→DHW Sizing vs. Actual Load

ET26SWG0004

GAS EMERGING TECHOLOGIES PROGRAM (GET)
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CONTENTS

LIST OF TABLES

LIST OF FIGURES

Acknowledgements

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Disclaimer

Executive Summary

This Study expands on the ASHRAE paper *Comparing Current DHW Sizing Methods with Reality* (the "ASHRAE Paper"), which was presented at the ASHRAE 2025 Winter Conference [1]. The ASHRAE paper was based upon and analysis done in a previous Gas Emerging Technology (GET) study "Research GAHP Screening Criteria and Design" [2]. It updates the evaluation of three previously assessed sites using new gas data and includes five more sites for further comparison.

Gas absorption heat pump water heaters (GAHPs) are an innovative technology for heating domestic hot water (DHW). GAHPs can achieve higher annual efficiency than traditional gas-fired boilers or water heaters. However, their adoption is often limited by higher installation costs and the need to understand the minimum DHW load required for optimal performance. Identifying this minimum load helps stakeholders determine whether a GAHP system is suitable for a specific site.

Current sizing methods, such as ASHRAE guidelines, manufacturer tools, and like-for-like equipment replacements do not adequately estimate minimum DHW loads. These methods typically size systems for peak winter loads, failing to inform users about the minimum requirements for efficient GAHP operation.

This study extends the findings of the ASHRAE Paper by confirming that the observed differences in sizing methods and real DHW loads remain consistent with newly collected data from previously evaluated sites. Furthermore, it demonstrates that the identified sizing discrepancies persist across a broader dataset.

Methodology

Equivalent Peak Capacity

There are several approaches and tools available for determining the appropriate size of a DHW system and its storage tank. Some methods prioritize a higher heating capacity, resulting in smaller storage tanks, while others opt for a lower heating capacity paired with larger storage tanks. The balance between heat rate capacity and storage size is influenced by factors such as installation costs, available space, and specific site requirements.

Equivalent peak capacity (EPC), introduced in the ASHRAE Paper, combines DHW heating capacity with the capacity of the stored hot water, as follows:

$$Q_{EPC} = Q_{he} \quad + Q_{stored} \tag{1}$$

Where:

Q_{EPC} is the equivalent peak capacity in Btu,

Q_{heat} is the equivalent heat rate capacity in Btu,

And Q_{stored} is the equivalent stored hot water capacity in Btu.

The equivalent heat rate capacity, Q_{heat}, is calculated using Equation 2 as

$$Q_{he} \quad = Q_{out} = Q_{in} \cdot \eta \tag{2}$$

Where:

Q_{out} is the DHW output capacity in Btu,

Q_{in} is the DHW input capacity in Btu,

And η is the rated efficiency.

The equivalent stored hot water capacity, Q_{stored}, is calculated using Equation 3 as,

$$Q_{stored} = V_{tank} \cdot F \cdot \rho \cdot c \cdot \Delta T \tag{3}$$

Where:

V_{tank} is the nominal volume of the storage tank in gallons,

F is the useful tank fraction, assumed to be 70% per ASHRAE Simplified Method [3],

ρ is the density of water, equal to 8.4 lbm/gallon per ASHRAE,

c is the specific heat of water, equal to 1 Btu/lbm-°F,

ΔT is the difference in temperature between the supply and makeup water temperature, in °F.

System Sizing Tools

The EPC of the system available on site (AOS) was evaluated against the ASHRAE sizing method, three gas boiler/water heater manufacturer tools, and a theoretical electric heat pump water heater (EHPWH) calculator at eight multifamily sites. This comparison demonstrates how different methods yield varying recommendations for system capacity and storage size.

Data pertaining to AOS systems at multifamily sites was gathered through ASHRAE Level II audits. These audits documented water heating system nameplate information and associated data such as capacity, efficiency, and storage tank size to facilitate comparison with actual DHW load and recommendations from alternative assessment tools.

ASHRAE sizing calculations followed the method outlined Chapter 51 of the ASHRAE HVAC Applications Handbook [3]. Site data from Level II audits was entered into three gas boiler/water heater manufacturer tools and an EHPWH sizing tool for comparison. Heating capacity and storage sizes were converted into EPC values, which were compared across methods and against actual site gas usage (see Figure 4 in the Results section).

Actual DHW Loads

Gas Bill Data

To determine how the results from sizing tools differ from the actual DHW usage at these sites, the DHW load was estimated from hourly gas meter data.

Hourly gas meter data was collected for eight multifamily sites in Southern California from January 1, 2023, through June 30, 2025. The data was categorized by season (summer or winter), with the summer months defined as June through September. For each hour, gas consumption was averaged to develop gas bill load profiles for both summer and winter. graphical representations of these load profiles for each site are provided in Appendix B.

Additionally, the 100th, 99th, and 95th percentiles of gas consumption were calculated for each site for summer and winter.

For three sites (Sites #1, #5, and #8), DHW is the only building system that consumes gas (these are named "DHW-Only sites"), so no space heating adjustments to the gas billing data were needed. However, the remaining five sites use gas for both DHW and space heating (these are named DHW-Space-Heatin). The DHW-Only sites and the DHW-Space-

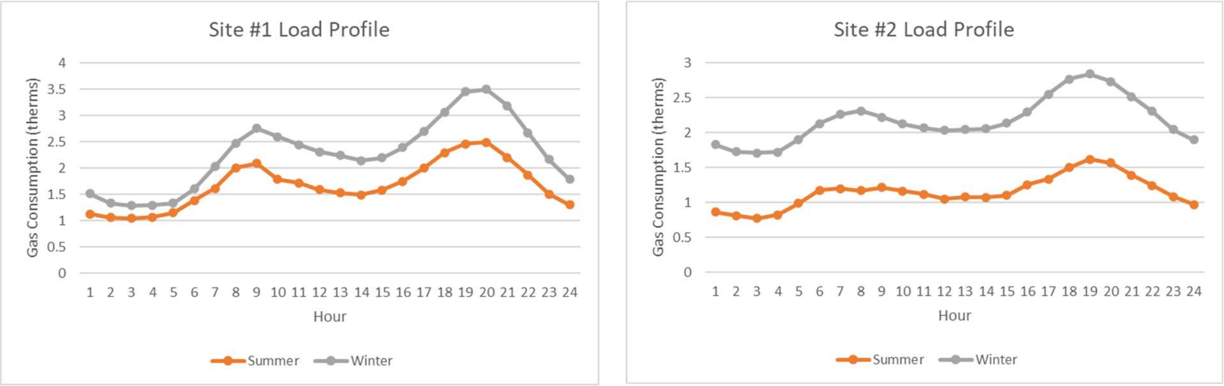
Heating sites require different calculation methods and will be distinguished using these labels throughout this study for clarity (see Table 1).

Table 1: Gas usage labels for eight multifamily sites analyzed in this Study.

Site Number	Gas Usage Label
1	DHW-Only
2	DHW-Space-Heating
3	DHW-Space-Heating
4	DHW-Space-Heating
5	DHW-Only
6	DHW-Space-Heating
7	DHW-Space-Heating
8	DHW-Only

Removing Space Heating Load

Winter gas bill profiles exceed those in summer for all sites due to colder city water, increased hot water usage, and greater heat loss in cold weather. However, a larger difference between the summer gas bill profile and winter gas bill profile can be observed in DHW-Space-Heating sites compared to DHW-Only sites due to the additional space heating load. To demonstrate the impact of gas space heating on the winter gas bill profile, refer to Figure . The Winter and Summer gas bill profiles for Site #1 (DHW-Only) are much closer than those for Site #2 (DHW-Space-Heating). The same pattern can be observed in the complete set of gas data profiles, compiled in Appendix B.



(a) (b)

Figure 1: Gas profiles for Sites #1 and #2.

Average summer and winter gas bill load profiles for Site #1 (DHW-Only) (a) and Site #2 (DHW-Space-Heating) (b).

DHW-Only

DHW-Only sites were used as a reference to develop a Projection Factor to apply to the DHW-Space-Heating sites.

Projection Factor

This Projection Factor is the ratio between the average therms in the winter gas bill profile compared to those in the summer gas bill profile on an hourly basis, calculated using Equation 4 as,

$$PF_t = \bar{Q}_{winter,t} / \bar{Q}_{summer,t} > 1 \tag{4}$$

Where:

PF_t is the Projection Factor at hour *t*,

$\bar{Q}_{winter,t}$ is the average gas consumption in the winter gas bill profile at hour *t*, in therms,

$\bar{Q}_{summer,t}$ is the average gas consumption in the summer gas bill profile at hour *t*, in therms,

t is the hour.

Note that the Projection Factor is strictly greater than one because the winter gas bill profile is always greater than the summer gas bill profile.

The Projection Factor was then averaged across all hours using Equation 5.

$$PF = \frac{\sum_{t=0}^{23} PF_t}{24} \tag{5}$$

The Projection Factors were then averaged across the three DHW-Only sites to develop a representative Projection Factor. The representative Project Factor was calculated as 1.5.

DHW-Space-Heating

At the DHW-Space-Heating sites, the gas consumption attributed to space heating must be subtracted from the winter gas bill profile to isolate the DHW profile. It is assumed that there is no space heating present in the summer gas bill profile. The Projection Factor calculated using Equations 4 and 5 was used to scale the DHW-Space-Heating summer gas bill load profiles to a projected winter load profile, as follows in Equation 6.

$$\bar{Q}_{projected,t} = PF \cdot \bar{Q}_{summer,t} = 1.5 \cdot \bar{Q}_{summer,t} \tag{6}$$

Where:

PF is the Projection Factor, 1.5 in this Study,

$\bar{Q}_{projected,t}$ is the average gas consumption of the projected winter gas profile at hour t, in therms,

$\bar{Q}_{summer,t}$ is the average gas consumption in the summer gas bill profile at hour t, in therms.

Figure 2 shows the projected winter gas profile for Site #2 after the Projection Factor was applied to the summer gas bill profile. This methodology was applied to all DHW-Space-Heating sites.

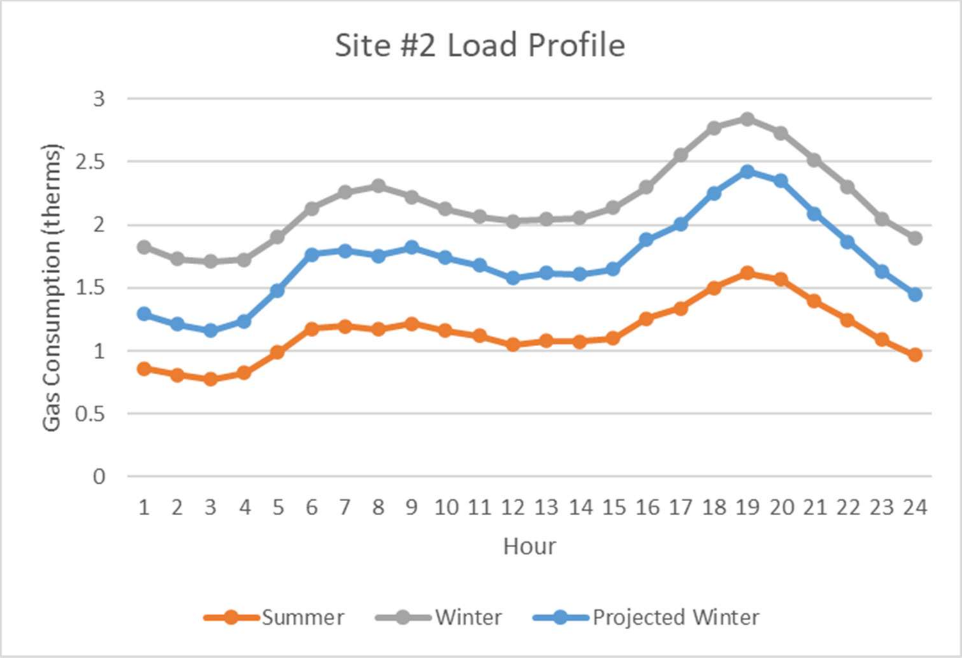


Figure 2: Gas profiles for Site #2.

Summer gas bill, winter gas bill, and winter projected gas load profiles for Site #2.

Removing Temperature Maintenance Load

The recirculation or temperature maintenance system (TMS) load is the amount of energy required to maintain the temperature of the water via a recirculation loop. All the sites analyzed had a recirculation system.

The TMS load was estimated as the lowest point observed on the gas profile for each season (summer/winter). This estimate relies on the assumption that, at this minimum point, typically between 2 and 4 am, DHW usage by occupants is negligible, and the gas demand arises exclusively from the recirculation loop. The TMS load was assumed to be one constant during the Summer and another higher constant during the winter.

At DHW-Only sites, the TMS load was determined with gas bill data for both winter and summer using Equation 7 as,

$$TMS_{summer} = MIN\left(\bar{Q}_{summer,t}\right) \tag{7a}$$

$$TMS_{winter} = MIN\left(\bar{Q}_{winter,t}\right) \tag{7b}$$

Where:

TMS_{summer} is the TMS load in the summer,

$\bar{Q}_{summer,t}$ is the average gas consumption in the summer gas bill profile at hour t, in therms,

TMS_{winter} is the TMS load in the winter,

$\bar{Q}_{winter,t}$ is the average gas consumption in the winter gas bill profile at hour t, in therms.

For DHW-Space-Heating sites, the summer TMS load was estimated using the summer gas bill data, using Equation 7a. Then, the winter TMS load was calculated by adjusting the summer TMS load with the Projection Factor, shown in Equation 8. This is equivalent to finding the minimum value from the projected winter load profile. The Projection Factor was assumed to be the same for the TMS load as it was for the total DHW consumption.

$$TMS_{winter} = PF \cdot TMS_{summer} = 1.5 \cdot TMS_{summer} \tag{8}$$

Where:

PF is the Projection Factor, 1.5 in this study,

TMS_{summer} is the TMS load in the summer, calculated in Equation 7a,

TMS_{winter} is the TMS load in the winter.

Visually, this takes the summer gas bill profile and winter gas bill or winter projected gas profile (depending on the gas usage category for the site) and shifts them down to rest on the x-axis, shown in Figure 3 using Site #2 (DHW-Space-Heating) as an example.

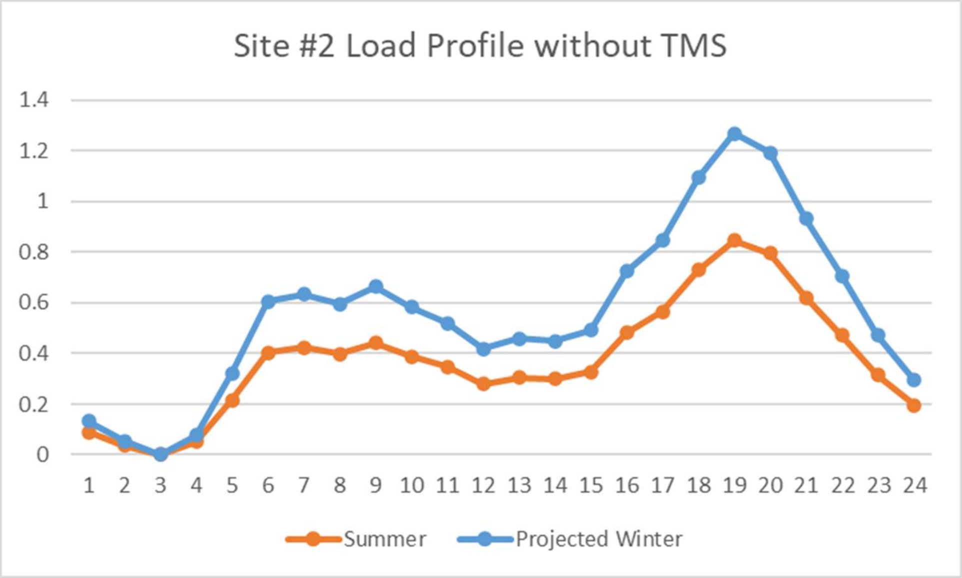


Figure 3: Gas profiles without TMS for Site #2.

Summer gas bill and winter projected gas profile without TMS load.

Minimum DHW Load

Table 2 shows the minimum DHW load, assumed to be the TMS load, for each site. The winter TMS load is taken to be the winter minimum for DHW-Only sites and the projected winter minimum for DHW-Space-Heating sites.

Table 2: Assumed summer and winter hourly TMS load for each site.

Site Number	Gas Usage Label	Minimum Summer Load (therms)	Minimum Winter Load (therms)	Minimum Projected Winter Load (therms)
1	DHW-Only	1.05	1.29	-
2	DHW-Space-Heating	0.77	-	1.16
3	DHW-Space-Heating	0.82	-	1.23
4	DHW-Space-Heating	0.18	-	0.27
5	DHW-Only	0.36	0.63	-
6	DHW-Space-Heating	0.14	-	0.21
7	DHW-Space-Heating	0.35	-	0.53
8	DHW-Only	0.14	0.17	-

Load Percentiles

The percentiles must also be adjusted for TMS load. In this Study, the 100th, 99th, and 95th percentiles were analyzed, which all occur in the winter. DHW-Only sites simply subtracted the winter TMS load from the winter percentiles, just as load profiles were calculated, shown in Equation 9 as,

$$P_{x,adjusted} = P_x - TMS_{winter} \quad x = 100,99,95 \tag{9}$$

Where:

TMS_{winter} is the TMS load in the winter,

$P_{x,adjusted}$ is the adjusted percentile value where TMS load has been removed.

P_x is the original percentile value determined from the hourly gas bill data. These are the percentiles for the entire data set.

Meanwhile, DHW-Space-Heating sites exclude winter data from percentile calculations due to space heating. Instead, they use the 100th, 99th, and 95th percentiles from the summer data set, subtract the summer TMS load, and adjust the result with the Projection Factor, as follows in Equation 10,

$$P_{x,adjusted} = (P_{x,summer} - TMS_{summer}) \cdot \mathrm{PF} \quad x = 100,99,95 \tag{10}$$

Where:

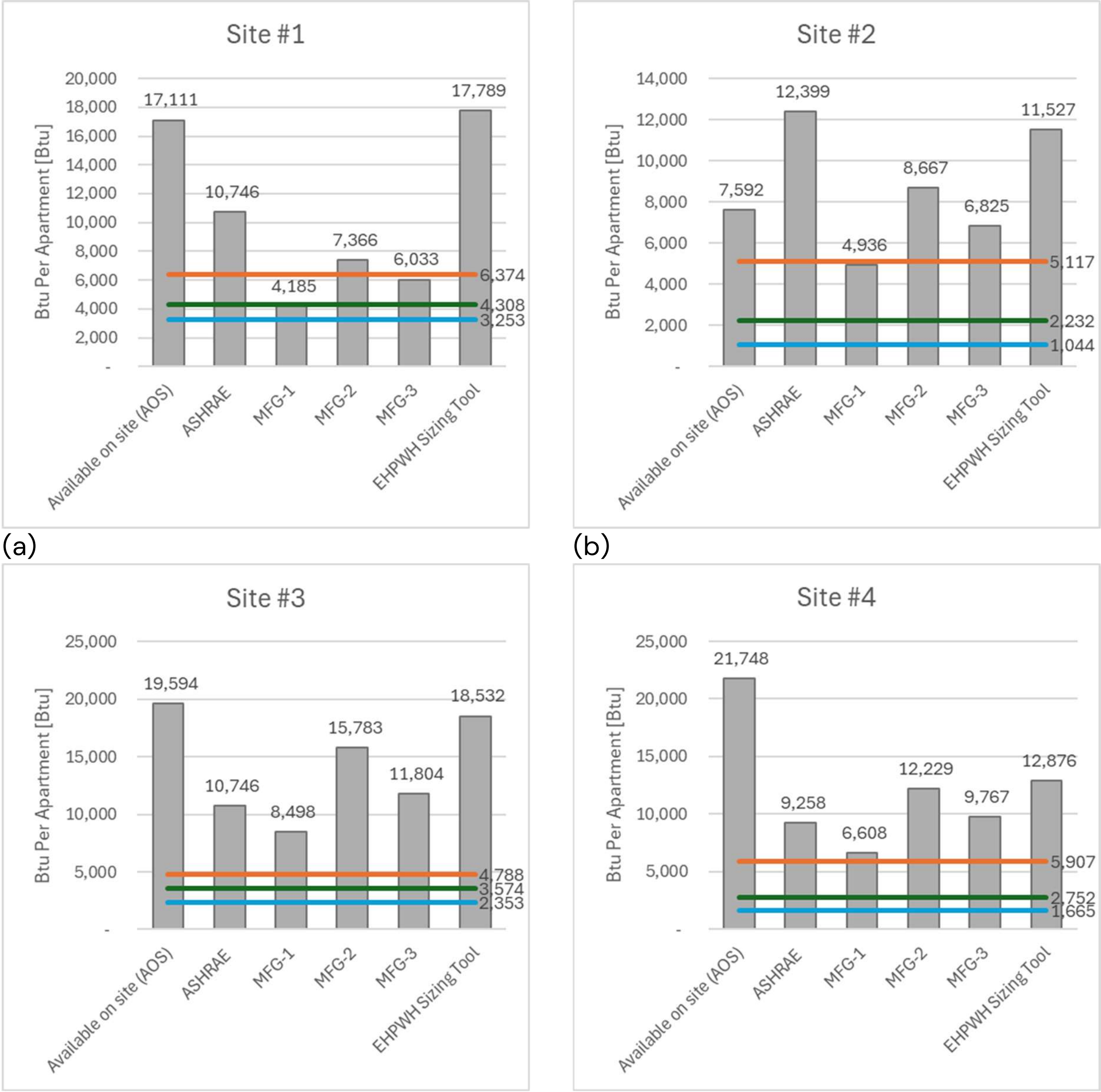
PF is the Projection Factor, 1.5 in this study,

$P_{x,adjusted}$ is the adjusted percentile value where TMS load has been removed.

$P_{x,summer}$ is the percentile value determined from the hourly gas bill data from the summer season only.

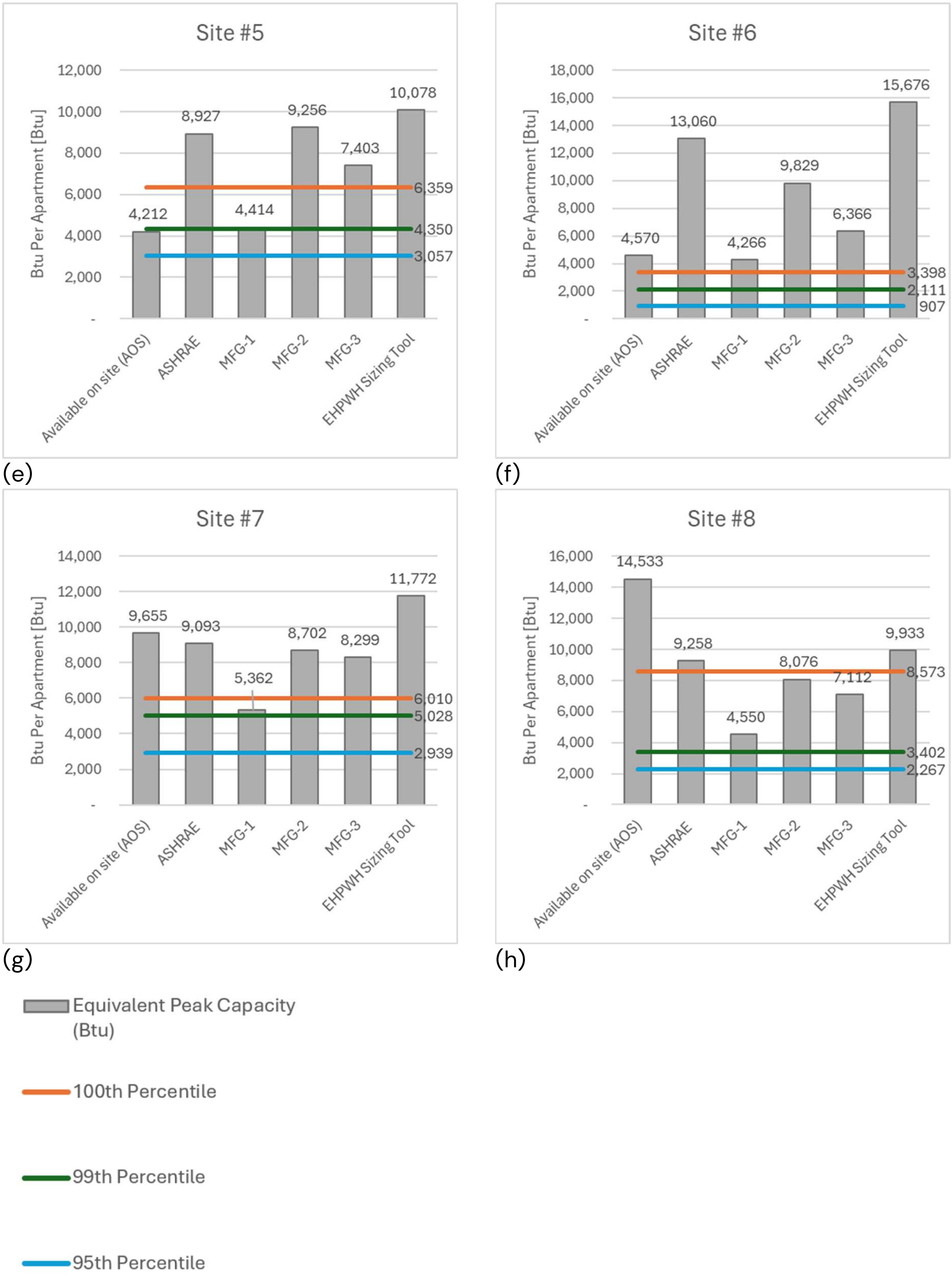
Results

The EPC values and gas bill loads were normalized by the number of units at each site to facilitate comparative analysis across locations. Figure 4 presents the EPC values determined for each sizing method described in the System Sizing Tools section, along with the calculated 100th, 199th, and 95th percentile DHW loads for the eight multifamily sites. This figure enables a direct comparison of sizing methodologies on a site-by-site basis and allows for the identification of broader patterns, providing valuable insights into the effectiveness of each approach in meeting actual DHW demand. For more detail on this method of comparison, refer to the prior work done in the ASHRAE Paper.


Site #1
Btu Per Apartment [Btu]
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
-
17,111
10,746
4,185
7,366
6,033
17,789
6,374
4,308
3,253
Available on site (AOS)
ASHRAE
MFG-1
MFG-2
MFG-3
EHPWH Sizing Tool
Site #2
Btu Per Apartment [Btu]
14,000
12,000
10,000
8,000
6,000
4,000
2,000
-
7,592
12,399
4,936
8,667
6,825
11,527
5,117
2,232
1,044
Available on site (AOS)
ASHRAE
MFG-1
MFG-2
MFG-3
EHPWH Sizing Tool
Site #3
Btu Per Apartment [Btu]
25,000
20,000
15,000
10,000
5,000
-
19,594
10,746
8,498
15,783
11,804
18,532
4,788
3,574
2,353
Available on site (AOS)
ASHRAE
MFG-1
MFG-2
MFG-3
EHPWH Sizing Tool
Site #4
Btu Per Apartment [Btu]
25,000
20,000
15,000
10,000
5,000
-
21,748
9,258
6,608
12,229
9,767
12,876
5,907
2,752
1,665
Available on site (AOS)
ASHRAE
MFG-1
MFG-2
MFG-3
EHPWH Sizing Tool

(a) (b)

(c) (d)



(e) (f) (g) (h)

Figure 4: Comparison of actual DHW loads and EPC from sizing methods.

Comparison of Actual DHW Loads with AOS, ASHRAE, Manufacturer (MFG), and EHPWH Tool Capacity Recommendations for (a) Site #1, (b) Site #2, (c) Site #3, (d) Site #4, (e) Site #5, (f) Site #6, (g) Site #7, and (h) Site #8.

Discussion

The following can be observed from Figure 4.

Real Demand

- The 100th percentile represents the highest observed demand within the analysis period. This value often deviates considerably from the 95th or even the 99th percentile. Among eight sites studied, the gap between the 99th and 100th percentiles ranged from 16% at Site #7 to 60% at Site #8.

AOS System

- Although the sites examined belong to the same portfolio of comparably sized multifamily buildings in Southern California, there is considerable variation in the sizing of their on-site DHW equipment, as evidenced by the differing Btu per apartment values across the locations.
- Sites #1, #3, and #4 exhibited an average oversizing of 248% relative to the 100th percentile, with individual values ranging from 168% (Site #1) to 309% (Site #3). A direct replacement for these sites would likely result in excessive capacity. Conversely, Site #5 was undersized by 34% compared to the 100th percentile.

ASHRAE Method

- The ASHRAE method oversized water heaters at all sites, from 8% (Site #8) to 284% (Site #6) compared to the 100th percentile, with an average oversizing of 97%.
- The Study Team used California RASS data to assume an average occupancy of 2.6 people per apartment for 2-bedroom units [4]. In contrast, some other tools generate more precise occupancy estimates by considering the number of bedrooms and bathrooms. The ASHRAE method used in this study applies the same occupancy assumption to every site, so the only variables among the eight locations were heating device efficiency (matched to AOS equipment efficiency) and the temperature difference between supply and incoming water. This difference was calculated from the measured supply temperature at each site and the expected mains temperature based on the local climate zone.
- Sites #2 and #6 were much more oversized than the rest of the sites. This is likely due to their much higher supply temperatures. Most other sites had supply temperatures between 120°F and 130°F, whereas Sites #2 and #6 had supply temperatures of 140°F and 143°F, respectively.

Manufacturer (MFG) Sizing Tools

- MFG #1 was consistently the lowest in EPC but still met the 99th percentile for all sites except Site #1. This tool tends to favor small tank sizes compared to some of the other methods[1].
- MFG #2 consistently demonstrated the highest EPC and frequently selected larger system sizes. The recommended tank size was generally a bit bigger than those from competing manufacturer tools, and its heating capacity often reached twice that of MFG #1.
- MFG #3 was often a middle ground between MFG #1 and #2. This tool was less consistent on preferring tank size or heat capacity.
- All MFG tools are undersized relative to the 100th percentile for Site #8. It appears that Site #8 experienced an atypical demand event, as indicated by the notable disparity between the 100th and 99th percentiles. Given this discrepancy, MFG #1 offers the most appropriate tool sizing for this site.

EHPWH Sizing Tool

- This online tool, designed for EHPWHs rather than gas systems, resulted in system oversizing across all sites, ranging from 16% at Site #8 to 361% at Site #6. Although the heating capacities were generally comparable or lower than those produced by alternative methods, the tank sizes recommended by the tool were substantially larger than those suggested by any other approach.

Comparison to the ASHRAE Paper

Sites #1, #2, and #3 are the same sites assessed in the ASHRAE paper (with the same numbering convention). These EPC calculations were redone to account for any updates in sizing tool methodology. The percentiles were also updated based on the new data set. The following observations were made between the previous analysis and these new results:

- The 100th and 99th percentile are lower than the previous dataset, especially at sites #1 and #3.
- The AOS equipment is unchanged because there have been no equipment upgrades.
- Small variations in the ASHRAE method and AOS are attributed to slight differences in the measured supply temperature at each site from when they were measured for the ASHRAE paper and for this Study.
- MFG #1 still provides the lowest EPC values at each site. However, between the previous version and this version, the EPC has increased and improved in meeting the 99th percentile load.

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[1] MFG #1 also requires the inlet temperature to be raised to 140F when including laundry.

- MFG #2 also increased in the suggested EPC. In the previous analysis, this tool met the 99th percentile. Now, it exceeds the 100th percentile for all three sites. Site #3 is significantly oversized this time because the EPC increased and the 100th percentile is also much lower than before.
- MFG #3 was previously oversizing the system quite a bit. Now the provided Btu/apartment values are more aligned with the real load.
- The EPHWH sizing tool likely changed their calculation methodology slightly because the EPC values generally increased 1,000-2,000 Btu/apartment across all eight sites.

Minimum and Maximum DHW Loads

The following table shows the minimum and maximum DHW load for each site from the gas bill load profiles.

Table 3: Minimum and Maximum Total[2] Hourly DHW load in therms from summer gas bill load profiles and Winter gas bill profiles or Projected winter load profiles.

Site	Gas Usage	Minimum hourly DHW Load, Summer [therms][3]	Maximum hourly DHW Load, Winter [therms]	Maximum hourly DHW Load, Projected Winter [therms]
1	DHW-Only	1.05	3.50	-
2	DHW-Space-Heating	0.77	-	2.43
3	DHW-Space-Heating	0.82	-	2.57
4	DHW-Space-Heating	0.18	-	1.19
5	DHW-Only	0.36	1.75	-
6	DHW-Space-Heating	0.14	-	0.91
7	DHW-Space-Heating	0.35	-	1.43
8	DHW-Only	0.14	0.73	-

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[2] This is the total DHW including the primary water heating load and the temperature maintenance water heating load.

[3] This is used to estimate the summer temperature maintenance load

Recommendations

GAHPs are the emerging gas-fired DHW heating technology[4]. A GAHP costs more to install than a condensing gas-fired boiler or water heater, making it less appealing unless its annual efficiency is higher. Conclusions from previous GET Program work indicate that GAHP systems require a minimum DHW load to operate more efficiently than a condensing gas-fired boiler or water heater (the minimum load required depends upon the GAHP capacity and manufacturer) [2], [5].

However, market actors such as manufacturers, distributors, and contractors do not have a way to estimate the minimum or DHW loads using existing methods. The existing methods include ASHRAE, manufacturer sizing tools or doing a like-for-like replacement of the DHW equipment available on site. The results from this study show that existing methods will result in sizing to higher winter loads rather than telling a market actor what the minimum DHW load is so they can decide if a GAHP is a good fit for a site.

GAHP market actors need a “GAHP Screening Tool” that estimates the minimum DHW load. The tool would be used to estimate the GAHP efficiency at the minimum DHW load. An important input to this tool is a data set with minimum DHW loads.

All sizing methods (except like-for-like replacement using what is available on site) examined in this study have some basic data set that is being used to size the DHW system. That data set is transparent in ASHRAE and somewhat transparent in the EHPWH tool[5], but it is not transparent in manufacturer sizing tools. In the ASHRAE method, only the peak DHW load is provided, not the minimum DHW load. Therefore, the ASHRAE data cannot be used as an input to the GAHP Screening Tool.

It is recommended that the data from this study be gathered along with additional data from GET studies, gas bills, and other third-party studies to build a dataset of hourly DHW loads[6] for use in a “GAHP Screening Tool.” Additionally, site characteristics should be attached to the hourly data so hourly DHW load profiles can be sorted by climate zone, building type, occupancy type, tenant demographics, building size, etc.

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[4] As opposed to electric heat pump water heaters (EHPWHs) which are the electric DHW heating technology.

[5] The data for the EHPWH tool is available on GitHub so it could, in theory, be extracted by a team with the right skills.

[6] Hourly DHW loads are necessary to determine a minimum DHW load, and hourly loads are more useful than a minimum load because hourly GAHP efficiencies can be determined using hourly loads. Hourly GAHP can then be averaged to determine annual GAHP efficiencies which be better than estimating the minimum GAHP efficiency based on a single minimum DHW load.

Appendix A

Table A-1 summarized the site characteristics used as inputs in the various sizing tools.

Table A- 1: Summary of site characteristics.

Site	1	2	3	4	5	6	7	8
Gas Usage	DHW-Only	DHW-Space-Heating	DHW-Space-Heating	DHW-Space-Heating	DHW-Only	DHW-Space-Heating	DHW-Space-Heating	DHW-Only
Climate Zone	CZ09	CZ09	CZ09	CZ09	CZ09	CZ06	CZ09	CZ09
Number of Units	72	62	49	27	46	45	26	35
Unit Split	72 2B/1b	62 Studio	1 Studio 36 2B/2b 12 3B/2b	2 Studio 8 1B/1b 16 2B/2b 1 3B/2b	40 1B/1b 6 2B/2b	45 1B/1b	1 Studio 13 1B/1b 5 2B/1b 8 2B/2b	35 1B/1b
Assumed Demographic	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
Assumed Inlet Water Temperature (F)	65	65	65	65	65	64	65	65
Measured Outlet Water Temperature (F)	130	140	130	121	119	143	120	121
AOS Capacity (Btu/h)	1,400,000	500,000	798,000	399,000	199,000	199,000	270,000	540,000
AOS Storage (gal)	238	115	800	620	100	100	100	200
AOS Efficiency	0.815	0.84	0.82	0.96	0.814	0.8	0.81	0.82

Appendix B

Figures B-1 through B-8 show the gas bill load profiles for the eight sites analyzed in this study. For DHW-Space-Heating sites, the projected winter profile is also shown. All figures have the maximum and minimum load points marked.

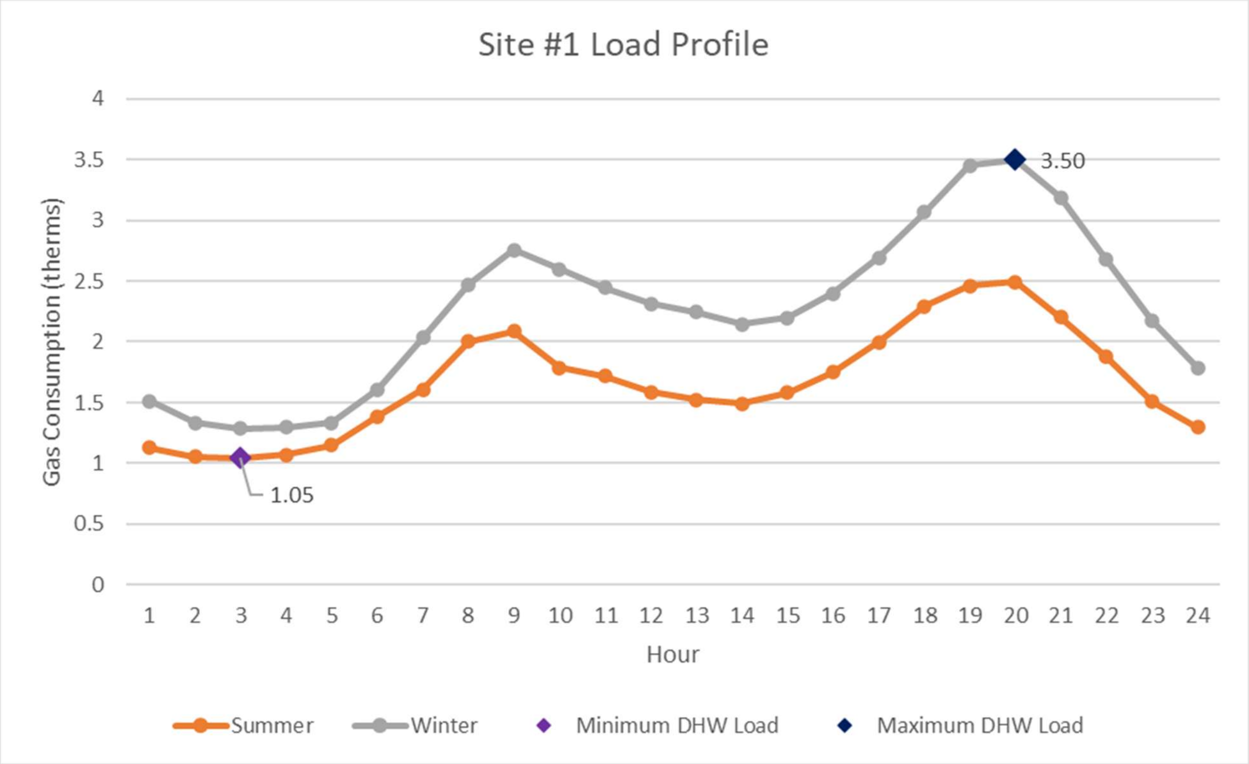

Figure B- 1: Site #1 load profile.

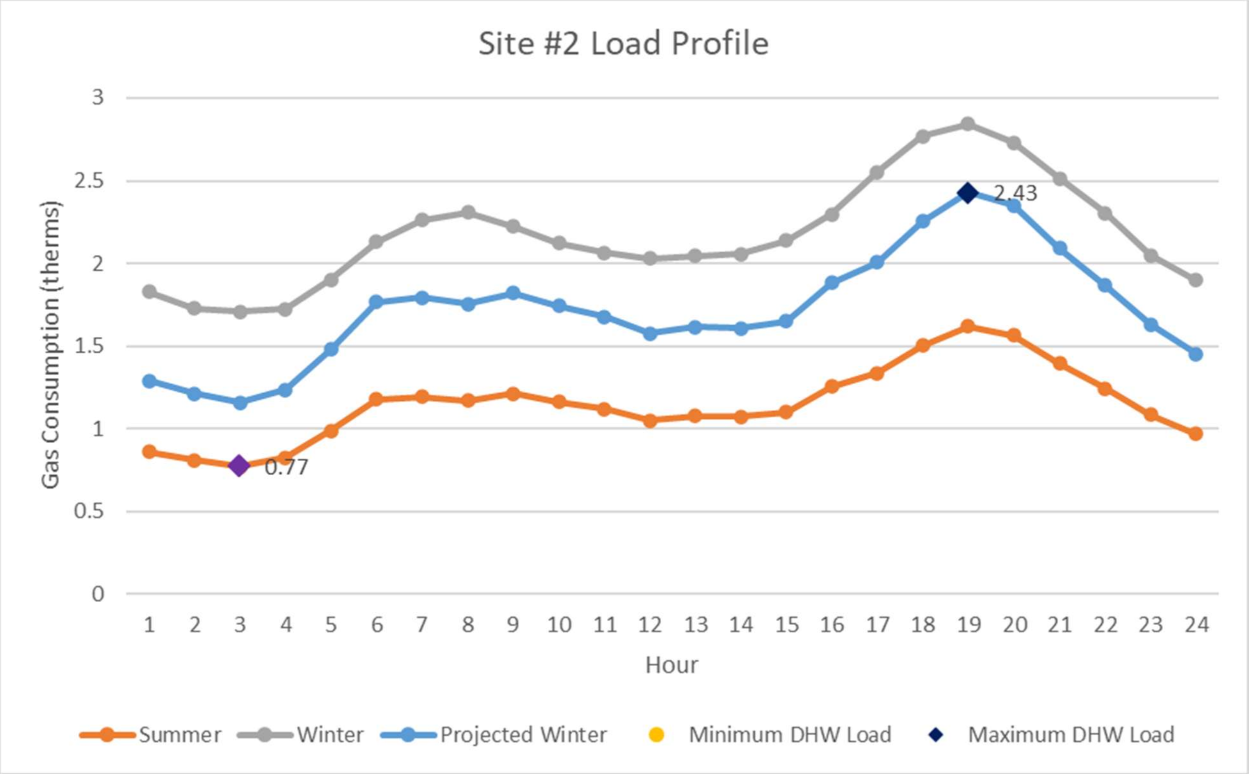

Figure B- 2: Site #2 load profile.

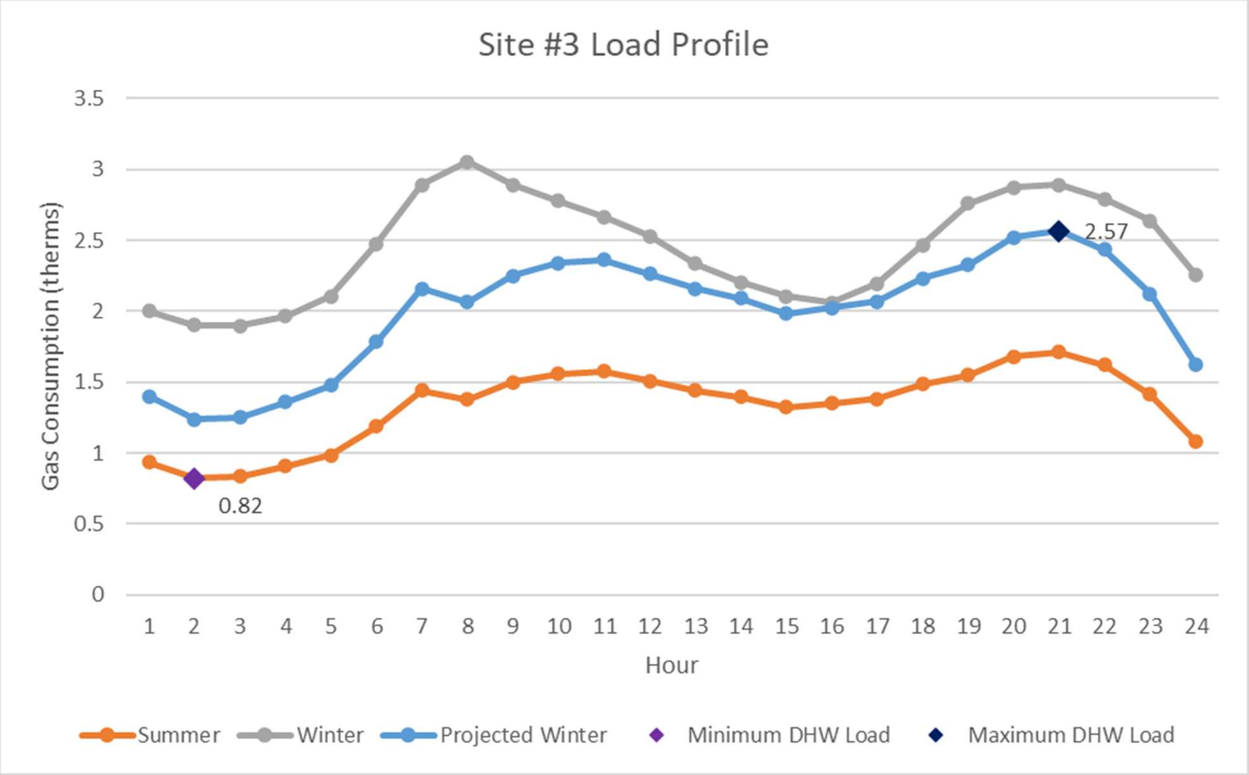

Figure B- 3: Site #3 load profile.

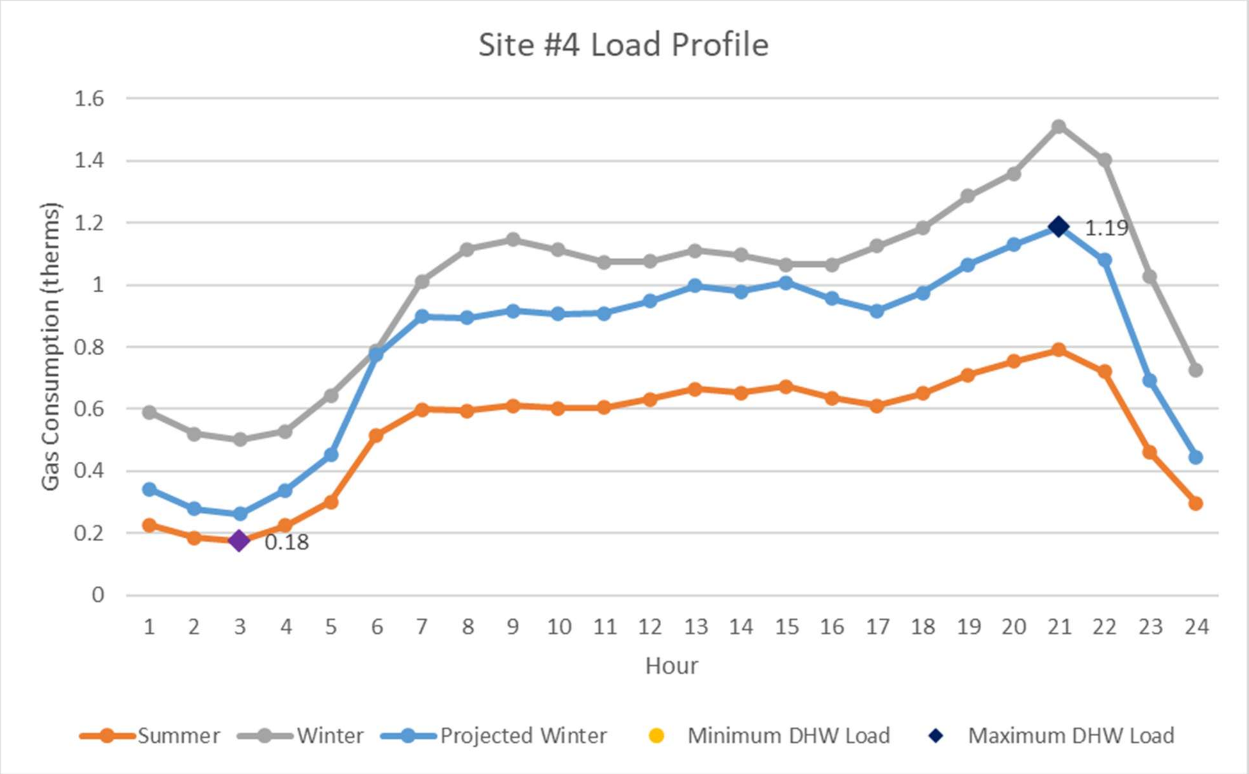

Figure B- 4: Site #4 load profile.

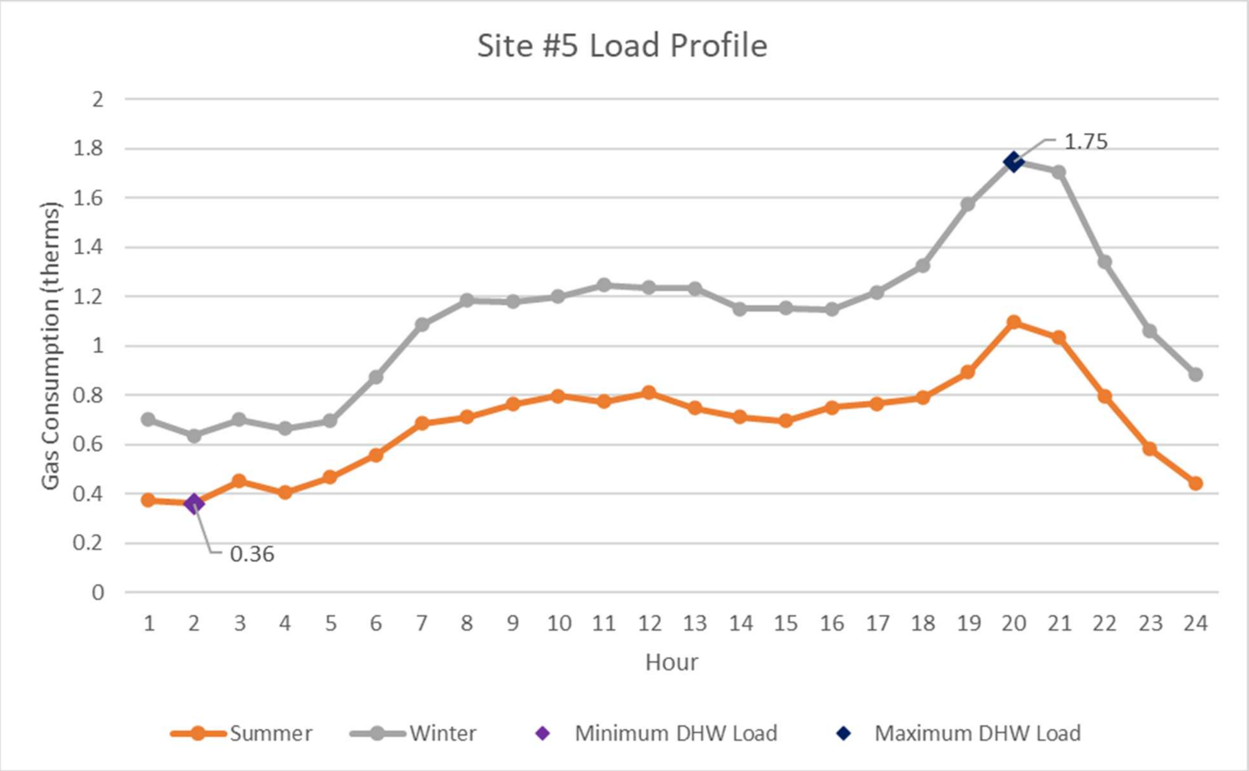

Figure B- 5: Site #5 load profile.

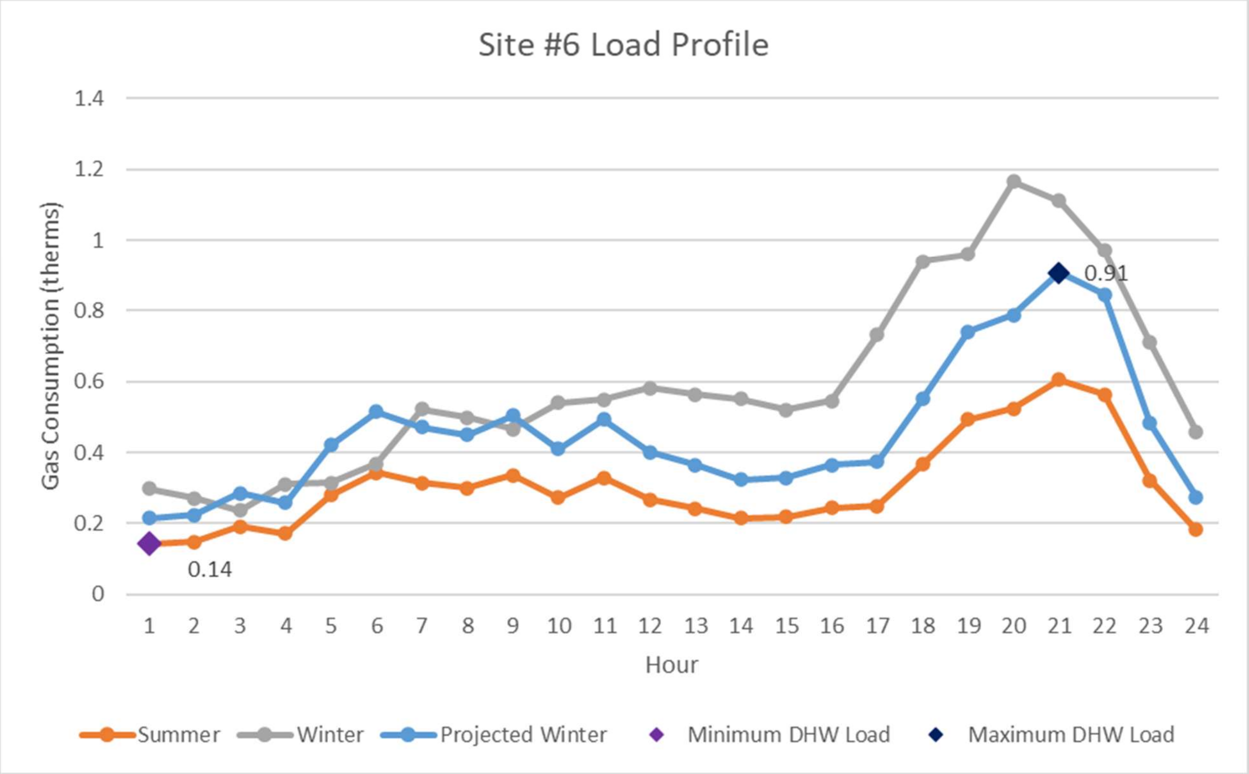

Figure B- 6: Site #6 load profile.

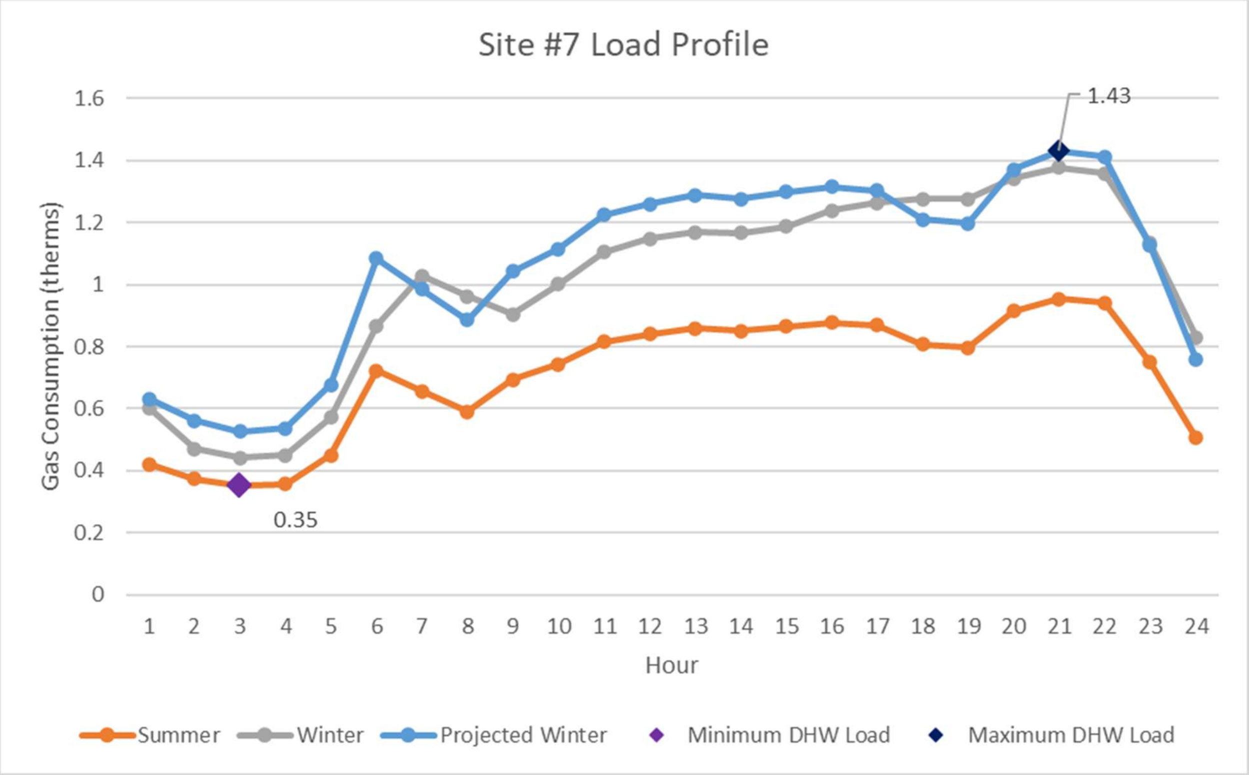

Figure B- 7: Site #7 load profile.

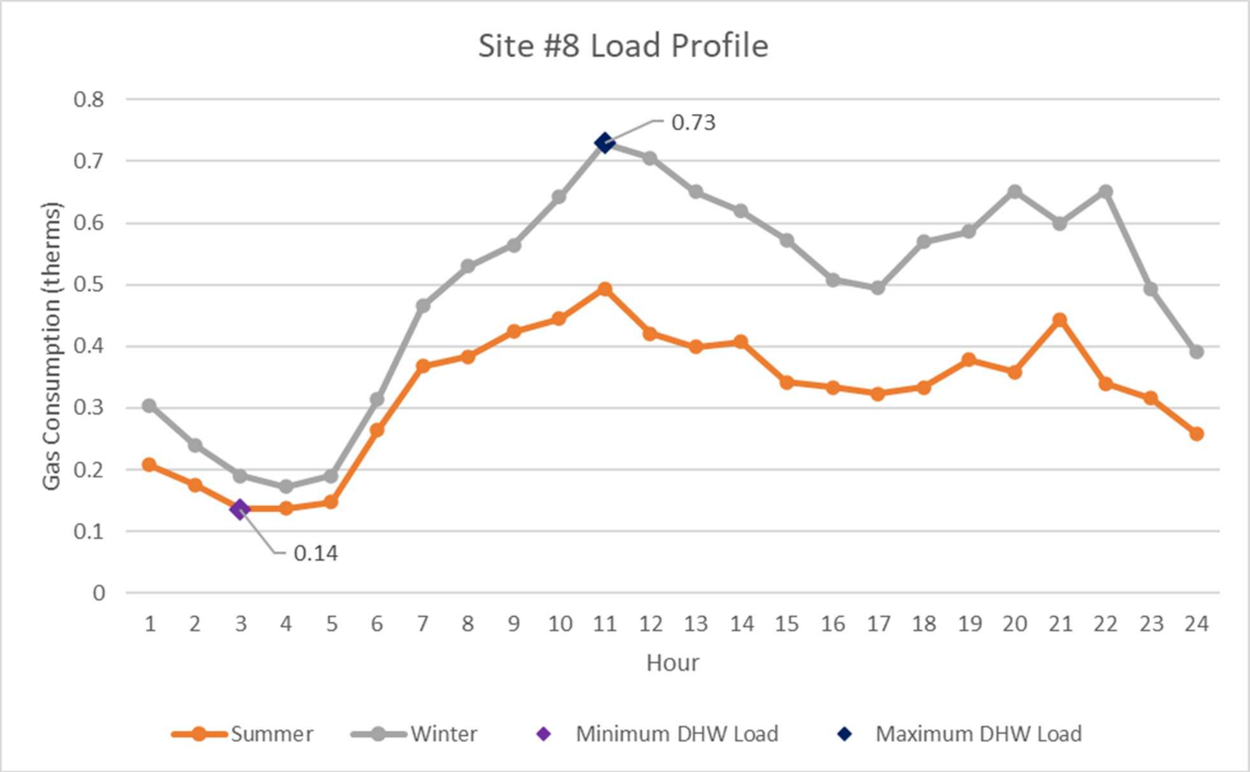

Figure B- 8: Site #8 load profile.

References

[1] P. Cristalle Mauleon, "Comparing Current DHW Sizing," in *ASHRAE Winter Conference*, Orlando, FL, 2025.

[2] Gas Emerging Technology Program, "Research GAHP Screening Criteria and Desgin," 2023. [Online]. Available: https://www.etcc-ca.com/reports/research-gahp-screening-criteria-design.

[3] ASHRAE, "Chapter 51: Service Water Heating," in *ASHRAE Handbook HVAC Applications*, 2023.

[4] California Energy Commission, "California Residential Appliance Saturation Study (RASS)," 2019.

[5] Gas Emerging Technology Program, "Gas-Fired Heat Pump Water Heating & Combi System Pilot Phase 1," 2022. [Online]. Available: https://www.etcc-ca.com/reports/gas-fired-heat-pump-water-heating-combination-system-pilot-phase-1.