Water Heater Right-Sizing

ASHRAE Recommendations vs. Actual Hot Water Use

Presented at: *2025 ACEEE Hot Water & Hot Air Forums*

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on Behalf of the Statewide Utility Codes and Standards Program

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CALIFORNIA ENERGY CODES & STANDARDS
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Objectives

- Develop a retrospective HPWH sizing approach leveraging hot water consumption data collected from multifamily central HPWH installations.
- Compare the retrospective HPWH sizing with ASHRAE predictive sizing methods.

Predicting & Assessing Peak Hot Water Demand

Methods Evaluated

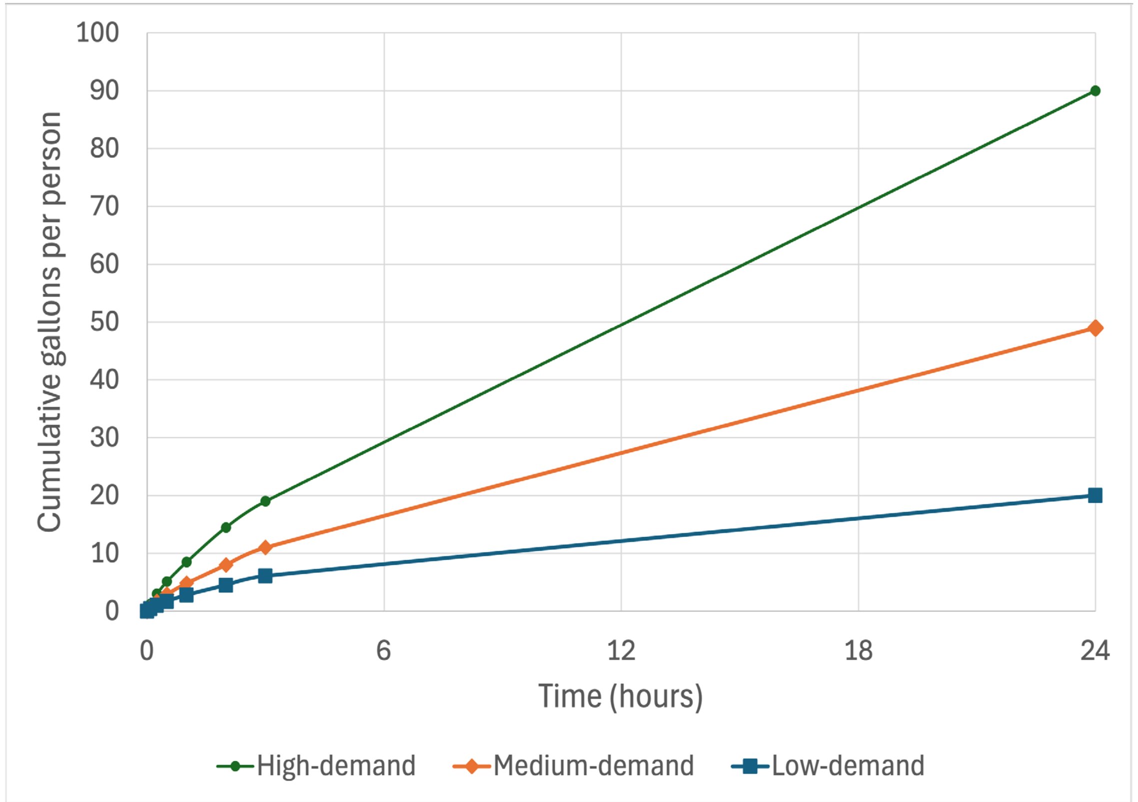
- ASHRAE Average Method
- ASHRAE Incremental Method
- Retrospective Demand Method

ASHRAE Predictive Methods

ASHRAE Cumulative Peak Hot Water Gallons Per Person Over 24 Hours

Hot Water Demand	Low-Demand	Medium-Demand	High-Demand
5 min	0.4	0.7	1.2
15 min	1.0	1.7	3.0
30 min	1.7	2.9	5.1
1 hour	2.8	4.8	8.5
2 hours	4.5	8.0	14.5
3 hours	6.1	11.0	19.0
24 hours	20	49	90

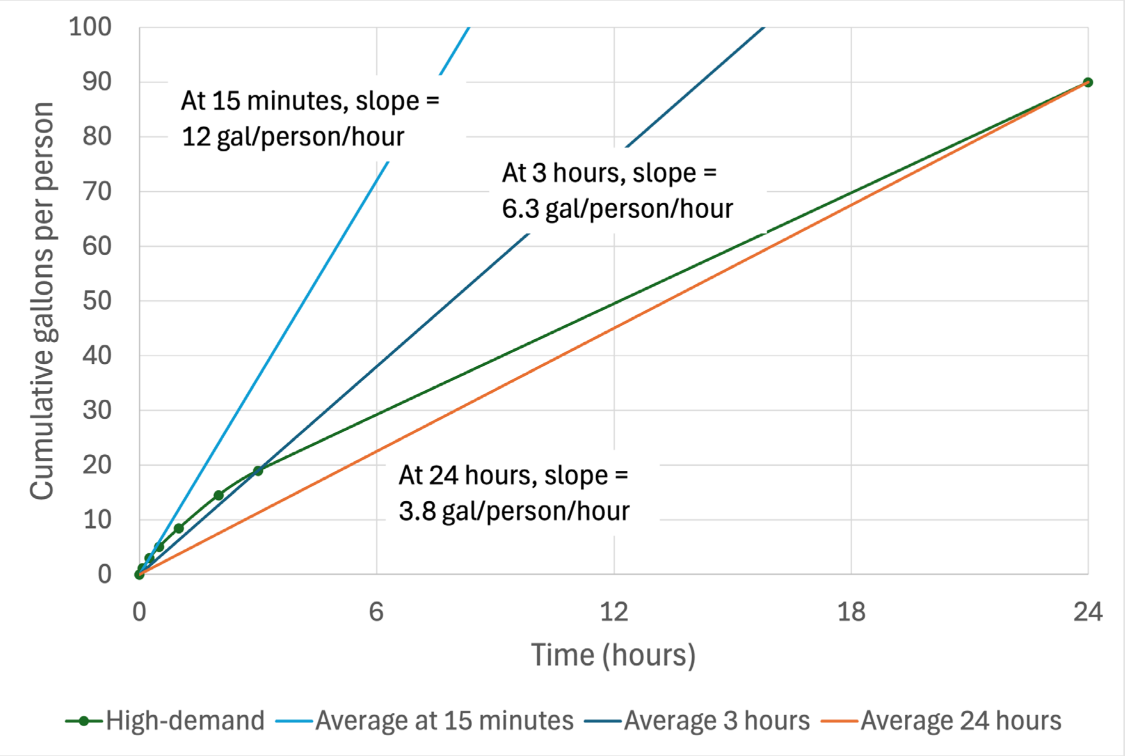
For apartment buildings, water delivered at 120°F



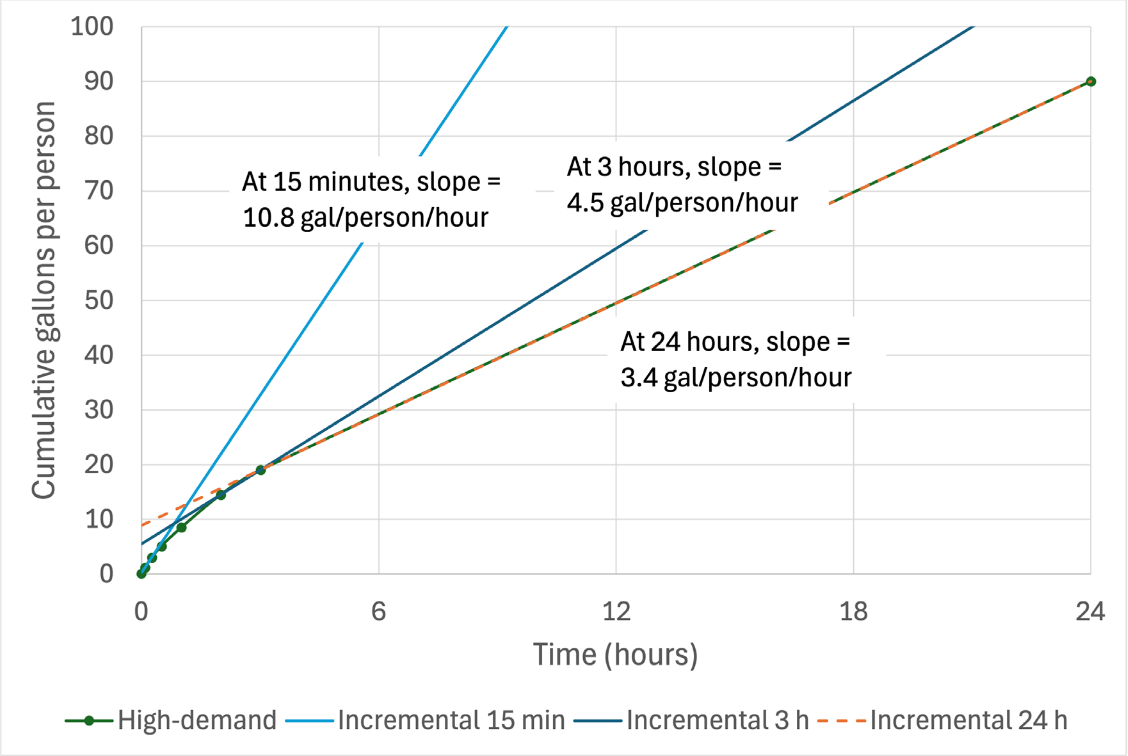
ASHRAE Handbook – HVAC Applications. American Society of Heating Refrigerating and Air-Conditioning Engineers. Chapter 51, Section 9. Hot-Water Load and Equipment Sizing. 2023.

ASHRAE Predictive Methods

Average Method



Incremental Method



Retrospective Demand Method

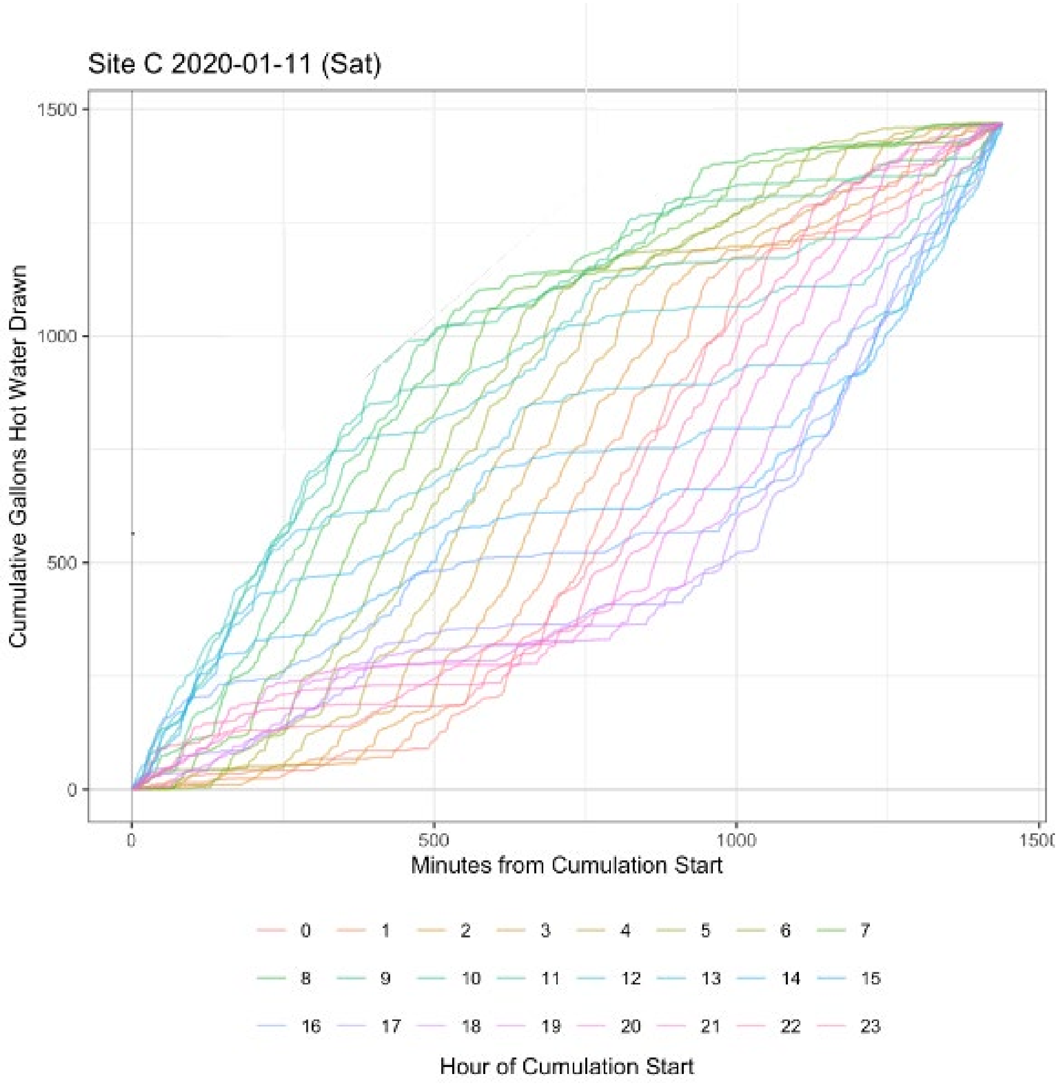
Retroactively right-sizing a HPWH using building hot water consumption data

1. Convert hourly hot water use to 24 cumulative demand curves, each representing a different start time
2. Identify maximum volumetric heat rate demanded
3. Identify storage to pair with identified heat rate (Iterative process)
4. Convert volumetric heat rate to heat pump capacity

Zhang, Y., R. Higa, C. Kim. “Balancing Heating Capacity and Storage Volume in Heat Pump Water Heater Systems.” ACEEE. 2020 Summer Study on Energy Efficiency in Buildings. 1-431.

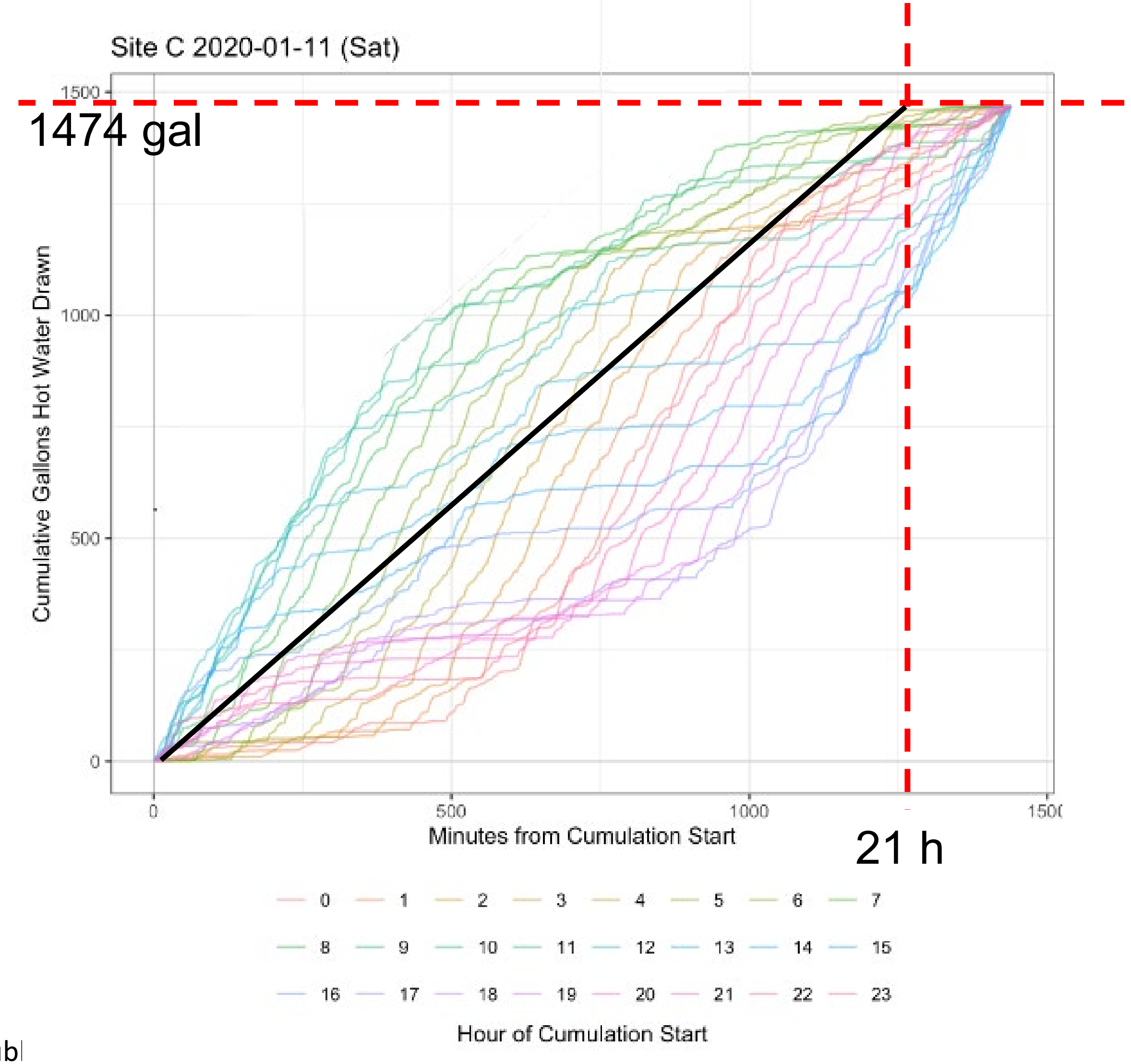
Convert Hourly Hot Water Use to 24 Cumulative Demand Curves

Each colored curve represents a different cumulation start time.



Identify Maximum Volumetric Heat Rate Demanded

- Identify the highest value of all 24-hour curves at each minute (cumulative-minute-maximums curve)
- Define a line with a slope that represents the volumetric heat rate, where volumetric heat rate = total daily hot water use divided by active heat pump time
- In this example, the heat pump runs for 21 hours and needs to produce 1474 gallons. This requires a heat rate of 1.17 gpm

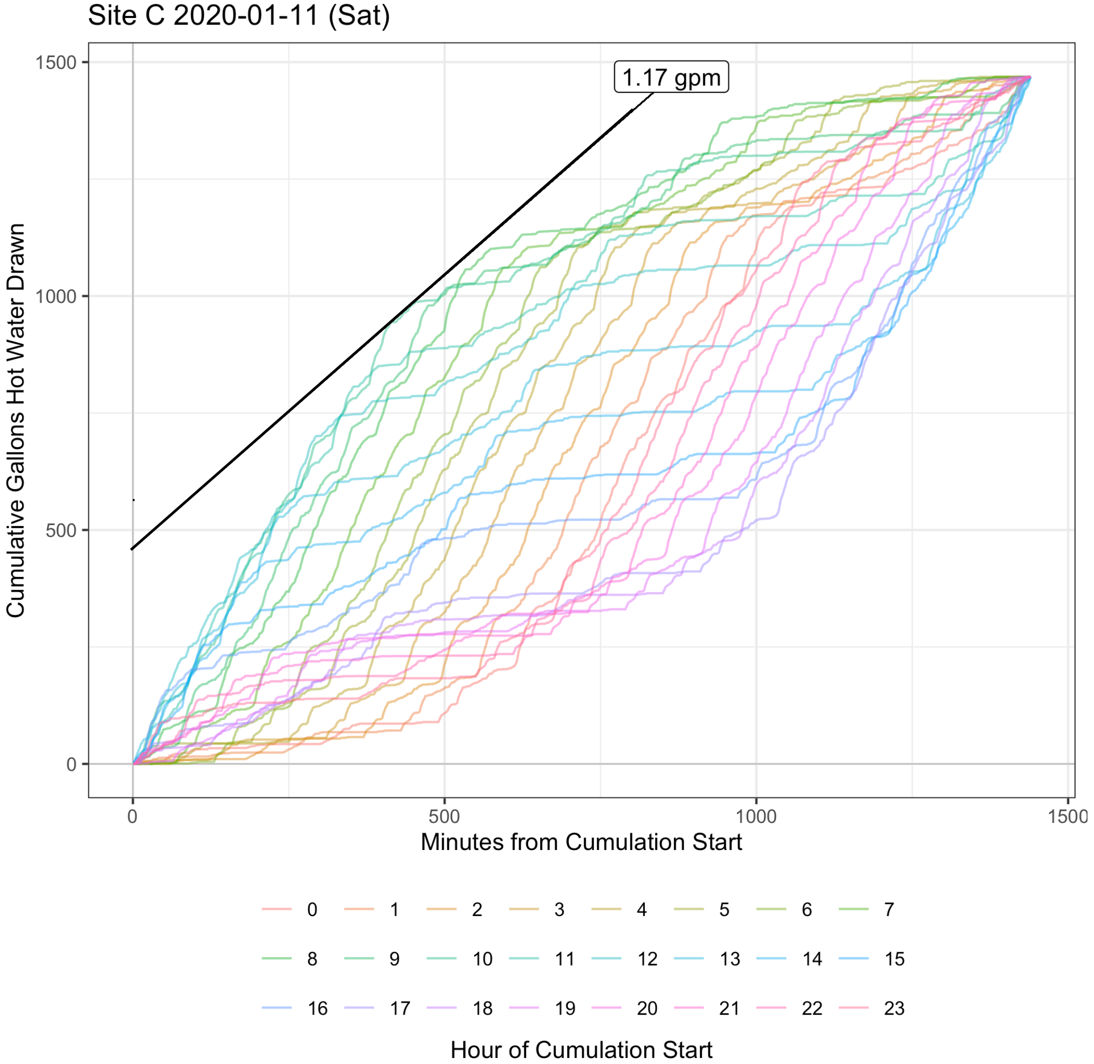


Publ

Identify Smallest Necessary Storage Tank Size

Step 1: Identify Storage Floor

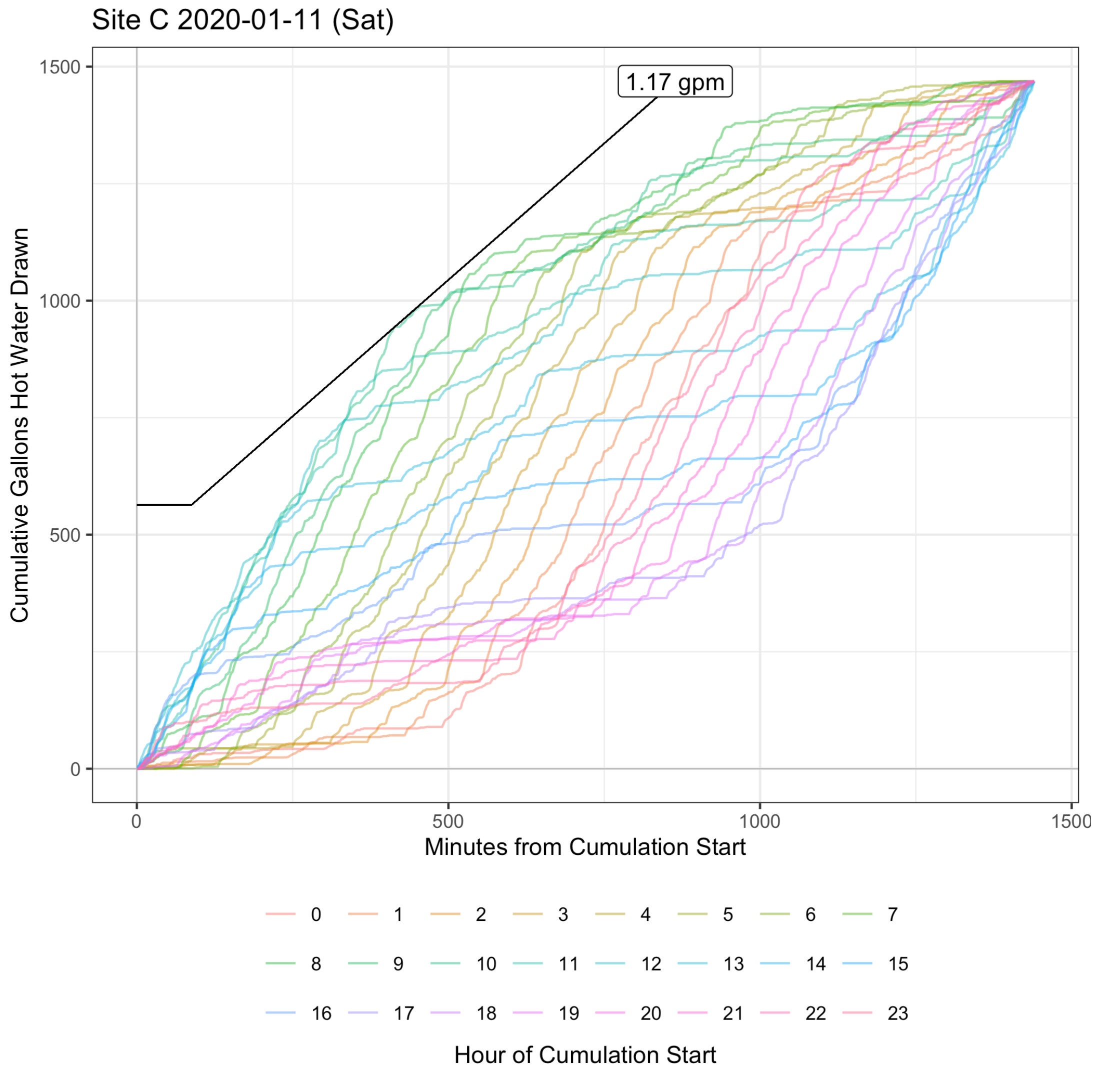
- Increase y-intercept of this line until the line is tangent to the top of the cumulative-minute-maximums curve set (peak hot-water use)
- y-intercept is an initial guess for the minimum storage needed to ensure the HPWH has sufficient buffer to provide hot water during highest demand



Identify Smallest Necessary Storage Tank Size

Step 2: Iterate

- Assume a starting storage volume
- Determine how long this volume will last during peak hour
- Assess if the determined heat rate could supply the remaining volume demanded in the time allotted
- Increase assumed volume until heat rate meets peak demand.



Convert Volumetric Heat Rate to Capacity

$$\boldsymbol{Q = 0.504\left(\frac{V}{t} \times C_p \times \Delta T\right)}$$

Q = Heat pump capacity in kBtu/hr

V = hot water use for measured day (gallons)

t = assumed heat pump operation time (hours)

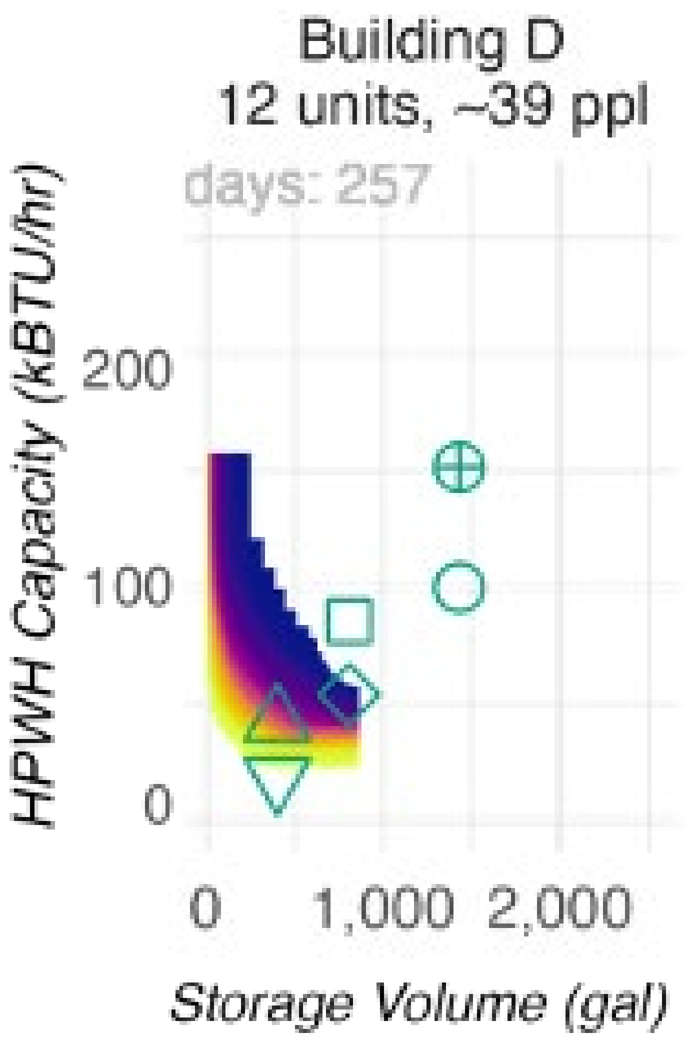
ΔT = difference between heated and supply water temperatures

Cp = heat capacity of water (1 Btu/lb-°F)

0.504 = conversion factor to obtain units of kBtu/hr

Results

ASHRAE Designs Can Be Too Hot, Too Cold, or Just Right

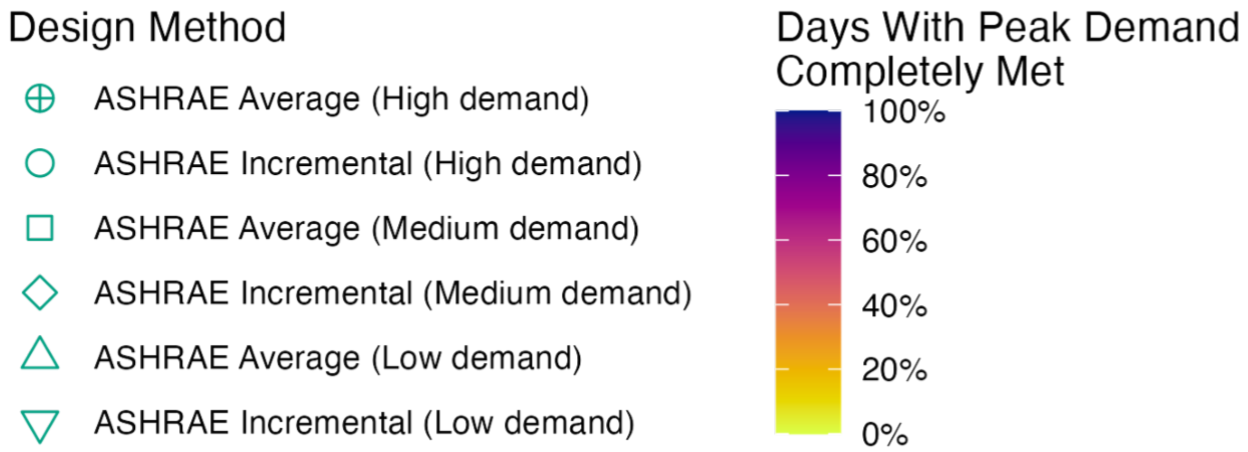


Colored regions show how different design pairs would meet peak demand

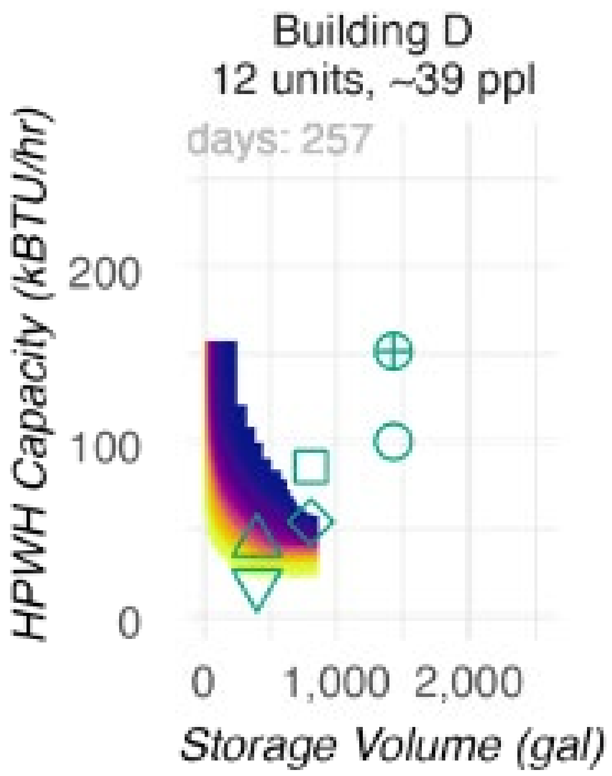
Some of these pairs would never run out of hot water (leading purple edge)

Multiple heat pump and storage pairs can meet demand

A more powerful heat pump needs less storage



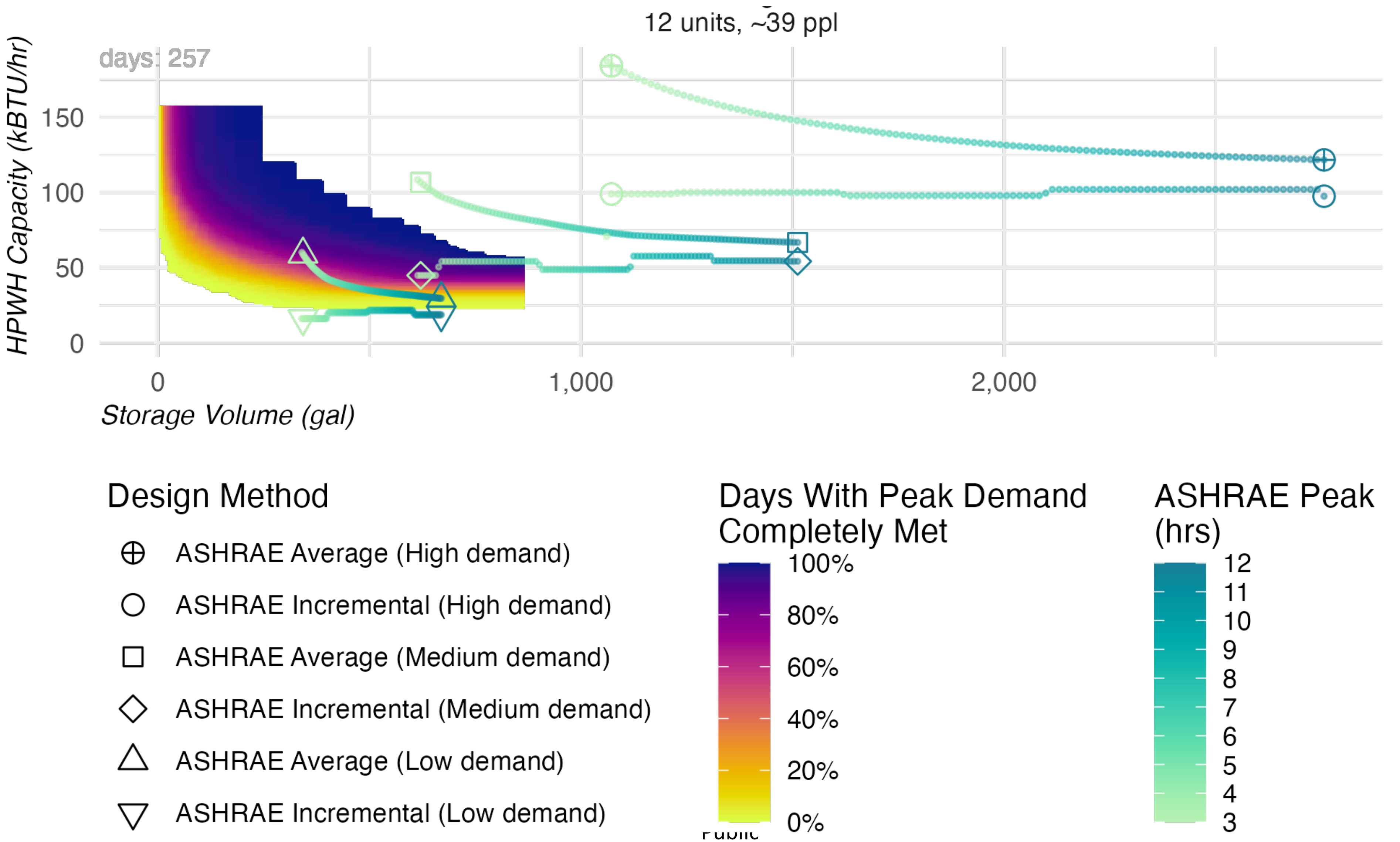
Comparing Sizing Methods in Building D



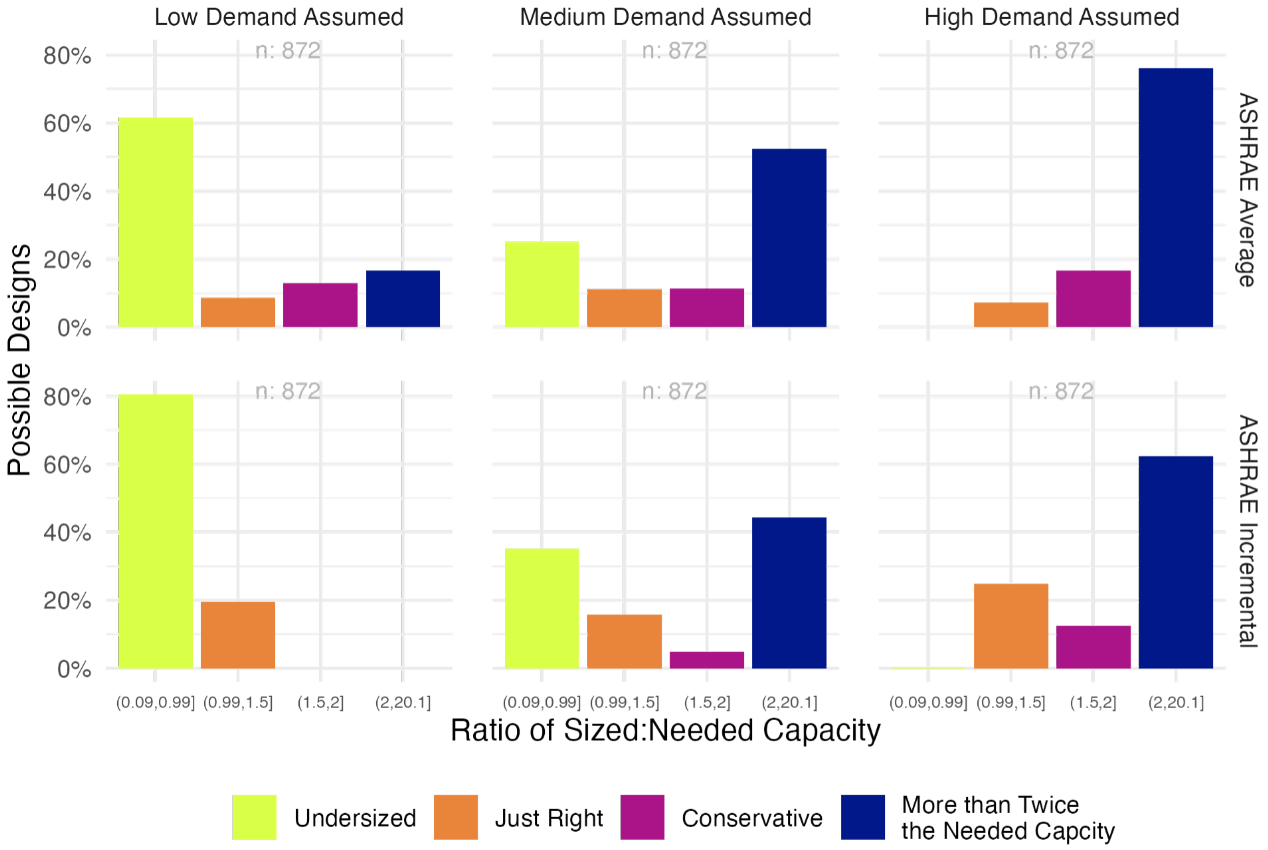
ASHRAE Design Method	Demand Assumed	Percent of Days With Peak Demand Fully Met	Capacity Design Assessment Ratio	Storage Design Assessment Ratio
Average	Low-use	45%	0.43	1.03
Incremental	Low-use	0%	0.19	1.03
Average	Medium-use	>100%	1.50	0.98
Incremental	Medium-use	99%	0.95	0.98
Average	High-use	>100%	2.66	1.74
Incremental	High-use	>100%	1.75	1.74

Triangles = Low-Demand; Diamond/Square = Medium—Demand; Circles = High-Demand. Average estimates always estimate higher heat pump capacity than incremental estimates.

Designer Assumptions Have a Huge Impact on ASHRAE Sizing

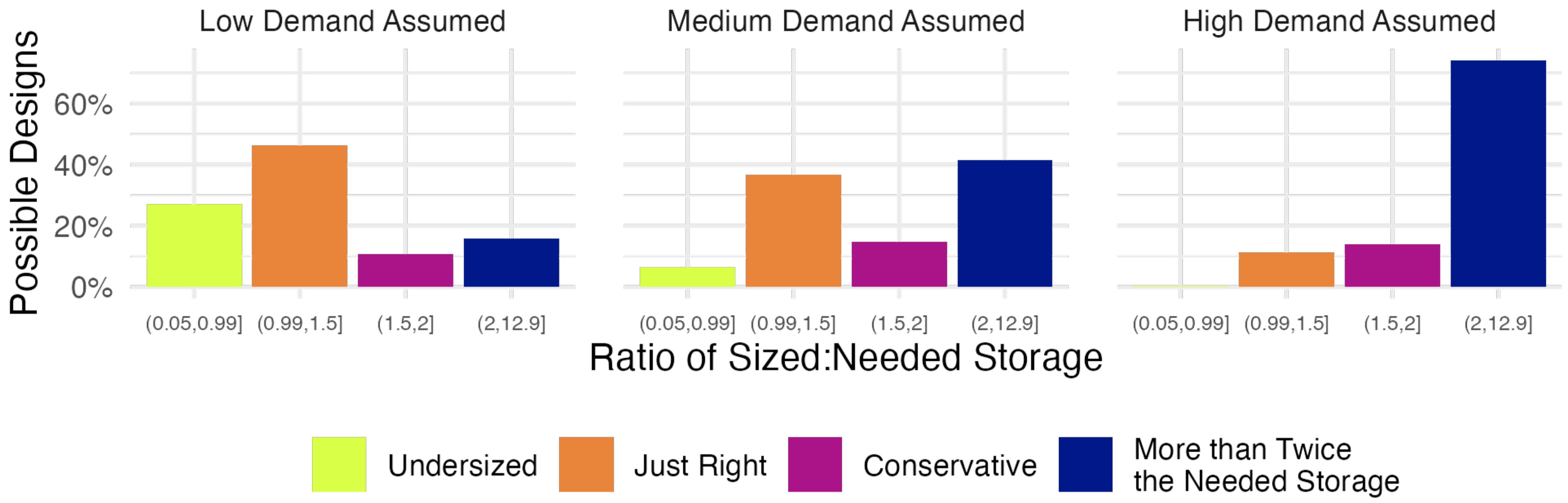


Neither ASHRAE Method Consistently Right-Sizes Capacity



- Neither ASHRAE method realistically estimate heat pump capacity for all buildings
- ASHRAE incremental method generally performs better than the ASHRAE average
- A heat pump/storage volume system would be right-sized 13% of the time if the assumptions and method were chosen randomly.

Neither ASHRAE Method Consistently Sizes Storage Volume



- Neither the ASHRAE average nor ASHRAE incremental methods realistically predict storage volume for all buildings.
- ASHRAE low- and medium-demand appropriately size storage volume for roughly half of the buildings evaluated.
- Under the ASHRAE high-demand scenario, most storage would be oversized.

Summary and Recommendations

Summary

- The ASHRAE building characteristics and ASHRAE hot water use data in the ASHRAE Handbook do not provide sufficient information to appropriately and consistently size multi-family HPWHs.
- The ASHRAE incremental approach provides more realistic heating capacity estimates than the ASHRAE average approach.

Recommendations for Future Work

- Support the development of a central HPWH design guidance document through ASHRAE GPC-47.
- Identify opportunities for leveraging our compiled building hot water data to refine and/or validate the EcoSizer tool.
- Evaluate the opportunities for a code change proposal in IAPMO's Uniform Plumbing Code, the California Plumbing Code (CPC), and/or the California Energy Code once the ASHRAE design guidance document is developed.

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Our team

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Building hot water data provided by Association for Energy Affordability (AEA)

Thank you

Appendix

Analyzed Building Characteristics

Building	City	Monitored Apartments	Monitoring Period (day)	Logging Interval (sec)	Occupancy Type
B	Oakland, CA	8	10	1	Market Rate
C*	Atascadero, CA	10	257	60	Low Income
D*	Atascadero, CA	12	257	60	Low Income
F	Oakland, CA	24	14	1	Market Rate
H	San Francisco, CA	15	9	1	Low Income
M	San Francisco, CA	120	12	1	Low Income
N	San Francisco, CA	134	12	1	Low Income
Q	Sunnyvale, CA	24	272	60	Low Income
*** Buildings C and D are similar; part of a larger complex.**					

Data provided by AEA. Sites evaluated if they met the following criteria: 1) Estimated occupancy counts available (since ASHRAE sizing methods rely on this information); 2) High data quality at the highest flow rates.