16,286	82%	13,354	16	6,188	19,542	474%	91%
ASHRAE	6,526	82%	5,351	14	5,350	10,701	214%	5%
MFG Tool 1	8,161	85%	6,937	2	619	7,556	122%	-26%
MFG Tool 2	12,245	96%	11,755	5	1,841	13,596	299%	33%
MFG Tool 3	29,184	80%	23,347	4	1,392	24,739	627%	142%
EHPWH Tool	4,243	100%	4,243	35	13,119	17,361	474%	91%

Site 5 Conclusions and comparisons

The onsite unit at Site 5 is oversized compared to the 75th percentile and 100th percentile demand. It is 474% oversized compared to the 75th percentile and 91% oversized compared to the 100th percentile.

The manufacturer tools recommended units that were oversized compared to the 75th percentile, but only MFG Tool 2 and MFG Tool 3 were oversized compared to the 100th percentile. MFG Tool 2 was oversized by 33% and MFG Tool 3 was oversized by 142% compared to the 100th percentile. MFG Tool 1 was undersized by 26% compared to the 100th percentile.

The recommended equivalent peak capacity using the ASHRAE method was oversized by 214 % compared to the 75th percentile and by only 5% compared to the 100th percentile. The EHPWH Tool recommended an equivalent peak capacity that was oversized by 410% compared to the 75th percentile and by 70% compared to the 100th percentile.

The manufacturer tools recommend the smallest storage tank volume, followed by ASHRAE, followed by the EHPWH Tool.

At Site 5, the ASHRAE method recommended an equivalent peak capacity that was the closest to the 100th percentile without under sizing.

Site 6

Figure 33 illustrates the DHW capacity estimated by each sizing method in comparison to the DHW loads recorded in Site 6's gas bills during the peak winter season. Table 28 shows the sizing tool outputs, equivalent peak capacity, and comparison of outputs to actual DHW loads.

Figure 33: Site 6 DHW Comparison (Per Apartment Unit)

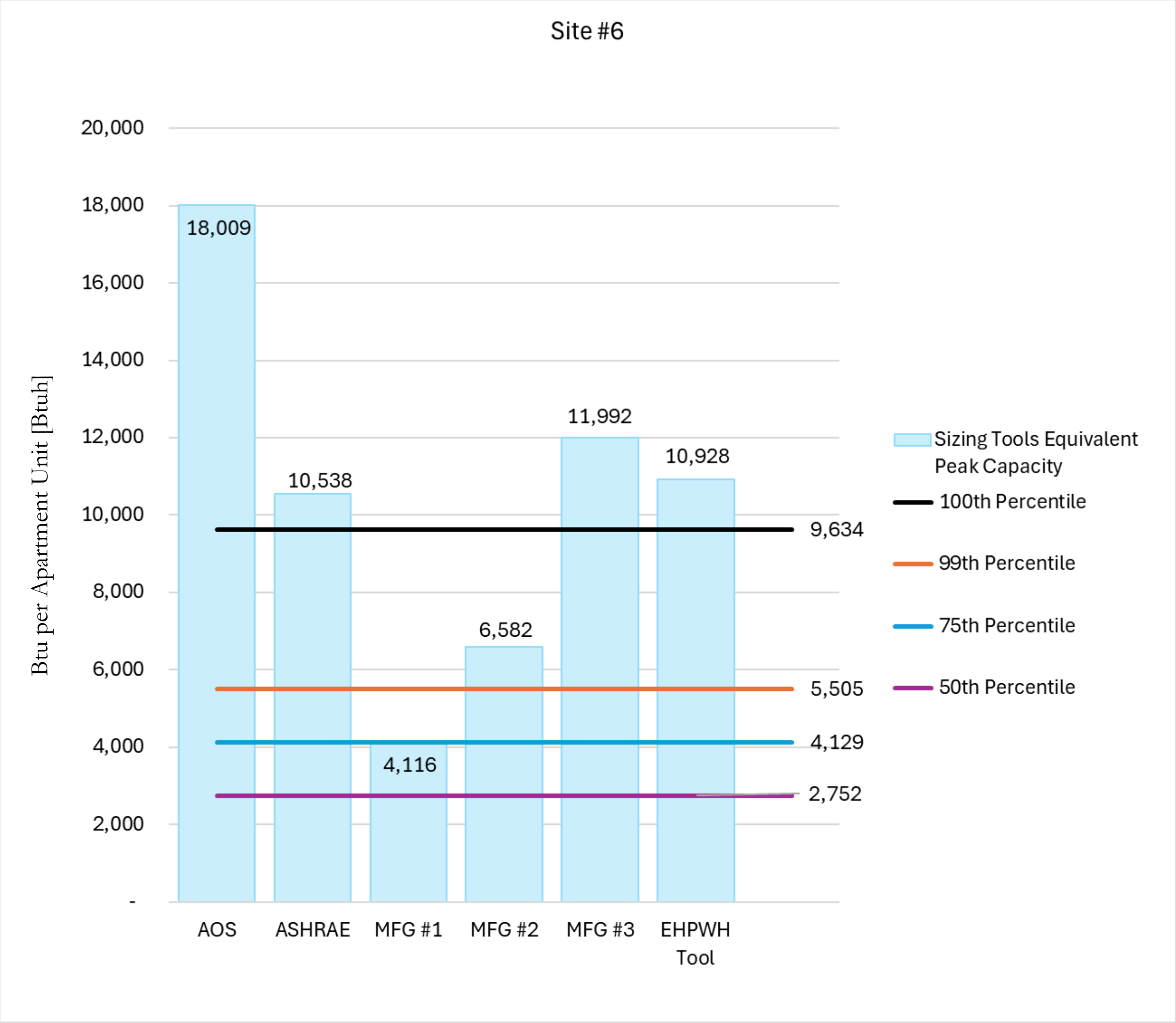


Table 28: Site 6 DHW Comparison (Per Apartment Unit)

Tool	Actual/ Recommended Capacity (Btuh)	Efficiency	Available Capacity (Btuh)	Actual/ Recommended Storge Tank Size (gal)	Stored Hot Water Capacity (Btuh)	Equivalent Peak Capacity (Btuh)	% Difference of Equivalent Peak Capacity (Btuh) to 75th Percentile	% Difference of Equivalent Peak Capacity (Btuh) to 100th percentile (Maximum DHW Load)
Available on Site	18,584	81%	15,053	8	2,956	18,009	336%	87%
ASHRAE	6,426	82%	5,269	14	5,269	10,538	155%	9%
MFG Tool 1	3,950	97%	3,820	1	296	4,116	0%	-57%
MFG Tool 2	5,941	96%	5,703	2	879	6,582	59%	-32%
MFG Tool 3	14,158	80%	11,327	2	665	11,992	190%	24%
EHPWH Tool	2,685	100%	2,685	22	8,243	10,928	165%	13%

Site 6 Conclusions and comparisons

At Site 6 onsite unit is oversized compared to the 75th and 100th percentile DHW demand. The onsite unit is 336% oversized compared to the 75th percentile and 87% oversized compared to the 100th percentile.

At Site 6, two manufacturer tools oversized compared to the 75th percentile and only one oversized compared to the 100th percentile. MFG Tool 3 oversized by 24% compared to the 100th percentile while MFG Tool 1 undersized by 57% and MFG Tool 2 undersized by 32%. This is the only site where MFG Tool 2 undersizes compared to the 100th percentile.

The recommended equivalent peak capacity using the ASHRAE method was oversized by 336% compared to the 75th percentile and by only 9% compared to the 100th percentile. The EHPWH Tool recommended an equivalent peak capacity that was oversized by 190% compared to the 75th percentile and by only 13% compared to the 100th percentile.

The manufacturer tools recommend the smallest storage tank volume, followed by ASHRAE, followed by the EHPWH Tool.

At Site 6, the ASHRAE method recommended an equivalent peak capacity that was the closest to the 100th percentile without under sizing followed closely by the EHPWH Tool.

Summary & Findings

In this section, the Study Team compared sizing recommendations from various tools with the site data. Below is the summary and important findings from this analysis. Table 29 shows a comparison of the over/under sizing for all of the tools at all of the sites. The bolded value in Table 29 indicates which tool (not including what was available on site) was the closest to the actual 100th percentile without under sizing.

Table 29: Percent Difference: 100th percentile vs Sizing Tools

Site	%Difference: Available on site	%Difference: ASHRAE	%Difference: MFG Tool 1	%Difference: MFG Tool 2	%Difference: MFG Tool 3	%Difference: EHPWH Tool
Site 1	52%	-5%	-63%	-36%	**17%**	48%
Site 2	81%	31%	**1%**	9%	80%	26%
Site 3	160%	**18%**	-7%	50%	252%	85%
Site 4	17%	90%	-7%	**31%**	110%	53%
Site 5	91%	**5%**	-26%	33%	142%	91%
Site 6	87%	**9%**	-57%	-32%	24%	13%

- In the section titled "Analysis of Methods" the manufacturer tools were presumed to use the ASHRAE methodology for estimating DHW loads. MFG Tool 1 was presumed to use a consumption profile similar to ASHRAE's "low," MFG Tool 2 was presumed to use a consumption profile in between ASHRAE's "Medium" and "High," and MFG Tool 3 was presumed to use a consumption profile greater than ASHRAE's "High." At all sites MFG Tool 1 had the lowest equivalent peak capacity followed by MFG Tool 2 and MFG Tool 3. MFG Tool 3 is the only one that recommended an equivalent peak capacity that always met the 100th percentile of DHW demand.
- The manufacturer tools recommend the smallest storage tank volume, followed by ASHRAE, followed by the EHPWH Tool. The manufacturer tools appear to make up for smaller storage tank volumes with higher capacities while the EHPWH Tool makes up for smaller capacities with larger storage tank volumes. ASHRAE's storage tank volumes and capacities fall in between the EHPWH Tool and the manufacturer tools.
- MFG Tool 1 recommends tools which are usually undersized. The study team believes this is because it is using estimates of hot water use similar to ASHRAE's low profile.
- MFG Tool 2 oversizes at four sites and undersizes at two sites compared to the 100th percentile.
- MFG Tool 3 overshoots the 100th percentile by a modest amount on sites #1 and #6 and by a lot on sites #2, #3, #4, and #5. Sites #3 and #5 (where MFG Tool 3 is oversized by 252% and 142%, respectively) are the only sites with 2-bathroom units. It appears that the number of bathrooms influences the sizing recommendations for MFG Tool 3 quite a lot. Sites #2 and #3 have been discussed earlier. The Study Team thinks that the reason MFG Tool 3 is oversizing by such a large margin (110%) at Site #4 is because that site only has studio apartments, and the tool is assuming a larger hot water usage per bathroom than it should for a studio.
- The equivalent peak capacity is oversized with respect to the 100th percentile at all sites. A like-for-like replacement would result in oversizing because a smaller DHW heater would suffice. The exception is Site #4 where the AOS is much closer to the maximum load.
- The 100th and 99th percentile can be as much as 47% different (at site #1).
- ASHRAE gets the closest to the actual 100th percentile on half of the sites and it is right more than the other tools. The Study Team doesn't know why ASHRAE under sizes with respect to the 100th percentile at Site #1. The Study Team thinks ASHRAE greatly oversizes at Site #4 and #5 (by 90% and 31%, respectively) because the calculations use 2.6 people per apartment which is probably too high for the studio apartments at Sites #4 and #5.
- Even though the EHPWH tool was set to use the ASHRAE Medium profile, it only matches the ASHRAE estimates well at Sites #2 and #6. At site #4 (all studios), the EHPWH tool used 1.37 people/studio apartment, and ASHRAE used 2.6

people/apartment. Since 1.37 is less than 2.6, that explains why the EHPWH peak load is less than ASHRAE. At Site #5, the EHPWH tool uses a weighted average of 2.67 people/apartment, so it is unclear why it is so much higher than ASHRAE. Similarly, at Site #1 and #3 the EHPWH uses 2.57 people/2-bedroom apartment, so it is unclear why it predicts higher peak load than ASHRAE.

- The EHPWH tool overshoots the 100th percentile all of the time, but it gets closer to the actual peak load on Sites #2 and #6.

Overall, the DHW tools are very inconsistent in predicting the peak DHW loads. ASHRAE seems to be the most consistent of all the methods considered.

Site Screening, Sizing, and Design Criteria for GAHPs

GAHP Background

The Gas Absorption Heat Pump (GAHP) units perform best when supporting systems requiring continuous heating loads, making them ideal for replacing DHW systems typically served by conventional boilers [12]. GAHPs can be more affordable, reliable, and sustainable than DHW systems with only conventional boilers if installed at sites that meet the sizing and design criteria [12]. GAHPs are preferred to be used in hybrid configurations with traditional gas boilers. In this setup, GAHPs are sized to meet the base hot water load, while the auxiliary boilers provide auxiliary heating to meet the load during periods of high demand. GAHPs are manufactured by a handful of manufacturers, but this study evaluated two systems; GAHP 1, which has a rated fixed capacity of 123,500 Btuh, and GAHP 2 which has a rated variable capacity of up to 78,000 Btuh. Manufacturer/model names are removed to anonymize the report.

Site Screening Criteria

To assess whether a site is a suitable candidate for replacing its conventional boiler DHW system with a preheat GAHP and auxiliary boiler system, the following screening criteria must be considered:

- System design
- GAHP capacity and minimum flowrate
- Temperature limitations
- GAHP run time and cycle time requirements
- Indirect storage tank and buffer tank volume (if applicable)

Each of these criteria is further detailed in the sections below.

System Design

This part of the study considers a hybrid configuration combining a preheat GAHP with a traditional gas boiler DHW system. Successful integration of these systems involves several key factors. Figure 34 and

Figure 35 illustrate two different configurations. A preheat GAHP and auxiliary boiler system often requires an Indirect Storage Tank (IST). Some specific manufacturer units also require an additional buffer tank in addition to existing storage water tanks.

Based on discussions with the manufacturers of the GAHP units and web research, the following key factors must be considered for the system feasibility. First, adequate outdoor space is required for the GAHP unit, with the GAHP 1 unit requiring a minimum footprint of 5'10" by 9', and the GAHP 2 unit requiring 4' by 2.8'. Shared clearances can reduce space needs when installing multiple units. The installation area must be well-ventilated to ensure proper exhaust and to prevent evaporator coil air recirculation. Ground-level installations are preferred for ease of installation, although rooftop installations are possible, often resulting in higher project costs. GAHPs typically produce more noise than traditional boilers, so it is important to comply with applicable local municipal noise ordinances to ensure successful installation and community acceptance [12].

In the mechanical room, space is needed for a heat exchanger (or Indirect Storage Tank) and, for GAHP 1, a buffer tank to integrate the system with existing infrastructure. GAHP units should ideally be located within 20 feet of electrical and plumbing connections to minimize costs. Additionally, the building's occupancy should be considered; one manufacturer recommends a minimum of 30 to 50 apartments to ensure a sufficient DHW load. However, additional research conducted by the study team indicates that more than 50 units may be necessary.

Figure 34: Preheat configuration of GAHP and boiler system: GAHP 1

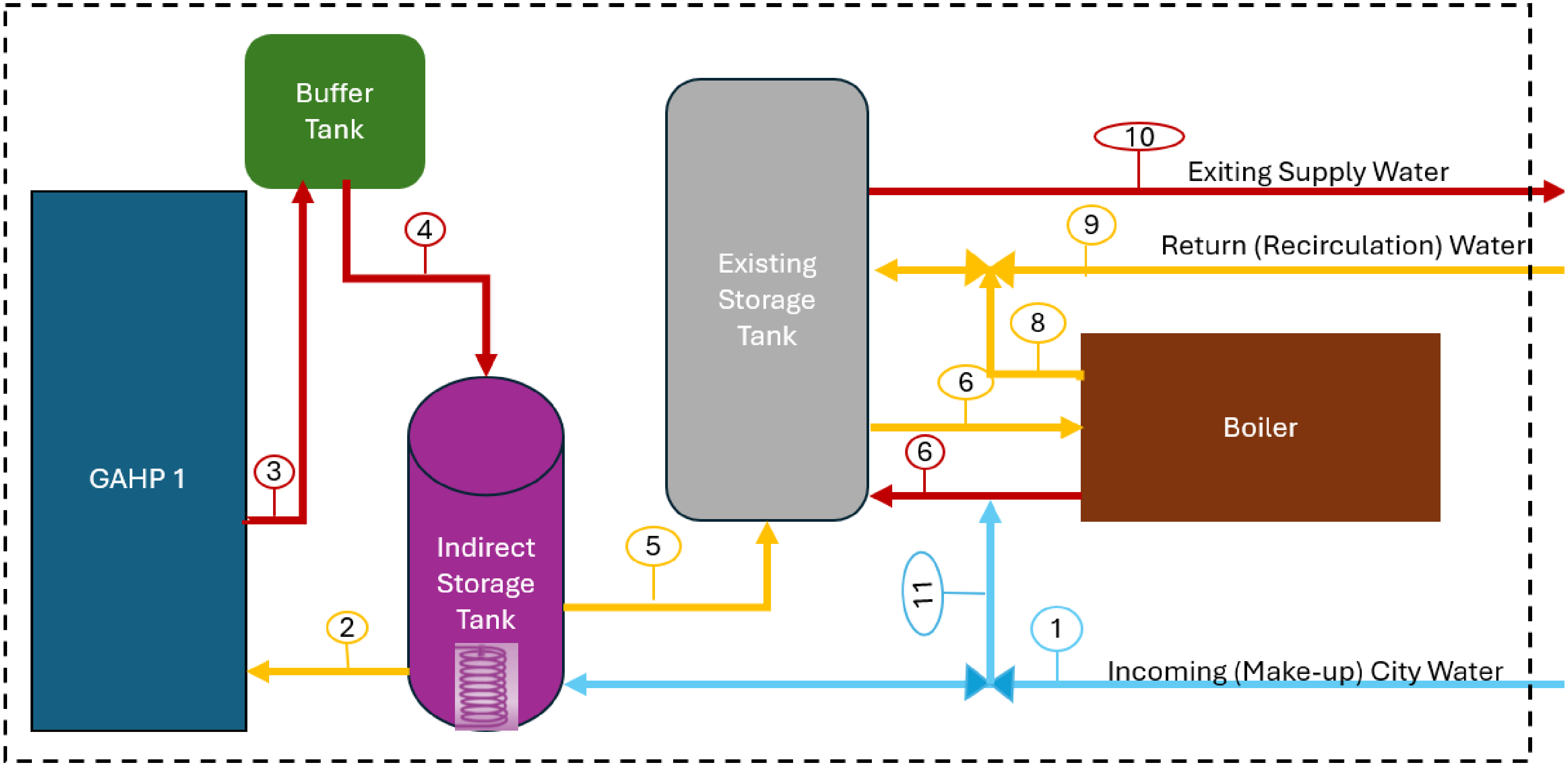
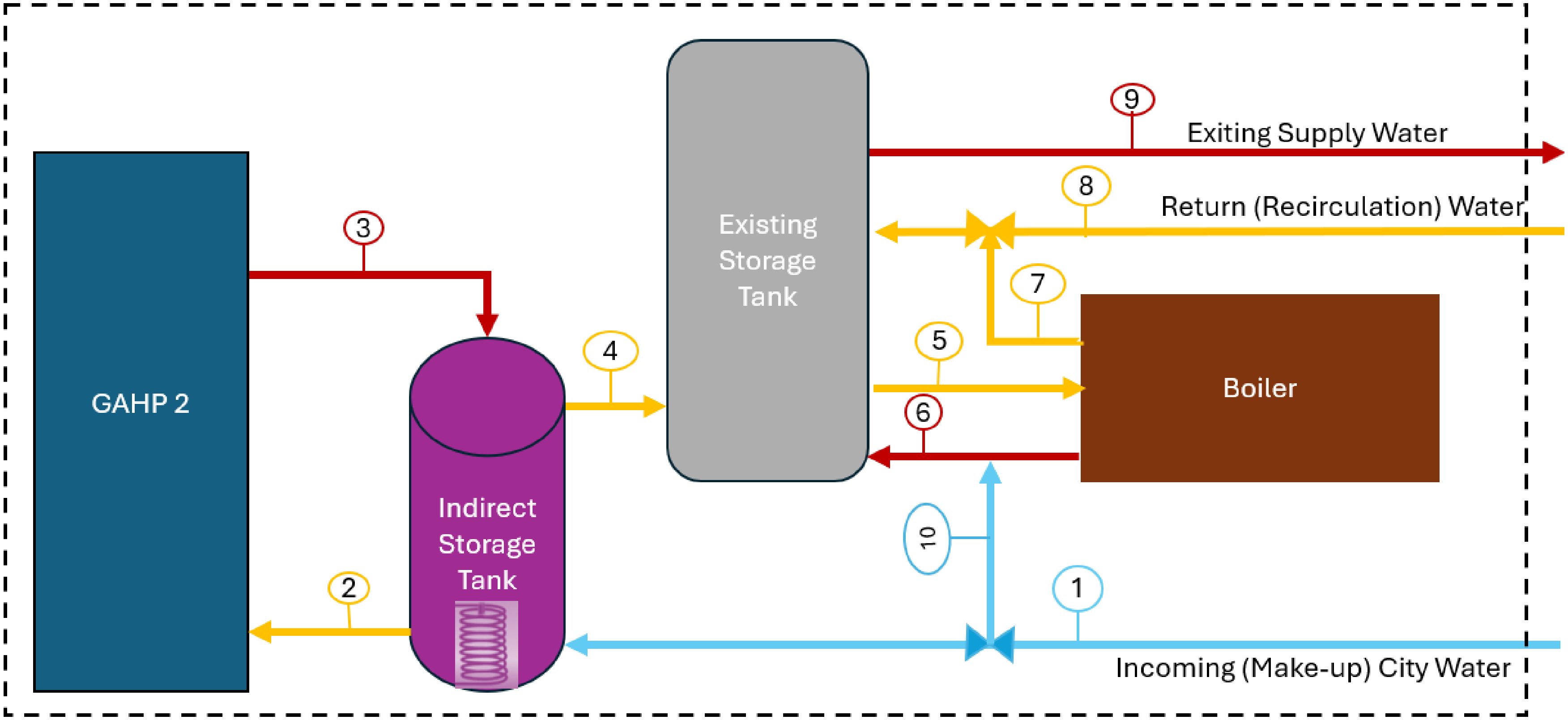


Figure 35: Preheat configuration of GAHP and boiler system: GAHP 2



GAHP Capacity and Minimum Flowrate

Minimum DHW Loads

The comparison of DHW sizing tools to actual site data showed that traditional sizing tools are aiming for the 100th percentile. This is because their systems have to meet the maximum DHW load without running out of hot water. The GAHP, on the other hand, does not need to meet the maximum 100th percentile load because it usually operates with a boiler that can meet that load. However, the GAHP is most efficient when it is running for long periods and its efficiency will degrade if run time is too low. The run time of a GAHP unit is dependent upon the minimum DHW load. That minimum DHW load takes place in the summer night-time or early morning hours. This is a new way of thinking about sizing DHW systems, so there is no DHW tool that can predict this.

If the DHW load is less than the GAHP capacity, the GAHP may not run continuously. This is shown using data from Site #1 in Figure 36 and Site #5 in Figure 37. At Site #1, the red line for the GAHP capacity is above the summer minimum DHW load, but it falls below the average hourly load (the green line) most hours of the day. So, although it is more than the summer minimum, a GAHP might be a good candidate for Site #1. However, at Site #5, the GAHP capacity is more than the summer minimum and it is less than the average hourly load most hours of the day. This means it will rarely run a full hour and will probably run 30-45 minutes on average because the summer minimum is about half of the GAHP capacity. GAHP from manufacturer #1 would not be a good candidate for Site #5.

Figure 36: Comparison of GAHP Capacity and Site #1 Summer DHW Loads

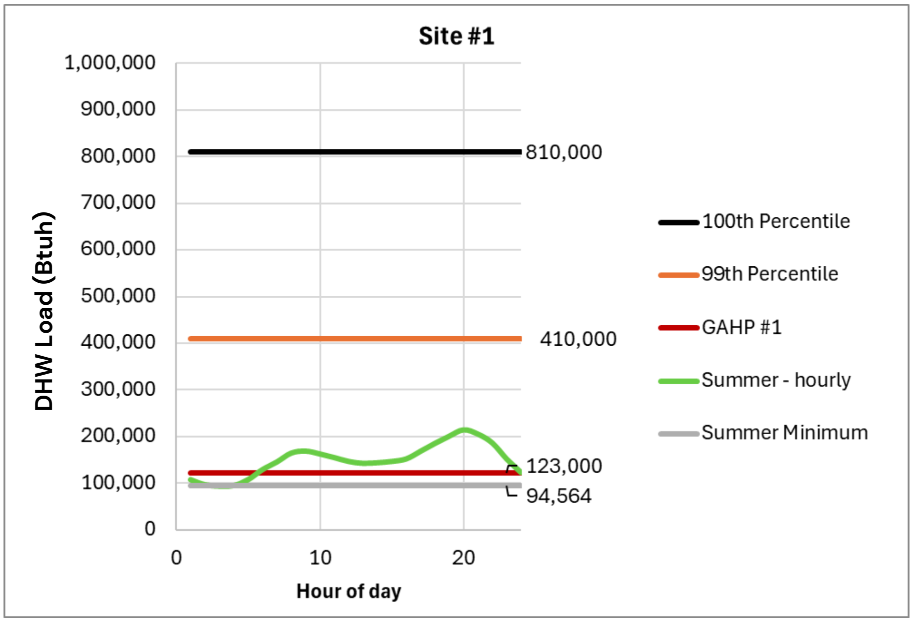
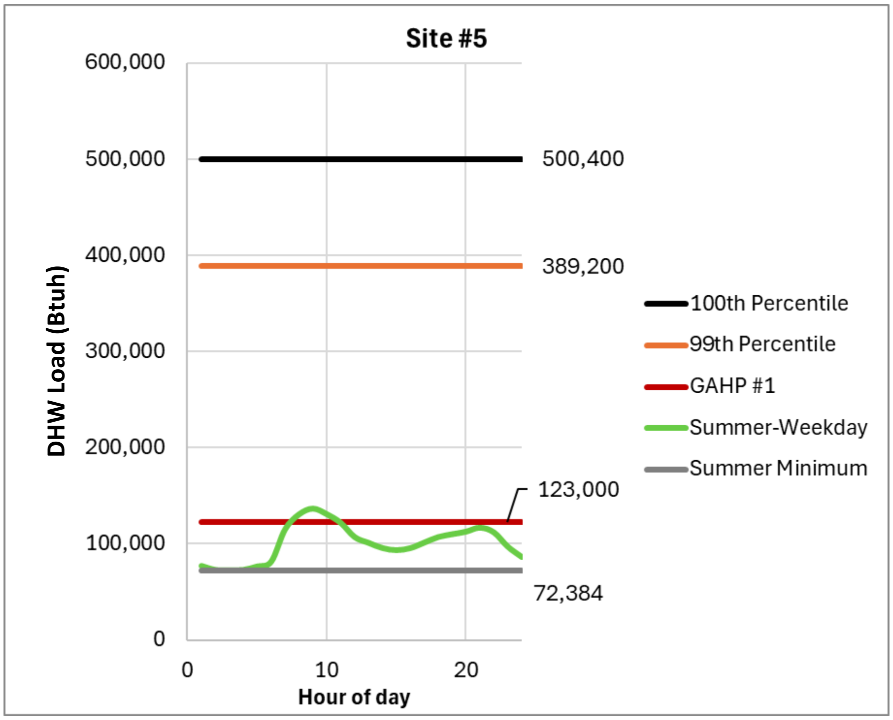


Figure 37: Comparison of GAHP Capacity and Site #5 Summer DHW Loads



Since there is no tool that can predict summer minimum DHW load at the time of this writing, the best practice is to measure the DHW load. This can be done using a combination of an ultrasonic flow meter and clamp-on temperature probes. The Study Team is testing out this method of determining summer minimum load on upcoming Gas Emerging Technology field studies for GAHP products. Ultrasonic metering is being used to screen sites before a project is initiated. There are many outstanding questions using this method that will be answered as field studies progress. These questions include:

- How many days is sufficient to accurately predict the summer minimum load?
- How can the summer minimum load be predicted if the ultrasonic measurement was done during fall, winter, or spring?
- Do both the recirculation load and make up water need to be measured to pick a suitable site for a GAHP?
- How much time does it take to install and uninstall the ultrasonic meter and analyze the data?
- How much does an ultrasonic meter cost?
- Will contractors be willing to purchase an ultrasonic meter to screen sites for GAHP installation?
- Can a sizing tool be created that predicts the summer minimum load?

The Study Team is working to answer these questions in future GAHP field work through the GET program.

Minimum Flowrate Calculation

It is recommended that each site has an average hot water demand that matches or exceeds the capacity of the GAHP system being considered. Discussions with GAHP manufacturers have highlighted the importance of accounting for the minimum flow rate for each GAHP unit to assess its viability for replacing traditional DHW systems or acting as a preheater. The following equation 6 is used to calculate the minimum flow rate based on the rated capacity of the GAHP unit and the difference between the incoming and exiting water temperature:

Equation 6: Minimum Flow Rate

$$Min\ Flow\ Rate\left[\frac{Gal}{hr}\right] = \frac{GAHP\ Capacity\left[\frac{Btu}{hr}\right]}{\rho\left[\frac{lbm}{gal}\right]c_p\left[\frac{Btu}{lbm-°\mathrm{F}}\right]\Delta T\ [°\mathrm{F}]} \tag{6}$$

where,

$GAHP\ Capacity =$
$\text{Rated Capacity of the GAHP Unit}\left[\frac{Btu}{hr}\right]: \text{123,500 Btuh for GAHP and 78,000 Btuh for GAHP 2}$

$\rho = \text{ density}\left[\frac{lbm}{gal}\right]: 8.33$

$$c_p = \text{ Specific heat}\left[\frac{Btu}{lbm-°\mathrm{F}}\right]: 1$$

$\Delta T = T_{delivery} - T_{incoming}\ [°\mathrm{F}]$

The minimum flow rate allows for continuous operation of the unit. If the minimum flow rate were consistently maintained, the GAHP could function as a preheat unit without requiring additional IST. However, DHW demand varies, and during low demand periods, the flow rate may drop below the minimum required for continuous operation. These variations in flowrate can affect the unit's cycle and run times, potentially necessitating the use of an IST. The impact of GAHP run and cycle times on the required flow rate is explained in the following section.

GAHP run time and Cycle time requirements

GAHP units perform at optimal efficiency when supporting systems with continuous heating loads. However, since continuous load is uncommon in DHW systems, there must be a minimum load that allows the unit to cycle on and off without short cycling. Short cycling can reduce efficiency and strain the equipment.

Equation 7: Tank Volume

$$Tank\ Vol\ [Gal] = \frac{GAHP\ Capacity\ [Btuh]*GAHP\ run\ time\ [hr]}{\rho\left[\frac{lbm}{gal}\right]c_p\left[\frac{Btu}{°F-lbm}\right]\Delta T\ [°F]} \qquad (7)$$

Where

$GAHP\ Capacity$= Rated Capacity of the GAHP Unit $\left[\frac{Btu}{hr}\right]$: 123,500 Btuh for GAHP 1 and 78,000 Btuh for GAHP 2

ρ= density $\left[\frac{lbm}{gal}\right]$: 8.33

c_p= Specific heat $\left[\frac{Btu}{lbm-°F}\right]$: 1

ΔT= $T_{delivery} - T_{incoming}$ [°F]

$GAHP\ run\ time\ [min]$: Site specific optimal time for GAHP unit

The cycle time as defined by equation 8, is the sum of GAHP run time, and the time required to fill the IST.

Equation 8: Tank Charge Time

$$Tank\ charge\ time\ [min] = Cycle\ Time\ [\text{min}] -\ GAHP\ run\ time\ [min] \qquad (8)$$

where,

$Tank\ charge\ Time\ [min]$: Site specific time required to fill indirect storage tank (if needed)

$Cycle\ Time\ [\text{min}]$: Site specific optimal cycle time determined by minimum desired cycles per day.

According to discussions with the GAHP manufacturers, each unit has a minimum run time and a specified maximum number of cycles per day to optimize its performance. Representatives for the GAHP 1 unit indicated that it does not reach a steady-state Coefficient of Performance (COP) until it has been running for at least 10 minutes. However, the minimum run time in Equation 7 and 8 will vary depending on the targeted average GAHP COP, which considers the COP during the startup phase before the unit reaches steady state. **There is not currently enough data to provide the GAHP COP as a function of the GAHP run time. The Study Team recommends research be put out to provide this data for IST sizing.**

Before sizing a unit, every user must determine the number of cycles per day and run time required to reach the breakeven point. Theoretically, the GAHP could run for 2 hours if the IST were sized for that, but if the minimum flow rate was low enough, it might only run 2 hours/day and take the other 22 hours to fill the tank. In other words, the GAHP run time would be 2 hours but the tank fill time would be be 22 hours making the cycle time 24 hours

(1 cycle per day). The ideal GAHP run time and number of cycles per day will vary by site, based on the GAHP installation cost, natural gas prices, and if there are any CO_2 emissions reduction goals. There is currently no tool to take these considerations as inputs and give recommendations for GAHP run times and number of cycles per day. **Therefore, it is recommended to develop a tool that incorporates these variables to recommend GAHP run times, number of cycles per day and calculate system payback period and other benefits.**

Example Cycle Time and Cycles/Day Calculation

M&V data from Site 1[4] from the above section was used to calculate the minimum GAHP run time. The GAHP run time is determined when the targeted weighted average GAHP COP is the same as a condensing boiler. At Site 1, it takes approximately 45 minutes for the GAHP's weighted average efficiency to reach 94%, which is the minimum efficiency for an Energy Star® condensing boiler [13].

The number of cycles per day for a GAHP system is influenced by the customer's specific needs. For this example, it is assumed that the GAHP would need to run a maximum of 12 cycles per day to be a cost-effective investment. Equation 9 and 10 calculates the minimum flow rate of incoming city water needed to determine if the site is a candidate for a preheat configuration of GAHP and an auxiliary boiler system.

Equation 9: Minimum Flow Rate

$$Min\ Flow\ Rate\ \left[\frac{gal}{min}\right] = \frac{Tank\ vol\ [gal]}{Tank\ charge\ time\ [min]} \tag{9}$$

Equation 10: Min Flowrate for 12 cycles per day

$$Min\ Flow\ Rate\ for\ 12\ cycles\ per\ day\ \left[\frac{gal}{min}\right] = \frac{GAHP\ Capacity\ [Btuh]*GAHP\ Run\ Time\ [hr]}{\rho\left[\frac{lbm}{gal}\right]c_p\left[\frac{Btu}{°\mathrm{F}-lbm}\right]\Delta T\ [°\mathrm{F}]\ (Tank\ Charge\ Time\ [min])} \tag{10}$$

Where

$GAHP\ run\ time\ [min] = 45\ min$

$Cycle\ Time\ for\ 12\ cycles\ per\ day\ [\mathrm{min}] = 120\ min$

$$GAHP\ Capacity = \text{ Rated Capacity of the GAHP1 Unit } \left[\frac{Btu}{hr}\right]: 123{,}500\ \mathrm{Btuh}$$

$\rho = \text{ density } \left[\frac{lbm}{gal}\right]: 8.33$

$c_p = \text{ Specific heat } \left[\frac{Btu}{lbm-°\mathrm{F}}\right]: 1$

---

[4] This data comes from GAHP Field Site #1

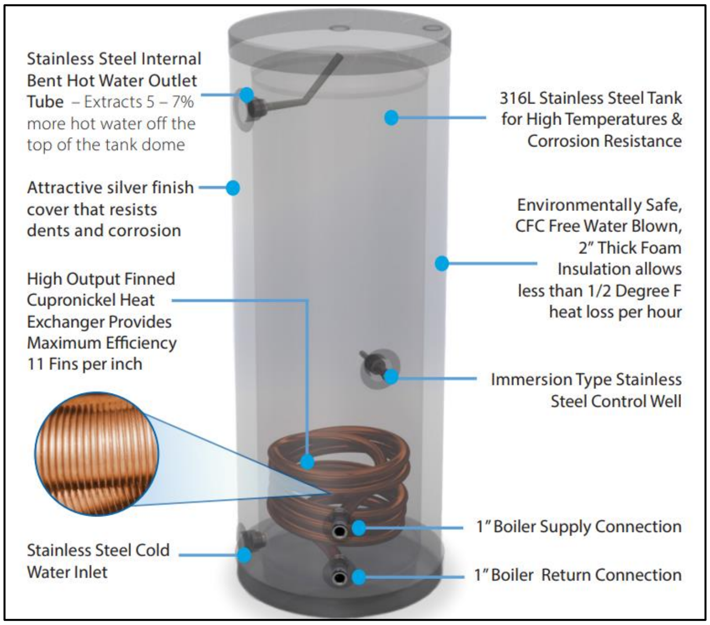
$$\Delta T = T_{delivery} - T_{incoming}\ [°\mathrm{F}] = 120 - 65 = 55$$

The minimum flowrate calculated is 2.68 gal/min or 3,866 gal/ day to ensure the GAHP would be able to run for 45 minutes per cycle with 12 cycles per day. In the case of other sites, the calculated minimum flow rate should be feasible for it to be a viable candidate for GAHP installation.

Indirect Storage Tank

Figure 38 and Figure 39 illustrate that to replace traditional DHW systems with a preheat GAHP and auxiliary boiler, it is advisable to include an Indirect Storage Tank (IST). Additionally, for GAHP 1, a buffer tank is also recommended. The IST tank functions as a thermal storage, which allows the tank to discharge hot water when the GAHP unit is not in operation, ensuring steady flow and efficient operation. Figure 38 below shows a screenshot from one manufacturer of ISTs and includes the high output heat exchanger near the bottom of the tank [14].

Figure 38: Commercial Indirect Storage Tank with Heat Exchanger [14]



Indirect Storage Tank Stratification

The ISTs considered in this study would likely be "stratified", similar to those used in solar thermal DHW systems. Stratification refers to the layering effect within the IST, where hot, less dense water accumulates at the top, while colder, denser water settles at the bottom. Figure 39 shows a fully stratified storage tank, with red symbolizing hot water and blue symbolizing cold water [15].

Figure 39 Stratified Solar Thermal Storage Tank [15]

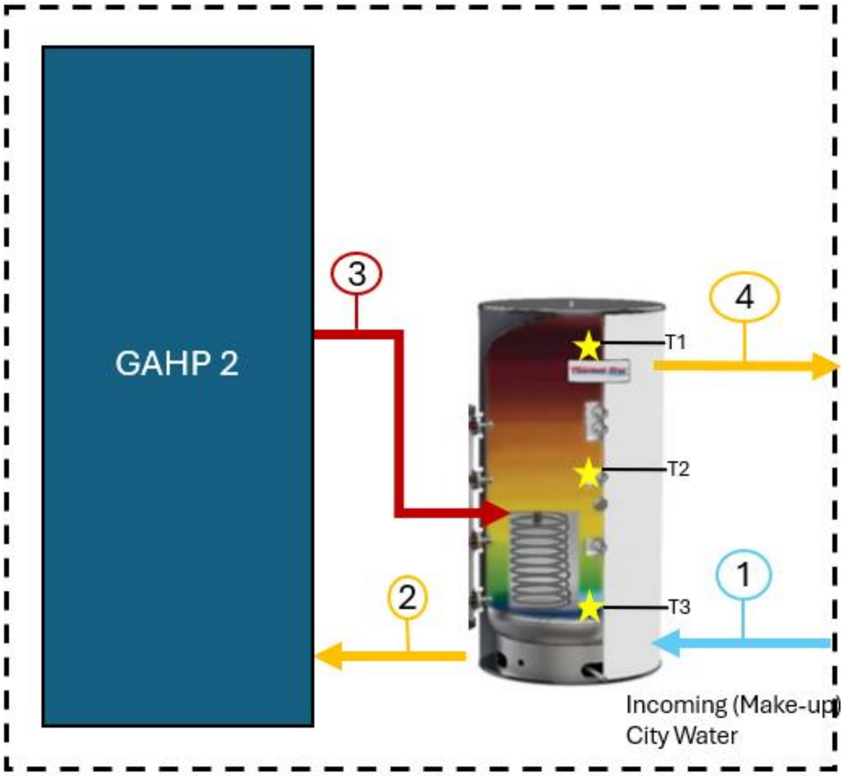
Tank stratification is advantageous for preheat GAHP systems. In a stratified tank, the hottest water resides at the top, allowing it to be delivered to the existing storage tanks. Meanwhile, the GAHP heat exchange coils can be positioned at the bottom, where the cooler water is located, ensuring that the coldest water is heated by the GAHP.

See Figure 40 for the visual representation:

- #4 indicates the hottest water being delivered to the storage tank.
- #3 indicates the water exiting the GAHP at the maximum output temperature.
- #2 shows the water entering the GAHP.
- #1 is the incoming city water.

By placing the heat exchange coils at the bottom of the IST, the temperature of the water entering the GAHP is lowered, which enhances the GAHP's COP and run time. Both of these factors contribute to optimized performance and improved overall system efficiency.

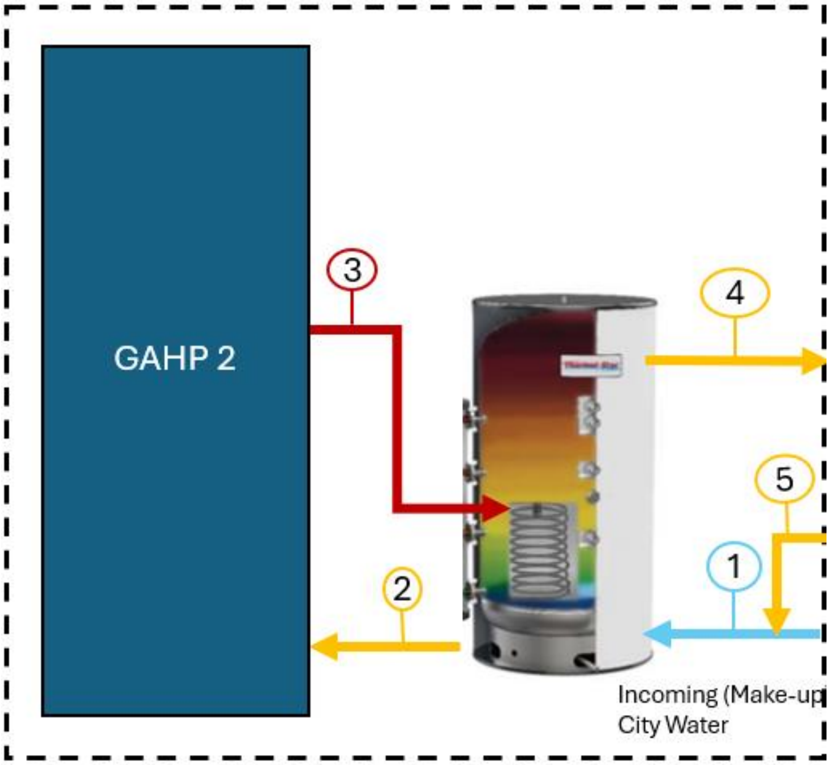
Figure 40: Preheat GAHP 2 and stratified IST with Heat Exchanger



As seen in Figure 40 above, the water/glycol temperature entering the GAHP unit (#2) should not exceed 140°F to prevent the unit from cycling off. It may be necessary to use inlet temperature control, such as a variable frequency drive (VFD) on a recirculation pump or a flow control valve, to allow flow control and thereby regulate/lower the inlet temperatures of the GAHP unit. This is applicable when the recirculation water is mixing with the makeup city water as seen in Figure 41, where #5 is the recirculation line mixing with the city make-up water. During periods of minimal DHW usage, such as at night when there is little to no cold city make-up water, the inlet temperatures to the GAHP unit can rise above the unit's operational limit. This causes the GAHP unit to shut down, requiring the hot water load to be fully handled by existing auxiliary boiler. The water/glycol temperature exiting the GAHP 1 unit, flow line 3 in Figure 42, typically ranges between 130°F and 140°F. Based on typical heat exchanger characteristics, this temperature range translates to a maximum DHW delivery temperature of 120°F to 130°F. To meet peak loads, an auxiliary boiler may be required as shown in

Figure 35.

Figure 41: Preheat GAHP 2 and stratified IST with Recirculation Line

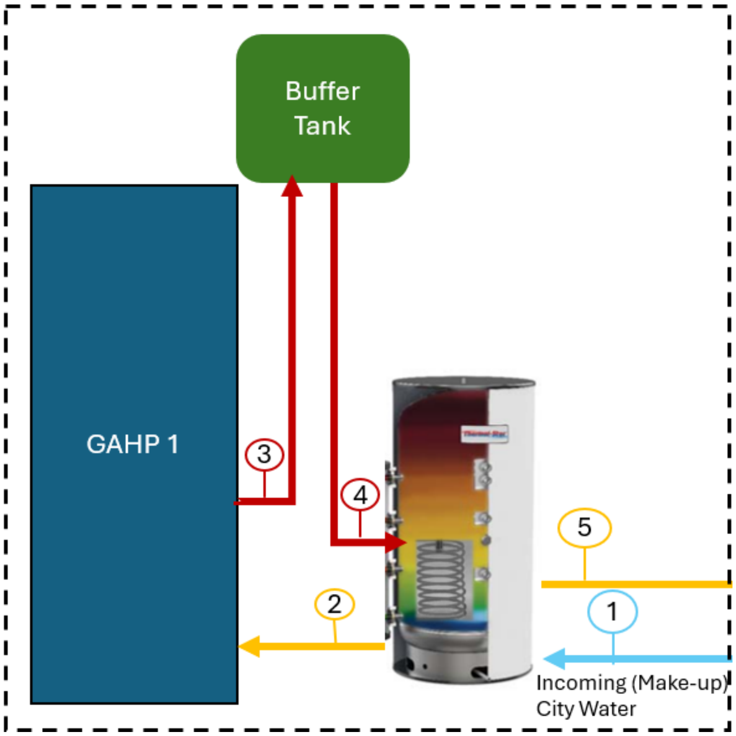


Temperature Limitations

GAHP units tend to have specific temperature requirements that should be met prior to replacing traditional DHW systems with a preheat GAHP and auxiliary boiler system. It is recommended that the controls be configured so that the storage tank can cycle between the GAHP maximum output temperature and the incoming city water temperature, providing sufficient thermal inertia in the IST for the GAHP unit to run efficiently. The temperature difference between incoming city water and maximum GAHP output temperature may range from 50°F to 70°F. This delta allows cold water to accumulate in the IST, enabling the GAHP unit to operate longer. However, the temperature delta is site-specific because incoming city water temperature depends on the site climate zone and the maximum GAHP output temperature depends on the specific GAHP unit. The temperature delta is also season-specific because the incoming city water temperature also depends on the season.

The GAHP 1 unit has an assumed maximum GAHP output temperature of 122°F when connected to an IST. The unit shuts off when the temperature of the return flow going into the GAHP 1 unit from the IST reaches 122°F. The maximum output temperature of GAHP 1 is closer to 140°F, but as the IST heats up to 122°F, the return temperature to GAHP 1 will trend toward 122°F and shut the unit off. In contrast, the GAHP 2 unit has a maximum GAHP output temperature range of 130°F to 140°F.

Figure 42: Preheat GAHP 1 and Stratified IST with Heat Exchanger



IST Temperature Sensor Placement

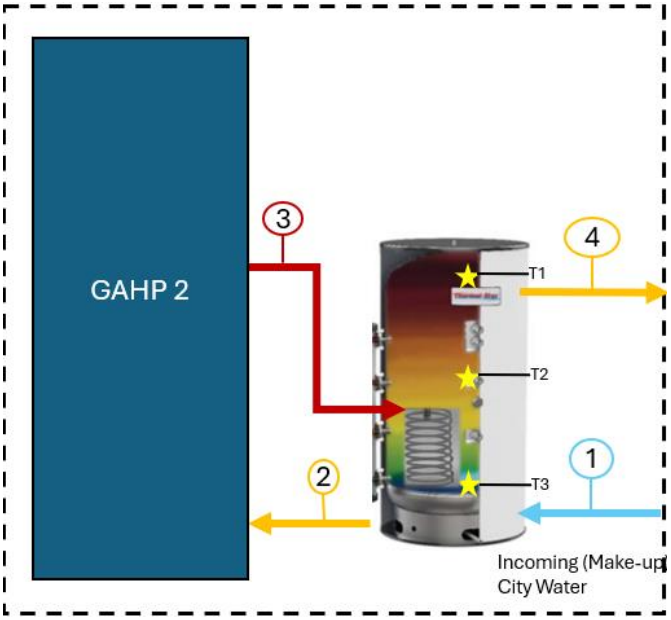
The study team also considered the placement of temperature sensors in the IST during the design and installation phases of the GAHP systems to ensure optimal performance. Proper sensor placement allows the GAHP to respond efficiently. The GAHP 2 controls use an Aquastat, a controller that turns the GAHP off or on to maintain temperature control. This means that when the temperature sensor reads 140°F, the system will turn off. Based on conversations with the manufacturer, the system will not turn back on until the temperature drops to 125°F, as there is a 15°F default deadband.

Figure 43 depicts the GAHP, IST, and possible temperature sensor placements. In

Figure 43, the sensor's location within the IST will affect the GAHP run time and there are pros and cons for each. If the Sensor is placed at top point T1, the system can respond quickly when the water reaches the desired temperature, preventing overheating. However, it might shut off too soon, leaving the lower parts of the tank cooler, leading to uneven heating and frequent on-off cycling. If the sensor is placed at mid-point T2, it may accurately reflect the overall temperature of the tank and reduce the chances of frequent cycling. However, the sensor might not detect when the top of the tank is fully heated, leading to a delayed shutdown of the heating system, which could slightly overheat the top layer. Finally, if the sensor is placed at low point T3, it can ensure that the entire tank reaches the desired temperature before the system shuts off, providing more consistent hot water availability. However, it might take longer to turn off, leading to potential overheating at the top and slower system response, which could waste energy. The location of the temperature sensor may impact system performance and efficiency and needs to be studied with further testing.

In Figure 42, the sensor placement is less critical since the temperature entering GAHP 1 unit(#2) is assumed to match the temperature exiting the IST (#5). Note that #5 could be higher than #2, but the Study Team has no data to determine how much higher it could be because there is no field data to show GAHP performance with an IST.

Figure 43: GAHP 2 and Indirect Storage Tank diagram



IST and Buffer Tank Volume

According to discussions with one manufacturer, the size of the IST is determined by the GAHP manufacturing team and sold in conjunction with the GAHP unit. However, with other GAHP manufacturers, the responsibility for determining the size of the IST is left to the customer or contractor at the installation site. One manufacturer of ISTs suggested a sizing methodology based not on formulas, but rather on the first-hour rating and gallons per minute (GPM) of the system [14]. Since the study team did not have access to first-hour ratings and accurate GPM data, they recommend an alternative approach for sizing the indirect storage tank, which considers the specific type of GAHP, as outlined in equation 7.

This study includes a very simplified calculation with the assumption that the temperature in the whole IST is the same. This is not often the case as discussed in an earlier section.

The thermal storage capacity of the indirect storage tank is determined by the temperature difference between the maximum GAHP outlet temperature, which varies by unit, and the incoming city water temperature, which is influenced by the local climate zone. **Error! Not a valid bookmark self-reference.**,

Figure 45, and Figure 46 illustrate how the volume of the indirect storage tank changes considering a 45-minute GAHP run time as the average incoming water temperature varies across different climate zones. The recommended tank volume is based on average temperatures, but an important consideration is that the GAHP run time will be shorter in the summer when the incoming water temperature is higher than average. Although these calculations use average water temperatures, it is important that the GAHP controls are not set to activate the unit only when the tank temperature equals the average city water temperature, as this would cause the unit to rarely operate in the summer. For example, if the average makeup temperature is 65°F, but the summer temperature rises to 70°F, the GAHP would never turn on.

Figure 44: GAHP 1 (max delivery temp of 120 F) Indirect Storage Tank volume vs Incoming temperature for a 45-minute GAHP run time

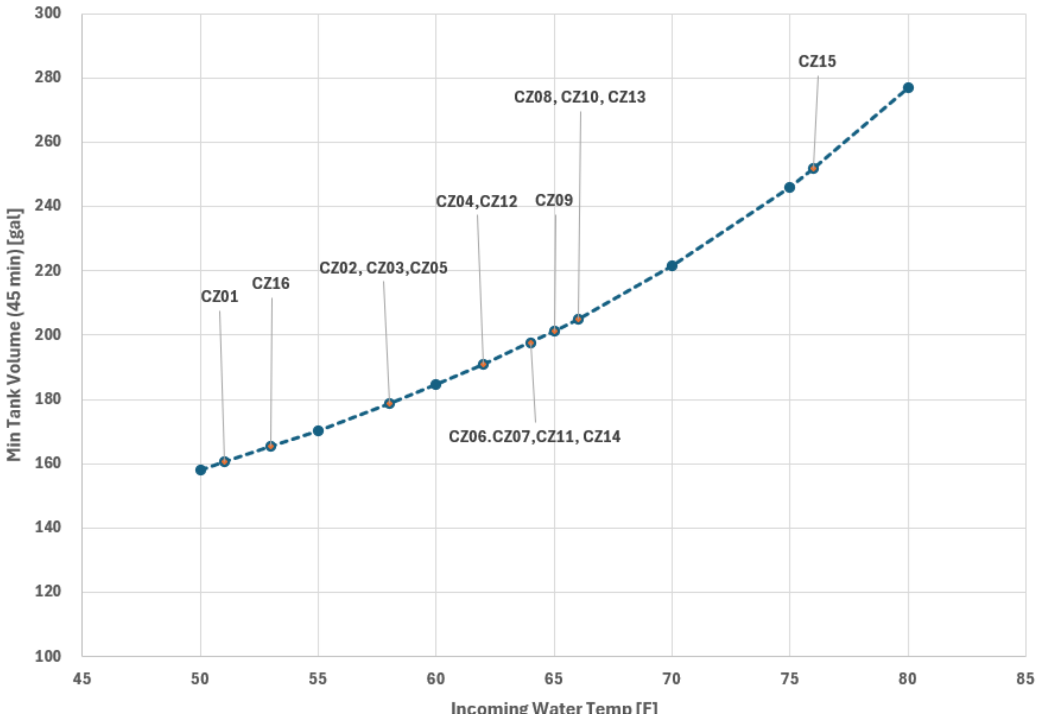


Figure 45: GAHP 2 (max delivery temp of 130F) Indirect Storage Tank volume vs Incoming temperature for a 45-minute GAHP run time

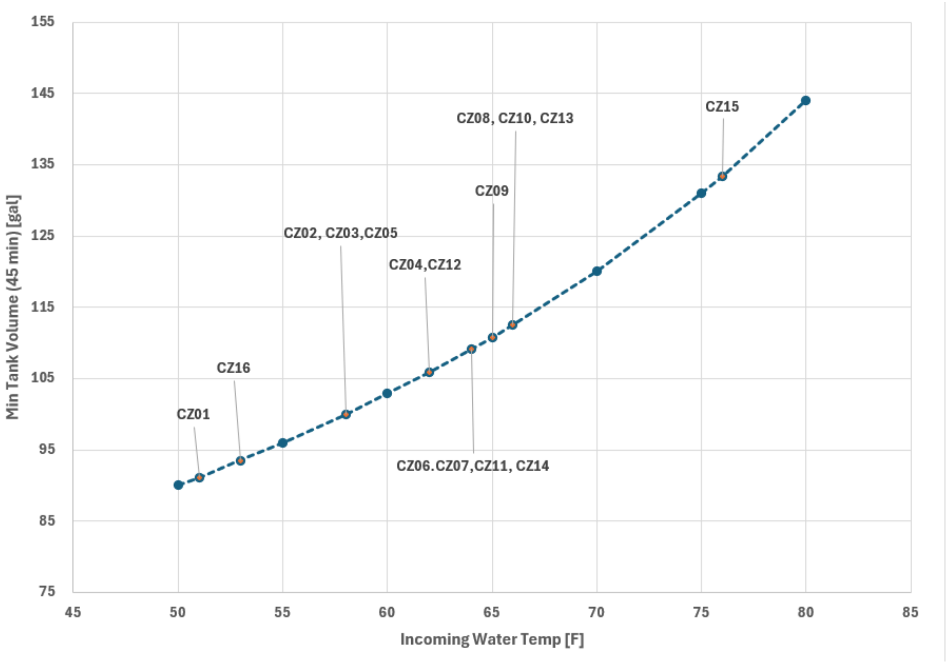
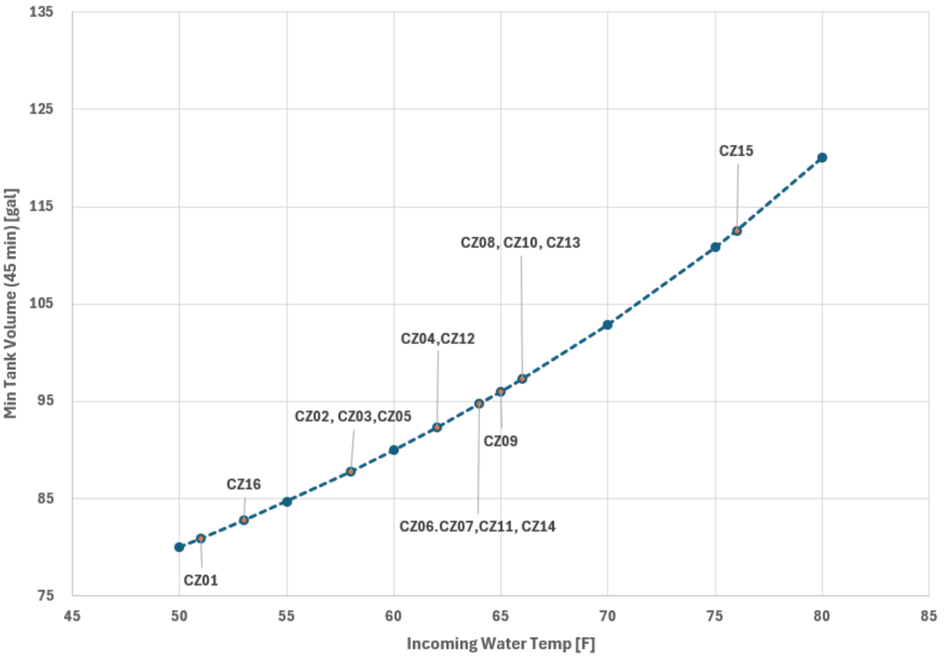


Figure 46: GAHP 2 (max delivery temp of 140F) Indirect Storage Tank volume vs Incoming temperature for a 45-minute GAHP run time



As shown in

Figure 35, the GAHP 1 unit requires a buffer tank, while the GAHP 2 does not. The purpose of a buffer tank is to provide thermal inertia, which stabilizes the system during periods of low demand. This helps to reduce the frequency of the heat generators, such as boilers or heat pumps, short cycling, which potentially improves the overall efficiency of the system. This helps maintain the desired temperature range and protects the system from potential damage caused by rapid temperature changes. Buffer tanks are a simple and cost-effective way to enhance the overall operating efficiency and lifespan of a heating system by reducing unnecessary equipment short cycling. The recommended volume for a buffer tank is determined using equation 11 below:

Equation 11: Buffer Tank Volume

$$Buffer\ Tank\ Vol\ [Gal] = \frac{GAHP\ Run\ Time\ [min] * (GAHP\ Capacity\ [Btuh] - Q_{\min heat\ load}\ [Btuh])}{\Delta T\ [°\mathrm{F}] * 500^{5}} \quad (11)$$

Where

$GAHP\ run\ time\ [min] = Site\ specific\ optimal\ time\ for\ GAHP\ unit$

$GAHP\ Capacity$= Rated Capacity of the GAHP Unit $\left[\frac{Btu}{hr}\right]$: 123,500 Btuh for GAHP 1 and 78,000 Btuh for GAHP 2

$Q_{\min heat\ load} = Heat\ output\ to\ site\ specific\ minimum\ load$

ΔT= $T_{delivery} - T_{incoming}$ [°F]

Similar to the IST, the size of a buffer tank depends on factors such as the type and size of the GAHP, the manufacturer, the site-specific temperature difference, and the heating load of the site. To determine if a site will be a good candidate for replacing the DHW system with a combined GAHP 1 and auxiliary boiler system, it is crucial to ensure that an appropriately sized buffer tank is available. **The study team's recommendations are preliminary estimates, and further optimization, modeling, and fieldwork are necessary to accurately determine the appropriate tank types, size, temperature settings, and cycling frequency. These are important design considerations for sizing the combined GAHP and boiler DHW system, which currently has limited guidance.**

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[5] A constant used for standard water properties where density $8.33\ \frac{lbm}{gal} * 60\ \frac{gal}{min}$

Screening, Sizing, and Design Criteria for GAHPs Findings

The purpose of this part of the study was to provide recommendations for screening sites and assess viability for replacing the existing traditional gas boiler system with a GAHP preheater and auxiliary boiler system. The findings are summarized below:

- **Pre-Heat Configuration**: GAHP units are well-suited for pre-heat configuration with traditional gas boilers. In this setup, the GAHP handles the base hot water load, and the gas boilers provide supplemental heating to meet peak demand.
- **Site Requirements**: Sites for integrating GAHP units with traditional gas boiler DHW systems require sufficient outdoor space, proper ventilation, proximity to electrical and plumbing connections, noise mitigation, and ensuring an adequate flowrate to maintain efficient operation.
- **Hot Water Demand**: Each site must have sufficient hot water demand that allows for the minimum required flow rate for the GAHP system, which is calculated based on the unit's rated capacity and difference between the makeup city water and the GAHP exit temperature. Consistent flow rates are crucial for continuous operation, and variations can impact the GAHP's effectiveness and necessitate additional ISTs.
- **Operational Efficiency**: GAHP units perform optimally with continuous heating load. If continuous operation is not feasible, a minimum flow rate must be maintained to prevent short cycling. Each unit has a specific run time to reach optimal performance, so calculating minimum flow rates and cycle times is essential to determine a site's suitability for a hybrid GAHP system.
- **Temperature Requirements:** Optimal efficiency for GAHP units depends on specific temperature differentials across the unit. For example, the GAHP 1 unit supplies water at a maximum temperature of 120°F when it is connected to an IST, while the GAHP 2 unit can supply higher temperatures between 130-140°F when connected to ISTs. During periods of low demand or peak demand, auxiliary boilers may be used.
- **Storage Tank Requirements**: When replacing traditional DHW systems with a GAHP and boiler system, it is recommended to include an indirect storage tank, and for GAHP 1 systems, a buffer tank. The indirect storage tank helps maintain system efficiency by ensuring steady flow and sufficient run time for the GAHP. The buffer tank, required for the GAHP 1 but not GAHP 2, offers thermal inertia to stabilize the system during low demand, reduces equipment short cycling, and improves overall efficiency. The tank sizes are determined by the GAHP's capacity, run time, and temperature differentials.

When evaluating GAHP units, contractors often depend on external engineers or manufacturers for recommendations on domestic hot water heaters and boiler capacities and designs. For GAHPs to be effectively implemented and be successful as an energy efficiency measure in California, it is crucial for contractors to have guidelines for screening sites and sizing GAHP systems. This study addresses that need by leveraging existing DHW sizing research to provide recommendations for GAHP system design and site criteria. Current sizing tools are meant to size to the 100th percentile of DHW demand, so the Study Team suggests further research to investigate how to screen sites for summer minimum DHW loads, and how to calculate a return on investment for a GAHP unit when the summer minimum DHW load is not enough for the GAHP to run continuously.

Conclusions

This report examined the sizing methodologies and performance of DHW systems across multiple sites, revealing significant issues with DHW sizing in general and as it relates to GAHP site screening. The study gathered insights from SME interviews, sizing methodologies from ASHRAE, ASPE, and manufacturers in order to identify differences in system sizing. These sizing methods were then compared to actual site data. Finally, the report discusses the transition to EHPWH and GAHPs which introduced new challenges, and the findings underscored the need for refined sizing methodologies and screening tools for GAHPs that can calculate economic viability. The conclusions are outlined below:

- **Inconsistencies in Sizing Methodologies and Oversizing:**
  - Existing DHW systems across six sites were found to be oversized by 17% to 160% compared to the maximum DHW load (the 100th percentile of the hourly DHW load).
  - While ASHRAE, manufacturer tools, and an EHPWH tool provide valuable sizing outputs (heat rate and storage tank volume), their predictions of maximum DHW load is inconsistent. The tools examined in this study sized DHW systems anywhere from -57% (under sized) to 252% (oversized) of the actual maximum DHW load depending on the tool and site.
  - In most cases, DHW tools oversize with respect to the actual maximum DHW load
- **Insights from Subject Matter Expert Interviews:**
  - **DHW Oversizing**: Oversizing is a common issue, especially when replacing failed systems.
  - **Sizing Factor**: The number of occupants was consistently identified as the most important factor when sizing DHW systems.
  - **Preferred Sizing Tools**: ASHRAE's handbook remains the most preferred sizing tool, though newer tools like the EHPWH tool are valued for their use of updated, site-specific data.
  - **Heat Rate:** Heat rate (capacity) is the most crucial factor in equipment selection.
  - **Brand Loyalty**: Contractors tend to show brand loyalty when selecting DHW equipment, even if the right-size equipment is not available with the preferred brand.
- **Variations in Manufacturer Tools:**
  - Manufacturer tools often yielded different recommended sizes due to variations in the background assumptions.
  - The three manufacturer tools evaluated and the EHPWH are very inconsistent at predicting the peak loads. On the other hand, the ASHRAE method using the

    medium consumption profile was usually the least oversized compared to the 100th percentile. The Study Team thinks this is because ASHRAE predicts the load using the number of people rather than the number of bathrooms or bedrooms.
  - None of the existing DHW sizing methods are suitable for sizing GAHP systems because they cannot predict summer minimum loads.
- **Methodological Similarities:**
  - Manufacturer tools and ASHRAE/ASPE equations follow similar sizing methods, particularly for calculating heat output rates. However, manufacturer tools often recommend smaller storage tanks. The Study Team believes this is due to additional costs for tanks because of code requirements when they are more than 119 gallons.
- **Sizing Challenges with Electric Heat Pumps:**
  - As the industry transitions towards gas and electric HPWH systems, a knowledge/resource gap in proper sizing has emerged. These systems require different considerations than traditional gas systems, particularly regarding storage tank size and peak demand management.
  - GAHPs do not have the exact same sizing issues electric HPWHs, but they share some gaps in common like their smaller capacities and need for additional storage to maximize run time.
- **Application of pre-heat GAHP and Auxiliary Boiler Systems:**
  - **Pre-Heat Configuration**: GAHP units work effectively in a pre-heat configuration with auxiliary gas boilers. GAHP systems handle the base load, while auxiliary boilers manage peak demand during high-usage periods.
  - **Site Requirements**: Sites need adequate outdoor space, proper ventilation, access to electrical and plumbing connections, and minimal noise impact to support a GAHP-boiler hybrid system.
  - **Operational Efficiency**: GAHP systems perform best with continuous heating loads. Maintaining a minimum flow rate is crucial to prevent system short cycling and ensure operational efficiency.
  - **Temperature and Storage Requirements**: GAHP systems require specific temperature difference for optimal performance. An indirect storage tank is recommended to maintain steady flow, with a buffer tank necessary for certain GAHP models to prevent short cycling and improve efficiency.
- **Recommendations for GAHP Implementation:**
  - Contractors and site engineers often rely on external recommendations from manufacturers for final DHW system sizing and design.

  - Contractors need clear guidelines for screening sites and properly sizing GAHP systems to ensure their successful adoption as an energy efficiency measure in California.
  - Designers and installers implementing GAHPs should calculate the minimum flow rate. If the minimum flow rate is not enough to keep the GAHP running continuously, an IST should be used. The size of the IST depends on the desired GAHP COP which is influenced by the GAHP run time.
  - There is currently not enough data to provide the GAHP COP as a function of the GAHP run time. This was identified as a research need.
  - The GAHP run time, number of cycles per day, cost of natural gas and potential value of CO_2 emissions reductions all affect the viability of a GAHP project. There is currently no tool to take these things and provide recommendations on GAHP run time, number of cycles per day and calculate payback period and other non-energy benefits. This was identified as a research need.
  - There is currently no tool to predict summer minimum DHW load, the best way to get this is to measure the actual DHW load. This can be accomplished using an ultrasonic flow meter and a clamp on temperature probe. The Study Team is doing this in several upcoming field studies but does not have enough information to present conclusive recommendations at this time.
  - GAHPs need a tool to predict the summer minimum load as a way of screening a site for a cost-effective installation. The gas bills provide a start, but the gas bills do not distinguish between how much is hot water use and how much is recirculation. To create a more useful screening tool, we need make-up water flow rates and delta T between incoming and supply water temperatures. A good site is one where the summer hot water use load is greater than the capacity of the GAHP being proposed.
  - We recommend that data be gathered on the summer DHW use, exclusive of the recirculation loads. That data could be used to create a GAHP screening tool for contractors to use that would not require measurement at every site.
- **Further Research Needed:**
  - The study calls out the following additional research needs for GAHPs
    - **Need for accurate predictions of summer minimum DHW loads.** The Study Team is testing out the use of an ultrasonic flow meter combined with clamp-on temperature probes. The research questions that need to be answered using this method are the following:
      - How many days is sufficient to accurately predict the summer minimum load?
      - How can the summer minimum load be predicted if the ultrasonic measurement was done during fall, winter, or spring?

    - Do both the recirculation and make up water need to be measured to pick a suitable site for a GAHP?
    - How much time does it take to install and uninstall the ultrasonic meter and analyze the data?
    - How much does an ultrasonic meter cost?
    - Will contractors be willing to purchase an ultrasonic meter to screen sites for GAHP installation?
    - Can a sizing tool be created that predicts the summer minimum load?
  - **Need for GAHP COP as a function of run time.** The Study Team along with other GET researchers are gathering data which can be used to generate this.
  - **Need for GAHP Screening Tool.** There is a need for a tool where the GAHP run time, number of cycles per day, cost of natural gas, cost of the GAHP retrofit, and CO2 emissions benefits are all taken into consideration with outputs that tell a customer if the GAHP project will be economically viable.

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Appendices

Appendix 1: Raw SME Responses:

SME 1

Question 3

Here are some key components needed for the sizing of a water heating system. Are there any additional components? Please rank order the top five. Please explain your rankings.

		LMH (Low, Medium, High)	Rank	Explanation
A	Number of occupants	L		
B	Number of apartments	H	4	usage
C	Demographics of the occupancy (senior, affordable, families, etc.)	M		
D	Number of bathrooms	H	2	peak load is in bathrooms
E	Type of fixtures	H	1	this is for gpm
F	Age of the plumbing fixtures	M		
G	Number of washing machines	H	3	gpm (higher load), next biggest consumer
H	Location of washing machines (in apartments, shared)	L		
I	Time of day the peak uses occur	M		
J	Duration of the peak periods	H	5	total demand for how much to generate
K	Gallons per person per day	M		
L	Type of temperature maintenance system (do you prefer circulation, heat trace, etc.)	H		temp and movement
M	If circulation, the method of balancing the riser	H		find out what is a dead leg, how many branches. Method is not important
N	Hot water piping material	L		
O	Length of the hot water piping	M		
P	Diameter and volume of the hot water distribution network	M		
Q	Configuration of the hot water distribution network	H		discovery of dead points in system
R	Insulation on the hot water piping	M		
S	Effectiveness of the pipe insulation installation	M		
	Additional components			
	Additional components			

Question 4

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<tr><td>A</td><td>ASHRAE</td><td>H</td><td>3</td><td></td></tr>
<tr><td>B</td><td>ASPE</td><td>H</td><td>2</td><td></td></tr>
<tr><td>C</td><td>IPC</td><td>H</td><td>4</td><td></td></tr>
<tr><td>D</td><td>IAPMO/ UPC (Uniform Plumbing Code)</td><td>H</td><td>1</td><td></td></tr>
<tr><td>E</td><td>Manufacturer's method</td><td>L</td><td></td><td></td></tr>
<tr><td>F</td><td>EHPWH Tool</td><td>L</td><td></td><td></td></tr>
<tr><td>G</td><td>Measured data from the site or from a similar occupancy</td><td>M</td><td></td><td></td></tr>
<tr><td></td><td>Other method</td><td></td><td></td><td></td></tr>
<tr><td></td><td>Other method</td><td></td><td></td><td></td></tr>
</table>

Question 5

Here are some features that may be used to select a water heater. Are there any other features that are important. Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	Explanation
A	Water heater efficiency	M		
B	Cost	M		
C	Location where the water heater will be installed	L		
D	Incoming cold water temperature	M		
E	Hot water temperature	H	2	
F	Master mixing valve temperature	H	1	
G	First hour rating	L		
H	Recovery efficiency	M		
I	Heat rate	H	4	
J	Location where the storage tank(s) will be installed	M		
K	Volume of storage (one large tank or a number of smaller ones. ASME tanks?)	H	3	
L	Size of storage tanks (volume, dimensions, ASME tanks?)	H	5	
M	Heat losses of the circulation loop	M		
N	Brand	M		
O	Is water heater sizing adjusted based on the presence of preheat sources (Solar, etc.	M		
	Other features			
	Other features			

Question 6

Here are some ways to account for future increases in demand when selecting a water heater. Are there any others that you use? Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	Explanation
A	Provide space for additional water heaters	H	1	
B	Provide space for additional storage tanks	M		
C	Install larger storage as part of initial design	M		
D	Install additional storage tanks as part of initial design	M		
E	Install heater with larger heating capacity as part of initial design	H	2	
F	Provide additional capacity in the gas line or in the electrical panel	H	3	
	Others			
	Others			

SME 2

Question 3

Here are some key components needed for the sizing of a water heating system. Are there any additional components? Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	Explanation
A	Number of occupants	H	2	
B	Number of apartments	H	5	
C	Demographics of the occupancy (senior, affordable, families, etc.)	M		
D	Number of bathrooms	M		
E	Type of fixtures	M		
F	Age of the plumbing fixtures	M		
G	Number of washing machines	M		
H	Location of washing machines (in apartments, shared)	L		
I	Time of day the peak uses occur	H	3	
J	Duration of the peak periods	H	4	
K	Gallons per person per day	H	1	
L	Type of temperature maintenance system (do you prefer circulation, heat trace, etc.)	M		
M	If circulation, the method of balancing the riser	H		
N	Hot water piping material	L		
O	Length of the hot water piping	M		
P	Diameter and volume of the hot water distribution network	M		
Q	Configuration of the hot water distribution network	M		
R	Insulation on the hot water piping	M		
S	Effectiveness of the pipe insulation installation	M		
	Additional components			
	Additional components			

Question 4

Here are some resources used to size water heating systems. Are there any other resources that you use? Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	Explanation
A	ASHRAE	H	2	great for multifamily loads
B	ASPE	H	4	pipe sizing is crucial--peak flow sizing
C	IPC	L		
D	IAPMO/ UPC (Uniform Plumbing Code)	L		
E	Manufacturer's method	L		
F	EHPWH Tool	H	1	updated/efficient, custom loads from ASHRAE
G	Measured data from the site or from a similar occupancy	H	3	good for retrofit sizing
	Other method			
	Other method			

Question 5

Here are some features that may be used to select a water heater. Are there any other features that are important. Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	Explanation
A	Water heater efficiency	H		
B	Cost	H	4	
C	Location where the water heater will be installed	H	3	
D	Incoming cold water temperature	L		
E	Hot water temperature	M		
F	Master mixing valve temperature	H	5	
G	First hour rating	H	1	primary plant, capacity question, primary criteria
H	Recovery efficiency	H	2	
I	Heat rate	M		
J	Location where the storage tank(s) will be installed	H		
K	Volume of storage (one large tank or a number of smaller ones. ASME tanks?)	M		getting into the door (sizing consideration)
L	Size of storage tanks (volume, dimensions, ASME tanks?)	M		
M	Heat losses of the circulation loop	H		
N	Brand	L		
O	Is water heater sizing adjusted based on the presence of preheat sources (Solar, etc.)	L		
	Experience with a product	M		
	other features			

Question 6

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<tr><td>A</td><td>Provide space for additional water heaters</td><td>H</td><td>1</td><td></td></tr>
<tr><td>B</td><td>Provide space for additional storage tanks</td><td>M</td><td></td><td></td></tr>
<tr><td>C</td><td>Install larger storage as part of initial design</td><td>M</td><td></td><td></td></tr>
<tr><td>D</td><td>Install additional storage tanks as part of initial design</td><td>M</td><td></td><td></td></tr>
<tr><td>E</td><td>Install heater with larger heating capacity as part of initial design</td><td>H</td><td>2</td><td></td></tr>
<tr><td>F</td><td>Provide additional capacity in the gas line or in the electrical panel</td><td>H</td><td>3</td><td></td></tr>
<tr><td></td><td>Others</td><td></td><td></td><td></td></tr>
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</table>

SME 3

Question 3

Here are some key components needed for the sizing of a water heating system. Are there any additional components? Please rank order the top five. Please explain your rankings.

		LMH (Low, Medium, High)	Rank	Explanation
A	Number of occupants	H	1	gallons of usage can be calculated based on this (demand)
B	Number of apartments	H	3	demand
C	Demographics of the occupancy (senior, affordable, families, etc.)	L		size to current demographic, could be changed
D	Number of bathrooms	M		
E	Type of fixtures	M		
F	Age of the plumbing fixtures	L		
G	Number of washing machines	M		
H	Location of washing machines (in apartments, shared)	L		
I	Time of day the peak uses occur	L		
J	Duration of the peak periods	H	2	How long water is being used is necessary for sizing
K	Gallons per person per day	M		
L	Type of temperature maintenance system (do you prefer circulation, heat trace, etc.)	L		
M	If circulation, the method of balancing the riser	L		
N	Hot water piping material	L		
O	Length of the hot water piping	L		
P	Diameter and volume of the hot water distribution network	L		
Q	Configuration of the hot water distribution network	L		
R	Insulation on the hot water piping	M		
S	Effectiveness of the pipe insulation installation	M		
	Additional components			
	Additional components			

Question 4

Here are some resources used to size water heating systems. Are there any other resources that you use? Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	Explanation
A	ASHRAE	H	1	
B	ASPE	L		
C	IPC	H	3	
D	IAPMO/ UPC (Uniform Plumbing Code)	H	4	
E	Manufacturer's method	H	2	
F	EHPWH Tool	L		
G	Measured data from the site or from a similar occupancy	L		
	Other method			
	Other method			

Question 5

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<tr><td>A</td><td>Water heater efficiency</td><td>M</td><td></td><td></td></tr>
<tr><td>B</td><td>Cost</td><td>H</td><td>1</td><td></td></tr>
<tr><td>C</td><td>Location where the water heater will be installed</td><td>M</td><td></td><td></td></tr>
<tr><td>D</td><td>Incoming cold water temperature</td><td>H</td><td></td><td></td></tr>
<tr><td>E</td><td>Hot water temperature</td><td>L</td><td></td><td></td></tr>
<tr><td>F</td><td>Master mixing valve temperature</td><td>M</td><td></td><td></td></tr>
<tr><td>G</td><td>First hour rating</td><td>H</td><td>2</td><td></td></tr>
<tr><td>H</td><td>Recovery efficiency</td><td>M</td><td></td><td></td></tr>
<tr><td>I</td><td>Heat rate</td><td>H</td><td>5</td><td></td></tr>
<tr><td>J</td><td>Location where the storage tank(s) will be installed</td><td>M</td><td></td><td></td></tr>
<tr><td>K</td><td>Volume of storage (one large tank or a number of smaller ones. ASME tanks?)</td><td>M</td><td></td><td></td></tr>
<tr><td>L</td><td>Size of storage tanks (volume, dimensions, ASME tanks?)</td><td>H</td><td>3</td><td>relate to water storage</td></tr>
<tr><td>M</td><td>Heat losses of the circulation loop</td><td>M</td><td></td><td></td></tr>
<tr><td>N</td><td>Brand</td><td>H</td><td>4</td><td>plumber preference, loyalty</td></tr>
<tr><td>O</td><td>Is water heater sizing adjusted based on the presence of preheat sources (Solar, etc.)</td><td>L</td><td></td><td></td></tr>
<tr><td></td><td>Experience with a product</td><td></td><td></td><td></td></tr>
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Question 6

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<tr><td>B</td><td>Provide space for additional storage tanks</td><td>L</td><td></td><td></td></tr>
<tr><td>C</td><td>Install larger storage as part of initial design</td><td>H</td><td>2</td><td></td></tr>
<tr><td>D</td><td>Install additional storage tanks as part of initial design</td><td>H</td><td>3</td><td></td></tr>
<tr><td>E</td><td>Install heater with larger heating capacity as part of initial design</td><td>H</td><td>1</td><td>larger heating capacity is necessary as you scale up.</td></tr>
<tr><td>F</td><td>Provide additional capacity in the gas line or in the electrical panel</td><td>L</td><td></td><td></td></tr>
<tr><td></td><td>Others</td><td></td><td></td><td></td></tr>
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SME 4

Question 3

Here are some key components needed for the sizing of a water heating system. Are there any additional components? Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	Explanation
A	Number of occupants	H	3	
B	Number of apartments	H	1	
C	Demographics of the occupancy (senior, affordable, families, etc.)	M	5	
D	Number of bathrooms	M		
E	Type of fixtures	L		
F	Age of the plumbing fixtures	L		
G	Number of washing machines	L		
H	Location of washing machines (in apartments, shared)	L		
I	Time of day the peak uses occur	M		
J	Duration of the peak periods	H	4	
K	Gallons per person per day	M		
L	Type of temperature maintenance system (do you prefer circulation, heat trace, etc.)	M		
M	If circulation, the method of balancing the riser	L		
N	Hot water piping material	L		
O	Length of the hot water piping	L		
P	Diameter and volume of the hot water distribution network	M		
Q	Configuration of the hot water distribution network	L		
R	Insulation on the hot water piping	M		
S	Installation considerations (Building Height, space outdoors)	M		
	Additional components	H	2	location of GHPWH, non-traditional locations
	Additional components			

Question 4

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<tr><td>B</td><td>ASPE</td><td>M</td><td></td><td></td></tr>
<tr><td>C</td><td>IPC</td><td>M</td><td></td><td></td></tr>
<tr><td>D</td><td>IAPMO/ UPC (Uniform Plumbing Code)</td><td>M</td><td></td><td></td></tr>
<tr><td>E</td><td>Manufacturer's method</td><td>M</td><td></td><td></td></tr>
<tr><td>F</td><td>EHPWH Tool</td><td>H</td><td>3</td><td></td></tr>
<tr><td>G</td><td>Measured data from the site or from a similar occupancy</td><td>H</td><td>2</td><td></td></tr>
<tr><td></td><td>Other method</td><td>H</td><td>1</td><td></td></tr>
<tr><td></td><td>Other method</td><td></td><td></td><td></td></tr>
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Question 5

Here are some features that may be used to select a water heater. Are there any other features that are important. Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	Explanation
A	Water heater efficiency	H	1	lower emissions, upgrade to higher eff
B	Cost	H	3	
C	Location where the water heater will be installed	H	4	outside which is out the norm, closer to mech room, less piping, lower cost
D	Incoming cold water temperature	M		
E	Hot water temperature	H	2	limit 140, if higher needs to be considered
F	Master mixing valve temperature	L		
G	First hour rating	L		
H	Recovery efficiency	L		
I	Heat rate	L		
J	Location where the storage tank(s) will be installed	M		
K	Volume of storage (one large tank or a number of smaller ones. ASME tanks?)	M		
L	Size of storage tanks (volume, dimensions, ASME tanks?)	M		
M	Heat losses of the circulation loop	M		
N	Brand	H	5	manufacturer to brand, know it works
O	Is water heater sizing adjusted based on the presence of preheat sources (Solar, etc.)	L		
	Experience with a product			
	other features			

Question 6

Here are some ways to account for future increases in demand when selecting a water heater. Are there any others that you use? Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	Explanation
A	Provide space for additional water heaters	L		
B	Provide space for additional storage tanks	L		
C	Install larger storage as part of initial design	M	2	
D	Install additional storage tanks as part of initial design	M	3	
E	Install heater with larger heating capacity as part of initial design	L		
F	Provide additional capacity in the gas line or in the electrical panel	N/A		
	Others	H	1	
	Others			

SME 5

Question 3

Here are some key components needed for the sizing of a water heating system. Are there any additional components? Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	Explanation
A	Number of occupants	H	1	demand is based on the number of people
B	Number of apartments	H	3	
C	Demographics of the occupancy (senior, affordable, families, etc.)	M		
D	Number of bathrooms	M		
E	Type of fixtures	L		
F	Age of the plumbing fixtures	M		
G	Number of washing machines	H	4	demand focused
H	Location of washing machines (in apartments, shared)	L		
I	Time of day the peak uses occur	L		
J	Duration of the peak periods	H	5	demand
K	Gallons per person per day	H	2	
L	Type of temperature maintenance system (do you prefer circulation, heat trace, etc.)	L		
M	If circulation, the method of balancing the riser	M		
N	Hot water piping material	L		
O	Length of the hot water piping	L		
P	Diameter and volume of the hot water distribution network	L		
Q	Configuration of the hot water distribution network	L		
R	Insulation on the hot water piping	M		
S	Installation considerations (Building Height, space outdoors)	M		
	Additional components			
	Additional components			

Question 4

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<tr><td>C</td><td>IPC</td><td>L</td><td></td><td></td></tr>
<tr><td>D</td><td>IAPMO/ UPC (Uniform Plumbing Code)</td><td>L</td><td></td><td></td></tr>
<tr><td>E</td><td>Manufacturer's method</td><td>H</td><td>3</td><td></td></tr>
<tr><td>F</td><td>EHPWH Tool</td><td>M</td><td></td><td></td></tr>
<tr><td>G</td><td>Measured data from the site or from a similar occupancy</td><td>L</td><td></td><td></td></tr>
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Question 5

Here are some features that may be used to select a water heater. Are there any other features that are important. Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	Explanation
A	Water heater efficiency	H	3	
B	Cost	H	4	
C	Location where the water heater will be installed	L		
D	Incoming cold water temperature	L		
E	Hot water temperature	L		
F	Master mixing valve temperature	L		
G	First hour rating	L		
H	Recovery efficiency	L		
I	Heat rate	H	1	
J	Location where the storage tank(s) will be installed	L		
K	Volume of storage (one large tank or a number of smaller ones. ASME tanks?)	L		
L	Size of storage tanks (volume, dimensions, ASME tanks?)	H	2	
M	Heat losses of the circulation loop	L		
N	Brand	L		
O	Is water heater sizing adjusted based on the presence of preheat sources (Solar, etc.)	L		
	Experience with a product			
	other features			

Question 6

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<tr><td>B</td><td>Provide space for additional storage tanks</td><td></td><td></td><td></td></tr>
<tr><td>C</td><td>Install larger storage as part of initial design</td><td>H</td><td></td><td></td></tr>
<tr><td>D</td><td>Install additional storage tanks as part of initial design</td><td>H</td><td></td><td></td></tr>
<tr><td>E</td><td>Install heater with larger heating capacity as part of initial design</td><td></td><td></td><td></td></tr>
<tr><td>F</td><td>Provide additional capacity in the gas line or in the electrical panel</td><td>H</td><td></td><td></td></tr>
<tr><td></td><td>Others</td><td></td><td></td><td></td></tr>
<tr><td></td><td>Others</td><td></td><td></td><td></td></tr>
</table>

SME 6

Question 3

Here are some key components needed for the sizing of a water heating system. Are there any additional components? Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	Explanation
A	Number of occupants	H	2	establishing demand
B	Number of apartments	M		
C	Demographics of the occupancy (senior, affordable, families, etc.)	H	4	
D	Number of bathrooms	M		
E	Type of fixtures	M		
F	Age of the plumbing fixtures	H		
G	Number of washing machines	M		
H	Location of washing machines (in apartments, shared)	M		
I	Time of day the peak uses occur	M		
J	Duration of the peak periods	H	1	establishing demand
K	Gallons per person per day	H	3	
L	Type of temperature maintenance system (do you prefer circulation, heat trace, etc.)	H	4	
M	If circulation, the method of balancing the riser	L		
N	Hot water piping material	M		
O	Length of the hot water piping	H	4	
P	Diameter and volume of the hot water distribution network	H	4	
Q	Configuration of the hot water distribution network	H	4	
R	Insulation on the hot water piping	H	4	
S	Installation considerations (Building Height, space outdoors)	M		
	Additional components			
	Additional components	H	2	establishing demand

Question 4

Here are some resources used to size water heating systems. Are there any other resources that you use? Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	Explanation
A	ASHRAE	M	4	
B	ASPE	M	5	
C	IPC	L		
D	IAPMO/ UPC (Uniform Plumbing Code)	M	3	
E	Manufacturer's method	L		
F	EHPWH Tool	M	2	
G	Measured data from the site or from a similar occupancy	H	1	
	Other method	L		
	Other method			

Question 5

Here are some features that may be used to select a water heater. Are there any other features that are important. Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	Explanation
A	Water heater efficiency	H	1	
B	Cost	M		
C	Location where the water heater will be installed	H		
D	Incoming cold water temperature	M		
E	Hot water temperature	M		
F	Master mixing valve temperature	L		
G	First hour rating	H	3	
H	Recovery efficiency	H	4	
I	Heat rate	H	5	
J	Location where the storage tank(s) will be installed	L		
K	Volume of storage (one large tank or a number of smaller ones. ASME tanks?)	H	2	
L	Size of storage tanks (volume, dimensions, ASME tanks?)	L		
M	Heat losses of the circulation loop	H		
N	Brand	M		
O	Is water heater sizing adjusted based on the presence of preheat sources (Solar, etc.)	H		
	Experience with a product			
	other features			

Question 6

Here are some ways to account for future increases in demand when selecting a water heater. Are there any others that you use? Please rank order the top five. Please explain your rankings.

		LMH (Low, Medium, High)	Rank	Explanation
A	Provide space for additional water heaters	M	3	
B	Provide space for additional storage tanks	M	4	
C	Install larger storage as part of initial design	L		
D	Install additional storage tanks as part of initial design	L		
E	Install heater with larger heating capacity as part of initial design	L		
F	Provide additional capacity in the gas line or in the electrical panel	H	1	
	Plumbing options to make options to additional equipment	H	2	
	Others			

SME 7

Question 3

Here are some key components needed for the sizing of a water heating system. Are there any additional components? Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	Explanation
A	Number of occupants	H	1	establishing demand
B	Number of apartments	H	1	
C	Demographics of the occupancy (senior, affordable, families, etc.)	L		
D	Number of bathrooms	H	4	
E	Type of fixtures	H	5	demand related
F	Age of the plumbing fixtures	L		
G	Number of washing machines	M		
H	Location of washing machines (in apartments, shared)	M		
I	Time of day the peak uses occur	L		
J	Duration of the peak periods	H	3	
K	Gallons per person per day	H	2	
L	Type of temperature maintenance system (do you prefer circulation, heat trace, etc.)	M		
M	If circulation, the method of balancing the riser	L		
N	Hot water piping material	L		
O	Length of the hot water piping	M		
P	Diameter and volume of the hot water distribution network	M		
Q	Configuration of the hot water distribution network	L		
R	Insulation on the hot water piping	L		
S	Installation considerations (Building Height, space outdoors)	L		
	Additional components			
	Additional components			

Question 4

Here are some resources used to size water heating systems. Are there any other resources that you use? Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	Explanation
A	ASHRAE	H	1	ASHRAE is familiar, industry standard
B	ASPE	M	4	
C	IPC	M	3	
D	IAPMO/ UPC (Uniform Plumbing Code)	H	2	UPC is familiarity standard
E	Manufacturer's method	L		
F	EHPWH Tool	L		
G	Measured data from the site or from a similar occupancy	L		
	Other method			
	Other method			

Question 5

Here are some features that may be used to select a water heater. Are there any other features that are important. Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	Explanation
A	Water heater efficiency	H	5	ideal is high but not a determinant of the need to satisfy the job
B	Cost	M		
C	Location where the water heater will be installed	H		
D	Incoming cold water temperature	M		
E	Hot water temperature	M		
F	Master mixing valve temperature	M		
G	First hour rating	H	1	determine if peak demand can be met
H	Recovery efficiency	M		
I	Heat rate	H	4	
J	Location where the storage tank(s) will be installed	M		
K	Volume of storage (one large tank or a number of smaller ones. ASME tanks?)	H	2	critical question for space and redundancy efficiency
L	Size of storage tanks (volume, dimensions, ASME tanks?)	H	3	
M	Heat losses of the circulation loop	L		
N	Brand	L		
O	Is water heater sizing adjusted based on the presence of preheat sources (Solar, etc.)	L		
	Experience with a product			
	other features			

Question 6

<table>
<tr><td colspan="5">Here are some ways to account for future increases in demand when selecting a water heater. Are there any others that you use? Please rank order the top five. Please explain your rankings.</td></tr>
<tr><td colspan="2"></td><td>LMH (Low, Medium, High)</td><td>Rank</td><td>Explanation</td></tr>
<tr><td>A</td><td>Provide space for additional water heaters</td><td>H</td><td>2</td><td>no space no product</td></tr>
<tr><td>B</td><td>Provide space for additional storage tanks</td><td>H</td><td>2</td><td></td></tr>
<tr><td>C</td><td>Install larger storage as part of initial design</td><td>H</td><td>1</td><td>expecting increase demand, quick and easy</td></tr>
<tr><td>D</td><td>Install additional storage tanks as part of initial design</td><td>M</td><td>4</td><td></td></tr>
<tr><td>E</td><td>Install heater with larger heating capacity as part of initial design</td><td>M</td><td>3</td><td></td></tr>
<tr><td>F</td><td>Provide additional capacity in the gas line or in the electrical panel</td><td>L</td><td></td><td></td></tr>
<tr><td></td><td>Tankless units into storage tanks</td><td>M</td><td></td><td></td></tr>
<tr><td></td><td>Others</td><td></td><td></td><td></td></tr>
</table>

SME 8

Question 3

Here are some key components needed for the sizing of a water heating system. Are there any additional components? Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	Explanation
A	Number of occupants	H	1	
B	Number of apartments	H		
C	Demographics of the occupancy (senior, affordable, families, etc.)	M		
D	Number of bathrooms	H	2	
E	Type of fixtures	H		
F	Age of the plumbing fixtures	M		
G	Number of washing machines	H		
H	Location of washing machines (in apartments, shared)	H		
I	Time of day the peak uses occur	L		
J	Duration of the peak periods	H	4	
K	Gallons per person per day	H	3	
L	Type of temperature maintenance system (do you prefer circulation, heat trace, etc.)	M		
M	If circulation, the method of balancing the riser	H	5	
N	Hot water piping material	L		
O	Length of the hot water piping	L		
P	Diameter and volume of the hot water distribution network	M		
Q	Configuration of the hot water distribution network	H		
R	Insulation on the hot water piping	H		
S	Installation considerations (Building Height, space outdoors)	H		
	Additional components			
	Additional components			

Question 4

Here are some resources used to size water heating systems. Are there any other resources that you use? Please rank order the top five. Please explain your rankings.

		LMH (Low, Medium, High)	Rank	Explanation
A	ASHRAE	H	2	most established pluming and HVAC systems, most industry respect
B	ASPE	H	3	most established pluming and HVAC systems, most industry respect
C	IPC	M	5	
D	IAPMO/ UPC (Uniform Plumbing Code)	M	4	
E	Manufacturer's method	H	1	contractor standpoint, so many diff types as a contractor we want to take out as much liability as we can
F	EHPWH Tool	M		
G	Measured data from the site or from a similar occupancy	L		
	Other method			
	Other method			

Question 5

Here are some features that may be used to select a water heater. Are there any other features that are important. Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	Explanation
A	Water heater efficiency	H	4	
B	Cost	H	5	
C	Location where the water heater will be installed	M		
D	Incoming cold water temperature	L		
E	Hot water temperature	L		
F	Master mixing valve temperature	L		
G	First hour rating	H	1	how much capacity during peal
H	Recovery efficiency	H		
I	Heat rate	H	3	
J	Location where the storage tank(s) will be installed	M		
K	Volume of storage (one large tank or a number of smaller ones. ASME tanks?)	M		
L	Size of storage tanks (volume, dimensions, ASME tanks?)	M		
M	Heat losses of the circulation loop	H		
N	Brand	H	2	reputable manufacturer
O	Is water heater sizing adjusted based on the presence of preheat sources (Solar, etc.)	L		
	Electrical Capacity	H		
	other features	H	4	

Question 6

Here are some ways to account for future increases in demand when selecting a water heater. Are there any others that you use? Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	Explanation
A	Provide space for additional water heaters	M	4	
B	Provide space for additional storage tanks	H	1	
C	Install larger storage as part of initial design	H	3	
D	Install additional storage tanks as part of initial design	H	2	
E	Install heater with larger heating capacity as part of initial design	M		
F	Provide additional capacity in the gas line or in the electrical panel	M	5	electrical capacity
	More space in boiler room			
	Others			

SME 9

Question 3

Here are some key components needed for the sizing of a water heating system. Are there any additional components? Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	Explanation
A	Number of occupants			
B	Number of apartments	H		
C	Demographics of the occupancy (senior, affordable, families, etc.)	L		
D	Number of bathrooms			
E	Type of fixtures			
F	Age of the plumbing fixtures			
G	Number of washing machines			
H	Location of washing machines (in apartments, shared)			
I	Time of day the peak uses occur			
J	Duration of the peak periods	H		
K	Gallons per person per day			
L	Type of temperature maintenance system (do you prefer circulation, heat trace, etc.)	L		so many other factors, insignificant
M	If circulation, the method of balancing the riser	L		
N	Hot water piping material			
O	Length of the hot water piping			
P	Diameter and volume of the hot water distribution network			
Q	Configuration of the hot water distribution network	H		
R	Insulation on the hot water piping	L		code requirements
S	Installation considerations (Building Height, space outdoors)	L		
	Additional components			
	Additional components			

Question 4

Here are some resources used to size water heating systems. Are there any other resources that you use? Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	Explanation
A	ASHRAE	H	1	ASHRAE has become too complicated in time
B	ASPE	L		
C	IPC	L		
D	IAPMO/ UPC (Uniform Plumbing Code)	L		
E	Manufacturer's method	L		
F	EHPWH Tool	L		
G	Measured data from the site or from a similar occupancy	L		
	Other method			
	Other method			

Question 5

Here are some features that may be used to select a water heater. Are there any other features that are important. Please rank order the top five. Please explain your rankings.

A	Water heater efficiency	LMH (Low, Medium, High)	Rank	Explanation
B	Cost	H	4	
C	Location where the water heater will be installed	L		
D	Incoming cold water temperature	L		
E	Hot water temperature	L		
F	Master mixing valve temperature	L		
G	First hour rating	H	2	
H	Recovery efficiency	L		
I	Heat rate	H	3	
J	Location where the storage tank(s) will be installed	L		
K	Volume of storage (one large tank or a number of smaller ones. ASME tanks?)	H		
L	Size of storage tanks (volume, dimensions, ASME tanks?)	M		
M	Heat losses of the circulation loop	L		
N	Brand	L		
O	Is water heater sizing adjusted based on the presence of preheat sources (Solar, etc.)	L		rare to see
	Availability	H	1	existing buildings
	other features			

Question 6

Here are some ways to account for future increases in demand when selecting a water heater. Are there any others that you use? Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	Explanation
A	Provide space for additional water heaters	L		
B	Provide space for additional storage tanks	L		
C	Install larger storage as part of initial design	H		
D	Install additional storage tanks as part of initial design	L		
E	Install heater with larger heating capacity as part of initial design	H		
F	Provide additional capacity in the gas line or in the electrical panel	L		
	More space in boiler room			
	Others			

SME 10

Question 3

Here are some key components needed for the sizing of a water heating system. Are there any additional components? Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	Explanation
A	Number of occupants	M		
B	Number of apartments	H	1	establish demand
C	Demographics of the occupancy (senior, affordable, families, etc.)	H	2	largest driver for demand
D	Number of bathrooms	M		
E	Type of fixtures	L		
F	Age of the plumbing fixtures	M		
G	Number of washing machines	M		
H	Location of washing machines (in apartments, shared)	H	5	central laundry sees heavier usage, whereas in apartment more spread out
I	Time of day the peak uses occur	H	4	helps understand recovery rates necessary, storage
J	Duration of the peak periods	H	3	used to define storage
K	Gallons per person per day	L		
L	Type of temperature maintenance system (do you prefer circulation, heat trace, etc.)	L		
M	If circulation, the method of balancing the riser	L		automatic balancing
N	Hot water piping material	L		
O	Length of the hot water piping	L		
P	Diameter and volume of the hot water distribution network	M		
Q	Configuration of the hot water distribution network	M		
R	Insulation on the hot water piping	L		
S	Installation considerations (Building Height, space outdoors)	L		
	Type of water heating Systems (steam, gas, electric, instantaneous, storage)	H		more applicable to new construction
	Additional components			

Question 4

Here are some resources used to size water heating systems. Are there any other resources that you use? Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	Explanation
A	ASHRAE	H	1	Industry standard documents
B	ASPE	H	1	shared data between AHRAE and ASPE.
C	IPC	L		
D	IAPMO/ UPC (Uniform Plumbing Code)	L		
E	Manufacturer's method	M	3	
F	EHPWH Tool	M	2	becoming an industry standard, especially in PNW. Generates useful data
G	Measured data from the site or from a similar occupancy	M	4	
	Other method	M	5	most used in this case *based on ASHRAE/ASPE
	Other method			

Question 5

Here are some features that may be used to select a water heater. Are there any other features that are important. Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	Explanation
A	Water heater efficiency	L		code required, not a lot to consider
B	Cost	H	4	
C	Location where the water heater will be installed	M		
D	Incoming cold-water temperature	L		standard
E	Hot water temperature	L		standard- 140
F	Master mixing valve temperature	L		
G	First hour rating	H	1	important in MF because only 1 peak
H	Recovery efficiency	H	2	direct correlation to system design
I	Heat rate	H	3	direct correlation to system design
J	Location where the storage tank(s) will be installed	M		
K	Volume of storage (one large tank or a number of smaller ones. ASME tanks?)	M		
L	Size of storage tanks (volume, dimensions, ASME tanks?)	M		
M	Heat losses of the circulation loop	L		
N	Brand	L		
O	Is water heater sizing adjusted based on the presence of preheat sources (Solar, etc.)	M		
	Availability			
	other features			

Question 6

Here are some ways to account for future increases in demand when selecting a water heater. Are there any others that you use? Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	Explanation
A	Provide space for additional water heaters	M		
B	Provide space for additional storage tanks	M		
C	Install larger storage as part of initial design	H	3	storage tanks are cheaper to oversize
D	Install additional storage tanks as part of initial design	H	4	storage tanks are cheaper to oversize
E	Install heater with larger heating capacity as part of initial design	H	1	directly correlated to cost
F	Provide additional capacity in the gas line or in the electrical panel	H	2	could be impossible/difficult in the future
	Construction/build limitations			
	Others			

SME 11

Question 3

Here are some key components needed for the sizing of a water heating system. Are there any additional components? Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	Explanation
A	Number of occupants	H	2	establishes demand,
B	Number of apartments	L		
C	Demographics of the occupancy (senior, affordable, families, etc.)	H	3	correlated with how much usage per person
D	Number of bathrooms	L		
E	Type of fixtures	H	4	fixture efficiency/ capability affects demand
F	Age of the plumbing fixtures	H	5	fixture efficiency/ capability affects demand
G	Number of washing machines	M		
H	Location of washing machines (in apartments, shared)	M		
I	Time of day the peak uses occur	L		
J	Duration of the peak periods	L		
K	Gallons per person per day	H	1	derivate the other 4 Highs
L	Type of temperature maintenance system (do you prefer circulation, heat trace, etc.)	L		
M	If circulation, the method of balancing the riser	L		
N	Hot water piping material	L		
O	Length of the hot water piping	L		
P	Diameter and volume of the hot water distribution network	L		
Q	Configuration of the hot water distribution network	L		
R	Insulation on the hot water piping	L		
S	Installation considerations (Building Height, space outdoors)	L		
	Additional components			
	Additional components			

Question 4

Here are some resources used to size water heating systems. Are there any other resources that you use? Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	Explanation
A	ASHRAE	H	3	Industry standard, reduce liability, but not as up to date
B	ASPE	L		
C	IPC	L		
D	IAPMO/ UPC (Uniform Plumbing Code)	M	4	
E	Manufacturer's method	L		
F	EHPWH Tool	H	2	based on more update measured data. Specifically intended for heat pumps. More storage and less recovery. Personal preference
G	Measured data from the site or from a similar occupancy	H	1	if available
	Other method			
	Other method			

Question 5

Here are some features that may be used to select a water heater. Are there any other features that are important. Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	Explanation
A	Water heater efficiency	M		
B	Cost	H	1	client's deciding factor between 2 similar system s
C	Location where the water heater will be installed	M		
D	Incoming cold-water temperature	L		
E	Hot water temperature	L		
F	Master mixing valve temperature	L		
G	First hour rating	M		
H	Recovery efficiency	M		
I	Heat rate	H	2	Location is important based on layout of building and space
J	Location where the storage tank(s) will be installed	H	3	Tanks take up space, heavy need space in the building.
K	Volume of storage (one large tank or a number of smaller ones. ASME tanks?)	M		
L	Size of storage tanks (volume, dimensions, ASME tanks?)	L		
M	Heat losses of the circulation loop	L		
N	Brand	L		
O	Is water heater sizing adjusted based on the presence of preheat sources (Solar, etc.)	L		
P	Gallons per hour (recovery rate)	H	2	Almost identical to (heat rate)
	other features			

Question 6

Here are some ways to account for future increases in demand when selecting a water heater. Are there any others that you use? Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	Explanation
A	Provide space for additional water heaters	H	2	if additional demand is on the same peak as before then more heaters
B	Provide space for additional storage tanks	H	3	if additional demand is off peak then more heaters
C	Install larger storage as part of initial design	L		
D	Install additional storage tanks as part of initial design	L		
E	Install heater with larger heating capacity as part of initial design	L		
F	Provide additional capacity in the gas line or in the electrical panel	H	1	big deciding factor, most upstream. Hard/Impossible to update later
	Others			
	Others			

SME 12

Question 3

Here are some key components needed for the sizing of a water heating system. Are there any additional components? Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	Explanation
A	Number of occupants	H	1	
B	Number of apartments	H	4	
C	Demographics of the occupancy (senior, affordable, families, etc.)	H	2	
D	Number of bathrooms	L		
E	Type of fixtures	M		
F	Age of the plumbing fixtures	M		
G	Number of washing machines	L		
H	Location of washing machines (in apartments, shared)	L		
I	Time of day the peak uses occur	H	5	considering the load profile during peak, potentially during 2 peaks
J	Duration of the peak periods	H	5	considering the load profile during peak, potentially during 2 peaks
K	Gallons per person per day	H	2	
L	Type of temperature maintenance system (do you prefer circulation, heat trace, etc.)	H	3	important for recirc sizing
M	If circulation, the method of balancing the riser	L		
N	Hot water piping material	L		
O	Length of the hot water piping	M		important in design but not sizing
P	Diameter and volume of the hot water distribution network	M		important in design but not sizing
Q	Configuration of the hot water distribution network	M		important in design but not sizing
R	Insulation on the hot water piping	M		important in design but not sizing
S	Installation considerations (Building Height, space outdoors)	M		important in design but not sizing
	Additional components			
	Additional components			

Question 4

Here are some resources used to size water heating systems. Are there any other resources that you use? Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	Explanation
A	ASHRAE	M	4	
B	ASPE	M	4	not as updated with the times, accredited processes
C	IPC	L		
D	IAPMO/ UPC (Uniform Plumbing Code)	L		
E	Manufacturer's method	M	3	more liability
F	EHPWH Tool	H	1	only for heat pump water heaters
G	Measured data from the site or from a similar occupancy	M	2	important to gather these profiles especially with mixed loads
	Other method			
	Other method			

Question 5

Here are some features that may be used to select a water heater. Are there any other features that are important. Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	Explanation
A	Water heater efficiency	H	3	mission driven, be as efficient as possible
B	Cost	H	2	client determinant
C	Location where the water heater will be installed	H	4	safety/regulation considerations. Heater capabilities need for fan, ducts, vents etc.
D	Incoming cold-water temperature	M		
E	Hot water temperature	M		
F	Master mixing valve temperature	L		
G	First hour rating	H	1	
H	Recovery efficiency	H		
I	Heat rate	H	1	not flexible in need
J	Location where the storage tank(s) will be installed	L		
K	Volume of storage (one large tank or a number of smaller ones. ASME tanks?)	H		
L	Size of storage tanks (volume, dimensions, ASME tanks?)	H		
M	Heat losses of the circulation loop	H		
N	Brand	H	5	
O	Is water heater sizing adjusted based on the presence of preheat sources (Solar, etc.)	L		design considerations
P	Gallons per hour (recovery rate)	H	1	
	other features			

Question 6

Here are some ways to account for future increases in demand when selecting a water heater. Are there any others that you use? Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	Explanation
A	Provide space for additional water heaters	H	2	
B	Provide space for additional storage tanks	H	2	
C	Install larger storage as part of initial design	L		oversizing system leads to more stagnant water, more heat losses
D	Install additional storage tanks as part of initial design	L		oversizing system leads to more stagnant water, more heat losses
E	Install heater with larger heating capacity as part of initial design	L		oversizing system leads to more stagnant water, more heat losses
F	Provide additional capacity in the gas line or in the electrical panel	H	1	hard to retrofit, upstream change to make
	Others			
	Others			

SME 13

Question 3

Here are some key components needed for the sizing of a water heating system. Are there any additional components? Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	Explanation
A	Number of occupants	H	1	demand (people use the water)
B	Number of apartments	L		used more often than others
C	Demographics of the occupancy (senior, affordable, families, etc.)	H	2	families use more, singles use less
D	Number of bathrooms	M		
E	Type of fixtures	L		
F	Age of the plumbing fixtures	L		
G	Number of washing machines	M		
H	Location of washing machines (in apartments, shared)	L		
I	Time of day the peak uses occur	L		
J	Duration of the peak periods	H	3	
K	Gallons per person per day	L		
L	Type of temperature maintenance system (do you prefer circulation, heat trace, etc.)	L		
M	If circulation, the method of balancing the riser	L		
N	Hot water piping material	L		
O	Length of the hot water piping	L		
P	Diameter and volume of the hot water distribution network	L		
Q	Configuration of the hot water distribution network	L		
R	Insulation on the hot water piping	M		
S	Installation considerations (Building Height, space outdoors)	M		
	Water softener selection and operation			
	Additional components			

Question 4

Here are some resources used to size water heating systems. Are there any other resources that you use? Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	Explanation
A	ASHRAE	H	1	ASHRAE are professionals' industry standard
B	ASPE	H	2	same as ASHRAE for multifamily
C	IPC	L		
D	IAPMO/ UPC (Uniform Plumbing Code)	L		
E	Manufacturer's method	M		hesitant
F	EHPWH Tool	L		
G	Measured data from the site or from a similar occupancy	L		
	Other method			
	Other method			

Question 5

Here are some features that may be used to select a water heater. Are there any other features that are important. Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	Explanation
A	Water heater efficiency	H	3	
B	Cost	H	2	real life client preference
C	Location where the water heater will be installed	M		
D	Incoming cold-water temperature	L		
E	Hot water temperature	L		
F	Master mixing valve temperature	L		
G	First hour rating	M		
H	Recovery efficiency	M		
I	Heat rate	H	1	meet the load, client cares about
J	Location where the storage tank(s) will be installed	M		
K	Volume of storage (one large tank or a number of smaller ones. ASME tanks?)	L		
L	Size of storage tanks (volume, dimensions, ASME tanks?)	H	4	
M	Heat losses of the circulation loop	L		
N	Brand	M		
O	Is water heater sizing adjusted based on the presence of preheat sources (Solar, etc.)	N/A		
P	Gallons per hour (recovery rate)	H	5	
	other features			

Question 6

<table>
<tr><td colspan="5">Here are some ways to account for future increases in demand when selecting a water heater. Are there any others that you use? Please rank order the top five. Please explain your rankings.</td></tr>
<tr><td colspan="2"></td><td>LMH (Low, Medium, High)</td><td>Rank</td><td>Explanation</td></tr>
<tr><td>A</td><td>Provide space for additional water heaters</td><td>L</td><td></td><td></td></tr>
<tr><td>B</td><td>Provide space for additional storage tanks</td><td>H</td><td>2</td><td></td></tr>
<tr><td>C</td><td>Install larger storage as part of initial design</td><td>L</td><td></td><td></td></tr>
<tr><td>D</td><td>Install additional storage tanks as part of initial design</td><td>L</td><td></td><td></td></tr>
<tr><td>E</td><td>Install heater with larger heating capacity as part of initial design</td><td>H</td><td>1</td><td>20-30 year equipment and no engineer want to get a call 5 years down the line</td></tr>
<tr><td>F</td><td>Provide additional capacity in the gas line or in the electrical panel</td><td>L</td><td></td><td>function of E</td></tr>
<tr><td></td><td>Others</td><td></td><td></td><td></td></tr>
<tr><td></td><td>Others</td><td></td><td></td><td></td></tr>
</table>

SME 14

Question 3

Here are some key components needed for the sizing of a water heating system. Are there any additional components? Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	Explanation
A	Number of occupants	H	1	Inputs to BPA sizing calculator
B	Number of apartments	H	1	Inputs to BPA sizing calculator
C	Demographics of the occupancy (senior, affordable, families, etc.)	M	3	Important if there is load shifting
D	Number of bathrooms	L		Not used in BPA calculator
E	Type of fixtures	L		Not used in BPA calculator
F	Age of the plumbing fixtures	L		Not used in BPA calculator
G	Number of washing machines	L		Not used in BPA calculator
H	Location of washing machines (in apartments, shared)	L		Not used in BPA calculator
I	Time of day the peak uses occur	M	3	Important if there is load shifting. If time of use is not a concern, then sizing will be based on peak demand.
J	Duration of the peak periods	M	3	Important if there is load shifting
K	Gallons per person per day	H	2	Uses other inputs and ASHRAE load assumptions to find gallons per day per person
L	Type of temperature maintenance system (do you prefer circulation, heat trace, etc.)	L	5	Part of the prescribed design configurations.
M	If circulation, the method of balancing the riser	L		Not used in BPA calculator
N	Hot water piping material	L		Not used in BPA calculator

O	Length of the hot water piping	L		Not used in BPA calculator
P	Diameter and volume of the hot water distribution network	L	5	They already consider distribution loses in prescribed design configurations.
Q	Configuration of the hot water distribution network	L	5	They already consider distribution loses in prescribed design configurations.
R	Insulation on the hot water piping	L		Not used in BPA calculator
S	Installation considerations (Building Height, space outdoors)	L		Not used in BPA calculator
	Climate/OAT	H		Inputs to BPA sizing calculator
	Temp of return/supply water (@120F)	H		Inputs to BPA sizing calculator

Question 4

Here are some resources used to size water heating systems. Are there any other resources that you use? Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	Explanation
A	ASHRAE	H	4	Built into EHPWH Tool, but also used by field engineers to cross check the required gallons/day/person.
B	ASPE	L		Not familiar with this.
C	IPC	L		does not consider this.
D	IAPMO/ UPC (Uniform Plumbing Code)	L		does not consider this.
E	Manufacturer's method	M	5	Work with manufacturers to develop QPL and design sizing methods for each product. Specific products in certain design configurations that get approved on QPL. Manufacturers also need to submit performance curve for that product in that approved design configuration. BPA intervenes early to help manufacturers get the ET to market correctly.
F	EHPWH Tool	H	1	Primary calculator method used by BPA. Uses Title 24 engine.
G	Measured data from the site or from a similar occupancy	H	3	Data used to establish baseline energy usage and establish available inputs to sizing calculator (i.e. using temp sensors and flow meters)
	Other method			
	Other method			

Question 5

Here are some features that may be used to select a water heater. Are there any other features that are important. Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	Explanation
A	Water heater efficiency	H	5	all QPL products are efficient, so this is less important
B	Cost	H	1	Top factor
C	Location where the water heater will be installed	H	4	Depends on ambient conditions to select product. i.e., cannot use a heat pump in an enclosed space
D	Incoming cold-water temperature	H	3	Used for sizing method + product selection. Ex. Dairies use a lot of hot water to milk cows uses 70F geothermal water source, so you cannot use a CO2 based HPWH since there is not enough lift or DT.
E	Hot water temperature	M		critical sizing parameter in sizing calculator, but also considered in product selection.
F	Master mixing valve temperature	L		critical in design, not product selection. Part of QPL.
G	First hour rating	M		critical sizing parameter in sizing calculator, but also considered in product selection.
H	Recovery efficiency	M		critical sizing parameter in sizing calculator, but also considered in product selection.
I	Heat rate	H	2	critical for product selection. Products that can provide optimal capacity without being oversized considering modular setups.
J	Location where the storage tank(s) will be installed	L		Already considered in QPL approved designs.
K	Volume of storage (one large tank or a number of smaller ones. ASME tanks?)	L		Already considered in QPL approved designs.
L	Size of storage tanks (volume, dimensions, ASME tanks?)	L		Already considered in QPL approved designs.
M	Heat losses of the circulation loop	L		Already considered in QPL approved designs.

N	Brand	M		Depends on available information on the brand to be selected for the QPL or may be selected as a great opportunity for demo
O	Is water heater sizing adjusted based on the presence of preheat sources (Solar, etc.)	H	3	Same importance as incoming water temperature, which is important for product selection
P	Gallons per hour (recovery rate)	L		
	other features			Validates the preapproved QPL designs. New tiers are established based on submitted MV data.

Question 6

Here are some ways to account for future increases in demand when selecting a water heater. Are there any others that you use? Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	Explanation
A	Provide space for additional water heaters	H	3	Along with tanks, WH space is needed to meet demand
B	Provide space for additional storage tanks	H	2	Storage tanks take up more space than additional WHs
C	Install larger storage as part of initial design	M	5	Hard to predict future demand beyond initial design phase
D	Install additional storage tanks as part of initial design	M	5	Hard to predict future demand beyond initial design phase
E	Install heater with larger heating capacity as part of initial design	H	1	This would reduce need for additional space
F	Provide additional capacity in the gas line or in the electrical panel	M	4	Hard to predict future demand beyond initial design phase
	Others	H	3	Along with tanks, WH space is needed to meet demand
	Others	H	2	Storage tanks take up more space than additional WHs

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Question 3

Here are some key components needed for the sizing of a water heating system. Are there any additional components? Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	Explanation
A	Number of occupants	L		
B	Number of apartments	M		
C	Demographics of the occupancy (senior, affordable, families, etc.)	L		
D	Number of bathrooms	M		multiple bathrooms multiple points of draw
E	Type of fixtures	M		
F	Age of the plumbing fixtures	M		older means higher flow
G	Number of washing machines	M		multiple washing machines means more draw
H	Location of washing machines (in apartments, shared)	M		location affects demand
I	Time of day the peak uses occur	M		in the morning or at night depending on demographic
J	Duration of the peak periods	M		
K	Gallons per person per day	H	1	
L	Type of temperature maintenance system (do you prefer circulation, heat trace, etc.)	H	2	not having adequate hot water in reasonable leads to waste
M	If circulation, the method of balancing the riser	M		
N	Hot water piping material	M		material is important
O	Length of the hot water piping	L		
P	Diameter and volume of the hot water distribution network	M		minimize if possible
Q	Configuration of the hot water distribution network	M		based on architectural layout of system
R	Insulation on the hot water piping	M		
S	Installation considerations (Building Height, space outdoors)	L		lower importance but of relevance
	Other			
	Other			

Question 4

Here are some resources used to size water heating systems. Are there any other resources that you use? Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	Explanation
A	ASHRAE	L		not of much use
B	ASPE	M		
C	IPC	L		
D	IAPMO/ UPC (Uniform Plumbing Code)	M		
E	Manufacturer's method	L		basing on historical data without verification
F	EHPWH Tool	L		
G	Measured data from the site or from a similar occupancy	H		
	Adding Scalability	M		
	Other method			

Question 5

Here are some features that may be used to select a water heater. Are there any other features that are important. Please rank order the top five. Please explain your rankings.

		LMH (Low, Medium, High)	Rank	Explanation
A	Water heater efficiency	H	3	
B	Cost	L		
C	Location where the water heater will be installed	M		
D	Incoming cold-water temperature	L		
E	Hot water temperature	M		scalding a concern
F	Master mixing valve temperature	L		electronic safety controls--MMV might be a waste
G	First hour rating	M		
H	Recovery efficiency	H	1	maintain efficiency of unit
I	Heat rate	H	2	high priority, too high is a waste of energy
J	Location where the storage tank(s) will be installed	M		
K	Volume of storage (one large tank or a number of smaller ones. ASME tanks?)	L		
L	Size of storage tanks (volume, dimensions, ASME tanks?)	H	5	determine dimensional requirements
M	Heat losses of the circulation loop	H	4	
N	Brand	M		reliability and loyalty
O	Is water heater sizing adjusted based on the presence of preheat sources (Solar, etc.)	L		owner driven
P	Gallons per hour (recovery rate)	H	1	
	other features			

Question 6

<table>
<tr><td colspan="5">Here are some ways to account for future increases in demand when selecting a water heater. Are there any others that you use? Please rank order the top five. Please explain your rankings.</td></tr>
<tr><td colspan="2"></td><td>LMH (Low, Medium, High)</td><td>Rank</td><td>Explanation</td></tr>
<tr><td>A</td><td>Provide space for additional water heaters</td><td>M</td><td></td><td></td></tr>
<tr><td>B</td><td>Provide space for additional storage tanks</td><td>M</td><td></td><td></td></tr>
<tr><td>C</td><td>Install larger storage as part of initial design</td><td>H</td><td>3</td><td></td></tr>
<tr><td>D</td><td>Install additional storage tanks as part of initial design</td><td>M</td><td></td><td></td></tr>
<tr><td>E</td><td>Install heater with larger heating capacity as part of initial design</td><td>H</td><td>2</td><td>higher capacity can make it so higher storage is not needed</td></tr>
<tr><td>F</td><td>Provide additional capacity in the gas line or in the electrical panel</td><td>H</td><td>1</td><td>need it for demand</td></tr>
<tr><td></td><td>Others</td><td></td><td></td><td></td></tr>
<tr><td></td><td>Others</td><td></td><td></td><td></td></tr>
</table>

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Question 3

Here are some key components needed for the sizing of a water heating system. Are there any additional components? Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	Explanation
A	Number of occupants	H	1	drives calculations from ASHRAE and ASPE. This establishes demand
B	Number of apartments	H	1	
C	Demographics of the occupancy (senior, affordable, families, etc.)	H	5	different demographics consume different amounts
D	Number of bathrooms	L		
E	Type of fixtures	L		
F	Age of the plumbing fixtures	L		
G	Number of washing machines	L		
H	Location of washing machines (in apartments, shared)	M		
I	Time of day the peak uses occur	L		
J	Duration of the peak periods	H	2	driver in the boiler system
K	Gallons per person per day	H	3	driver in the heat pump system
L	Type of temperature maintenance system (do you prefer circulation, heat trace, etc.)	H	4	
M	If circulation, the method of balancing the riser	L		
N	Hot water piping material	L		
O	Length of the hot water piping	L		
P	Diameter and volume of the hot water distribution network	M		swing tank sizing
Q	Configuration of the hot water distribution network	L		
R	Insulation on the hot water piping	M		
S	Installation considerations (Building Height, space outdoors)	L		
	Other			
	Other			

Question 4

Here are some resources used to size water heating systems. Are there any other resources that you use? Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	Explanation
A	ASHRAE	H	2	
B	ASPE	H	1	
C	IPC	L		
D	IAPMO/ UPC (Uniform Plumbing Code)	L		
E	Manufacturer's method	M		
F	EHPWH Tool	H	3	only for use in Heat Pump
G	Measured data from the site or from a similar occupancy	L		
	Other method			
	Other method			

Question 5

Here are some features that may be used to select a water heater. Are there any other features that are important. Please rank order the top five. Please explain your rankings.

		LMH (Low, Medium, High)	Rank	Explanation
A	Water heater efficiency	M		
B	Cost	M		
C	Location where the water heater will be installed	H	4	
D	Incoming cold-water temperature	L		
E	Hot water temperature	L		
F	Master mixing valve temperature	L		
G	First hour rating	L		
H	Recovery efficiency	H	3	
I	Heat rate	H	1	
J	Location where the storage tank(s) will be installed	M		
K	Volume of storage (one large tank or a number of smaller ones. ASME tanks?)	M		
L	Size of storage tanks (volume, dimensions, ASME tanks?)	H	2	
M	Heat losses of the circulation loop	M		
N	Brand	M		familiarity of certain products
O	Is water heater sizing adjusted based on the presence of preheat sources (Solar, etc.)	M		high if avail
P	Gallons per hour (recovery rate)	H	1	
	other features			

Question 6

Here are some ways to account for future increases in demand when selecting a water heater. Are there any others that you use? Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	Explanation
A	Provide space for additional water heaters	H	2	more flexible with size
B	Provide space for additional storage tanks	H	1	heaviest and hardest to get into building
C	Install larger storage as part of initial design	L		
D	Install additional storage tanks as part of initial design	L		
E	Install heater with larger heating capacity as part of initial design	L		
F	Provide additional capacity in the gas line or in the electrical panel	H	3	
	Others			
	Others			

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Question 3

<table>
<tr><td colspan="5">Here are some key components needed for the sizing of a water heating system. Are there any additional components? Please rank order the top five. Please explain your rankings.</td></tr>
<tr><td></td><td></td><td>LMH (Low, Medium, High)</td><td>Rank</td><td>Explanation</td></tr>
<tr><td>A</td><td>Number of occupants</td><td>H</td><td>1</td><td>drives calculations from ASHRAE and ASPE. This establishes demand</td></tr>
<tr><td>B</td><td>Number of apartments</td><td>H</td><td>1</td><td></td></tr>
<tr><td>C</td><td>Demographics of the occupancy (senior, affordable, families, etc.)</td><td>H</td><td>5</td><td>different demographics consume different amounts</td></tr>
<tr><td>D</td><td>Number of bathrooms</td><td>L</td><td></td><td></td></tr>
<tr><td>E</td><td>Type of fixtures</td><td>L</td><td></td><td></td></tr>
<tr><td>F</td><td>Age of the plumbing fixtures</td><td>L</td><td></td><td></td></tr>
<tr><td>G</td><td>Number of washing machines</td><td>L</td><td></td><td></td></tr>
<tr><td>H</td><td>Location of washing machines (in apartments, shared)</td><td>M</td><td></td><td></td></tr>
<tr><td>I</td><td>Time of day the peak uses occur</td><td>L</td><td></td><td></td></tr>
<tr><td>J</td><td>Duration of the peak periods</td><td>H</td><td>2</td><td>driver in the boiler system</td></tr>
<tr><td>K</td><td>Gallons per person per day</td><td>H</td><td>3</td><td>driver in the heat pump system</td></tr>
<tr><td>L</td><td>Type of temperature maintenance system (do you prefer circulation, heat trace, etc.)</td><td>H</td><td>4</td><td></td></tr>
<tr><td>M</td><td>If circulation, the method of balancing the riser</td><td>L</td><td></td><td></td></tr>
<tr><td>N</td><td>Hot water piping material</td><td>L</td><td></td><td></td></tr>
<tr><td>O</td><td>Length of the hot water piping</td><td>L</td><td></td><td></td></tr>
<tr><td>P</td><td>Diameter and volume of the hot water distribution network</td><td>M</td><td></td><td>swing tank sizing</td></tr>
<tr><td>Q</td><td>Configuration of the hot water distribution network</td><td>L</td><td></td><td></td></tr>
<tr><td>R</td><td>Insulation on the hot water piping</td><td>M</td><td></td><td></td></tr>
<tr><td>S</td><td>Installation considerations (Building Height, space outdoors)</td><td>L</td><td></td><td></td></tr>
<tr><td></td><td>Other</td><td></td><td></td><td></td></tr>
<tr><td></td><td>Other</td><td></td><td></td><td></td></tr>
</table>

Question 4

Here are some resources used to size water heating systems. Are there any other resources that you use? Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	Explanation
A	ASHRAE	H	2	
B	ASPE	H	1	
C	IPC	L		
D	IAPMO/ UPC (Uniform Plumbing Code)	L		
E	Manufacturer's method	M		
F	EHPWH Tool	H	3	only for use in Heat Pump
G	Measured data from the site or from a similar occupancy	L		
	Other method			
	Other method			

Question 5

Here are some features that may be used to select a water heater. Are there any other features that are important. Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	Explanation
A	Water heater efficiency	M		
B	Cost	M		
C	Location where the water heater will be installed	H	4	
D	Incoming cold-water temperature	L		
E	Hot water temperature	L		
F	Master mixing valve temperature	L		
G	First hour rating	L		
H	Recovery efficiency	H	3	
I	Heat rate	H	1	
J	Location where the storage tank(s) will be installed	M		
K	Volume of storage (one large tank or a number of smaller ones. ASME tanks?)	M		
L	Size of storage tanks (volume, dimensions, ASME tanks?)	H	2	
M	Heat losses of the circulation loop	M		
N	Brand	M		familiarity of certain products
O	Is water heater sizing adjusted based on the presence of preheat sources (Solar, etc.)	M		high if avail
P	Gallons per hour (recovery rate)	H	1	
	other features			

Question 6

Here are some ways to account for future increases in demand when selecting a water heater. Are there any others that you use? Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	Explanation
A	Provide space for additional water heaters	H	2	more flexible with size
B	Provide space for additional storage tanks	H	1	heaviest and hardest to get into building
C	Install larger storage as part of initial design	L		
D	Install additional storage tanks as part of initial design	L		
E	Install heater with larger heating capacity as part of initial design	L		
F	Provide additional capacity in the gas line or in the electrical panel	H	3	
	Others			
	Others			

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Question 3

Here are some key components needed for the sizing of a water heating system. Are there any additional components? Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	Explanation
A	Number of occupants	H	1	how many people are using the water with cover expected density. Demand understanding
B	Number of apartments	M		
C	Demographics of the occupancy (senior, affordable, families, etc.)	M		
D	Number of bathrooms	L		
E	Type of fixtures	L		
F	Age of the plumbing fixtures	L		
G	Number of washing machines	M		
H	Location of washing machines (in apartments, shared)	L		
I	Time of day the peak uses occur	H	5	
J	Duration of the peak periods	H	5	
K	Gallons per person per day	H	2	Demand understanding
L	Type of temperature maintenance system (do you prefer circulation, heat trace, etc.)	H	3	energy to push hot water around the building can be 1/2 to 1/3 of the total domestic hot water use.
M	If circulation, the method of balancing the riser	H	3	MF is a 24/7 energy drain on the building.
N	Hot water piping material	L		
O	Length of the hot water piping	M		
P	Diameter and volume of the hot water distribution network	M		
Q	Configuration of the hot water distribution network	M		
R	Insulation on the hot water piping	M		
S	Installation considerations (Building Height, space outdoors)	M		
	Other			
	Other			

Question 4

Here are some resources used to size water heating systems. Are there any other resources that you use? Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	Explanation
A	ASHRAE	H	2	traditional sizing tool
B	ASPE	M		
C	IPC	M		
D	IAPMO/ UPC (Uniform Plumbing Code)	H	4	
E	Manufacturer's method	L		
F	EHPWH Tool	H	1	Updating with lots of data
G	Measured data from the site or from a similar occupancy	H	3	affective if possible
	Other method	H	2	traditional sizing tool
	Other method			

Question 5

Here are some features that may be used to select a water heater. Are there any other features that are important. Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	Explanation
A	Water heater efficiency	H	4	
B	Cost	M		
C	Location where the water heater will be installed	H	2	depending on equipment/ refrigerant type. Location can have a huge impact on capacity, efficiency, and reliability
D	Incoming cold-water temperature	L		
E	Hot water temperature	L		
F	Master mixing valve temperature	L		
G	First hour rating	M		
H	Recovery efficiency	M		
I	Heat rate	H	1	central plants need a balance between capacity and storage. Equipment costs more but storage tanks take up more space. More storage can handle longer peak
J	Location where the storage tank(s) will be installed	L		
K	Volume of storage (one large tank or a number of smaller ones. ASME tanks?)	M		
L	Size of storage tanks (volume, dimensions, ASME tanks?)	H	1	central plants need a balance between capacity and storage. Equipment costs more but storage tanks take up more space. More storage can handle longer peak
M	Heat losses of the circulation loop	M		
N	Brand	M		
O	Is water heater sizing adjusted based on the presence of preheat sources (Solar, etc.)	L		
P	Gallons per hour (recovery rate)	M		
	Average expected air temperature of water heater location (outside/inside/temp outside)	H	3	some refrigerants are effective in different temps

Question 6

Here are some ways to account for future increases in demand when selecting a water heater. Are there any others that you use? Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	Explanation
A	Provide space for additional water heaters	H	2	central plant tanks take up a lot of space so necessary to account for space
B	Provide space for additional storage tanks	H	2	central plant tanks take up a lot of space so necessary to account for space
C	Install larger storage as part of initial design	H	4	oversizing can lead to issues in efficiency and capacity
D	Install additional storage tanks as part of initial design	L		
E	Install heater with larger heating capacity as part of initial design	M		
F	Provide additional capacity in the gas line or in the electrical panel	H	1	if not big enough, huge barrier to increase in demand
	Controls capability to manage plant functionality	H	3	Increase capacity by telling things to turn on sooner rather than later
	Others			

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Question 3

Here are some key components needed for the sizing of a water heating system. Are there any additional components? Please rank order the top five. Please explain your rankings.

		LMH (Low, Medium, High)	Rank	Explanation
A	Number of occupants	H	1	accessible information from ASHRAE and anecdotal sources regarding per person consumption
B	Number of apartments	H	5	
C	Demographics of the occupancy (senior, affordable, families, etc.)	L		
D	Number of bathrooms	M		
E	Type of fixtures	L		all of sizing literature focus on high flow
F	Age of the plumbing fixtures	L		
G	Number of washing machines	M		
H	Location of washing machines (in apartments, shared)	H	4	
I	Time of day the peak uses occur	L		
J	Duration of the peak periods	H	2	
K	Gallons per person per day	H	3	if available
L	Type of temperature maintenance system (do you prefer circulation, heat trace, etc.)	M		
M	If circulation, the method of balancing the riser	M		
N	Hot water piping material	L		
O	Length of the hot water piping	M		
P	Diameter and volume of the hot water distribution network	M		
Q	Configuration of the hot water distribution network	M		
R	Insulation on the hot water piping	M		
S	Installation considerations (Building Height, space outdoors)	M		
	Other			
	Other			

Question 4

Here are some resources used to size water heating systems. Are there any other resources that you use? Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	Explanation
A	ASHRAE	H	3	useful to check as a reference because familiarity and availability
B	ASPE	M		
C	IPC	L		
D	IAPMO/ UPC (Uniform Plumbing Code)	L		
E	Manufacturer's method	H	1	
F	EHPWH Tool	M		useful as a reference
G	Measured data from the site or from a similar occupancy	H	2	if available
	Other method			
	Other method			

Question 5

Here are some features that may be used to select a water heater. Are there any other features that are important? Please rank order the top five. Please explain your rankings.

		LMH (Low, Medium, High)	Rank	Explanation
A	Water heater efficiency	H	3	in initial sizing
B	Cost	H	2	especially for heat pumps
C	Location where the water heater will be installed	H	5	L for gas, H heat pumps
D	Incoming cold-water temperature	L		
E	Hot water temperature	L		standard
F	Master mixing valve temperature	L		
G	First hour rating	L		
H	Recovery efficiency	H	4	
I	Heat rate	H	1	heat rate and size can be inversely proportional
J	Location where the storage tank(s) will be installed	M		
K	Volume of storage (one large tank or a number of smaller ones. ASME tanks?)	L		
L	Size of storage tanks (volume, dimensions, ASME tanks?)	H	1	
M	Heat losses of the circulation loop	M		
N	Brand	H	1	
O	Is water heater sizing adjusted based on the presence of preheat sources (Solar, etc.)	L		
P	Gallons per hour (recovery rate)	H	1	related to capacity
	Others			

Question 6

Here are some ways to account for future increases in demand when selecting a water heater. Are there any others that you use? Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	Explanation
A	Provide space for additional water heaters	H	3	
B	Provide space for additional storage tanks	H	2	
C	Install larger storage as part of initial design	L		
D	Install additional storage tanks as part of initial design	L		
E	Install heater with larger heating capacity as part of initial design	H	1	the easiest and cheapest. Not a lot of infrastructure changes
F	Provide additional capacity in the gas line or in the electrical panel	M		
	Conversion to Heat pump	H	2	region specific
	Others			

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Question 3

Here are some key components needed for the sizing of a water heating system. Are there any additional components? Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	Explanation
A	Number of occupants	H	1	accessible information from ASHRAE and anecdotal sources regarding per person consumption
B	Number of apartments	H	5	
C	Demographics of the occupancy (senior, affordable, families, etc.)	L		
D	Number of bathrooms	M		
E	Type of fixtures	L		all of sizing literature focus on high flow
F	Age of the plumbing fixtures	L		
G	Number of washing machines	M		
H	Location of washing machines (in apartments, shared)	H	4	
I	Time of day the peak uses occur	L		
J	Duration of the peak periods	H	2	
K	Gallons per person per day	H	3	if available
L	Type of temperature maintenance system (do you prefer circulation, heat trace, etc.)	M		
M	If circulation, the method of balancing the riser	M		
N	Hot water piping material	L		
O	Length of the hot water piping	M		
P	Diameter and volume of the hot water distribution network	M		
Q	Configuration of the hot water distribution network	M		
R	Insulation on the hot water piping	M		
S	Installation considerations (Building Height, space outdoors)	M		
	Other			
	Other			

Question 4

Here are some resources used to size water heating systems. Are there any other resources that you use? Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	explanation
A	ASHRAE	H	3	useful to check as a reference because familiarity and availability
B	ASPE	M		
C	IPC	L		
D	IAPMO/ UPC (Uniform Plumbing Code)	L		
E	Manufacturer's method	H	1	
F	EHPWH Tool	M		useful as a reference
G	Measured data from the site or from a similar occupancy	H	2	if available
	Other method			
	Other method			

Question 5

Here are some features that may be used to select a water heater. Are there any other features that are important. Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	Explanation
A	Water heater efficiency	H	3	in initial sizing
B	Cost	H	2	especially for heat pumps
C	Location where the water heater will be installed	H	5	L for gas, H heat pumps
D	Incoming cold-water temperature	L		
E	Hot water temperature	L		standard
F	Master mixing valve temperature	L		
G	First hour rating	L		
H	Recovery efficiency	H	4	
I	Heat rate	H	1	heat rate and size can be inversely proportional
J	Location where the storage tank(s) will be installed	M		
K	Volume of storage (one large tank or a number of smaller ones. ASME tanks?)	L		
L	Size of storage tanks (volume, dimensions, ASME tanks?)	H	1	
M	Heat losses of the circulation loop	M		
N	Brand	H	1	
O	Is water heater sizing adjusted based on the presence of preheat sources (Solar, etc.)	L		
P	Gallons per hour (recovery rate)	H	1	related to capacity
	Others			

Question 6

Here are some ways to account for future increases in demand when selecting a water heater. Are there any others that you use? Please rank order the top five. Please explain your rankings.

		LMH (Low, Medium, High)	Rank	Explanation
A	Provide space for additional water heaters	H	3	
B	Provide space for additional storage tanks	H	2	
C	Install larger storage as part of initial design	L		
D	Install additional storage tanks as part of initial design	L		
E	Install heater with larger heating capacity as part of initial design	H	1	the easiest and cheapest. Not a lot of infrastructure changes
F	Provide additional capacity in the gas line or in the electrical panel	M		
	Others	H	2	region specific
	Others			

SME 21

Question 3

Here are some key components needed for the sizing of a water heating system. Are there any additional components? Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	Explanation
A	Number of occupants	H	1	
B	Number of apartments	H	2	
C	Demographics of the occupancy (senior, affordable, families, etc.)	H	3	not commonly discussed, but necessary
D	Number of bathrooms	M		
E	Type of fixtures	H	1	types of fixtures= number of water closets, showers,
F	Age of the plumbing fixtures	M		
G	Number of washing machines	M		
H	Location of washing machines (in apartments, shared)	L		
I	Time of day the peak uses occur	L		
J	Duration of the peak periods	M		
K	Gallons per person per day	M		
L	Type of temperature maintenance system (do you prefer circulation, heat trace, etc.)	L		
M	If circulation, the method of balancing the riser	L		
N	Hot water piping material	M		
O	Length of the hot water piping	M		
P	Diameter and volume of the hot water distribution network	M		
Q	Configuration of the hot water distribution network	M		
R	Insulation on the hot water piping	L		design consideration, but not sizing
S	Installation considerations (Building Height, space outdoors)	L		design consideration, but not sizing
	Other			
	Other			

Question 4

Here are some resources used to size water heating systems. Are there any other resources that you use? Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Number Rank	Explanation
A	ASHRAE	H	1	a lot of resources in this case
B	ASPE	M		
C	IPC	H	2	
D	IAPMO/ UPC (Uniform Plumbing Code)	H	3	
E	Manufacturer's method	L		
F	EHPWH Tool	M		
G	Measured data from the site or from a similar occupancy	L		ideal if available
	Other method			
	Other method			

Question 5

Here are some features that may be used to select a water heater. Are there any other features that are important. Please rank order the top five. Please explain your rankings.

		LMH (Low, Medium, High)	Rank	Explanation
A	Water heater efficiency	M		
B	Cost	M		
C	Location where the water heater will be installed	H	5	
D	Incoming cold-water temperature	L		
E	Hot water temperature	L		
F	Master mixing valve temperature	L		
G	First hour rating	H	2	
H	Recovery efficiency	H	4	
I	Heat rate	H	3	
J	Location where the storage tank(s) will be installed	M		
K	Volume of storage (one large tank or a number of smaller ones. ASME tanks?)	M		
L	Size of storage tanks (volume, dimensions, ASME tanks?)	M		
M	Heat losses of the circulation loop	L		
N	Brand	L		
O	Is water heater sizing adjusted based on the presence of preheat sources (Solar, etc.)	L		
P	Gallons per hour (recovery rate)	H	1	the one that is biggest difference between gas and HP system. Factor to adjust
	Others			

Question 6

Here are some ways to account for future increases in demand when selecting a water heater. Are there any others that you use? Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	Explanation
A	Provide space for additional water heaters	M		
B	Provide space for additional storage tanks	H	1	easiest, cheapest to plan for
C	Install larger storage as part of initial design	L		
D	Install additional storage tanks as part of initial design	L		
E	Install heater with larger heating capacity as part of initial design	M		
F	Provide additional capacity in the gas line or in the electrical panel	M		
	Others			
	Others			

SME 22

Question 3

Here are some key components needed for the sizing of a water heating system. Are there any additional components? Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	Explanation
A	Number of occupants	H	1	
B	Number of apartments	L		
C	Demographics of the occupancy (senior, affordable, families, etc.)	H		
D	Number of bathrooms	L		
E	Type of fixtures	M		
F	Age of the plumbing fixtures	L		
G	Number of washing machines	M		
H	Location of washing machines (in apartments, shared)	M		
I	Time of day the peak uses occur	L		
J	Duration of the peak periods	H		
K	Gallons per person per day	H	2	number of occupants gppd leads to demand
L	Type of temperature maintenance system (do you prefer circulation, heat trace, etc.)	H	4	circulation is most common, if not important to distinguish. Code requirements for temperature maintenance in NY
M	If circulation, the method of balancing the riser	M		
N	Hot water piping material	L		
O	Length of the hot water piping	M		
P	Diameter and volume of the hot water distribution network	H	5	best way to account for heat loss from distribution network. Nonconsumption load used by the central plant
Q	Configuration of the hot water distribution network	H		
R	Insulation on the hot water piping	H		

S	Installation considerations (Building Height, space outdoors)	H		
	Collected data from an existing building	H	3	actual collected data gives you the duration of the peak, retrofit
	Other			

Question 4

Here are some resources used to size water heating systems. Are there any other resources that you use? Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	Explanation
A	ASHRAE	H	3	caveat that some inconsistencies in ASHRAE
B	ASPE	L		do not use
C	IPC	L		do not use
D	IAPMO/ UPC (Uniform Plumbing Code)	L		do not use
E	Manufacturer's method	M		
F	EHPWH Tool	H	2	like ASHRAE, but easier to point to and more defensible
G	Measured data from the site or from a similar occupancy	H	1	Best way to gather the true load profile
	Utility Bills	H	4	cross check measured data
	Other method			

Question 5

Here are some features that may be used to select a water heater. Are there any other features that are important. Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	explanation
A	Water heater efficiency	H	4	
B	Cost	M		
C	Location where the water heater will be installed	H		
D	Incoming cold-water temperature	L		L in the case of site condition, H in the case of what the heater can handle
E	Hot water temperature	H	3	market cares about legionella, health/safety concerns
F	Master mixing valve temperature	L		less important that hot water temp. hot water temp ensures MMV is met
G	First hour rating	M		
H	Recovery efficiency	M		
I	Heat rate	H	1	need to meet load demand
J	Location where the storage tank(s) will be installed	L		
K	Volume of storage (one large tank or a number of smaller ones. ASME tanks?)	L		
L	Size of storage tanks (volume, dimensions, ASME tanks?)	H	2	dimensions of whole system due to limited space in doorways, buildings, etc.
M	Heat losses of the circulation loop	L		
N	Brand	H	5	Special consideration to previous experience and brand reputation
O	Is water heater sizing adjusted based on the presence of preheat sources (Solar, etc.)	H		
P	Gallons per hour (recovery rate)	L		
	Others			

Question 6

Here are some ways to account for future increases in demand when selecting a water heater. Are there any others that you use? Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	Explanation
A	Provide space for additional water heaters	H	2	
B	Provide space for additional storage tanks	H	1	due to square footage limitation in NY, a huge commodity
C	Install larger storage as part of initial design	L		
D	Install additional storage tanks as part of initial design	L		
E	Install heater with larger heating capacity as part of initial design	L		
F	Provide additional capacity in the gas line or in the electrical panel	H	3	
	Space and Structure	H	1	doorways and square footage.
	Others			

SME 23

Question 3

Here are some key components needed for the sizing of a water heating system. Are there any additional components? Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	Explanation
A	Number of occupants	H	1	this is the primary driver of hot water demand
B	Number of apartments	H	1	surrogate for number of occupants
C	Demographics of the occupancy (senior, affordable, families, etc.)	M		
D	Number of bathrooms	H	2	related to demand
E	Type of fixtures	M		
F	Age of the plumbing fixtures	L		
G	Number of washing machines	H	4	high usage of hot water
H	Location of washing machines (in apartments, shared)	M		
I	Time of day the peak uses occur	M		
J	Duration of the peak periods	H	5	demand
K	Gallons per person per day	H	3	
L	Type of temperature maintenance system (do you prefer circulation, heat trace, etc.)	H		
M	If circulation, the method of balancing the riser	M		
N	Hot water piping material	L		
O	Length of the hot water piping	M		
P	Diameter and volume of the hot water distribution network	M		
Q	Configuration of the hot water distribution network	M		
R	Insulation on the hot water piping	M		
S	Installation considerations (Building Height, space outdoors)	M		
	Other			
	Other			

Question 4

Here are some resources used to size water heating systems. Are there any other resources that you use? Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Number Rank	explanation
A	ASHRAE			
B	ASPE			
C	IPC			
D	IAPMO/ UPC (Uniform Plumbing Code)			
E	Manufacturer's method			
F	EHPWH Tool			
G	Measured data from the site or from a similar occupancy			
	Utility Bills			
	Other method			

Question 5

Here are some features that may be used to select a water heater. Are there any other features that are important. Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	Explanation
A	Water heater efficiency	H	4	overall lifecycle cost, for people motivated by carbon/sustainability
B	Cost	H	3	
C	Location where the water heater will be installed	H	1	can be major limiting case, making it a fundamental design consideration
D	Incoming cold-water temperature	M		
E	Hot water temperature	M		
F	Master mixing valve temperature	M		
G	First hour rating	L		mostly single family, not as much for MF
H	Recovery efficiency	H		
I	Heat rate	H	2	must meet requirements
J	Location where the storage tank(s) will be installed	H		
K	Volume of storage (one large tank or a number of smaller ones. ASME tanks?)	H	1	can be major limiting case, making it a fundamental design case
L	Size of storage tanks (volume, dimensions, ASME tanks?)	H	1	can be major limiting case, making it a fundamental design consideration
M	Heat losses of the circulation loop	L		
N	Brand	L		
O	Is water heater sizing adjusted based on the presence of preheat sources (Solar, etc.)	H	5	if available, big impact on sizing.
P	Gallons per hour (recovery rate)	H	2	FHR for MF, also speaks to delivery
	Warranties (how anode rods)	M		

Question 6

<table>
<tr><td colspan="5">Here are some ways to account for future increases in demand when selecting a water heater. Are there any others that you use? Please rank order the top five. Please explain your rankings.</td></tr>
<tr><td colspan="2"></td><td>LMH (Low, Medium, High)</td><td>Rank</td><td>Explanation</td></tr>
<tr><td>A</td><td>Provide space for additional water heaters</td><td>M</td><td></td><td></td></tr>
<tr><td>B</td><td>Provide space for additional storage tanks</td><td>M</td><td></td><td></td></tr>
<tr><td>C</td><td>Install larger storage as part of initial design</td><td>H</td><td>2</td><td>larger storage, standby losses would be greater</td></tr>
<tr><td>D</td><td>Install additional storage tanks as part of initial design</td><td>M</td><td></td><td></td></tr>
<tr><td>E</td><td>Install heater with larger heating capacity as part of initial design</td><td>H</td><td>1</td><td>oversizing, won’t require more space</td></tr>
<tr><td>F</td><td>Provide additional capacity in the gas line or in the electrical panel</td><td>H</td><td>3</td><td>as an insurance policy would be low cost</td></tr>
<tr><td></td><td>Others</td><td></td><td></td><td></td></tr>
<tr><td></td><td>Others</td><td></td><td></td><td></td></tr>
</table>

SME 24

Question 3

Here are some key components needed for the sizing of a water heating system. Are there any additional components? Please rank order the top five. Please explain your rankings.

		LMH (Low, Medium, High)	Rank	Explanation
A	Number of occupants	H	1	key information on demand
B	Number of apartments	H	4	
C	Demographics of the occupancy (senior, affordable, families, etc.)	H	4	
D	Number of bathrooms	H		
E	Type of fixtures	H	5	water efficiency of the fixtures
F	Age of the plumbing fixtures	H		
G	Number of washing machines	M		
H	Location of washing machines (in apartments, shared)	M		
I	Time of day the peak uses occur	H	3	important for recovery time
J	Duration of the peak periods	H	2	
K	Gallons per person per day	H	1	a result of the prior information, key information on demand
L	Type of temperature maintenance system (do you prefer circulation, heat trace, etc.)	L		
M	If circulation, the method of balancing the riser	L		
N	Hot water piping material	L		
O	Length of the hot water piping	L		
P	Diameter and volume of the hot water distribution network	M		
Q	Configuration of the hot water distribution network	L		
R	Insulation on the hot water piping	L		
S	Installation considerations (Building Height, space outdoors)	L		
	Other			
	Other			

Question 4

Here are some resources used to size water heating systems. Are there any other resources that you use? Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	Explanation
A	ASHRAE	H	2	less accurate then EHPWH Tool
B	ASPE	H	3	
C	IPC	L		
D	IAPMO/ UPC (Uniform Plumbing Code)	L		
E	Manufacturer's method	H	1	not because of trust but need Manufacturer approval and buy off
F	EHPWH Tool	H	1	well-developed tool, more updated ASHRAE values
G	Measured data from the site or from a similar occupancy	H	1	
	Utility Bills			
	Other method			

Question 5

Here are some features that may be used to select a water heater. Are there any other features that are important. Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	Explanation
A	Water heater efficiency	H	2	
B	Cost	H	3	
C	Location where the water heater will be installed	M		
D	Incoming cold-water temperature	H	5	almost no limitations on sizing systems
E	Hot water temperature	H	4	
F	Master mixing valve temperature	L		
G	First hour rating	M		
H	Recovery efficiency	M		
I	Heat rate	M		
J	Location where the storage tank(s) will be installed	M		
K	Volume of storage (one large tank or a number of smaller ones. ASME tanks?)	M		
L	Size of storage tanks (volume, dimensions, ASME tanks?)	H	1	energy storage
M	Heat losses of the circulation loop	L		
N	Brand	L		
O	Is water heater sizing adjusted based on the presence of preheat sources (Solar, etc.)	M		
P	Gallons per hour (recovery rate)	H	1	
	Refrigeration type	M		

Question 6

Here are some ways to account for future increases in demand when selecting a water heater. Are there any others that you use? Please rank order the top five. Please explain your rankings.

		LMH (Low, Medium, High)	Number Rank	Explanation
A	Provide space for additional water heaters	H	3	
B	Provide space for additional storage tanks	H	2	
C	Install larger storage as part of initial design	H	1	If gas system, easily switch out hot water generator. Cap the gas system and switch with electric water heater
D	Install additional storage tanks as part of initial design	H	1	
E	Install heater with larger heating capacity as part of initial design	H	4	
F	Provide additional capacity in the gas line or in the electrical panel	H	1	more electrical
	Others			
	Others			

SME 25

Question 3

Here are some key components needed for the sizing of a water heating system. Are there any additional components? Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	explanation
A	Number of occupants	H	3	Above apartments, In L-income there may be much Her occupancy than typically assumed due to multi-generational living situations.
B	Number of apartments	M		
C	Demographics of the occupancy (senior, affordable, families, etc.)	M		
D	Number of bathrooms	M		
E	Type of fixtures	H	2	When considering building with existing fixtures that were last installed in the 90s compared to new fixtures, this would be an H consideration. AEA typically does not consider but this is important in the "real world"
F	Age of the plumbing fixtures	L		
G	Number of washing machines	M		Typically deals with central washing systems, L income
H	Location of washing machines (in apartments, shared)	L		
I	Time of day the peak uses occur	M		
J	Duration of the peak periods	M		
K	Gallons per person per day	H	1	Based on the type of building, load shapes are consistent across this building type. So, he can consider the overall consumption assuming the same load shape. Considers demographic.

L	Type of temperature maintenance system (do you prefer circulation, heat trace, etc.)	M		
M	If circulation, the method of balancing the riser	H		Typically, all risers are located next to each other. supply, return, etc.
N	Hot water piping material	L		
O	Length of the hot water piping	M		
P	Diameter and volume of the hot water distribution network	M		
Q	Configuration of the hot water distribution network	H	4	Network could be tight or sprawling. Architect does not typically consider this and locates central system that is convenient for design but not optimal for distribution.
R	Insulation on the hot water piping	H	5	Addressed in existing buildings to bring load down for electric replacements. Huge issue for existing
S	Installation considerations (Building Height, space outdoors)	M		
	Other			
	Other			

Question 4

<table>
<tr><td colspan="5">Here are some resources used to size water heating systems. Are there any other resources that you use? Please rank order the top five. Please explain your rankings.</td></tr>
<tr><td></td><td></td><td>LMH (Low, Medium, High)</td><td>Rank</td><td>explanation</td></tr>
<tr><td>A</td><td>ASHRAE</td><td>H</td><td>1</td><td>Used by Company A Tool, so equally important</td></tr>
<tr><td>B</td><td>ASPE</td><td>H</td><td>2</td><td>Used for smaller systems, using fixture counts.</td></tr>
<tr><td>C</td><td>IPC</td><td>L</td><td></td><td></td></tr>
<tr><td>D</td><td>IAPMO/ UPC (Uniform Plumbing Code)</td><td>L</td><td></td><td></td></tr>
<tr><td>E</td><td>Manufacturer's method</td><td>M</td><td>4</td><td>Sometimes used based on manufacturer</td></tr>
<tr><td>F</td><td>EHPWH Tool</td><td>H</td><td>1</td><td>Work directly with Company A, i.e. Company A project. But they have considered if this tool is oversized. All comparing storage and recovery, which are important.</td></tr>
<tr><td>G</td><td>Measured data from the site or from a similar occupancy</td><td>H</td><td>3</td><td>Very effective way to meet demand for similar sites.</td></tr>
<tr><td></td><td>Utility Bills</td><td></td><td></td><td></td></tr>
<tr><td></td><td>Other method</td><td></td><td></td><td></td></tr>
</table>

Question 5

Here are some features that may be used to select a water heater. Are there any other features that are important. Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	explanation
A	Water heater efficiency	H	4	The variations in efficiency between different HPWH is typically not an important factor when replacing gas equipment. Typically plant efficiency is considered independent of individual HPWH efficiency. Efficiency can be important to consider in colder environments, i.e. CO2 vs Model A heat pumps, to meet loads at Ler temps.
B	Cost	H	3	May have a few viable options, but significant cost difference will favor least expensive.
C	Location where the water heater will be installed	H	1	very different forms factors for HPWH systems.
D	Incoming cold-water temperature	L		
E	Hot water temperature	L		
F	Master mixing valve temperature	L		
G	First hour rating	L		
H	Recovery efficiency	M		
I	Heat rate	H	2	Must meet the sizing demand. Look at capacity and space to determine design.
J	Location where the storage tank(s) will be installed	M		
K	Volume of storage (one large tank or a number of smaller ones. ASME tanks?)	M	5	Tradeoffs between storage and recovery. Designer can opt for either to meet load.
L	Size of storage tanks (volume, dimensions, ASME tanks?)	M		
M	Heat losses of the circulation loop	L		
N	Brand	M		

O	Is water heater sizing adjusted based on the presence of preheat sources (Solar, etc.)	L		
P	Gallons per hour (recovery rate)	M		
	Others			

Question 6

Here are some ways to account for future increases in demand when selecting a water heater. Are there any others that you use? Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	Explanation
A	Provide space for additional water heaters	M	5	
B	Provide space for additional storage tanks	M	4	Not seen
C	Install larger storage as part of initial design	H	1	Can benefit project to all for load shifting without need for increased demand.
D	Install additional storage tanks as part of initial design	H	2	Same as (c)
E	Install heater with larger heating capacity as part of initial design	H	3	If load shifting, you need to recover storage in smaller timeframe. So, it can be beneficial without the need for Her load. There are more heat pumps installed instead of larger heat pumps for redundancy and prevent downtime.
F	Provide additional capacity in the gas line or in the electrical panel	L		
	Others			
	Others			

SME 26

Question 3

Here are some key components needed for the sizing of a water heating system. Are there any additional components? Please rank order the top five. Please explain your rankings.

		LMH (Low, Medium, High)	Rank	explanation
A	Number of occupants	M		
B	Number of apartments	H	2	driver for how much water is needed
C	Demographics of the occupancy (senior, affordable, families, etc.)	H	3	demographics speak to peak period/ time
D	Number of bathrooms	H	1	#1 because usually the amount of water/ flow needed
E	Type of fixtures	L		don't apply in new construction,
F	Age of the plumbing fixtures	L		
G	Number of washing machines	H	4	
H	Location of washing machines (in apartments, shared)	H	5	
I	Time of day the peak uses occur	M		
J	Duration of the peak periods	M		
K	Gallons per person per day	M		
L	Type of temperature maintenance system (do you prefer circulation, heat trace, etc.)	M		
M	If circulation, the method of balancing the riser	H		
N	Hot water piping material	M		
O	Length of the hot water piping	H		
P	Diameter and volume of the hot water distribution network	L		
Q	Configuration of the hot water distribution network	M		
R	Insulation on the hot water piping	L		NA in new construction
S	Installation considerations (Building Height, space outdoors)	L		
	Other			
	Other			

Question 4

Here are some resources used to size water heating systems. Are there any other resources that you use? Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	explanation
A	ASHRAE	L		
B	ASPE	L		
C	IPC	M		
D	IAPMO/ UPC (Uniform Plumbing Code)	H	2	more of sizing pipes than system sizing
E	Manufacturer's method	H	1	sizing systems globally
F	EHPWH Tool	L		
G	Measured data from the site or from a similar occupancy	H	3	if avail
	Utility Bills	H	4	
	Other method			

Question 5

Here are some features that may be used to select a water heater. Are there any other features that are important. Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	explanation
A	Water heater efficiency	M		
B	Cost	H	2	the biggest driver in new construction
C	Location where the water heater will be installed	H	4	
D	Incoming cold-water temperature	H	5	
E	Hot water temperature	M		
F	Master mixing valve temperature	M		
G	First hour rating	M		individual water heaters
H	Recovery efficiency	H		
I	Heat rate	M		new construction allowing for more flexibility
J	Location where the storage tank(s) will be installed	M		
K	Volume of storage (one large tank or a number of smaller ones. ASME tanks?)	M		
L	Size of storage tanks (volume, dimensions, ASME tanks?)	H	3	
M	Heat losses of the circulation loop	L		
N	Brand	L		
O	Is water heater sizing adjusted based on the presence of preheat sources (Solar, etc.)	M		
P	Gallons per hour (recovery rate)	H	1	Determines how much storage and would determine sizing
	Others			

Question 6

Here are some ways to account for future increases in demand when selecting a water heater. Are there any others that you use? Please rank order the top five. Please explain your rankings.

		LMH (Low, Medium, High)	Rank	Explanation
A	Provide space for additional water heaters	M		
B	Provide space for additional storage tanks	H	1	expandability
C	Install larger storage as part of initial design	H	2	
D	Install additional storage tanks as part of initial design	H	2	
E	Install heater with larger heating capacity as part of initial design	M		
F	Provide additional capacity in the gas line or in the electrical panel	M		
	Others			
	Others			

SME 27

Question 3

Here are some key components needed for the sizing of a water heating system. Are there any additional components? Please rank order the top five. Please explain your rankings.

		LMH (Low, Medium, High)	Rank	explanation
A	Number of occupants	H	1	
B	Number of apartments	H	1	for heat pump systems
C	Demographics of the occupancy (senior, affordable, families, etc.)	M		
D	Number of bathrooms	H	1	number of fixtures
E	Type of fixtures	L		
F	Age of the plumbing fixtures	H	1	flowrate
G	Number of washing machines	L		
H	Location of washing machines (in apartments, shared)	L		
I	Time of day the peak uses occur	L/H	2	L for combustion, H for heat pump
J	Duration of the peak periods	L/H	1	L for combustion, H for heat pump
K	Gallons per person per day	H	1	heat pumps
L	Type of temperature maintenance system (do you prefer circulation, heat trace, etc.)	L/H	3	L for gas, H for heat pump
M	If circulation, the method of balancing the riser	L		
N	Hot water piping material	L		
O	Length of the hot water piping	L		
P	Diameter and volume of the hot water distribution network	L		
Q	Configuration of the hot water distribution network	H	3	heat pumps
R	Insulation on the hot water piping	H	2	very important for [customer]
S	Installation considerations (Building Height, space outdoors)	H	2	very important for [customer]
	Other			
	Other			

Question 4

Here are some resources used to size water heating systems. Are there any other resources that you use? Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	explanation
A	ASHRAE	H	1	more scientific resources, more empirical evidence with ASHRAE
B	ASPE	H	2	
C	IPC	M		
D	IAPMO/ UPC (Uniform Plumbing Code)	M		
E	Manufacturer's method	L		a function of the others more traditional resources
F	EHPWH Tool	H	1	heat pumps, Company A has most empirical evidence
G	Measured data from the site or from a similar occupancy	M		
	Utility Bills			
	Other method			

Question 5

Here are some features that may be used to select a water heater. Are there any other features that are important. Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	explanation
A	Water heater efficiency	H	1	MF buildings, cost of energy is top priority
B	Cost	H	2	
C	Location where the water heater will be installed	H	2	physical size of tool
D	Incoming cold-water temperature	L		
E	Hot water temperature	L		
F	Master mixing valve temperature	L		
G	First hour rating	H		storage water heater
H	Recovery efficiency	H		storage water heater
I	Heat rate	H	4	how to balance capacity and storage capability
J	Location where the storage tank(s) will be installed	L		so long as not freezing
K	Volume of storage (one large tank or a number of smaller ones. ASME tanks?)	L		
L	Size of storage tanks (volume, dimensions, ASME tanks?)	H	3	
M	Heat losses of the circulation loop	L		H for heat pumps
N	Brand	H		
O	Is water heater sizing adjusted based on the presence of preheat sources (Solar, etc.)	L		
P	Gallons per hour (recovery rate)	H	5	def for heat pumps
	Others			

Question 6

Here are some ways to account for future increases in demand when selecting a water heater. Are there any others that you use? Please rank order the top five. Please explain your rankings.

		LMH (Low, Medium, High)	Rank	Explanation
A	Provide space for additional water heaters	M		
B	Provide space for additional storage tanks	H	1	heat pumps
C	Install larger storage as part of initial design	H	1	
D	Install additional storage tanks as part of initial design	M		
E	Install heater with larger heating capacity as part of initial design	M	2	
F	Provide additional capacity in the gas line or in the electrical panel	H	2,5	heat pumps 2, gas 5
	Others			
	Others			

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Question 3

Here are some key components needed for the sizing of a water heating system. Are there any additional components? Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	explanation
A	Number of occupants	H	1	First thing to consider when using sizing tool.
B	Number of apartments	M		Related to number of occupants.
C	Demographics of the occupancy (senior, affordable, families, etc.)	M		Related to number of occupants.
D	Number of bathrooms	H	2	Next thing to consider when using sizing tool.
E	Type of fixtures	H	3	Next thing to consider when using sizing tool.
F	Age of the plumbing fixtures	L		
G	Number of washing machines	H	4	Next thing to consider when using sizing tool.
H	Location of washing machines (in apartments, shared)	L		
I	Time of day the peak uses occur	L		
J	Duration of the peak periods	L		
K	Gallons per person per day	M		Result from using sizing tools.
L	Type of temperature maintenance system (do you prefer circulation, heat trace, etc.)	L		need to install fL meter on return to properly manage circulation. Temperature maintenance is not preferred for constant pumps without knowing fL. Even systems with variable fL options are typically bypassed since it is hard to properly manage fL and temperature.
M	If circulation, the method of balancing the riser	H	5	Last thing to consider in sizing tool.
N	Hot water piping material	L		
O	Length of the hot water piping	L		

P	Diameter and volume of the hot water distribution network	L		
Q	Configuration of the hot water distribution network	L		
R	Insulation on the hot water piping	M		Depends if insulation on the entire system or just exposed piping. Oversized systems typically cover poor insulation anyways, so this is not considered.
S	Installation considerations (Building Height, space outdoors)	M		Same as previous (r)
	Other			
	Other			

Question 4

Here are some resources used to size water heating systems. Are there any other resources that you use? Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	explanation
A	ASHRAE	L		Doesn't use this.
B	ASPE	L		Doesn't use this.
C	IPC	L		Doesn't use this.
D	IAPMO/ UPC (Uniform Plumbing Code)	L		Doesn't use this.
E	Manufacturer's method	H	3	[Company B, Company C] (direct fired)
F	EHPWH Tool	H	1	used for heat pumps. Recently used the most due to increased HPWH installs.
G	Measured data from the site or from a similar occupancy	M	4	Backup method. Based on experience you can backup final design. Cannot size a site since they are unique.
	Utility Bills			
	Other method			

Question 5

Here are some features that may be used to select a water heater. Are there any other features that are important. Please rank order the top five. Please explain your rankings.

		LMH (Low, Medium, High)	Rank	explanation
A	Water heater efficiency	M		
B	Cost	H	4	Cost depends on location. Again, the cost for larger water heaters is usually not that much for the same models. The location may increase/decrease costs for installation or retrofitting depending on available space, indoor/outdoor.
C	Location where the water heater will be installed	H	3	Location affects the type of water heaters and affects the cost as mentioned above.
D	Incoming cold-water temperature	L		More important for heat pumps in colder environments. typical constant 63.8F cold water in found across CA so this is not considered when selecting.
E	Hot water temperature	L		These days, there is no need to supply greater than 120F unless there is a bad circulation system or bad crossover. Most water heaters can be easily adjusted to Her temps, so this not important.
F	Master mixing valve temperature	L		Same reasoning as response for (E)
G	First hour rating	L		Sizing tools already do this
H	Recovery efficiency	L		Sizing tools already do this
I	Heat rate	H	1	Essential to sizing. Primary consideration when selecting.
J	Location where the storage tank(s) will be installed	M	5	Storage should be as close as possible to the water heater to avoid losses. But this is not as important as other factors.
K	Volume of storage (one large tank or a number of smaller ones. ASME tanks?)	L		
L	Size of storage tanks (volume, dimensions, ASME tanks?)	H	2	interrelated with capacity. Designer can consider Ler capacity heater with more storage, or vice versa to meet demand for storage water heating systems.
M	Heat losses of the circulation loop	L		

N	Brand	L		Depends on business relationships.
O	Is water heater sizing adjusted based on the presence of preheat sources (Solar, etc.)	L		Water heater sizing is done considering these additional heat sources are not always available. So, these are considered redundancies.
P	Gallons per hour (recovery rate)	L		
	Others			

Question 6

Here are some ways to account for future increases in demand when selecting a water heater. Are there any others that you use? Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	Explanation
A	Provide space for additional water heaters	H	2	This is important especially for indoor/enclosed installations.
B	Provide space for additional storage tanks	H	3	Equally important as additional space for water heaters. Depends on how much more demand to meet. If there is only a small increase demand that can be met from increasing from 40-50gallon to 70-80 gallons then water heater storage will only increase in height. But larger demands will require much more space. Designer can choose more water heaters or increased storage to meet demand, so it depends on the designer.
C	Install larger storage as part of initial design	L		
D	Install additional storage tanks as part of initial design	L		
E	Install heater with larger heating capacity as part of initial design	L	5	Last resort unless you know the future demand to reduce costs.
F	Provide additional capacity in the gas line or in the electrical panel	H	1	most expensive retrofit.
	ensure proper ventilation for combustible water heaters	M	4	This is something to consider for indoor installations.
	Others			

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Question 3

Here are some key components needed for the sizing of a water heating system. Are there any additional components? Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	explanation
A	Number of occupants	L		
B	Number of apartments	H	2	determine demand
C	Demographics of the occupancy (senior, affordable, families, etc.)	M		
D	Number of bathrooms	H	1	overall peak capacity and load (specifically # of showers)
E	Type of fixtures	L		
F	Age of the plumbing fixtures	L		
G	Number of washing machines	H	3	determining peak demand/ load
H	Location of washing machines (in apartments, shared)	H	4	
I	Time of day the peak uses occur	M		
J	Duration of the peak periods	L		
K	Gallons per person per day	L		
L	Type of temperature maintenance system (do you prefer circulation, heat trace, etc.)	L		
M	If circulation, the method of balancing the riser	L		
N	Hot water piping material	L		
O	Length of the hot water piping	M		
P	Diameter and volume of the hot water distribution network	M		
Q	Configuration of the hot water distribution network	M		
R	Insulation on the hot water piping	L		
S	Installation considerations (Building Height, space outdoors)	L		
	Other			
	Other			

Question 4

Here are some resources used to size water heating systems. Are there any other resources that you use? Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	explanation
A	ASHRAE	L		
B	ASPE	L		
C	IPC	L		
D	IAPMO/ UPC (Uniform Plumbing Code)	M		
E	Manufacturer's method	H	1	no engineers on staff to ensure proper sizing--manufacturers can ensure proper sizing
F	EHPWH Tool	L		
G	Measured data from the site or from a similar occupancy	M		
	Utility Bills			
	Other method			

Question 5

Here are some features that may be used to select a water heater. Are there any other features that are important. Please rank order the top five. Please explain your rankings.

		LMH (Low, Medium, High)	Rank	explanation
A	Water heater efficiency	M		
B	Cost	H	1	customer is paying-- v important
C	Location where the water heater will be installed	L		
D	Incoming cold-water temperature	L		
E	Hot water temperature	M		
F	Master mixing valve temperature	L		
G	First hour rating	H	3	ensure proper sizing
H	Recovery efficiency	M		
I	Heat rate	M		
J	Location where the storage tank(s) will be installed	L		
K	Volume of storage (one large tank or a number of smaller ones. ASME tanks?)	M		
L	Size of storage tanks (volume, dimensions, ASME tanks?)	M		
M	Heat losses of the circulation loop	M		
N	Brand	H	4	loyalty- will the manufacturer stand beside a project
O	Is water heater sizing adjusted based on the presence of preheat sources (Solar, etc.)	L		
P	Gallons per hour (recovery rate)	H	2	ensure its ability to meet demand
	Incentives	H	1	

Question 6

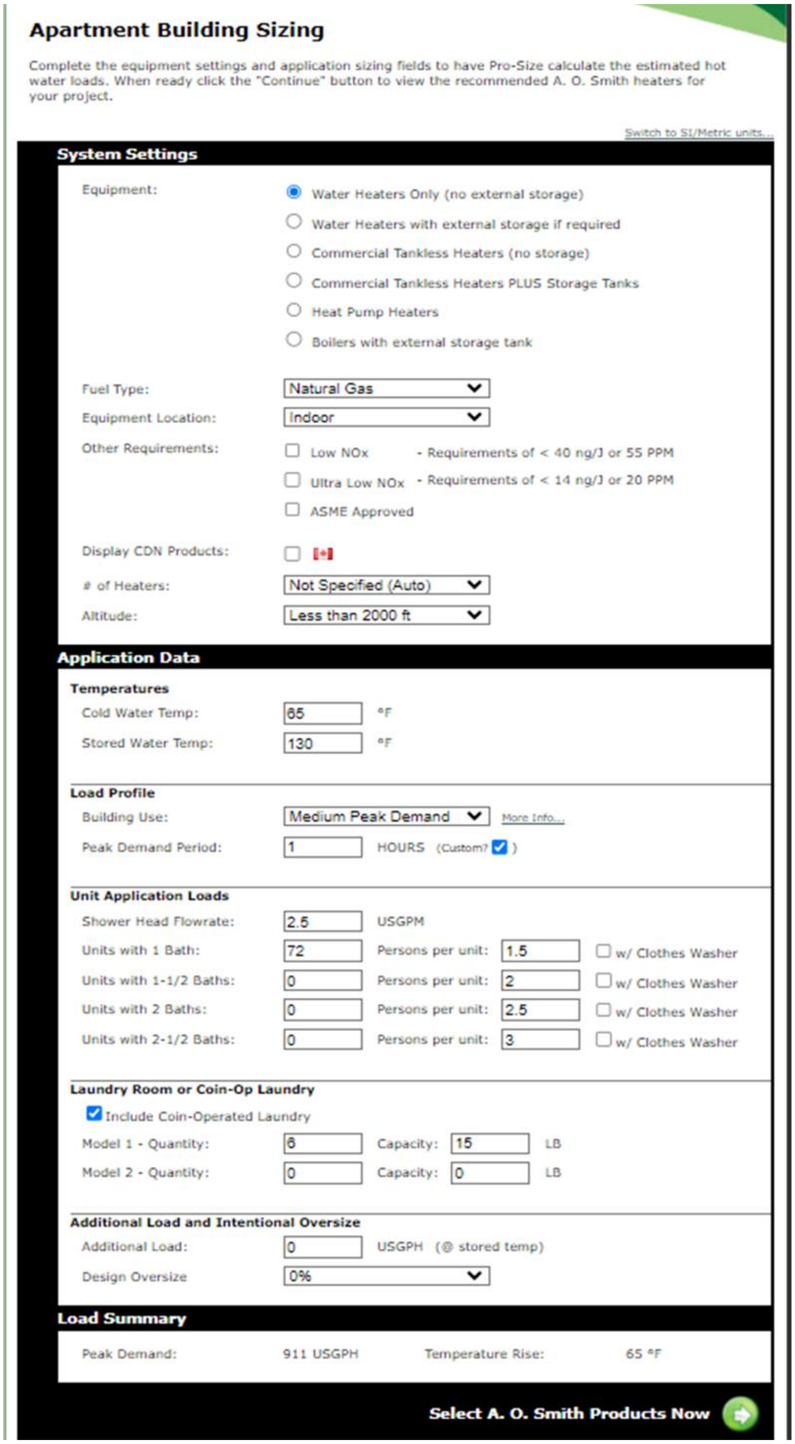
Here are some ways to account for future increases in demand when selecting a water heater. Are there any others that you use? Please rank order the top five. Please explain your rankings.				
		LMH (Low, Medium, High)	Rank	Explanation
A	Provide space for additional water heaters	H	2	
B	Provide space for additional storage tanks	H	4	
C	Install larger storage as part of initial design	H	3	
D	Install additional storage tanks as part of initial design	L		
E	Install heater with larger heating capacity as part of initial design	H	1	simplest way to increase demand
F	Provide additional capacity in the gas line or in the electrical panel	M		
	Others			
	Others			

Appendix 2: Site Specific Sizing Tool Screenshots

Site 1

MFG Tool 2

Input



Apartment Building Sizing

Complete the equipment settings and application sizing fields to have Pro-Size calculate the estimated hot water loads. When ready click the "Continue" button to view the recommended A. O. Smith heaters for your project.

Switch to SI/Metric units...

System Settings

Equipment:
● Water Heaters Only (no external storage)
○ Water Heaters with external storage if required
○ Commercial Tankless Heaters (no storage)
○ Commercial Tankless Heaters PLUS Storage Tanks
○ Heat Pump Heaters
○ Boilers with external storage tank

Fuel Type: Natural Gas
Equipment Location: Indoor
Other Requirements:
☐ Low NOx - Requirements of < 40 ng/J or 55 PPM
☐ Ultra Low NOx - Requirements of < 14 ng/J or 20 PPM
☐ ASME Approved

Display CDN Products: ☐
\# of Heaters: Not Specified (Auto)
Altitude: Less than 2000 ft

Application Data

Temperatures
Cold Water Temp: 65 °F
Stored Water Temp: 130 °F

Load Profile
Building Use: Medium Peak Demand More Info...
Peak Demand Period: 1 HOURS (Custom? ☑)

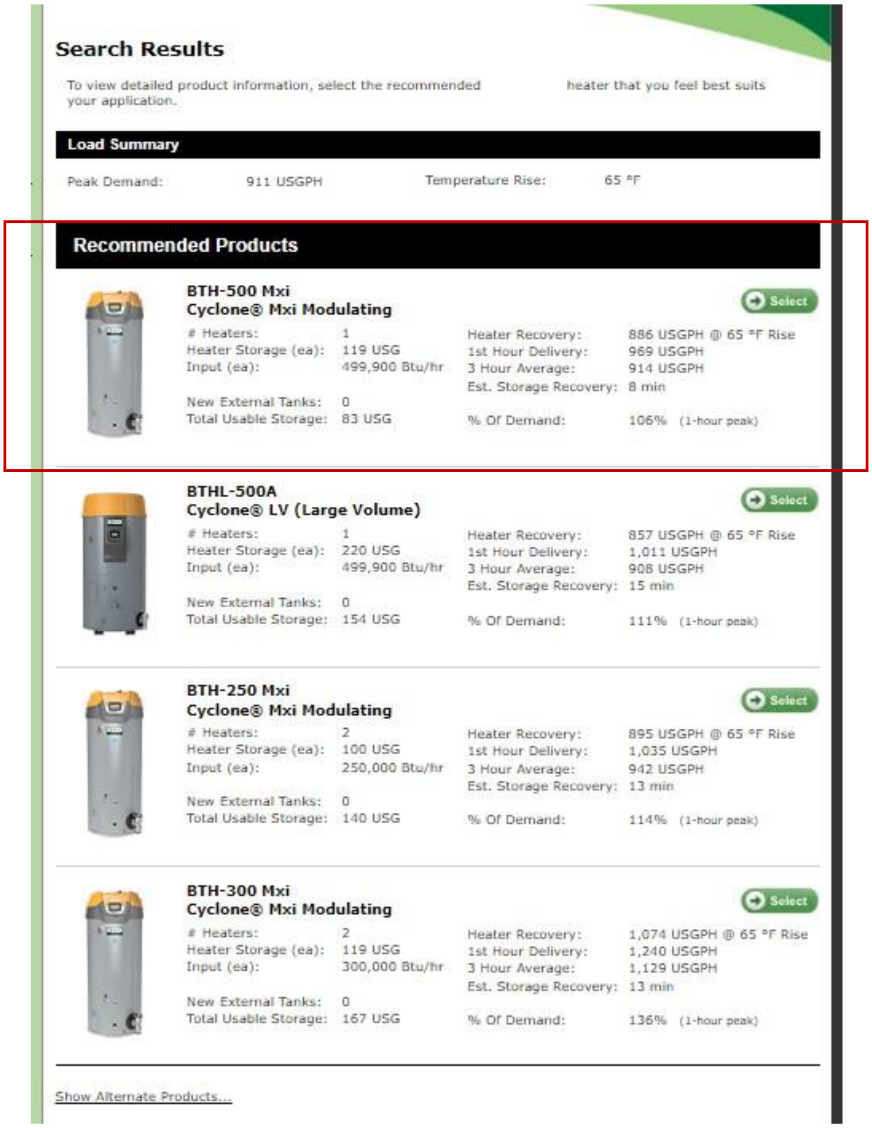
Unit Application Loads
Shower Head Flowrate: 2.5 USGPM
Units with 1 Bath: 72 Persons per unit: 1.5 ☐ w/ Clothes Washer
Units with 1-1/2 Baths: 0 Persons per unit: 2 ☐ w/ Clothes Washer
Units with 2 Baths: 0 Persons per unit: 2.5 ☐ w/ Clothes Washer
Units with 2-1/2 Baths: 0 Persons per unit: 3 ☐ w/ Clothes Washer

Laundry Room or Coin-Op Laundry
☑ Include Coin-Operated Laundry
Model 1 - Quantity: 6 Capacity: 15 LB
Model 2 - Quantity: 0 Capacity: 0 LB

Additional Load and Intentional Oversize
Additional Load: 0 USGPH (@ stored temp)
Design Oversize 0%

Load Summary
Peak Demand: 911 USGPH Temperature Rise: 65 °F

Output



Search Results

To view detailed product information, select the recommended heater that you feel best suits your application.

Load Summary

Peak Demand: 911 USGPH
Temperature Rise: 65 °F

Recommended Products

BTH-500 Mxi
Cyclone® Mxi Modulating
Heaters: 1
Heater Storage (ea): 119 USG
Input (ea): 499,900 Btu/hr
New External Tanks: 0
Total Usable Storage: 83 USG
Heater Recovery: 886 USGPH @ 65 °F Rise
1st Hour Delivery: 969 USGPH
3 Hour Average: 914 USGPH
Est. Storage Recovery: 8 min
% Of Demand: 106% (1-hour peak)

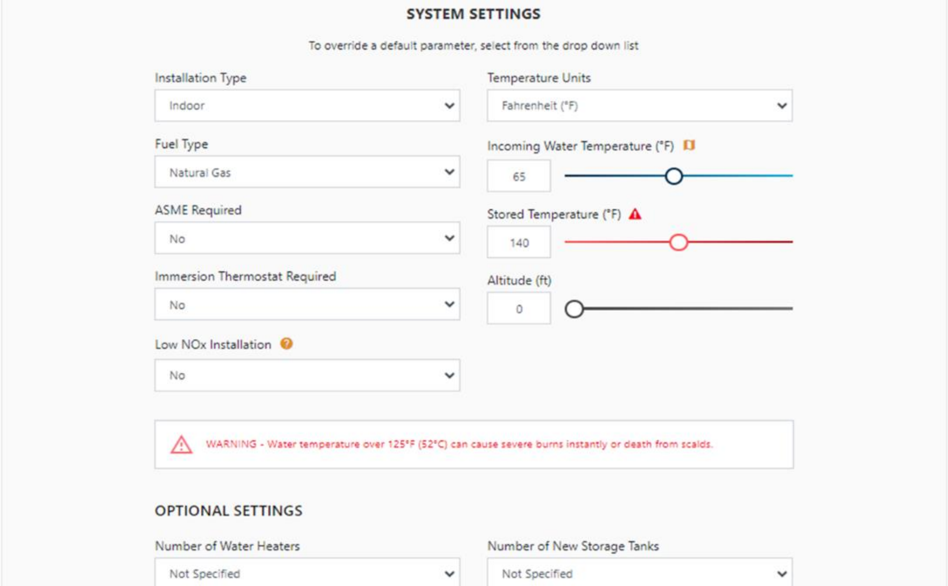
BTHL-500A
Cyclone® LV (Large Volume)
Heaters: 1
Heater Storage (ea): 220 USG
Input (ea): 499,900 Btu/hr
New External Tanks: 0
Total Usable Storage: 154 USG
Heater Recovery: 857 USGPH @ 65 °F Rise
1st Hour Delivery: 1,011 USGPH
3 Hour Average: 908 USGPH
Est. Storage Recovery: 15 min
% Of Demand: 111% (1-hour peak)

BTH-250 Mxi
Cyclone® Mxi Modulating
Heaters: 2
Heater Storage (ea): 100 USG
Input (ea): 250,000 Btu/hr
New External Tanks: 0
Total Usable Storage: 140 USG
Heater Recovery: 895 USGPH @ 65 °F Rise
1st Hour Delivery: 1,035 USGPH
3 Hour Average: 942 USGPH
Est. Storage Recovery: 13 min
% Of Demand: 114% (1-hour peak)

BTH-300 Mxi
Cyclone® Mxi Modulating
Heaters: 2
Heater Storage (ea): 119 USG
Input (ea): 300,000 Btu/hr
New External Tanks: 0
Total Usable Storage: 167 USG
Heater Recovery: 1,074 USGPH @ 65 °F Rise
1st Hour Delivery: 1,240 USGPH
3 Hour Average: 1,129 USGPH
Est. Storage Recovery: 13 min
% Of Demand: 136% (1-hour peak)

MFG Tool 1

Input



SYSTEM SETTINGS

To override a default parameter, select from the drop down list

Installation Type: Indoor

Temperature Units: Fahrenheit (°F)

Fuel Type: Natural Gas

Incoming Water Temperature (°F): 65

ASME Required: No

Stored Temperature (°F): 140

Immersion Thermostat Required: No

Altitude (ft): 0

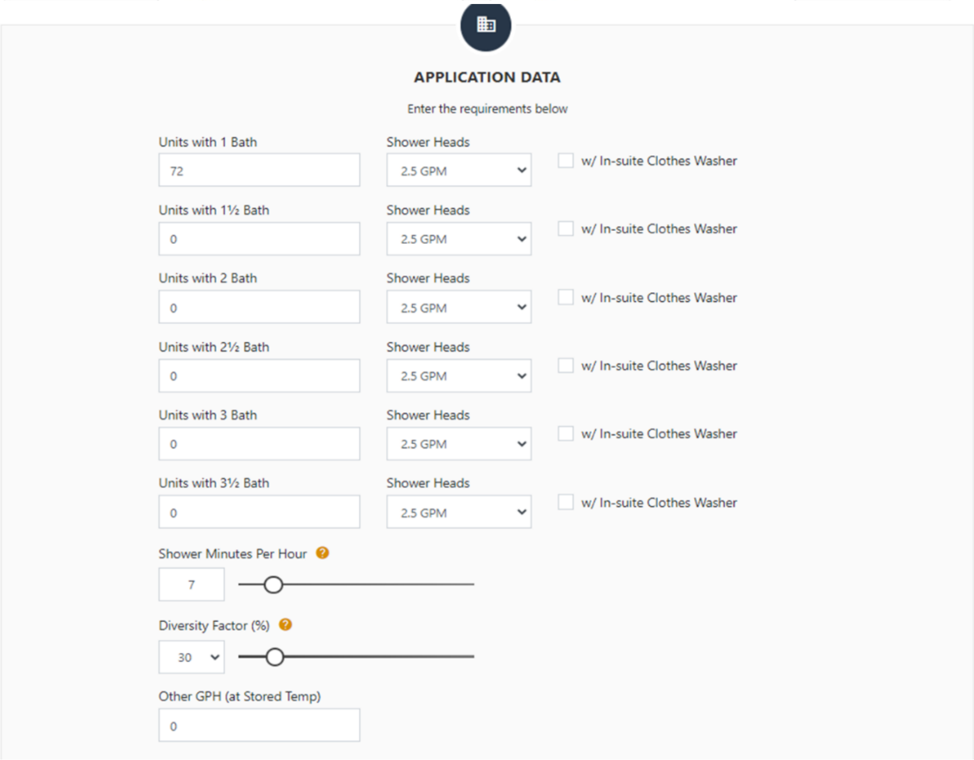
Low NOx Installation: No

WARNING - Water temperature over 125°F (52°C) can cause severe burns instantly or death from scalds.

OPTIONAL SETTINGS

Number of Water Heaters: Not Specified

Number of New Storage Tanks: Not Specified



APPLICATION DATA

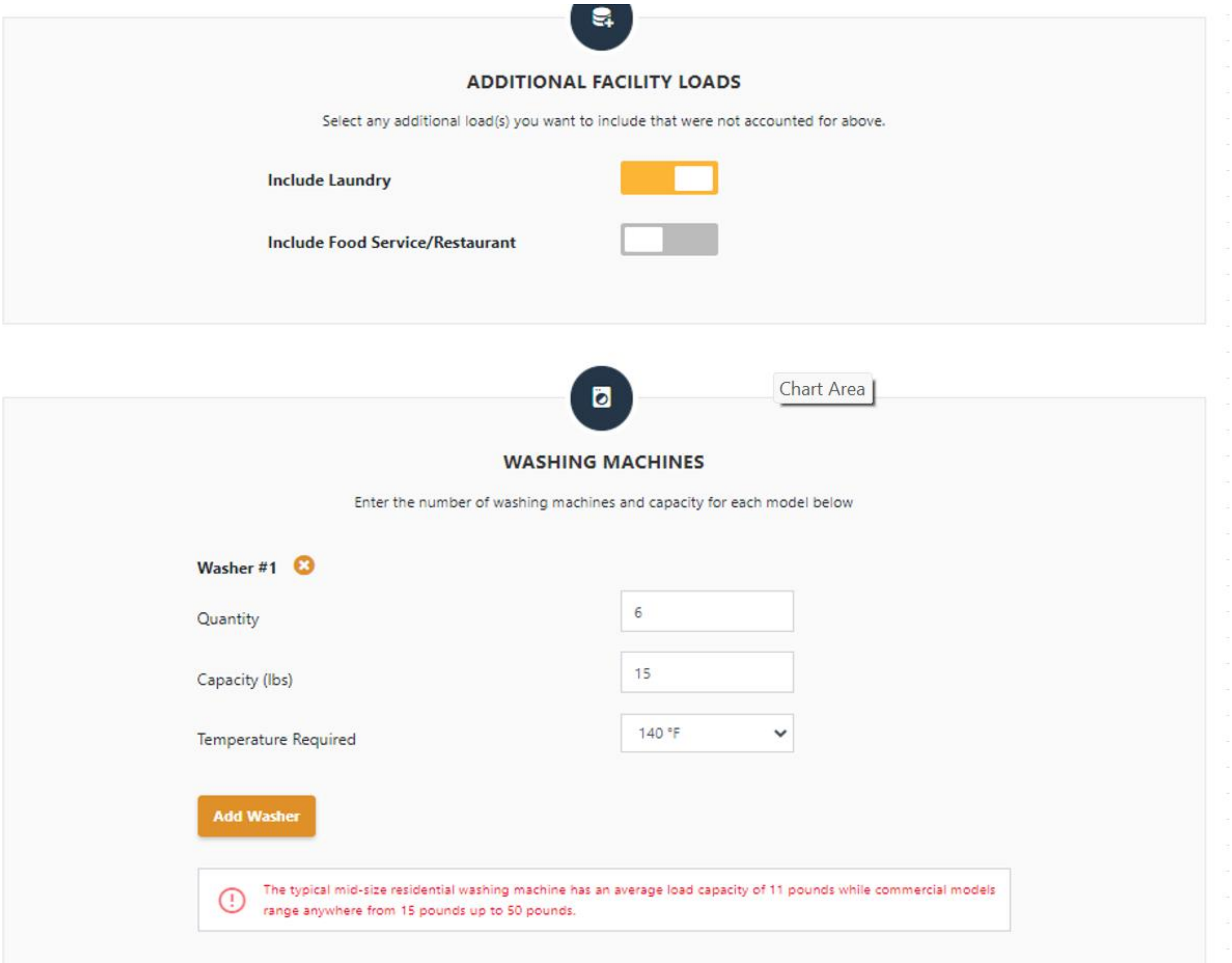
Enter the requirements below

Units with 1 Bath: 72	Shower Heads: 2.5 GPM	☐ w/ In-suite Clothes Washer
Units with 1½ Bath: 0	Shower Heads: 2.5 GPM	☐ w/ In-suite Clothes Washer
Units with 2 Bath: 0	Shower Heads: 2.5 GPM	☐ w/ In-suite Clothes Washer
Units with 2½ Bath: 0	Shower Heads: 2.5 GPM	☐ w/ In-suite Clothes Washer
Units with 3 Bath: 0	Shower Heads: 2.5 GPM	☐ w/ In-suite Clothes Washer
Units with 3½ Bath: 0	Shower Heads: 2.5 GPM	☐ w/ In-suite Clothes Washer

Shower Minutes Per Hour: 7

Diversity Factor (%): 30

Other GPH (at Stored Temp): 0



ADDITIONAL FACILITY LOADS

Select any additional load(s) you want to include that were not accounted for above.

Include Laundry

Include Food Service/Restaurant

WASHING MACHINES

Enter the number of washing machines and capacity for each model below

Washer #1

Quantity: 6

Capacity (lbs): 15

Temperature Required: 140 °F

The typical mid-size residential washing machine has an average load capacity of 11 pounds while commercial models range anywhere from 15 pounds up to 50 pounds.

Output

CONDENSING RECOMMENDATION

U.H.E® Commercial Water Heater (60-100 Gallon)

Heaters Required	1	Heater Model No.	LUHE100T300E3N(A)
Heater Capacity	100 USG	Input per Hour	300,000 BTU/HR
Thermal Efficiency	92%	Venting	Power / Power Direct
Storage Tanks	None	Usable Storage	70 USG
Recovery	442 USGPH @ 75 °F Rise	Approx. 1st Hour Delivery	512 USG
Approx. 3 Hour Avg. Delivery	465 USG	Approx. Storage Recovery	14 MINUTES
% of Demand Satisfied	105%		

CONDENSING RECOMMENDATION

U.H.E® Commercial Water Heater (120 Gallon)

Heaters Required	1	Heater Model No.	LUHE120T4003N(A)
Heater Capacity	119 USG	Input per Hour	399,999 BTU/HR
Thermal Efficiency	94%	Venting	Power / Power Direct
Storage Tanks	None	Usable Storage	83 USG
Recovery	602 USGPH @ 75 °F Rise	Approx. 1st Hour Delivery	685 USG
Approx. 3 Hour Avg. Delivery	630 USG	Approx. Storage Recovery	12 MINUTES
% of Demand Satisfied	140%		

VOLUME WATER HEATER RECOMMENDATION
#1

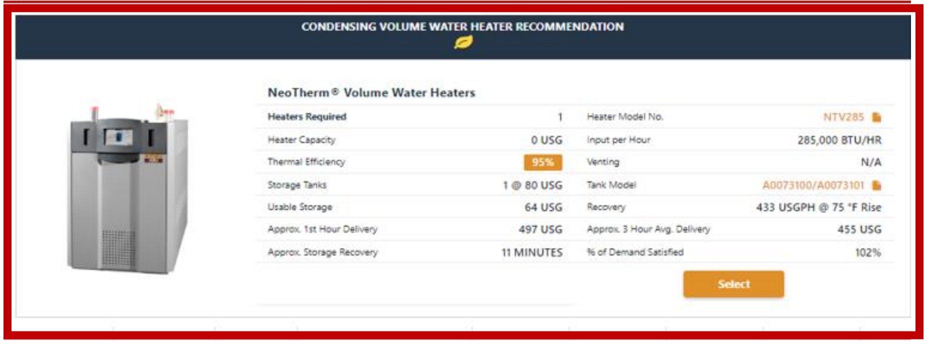
Mighty Therm®2 Volume Water Heaters

Heaters Required	1	Heater Model No.	MT2V0300 No Pump 200-400 Pump Mounted 200-400
Heater Capacity	0 USG	Input per Hour	300,000 BTU/HR
Thermal Efficiency	85%	Venting	N/A
Storage Tanks	1 @ 119 USG	Tank Model	A0078800/A0070101
Usable Storage	95 USG	Recovery	408 USGPH @ 75 °F Rise
Approx. 1st Hour Delivery	503 USG	Approx. 3 Hour Avg. Delivery	440 USG
Approx. Storage Recovery	17 MINUTES	% of Demand Satisfied	103%

VOLUME WATER HEATER RECOMMENDATION
#2

Mighty Therm®2 Volume Water Heaters

Heaters Required	1	Heater Model No.	MT2V0400 No Pump 200-400 Pump Mounted 200-400
Heater Capacity	0 USG	Input per Hour	399,900 BTU/HR
Thermal Efficiency	85%	Venting	N/A
Storage Tanks	1 @ 80 USG	Tank Model	A0073100/A0073101
Usable Storage	64 USG	Recovery	544 USGPH @ 75 °F Rise
Approx. 1st Hour Delivery	608 USG	Approx. 3 Hour Avg. Delivery	565 USG
Approx. Storage Recovery	9 MINUTES	% of Demand Satisfied	124%



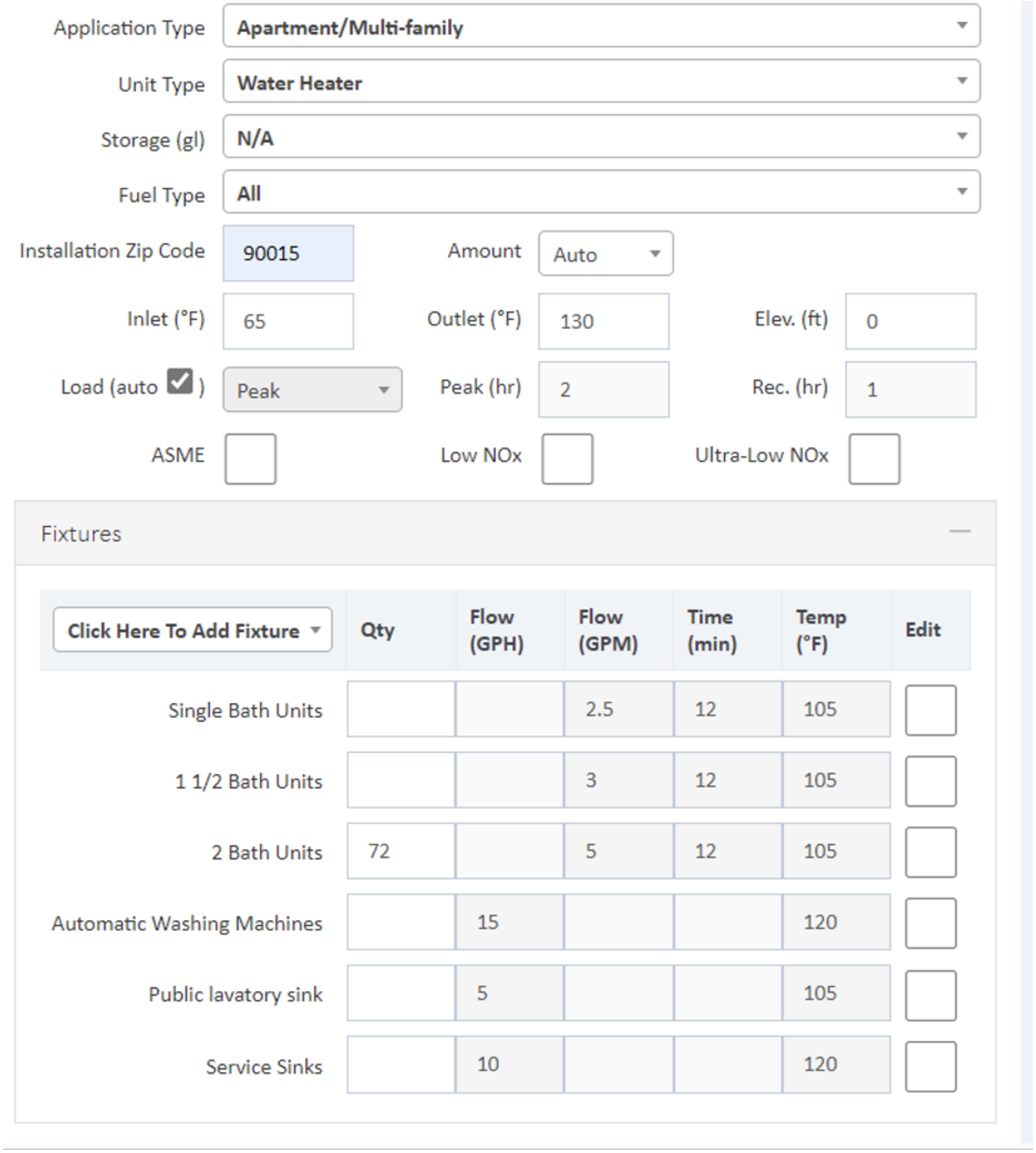
CONDENSING VOLUME WATER HEATER RECOMMENDATION

NeoTherm® Volume Water Heaters

Heaters Required	1	Heater Model No.	NTV285
Heater Capacity	0 USG	Input per Hour	285,000 BTU/HR
Thermal Efficiency	95%	Venting	N/A
Storage Tanks	1 @ 80 USG	Tank Model	A0073100/A0073101
Usable Storage	64 USG	Recovery	433 USGPH @ 75 °F Rise
Approx. 1st Hour Delivery	497 USG	Approx. 3 Hour Avg. Delivery	455 USG
Approx. Storage Recovery	11 MINUTES	% of Demand Satisfied	102%

MFG Tool 3

Input



Application Type: Apartment/Multi-family

Unit Type: Water Heater

Storage (gl): N/A

Fuel Type: All

Installation Zip Code: 90015

Amount: Auto

Inlet (°F): 65

Outlet (°F): 130

Elev. (ft): 0

Load (auto ☑): Peak

Peak (hr): 2

Rec. (hr): 1

ASME ☐

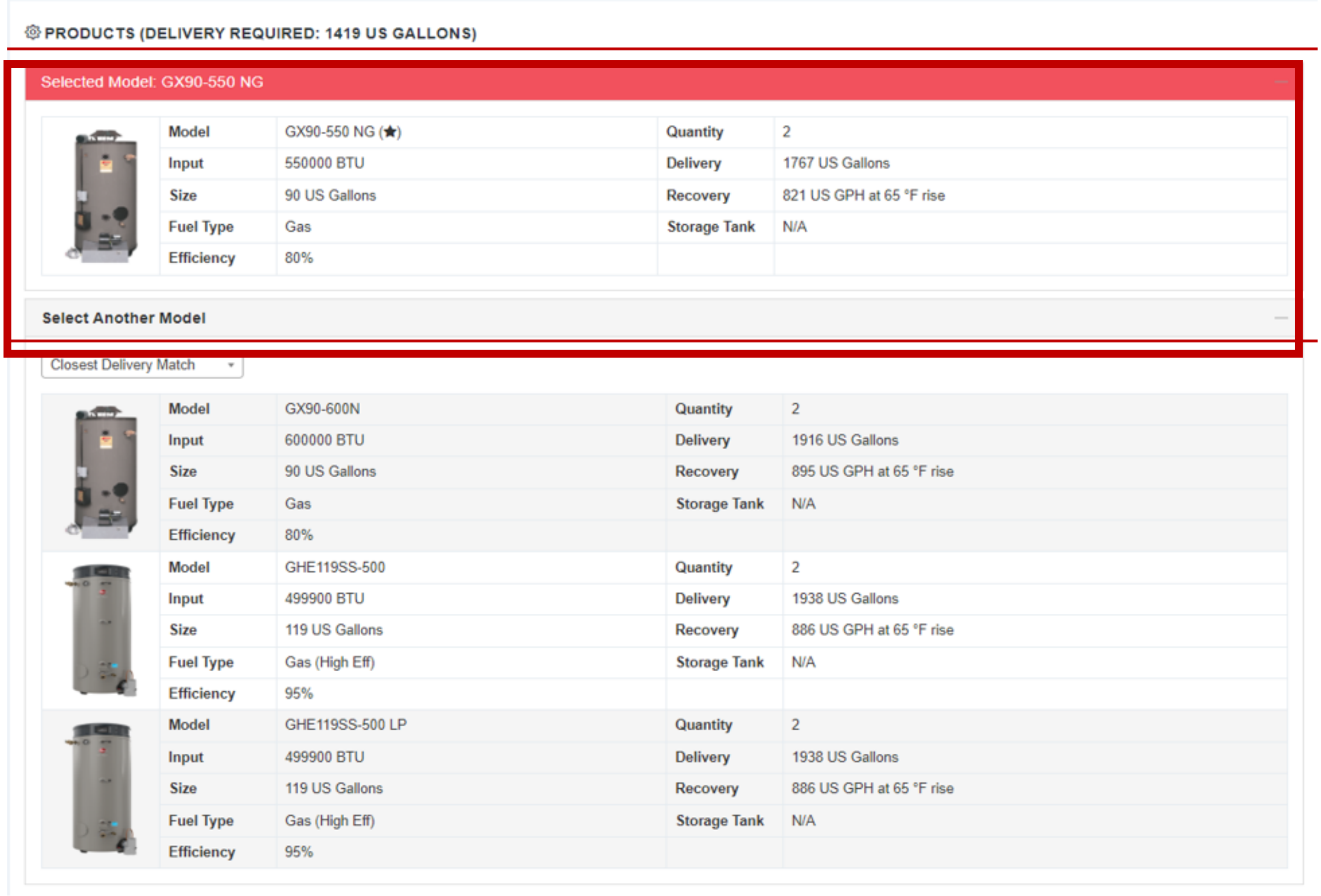
Low NOx ☐

Ultra-Low NOx ☐

Fixtures

Click Here To Add Fixture	Qty	Flow (GPH)	Flow (GPM)	Time (min)	Temp (°F)	Edit
Single Bath Units			2.5	12	105	☐
1 1/2 Bath Units			3	12	105	☐
2 Bath Units	72		5	12	105	☐
Automatic Washing Machines		15			120	☐
Public lavatory sink		5			105	☐
Service Sinks		10			120	☐

Output



PRODUCTS (DELIVERY REQUIRED: 1419 US GALLONS)

Selected Model: GX90-550 NG

Model	GX90-550 NG (★)	**Quantity**	2
Input	550000 BTU	**Delivery**	1767 US Gallons
Size	90 US Gallons	**Recovery**	821 US GPH at 65 °F rise
Fuel Type	Gas	**Storage Tank**	N/A
Efficiency	80%		

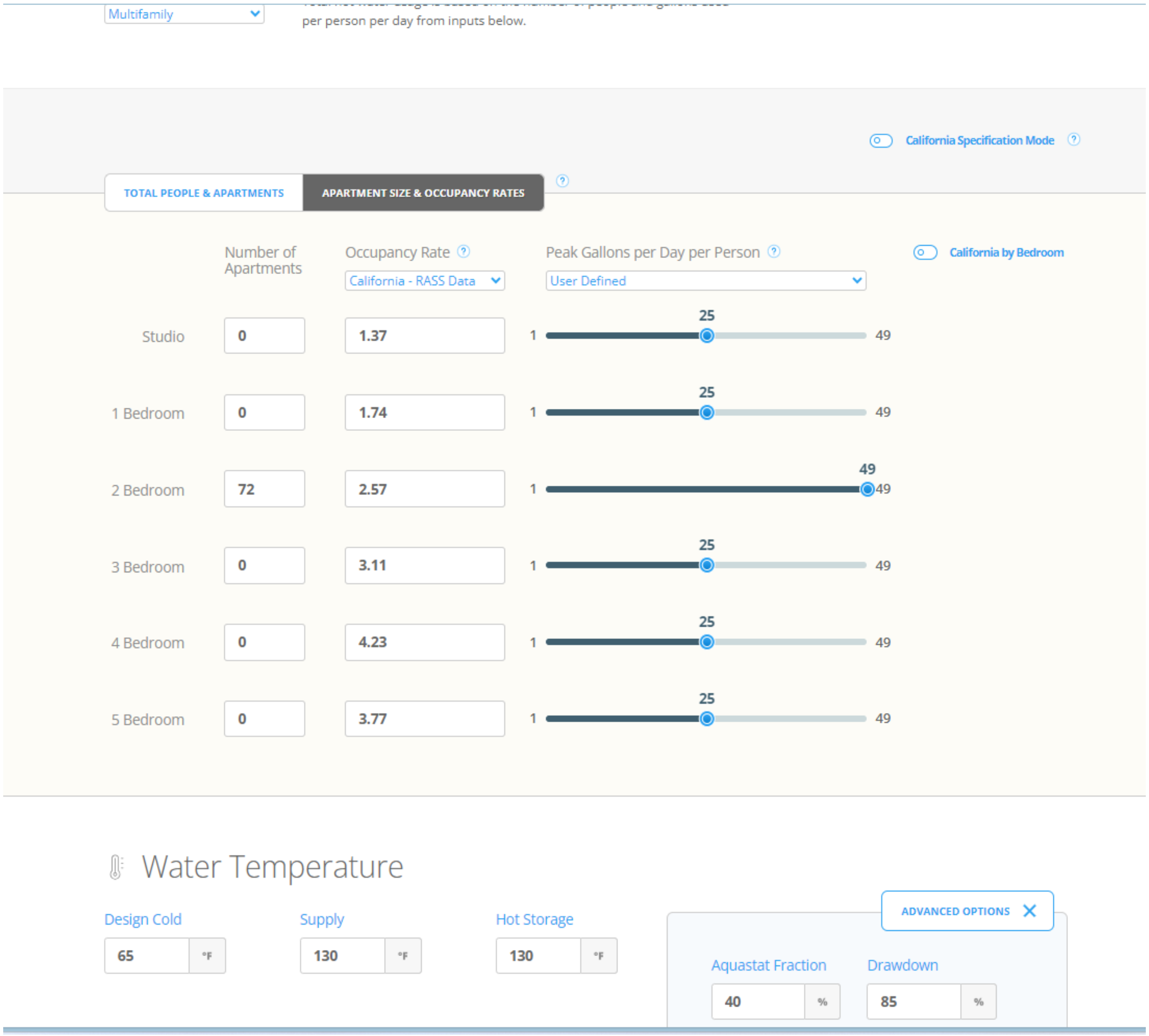
Select Another Model

Closest Delivery Match

Model	GX90-600N	**Quantity**	2
Input	600000 BTU	**Delivery**	1916 US Gallons
Size	90 US Gallons	**Recovery**	895 US GPH at 65 °F rise
Fuel Type	Gas	**Storage Tank**	N/A
Efficiency	80%		
Model	GHE119SS-500	**Quantity**	2
Input	499900 BTU	**Delivery**	1938 US Gallons
Size	119 US Gallons	**Recovery**	886 US GPH at 65 °F rise
Fuel Type	Gas (High Eff)	**Storage Tank**	N/A
Efficiency	95%		
Model	GHE119SS-500 LP	**Quantity**	2
Input	499900 BTU	**Delivery**	1938 US Gallons
Size	119 US Gallons	**Recovery**	886 US GPH at 65 °F rise
Fuel Type	Gas (High Eff)	**Storage Tank**	N/A
Efficiency	95%		

EHPWH Tool

Input



Multifamily

per person per day from inputs below.

Occupancy Rate: California - RASS Data

Peak Gallons per Day per Person: User Defined

	Number of Apartments	Occupancy Rate	Peak Gallons per Day per Person
Studio	0	1.37	25
1 Bedroom	0	1.74	25
2 Bedroom	72	2.57	49
3 Bedroom	0	3.11	25
4 Bedroom	0	4.23	25
5 Bedroom	0	3.77	25

Water Temperature

Design Cold: 65 °F

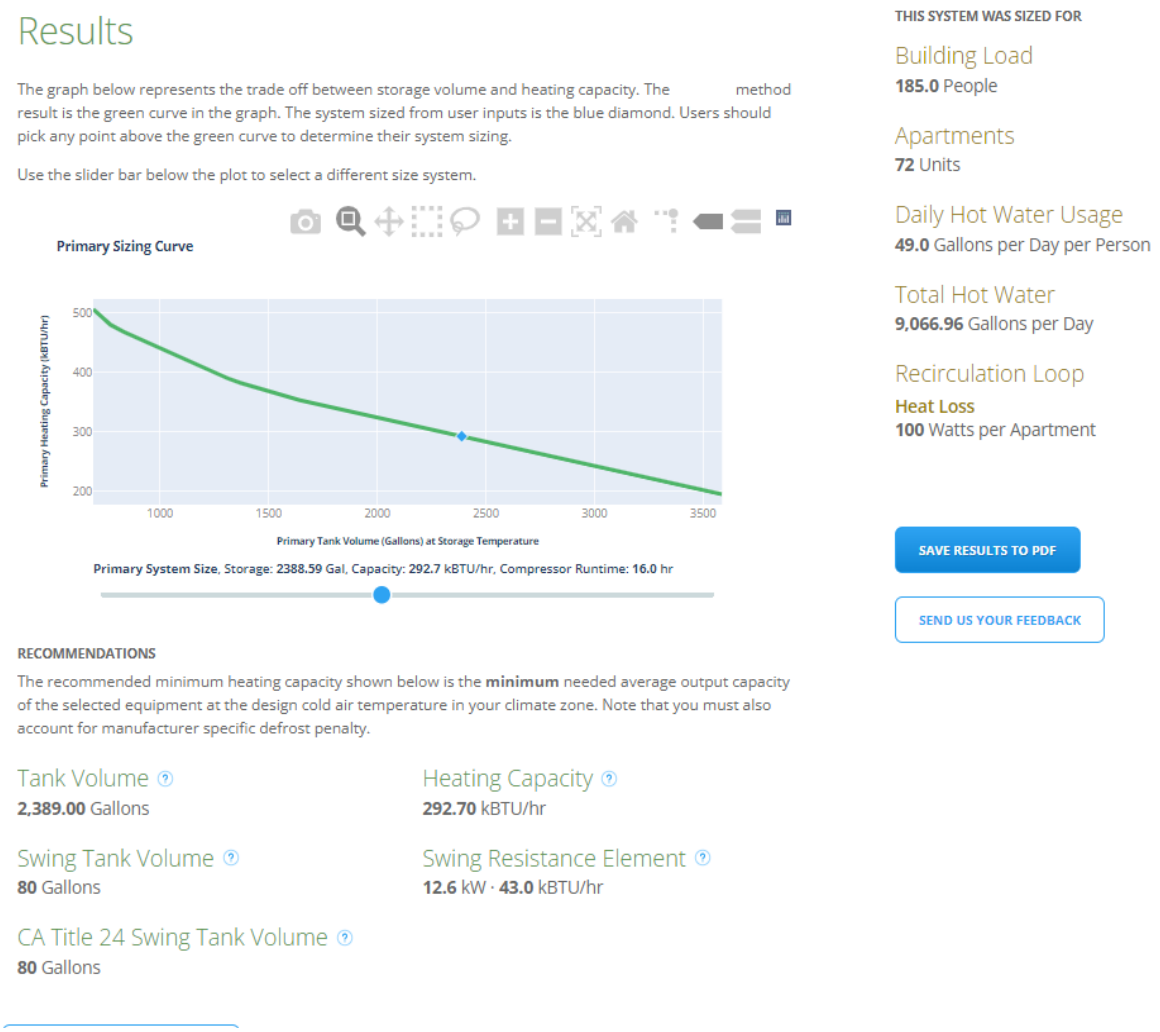
Supply: 130 °F

Hot Storage: 130 °F

Aquastat Fraction: 40 %

Drawdown: 85 %

Output



Results

The graph below represents the trade off between storage volume and heating capacity. The method result is the green curve in the graph. The system sized from user inputs is the blue diamond. Users should pick any point above the green curve to determine their system sizing.

Use the slider bar below the plot to select a different size system.

Primary System Size, Storage: **2388.59** Gal, Capacity: **292.7** kBTU/hr, Compressor Runtime: **16.0** hr

RECOMMENDATIONS

The recommended minimum heating capacity shown below is the **minimum** needed average output capacity of the selected equipment at the design cold air temperature in your climate zone. Note that you must also account for manufacturer specific defrost penalty.

Tank Volume ?
2,389.00 Gallons

Heating Capacity ?
292.70 kBTU/hr

Swing Tank Volume ?
80 Gallons

Swing Resistance Element ?
12.6 kW · **43.0** kBTU/hr

CA Title 24 Swing Tank Volume ?
80 Gallons

THIS SYSTEM WAS SIZED FOR

Building Load
185.0 People

Apartments
72 Units

Daily Hot Water Usage
49.0 Gallons per Day per Person

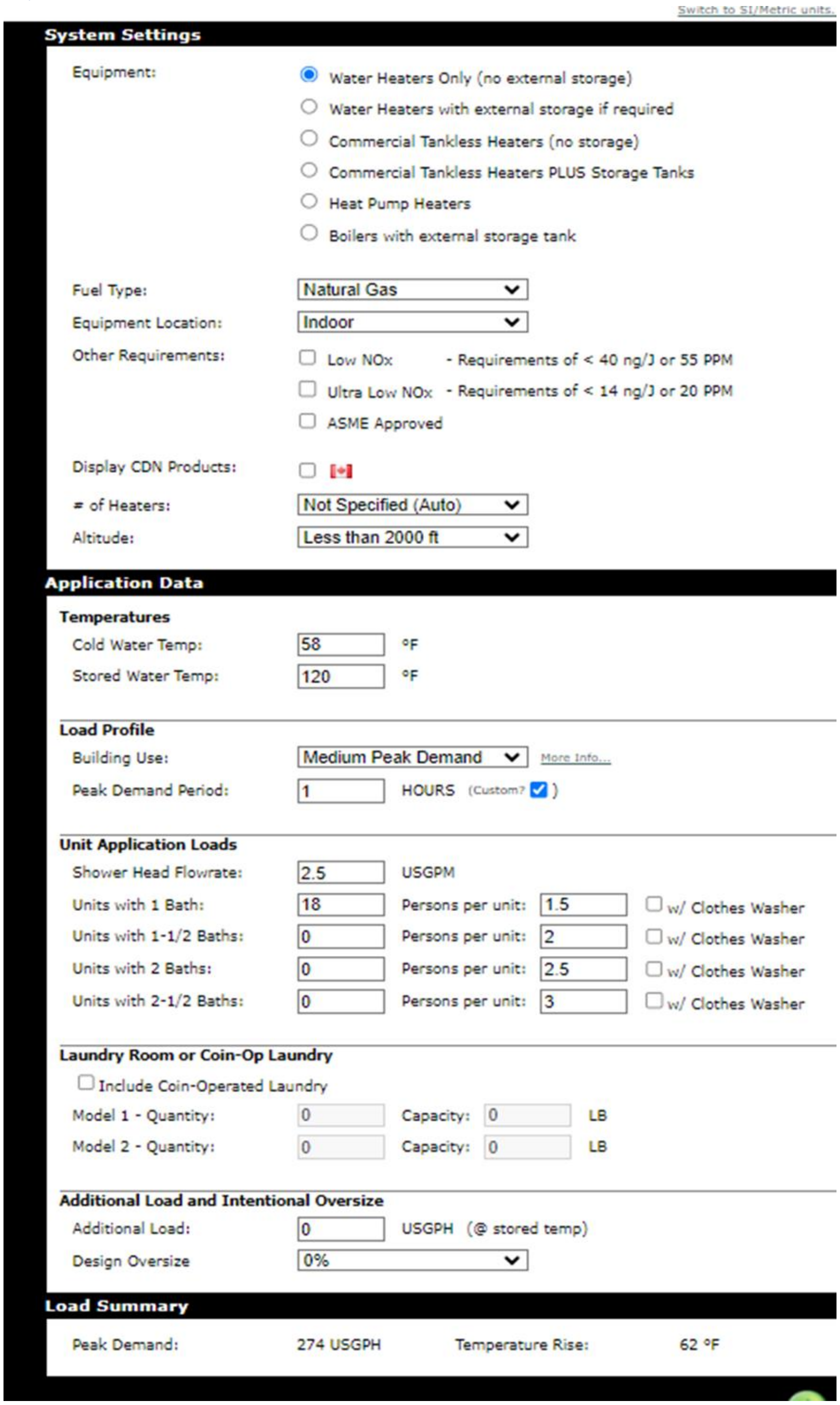
Total Hot Water
9,066.96 Gallons per Day

Recirculation Loop
Heat Loss
100 Watts per Apartment

Site 2

MFG Tool 2

Input



System Settings

Equipment:
- ● Water Heaters Only (no external storage)
- ○ Water Heaters with external storage if required
- ○ Commercial Tankless Heaters (no storage)
- ○ Commercial Tankless Heaters PLUS Storage Tanks
- ○ Heat Pump Heaters
- ○ Boilers with external storage tank

Fuel Type: Natural Gas

Equipment Location: Indoor

Other Requirements:
- ☐ Low NOx - Requirements of < 40 ng/J or 55 PPM
- ☐ Ultra Low NOx - Requirements of < 14 ng/J or 20 PPM
- ☐ ASME Approved

Display CDN Products: ☐

# of Heaters: Not Specified (Auto)

Altitude: Less than 2000 ft

Application Data

Temperatures

Cold Water Temp: 58 °F

Stored Water Temp: 120 °F

Load Profile

Building Use: Medium Peak Demand

Peak Demand Period: 1 HOURS (Custom? ☑)

Unit Application Loads

Shower Head Flowrate: 2.5 USGPM

Units with 1 Bath: 18 Persons per unit: 1.5 ☐ w/ Clothes Washer

Units with 1-1/2 Baths: 0 Persons per unit: 2 ☐ w/ Clothes Washer

Units with 2 Baths: 0 Persons per unit: 2.5 ☐ w/ Clothes Washer

Units with 2-1/2 Baths: 0 Persons per unit: 3 ☐ w/ Clothes Washer

Laundry Room or Coin-Op Laundry

☐ Include Coin-Operated Laundry

Model 1 - Quantity: 0 Capacity: 0 LB

Model 2 - Quantity: 0 Capacity: 0 LB

Additional Load and Intentional Oversize

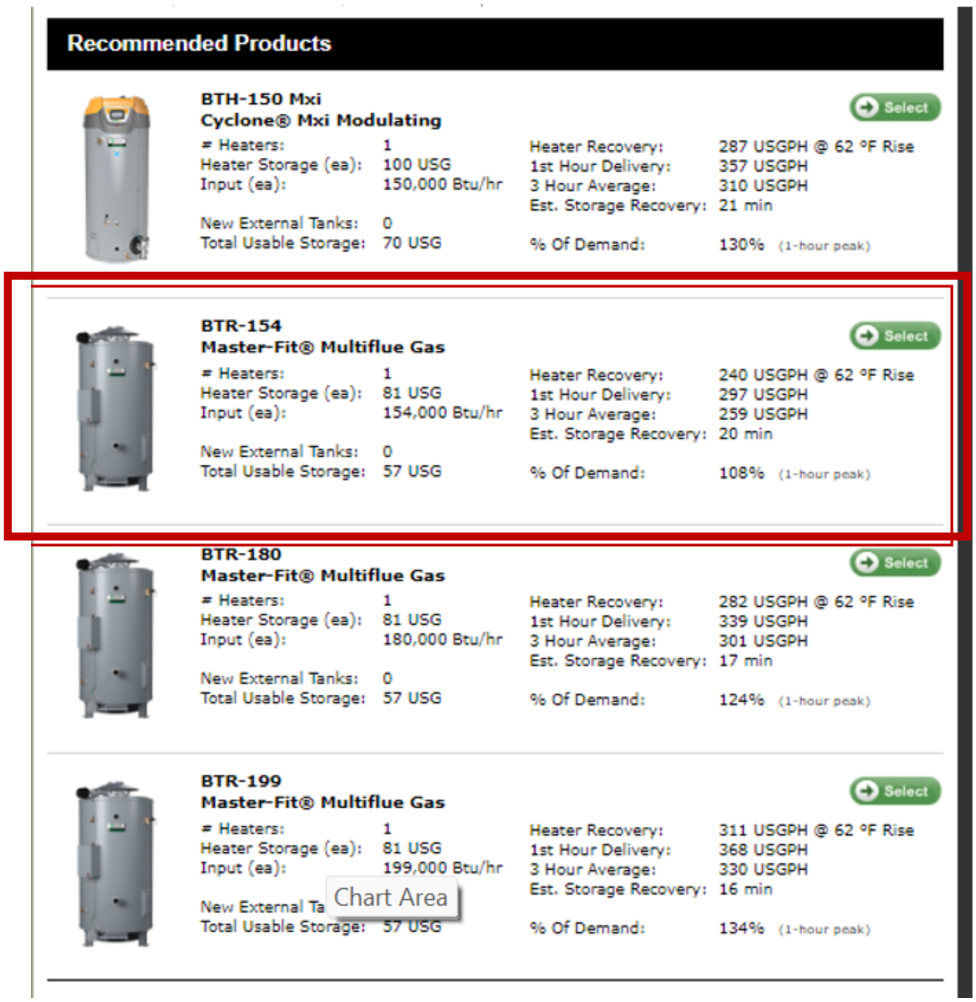
Additional Load: 0 USGPH (@ stored temp)

Design Oversize 0%

Load Summary

Peak Demand: 274 USGPH Temperature Rise: 62 °F

Output



Recommended Products

BTH-150 Mxi
Cyclone® Mxi Modulating

# Heaters:	1	Heater Recovery:	287 USGPH @ 62 °F Rise
Heater Storage (ea):	100 USG	1st Hour Delivery:	357 USGPH
Input (ea):	150,000 Btu/hr	3 Hour Average:	310 USGPH
		Est. Storage Recovery:	21 min
New External Tanks:	0		
Total Usable Storage:	70 USG	% Of Demand:	130% (1-hour peak)

BTR-154
Master-Fit® Multiflue Gas

# Heaters:	1	Heater Recovery:	240 USGPH @ 62 °F Rise
Heater Storage (ea):	81 USG	1st Hour Delivery:	297 USGPH
Input (ea):	154,000 Btu/hr	3 Hour Average:	259 USGPH
		Est. Storage Recovery:	20 min
New External Tanks:	0		
Total Usable Storage:	57 USG	% Of Demand:	108% (1-hour peak)

BTR-180
Master-Fit® Multiflue Gas

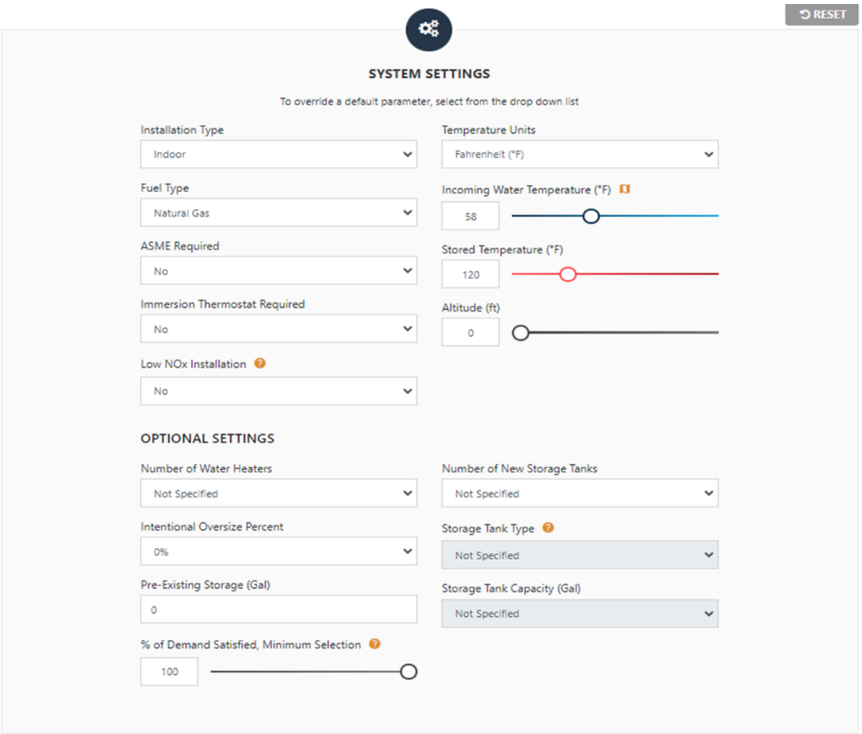
# Heaters:	1	Heater Recovery:	282 USGPH @ 62 °F Rise
Heater Storage (ea):	81 USG	1st Hour Delivery:	339 USGPH
Input (ea):	180,000 Btu/hr	3 Hour Average:	301 USGPH
		Est. Storage Recovery:	17 min
New External Tanks:	0		
Total Usable Storage:	57 USG	% Of Demand:	124% (1-hour peak)

BTR-199
Master-Fit® Multiflue Gas

# Heaters:	1	Heater Recovery:	311 USGPH @ 62 °F Rise
Heater Storage (ea):	81 USG	1st Hour Delivery:	368 USGPH
Input (ea):	199,000 Btu/hr	3 Hour Average:	330 USGPH
		Est. Storage Recovery:	16 min
New External Ta			
Total Usable Storage:	57 USG	% Of Demand:	134% (1-hour peak)

MFG Tool 1

Input



SYSTEM SETTINGS

To override a default parameter, select from the drop down list

Installation Type: Indoor

Temperature Units: Fahrenheit (°F)

Fuel Type: Natural Gas

Incoming Water Temperature (°F): 58

ASME Required: No

Stored Temperature (°F): 120

Immersion Thermostat Required: No

Altitude (ft): 0

Low NOx Installation: No

OPTIONAL SETTINGS

Number of Water Heaters: Not Specified

Number of New Storage Tanks: Not Specified

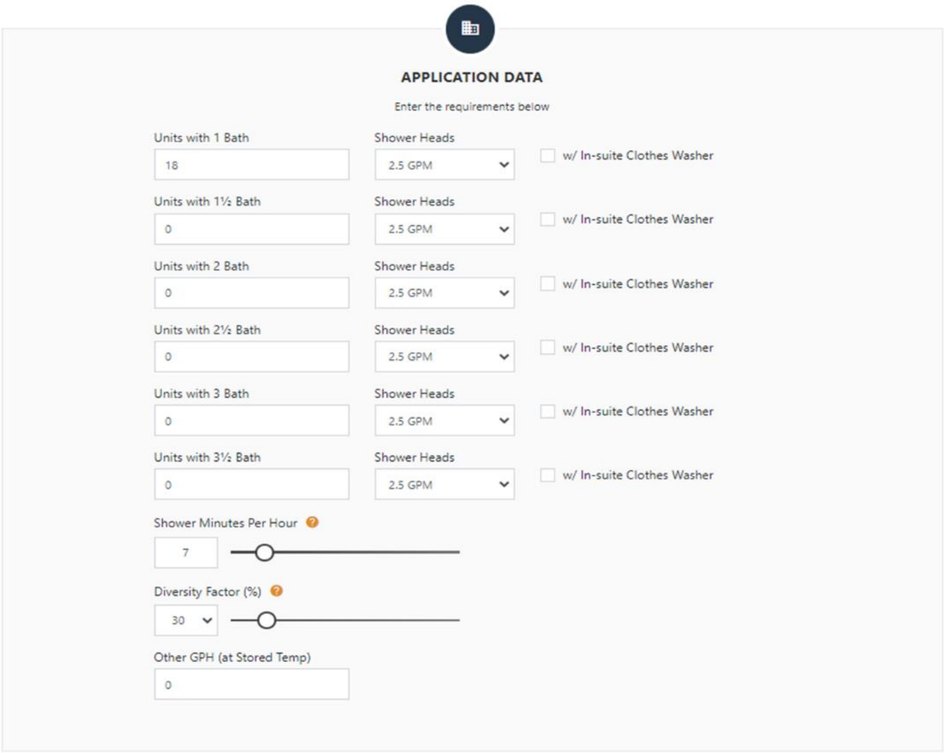
Intentional Oversize Percent: 0%

Storage Tank Type: Not Specified

Pre-Existing Storage (Gal): 0

Storage Tank Capacity (Gal): Not Specified

% of Demand Satisfied, Minimum Selection: 100



APPLICATION DATA

Enter the requirements below

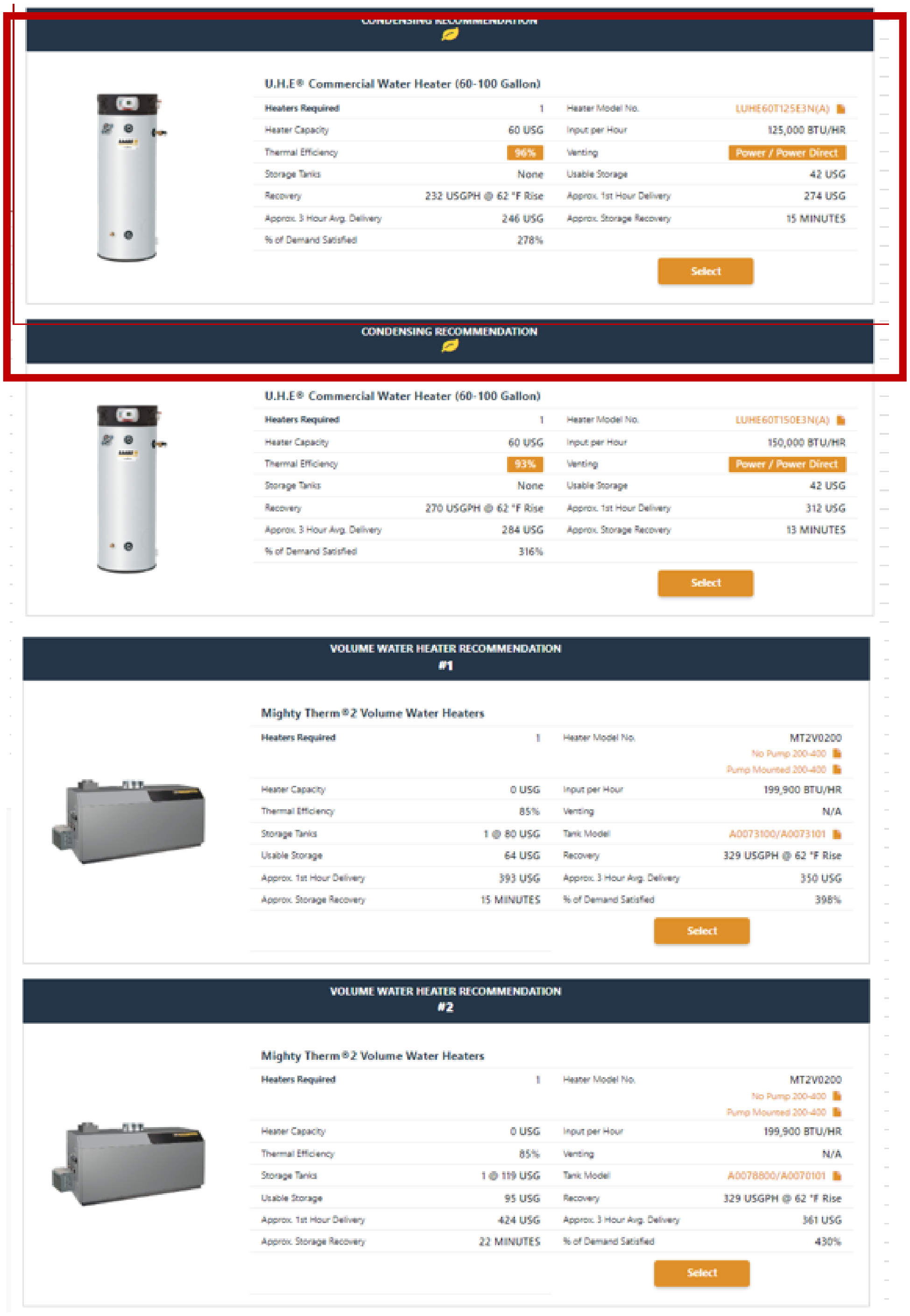
Units with 1 Bath: 18	Shower Heads: 2.5 GPM	☐ w/ In-suite Clothes Washer
Units with 1½ Bath: 0	Shower Heads: 2.5 GPM	☐ w/ In-suite Clothes Washer
Units with 2 Bath: 0	Shower Heads: 2.5 GPM	☐ w/ In-suite Clothes Washer
Units with 2½ Bath: 0	Shower Heads: 2.5 GPM	☐ w/ In-suite Clothes Washer
Units with 3 Bath: 0	Shower Heads: 2.5 GPM	☐ w/ In-suite Clothes Washer
Units with 3½ Bath: 0	Shower Heads: 2.5 GPM	☐ w/ In-suite Clothes Washer

Shower Minutes Per Hour: 7

Diversity Factor (%): 30

Other GPH (at Stored Temp): 0

Output



CONDENSING RECOMMENDATION

U.H.E® Commercial Water Heater (60-100 Gallon)

Heaters Required	1	Heater Model No.	LUHE60T125E3N(A)
Heater Capacity	60 USG	Input per Hour	125,000 BTU/HR
Thermal Efficiency	96%	Venting	Power / Power Direct
Storage Tanks	None	Usable Storage	42 USG
Recovery	232 USGPH @ 62 °F Rise	Approx. 1st Hour Delivery	274 USG
Approx. 3 Hour Avg. Delivery	246 USG	Approx. Storage Recovery	15 MINUTES
% of Demand Satisfied	278%		

CONDENSING RECOMMENDATION

U.H.E® Commercial Water Heater (60-100 Gallon)

Heaters Required	1	Heater Model No.	LUHE60T150E3N(A)
Heater Capacity	60 USG	Input per Hour	150,000 BTU/HR
Thermal Efficiency	93%	Venting	Power / Power Direct
Storage Tanks	None	Usable Storage	42 USG
Recovery	270 USGPH @ 62 °F Rise	Approx. 1st Hour Delivery	312 USG
Approx. 3 Hour Avg. Delivery	284 USG	Approx. Storage Recovery	13 MINUTES
% of Demand Satisfied	316%		

VOLUME WATER HEATER RECOMMENDATION
#1

Mighty Therm®2 Volume Water Heaters

Heaters Required	1	Heater Model No.	MT2V0200 No Pump 200-400 Pump Mounted 200-400
Heater Capacity	0 USG	Input per Hour	199,900 BTU/HR
Thermal Efficiency	85%	Venting	N/A
Storage Tanks	1 @ 80 USG	Tank Model	A0073100/A0073101
Usable Storage	64 USG	Recovery	329 USGPH @ 62 °F Rise
Approx. 1st Hour Delivery	393 USG	Approx. 3 Hour Avg. Delivery	350 USG
Approx. Storage Recovery	15 MINUTES	% of Demand Satisfied	398%

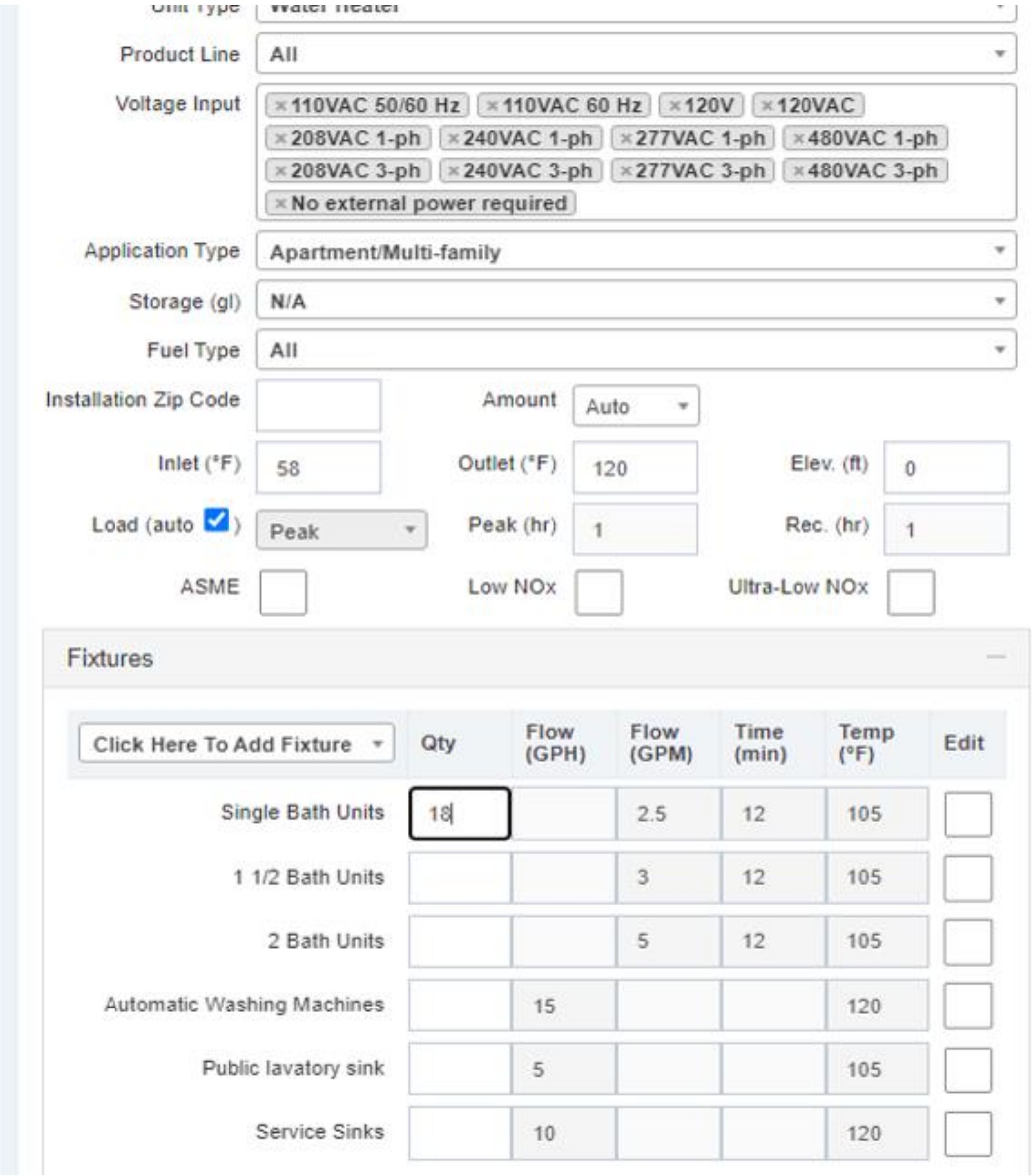
VOLUME WATER HEATER RECOMMENDATION
#2

Mighty Therm®2 Volume Water Heaters

Heaters Required	1	Heater Model No.	MT2V0200 No Pump 200-400 Pump Mounted 200-400
Heater Capacity	0 USG	Input per Hour	199,900 BTU/HR
Thermal Efficiency	85%	Venting	N/A
Storage Tanks	1 @ 119 USG	Tank Model	A0078800/A0070101
Usable Storage	95 USG	Recovery	329 USGPH @ 62 °F Rise
Approx. 1st Hour Delivery	424 USG	Approx. 3 Hour Avg. Delivery	361 USG
Approx. Storage Recovery	22 MINUTES	% of Demand Satisfied	430%

MFG Tool 3

Input



Product Line: All

Voltage Input: ×110VAC 50/60 Hz ×110VAC 60 Hz ×120V ×120VAC ×208VAC 1-ph ×240VAC 1-ph ×277VAC 1-ph ×480VAC 1-ph ×208VAC 3-ph ×240VAC 3-ph ×277VAC 3-ph ×480VAC 3-ph ×No external power required

Application Type: Apartment/Multi-family

Storage (gl): N/A

Fuel Type: All

Installation Zip Code:

Amount: Auto

Inlet (°F): 58

Outlet (°F): 120

Elev. (ft): 0

Load (auto ☑): Peak

Peak (hr): 1

Rec. (hr): 1

ASME ☐

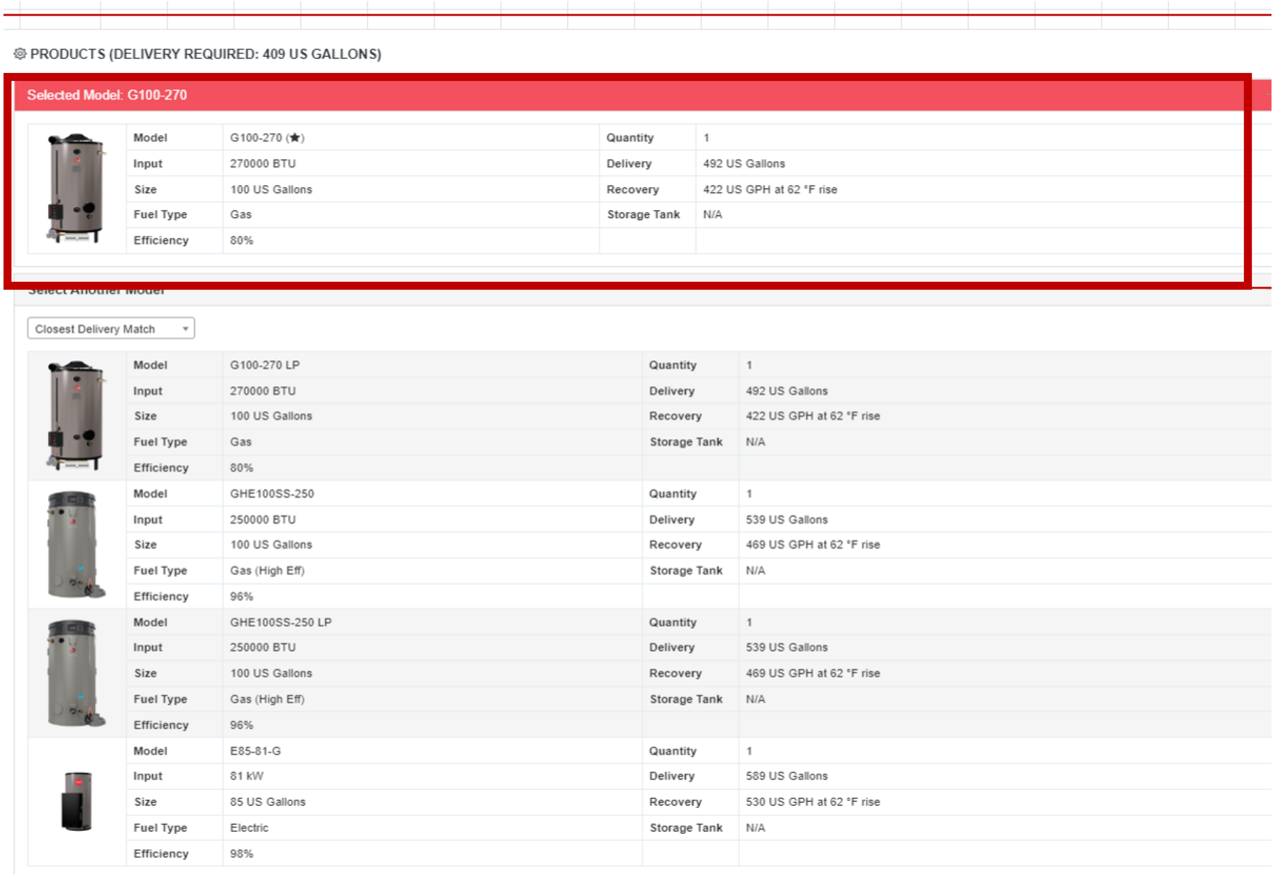
Low NOx ☐

Ultra-Low NOx ☐

Fixtures

Click Here To Add Fixture	Qty	Flow (GPH)	Flow (GPM)	Time (min)	Temp (°F)	Edit
Single Bath Units	18		2.5	12	105	☐
1 1/2 Bath Units			3	12	105	☐
2 Bath Units			5	12	105	☐
Automatic Washing Machines		15			120	☐
Public lavatory sink		5			105	☐
Service Sinks		10			120	☐

Output



PRODUCTS (DELIVERY REQUIRED: 409 US GALLONS)

Selected Model: G100-270

Model	G100-270 (★)	**Quantity**	1
Input	270000 BTU	**Delivery**	492 US Gallons
Size	100 US Gallons	**Recovery**	422 US GPH at 62 °F rise
Fuel Type	Gas	**Storage Tank**	N/A
Efficiency	80%		

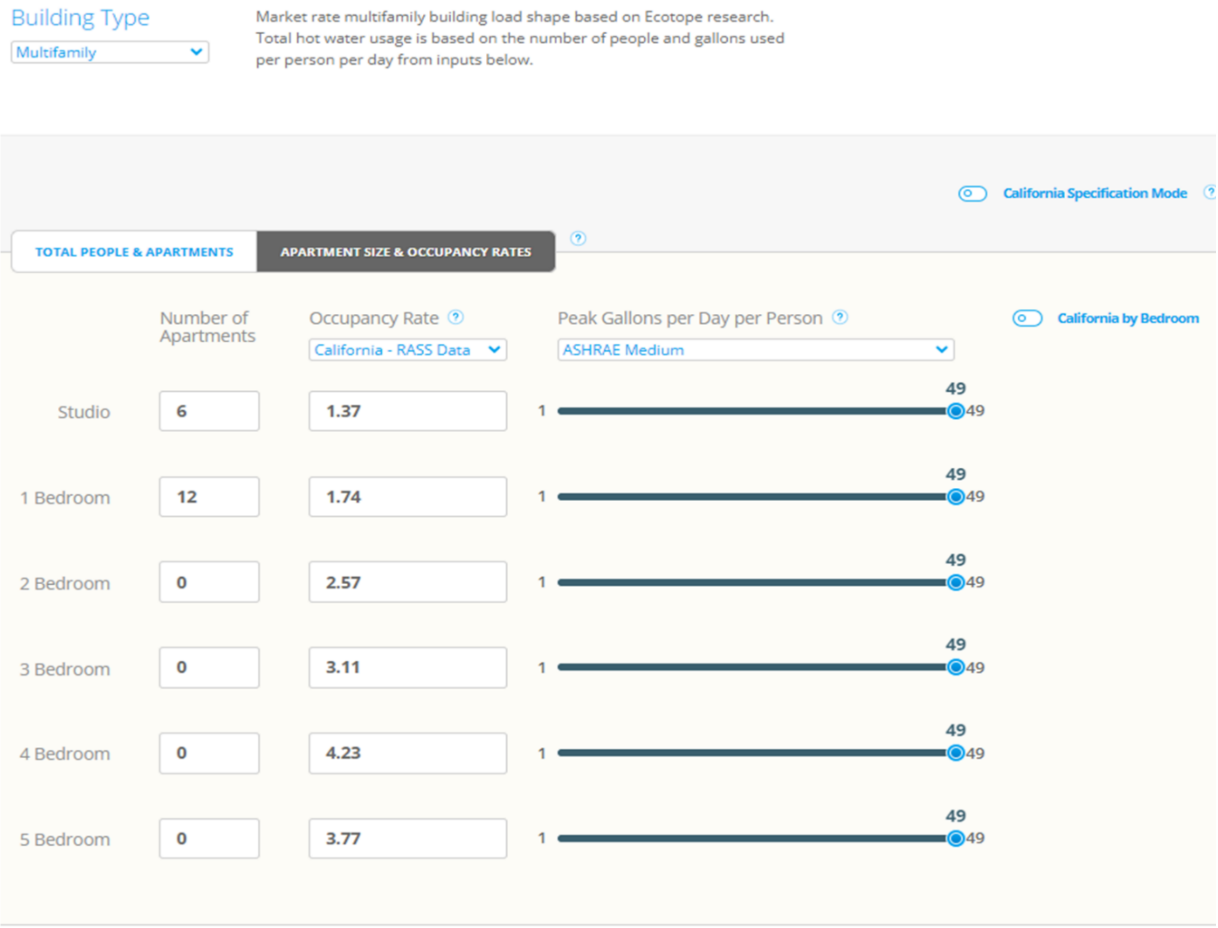
Select Another Model

Closest Delivery Match ▾

Model	G100-270 LP	**Quantity**	1
Input	270000 BTU	**Delivery**	492 US Gallons
Size	100 US Gallons	**Recovery**	422 US GPH at 62 °F rise
Fuel Type	Gas	**Storage Tank**	N/A
Efficiency	80%		
Model	GHE100SS-250	**Quantity**	1
Input	250000 BTU	**Delivery**	539 US Gallons
Size	100 US Gallons	**Recovery**	469 US GPH at 62 °F rise
Fuel Type	Gas (High Eff)	**Storage Tank**	N/A
Efficiency	96%		
Model	GHE100SS-250 LP	**Quantity**	1
Input	250000 BTU	**Delivery**	539 US Gallons
Size	100 US Gallons	**Recovery**	469 US GPH at 62 °F rise
Fuel Type	Gas (High Eff)	**Storage Tank**	N/A
Efficiency	96%		
Model	E85-81-G	**Quantity**	1
Input	81 kW	**Delivery**	589 US Gallons
Size	85 US Gallons	**Recovery**	530 US GPH at 62 °F rise
Fuel Type	Electric	**Storage Tank**	N/A
Efficiency	98%		

EHPWH Tool

Input



Building Type

Multifamily

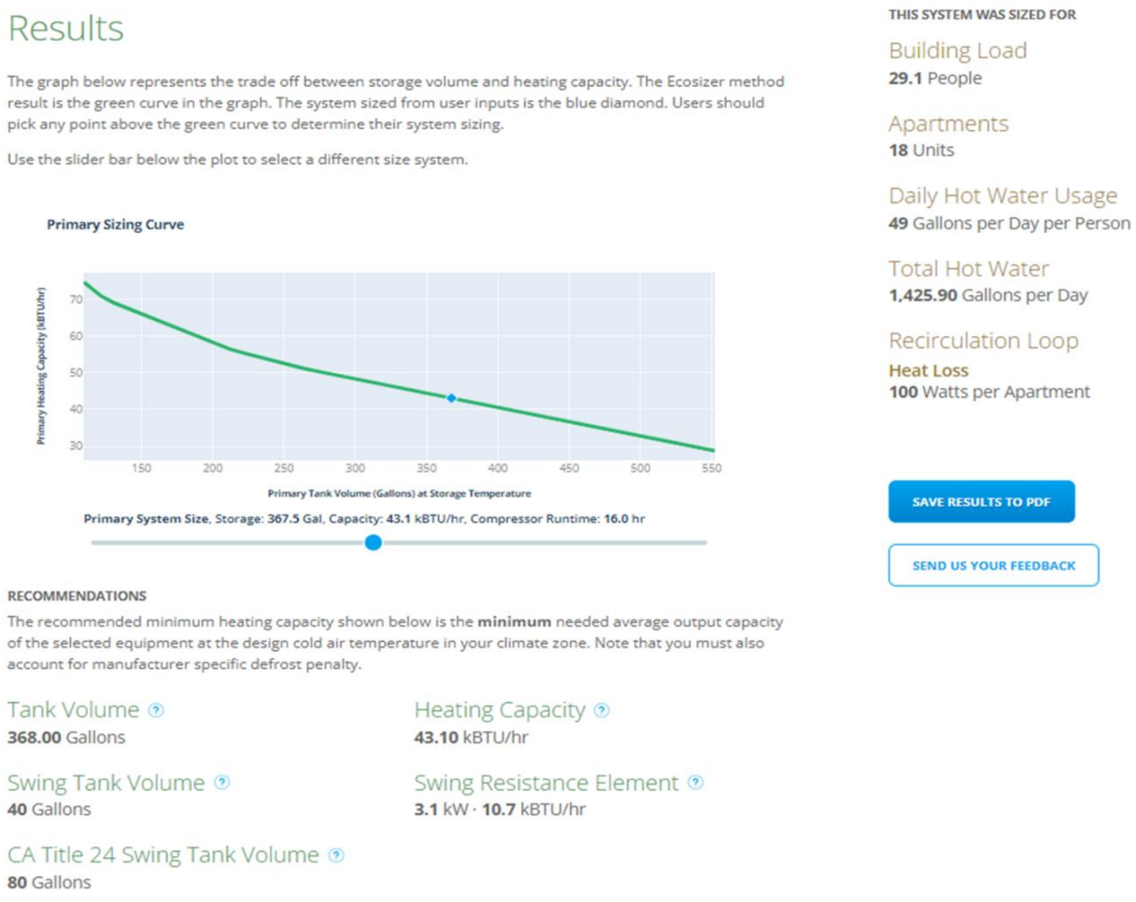
Market rate multifamily building load shape based on Ecotope research. Total hot water usage is based on the number of people and gallons used per person per day from inputs below.

Occupancy Rate: California - RASS Data

Peak Gallons per Day per Person: ASHRAE Medium

	Number of Apartments	Occupancy Rate	Peak Gallons per Day per Person
Studio	6	1.37	49
1 Bedroom	12	1.74	49
2 Bedroom	0	2.57	49
3 Bedroom	0	3.11	49
4 Bedroom	0	4.23	49
5 Bedroom	0	3.77	49

Output



Results

The graph below represents the trade off between storage volume and heating capacity. The Ecosizer method result is the green curve in the graph. The system sized from user inputs is the blue diamond. Users should pick any point above the green curve to determine their system sizing.

Use the slider bar below the plot to select a different size system.

Primary System Size, Storage: **367.5** Gal, Capacity: **43.1** kBTU/hr, Compressor Runtime: **16.0** hr

RECOMMENDATIONS

The recommended minimum heating capacity shown below is the **minimum** needed average output capacity of the selected equipment at the design cold air temperature in your climate zone. Note that you must also account for manufacturer specific defrost penalty.

Tank Volume
368.00 Gallons

Heating Capacity
43.10 kBTU/hr

Swing Tank Volume
40 Gallons

Swing Resistance Element
3.1 kW · **10.7** kBTU/hr

CA Title 24 Swing Tank Volume
80 Gallons

THIS SYSTEM WAS SIZED FOR

Building Load
29.1 People

Apartments
18 Units

Daily Hot Water Usage
49 Gallons per Day per Person

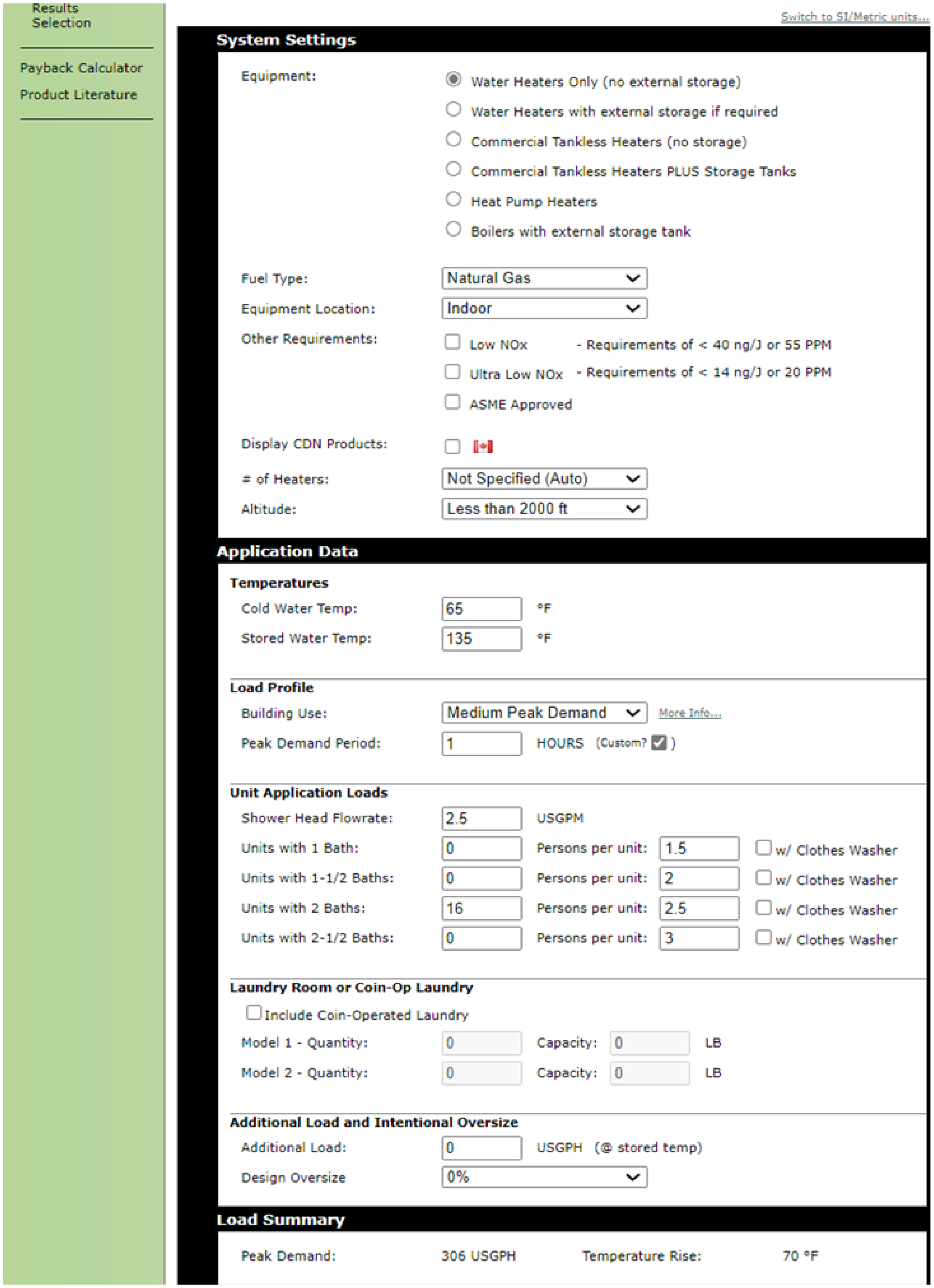
Total Hot Water
1,425.90 Gallons per Day

Recirculation Loop
Heat Loss
100 Watts per Apartment

Site 3

MFG Tool 2

Input



System Settings

Equipment:
● Water Heaters Only (no external storage)
○ Water Heaters with external storage if required
○ Commercial Tankless Heaters (no storage)
○ Commercial Tankless Heaters PLUS Storage Tanks
○ Heat Pump Heaters
○ Boilers with external storage tank

Fuel Type: Natural Gas
Equipment Location: Indoor
Other Requirements:
☐ Low NOx - Requirements of < 40 ng/J or 55 PPM
☐ Ultra Low NOx - Requirements of < 14 ng/J or 20 PPM
☐ ASME Approved

Display CDN Products: ☐
# of Heaters: Not Specified (Auto)
Altitude: Less than 2000 ft

Application Data

Temperatures
Cold Water Temp: 65 °F
Stored Water Temp: 135 °F

Load Profile
Building Use: Medium Peak Demand More Info...
Peak Demand Period: 1 HOURS (Custom? ☑)

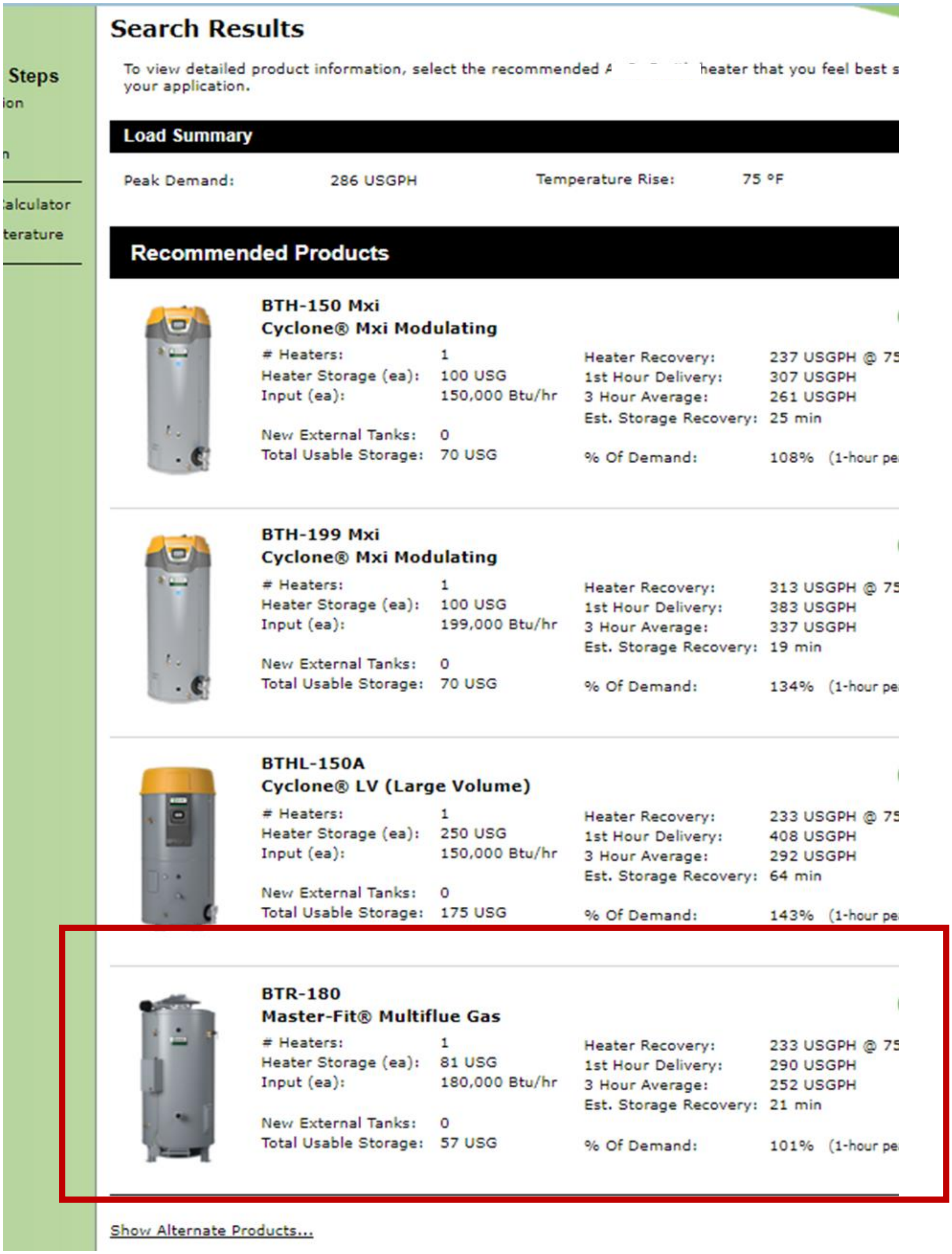
Unit Application Loads
Shower Head Flowrate: 2.5 USGPM
Units with 1 Bath: 0 Persons per unit: 1.5 ☐ w/ Clothes Washer
Units with 1-1/2 Baths: 0 Persons per unit: 2 ☐ w/ Clothes Washer
Units with 2 Baths: 16 Persons per unit: 2.5 ☐ w/ Clothes Washer
Units with 2-1/2 Baths: 0 Persons per unit: 3 ☐ w/ Clothes Washer

Laundry Room or Coin-Op Laundry
☐ Include Coin-Operated Laundry
Model 1 - Quantity: 0 Capacity: 0 LB
Model 2 - Quantity: 0 Capacity: 0 LB

Additional Load and Intentional Oversize
Additional Load: 0 USGPH (@ stored temp)
Design Oversize 0%

Load Summary
Peak Demand: 306 USGPH Temperature Rise: 70 °F

Output



Search Results

To view detailed product information, select the recommended A heater that you feel best s
your application.

Load Summary

Peak Demand: 286 USGPH
Temperature Rise: 75 °F

Recommended Products

BTH-150 Mxi
Cyclone® Mxi Modulating

# Heaters:	1	Heater Recovery:	237 USGPH @ 75
Heater Storage (ea):	100 USG	1st Hour Delivery:	307 USGPH
Input (ea):	150,000 Btu/hr	3 Hour Average:	261 USGPH
		Est. Storage Recovery:	25 min
New External Tanks:	0		
Total Usable Storage:	70 USG	% Of Demand:	108% (1-hour pe

BTH-199 Mxi
Cyclone® Mxi Modulating

# Heaters:	1	Heater Recovery:	313 USGPH @ 75
Heater Storage (ea):	100 USG	1st Hour Delivery:	383 USGPH
Input (ea):	199,000 Btu/hr	3 Hour Average:	337 USGPH
		Est. Storage Recovery:	19 min
New External Tanks:	0		
Total Usable Storage:	70 USG	% Of Demand:	134% (1-hour pe

BTHL-150A
Cyclone® LV (Large Volume)

# Heaters:	1	Heater Recovery:	233 USGPH @ 75
Heater Storage (ea):	250 USG	1st Hour Delivery:	408 USGPH
Input (ea):	150,000 Btu/hr	3 Hour Average:	292 USGPH
		Est. Storage Recovery:	64 min
New External Tanks:	0		
Total Usable Storage:	175 USG	% Of Demand:	143% (1-hour pe

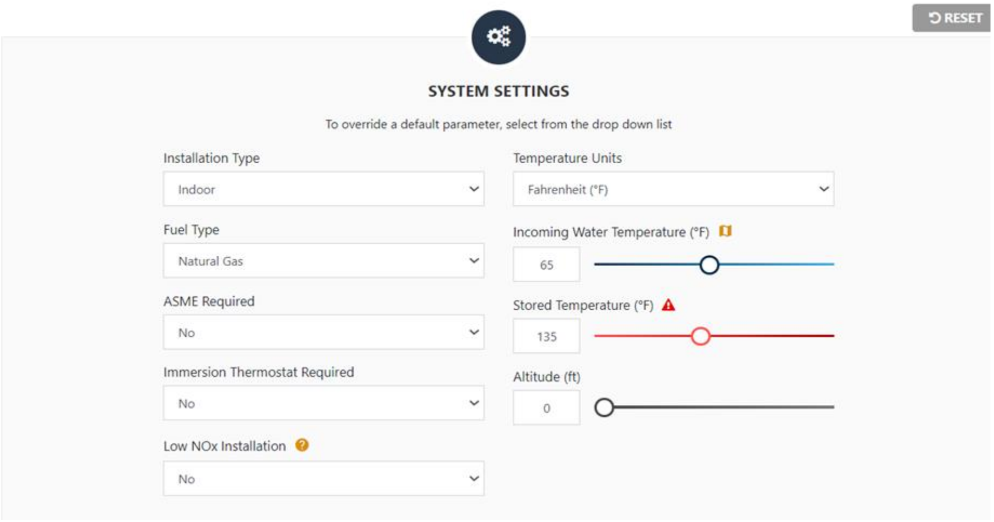
BTR-180
Master-Fit® Multiflue Gas

# Heaters:	1	Heater Recovery:	233 USGPH @ 75
Heater Storage (ea):	81 USG	1st Hour Delivery:	290 USGPH
Input (ea):	180,000 Btu/hr	3 Hour Average:	252 USGPH
		Est. Storage Recovery:	21 min
New External Tanks:	0		
Total Usable Storage:	57 USG	% Of Demand:	101% (1-hour pe

Show Alternate Products...

MFG Tool 1

Input



SYSTEM SETTINGS

To override a default parameter, select from the drop down list

Installation Type: Indoor

Fuel Type: Natural Gas

ASME Required: No

Immersion Thermostat Required: No

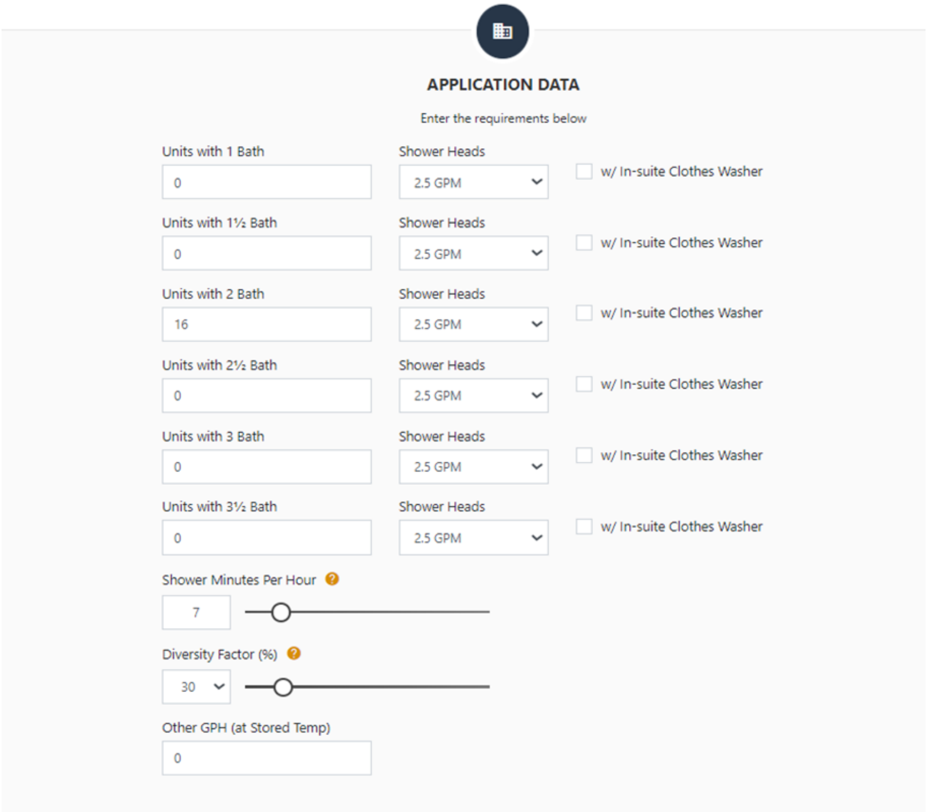
Low NOx Installation: No

Temperature Units: Fahrenheit (°F)

Incoming Water Temperature (°F): 65

Stored Temperature (°F): 135

Altitude (ft): 0



APPLICATION DATA

Enter the requirements below

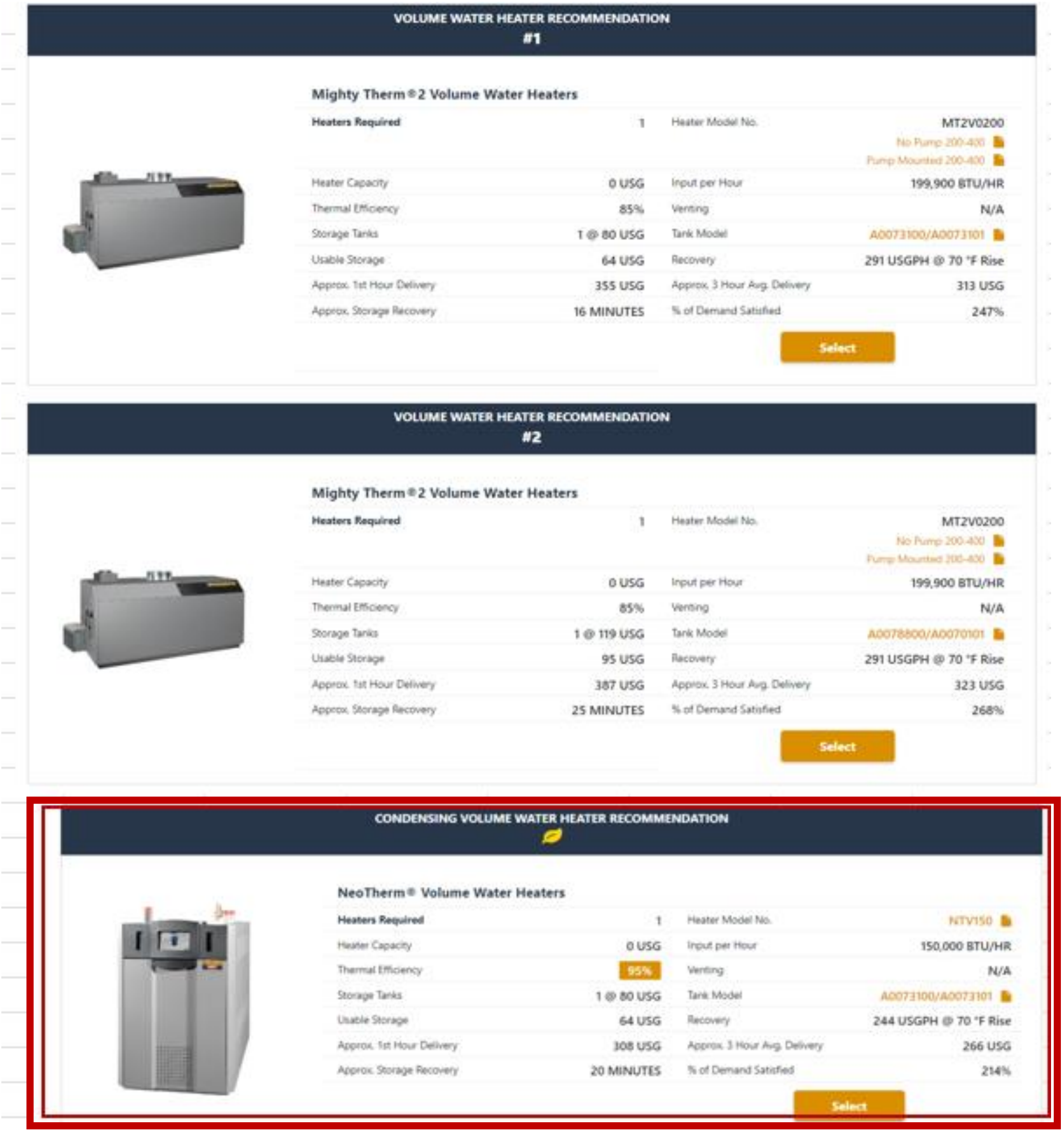
Units with 1 Bath: 0	Shower Heads: 2.5 GPM	☐ w/ In-suite Clothes Washer
Units with 1½ Bath: 0	Shower Heads: 2.5 GPM	☐ w/ In-suite Clothes Washer
Units with 2 Bath: 16	Shower Heads: 2.5 GPM	☐ w/ In-suite Clothes Washer
Units with 2½ Bath: 0	Shower Heads: 2.5 GPM	☐ w/ In-suite Clothes Washer
Units with 3 Bath: 0	Shower Heads: 2.5 GPM	☐ w/ In-suite Clothes Washer
Units with 3½ Bath: 0	Shower Heads: 2.5 GPM	☐ w/ In-suite Clothes Washer

Shower Minutes Per Hour: 7

Diversity Factor (%): 30

Other GPH (at Stored Temp): 0

Output



VOLUME WATER HEATER RECOMMENDATION
#1

Mighty Therm® 2 Volume Water Heaters

Heaters Required	1	Heater Model No.	MT2V0200 No Pump 200-400 Pump Mounted 200-400
Heater Capacity	0 USG	Input per Hour	199,900 BTU/HR
Thermal Efficiency	85%	Venting	N/A
Storage Tanks	1 @ 80 USG	Tank Model	A0073100/A0073101
Usable Storage	64 USG	Recovery	291 USGPH @ 70 °F Rise
Approx. 1st Hour Delivery	355 USG	Approx. 3 Hour Avg. Delivery	313 USG
Approx. Storage Recovery	16 MINUTES	% of Demand Satisfied	247%

VOLUME WATER HEATER RECOMMENDATION
#2

Mighty Therm® 2 Volume Water Heaters

Heaters Required	1	Heater Model No.	MT2V0200 No Pump 200-400 Pump Mounted 200-400
Heater Capacity	0 USG	Input per Hour	199,900 BTU/HR
Thermal Efficiency	85%	Venting	N/A
Storage Tanks	1 @ 119 USG	Tank Model	A0078800/A0070101
Usable Storage	95 USG	Recovery	291 USGPH @ 70 °F Rise
Approx. 1st Hour Delivery	387 USG	Approx. 3 Hour Avg. Delivery	323 USG
Approx. Storage Recovery	25 MINUTES	% of Demand Satisfied	268%

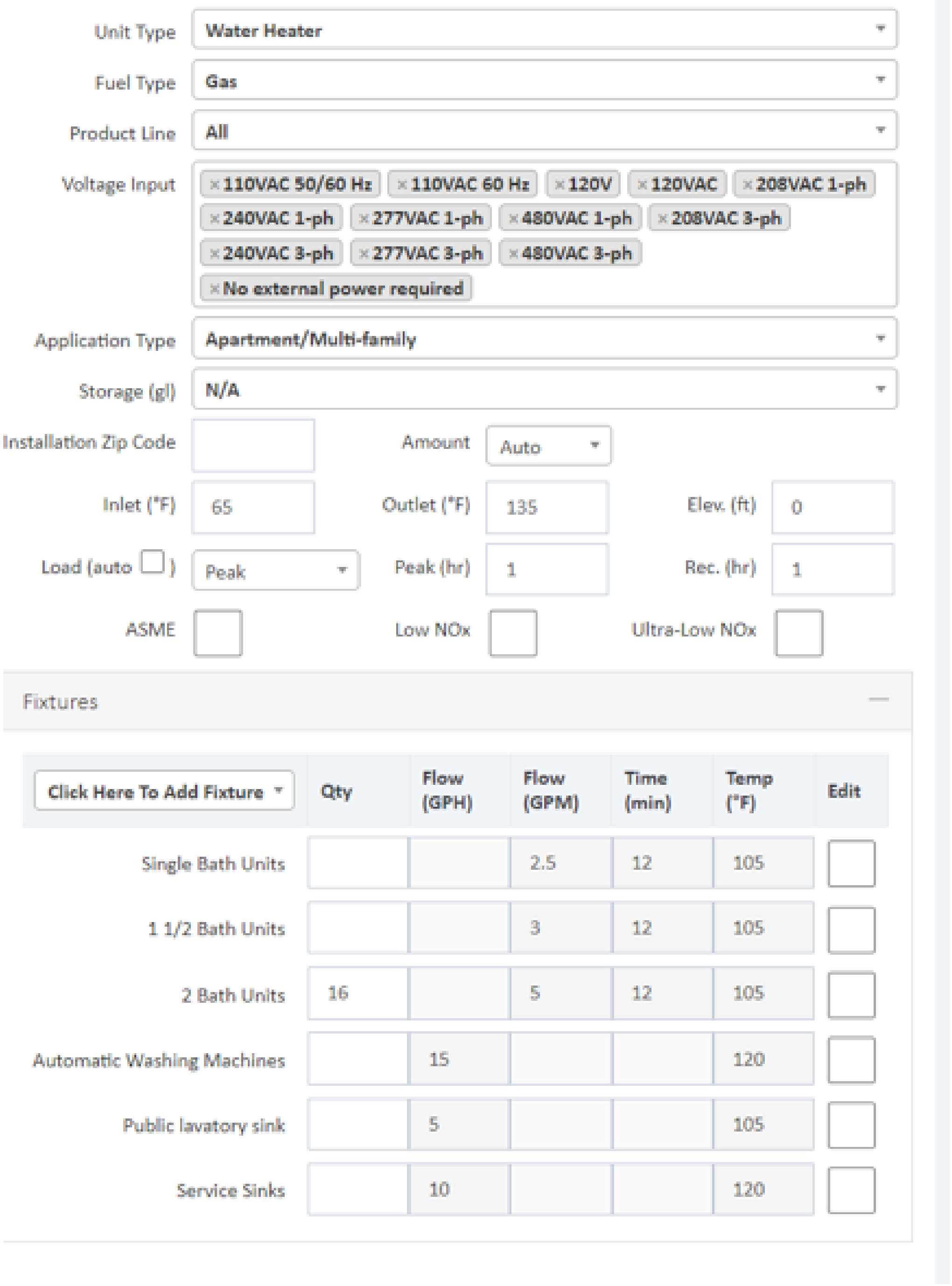
CONDENSING VOLUME WATER HEATER RECOMMENDATION

NeoTherm® Volume Water Heaters

Heaters Required	1	Heater Model No.	NTV150
Heater Capacity	0 USG	Input per Hour	150,000 BTU/HR
Thermal Efficiency	95%	Venting	N/A
Storage Tanks	1 @ 80 USG	Tank Model	A0073100/A0073101
Usable Storage	64 USG	Recovery	244 USGPH @ 70 °F Rise
Approx. 1st Hour Delivery	308 USG	Approx. 3 Hour Avg. Delivery	266 USG
Approx. Storage Recovery	20 MINUTES	% of Demand Satisfied	214%

MFG Tool 3

Input



Unit Type: Water Heater

Fuel Type: Gas

Product Line: All

Voltage Input: ×110VAC 50/60 Hz ×110VAC 60 Hz ×120V ×120VAC ×208VAC 1-ph ×240VAC 1-ph ×277VAC 1-ph ×480VAC 1-ph ×208VAC 3-ph ×240VAC 3-ph ×277VAC 3-ph ×480VAC 3-ph ×No external power required

Application Type: Apartment/Multi-family

Storage (gl): N/A

Installation Zip Code:

Amount: Auto

Inlet (°F): 65

Outlet (°F): 135

Elev. (ft): 0

Load (auto ☐): Peak

Peak (hr): 1

Rec. (hr): 1

ASME ☐

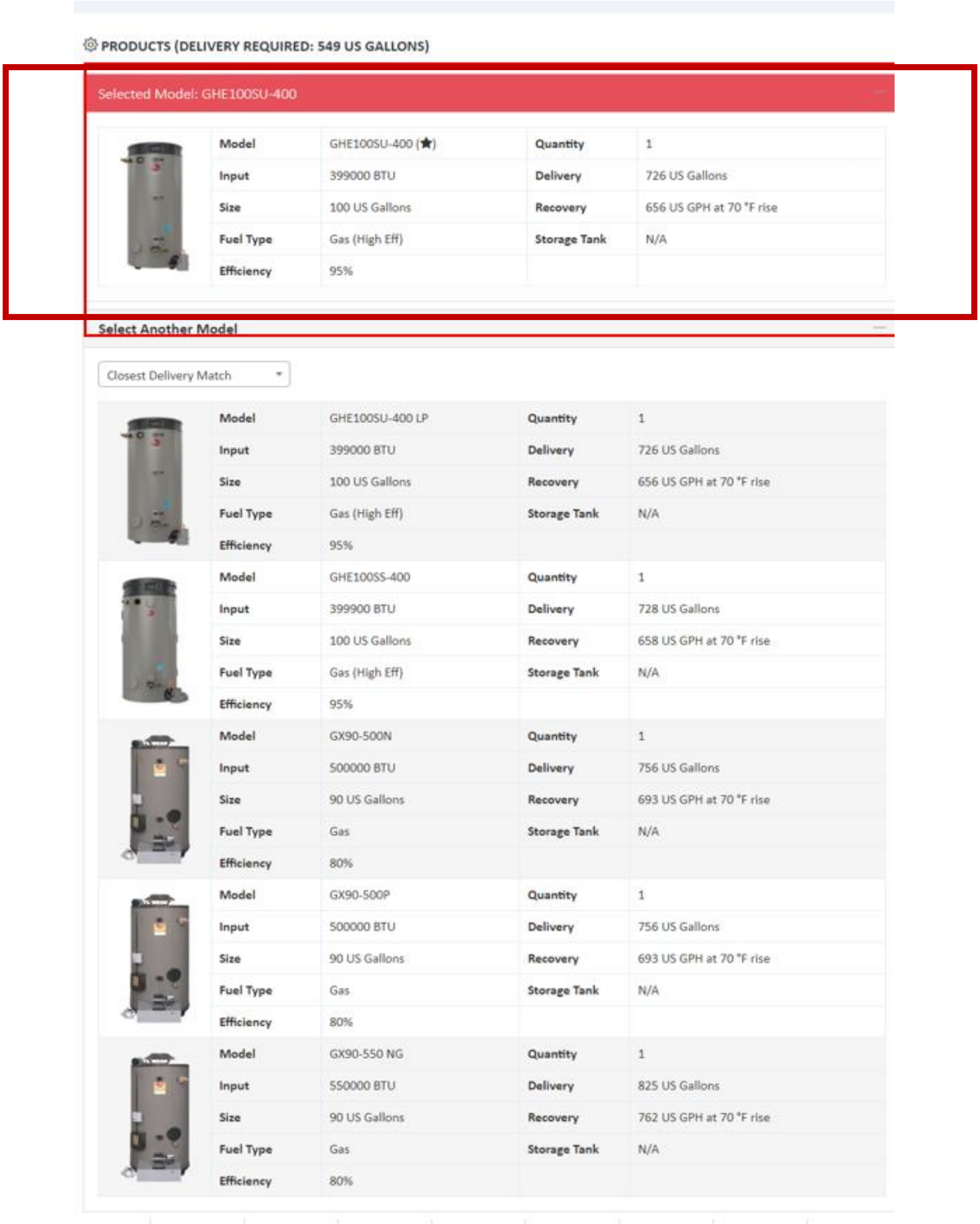
Low NOx ☐

Ultra-Low NOx ☐

Fixtures

Click Here To Add Fixture	Qty	Flow (GPH)	Flow (GPM)	Time (min)	Temp (°F)	Edit
Single Bath Units			2.5	12	105	☐
1 1/2 Bath Units			3	12	105	☐
2 Bath Units	16		5	12	105	☐
Automatic Washing Machines		15			120	☐
Public lavatory sink		5			105	☐
Service Sinks		10			120	☐

Output



PRODUCTS (DELIVERY REQUIRED: 549 US GALLONS)

Selected Model: GHE100SU-400

Model	GHE100SU-400 (★)	**Quantity**	1
Input	399000 BTU	**Delivery**	726 US Gallons
Size	100 US Gallons	**Recovery**	656 US GPH at 70 °F rise
Fuel Type	Gas (High Eff)	**Storage Tank**	N/A
Efficiency	95%		

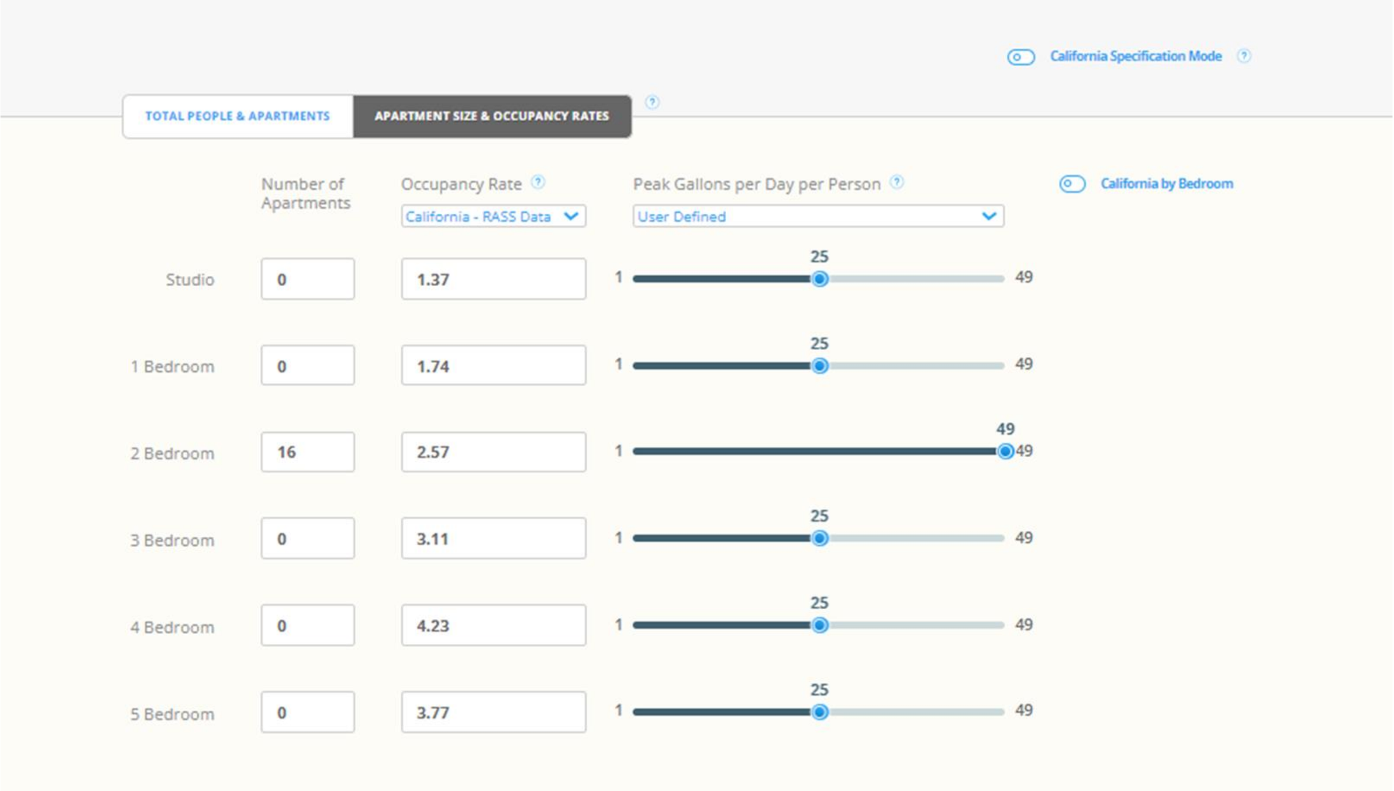
Select Another Model

Closest Delivery Match

Model	GHE100SU-400 LP	**Quantity**	1
Input	399000 BTU	**Delivery**	726 US Gallons
Size	100 US Gallons	**Recovery**	656 US GPH at 70 °F rise
Fuel Type	Gas (High Eff)	**Storage Tank**	N/A
Efficiency	95%		
Model	GHE100SS-400	**Quantity**	1
Input	399900 BTU	**Delivery**	728 US Gallons
Size	100 US Gallons	**Recovery**	658 US GPH at 70 °F rise
Fuel Type	Gas (High Eff)	**Storage Tank**	N/A
Efficiency	95%		
Model	GX90-500N	**Quantity**	1
Input	500000 BTU	**Delivery**	756 US Gallons
Size	90 US Gallons	**Recovery**	693 US GPH at 70 °F rise
Fuel Type	Gas	**Storage Tank**	N/A
Efficiency	80%		
Model	GX90-500P	**Quantity**	1
Input	500000 BTU	**Delivery**	756 US Gallons
Size	90 US Gallons	**Recovery**	693 US GPH at 70 °F rise
Fuel Type	Gas	**Storage Tank**	N/A
Efficiency	80%		
Model	GX90-550 NG	**Quantity**	1
Input	550000 BTU	**Delivery**	825 US Gallons
Size	90 US Gallons	**Recovery**	762 US GPH at 70 °F rise
Fuel Type	Gas	**Storage Tank**	N/A
Efficiency	80%		

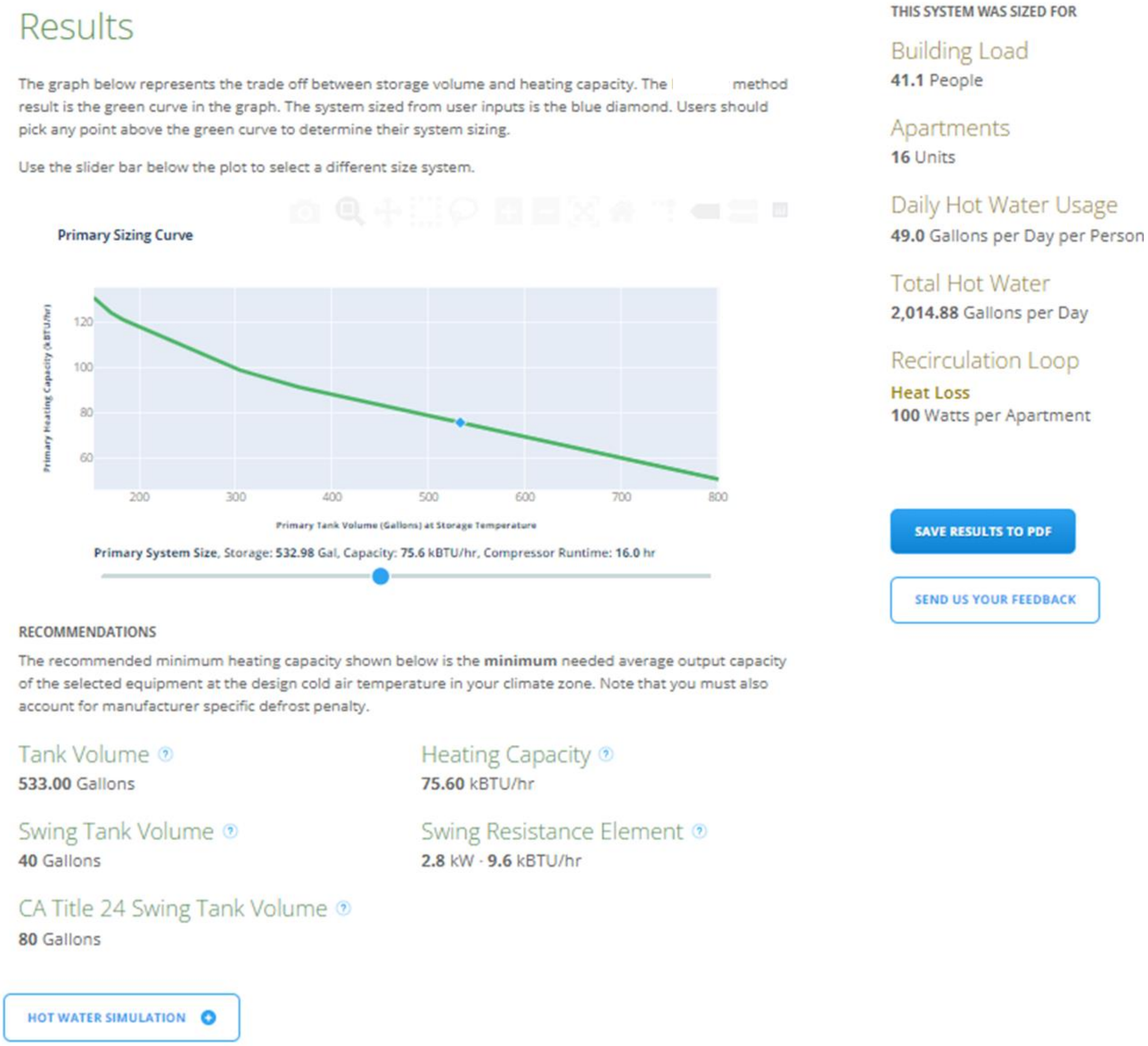
EHPWH Tool

Input



	Number of Apartments	Occupancy Rate California - RASS Data	Peak Gallons per Day per Person User Defined
Studio	0	1.37	1 — 25 — 49
1 Bedroom	0	1.74	1 — 25 — 49
2 Bedroom	16	2.57	1 — 49 — 49
3 Bedroom	0	3.11	1 — 25 — 49
4 Bedroom	0	4.23	1 — 25 — 49
5 Bedroom	0	3.77	1 — 25 — 49

Output



Results

The graph below represents the trade off between storage volume and heating capacity. The [redacted] method result is the green curve in the graph. The system sized from user inputs is the blue diamond. Users should pick any point above the green curve to determine their system sizing.

Use the slider bar below the plot to select a different size system.

Primary System Size, Storage: **532.98** Gal, Capacity: **75.6** kBTU/hr, Compressor Runtime: **16.0** hr

RECOMMENDATIONS

The recommended minimum heating capacity shown below is the **minimum** needed average output capacity of the selected equipment at the design cold air temperature in your climate zone. Note that you must also account for manufacturer specific defrost penalty.

Tank Volume
533.00 Gallons

Heating Capacity
75.60 kBTU/hr

Swing Tank Volume
40 Gallons

Swing Resistance Element
2.8 kW - **9.6** kBTU/hr

CA Title 24 Swing Tank Volume
80 Gallons

THIS SYSTEM WAS SIZED FOR

Building Load
41.1 People

Apartments
16 Units

Daily Hot Water Usage
49.0 Gallons per Day per Person

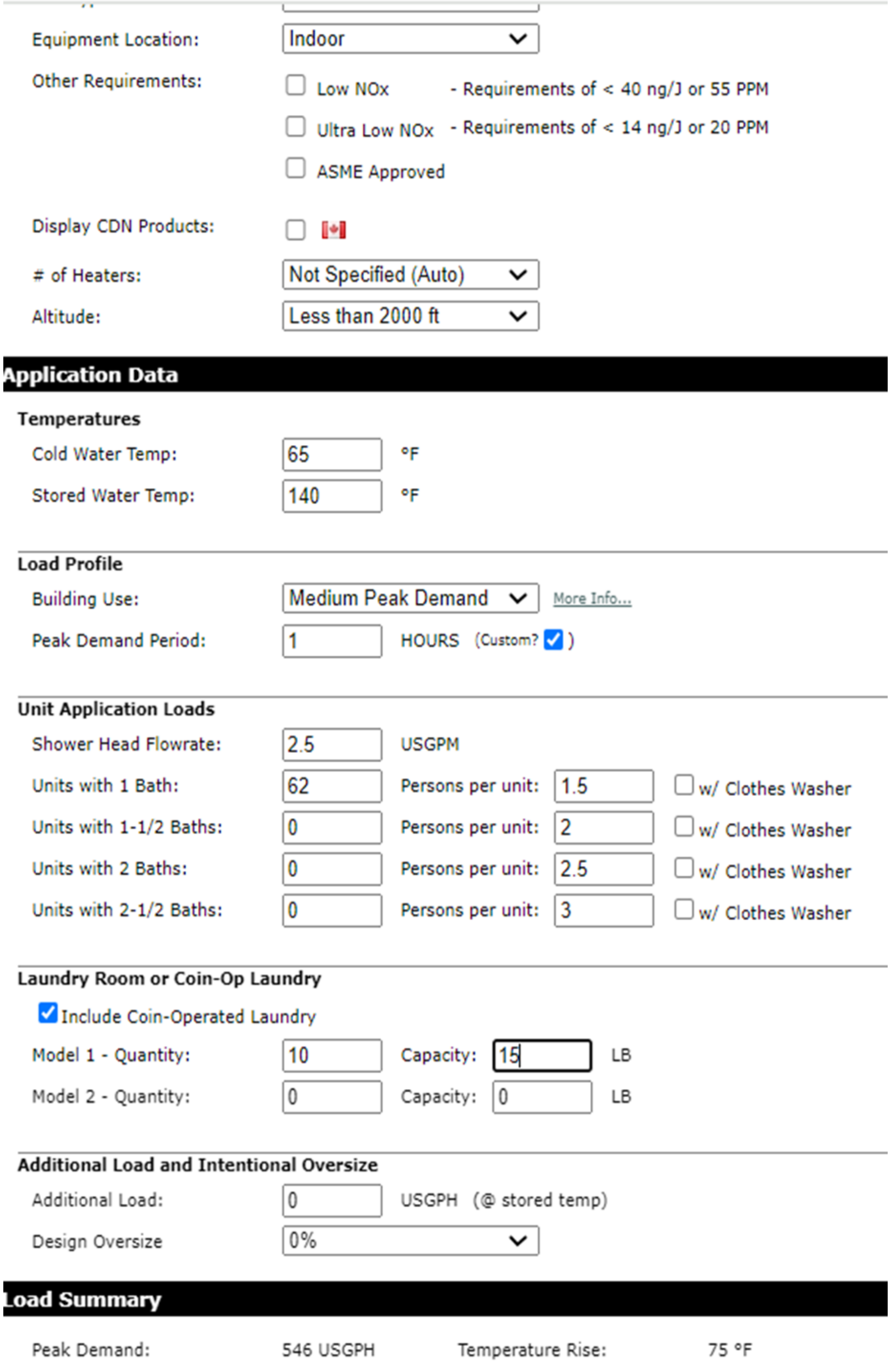
Total Hot Water
2,014.88 Gallons per Day

Recirculation Loop
Heat Loss
100 Watts per Apartment

Site 4

MFG Tool 2

Input



Equipment Location: Indoor

Other Requirements:

☐ Low NOx - Requirements of < 40 ng/J or 55 PPM

☐ Ultra Low NOx - Requirements of < 14 ng/J or 20 PPM

☐ ASME Approved

Display CDN Products: ☐

# of Heaters: Not Specified (Auto)

Altitude: Less than 2000 ft

Application Data

Temperatures

Cold Water Temp: 65 °F

Stored Water Temp: 140 °F

Load Profile

Building Use: Medium Peak Demand More Info...

Peak Demand Period: 1 HOURS (Custom? ☑)

Unit Application Loads

Shower Head Flowrate: 2.5 USGPM

Units with 1 Bath: 62 Persons per unit: 1.5 ☐ w/ Clothes Washer

Units with 1-1/2 Baths: 0 Persons per unit: 2 ☐ w/ Clothes Washer

Units with 2 Baths: 0 Persons per unit: 2.5 ☐ w/ Clothes Washer

Units with 2-1/2 Baths: 0 Persons per unit: 3 ☐ w/ Clothes Washer

Laundry Room or Coin-Op Laundry

☑ Include Coin-Operated Laundry

Model 1 - Quantity: 10 Capacity: 15 LB

Model 2 - Quantity: 0 Capacity: 0 LB

Additional Load and Intentional Oversize

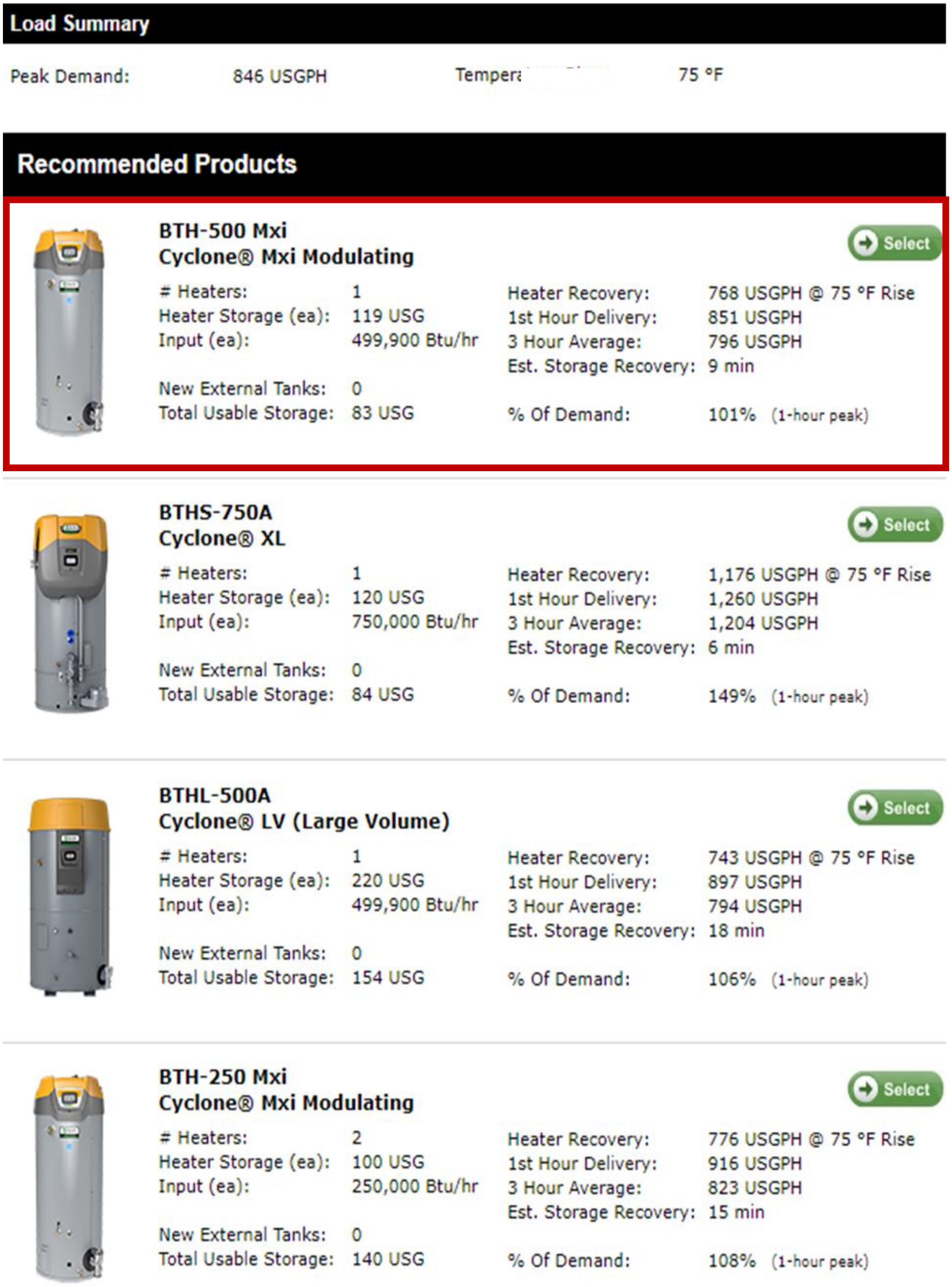
Additional Load: 0 USGPH (@ stored temp)

Design Oversize 0%

Load Summary

Peak Demand: 546 USGPH Temperature Rise: 75 °F

Output



Load Summary

Peak Demand: 846 USGPH

Tempera 75 °F

Recommended Products

BTH-500 Mxi
Cyclone® Mxi Modulating

Heaters: 1
Heater Storage (ea): 119 USG
Input (ea): 499,900 Btu/hr
New External Tanks: 0
Total Usable Storage: 83 USG
Heater Recovery: 768 USGPH @ 75 °F Rise
1st Hour Delivery: 851 USGPH
3 Hour Average: 796 USGPH
Est. Storage Recovery: 9 min
% Of Demand: 101% (1-hour peak)

BTHS-750A
Cyclone® XL

Heaters: 1
Heater Storage (ea): 120 USG
Input (ea): 750,000 Btu/hr
New External Tanks: 0
Total Usable Storage: 84 USG
Heater Recovery: 1,176 USGPH @ 75 °F Rise
1st Hour Delivery: 1,260 USGPH
3 Hour Average: 1,204 USGPH
Est. Storage Recovery: 6 min
% Of Demand: 149% (1-hour peak)

BTHL-500A
Cyclone® LV (Large Volume)

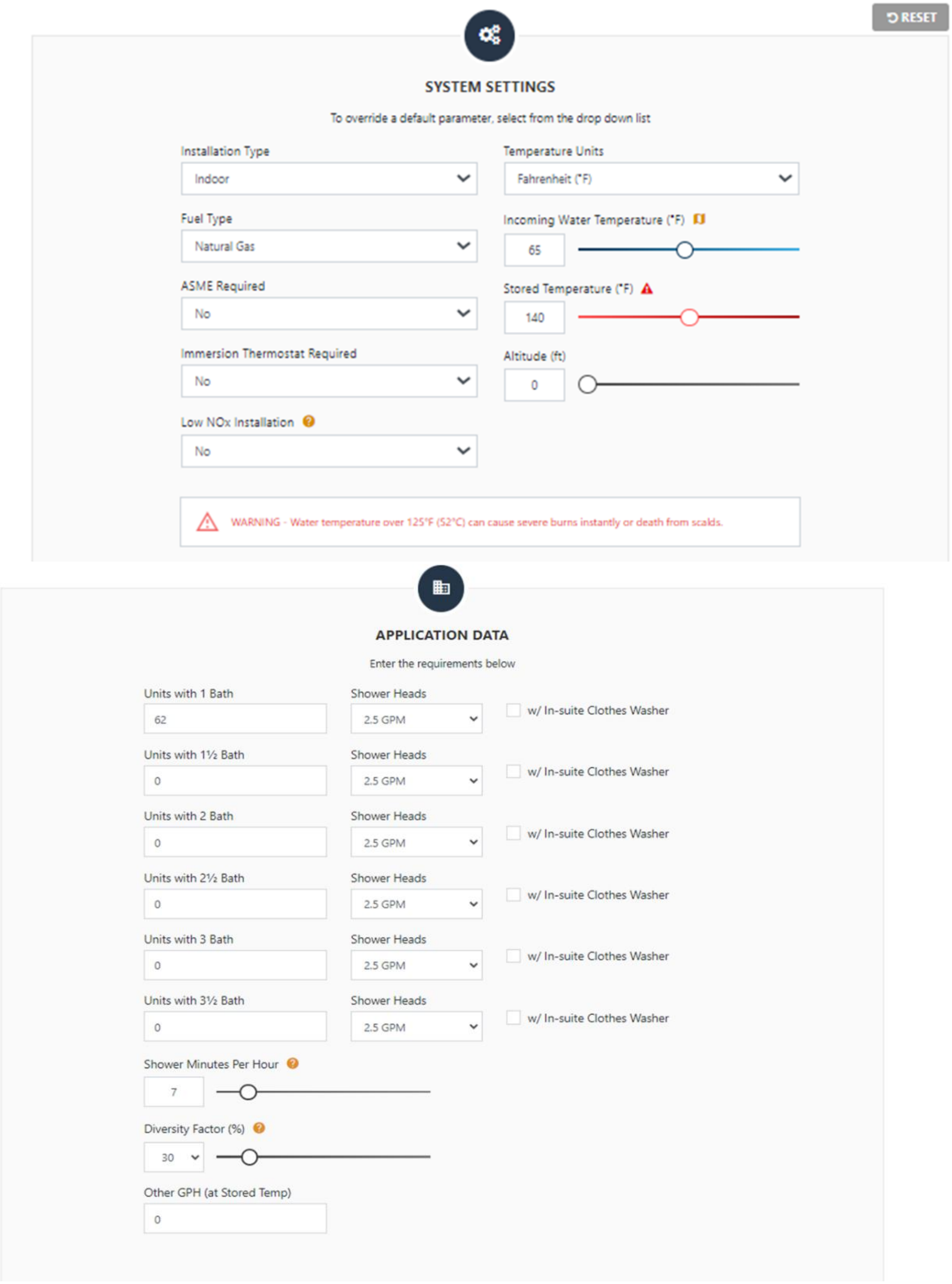
Heaters: 1
Heater Storage (ea): 220 USG
Input (ea): 499,900 Btu/hr
New External Tanks: 0
Total Usable Storage: 154 USG
Heater Recovery: 743 USGPH @ 75 °F Rise
1st Hour Delivery: 897 USGPH
3 Hour Average: 794 USGPH
Est. Storage Recovery: 18 min
% Of Demand: 106% (1-hour peak)

BTH-250 Mxi
Cyclone® Mxi Modulating

Heaters: 2
Heater Storage (ea): 100 USG
Input (ea): 250,000 Btu/hr
New External Tanks: 0
Total Usable Storage: 140 USG
Heater Recovery: 776 USGPH @ 75 °F Rise
1st Hour Delivery: 916 USGPH
3 Hour Average: 823 USGPH
Est. Storage Recovery: 15 min
% Of Demand: 108% (1-hour peak)

MFG Tool 1

Input



SYSTEM SETTINGS

To override a default parameter, select from the drop down list

Installation Type: Indoor

Fuel Type: Natural Gas

ASME Required: No

Immersion Thermostat Required: No

Low NOx Installation: No

Temperature Units: Fahrenheit (°F)

Incoming Water Temperature (°F): 65

Stored Temperature (°F): 140

Altitude (ft): 0

WARNING - Water temperature over 125°F (52°C) can cause severe burns instantly or death from scalds.

APPLICATION DATA

Enter the requirements below

Units with 1 Bath: 62 | Shower Heads: 2.5 GPM | ☐ w/ In-suite Clothes Washer

Units with 1½ Bath: 0 | Shower Heads: 2.5 GPM | ☐ w/ In-suite Clothes Washer

Units with 2 Bath: 0 | Shower Heads: 2.5 GPM | ☐ w/ In-suite Clothes Washer

Units with 2½ Bath: 0 | Shower Heads: 2.5 GPM | ☐ w/ In-suite Clothes Washer

Units with 3 Bath: 0 | Shower Heads: 2.5 GPM | ☐ w/ In-suite Clothes Washer

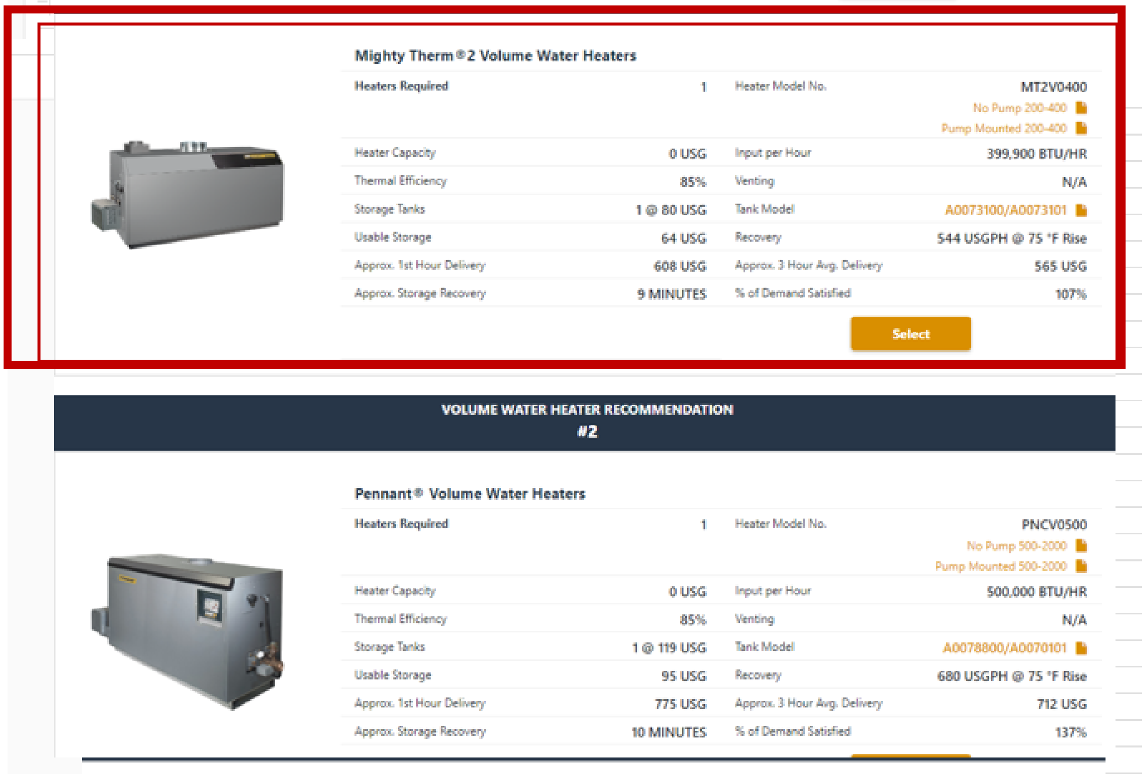
Units with 3½ Bath: 0 | Shower Heads: 2.5 GPM | ☐ w/ In-suite Clothes Washer

Shower Minutes Per Hour: 7

Diversity Factor (%): 30

Other GPH (at Stored Temp): 0

Output



Mighty Therm®2 Volume Water Heaters

Heaters Required	1	Heater Model No.	MT2V0400 No Pump 200-400 Pump Mounted 200-400
Heater Capacity	0 USG	Input per Hour	399,900 BTU/HR
Thermal Efficiency	85%	Venting	N/A
Storage Tanks	1 @ 80 USG	Tank Model	A0073100/A0073101
Usable Storage	64 USG	Recovery	544 USGPH @ 75 °F Rise
Approx. 1st Hour Delivery	608 USG	Approx. 3 Hour Avg. Delivery	565 USG
Approx. Storage Recovery	9 MINUTES	% of Demand Satisfied	107%

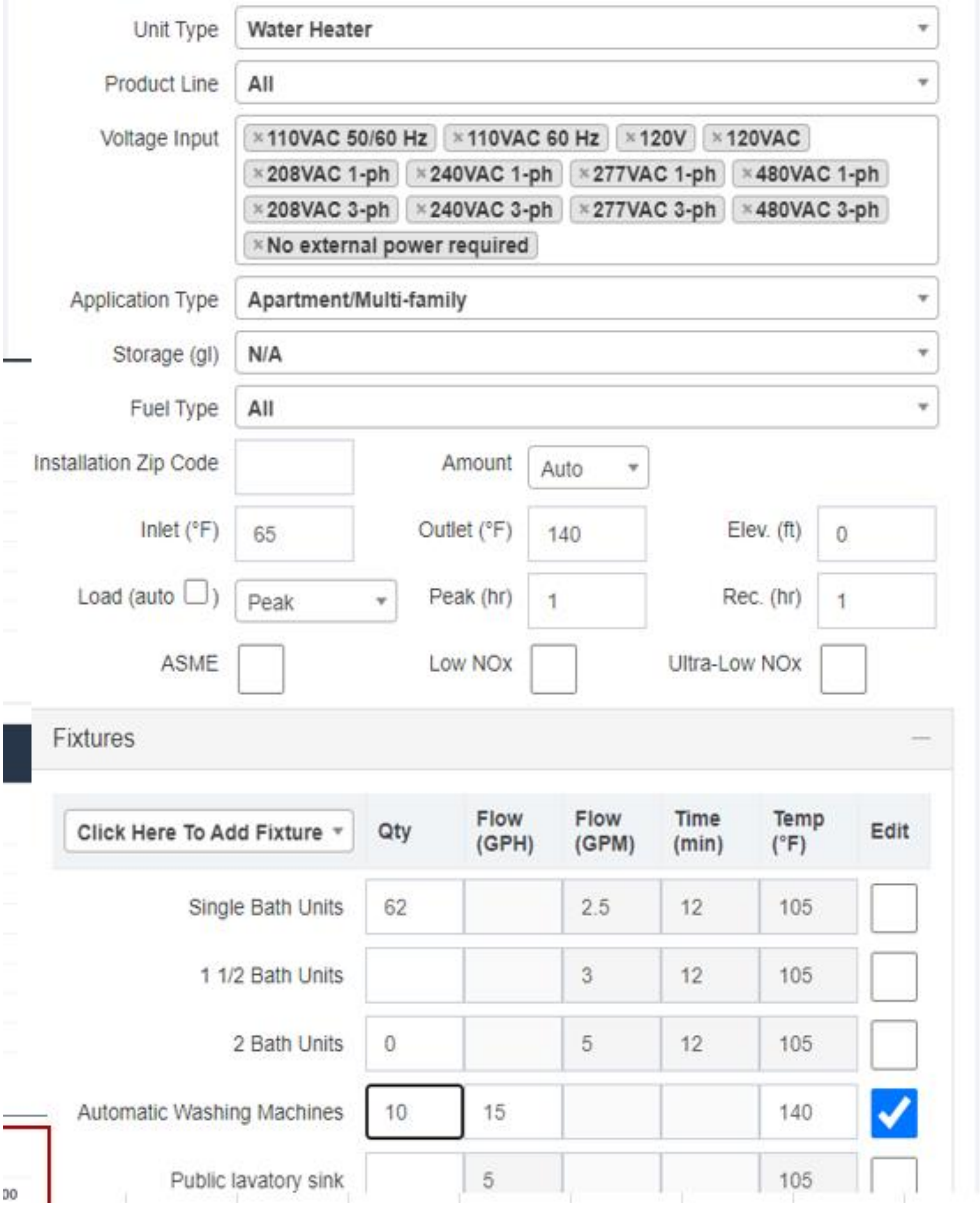
VOLUME WATER HEATER RECOMMENDATION
#2

Pennant® Volume Water Heaters

Heaters Required	1	Heater Model No.	PNCV0500 No Pump 500-2000 Pump Mounted 500-2000
Heater Capacity	0 USG	Input per Hour	500,000 BTU/HR
Thermal Efficiency	85%	Venting	N/A
Storage Tanks	1 @ 119 USG	Tank Model	A0078800/A0070101
Usable Storage	95 USG	Recovery	680 USGPH @ 75 °F Rise
Approx. 1st Hour Delivery	775 USG	Approx. 3 Hour Avg. Delivery	712 USG
Approx. Storage Recovery	10 MINUTES	% of Demand Satisfied	137%

MFG Tool 3

Input



Unit Type: Water Heater

Product Line: All

Voltage Input: ×110VAC 50/60 Hz ×110VAC 60 Hz ×120V ×120VAC ×208VAC 1-ph ×240VAC 1-ph ×277VAC 1-ph ×480VAC 1-ph ×208VAC 3-ph ×240VAC 3-ph ×277VAC 3-ph ×480VAC 3-ph ×No external power required

Application Type: Apartment/Multi-family

Storage (gl): N/A

Fuel Type: All

Installation Zip Code:

Amount: Auto

Inlet (°F): 65

Outlet (°F): 140

Elev. (ft): 0

Load (auto ☐): Peak

Peak (hr): 1

Rec. (hr): 1

ASME ☐

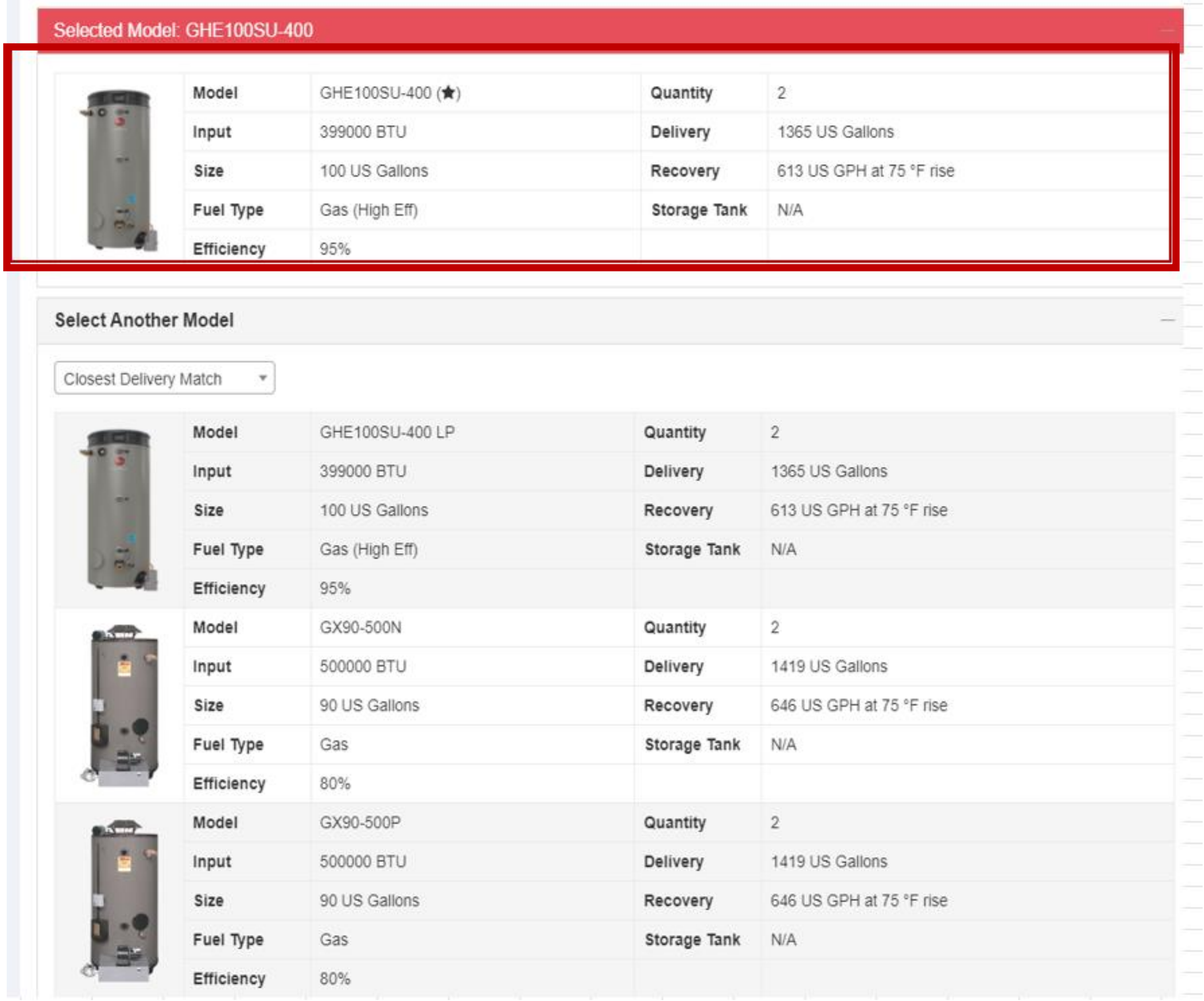
Low NOx ☐

Ultra-Low NOx ☐

Fixtures

Click Here To Add Fixture	Qty	Flow (GPH)	Flow (GPM)	Time (min)	Temp (°F)	Edit
Single Bath Units	62		2.5	12	105	☐
1 1/2 Bath Units			3	12	105	☐
2 Bath Units	0		5	12	105	☐
Automatic Washing Machines	10	15			140	☑
Public lavatory sink		5			105	☐

Output



Selected Model: GHE100SU-400

Model	GHE100SU-400 (★)	**Quantity**	2
Input	399000 BTU	**Delivery**	1365 US Gallons
Size	100 US Gallons	**Recovery**	613 US GPH at 75 °F rise
Fuel Type	Gas (High Eff)	**Storage Tank**	N/A
Efficiency	95%		

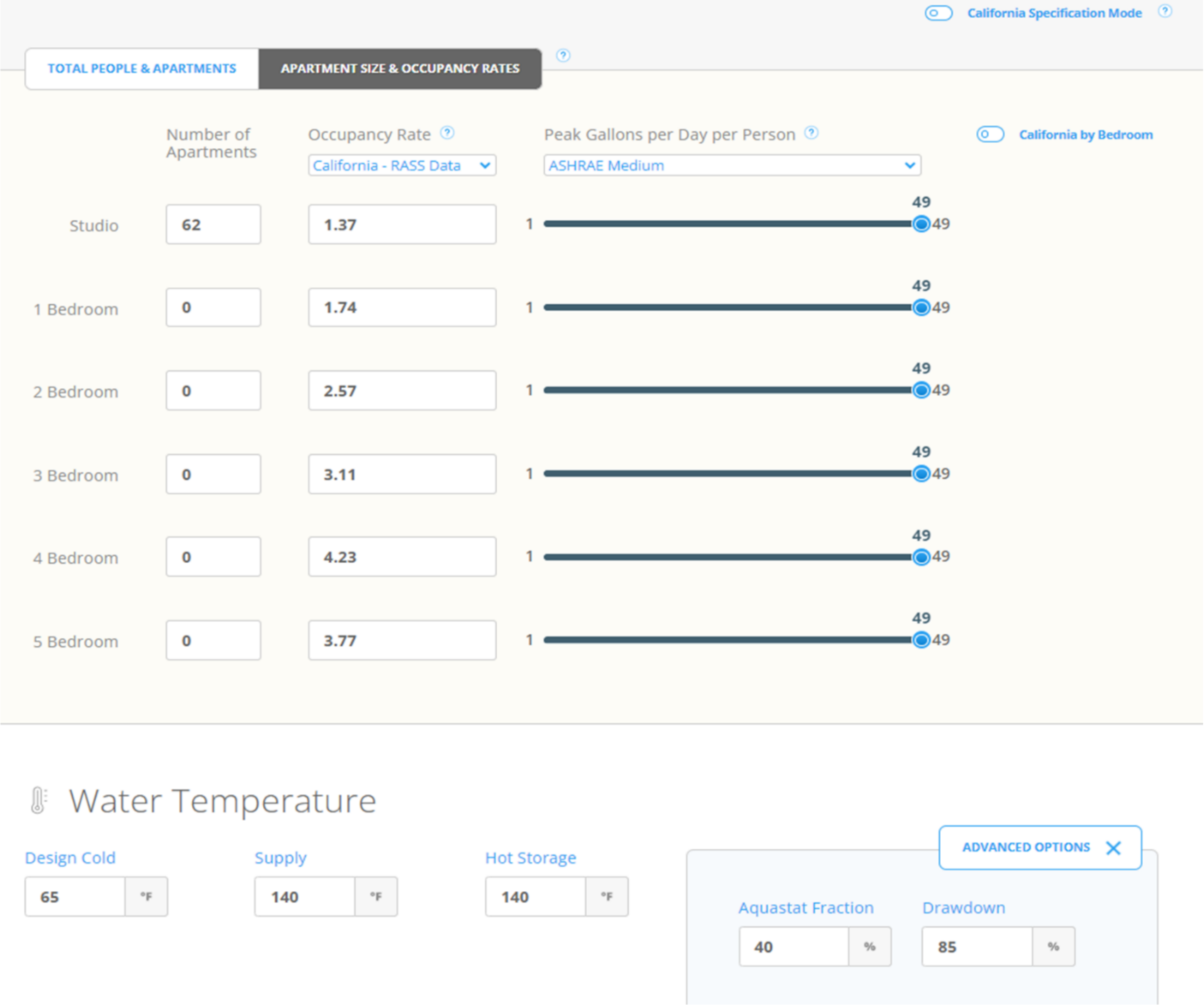
Select Another Model

Closest Delivery Match

Model	GHE100SU-400 LP	**Quantity**	2
Input	399000 BTU	**Delivery**	1365 US Gallons
Size	100 US Gallons	**Recovery**	613 US GPH at 75 °F rise
Fuel Type	Gas (High Eff)	**Storage Tank**	N/A
Efficiency	95%		
Model	GX90-500N	**Quantity**	2
Input	500000 BTU	**Delivery**	1419 US Gallons
Size	90 US Gallons	**Recovery**	646 US GPH at 75 °F rise
Fuel Type	Gas	**Storage Tank**	N/A
Efficiency	80%		
Model	GX90-500P	**Quantity**	2
Input	500000 BTU	**Delivery**	1419 US Gallons
Size	90 US Gallons	**Recovery**	646 US GPH at 75 °F rise
Fuel Type	Gas	**Storage Tank**	N/A
Efficiency	80%		

EHPWH Tool

Input



	Number of Apartments	Occupancy Rate	Peak Gallons per Day per Person
		California - RASS Data	ASHRAE Medium
Studio	62	1.37	49
1 Bedroom	0	1.74	49
2 Bedroom	0	2.57	49
3 Bedroom	0	3.11	49
4 Bedroom	0	4.23	49
5 Bedroom	0	3.77	49

Water Temperature

Design Cold: 65 °F

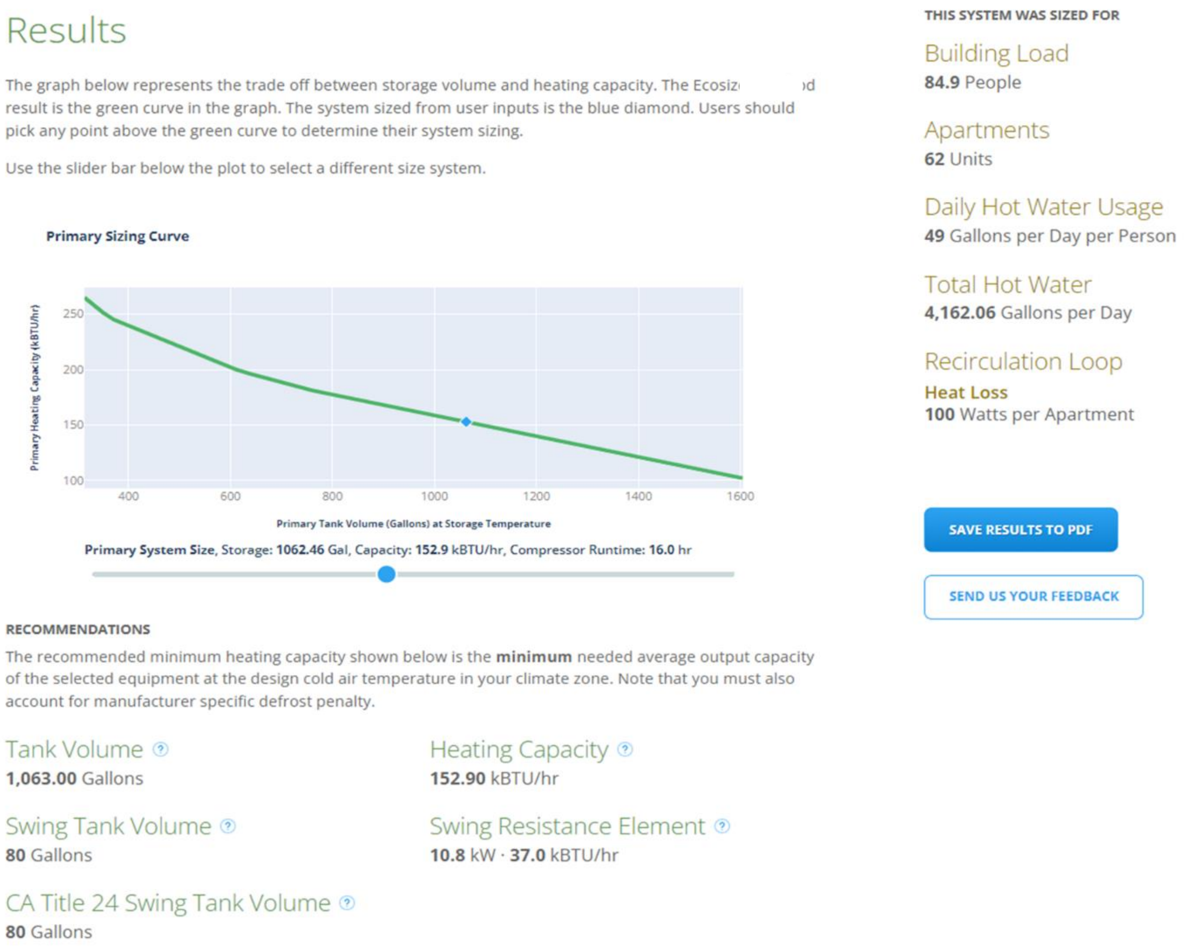
Supply: 140 °F

Hot Storage: 140 °F

Aquastat Fraction: 40 %

Drawdown: 85 %

Output



Results

The graph below represents the trade off between storage volume and heating capacity. The Ecosiz od result is the green curve in the graph. The system sized from user inputs is the blue diamond. Users should pick any point above the green curve to determine their system sizing.

Use the slider bar below the plot to select a different size system.

Primary System Size, Storage: **1062.46** Gal, Capacity: **152.9** kBTU/hr, Compressor Runtime: **16.0** hr

RECOMMENDATIONS

The recommended minimum heating capacity shown below is the **minimum** needed average output capacity of the selected equipment at the design cold air temperature in your climate zone. Note that you must also account for manufacturer specific defrost penalty.

Tank Volume
1,063.00 Gallons

Heating Capacity
152.90 kBTU/hr

Swing Tank Volume
80 Gallons

Swing Resistance Element
10.8 kW · **37.0** kBTU/hr

CA Title 24 Swing Tank Volume
80 Gallons

THIS SYSTEM WAS SIZED FOR

Building Load
84.9 People

Apartments
62 Units

Daily Hot Water Usage
49 Gallons per Day per Person

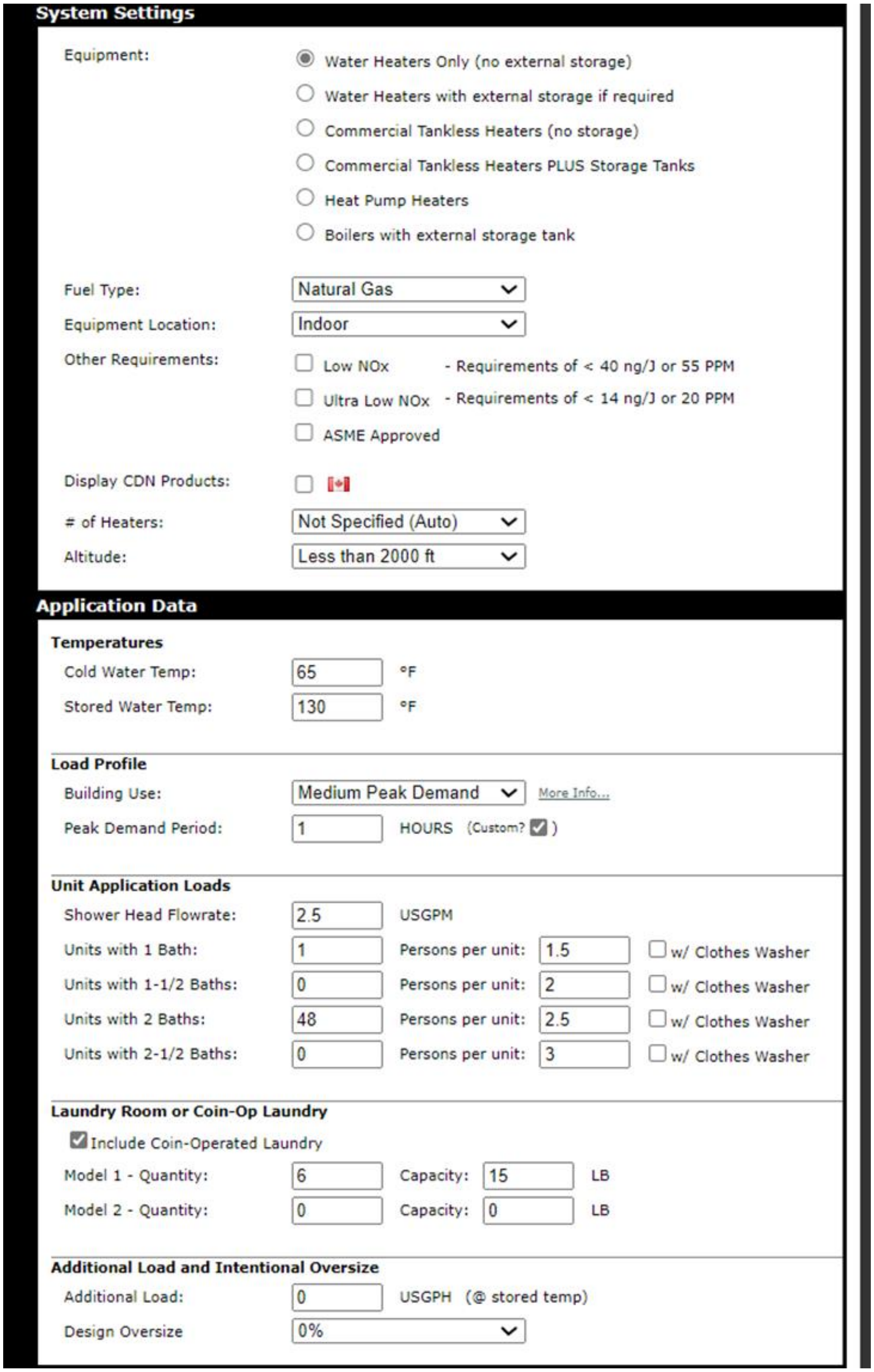
Total Hot Water
4,162.06 Gallons per Day

Recirculation Loop
Heat Loss
100 Watts per Apartment

Site 5

MFG Tool 2

Input



System Settings

Equipment:
● Water Heaters Only (no external storage)
○ Water Heaters with external storage if required
○ Commercial Tankless Heaters (no storage)
○ Commercial Tankless Heaters PLUS Storage Tanks
○ Heat Pump Heaters
○ Boilers with external storage tank

Fuel Type: Natural Gas

Equipment Location: Indoor

Other Requirements:
☐ Low NOx - Requirements of < 40 ng/J or 55 PPM
☐ Ultra Low NOx - Requirements of < 14 ng/J or 20 PPM
☐ ASME Approved

Display CDN Products: ☐

\# of Heaters: Not Specified (Auto)

Altitude: Less than 2000 ft

Application Data

Temperatures

Cold Water Temp: 65 °F

Stored Water Temp: 130 °F

Load Profile

Building Use: Medium Peak Demand More Info...

Peak Demand Period: 1 HOURS (Custom? ☑)

Unit Application Loads

Shower Head Flowrate: 2.5 USGPM

Units with 1 Bath:	1	Persons per unit:	1.5	☐ w/ Clothes Washer
Units with 1-1/2 Baths:	0	Persons per unit:	2	☐ w/ Clothes Washer
Units with 2 Baths:	48	Persons per unit:	2.5	☐ w/ Clothes Washer
Units with 2-1/2 Baths:	0	Persons per unit:	3	☐ w/ Clothes Washer

Laundry Room or Coin-Op Laundry

☑ Include Coin-Operated Laundry

Model 1 - Quantity: 6 Capacity: 15 LB

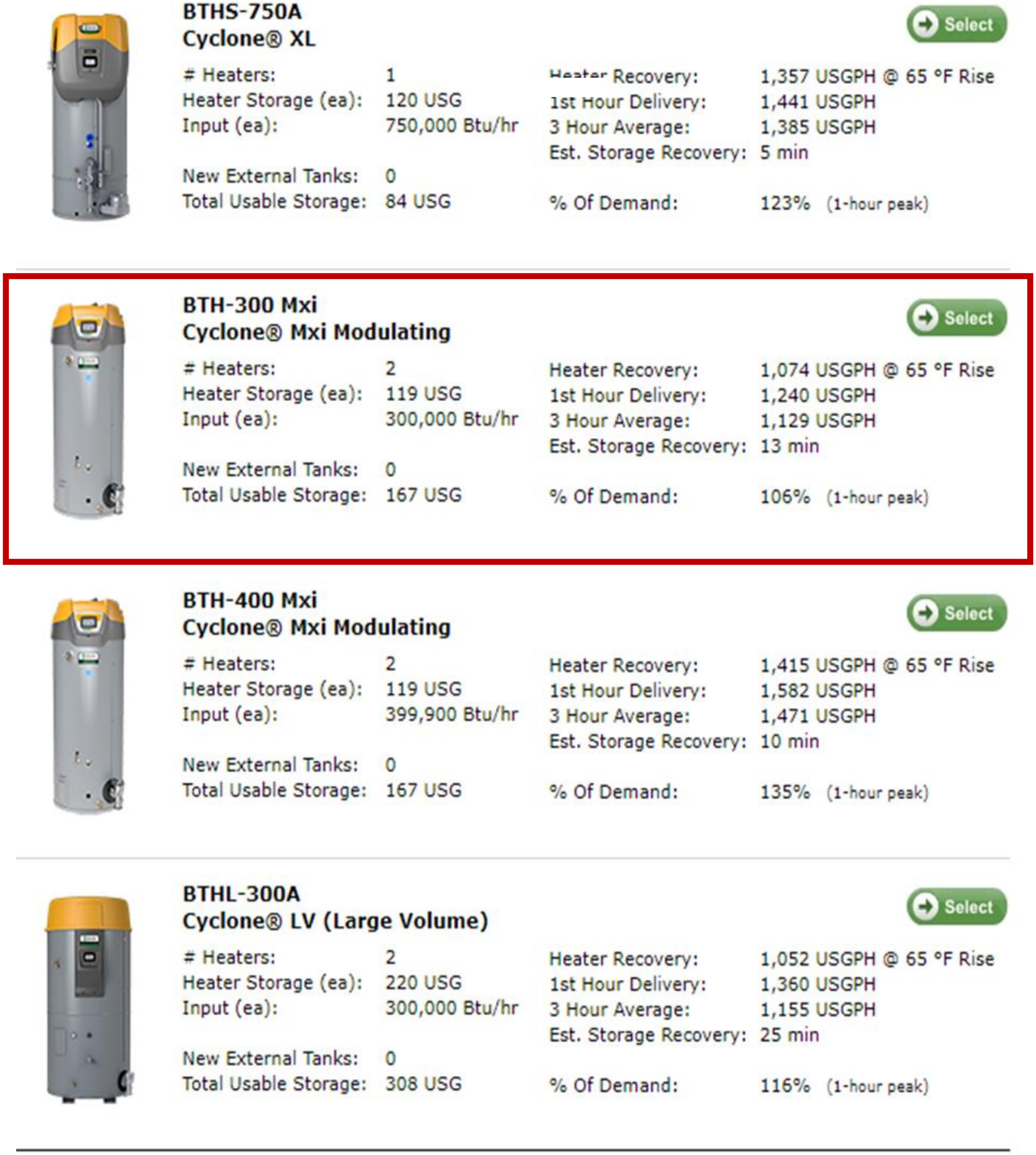
Model 2 - Quantity: 0 Capacity: 0 LB

Additional Load and Intentional Oversize

Additional Load: 0 USGPH (@ stored temp)

Design Oversize 0%

Output



BTHS-750A
Cyclone® XL

Heaters: 1
Heater Storage (ea): 120 USG
Input (ea): 750,000 Btu/hr

New External Tanks: 0
Total Usable Storage: 84 USG

Heater Recovery: 1,357 USGPH @ 65 °F Rise
1st Hour Delivery: 1,441 USGPH
3 Hour Average: 1,385 USGPH
Est. Storage Recovery: 5 min

% Of Demand: 123% (1-hour peak)

BTH-300 Mxi
Cyclone® Mxi Modulating

Heaters: 2
Heater Storage (ea): 119 USG
Input (ea): 300,000 Btu/hr

New External Tanks: 0
Total Usable Storage: 167 USG

Heater Recovery: 1,074 USGPH @ 65 °F Rise
1st Hour Delivery: 1,240 USGPH
3 Hour Average: 1,129 USGPH
Est. Storage Recovery: 13 min

% Of Demand: 106% (1-hour peak)

BTH-400 Mxi
Cyclone® Mxi Modulating

Heaters: 2
Heater Storage (ea): 119 USG
Input (ea): 399,900 Btu/hr

New External Tanks: 0
Total Usable Storage: 167 USG

Heater Recovery: 1,415 USGPH @ 65 °F Rise
1st Hour Delivery: 1,582 USGPH
3 Hour Average: 1,471 USGPH
Est. Storage Recovery: 10 min

% Of Demand: 135% (1-hour peak)

BTHL-300A
Cyclone® LV (Large Volume)

Heaters: 2
Heater Storage (ea): 220 USG
Input (ea): 300,000 Btu/hr

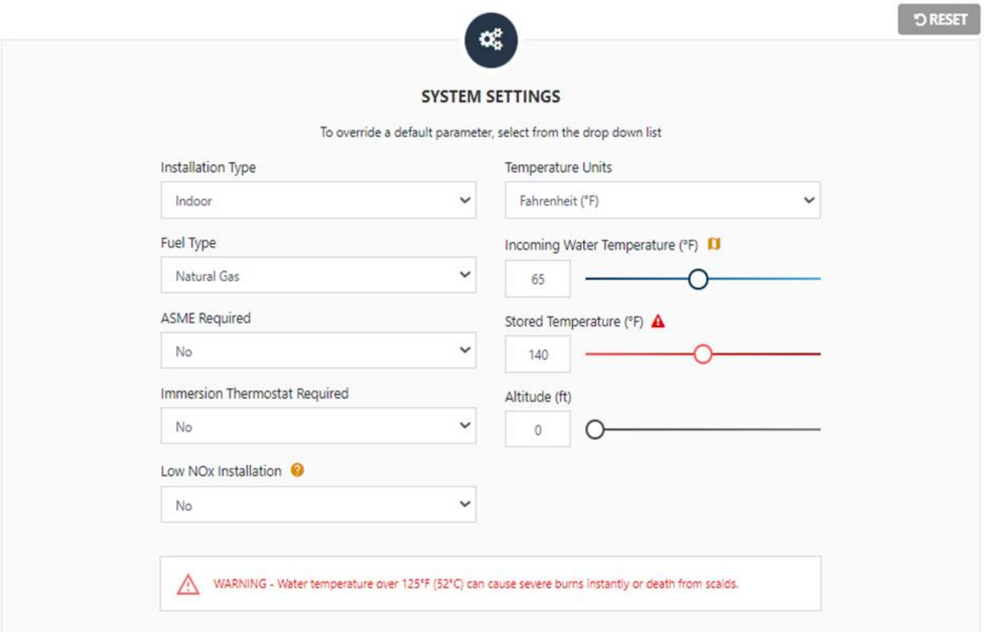
New External Tanks: 0
Total Usable Storage: 308 USG

Heater Recovery: 1,052 USGPH @ 65 °F Rise
1st Hour Delivery: 1,360 USGPH
3 Hour Average: 1,155 USGPH
Est. Storage Recovery: 25 min

% Of Demand: 116% (1-hour peak)

MFG Tool 1

Input



SYSTEM SETTINGS

To override a default parameter, select from the drop down list

Installation Type: Indoor

Temperature Units: Fahrenheit (°F)

Fuel Type: Natural Gas

Incoming Water Temperature (°F): 65

ASME Required: No

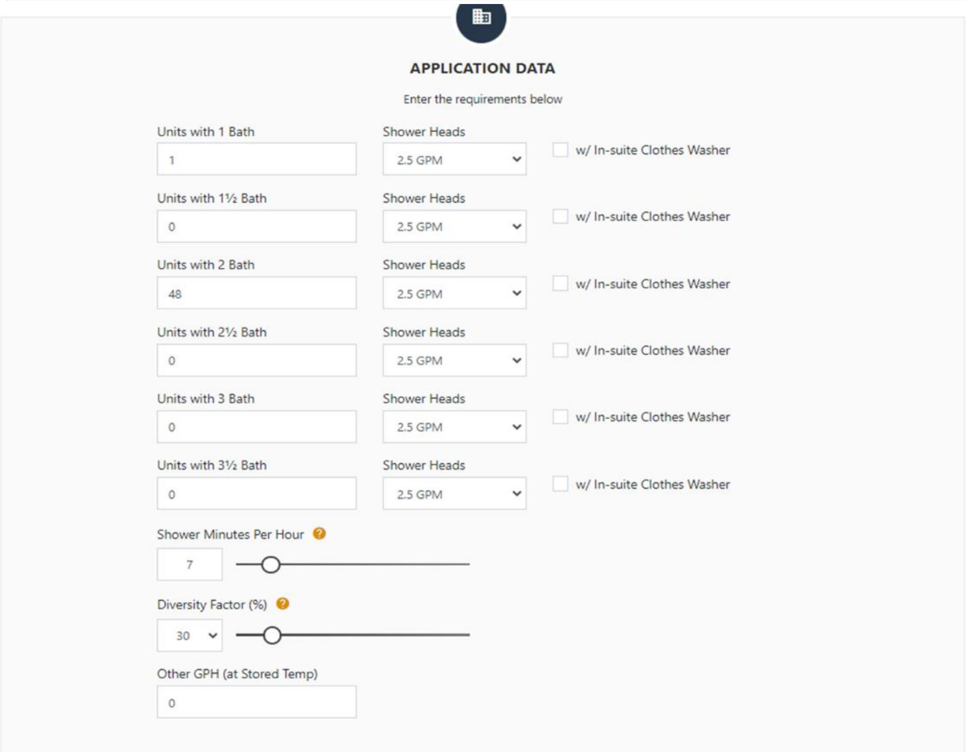
Stored Temperature (°F): 140

Immersion Thermostat Required: No

Altitude (ft): 0

Low NOx Installation: No

WARNING - Water temperature over 125°F (52°C) can cause severe burns instantly or death from scalds.



APPLICATION DATA

Enter the requirements below

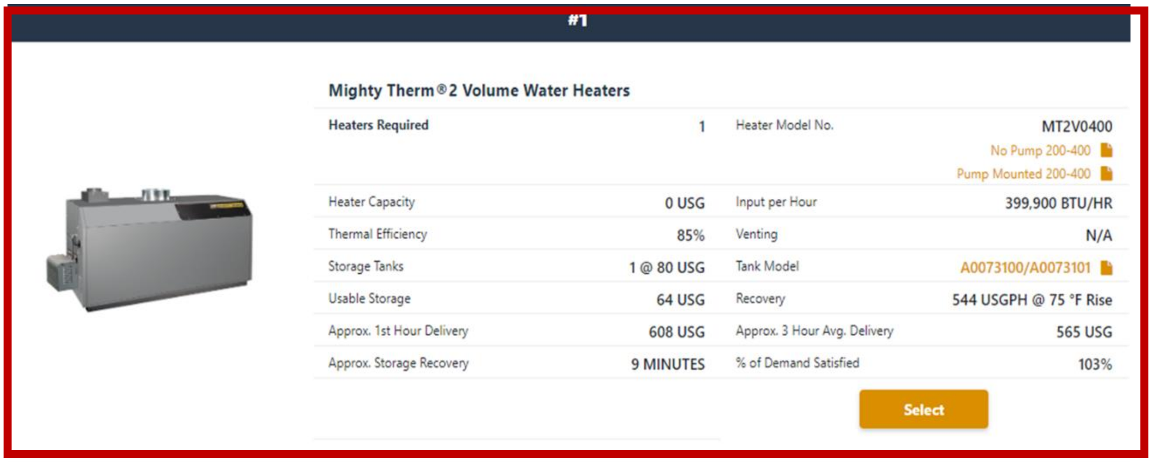
Units	Shower Heads	
Units with 1 Bath: 1	2.5 GPM	☐ w/ In-suite Clothes Washer
Units with 1½ Bath: 0	2.5 GPM	☐ w/ In-suite Clothes Washer
Units with 2 Bath: 48	2.5 GPM	☐ w/ In-suite Clothes Washer
Units with 2½ Bath: 0	2.5 GPM	☐ w/ In-suite Clothes Washer
Units with 3 Bath: 0	2.5 GPM	☐ w/ In-suite Clothes Washer
Units with 3½ Bath: 0	2.5 GPM	☐ w/ In-suite Clothes Washer

Shower Minutes Per Hour: 7

Diversity Factor (%): 30

Other GPH (at Stored Temp): 0

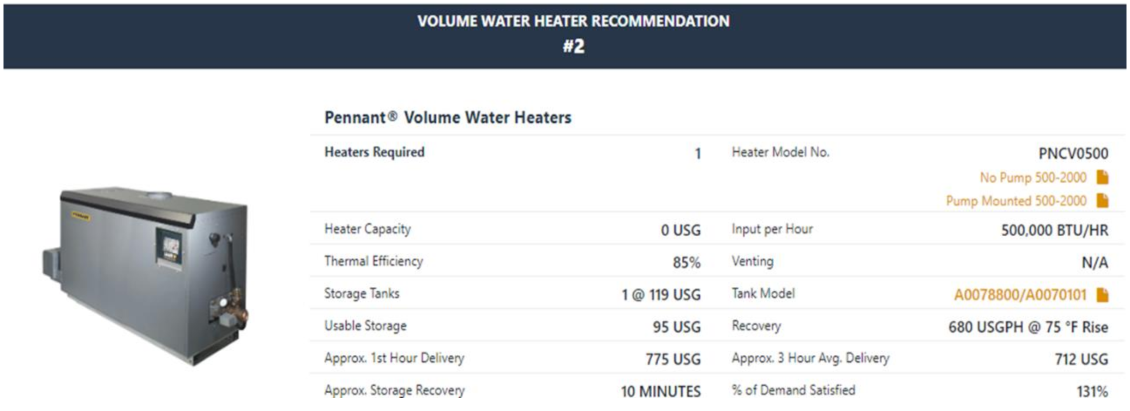
Output



#1

Mighty Therm®2 Volume Water Heaters

Heaters Required	1	Heater Model No.	MT2V0400 No Pump 200-400 Pump Mounted 200-400
Heater Capacity	0 USG	Input per Hour	399,900 BTU/HR
Thermal Efficiency	85%	Venting	N/A
Storage Tanks	1 @ 80 USG	Tank Model	A0073100/A0073101
Usable Storage	64 USG	Recovery	544 USGPH @ 75 °F Rise
Approx. 1st Hour Delivery	608 USG	Approx. 3 Hour Avg. Delivery	565 USG
Approx. Storage Recovery	9 MINUTES	% of Demand Satisfied	103%



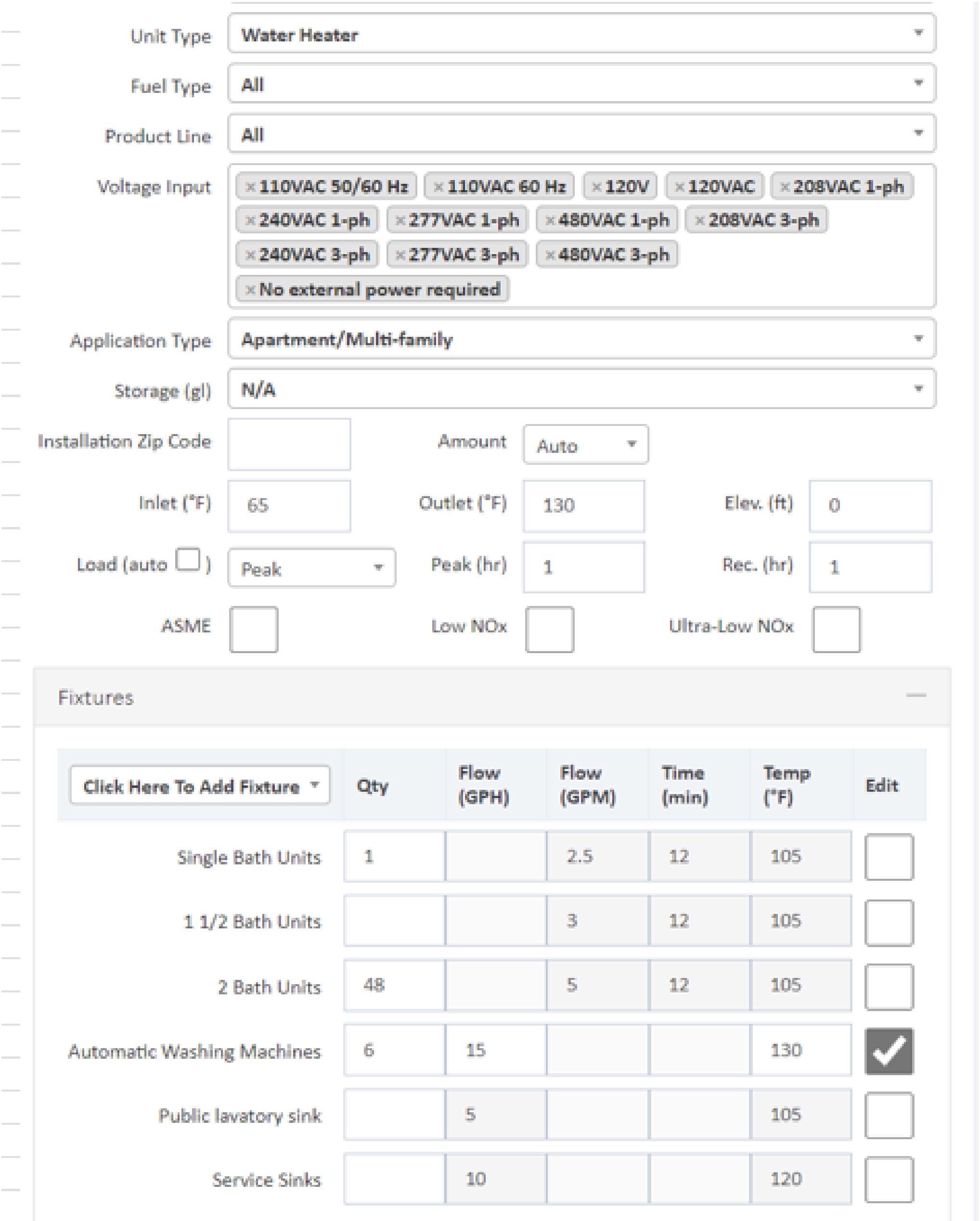
VOLUME WATER HEATER RECOMMENDATION
#2

Pennant® Volume Water Heaters

Heaters Required	1	Heater Model No.	PNCV0500 No Pump 500-2000 Pump Mounted 500-2000
Heater Capacity	0 USG	Input per Hour	500,000 BTU/HR
Thermal Efficiency	85%	Venting	N/A
Storage Tanks	1 @ 119 USG	Tank Model	A0078800/A0070101
Usable Storage	95 USG	Recovery	680 USGPH @ 75 °F Rise
Approx. 1st Hour Delivery	775 USG	Approx. 3 Hour Avg. Delivery	712 USG
Approx. Storage Recovery	10 MINUTES	% of Demand Satisfied	131%

MFG Tool 3

Input



Unit Type: Water Heater

Fuel Type: All

Product Line: All

Voltage Input: × 110VAC 50/60 Hz × 110VAC 60 Hz × 120V × 120VAC × 208VAC 1-ph × 240VAC 1-ph × 277VAC 1-ph × 480VAC 1-ph × 208VAC 3-ph × 240VAC 3-ph × 277VAC 3-ph × 480VAC 3-ph × No external power required

Application Type: Apartment/Multi-family

Storage (gl): N/A

Installation Zip Code:

Amount: Auto

Inlet (°F): 65

Outlet (°F): 130

Elev. (ft): 0

Load (auto ☐): Peak

Peak (hr): 1

Rec. (hr): 1

ASME ☐

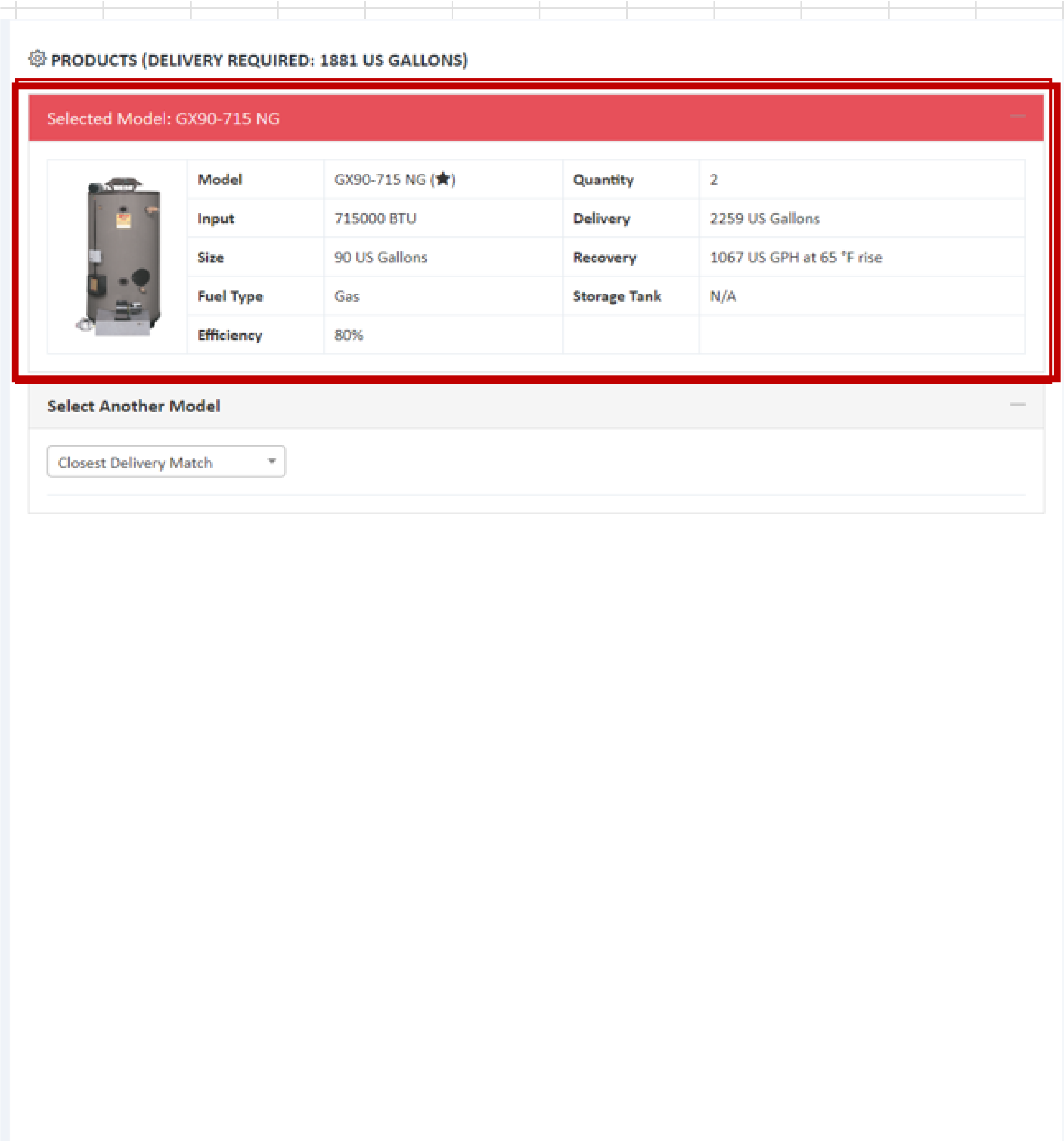
Low NOx ☐

Ultra-Low NOx ☐

Fixtures

Click Here To Add Fixture	Qty	Flow (GPH)	Flow (GPM)	Time (min)	Temp (°F)	Edit
Single Bath Units	1		2.5	12	105	☐
1 1/2 Bath Units			3	12	105	☐
2 Bath Units	48		5	12	105	☐
Automatic Washing Machines	6	15			130	☑
Public lavatory sink		5			105	☐
Service Sinks		10			120	☐

Output



PRODUCTS (DELIVERY REQUIRED: 1881 US GALLONS)

Selected Model: GX90-715 NG

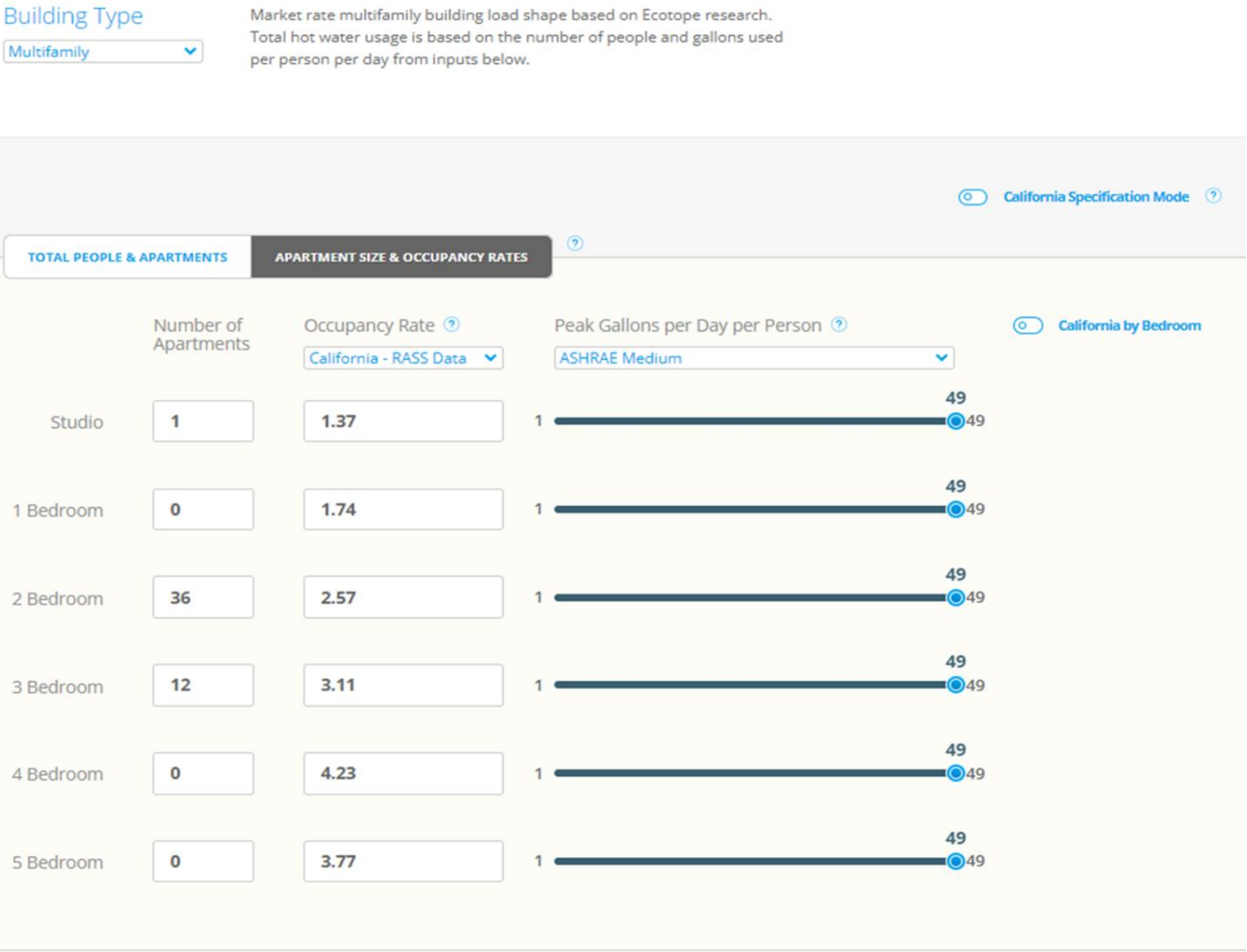
Model	GX90-715 NG (★)	**Quantity**	2
Input	715000 BTU	**Delivery**	2259 US Gallons
Size	90 US Gallons	**Recovery**	1067 US GPH at 65 °F rise
Fuel Type	Gas	**Storage Tank**	N/A
Efficiency	80%		

Select Another Model

Closest Delivery Match ▾

EHPWH Tool

Input



Building Type: Multifamily

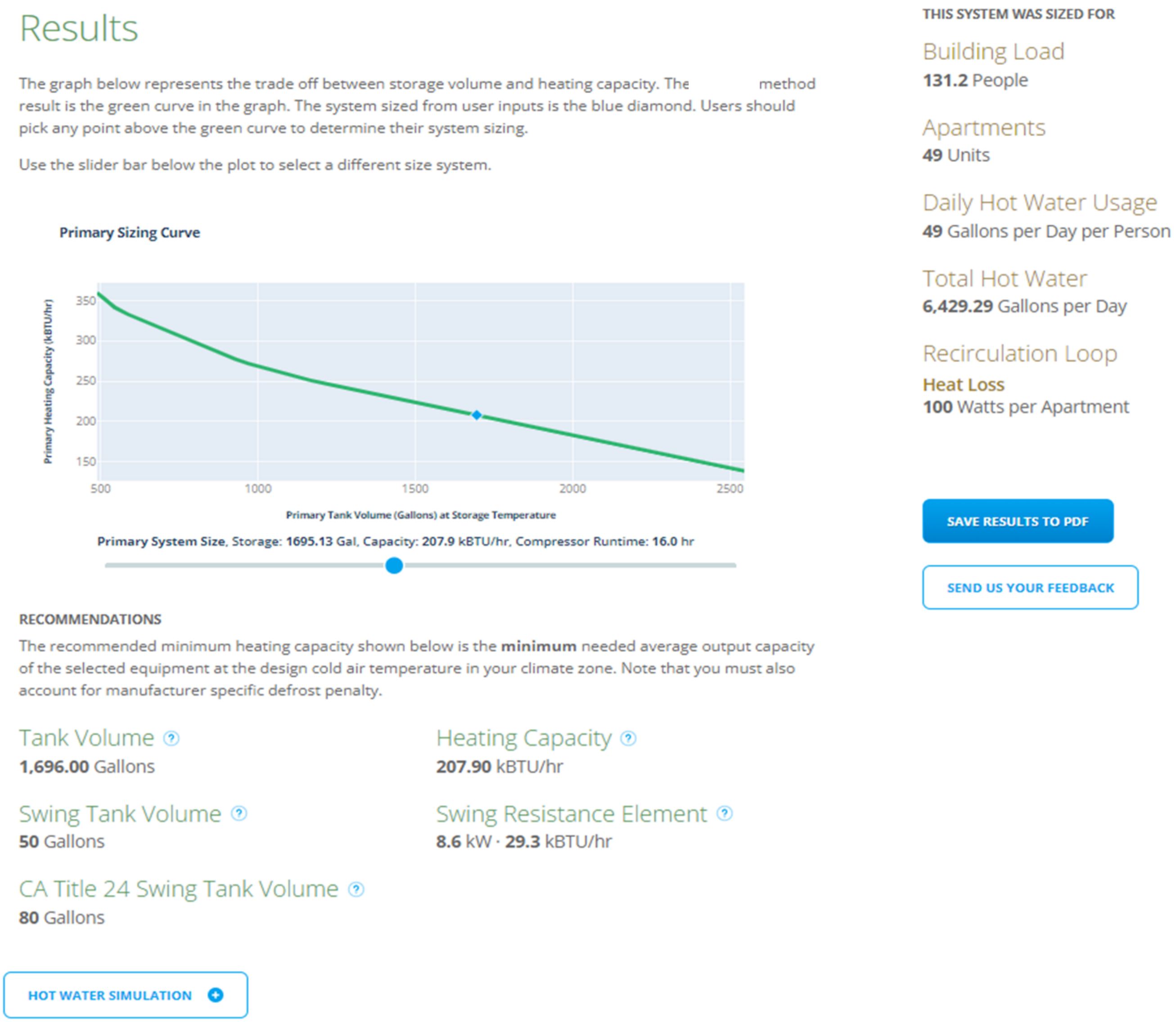
Market rate multifamily building load shape based on Ecotope research. Total hot water usage is based on the number of people and gallons used per person per day from inputs below.

Occupancy Rate: California - RASS Data

Peak Gallons per Day per Person: ASHRAE Medium

	Number of Apartments	Occupancy Rate	Peak Gallons per Day per Person
Studio	1	1.37	49
1 Bedroom	0	1.74	49
2 Bedroom	36	2.57	49
3 Bedroom	12	3.11	49
4 Bedroom	0	4.23	49
5 Bedroom	0	3.77	49

Output



Results

The graph below represents the trade off between storage volume and heating capacity. The method result is the green curve in the graph. The system sized from user inputs is the blue diamond. Users should pick any point above the green curve to determine their system sizing.

Use the slider bar below the plot to select a different size system.

Primary System Size, Storage: 1695.13 Gal, Capacity: 207.9 kBTU/hr, Compressor Runtime: 16.0 hr

RECOMMENDATIONS

The recommended minimum heating capacity shown below is the **minimum** needed average output capacity of the selected equipment at the design cold air temperature in your climate zone. Note that you must also account for manufacturer specific defrost penalty.

Tank Volume
1,696.00 Gallons

Heating Capacity
207.90 kBTU/hr

Swing Tank Volume
50 Gallons

Swing Resistance Element
8.6 kW · **29.3** kBTU/hr

CA Title 24 Swing Tank Volume
80 Gallons

THIS SYSTEM WAS SIZED FOR

Building Load
131.2 People

Apartments
49 Units

Daily Hot Water Usage
49 Gallons per Day per Person

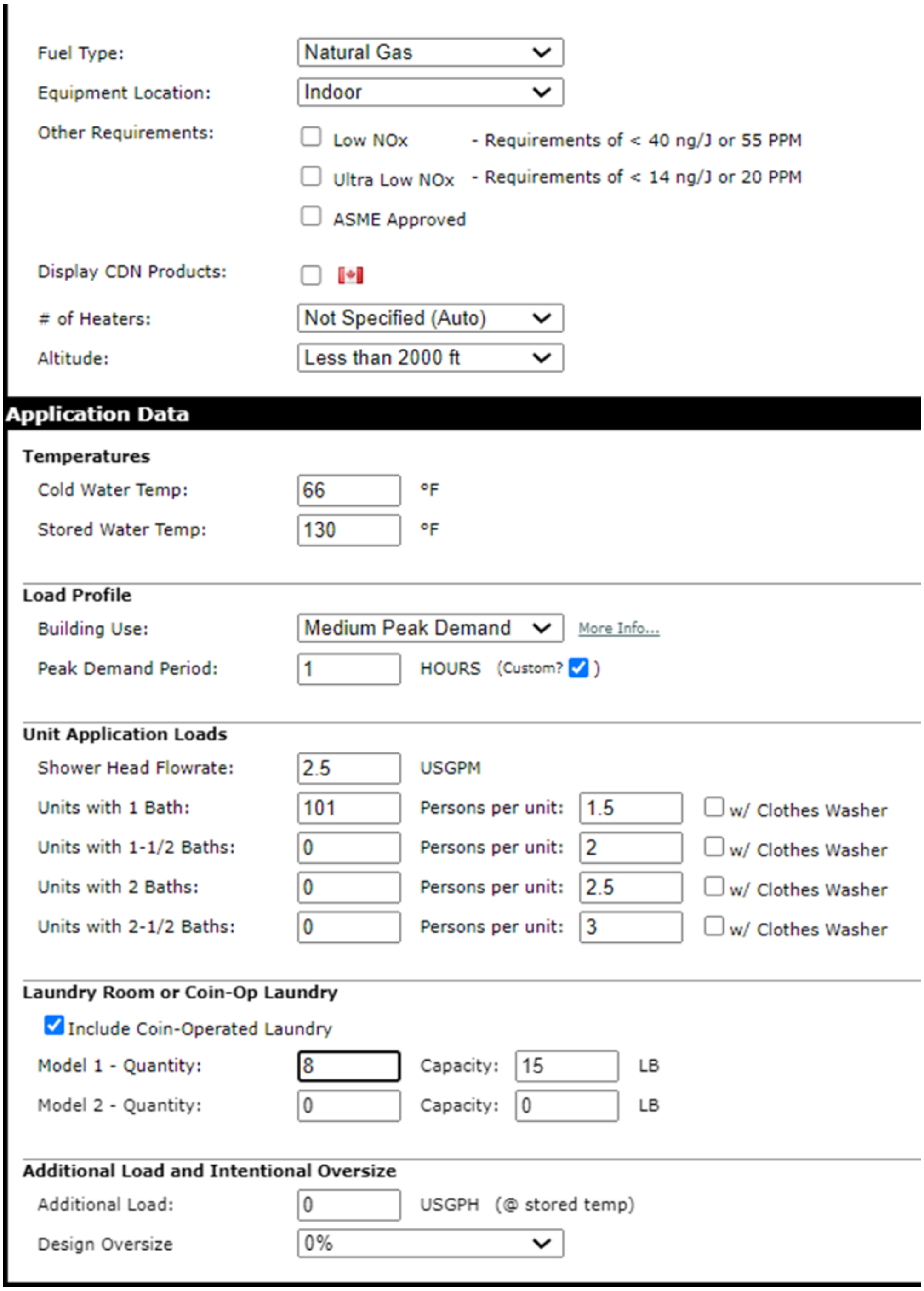
Total Hot Water
6,429.29 Gallons per Day

Recirculation Loop
Heat Loss
100 Watts per Apartment

Site 6

MFG Tool 2

Input



Fuel Type: Natural Gas

Equipment Location: Indoor

Other Requirements:
☐ Low NOx - Requirements of < 40 ng/J or 55 PPM
☐ Ultra Low NOx - Requirements of < 14 ng/J or 20 PPM
☐ ASME Approved

Display CDN Products: ☐

# of Heaters: Not Specified (Auto)

Altitude: Less than 2000 ft

Application Data

Temperatures

Cold Water Temp: 66 °F

Stored Water Temp: 130 °F

Load Profile

Building Use: Medium Peak Demand More Info...

Peak Demand Period: 1 HOURS (Custom? ☑)

Unit Application Loads

Shower Head Flowrate: 2.5 USGPM

Units with 1 Bath: 101 Persons per unit: 1.5 ☐ w/ Clothes Washer

Units with 1-1/2 Baths: 0 Persons per unit: 2 ☐ w/ Clothes Washer

Units with 2 Baths: 0 Persons per unit: 2.5 ☐ w/ Clothes Washer

Units with 2-1/2 Baths: 0 Persons per unit: 3 ☐ w/ Clothes Washer

Laundry Room or Coin-Op Laundry

☑ Include Coin-Operated Laundry

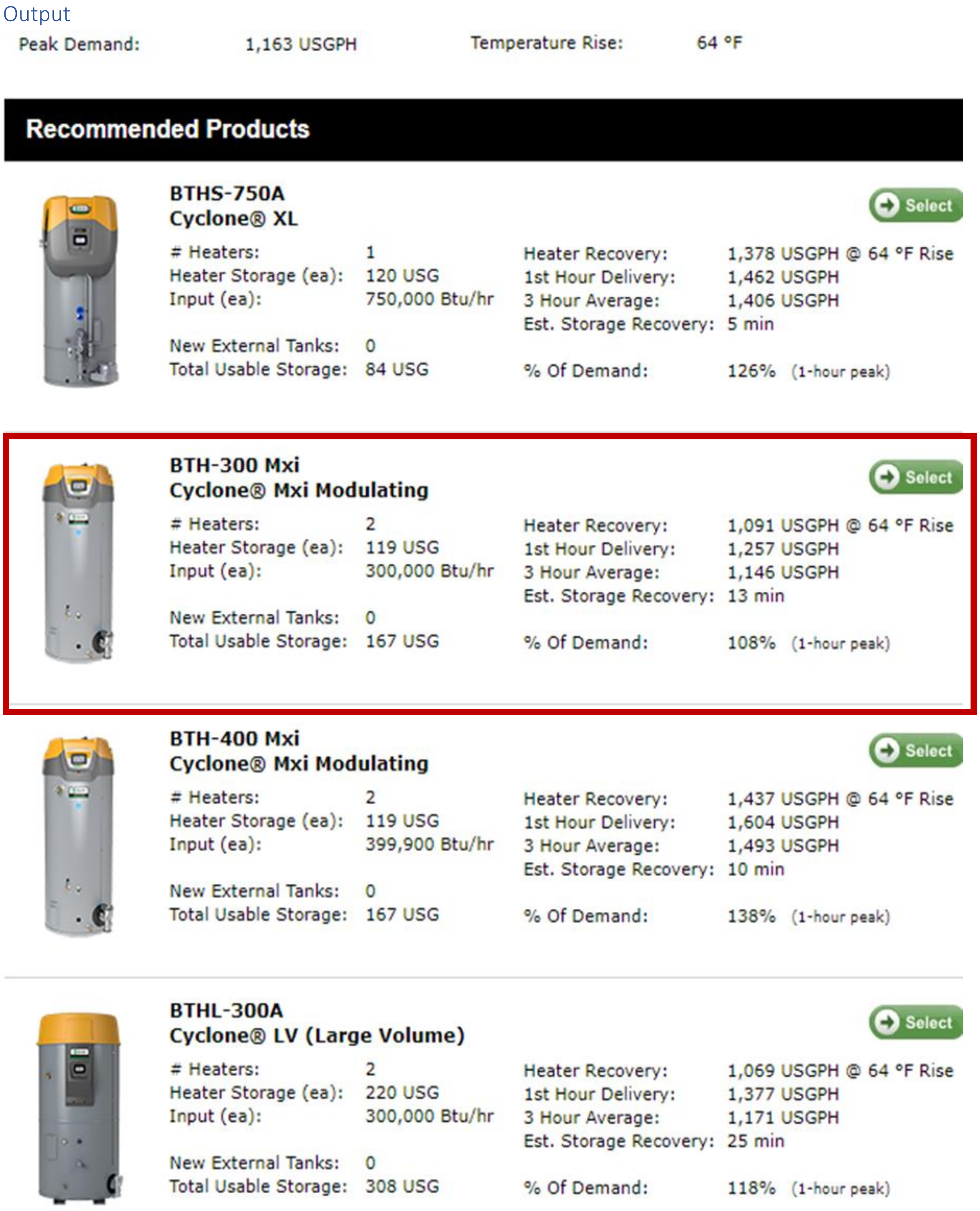
Model 1 - Quantity: 8 Capacity: 15 LB

Model 2 - Quantity: 0 Capacity: 0 LB

Additional Load and Intentional Oversize

Additional Load: 0 USGPH (@ stored temp)

Design Oversize 0%



Output

Peak Demand:	1,163 USGPH	Temperature Rise:	64 °F

Recommended Products

BTHS-750A
Cyclone® XL

# Heaters:	1	Heater Recovery:	1,378 USGPH @ 64 °F Rise
Heater Storage (ea):	120 USG	1st Hour Delivery:	1,462 USGPH
Input (ea):	750,000 Btu/hr	3 Hour Average:	1,406 USGPH
		Est. Storage Recovery:	5 min
New External Tanks:	0		
Total Usable Storage:	84 USG	% Of Demand:	126% (1-hour peak)

BTH-300 Mxi
Cyclone® Mxi Modulating

# Heaters:	2	Heater Recovery:	1,091 USGPH @ 64 °F Rise
Heater Storage (ea):	119 USG	1st Hour Delivery:	1,257 USGPH
Input (ea):	300,000 Btu/hr	3 Hour Average:	1,146 USGPH
		Est. Storage Recovery:	13 min
New External Tanks:	0		
Total Usable Storage:	167 USG	% Of Demand:	108% (1-hour peak)

BTH-400 Mxi
Cyclone® Mxi Modulating

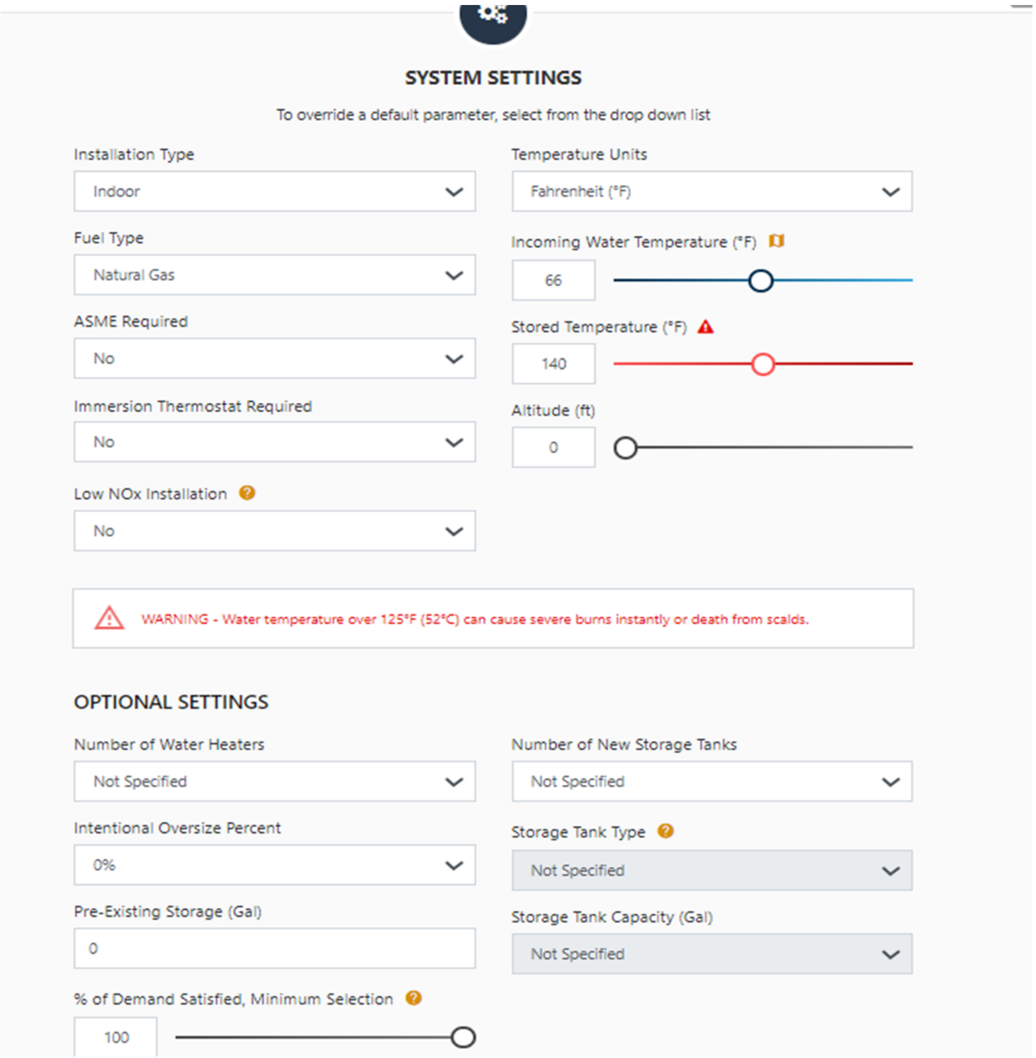
# Heaters:	2	Heater Recovery:	1,437 USGPH @ 64 °F Rise
Heater Storage (ea):	119 USG	1st Hour Delivery:	1,604 USGPH
Input (ea):	399,900 Btu/hr	3 Hour Average:	1,493 USGPH
		Est. Storage Recovery:	10 min
New External Tanks:	0		
Total Usable Storage:	167 USG	% Of Demand:	138% (1-hour peak)

BTHL-300A
Cyclone® LV (Large Volume)

# Heaters:	2	Heater Recovery:	1,069 USGPH @ 64 °F Rise
Heater Storage (ea):	220 USG	1st Hour Delivery:	1,377 USGPH
Input (ea):	300,000 Btu/hr	3 Hour Average:	1,171 USGPH
		Est. Storage Recovery:	25 min
New External Tanks:	0		
Total Usable Storage:	308 USG	% Of Demand:	118% (1-hour peak)

MFG Tool 1

Input



SYSTEM SETTINGS

To override a default parameter, select from the drop down list

Installation Type: Indoor

Temperature Units: Fahrenheit (°F)

Fuel Type: Natural Gas

Incoming Water Temperature (°F): 66

ASME Required: No

Stored Temperature (°F): 140

Immersion Thermostat Required: No

Altitude (ft): 0

Low NOx Installation: No

WARNING - Water temperature over 125°F (52°C) can cause severe burns instantly or death from scalds.

OPTIONAL SETTINGS

Number of Water Heaters: Not Specified

Number of New Storage Tanks: Not Specified

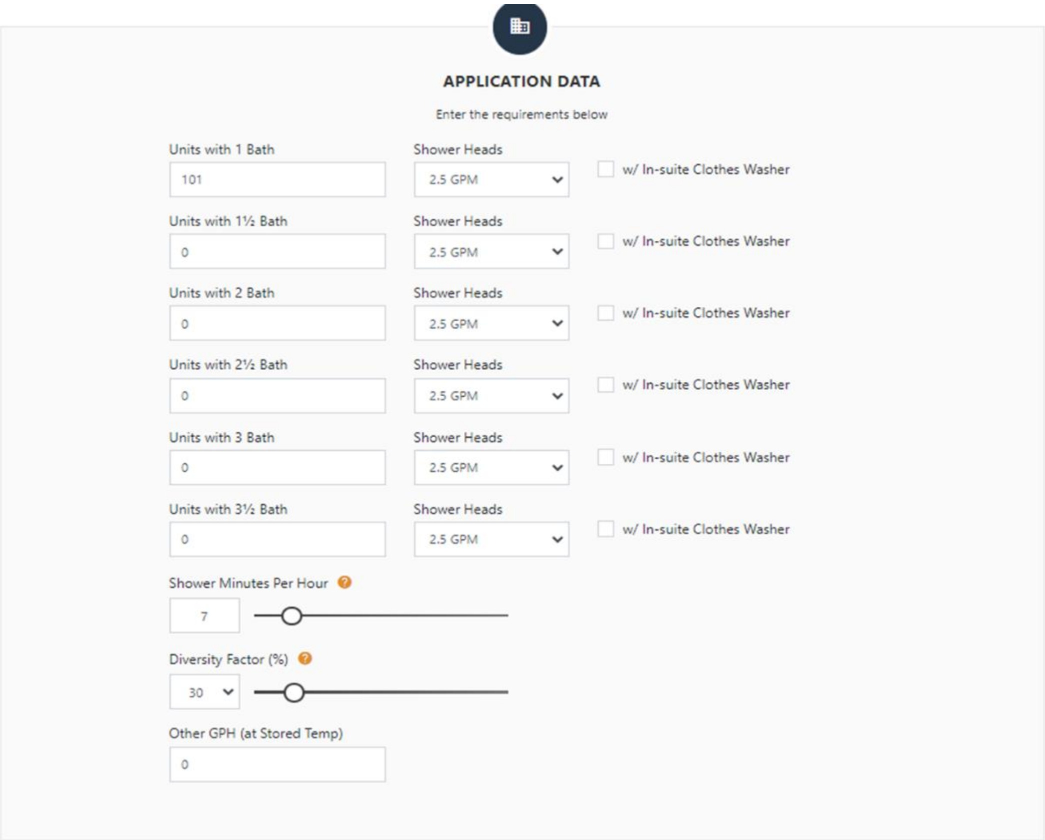
Intentional Oversize Percent: 0%

Storage Tank Type: Not Specified

Pre-Existing Storage (Gal): 0

Storage Tank Capacity (Gal): Not Specified

% of Demand Satisfied, Minimum Selection: 100



APPLICATION DATA

Enter the requirements below

Units with 1 Bath: 101
Shower Heads: 2.5 GPM
☐ w/ In-suite Clothes Washer

Units with 1½ Bath: 0
Shower Heads: 2.5 GPM
☐ w/ In-suite Clothes Washer

Units with 2 Bath: 0
Shower Heads: 2.5 GPM
☐ w/ In-suite Clothes Washer

Units with 2½ Bath: 0
Shower Heads: 2.5 GPM
☐ w/ In-suite Clothes Washer

Units with 3 Bath: 0
Shower Heads: 2.5 GPM
☐ w/ In-suite Clothes Washer

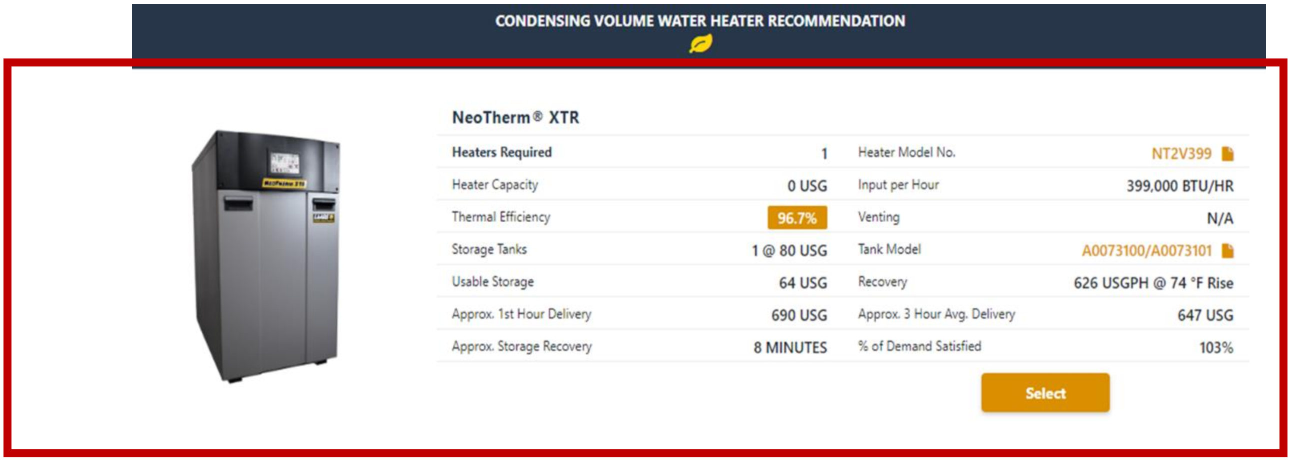
Units with 3½ Bath: 0
Shower Heads: 2.5 GPM
☐ w/ In-suite Clothes Washer

Shower Minutes Per Hour: 7

Diversity Factor (%): 30

Other GPH (at Stored Temp): 0

Output



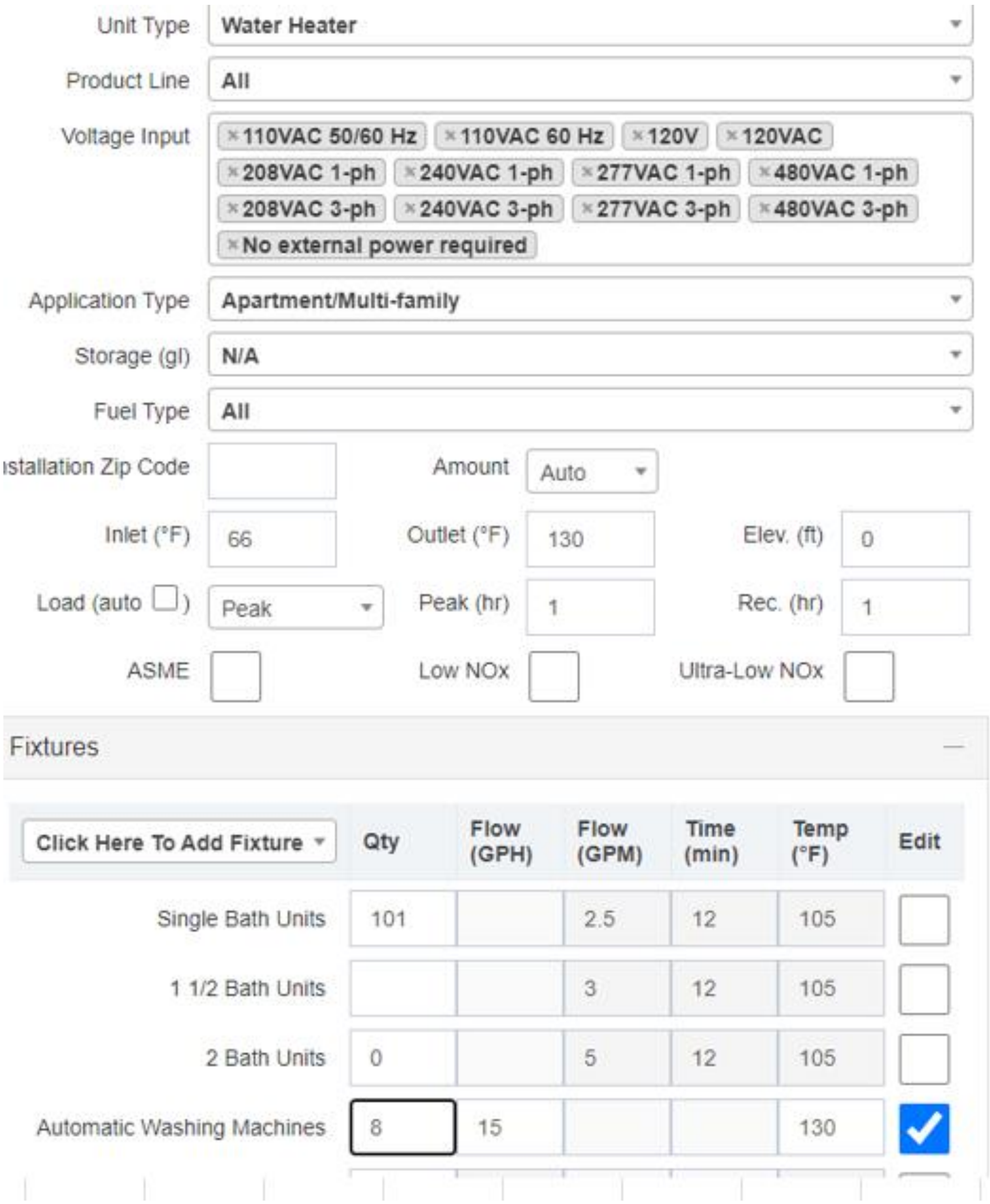
CONDENSING VOLUME WATER HEATER RECOMMENDATION

NeoTherm® XTR

Heaters Required	1	Heater Model No.	NT2V399
Heater Capacity	0 USG	Input per Hour	399,000 BTU/HR
Thermal Efficiency	96.7%	Venting	N/A
Storage Tanks	1 @ 80 USG	Tank Model	A0073100/A0073101
Usable Storage	64 USG	Recovery	626 USGPH @ 74 °F Rise
Approx. 1st Hour Delivery	690 USG	Approx. 3 Hour Avg. Delivery	647 USG
Approx. Storage Recovery	8 MINUTES	% of Demand Satisfied	103%

MFG Tool 3

Input



Unit Type: Water Heater

Product Line: All

Voltage Input: ×110VAC 50/60 Hz ×110VAC 60 Hz ×120V ×120VAC ×208VAC 1-ph ×240VAC 1-ph ×277VAC 1-ph ×480VAC 1-ph ×208VAC 3-ph ×240VAC 3-ph ×277VAC 3-ph ×480VAC 3-ph ×No external power required

Application Type: Apartment/Multi-family

Storage (gl): N/A

Fuel Type: All

nstallation Zip Code:

Amount: Auto

Inlet (°F): 66

Outlet (°F): 130

Elev. (ft): 0

Load (auto ☐): Peak

Peak (hr): 1

Rec. (hr): 1

ASME ☐

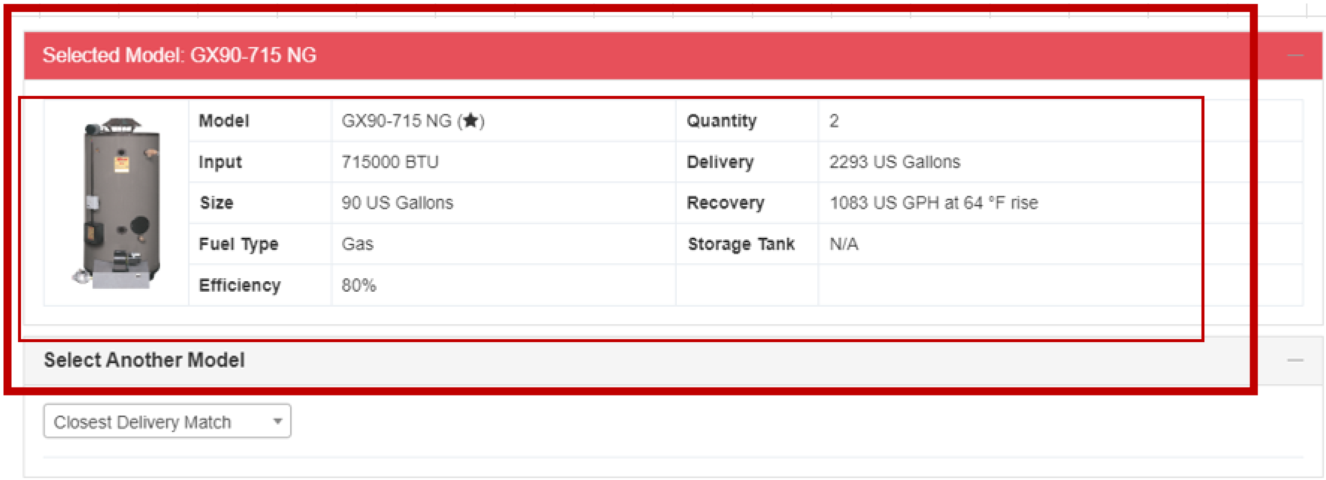
Low NOx ☐

Ultra-Low NOx ☐

Fixtures

Click Here To Add Fixture	Qty	Flow (GPH)	Flow (GPM)	Time (min)	Temp (°F)	Edit
Single Bath Units	101		2.5	12	105	☐
1 1/2 Bath Units			3	12	105	☐
2 Bath Units	0		5	12	105	☐
Automatic Washing Machines	8	15			130	☑

Output



Selected Model: GX90-715 NG

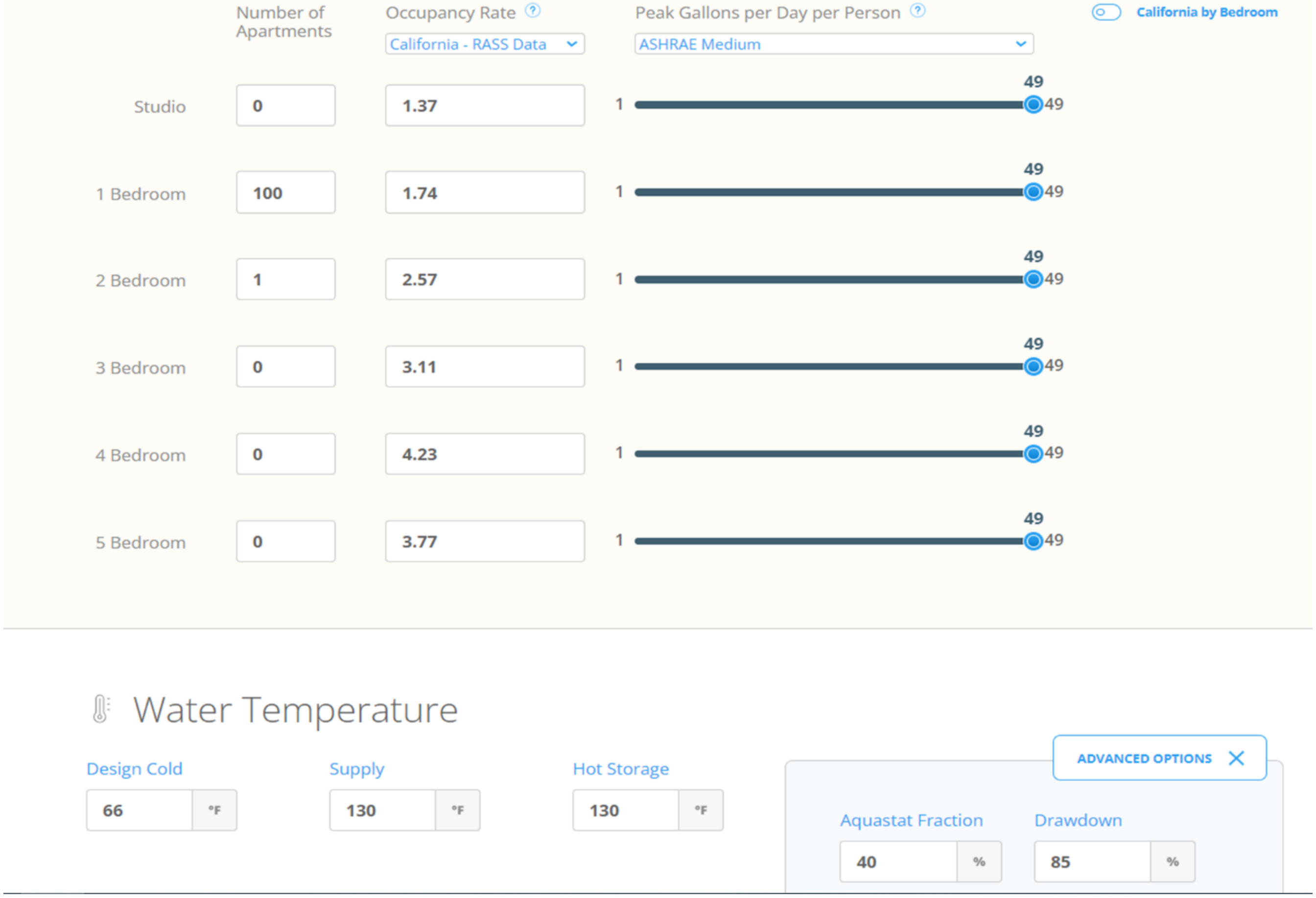
Model	GX90-715 NG (★)	**Quantity**	2
Input	715000 BTU	**Delivery**	2293 US Gallons
Size	90 US Gallons	**Recovery**	1083 US GPH at 64 °F rise
Fuel Type	Gas	**Storage Tank**	N/A
Efficiency	80%		

Select Another Model

Closest Delivery Match

EHPWH Tool

Input



Occupancy Rate: California - RASS Data

Peak Gallons per Day per Person: ASHRAE Medium

	Number of Apartments	Occupancy Rate	Peak Gallons per Day per Person
Studio	0	1.37	49
1 Bedroom	100	1.74	49
2 Bedroom	1	2.57	49
3 Bedroom	0	3.11	49
4 Bedroom	0	4.23	49
5 Bedroom	0	3.77	49

Design Cold: 66 °F

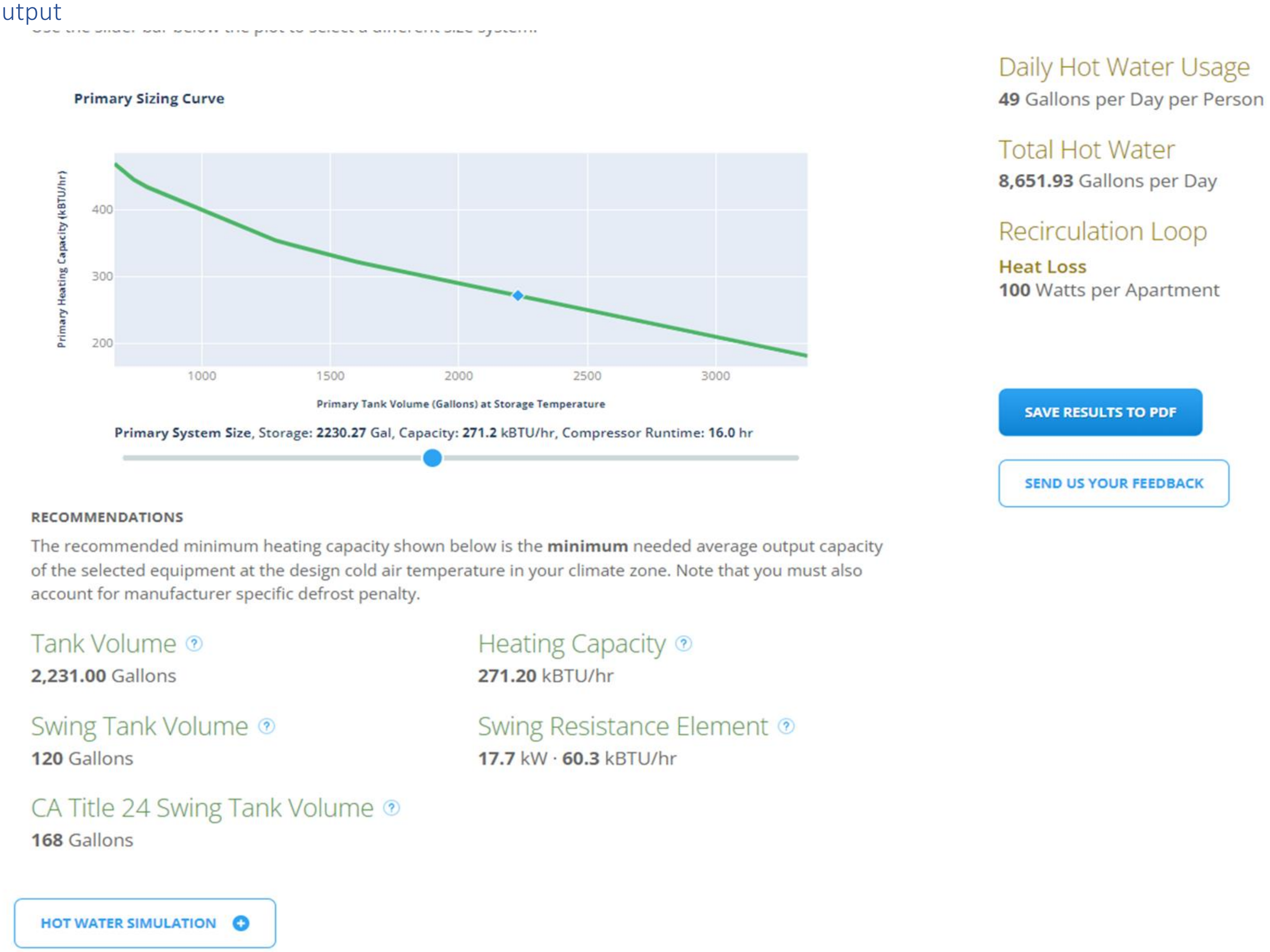
Supply: 130 °F

Hot Storage: 130 °F

Aquastat Fraction: 40 %

Drawdown: 85 %

Output



Primary System Size, Storage: **2230.27** Gal, Capacity: **271.2** kBTU/hr, Compressor Runtime: **16.0** hr

Daily Hot Water Usage
49 Gallons per Day per Person

Total Hot Water
8,651.93 Gallons per Day

Recirculation Loop
Heat Loss
100 Watts per Apartment

RECOMMENDATIONS

The recommended minimum heating capacity shown below is the **minimum** needed average output capacity of the selected equipment at the design cold air temperature in your climate zone. Note that you must also account for manufacturer specific defrost penalty.

Tank Volume
2,231.00 Gallons

Heating Capacity
271.20 kBTU/hr

Swing Tank Volume
120 Gallons

Swing Resistance Element
17.7 kW · **60.3** kBTU/hr

CA Title 24 Swing Tank Volume
168 Gallons