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REPORT #E24-342

Heat Pump Water Heaters in Multifamily New Construction: Design Charrette Findings

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Session Summary

Background & Objectives

A host of unique building design and installation challenges have prevented the widespread consideration and adoption of heat pump water heaters (HPWHs) in low-rise multifamily housing. To overcome these challenges, the Northwest Energy Efficiency Alliance (NEEA) worked in partnership with Energy Trust of Oregon to host a one-day design charrette with industry experts on November 8, 2022. The charrette's objective was to **identify barriers, including those pertaining to design, installation and market adoption, to HPWHs in multifamily housing,[1] and then propose practical solutions to overcome them.**

Through a series of hands-on workshops, participants were asked to collaboratively identify barriers, brainstorm solutions and draft potential designs for installing HPWHs in multifamily housing and bringing them to market.

The market intel and solutions resulting from this session will have a variety of valuable uses, including:

- Identifying potential design solutions to be lab tested to verify feasibility.
- Developing a plan to deploy HPWHs in multifamily housing.
- Metering and monitoring results—including energy performance, cost, customer experience and ease of installation—and comparing to standard application performance.
- Creating and deploying potential trainings and/or design guides.

Participants

NEEA and Energy Trust led the recruitment effort to assemble a panel of 12 experts, targeting industry professionals including architects, mechanical designers and installation contractors with a range of familiarity and experience with HPWHs. Participants were paid a $1,250 stipend for their time and contributions.

The final group consisted of seven designers and five contractors/raters/plumbers.

[1] For the purposes of this session, multifamily was further narrowed to low-rise new construction, ranging in size from studio to three bedrooms.

Appendix A—Design Charrette Details outlines the complete list of participants.

Each participant was provided with advanced reading material and asked to write down their initial thoughts regarding 1) challenges or barriers for HWPHs, and 2) potential solutions to overcome those challenges and barriers.

Approach & Activities

Prior Research

Led by Mark Frankel (Ecotope) and Ben Larson (Larson Energy Research), the day kicked off with a presentation of prior research, including energy and thermal studies, and examples of good and bad real-world installations. This existing body of research (included as **Appendix C**) provided valuable context to participants, ensuring the group started on the same page with what is and is not already known about the technology and its limitations in certain applications.

Barriers Brainstorm

For the first group exercise, participants were asked to write down and then discuss (real or perceived) barriers or challenges of selling, designing or installing HPWHs in small multifamily new construction for each of six categories:

- Product awareness
- Design and installation
- Training and education
- HPWH products
- Cost (first-cost and cost of ownership)
- Current code requirements

Breakout: Solutions Brainstorm—Part 1

Focusing on the top barriers (product awareness, design and installation, and training and education) identified in the Barriers Brainstorm, participants were broken into two groups (designers and contractors/plumbers) to come up with 3–5 proposed solutions to these barriers.

Breakout: Solutions Brainstorm—Part 2

The next exercise again broke the group into smaller working groups, this time mixing designers and contractors to compare notes from their previous groups, iterate on their initial ideas, generate new ideas and prepare to present their top proposed solutions.

Solution Presentations

The day concluded with each group from the second breakout sharing their solutions with the entire group. For this session only, participants were joined virtually by manufacturer and industry representatives and colleagues so those parties could listen in and ask questions.

For a complete breakdown of the day's activities, see the full session agenda in Appendix A—Design Charrette Details.

Photos of session whiteboards are available from the NEEA HPWH team.

Barriers Brainstorm

For the first group exercise, participants were asked to write down and then discuss (real or perceived) barriers or challenges of selling, designing or installing HPWHs in small multifamily new construction for each of six categories.

Below is a comprehensive summary of the challenges and barriers identified during the Barriers Brainstorm exercise. Similar responses have been consolidated, and the most frequently cited barriers per category have been bolded.

CHALLENGES AND BARRIERS IDENTIFIED	
DESIGN & INSTALLATION	PRODUCT
• **Occupant comfort** • **Space requirements for unit and ventilation** • **More complex than 1:1 swap** • **Sizing** • **Service space / access** • Fire ratings and placement • Dealing with condensate • Compressor noise • Temp. maintenance • Needs to be understood early on in design • Lack of common space for central tanks • Non-integrated systems limits opportunity • Air barrier penetrating • Small dwelling units don't have room for split system • Air barrier penetrations • Plumbing run distance for split systems • Access to exterior limits (economizer mode)	• Too big BTU/H • Controls prioritize electric resistance • Equipment noise • Side adapterless design options for venting • Control to space temp? • Large duct required • Doesn't look exciting • Colder climate limitations • Higher failure rate • Mfrs. build water heaters, not ventilation systems • Recovery 1st hr. rating for HP only • Tank design

CHALLENGES AND BARRIERS IDENTIFIED	
AWARENESS	TRAINING & EDUCATION

• General public does not know about them or understand impact
• Lack of understanding of lifecycle cost
• Perceived noise complaints
• People do not think about HPWHs as adding to sustainability efforts (in contrast to solar)
• Not integrated into Design Build early enough
• Plumbers are slow to embrace technology
	• **Lack of contractor education (for sales and installation)**
	• **Architects need info (e.g., one-pager) to help sell clients**
	• **Added complexity around the decision-making process compared to a standard water heater**
	• Chicken/egg scenario when architect designs space vs. when the HPWH is spec'd
	• Maintenance staff unfamiliar with operation (e.g., cleaning filters)
	• End user education
	  ○ Comfort training needed
	  ○ Understanding of cold discharge
	• Cost per sq. ft. space required
	• Plumber vs. HVAC/R roles in trade (perceived need for HVAC tech for maintenance)

CODE	COST
• **Code officials will need training on systems and venting requirements** • **Oregon code isn't pushing HPWHs/ while allowed, not strongly encouraged or "bonused"** • Plumbing code and performance are a mismatch • Efficiency rating confusion • Oregon 90.1 not on the same page as WA and CA • Thermal comfort • Requires R-10 under unit when installed on unconditioned slab • Have standard to follow that's **in**consistent from one area to the next	• **Return on investment** • **High first cost** • **Lack of experience leads to inflated bids** • Clear info on incentives needed (owners, developers love incentives) • For LEED energy models, no cost benefit over gas • Supply chain/lack of supply • Larger electric service needed, which costs more • Cost associated with programming space needs • Owner goals are at odds with the added cost • Payback can be hard to understand without pro help • 120VAC vs. 240VAC large scale savings

Key Takeaways

1. The impact of system operation on occupant comfort (primarily temperature, and secondarily noise) is the primary issue to be evaluated and resolved for the successful design and deployment of unitary HPWHs in multifamily housing. Although prevalent across all small multifamily applications, this issue is magnified in smaller apartment units (i.e., studio and one bedroom) since they have fewer spaces that could be considered remote from primary occupied spaces where thermal comfort is paramount.

2. The second-most persistent design and installation barrier is the increased size requirements of HPWHs compared to standard units. This is particularly challenging for multifamily applications where every square foot must be used as effectively as possible. The problem may be further exacerbated by the limited capacity increments of equipment currently on the market, which may be oversized for smaller apartment units.

3. Compared to standard gas or electric water heaters, HPWHs are more complex and require consideration early in the decision-making process. Education with each stakeholder (i.e., owner/developers, designers, trades, occupants and maintenance staff) at every step in the process is lacking, resulting in product misconceptions, missed opportunities, higher failure rates, increased costs and negative customer experiences.

4. Participants' sentiments were mixed on whether the greatest barriers were real (e.g., design, installation and/or product barriers) or perceived (e.g., awareness and education barriers). For instance, if a customer asked for HPWHs early in the design phase, the architect would presumably find ways to accommodate it, and the plumber would learn how to install it. However, all participants agreed that more work remains across all categories to accelerate product adoption, given the current cost and availability concerns.

Solutions Summary

Following the two small-group solutions brainstorm breakout sessions, each group presented its ideas and recommendations.

A recording of the group presentations and Q&A is available upon request from NEEA's HPWH Team.

General Takeaways

1. Current multifamily layouts are designed with electric resistance water heaters in mind and aren't optimized around the impacts of HPWHs on interior comfort or system performance.
2. While the participants proposed a handful of potential solutions, each idea generated a series of questions and recommendations for additional studies to verify feasibility and performance.
3. The groups did not see a viable path for solutions that required significant ducting.
4. Eventually, integrating HPWHs with HVAC design and viewing the whole building as a cohesive system would be ideal.
5. Each building is unique and has its own set of requirements and challenges. The groups found it difficult in the time permitted to solidify solutions that would be applicable to most, or even many, scenarios.

Proposed Solutions

Unitary System Design

Concerns around comfort and noise directed both groups, particularly the plumbers, toward a solution that (when possible) would locate unitary HPWHs in an outdoor "closet" that ventilates to the exterior. For example: In walk-ups, this could be accessible next to the front door; in corridor buildings, this would be next to an entry door and would exchange air with the hallway.

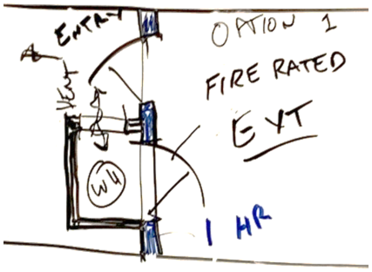
Configuration Options Suggested during Charrette

The groups presented two potential configurations from their brainstorming sessions:

1. Venting toward exterior corridor:

- Pro: Maintenance can access without disrupting tenant.
- Con: Increased energy use (and potential longer recovery time) due to the location in unconditioned space.

2. Venting into unit (near front door where some cold air is already expected/accepted):



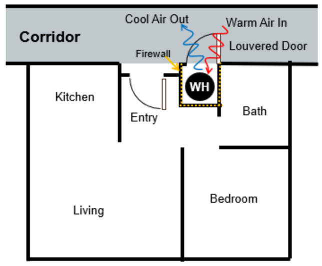
- Pro: Brings in cold air in the summer.
- Cons: Brings in cold air in the winter and requires a fire-rated wall.

Examples of Designs and Locations

Based upon the above solutions proposed during the design charrette, Larson Energy Research created additional examples of designs and locations, which are described and illustrated below:

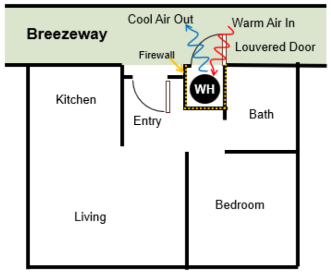
Corridor Closet

- For buildings with common corridors
- Plumber favorite. Maintenance can be conducted without entering unit.
- Firewall needs to separate WH closet from unit
- Suggest insulating for sound transmission between WH closet and unit



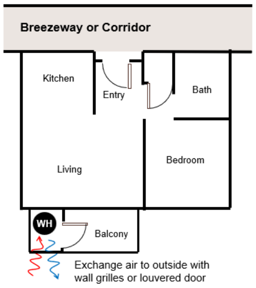
Exterior Closet Option 1

- For buildings with exterior entry "Garden Style"
- Plumber favorite. Maintenance can be conducted without entering unit.
- Firewall needs to separate WH closet from unit
- Suggest insulating for sound transmission between WH closet and unit



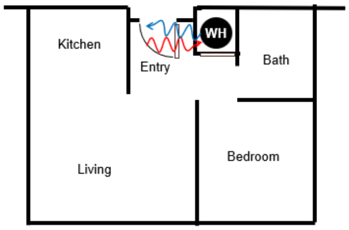
Exterior Closet Option 2

- Balcony / Patio Placement
- Normal Firewall
- Suggest insulating for sound transmission between WH closet and unit



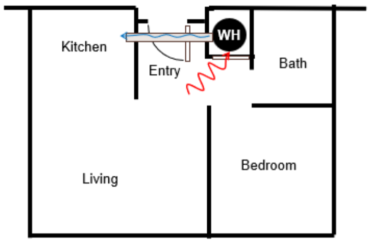
Interior Closet Option 1

- Exchange air entirely within unit
- Normal firewall configuration
- Access door in unit
- Cool air at entryway
- Suggest insulating for sound transmission between WH closet and unit



Interior Closet Option 2

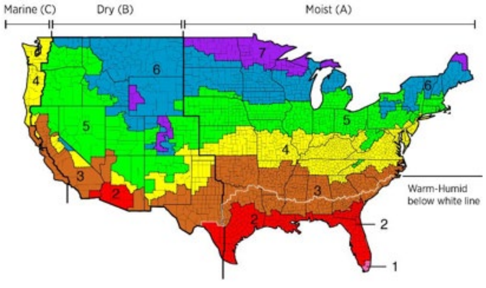
- Exchange air entirely within unit
- Duct exhaust (in ceiling soffit) to behind refrigerator or somewhere else inconspicuous
- Intake to closet with door undercut
- Normal firewall configuration
- Access door in unit
- Insulate for sound transmission between WH closet and unit



Placement for Energy Performance

The energy performance of solutions such as those described above varies based on climate zone. The following table summarizes the performance of each type of design based on its placement.

Climate Zone	Corridor Closet	Exterior Closet	Interior Closet
1	Best	Best	Best
2	Best	Best	Best
3	Best	Good	Best
4 A+B	Best	Poor	Best
4 C	Best	Okay	Best
5	Best	Poor	Best
6	Best	Poor	Best
7	Best	Poor	Best



Best Good Okay Poor

Another noted drawback of an exterior-located HPWH is that isolating equipment in buffer spaces or closets (and/or ducting airflows) will add complexity and cost to the deployment of unitary HPWH equipment.

For unitary systems to work in a variety of small multifamily applications, product diversification is needed to right-size the heat pump or tank, particularly for studio and one-bedroom units (currently, most products are oversized due to a pervasive one-size-fits-all approach.)

Split and Bundled System Design

1. While the groups didn't explore this option as thoroughly as they did for exterior placements, they briefly discussed a potential solution to locate the HPWH in the unit where the cold air output would be less noticeable or mitigated, such as behind the fridge where warm air is emitted.
2. The option of an outdoor split HPWH, which would have the tank within the unit and the heat pump located outside, was not discussed during the design charrette; however, this solution is being developed or a product design competition.
3. Bundled systems (i.e., clustered systems) serving multiple dwelling units were compelling to the groups as they solve the comfort issue and provide more layout flexibility. This design is particularly feasible where there are common areas like underground parking or other spaces that can be used for central equipment. However, these features are not common in small residential developments, and determining how billing would be allocated across tenants **introduces additional complexity**.

Appendix A includes an interior design schematic from a real-world project that a participant submitted following the session.

Recommendations

Research and Lab Testing

Test the performance impacts of locating the unit in an outdoor closet

1. Research Question: What is hot water delivery performance (i.e., recovery times) in the winter in an outdoor closet?
    - Do we need a different integrated HPWH product for outdoor closets that has better capacity in the 35–50F range in northern climates? Do we need them to operate colder?
        - Accomplishing this would require a larger heat exchanger, compressor and more airflow. This would likely cause the UEF to drop, which would make it harder to market.
        - Does the existing 120 volt (AO Smith & Rheem 120volt product) Phase 1 product work for this? It might work if it has a backup resistance element, and it would not have to be 120V. Instead, it could be 240V/15AMP, and it would be 2.25 kW with resistance heat.

2. Research Question: From an energy perspective, where does it make the most sense to locate an outdoor closet?
    - A modeling study could determine where the outdoor closet would make the most sense from an energy perspective.
    - In which climates is it possible?
    - If a new product entered the market, how would NEEA and/or the industry accommodate the climate range expansion?

Test thermal comfort parameters/occupant tolerance

Although participants discussed thermal comfort issues, they lacked context or metrics to understand the significant impact of unitary equipment's cool airflow and noise on occupant comfort in occupied spaces, and how to decide whether various proposed configurations represented effective mitigation strategies for these impacts. They recommended studies to determine the level of impact of these systems on perceived comfort in various adjacent spaces and configurations to inform design recommendations.

1. Research Question: How much cold air is tolerable?
    - At what velocity?
    - Where can it be dispersed inside the dwelling?
    - Is any amount of cold air acceptable in the winter?
    - Quantify and provide concrete direction to designers, if applicable.

Conduct a system capacity evaluation

In the charrette, participants identified market availability of system capacity as a potential barrier. They noted that it would be useful to develop sizing guidelines based on various prototype apartment sizes (e.g., number of bedrooms and number of occupants) to determine the ideal capacity range needed to meet domestic hot water loads in these units. These capacity ranges could be compared to available equipment on the market (both unitary and split systems) to determine whether there are market gaps in available capacity to serve different apartment loads. This could form the basis of discussions with manufacturers about market needs.

Conduct adjacency study with design examples

Although interior layout challenges and adjacency potential (e.g., locating HPWHs near the back of the refrigerator or near dryers) were discussed in the charrette, specific design layout solutions were not identified. An adjacency study followed by prototype unit layouts that optimize HPWH interaction with occupied spaces and minimize comfort impacts could serve as examples of effective HPWH design strategies to influence the industry.

Market Education

Document thresholds for different solutions/applications

To promote the optimal design for HPWHs at the start of a project, one breakout group suggested a resource that identifies scenarios or indicators to help understand when certain system designs may be more or less ideal.

Develop audience-specific one-pagers

Participants want to see one-page handouts for all audiences (6)—owners/developers, architects, engineers, installers, occupants and maintenance staff—that provide education on the unique benefits and considerations of HPWHs.

To be effective, the handouts shouldn't be entirely promotional. In addition to value propositions, educational material should outline what each audience needs to know about the product to align all stakeholders on effective design and execution principles early in the project (e.g., what does an architect need to know or do differently in their role to ensure the space is designed for HPWHs early in the project?) These brief handouts could link to more detailed design guides and/or manufacturer information, depending on the audience.

Appendix A—Design Charrette Details

Participant List

Name	Field	Organization
Steve Brotton	Plumber	Great Northwest Installations
Erin Connor	Rater	Keel Energy
Brian Ek	Plumber	Tapani Plumbing
Andrew Flanagan	Designer	Interface Engineering, Inc.
Mark Denyer	Designer	MFIA
Beth Lavelle	Designer	SERA
Cheryl McDermott	Designer	PAE
Darrin Stewart	Plumber	Atlas Mechanical
Johnny Walker	Plumber	Harder Mechanical
Alex Boetzel	Designer	Green Hammer
Katie MacKenzie	Designer	Glumac
Walter Currin	Designer	SERA

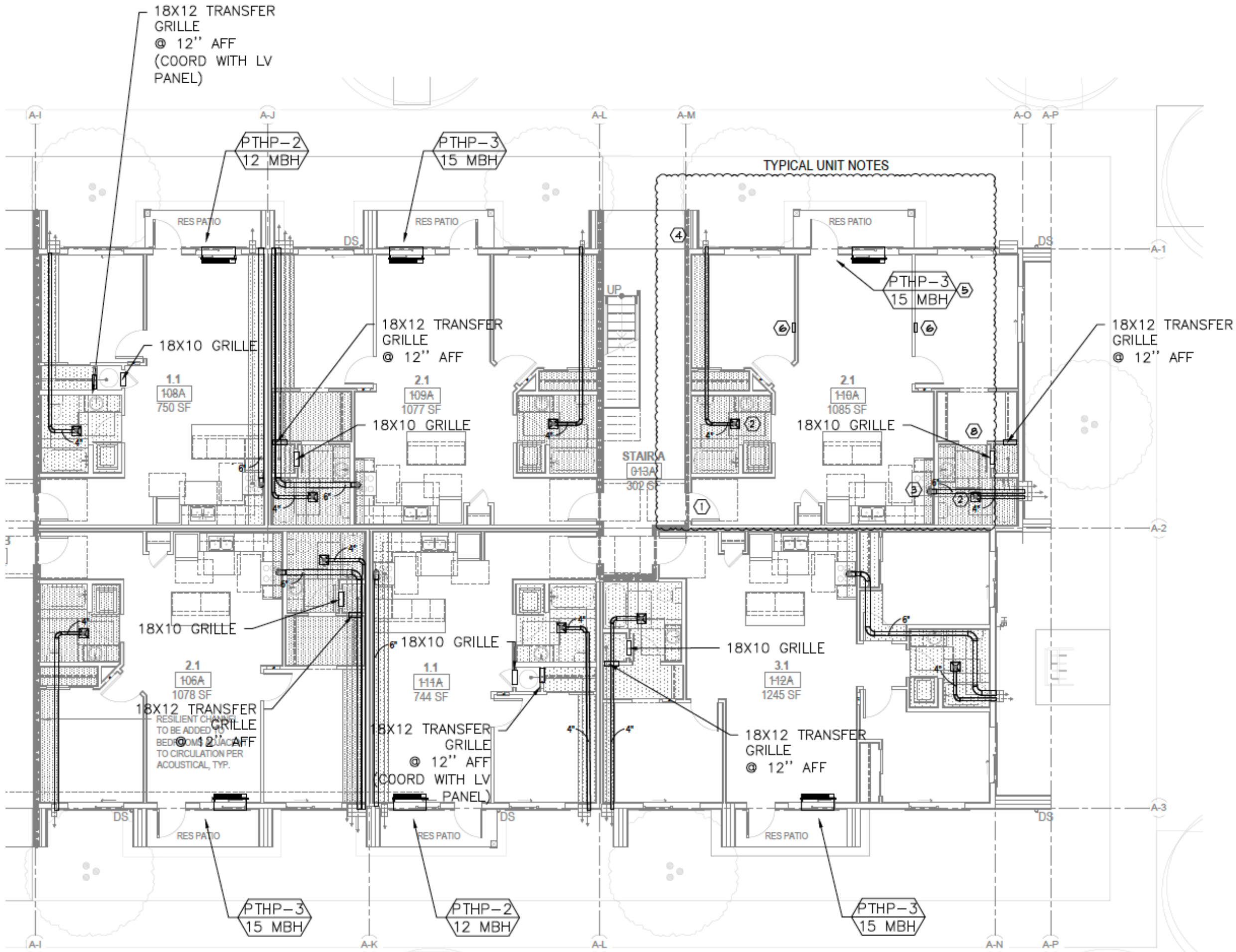
Session Agenda

Time	Topic	Description
9:00–9:25	Arrival and welcome	Welcome and introductions
9:25–9:35	Meeting objectives and outcomes	Review session objectives, desired outcomes, and run-of-show
9:35–10:25	Prior research	Presented by Ben Larson, Larson Energy Research and Mark Frankel, Ecotope
10:25–10:35	Break	
10:35–11:35	Barriers group discussion	Group discussion around technical and market barriers and challenges
11:35–12:35	Lunch	
12:35–1:30	Breakout activity #1	Working session to brainstorm and draft solutions to barriers
1:30–1:50	Reconvene	• High-level share-out • Address any questions from first breakout • Provide instructions for breakout #2
1:50–2:40	Breakout activity #2	Working session to brainstorm and draft solutions to barriers
2:40–2:55	Break	
2:55–3:55	Solutions share-out	• Ideas are presented and discussed • Group votes on the best approach(es) to move forward for lab and market testing
3:55–4:00	Wrap-up	Thank you and next steps

Post-Session Participant Schematic

Pictured on the following page is a real example from a session participant's project. The participant also sent the following unedited notes for how they problem-solved to accommodate the HPWH size and exhaust air:

- Per the AO Smith documentation and NEEA working group, the best strategy is to use high and low transfer grilles.
- All the rooms are venting by transfer grilles except for one ducted unit that's routing over to a closet.
- HPWH is pulling warm air into the closet via grille above the water heater closet door. Where we pull air in from the bathroom is even better as the water heater will use warm moist air and cool and dehumidify it and return it to the space at a lower RH.
- Cold is rejected/forced out of the water heater closet to mostly closets, so it will not cause thermal discomfort/drafts. One or two units will be near the entry, but it should not be an issue as no one would mind a slight draft near the unit entry door. Only one unit was an issue, and I ducted that over to a ceiling grille in the closet.


18X12 TRANSFER GRILLE @ 12'' AFF (COORD WITH LV PANEL)
PTHP-2 12 MBH
PTHP-3 15 MBH
TYPICAL UNIT NOTES
RES PATIO
PTHP-3 15 MBH
18X10 GRILLE
18X12 TRANSFER GRILLE @ 12'' AFF
18X12 TRANSFER GRILLE @ 12'' AFF
1.1
108A
750 SF
2.1
109A
1077 SF
18X10 GRILLE
STAIR A
2.1
110A
1085 SF
18X10 GRILLE
UP
DS
18X10 GRILLE
2.1
106A
1078 SF
18X12 TRANSFER GRILLE @ 12'' AFF
RESILIENT CHANNEL TO BE ADDED TO BEDROOMS ADJACENT TO CIRCULATION PER ACOUSTICAL, TYP.
18X10 GRILLE
1.1
111A
744 SF
18X12 TRANSFER GRILLE @ 12'' AFF (COORD WITH LV PANEL)
18X10 GRILLE
3.1
112A
1245 SF
18X12 TRANSFER GRILLE @ 12'' AFF
PTHP-3 15 MBH
PTHP-2 12 MBH
PTHP-3 15 MBH

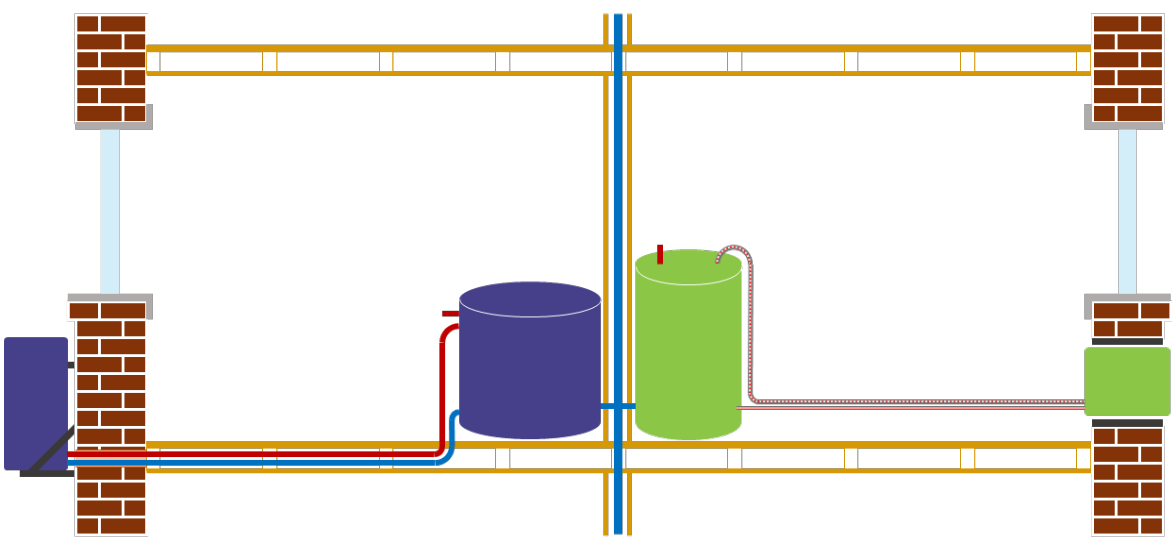
Next Steps

1) NEEA hosted a “Product Council” on the design charrette in Q2 2024.
2) NEEA is working with Larson Energy Research to explore lab evaluations of solutions in Q2 2023. Phase 2 of “the Amazing Shrinking Room” study will be published in Q1 2024.
3) NEEA will work with Ecotope to develop one-pagers for new construction solutions and socialize with a few architectural and engineering firms to explore whether they address the market’s questions.
4) NEEA will explore next steps in running another design charrette for existing low-rise multifamily (in 2024) solutions to determine whether some crossover solutions exist.
5) NEEA will reach out to existing manufacturers to educate them on the design charrette event and encourage them to update applicable technical bulletins for their respective products.
6) NEEA and its contractors, in partnership with OEMs, will develop a “multifamily split HPWH” solution that will be embedded in an external wall.

Appendix B — Product Innovation Design Competition

A split HPWH system with an outdoor compressor unit can mitigate challenges—such as size, space/ventilation requirements, and noise and cool exhaust—that render integrated HPWHs impractical in multifamily housing. Installation of such split HPWH systems in multifamily new construction will dramatically increase the penetration of HPWHs in multifamily housing.

The information in this Appendix outlines the specification for such a split HPWH system with outdoor compressor unit. The specification [is being/has been] developed by NEEA in partnership with XYZ as a potential solution for consideration in a product design competition.



Split-System Design

- Uses **outside air** as heat source
- Heat pump unit can be located **on or in an exterior wall**
- Tank can be located at least **50 ft.** from heat pump unit
- Design should allow quick installations:
  - New Construction: **≤2 hr.** average
  - Retrofit: **≤3 hr.** average

Ambient Temperature Tolerances

- Minimum compressor operating range:
  - Minimum Model: **37° – 110° F**
  - Cold Climate: **5° – 110° F**
- Withstand 24 hours at cold temperature without power and restart without failure:
  - Minimum Model: **20° F**
  - Cold Climate: **-5° F**

Water Heating Performance

- SCOP: ≥ **2.4**
- FHR: ≥ **38 gal.**
- Heating output capacity: ≥ **1kW** under all conditions
- Meets all **ENERGY STAR** requirements

Energy Input

- Maximum **12 Amps** at **120 Volts**

Storage Tank

- Maximum dimensions **24 in. x 26 in. x 36 in.** height, inclusive of all fittings
- Industry-standard **corrosion protection**

Condensate Management

- Condensate disposed **without dripping** or depositing on building exterior or surroundings

Sound Level

- Maximum **50 dBA** at a distance of 1m in a free-field environment

Control Interfaces

- User interface **at tank** or via dedicated **remote control**
- **EcoPort** built in, with UCM port accessible from within dwelling

Dependability

- No regular maintenance required by user
- 10-year warranty on heat pump unit
- Industry-standard warranty on storage tank

Market Support

- Installer training program materials
- Marketing campaign for product launch
- Installer manual
- Technical support for installation and maintenance

Price

- . . .

Details and Rationale

Few multifamily structures can successfully accommodate integrated HPWHs, due to their larger size (compared to ER or combustion), space/ventilation requirements, and discomfort caused by noise and cool exhaust. A split system with an outdoor compressor unit can overcome these barriers and make HPWHs a practical choice for more of the 40+ million multifamily dwellings in the U.S.

This specification describes a minimum model; manufacturers are encouraged to develop additional variants to effectively serve a variety of applications: different storage tank size (and FHR) options, versions with different electrical input requirements, etc.

1. Split-System Design

- **Use exterior air as heat source.** By exchanging air with the outside, the heat pump will not cool the dwelling.
- **Heat pump unit must be able to be mounted on an exterior wall, or in the wall** (like a PTAC). This reduces the amount of sound produced inside the dwelling and the volume of the interior equipment. Qualifying products may be designed for additional mounting options (like roof or patio/balcony), but these options are not required.
- **Tank can be located at least 50 ft. from heat pump unit.** This allows sufficient flexibility in the positioning of both the heat pump unit and the storage tank. There are no minimums for vertical separation of the two units.
- No requirement for heat pump-tank heat transfer medium (e.g. hydronic, refrigerant, other).
- Product design should allow quick installations to reduce product owners' first costs. The average installation time in a new-construction dwelling should be no more than **2 hrs.** For a retrofit in an existing structure: **3 hrs**.

2. Ambient Temperature Tolerances

The program specifies both a minimum model and a cold-climate model. Additional financial support will be made available for a product that meets the cold-climate specifications. The minimum model is intended to operate effectively in IECC climate zones 1-4. The cold-climate model is intended to operate effectively anywhere in the contiguous U.S.

The compressor operating range ensures that the product will run in heat pump mode a sufficient portion of the time to realize meaningful efficiency benefit. The freeze protection requirements ensure that the product will not be damaged in the case of a power outage during cold weather.

Minimum Model:

- Compressor must be able to operate in air temperatures of **37° - 110° F**
- Able to restart without failure after 24 hrs. at **20° F** without power.

Cold-Climate Model:

- Compressor must be able to operate in air temperatures of **5° – 110° F**
- Able to restart without failure after 24 hrs. at **-5° F** without power.

3. Water Heating Performance

- **Minimum SCOP: 2.4**. The SCOP (seasonal coefficient of performance) will be measured according to the procedure in Appendix B.4: Temperature Range Performance Testing–Split Systems of the Advanced Water Heating Specification, version 8.0. This procedure predicts an annual efficiency for an exterior air-source product based on the Northwest climate. Note that the minimum for a Tier 3 AWHS rating is 2.7.
- **Minimum FHR: 38 gal.** The Uniform Plumbing Code recommends a First Hour Rating of 38 gal. for one-bedroom dwellings, which make up about 40% of U.S. multifamily units. Variant models with greater FHR will be useful, but a significant portion of the market can be served with a modest FHR and a product targeting that segment is needed.
- **Minimum output capacity of 1 kW under all conditions.** Backup ER heating is not explicitly required, but the product must be able to produce hot water regardless of weather. If auxiliary heating elements are included in the design, they can be part of either or both the heat pump and tank units.
- **Meets all requirements of ENERGY STAR Residential Water Heaters Specification Version 5.0.** ENERGY STAR certification does not need to be completed in order to be eligible for award, but product must meet all of the requirements to become certified.

4. Energy Input

- System shall have a **maximum power draw of 12 Amps at 120 Volts.** This allows the product to run on a 120 Volt / 15 Amp circuit, which will allow for more retrofit installations without significant electrical work.

5. Storage Tank

- Maximum dimensions of **24 in. x 26 in. x 36 in.** height, inclusive of all fittings. Many multifamily units are equipped with "low-boy" water heaters installed in small spaces. A successful retrofit HPWH will need to fit tight quarters.
- If default storage temperature is greater than 125° F, a system to temper the delivered water to below 125° F must be integrated into the system and meet the dimensional requirement.
- Tank must meet industry standards for corrosion protection: replaceable anode rod, stainless steel construction, or other standard practice.

6. Condensate Management

- Condensate must not be deposited anywhere outside. Possible solutions include nebulizing the condensate outdoors or pumping to an interior drain. In built-up areas there may not be any place outdoors to discharge condensate from multiple heat pumps without causing water damage or safety risk.

7. Sound Level

- Maximum sound pressure level of the heat pump unit measured at a distance of 1 m in a free-field environment is **50 dBA**. Lower sound levels will reduce occupant irritation.

8. Control Interfaces

- Occupant must be able to control the water heater from within the dwelling unit, either by use of a **tank-mounted interface** or a dedicated **remote control**. An app for a mobile device does not satisfy this requirement.
- Product must have **EcoPort** (CTA-2045-B) capability integrated into the system, with all hardware and software integrated and ready out of the box. Must be able to attach an EcoPort UCM (universal communication module) from within the dwelling.

9. Dependability

- Product shall require **no regular maintenance by user** (filter cleaning, condensate draining, etc.). Infrequent and typical tank maintenance, such as draining for sediment and anode rod replacement, is acceptable.
- Heat pump unit shall carry a minimum **10-year parts warranty**.
- Storage tank shall carry an **industry-standard warranty**.

10. Market Support

To be eligible for the phase-three reward, manufacturer must develop:

- **Materials for an installer training program**.
- A **marketing campaign** for the product.
- **Installer manual**.
- **Technical support** for installers and maintenance personnel.

Appendix C—HPWHs in Multifamily Applications Design Charrette: Prior Research and Background

This appendix comprises the slides from a presentation by Mark Frankel of Ecotope and Ben Larson of Larson Energy Research on November 8, 2022.

HPWHs in Multifamily Applications Design Charrette: Prior Research and Background

Mark Frankel, Ecotope
Ben Larson, Larson Energy Research

8 November 2022

HPWH Market, Tools, Technology, and Opportunity

Mark Frankel, Ecotope

Ecotope is…

+ A research, engineering, and policy firm providing leading-edge MEP solutions to decarbonize buildings locally, regionally, and nationally.

ELECTRIFY BUILDINGS

DESIGN FOR OFF ™

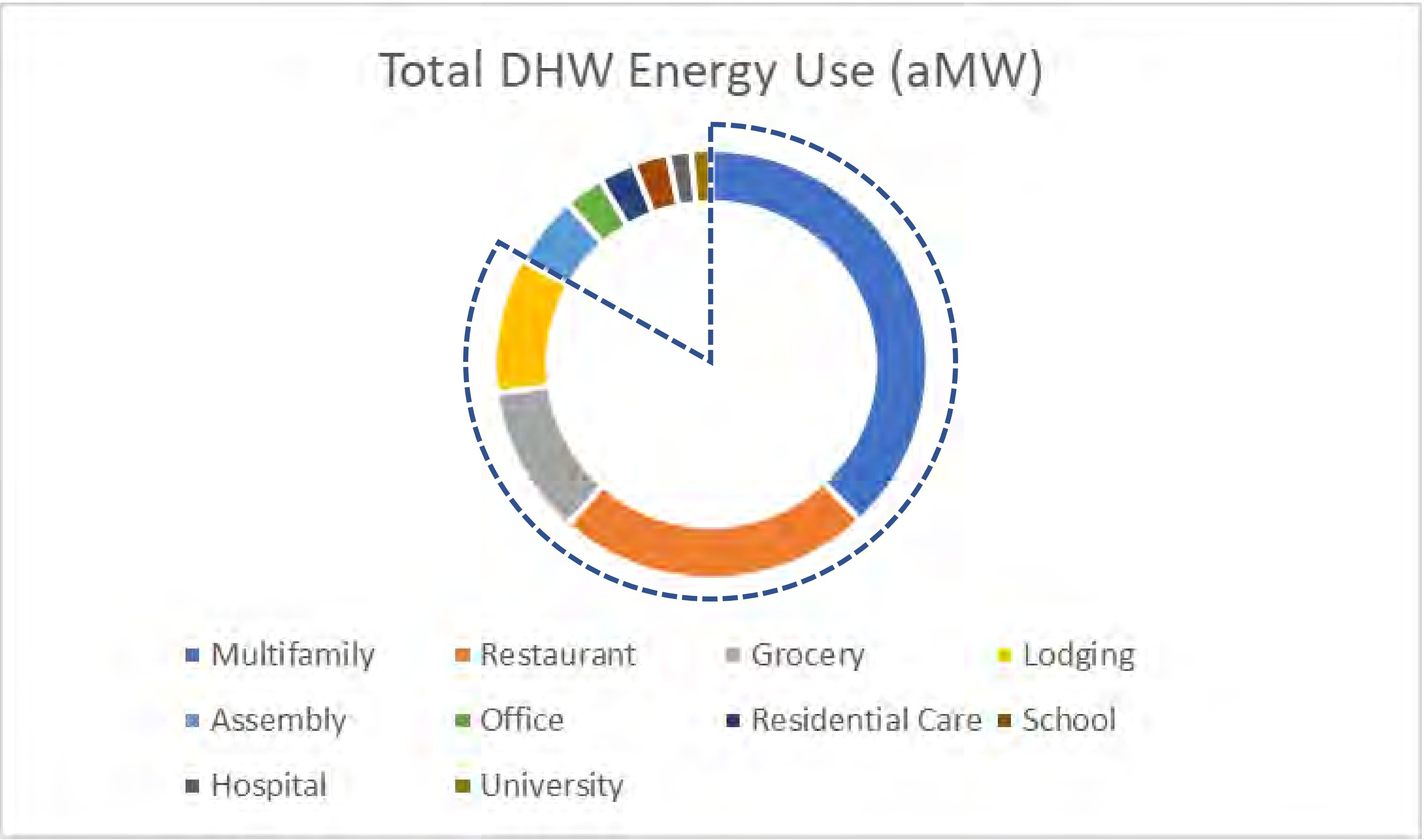
WHEN MATTERS

Multifamily HPWH Market Context

- Energy Savings
- Cost Implications
- Load Shape

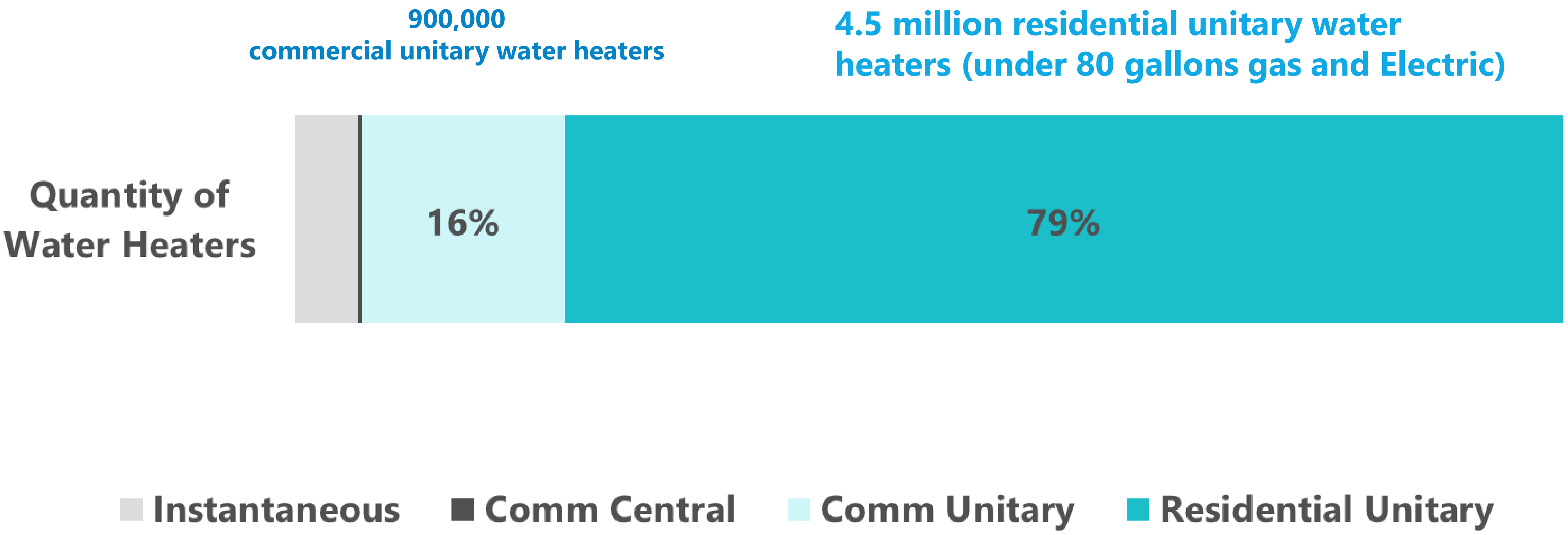
Targeting Sectors by Energy Use – PNW Region

ECOTOPE



Four building types represent over 80% of total DHW load

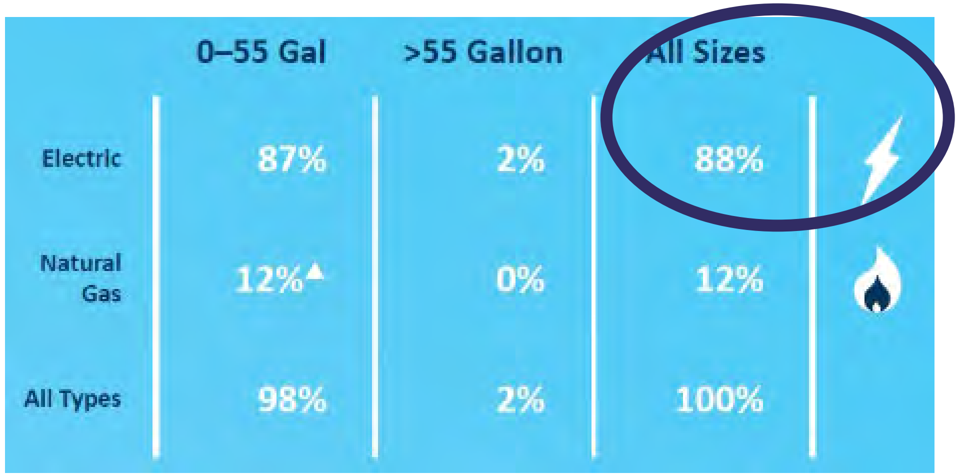
Residential unitary water heaters represent 79% of the existing water heaters in the Pacific Northwest



Water Heaters in Multifamily Buildings

- According to Residential Building Stock Assessment II (RBSA II)
  - Most Low-Rise buildings…
    - have in-unit water heater,
    - which is electrically heated,
    - and is installed within the dwelling unit in a space <1,000 ft3.

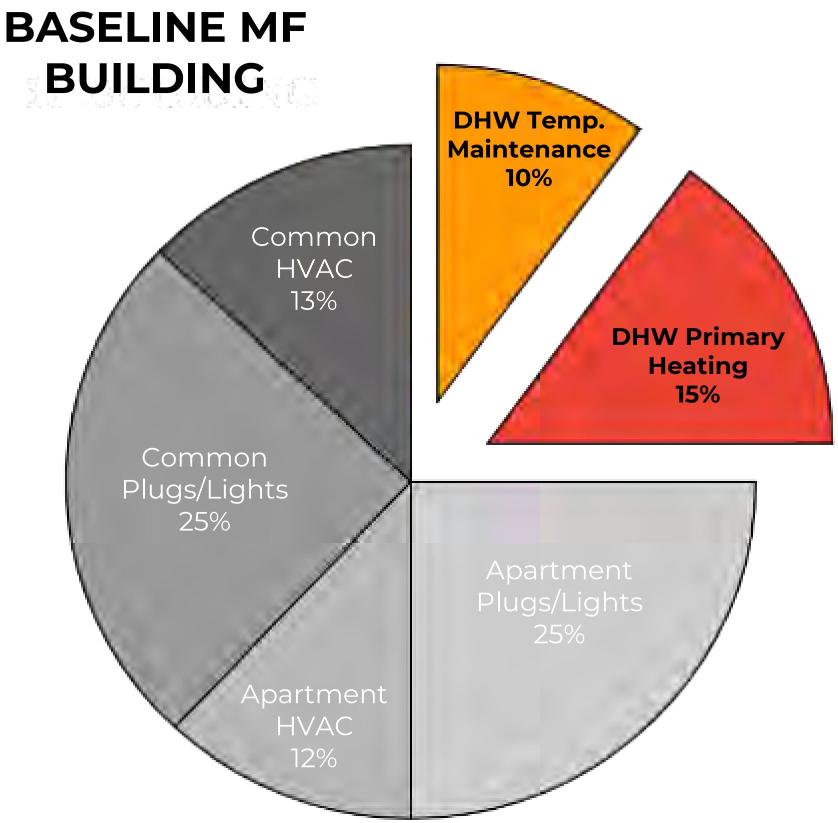
- This is for all existing buildings, but new construction can be designed for HPWH.
- In the 2021 Power Plan, the Northwest Power and Conservation Council expects construction of **20,000+** low-rise dwelling units per year for the foreseeable future.

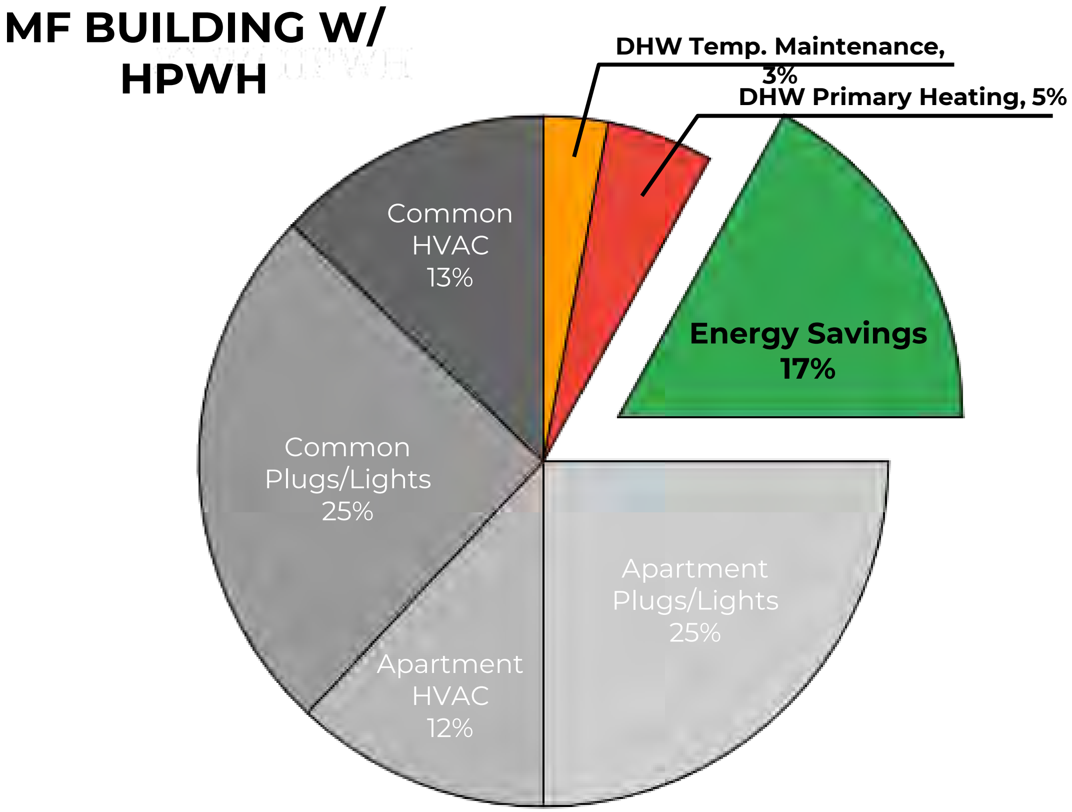


	0–55 Gal	>55 Gallon	All Sizes
Electric	87%	2%	88%
Natural Gas	12%	0%	12%
All Types	98%	2%	100%

HPWH Energy Savings

ECOTOPE

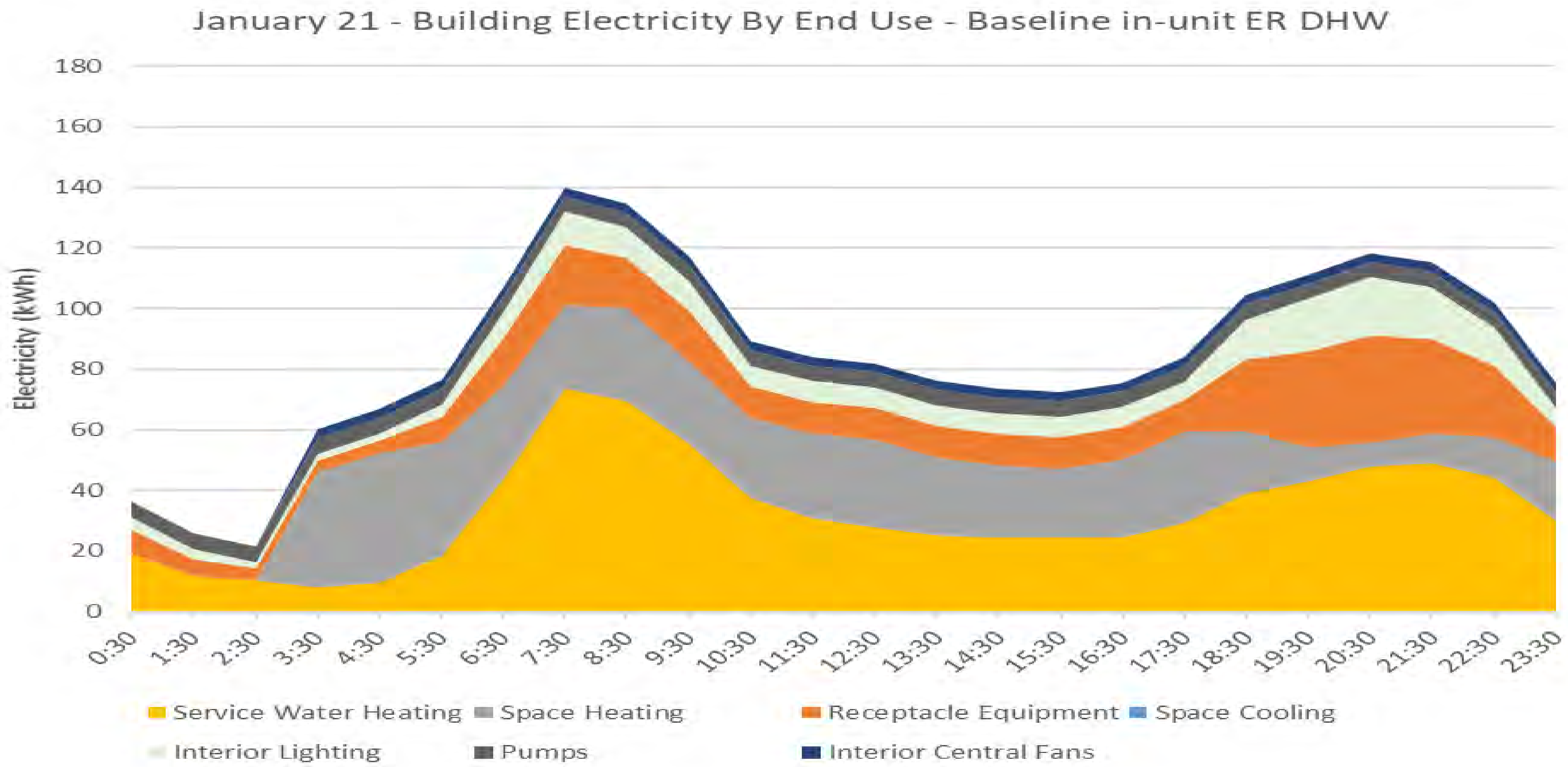




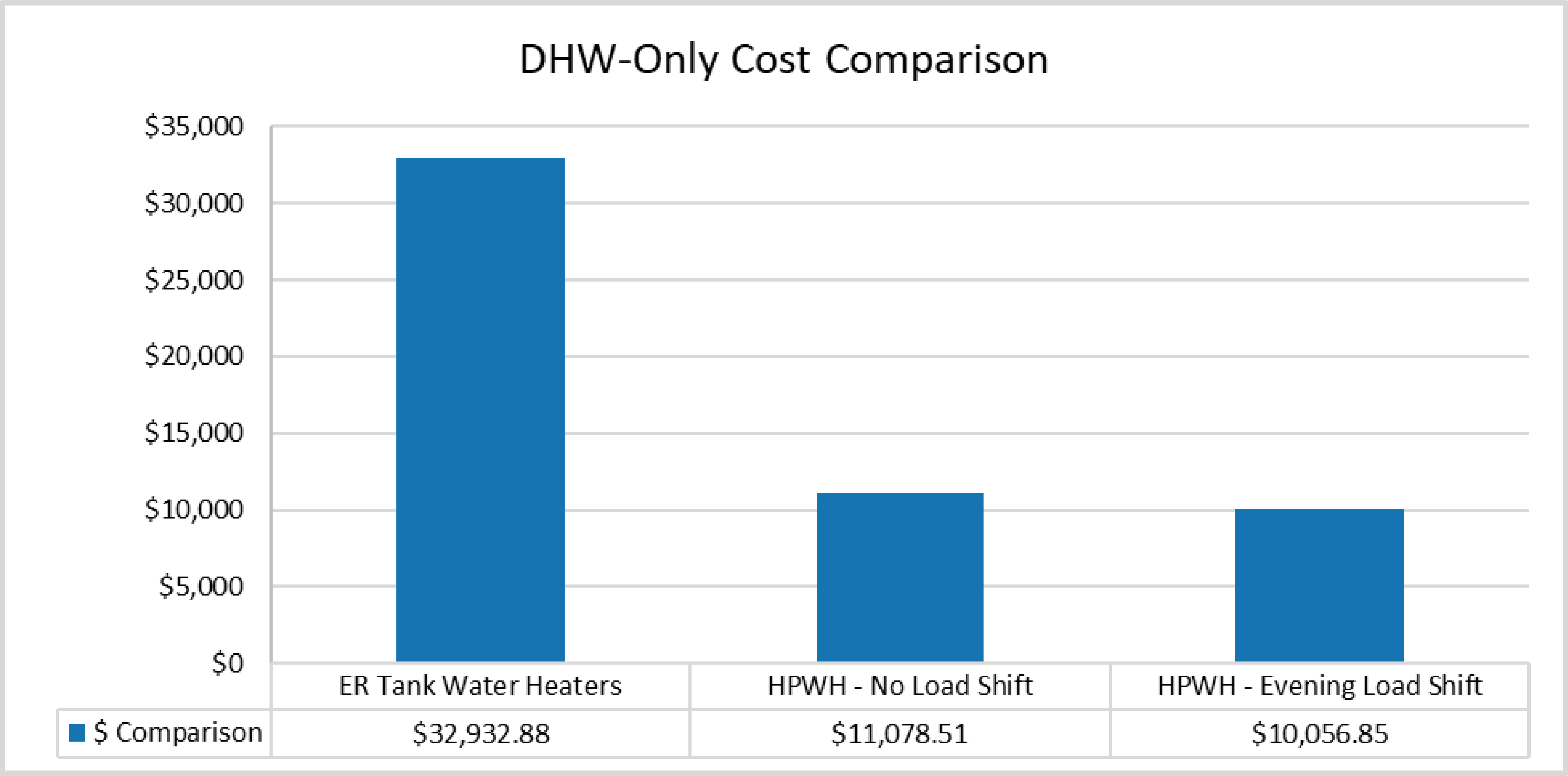
DHW represents 25% of annual building use

HPWH systems cut energy usage down by 3x

Multifamily End Use Load Shape



DHW Energy Cost Comparison



DHW % of Total Building Energy Cost:	45%	22%	20%

Cost of Code Options Analysis (WA)

Lowrise MF = 4.5cr Costs are incremental over code baseline and per dwelling unit	Elec Tank	CHPWH (SanCO2)	HPWH (Integrated)	Gas Tank
DHW Measure: Cost: Credits:	N/A	SanCO2 $1,200 3 credit	Integrated HPWH $300 2.5 credit	91 UEF Tankless Gas WH $300 1 credit
Heat/Cool Measure: Cost: Credits:	DHP w/ HSPF > 10 sized to meet entire load of unit $4,800 3 credit	Baseline DHP	Baseline DHP	DHP w/ HSPF > 10 $2,800 2 credit
Ventilation Measure: Cost: Credits:	2 ACH w/ 65% HRV $1,000 1.5 credit	2 ACH w/ 65% HRV $1,000 1.5 credit	1.5 ACH w/ 75% HRV $2,300 2.0 credit	2 ACH w/ 65% HRV $1,000 1.5 credit
Totals	**$5,800/ Dwelling unit**	**$2,200/dwelling unit**	**$2,600/dwelling unit**	**$4,100/dwelling unit**
Approx. Annual DHW Utility Cost	**$378**	**$126**	**$126**	**$270**

Ecotope CHPWH Engagement Landscape

ECOTOPE

- ## Technical Development
- Technology Innovation Model
- Manufacturer Engagement: product development and optimization
- AWHI: technical support to growing national initiative
- Evaluation of National Performance Standards
- Performance Research: lab testing and on-site M&V

- ## Design Tools
- Sizing Tools: EcoSizer
- Software: EcoSIM: developing rule-set for CBECC-Com; more simulation options needed
- AWHS: Prescriptive performance standard for program and policy adoption
- PADS/QPL: pre-approved product resource
- Training: 15 hours of training built, plus specific code official training program
- Design Guidance on Configuration and Performance implications
- Temperature Maintenance Best Practice

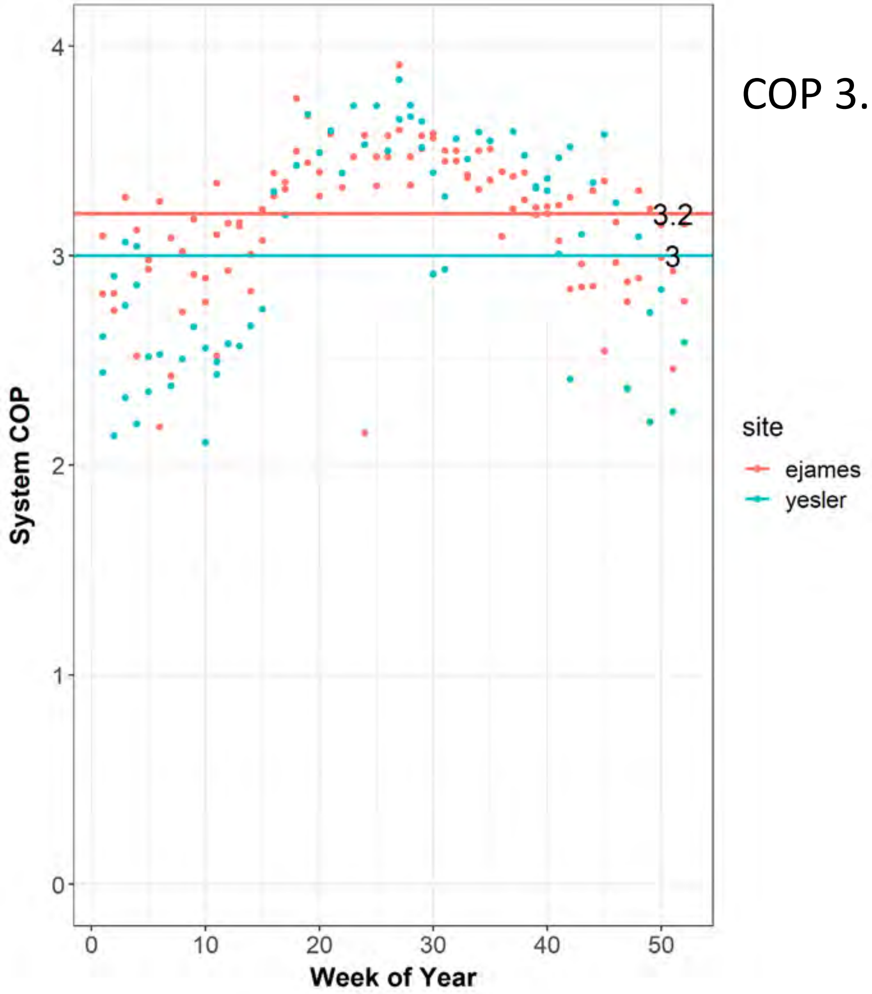
- ## Projects
- Design: Over 90 projects in various stages of delivery
- Regional Field Deployment
- Grid Integration Pilot Projects

- ## Programs
- Market Potential Analysis: PNW and National adoption potential
- Code Proposals: SEC, WSEC, IECC
- Load Shift: potential for major daily load shift
- Refrigerant Transition
- Pilot deploy and configuration deployment

M&V – Validation and Data Library

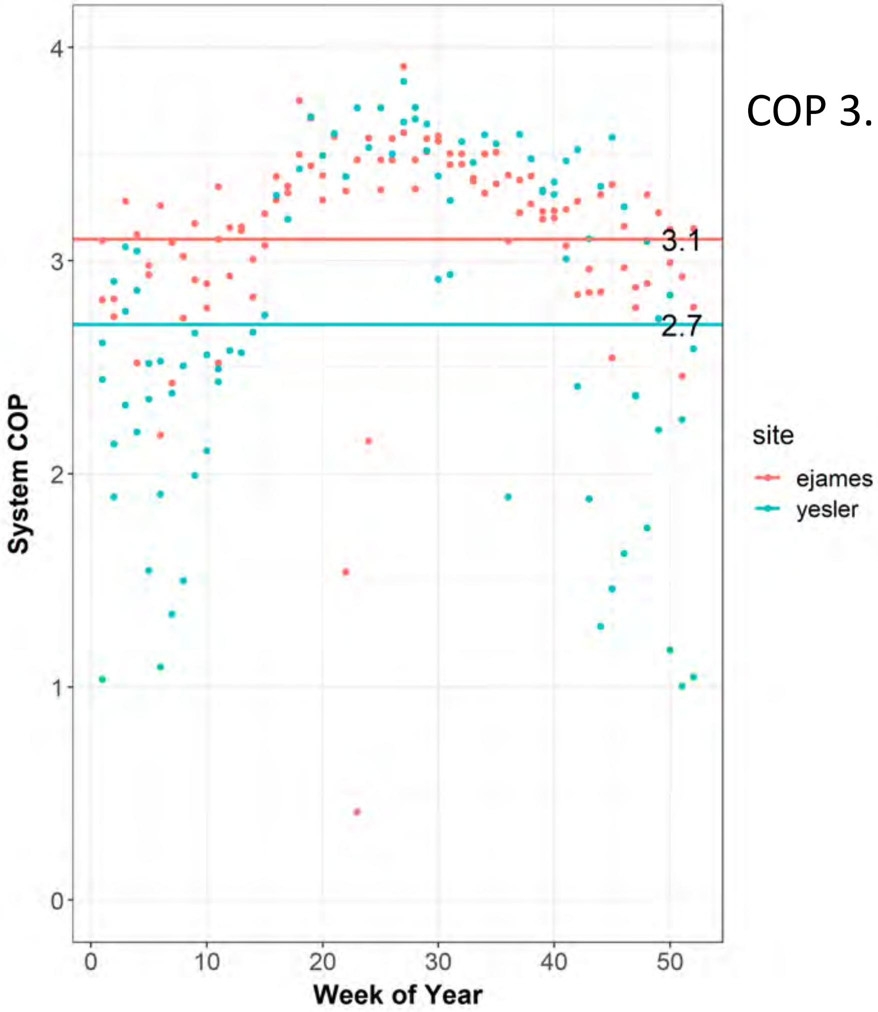
ECOTOPE

Ideal system performance



COP 3.2 - 3

Real-world system performance

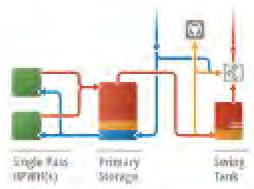


COP 3.1 – 2.7

Ecosizer

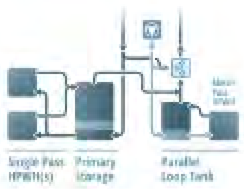
https://calbem.ibpsa.us/resources/ecosizer/

Temperature Maintenance System



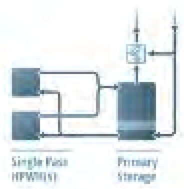
SWING TANK

Primary plant with a temperature maintenance plant in series



PARALLEL LOOP TANK

Primary plant with a temperature maintenance plant in parallel



PRIMARY - NO RECIRCULATION

Just the primary plant without a temperature maintenance load

ADVANCED SCHEMATIC OPTIONS

A temperature maintenance system provides hot water to the taps in a timely manner.

Load Shift

PERIOD 1 6–10

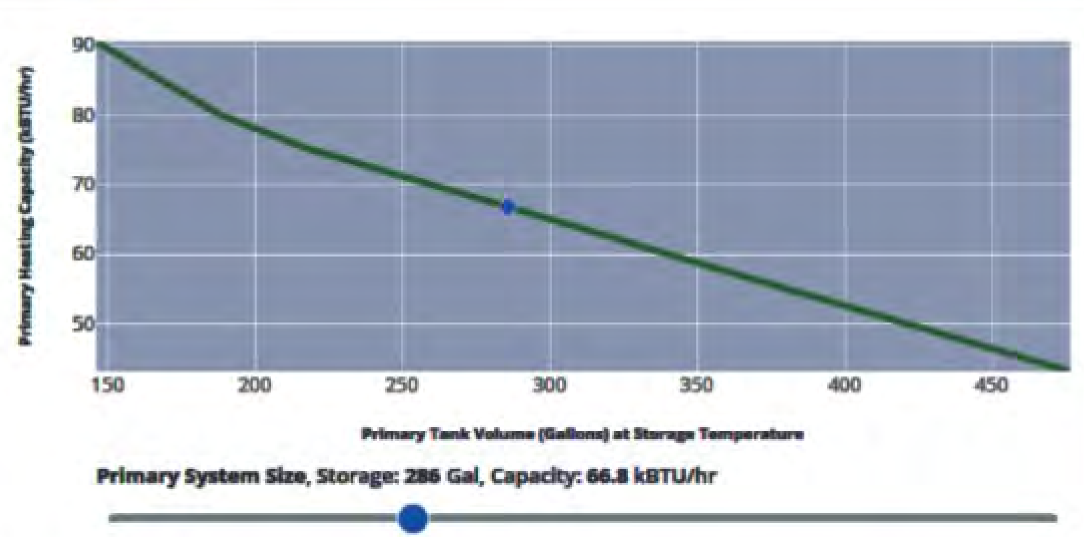
PERIOD 2 16–21

0 24

Select hours of day to exclude operation

Set the percentage of days the load shift will be met

Ecosizer™ Tool for CHPWH System Sizing



THIS SYSTEM WAS SIZED FOR

Occupancy
60.0 People

Apartments
30.0 Units

Daily Hot Water Usage
25.0 Gallons per Day per Person

Total Hot Water
1500 Gallons per Day

Tank Volume
285 Gallons

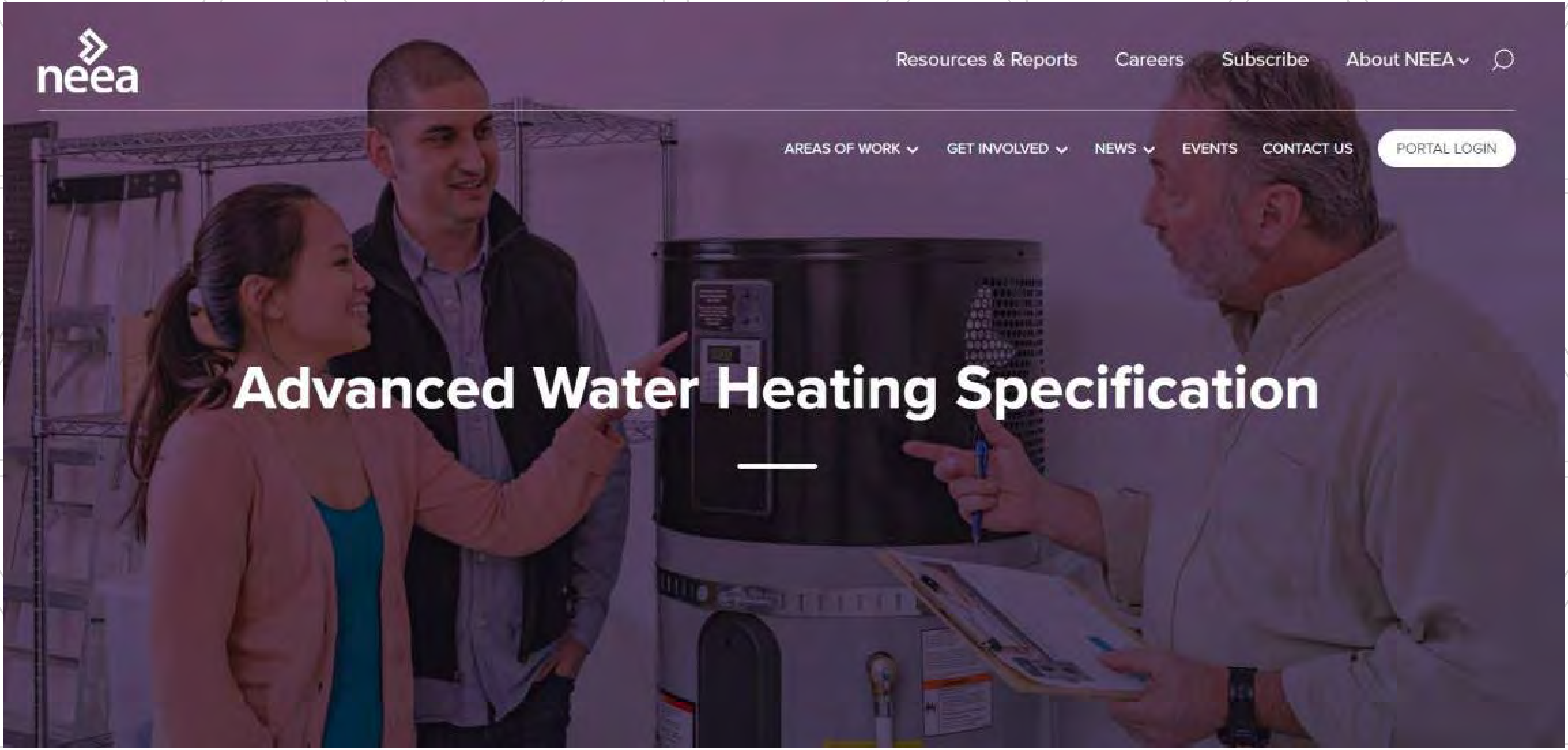
Heating Capacity
66.8 kBTU/hr

Swing Tank Volume
80 Gallons

Swing Resistance Element
4.7 kW · **15.9** kBTU/hr

https://calbem.ibpsa.us/resources/ecosizer/

Advanced Water Heating Specification



CHPWH Measure Development

Emerging Technologies

AWHS

Advanced Water Heater Specification

What:
Defines minimum design and performance criteria for a complete CHPWH system

Why:
Reduce risk and uncertainty for designers, owners, program implementers

PADS

Product Assessment Data Sheet

What:
Mechanism for manufacturers to submit their products for inclusion on the QPL

Why:
Demonstrates that product meets all requirements of the AWHS

EcoSim

EcoSim

What:
Energy modeling program used to predict performance of CHPWH systems

Why:
Provide savings estimates to use in incentive programs

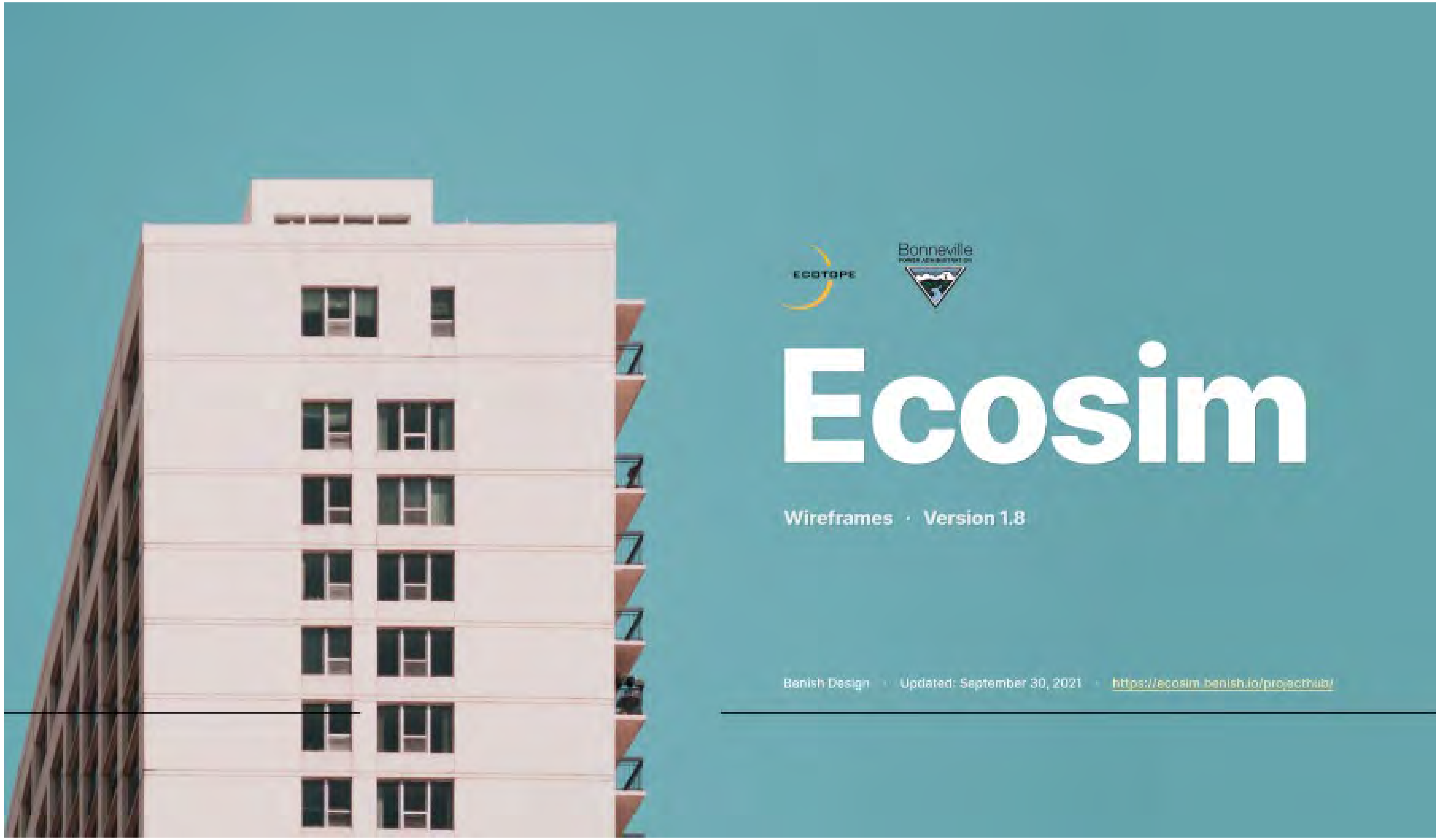
QPL

Qualified Products List

What:
Products which have submitted test data and demonstrated compliance with AWHS

Why:
Provide predicted average annual energy performance for vetted products

Ecosim



Ecosim is an energy analysis tool for multifamily central heat pump water heating systems.

Four core user groups:

- Design professional/system engineer
- Policy or program developer
- Equipment manufacturer
- Researcher

Model Codes and Model Programs

	2006	2009	2012	2015	2018	2021	2024	2027	2030
Residential	100%	82.7%	76.1%						
Commercial	100%	86.8%	82.0%						
Target: 8.75 % savings compared to the 2006 WSEC	100%	91%	83%	74%	65%	56%	48%	39%	30%
Target: 14% savings compared to each previous code	100%	86%	74%	64%	55%	47%	41%	35%	30%

Training

https://learn.drintl.com/commercial-hpwh-training-sdge

AWHi
ADVANCED WATER HEATING INITIATIVE

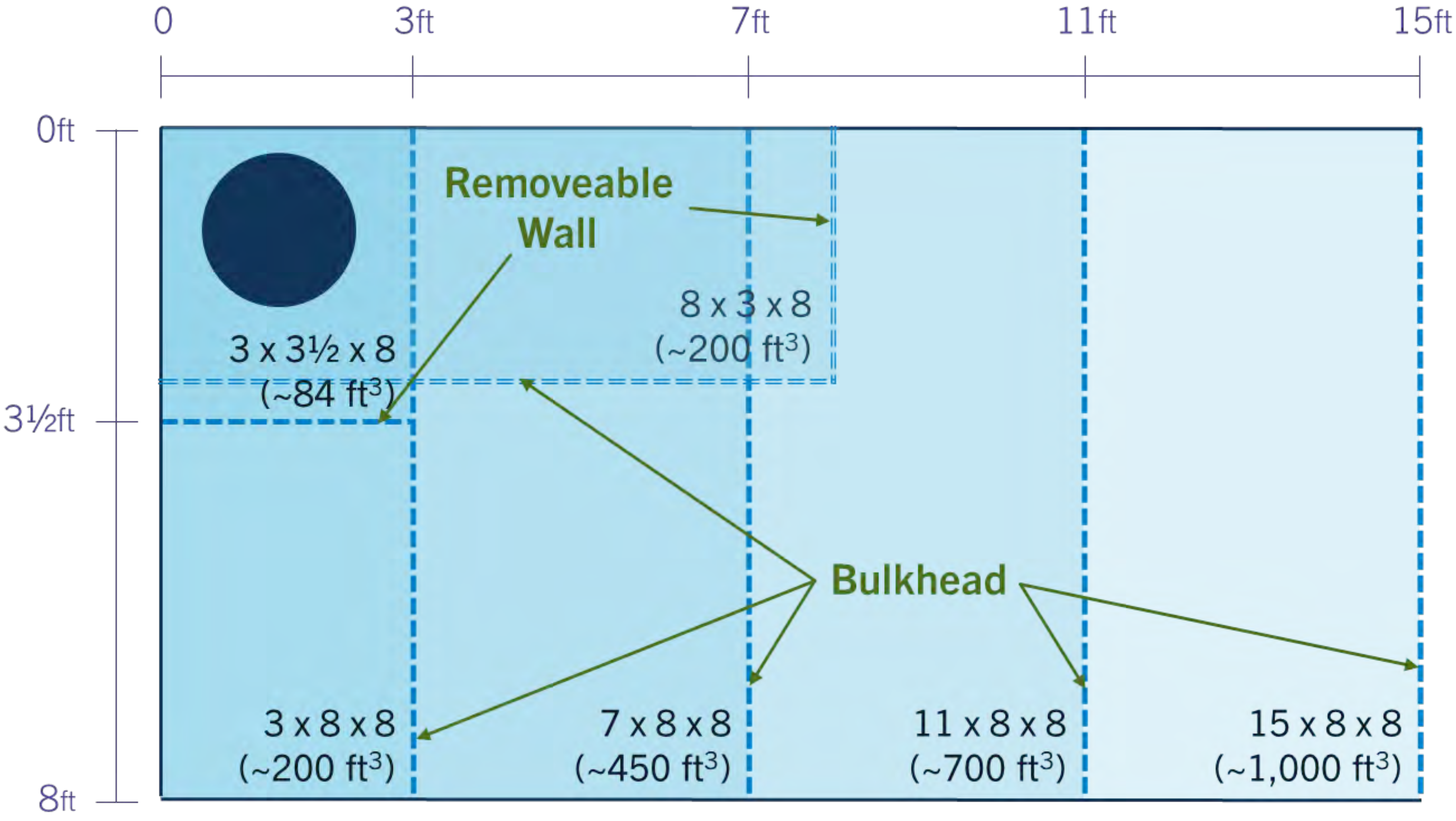
Advanced Water Heating Initiative

nbi new buildings institute

The Amazing Shrinking Room
–or –
How Can We Create an Efficient Install Location?

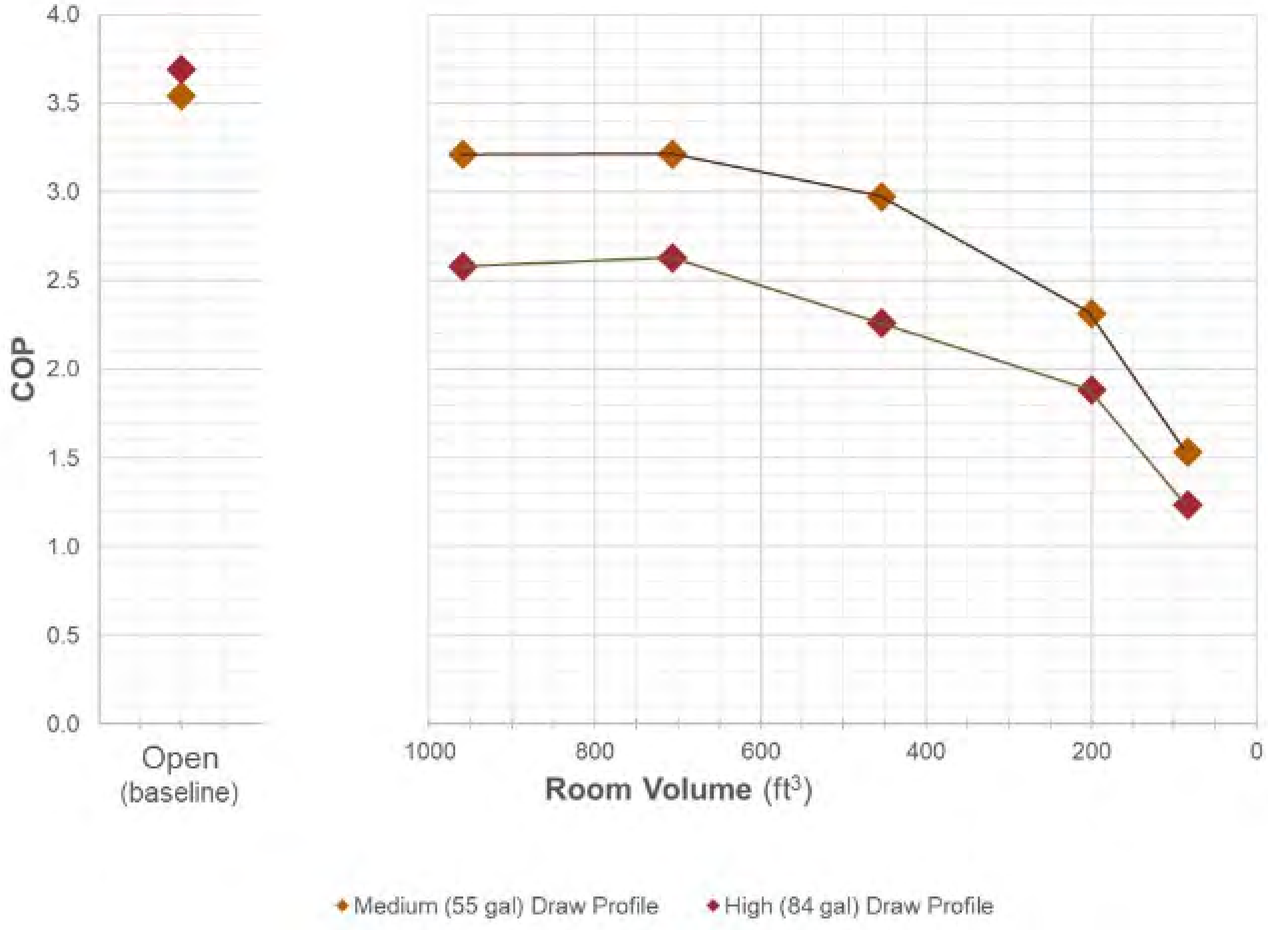
Amazing Shrinking Room

Amazing Shrinking Room



Amazing Shrinking Room

As install room volume decreases, so does efficiency



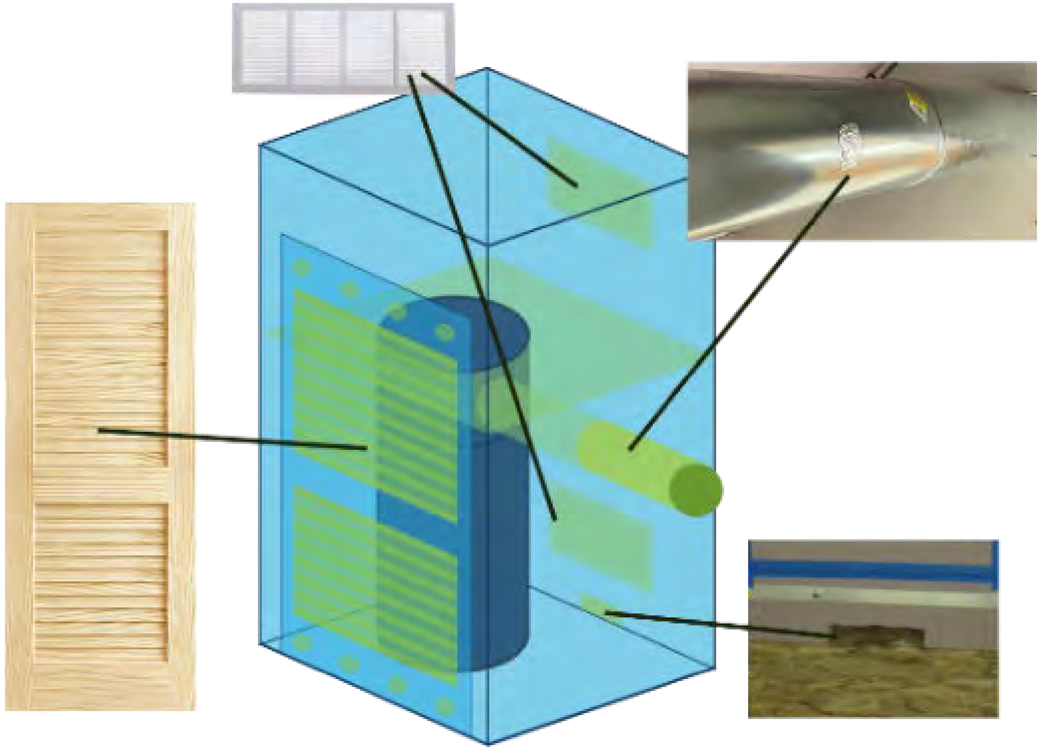
Even with install spaces of 450 ft^3, HPWHs are likely to use less than a third the energy of an ER water heater.

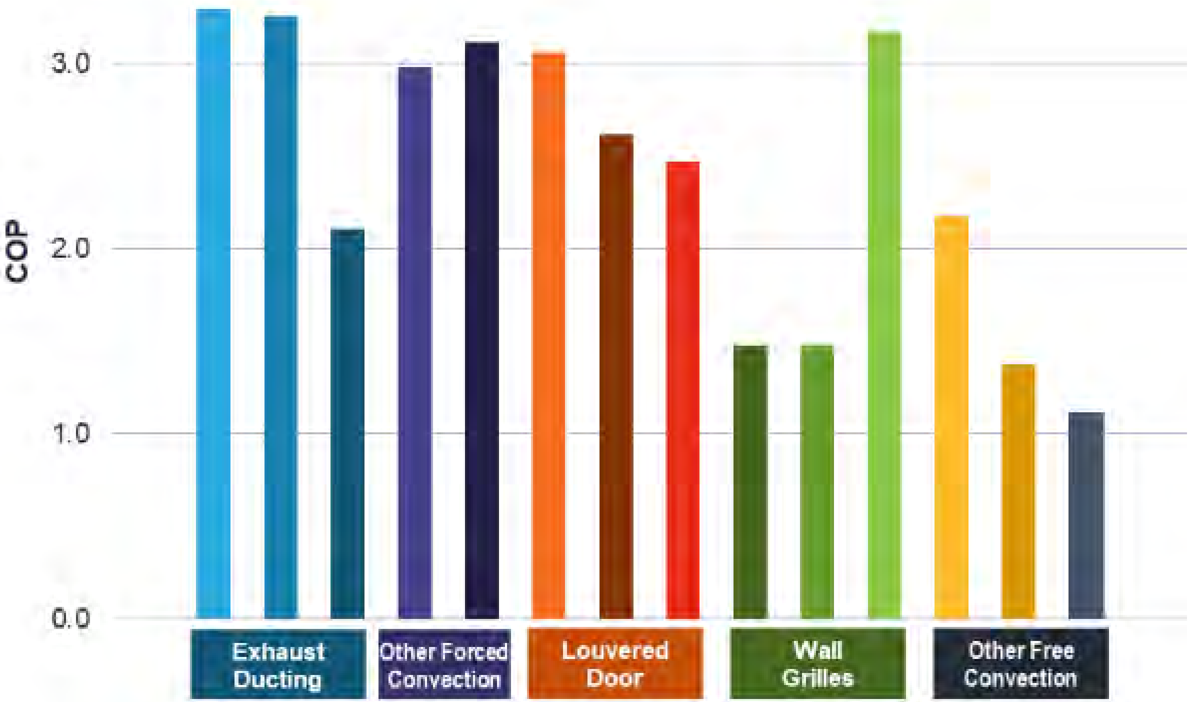
Lifetime cost benefit of HPWH over other technologies depends on many factors. Installation site conditions – including room size – are the most significant, controllable variables.

>> With a new building, you determine the efficiency of the HPWH for the life of the building – not just the water heater.

 |

I'm Stuck with a Small Closet. What Works?



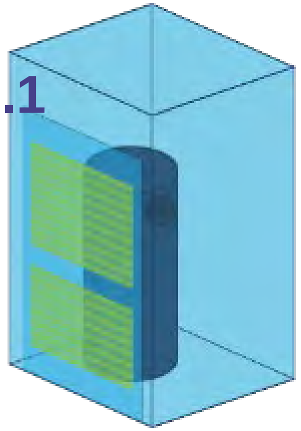


*Exhaust ducting is to adjacent space only – does not cross building envelope

Methods that Work

- Methods of improving make-up air (or thermal resource) availability differ in both effectiveness and cost.
- Best solution dependent on site factors.

Louvered Door
COP 3.1



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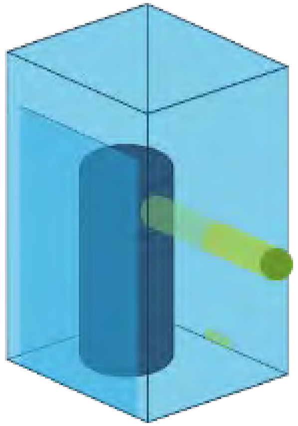
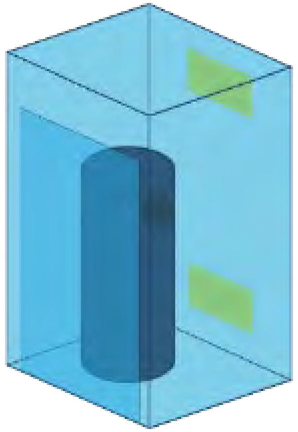


Ducting
COP 3.3



Wall Grilles
COP 3.2

COP 3

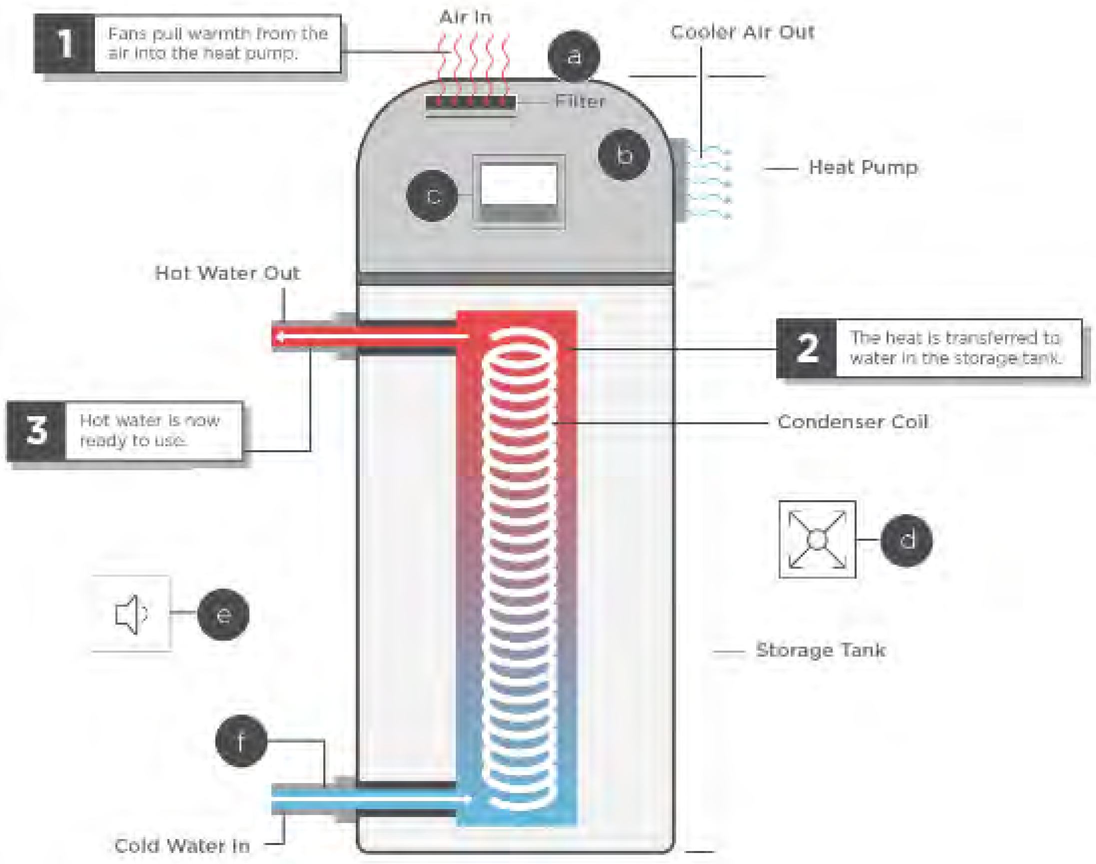
Amazing Takeaways

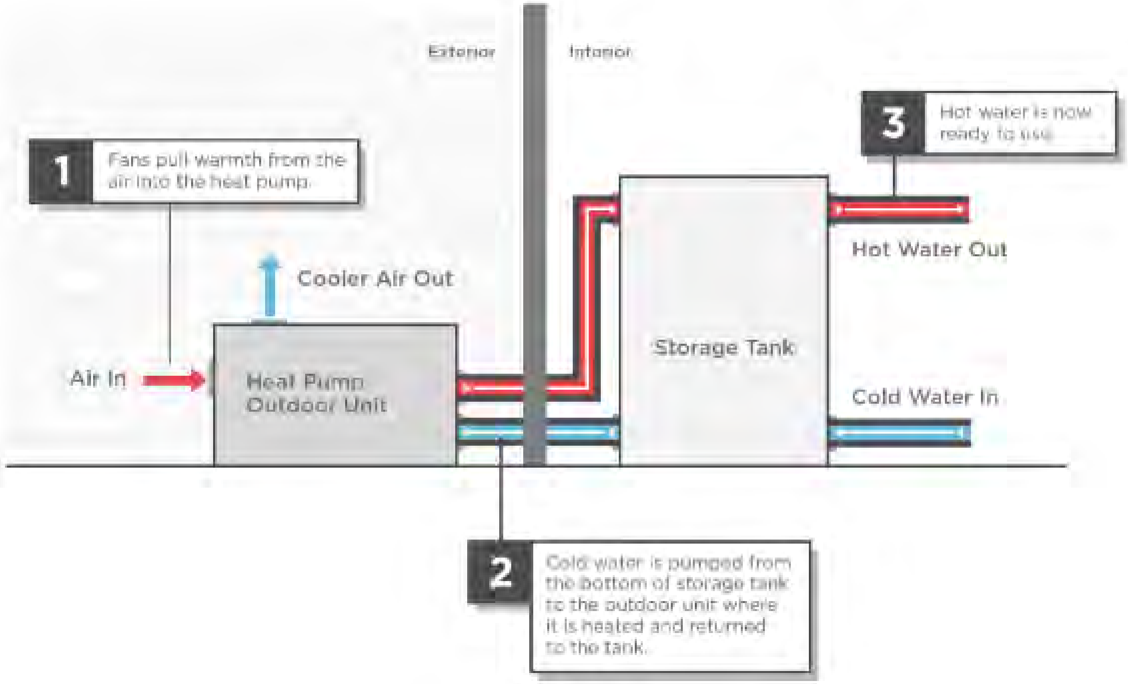
- Ideal HPWH install: garage or basement
- If necessary to install inside dwelling, rooms as small as 450 ft^3 (7’ x 8’ x 8’) allow reasonable efficiency
- For smaller spaces, do the following to achieve good efficiency
  - Louvered doors or wall grilles with net free area > 300 in^2
    - Openings both high and low critical to success
  - Duct to adjacent space inside the house (do not cross air barrier)
    - Provide for adequate make up air

 |

Space Conditioning Impact

Yep, HPWHs cool the air around them





Refrigerator or Water Heater?

ENERGYGUIDE

[redacted]

Estimated Yearly Energy Cost

$103

$120.0 $423.0

Cost Range of Similar Models

The estimated yearly operating cost of this model was not available when the range was published.

[redacted]

- Estimated energy cost based on a national average electricity cost of $0.12 per kWh
- Estimated yearly energy use: 855 kWh

ENERGYGUIDE

[redacted]

Estimated Yearly Energy Cost

$104

Cost Ranges

Models with similar features	$89	$104
All models	$74	$104

867 kWh

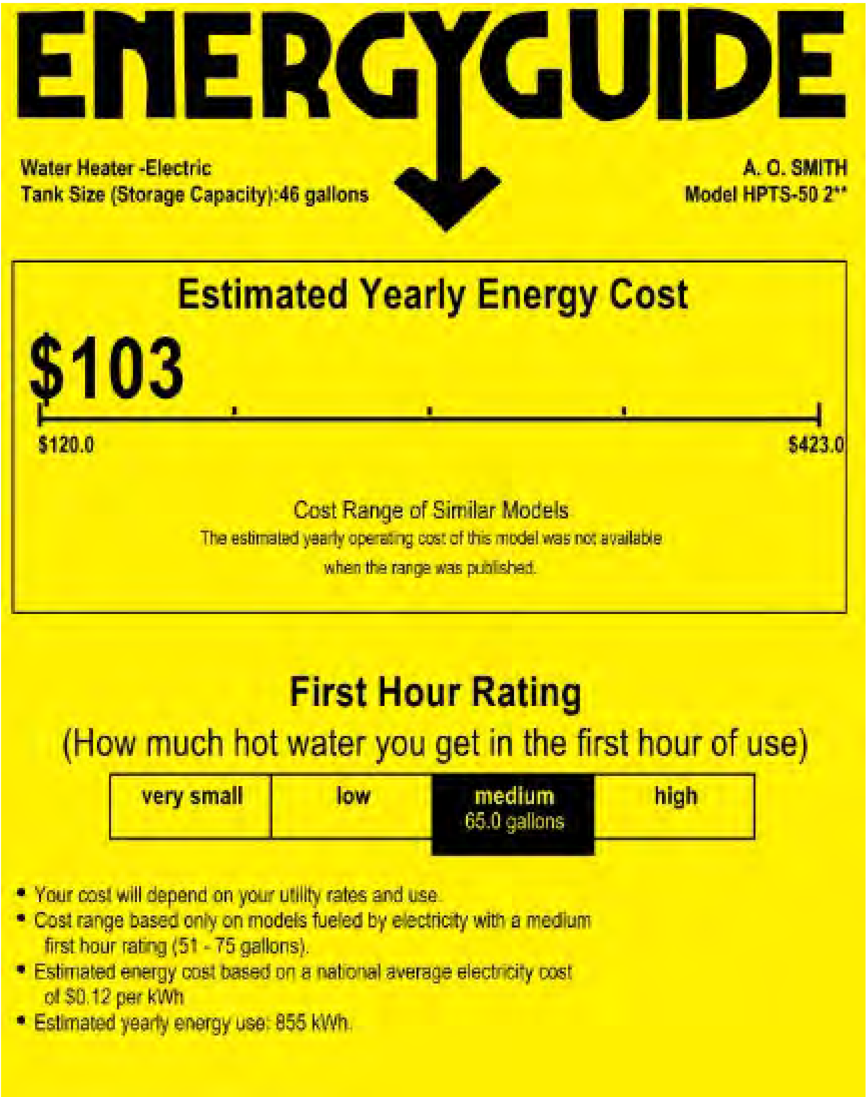
Estimated Yearly Electricity Use

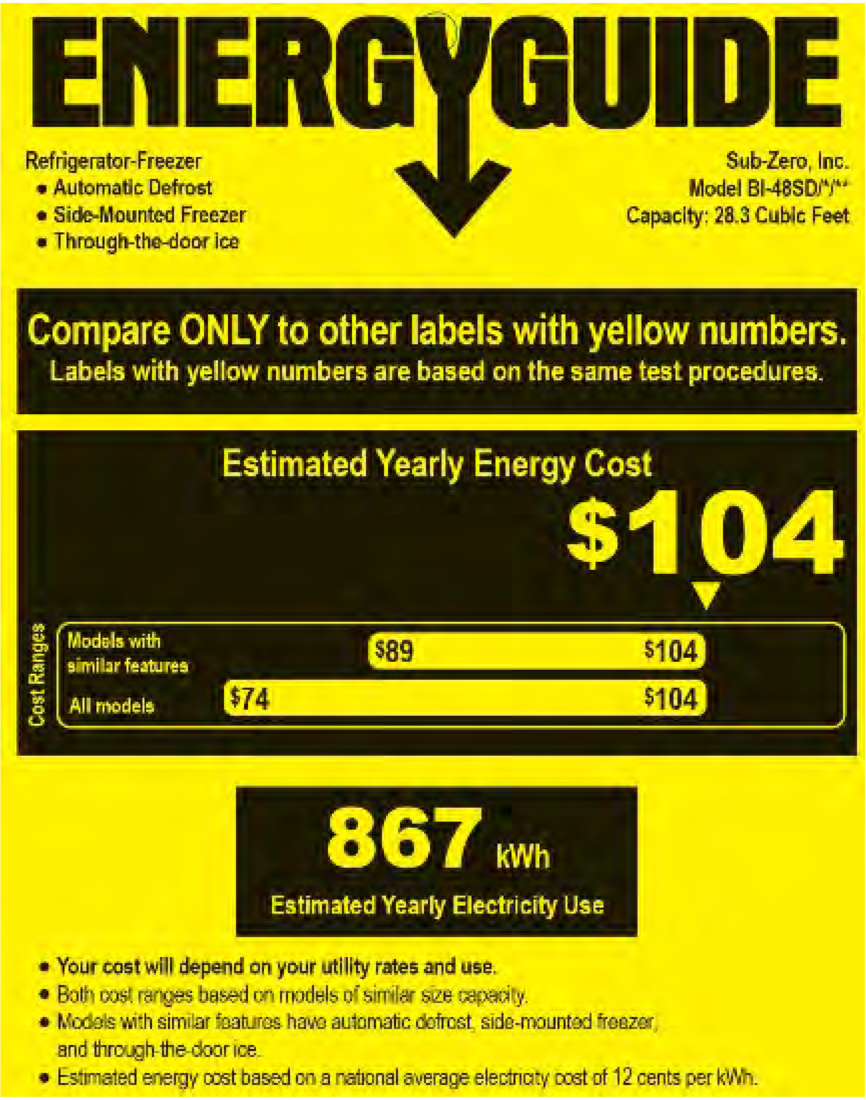
[redacted]

- Estimated energy cost based on a national average electricity cost of 12 cents per kWh.

 |

Water Heater | Refrigerator





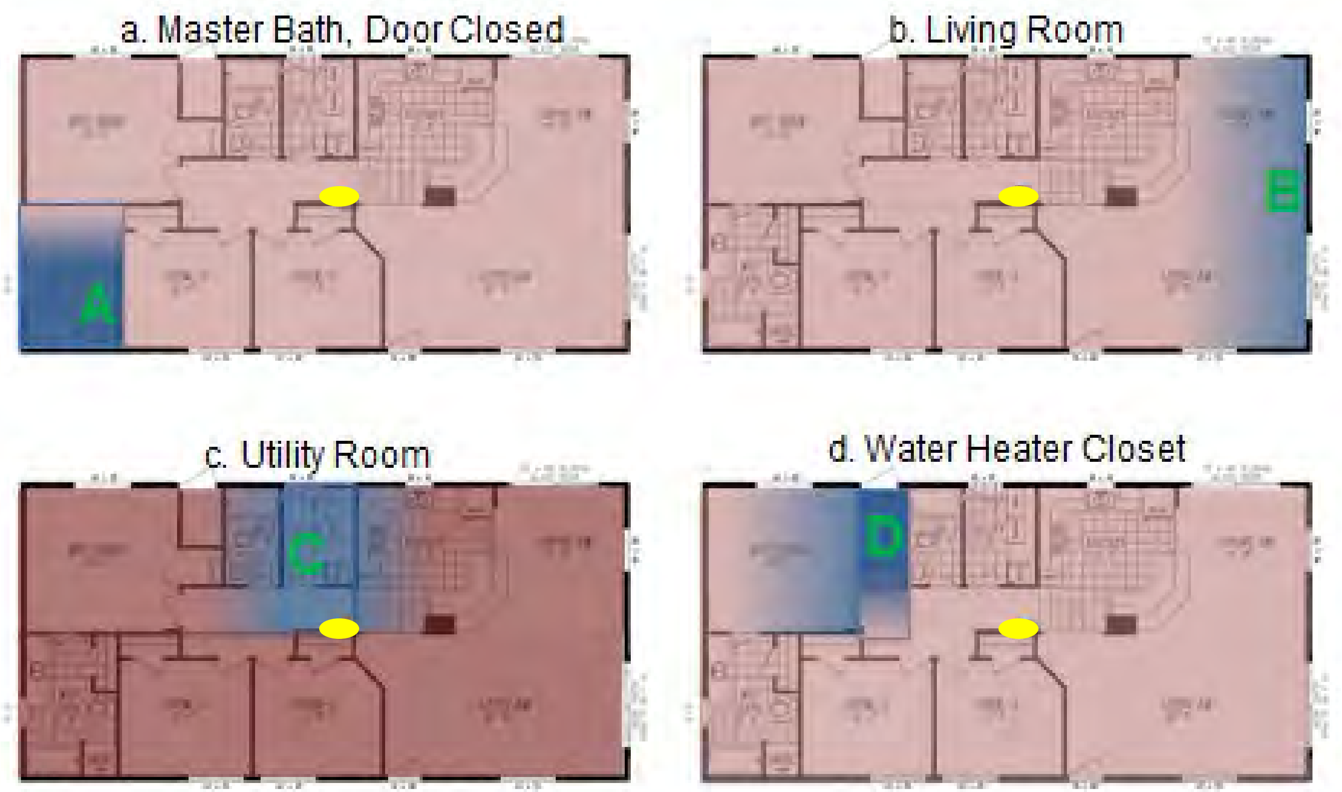
HPWH Cooling Not as Bad as You Think

- **Summer** – cooling is a benefit
- **Spring and Fall** – HPWH cooling is neutral
  - Dwelling not conditioned much anyway
- **Winter** – most cooling is a cost to the heating system except when the HPWH:
  - Dehumidifies (no change to sensible air T)
  - Turns excess waste heat into useful hot water
    - Dwelling air temperature or even local HPWH room temperature “floats” above thermostat setpoint – when it’s extra sunny or you are baking cookies

- Climate dependent
- When measured, field studies do not find increased heating load
- Even Better: Heat Pump Space Conditioning
- Much Worse: Exhaust Ducting

Thermal Distance

- Houses and even multifamily units are *not* "single well-mixed zones"
- Water heater install space not usually closely "coupled" with the thermostat. This creates thermal distance between the two.
  - When the HPWH runs, the heating system does not immediately turn on in response. It might later. In between maybe you bake a frozen pizza.



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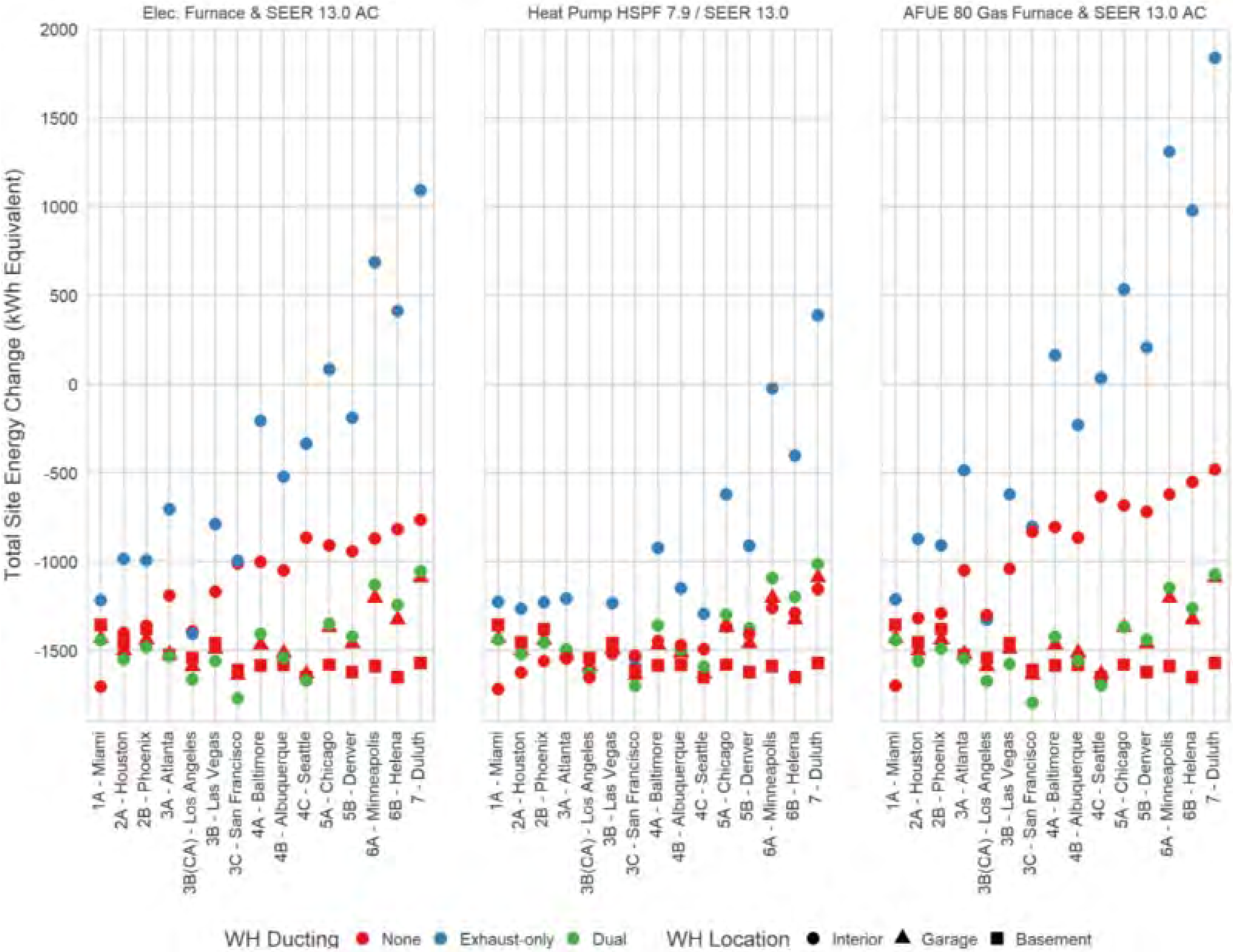


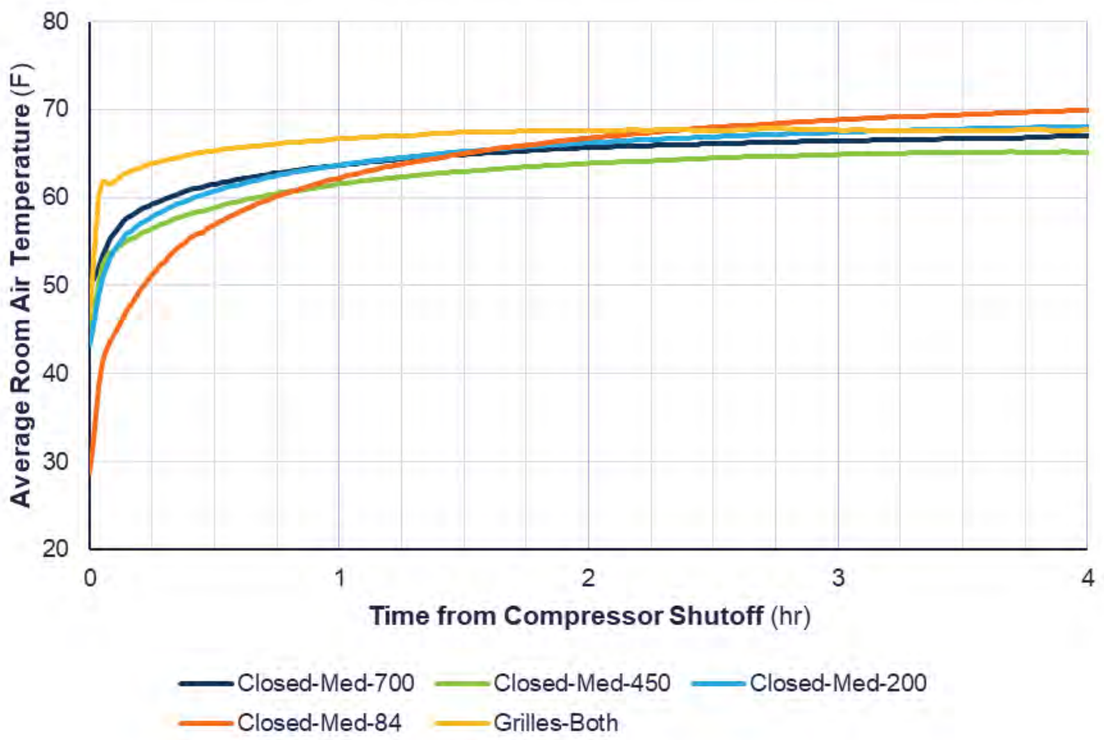
On an annual basis, HPWHs save energy

(but don't cross building envelope with exhaust ducting)

Comfort Management

Cool air from HPWH is a comfort management issue *not* an energy concern.

- Small dwellings pose clear challenges.
- Air around water heater cool when the heat pump runs but not all the time and rebounds shortly after run cycle.



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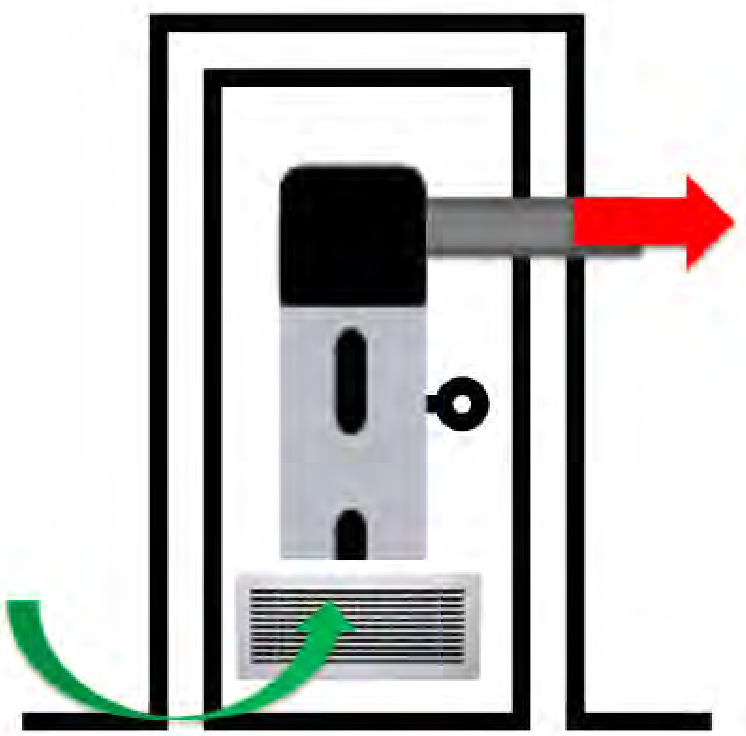
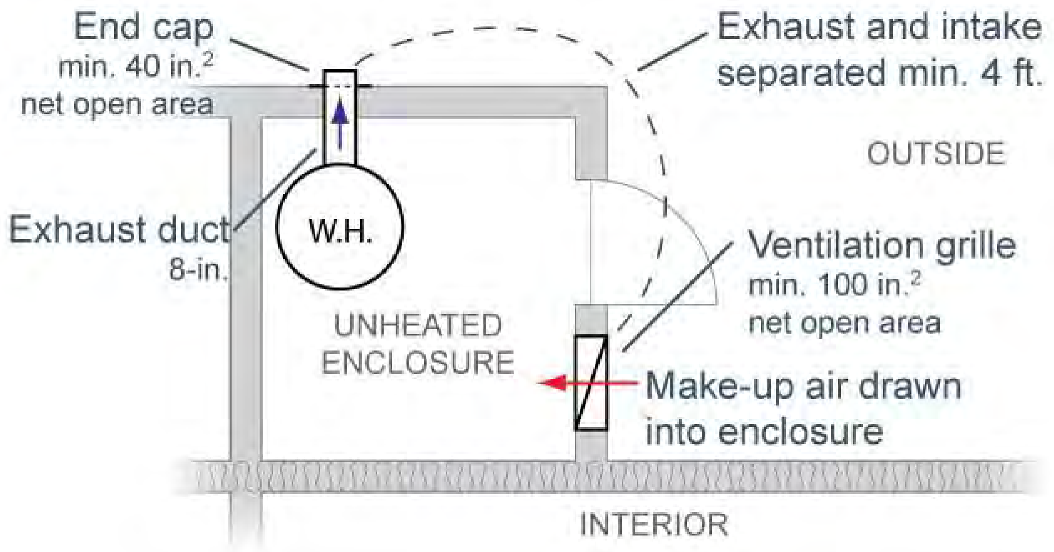
Examples – Actual Buildings

Vancouver, Washington: Exterior Closet Install

Water heater located in exterior closet of apartment complex

Exterior Closet Install: Fix





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Rooftop Shed: California

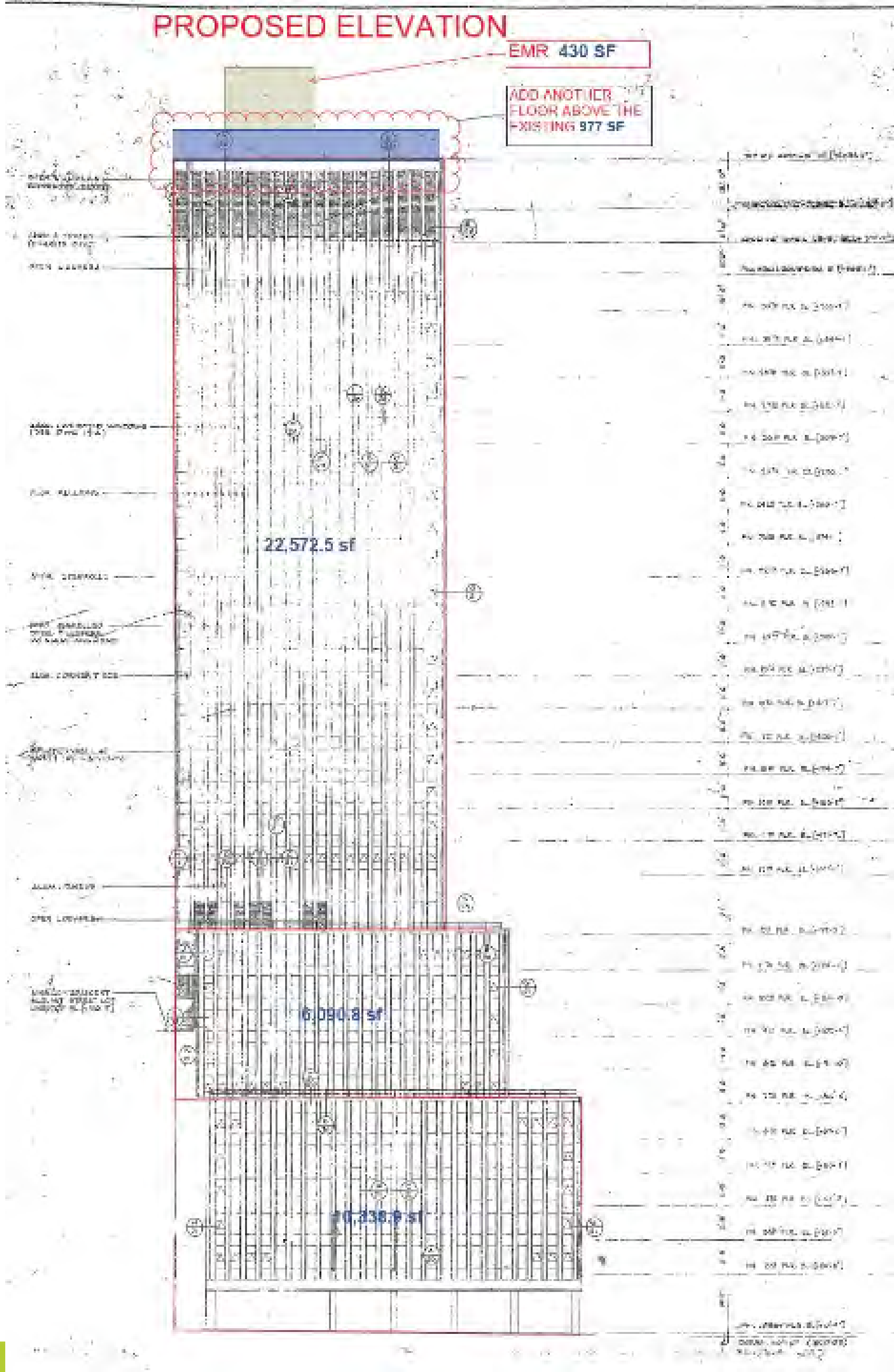
Figure 4. Atascadero Project

Water heaters inside metal shed

Figure 5. Rooftop Location for HVAC Outdoor Units and Heat Pump Water Heaters

New York High Rise

Red Dots are Water Heater Locations



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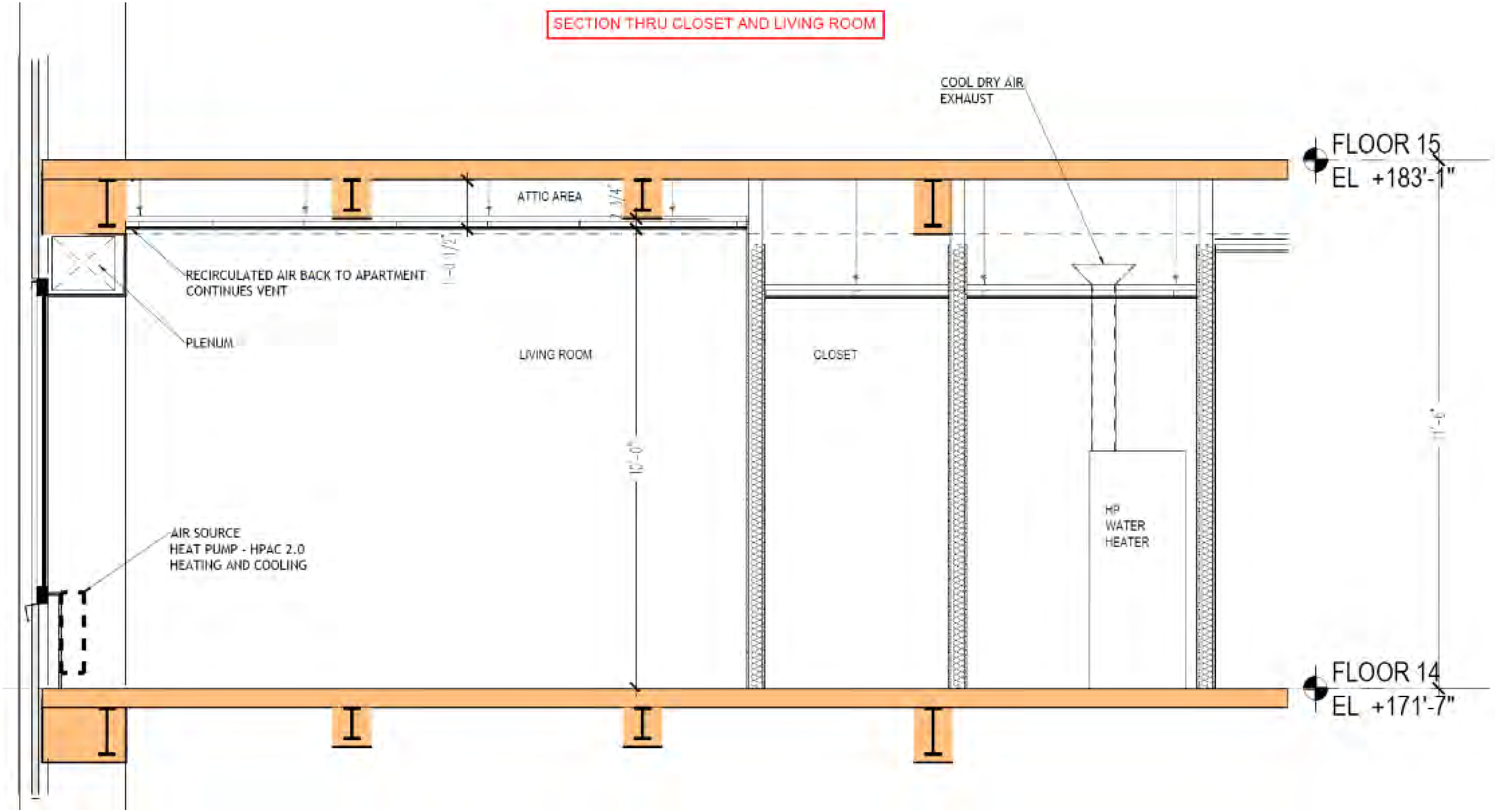
Discharge Exhaust into Soffit



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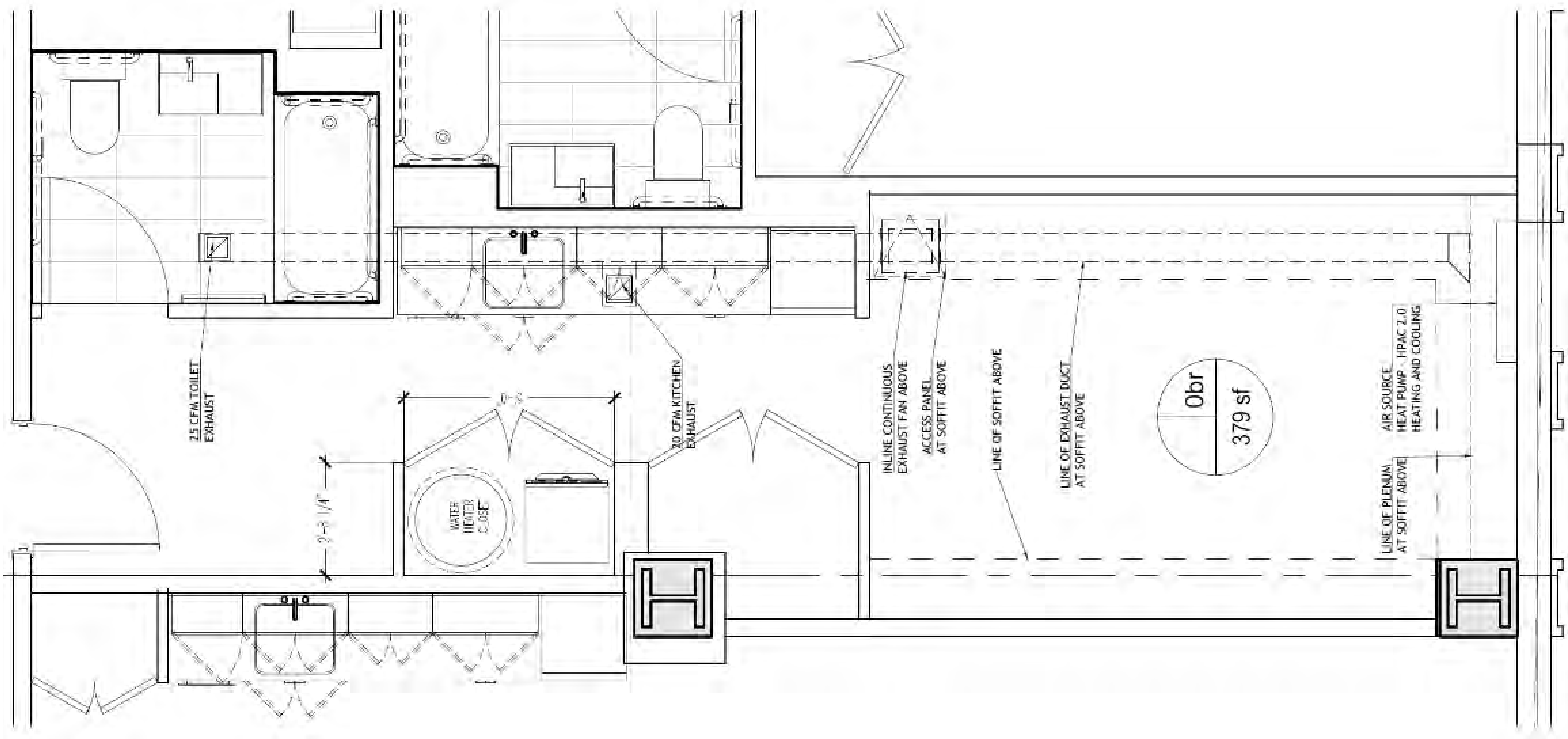
Discharge to Soffit – Relief at Refrigerator



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Portland Low-Rise: Interior Closet. Hmmm.

- Plan was to vent with 4” PVC.
- Also, if you exhaust duct, do you have the space?

 |

Ventilation Sidebar

506.0 Air for Combustion and Ventilation.

506.1 General. Air for combustion, ventilation, and dilution of flue gases for appliances installed in buildings shall be obtained by application of one of the methods covered in Section 506.2 through Section 506.7.3. Where the requirements of Section 506.2 are not met, outdoor air shall be introduced in accordance with methods covered in Section 506.4 through Section 506.7.3.

Exception: This provision shall not apply to direct-vent appliances. [NFPA 54:9.3.1.1]

506.1.1 Other Types of Appliances. Appliances of other than natural draft design, appliances not designated as Category I vented appliances, and appliances equipped with power burners shall be provided with combustion, ventilation, and dilution air in accordance with the appliance manufacturer's instructions. [NFPA 54:9.3.1.2]

506.1.2 Draft Hood and Regulators. Where used, a draft hood or a barometric draft regulator shall be installed in the same room or enclosure as the appliance served so as to prevent any difference in pressure between the hood or regulator and the combustion air supply. [NFPA 54:9.3.1.4]

506.1.3 Makeup Air. Where exhaust fans, clothes dryers, and kitchen ventilation systems interfere with the operation of appliances, makeup air shall be provided. [NFPA 54:9.3.1.5]

506.2 Indoor Combustion Air. The required volume of indoor air shall be determined in accordance with the method in Section 506.2.1 or Section 506.2.2 except that where the air infiltration rate is known to be less than 0.40 ACH (air change per hour), the method in Section 506.2.2 shall be used. The total required volume shall be the sum of the required volume calculated for all appliances located within the space. Rooms communicating directly with the space in which the

Ventilation

506.3 Indoor Opening Size and Location. Openings used to connect indoor spaces shall be sized and located in accordance with the following:

(1) Combining spaces on the same story. Each opening shall have a minimum free area of 1 square inch per 1000 Btu/h (0.002 m^2/kW) of the total input rating of all appliances in the space but not less than 100 square inches (0.065 m^2). One permanent opening shall commence within 12 inches (305 mm) of the top of the enclosure and one permanent opening shall commence within 12 inches (305 mm) of the bottom of the enclosure (see Figure 506.3). The minimum dimension of air openings shall not be less than 3 inches (76 mm).

2021 UNIFORM PLUMBING CODE

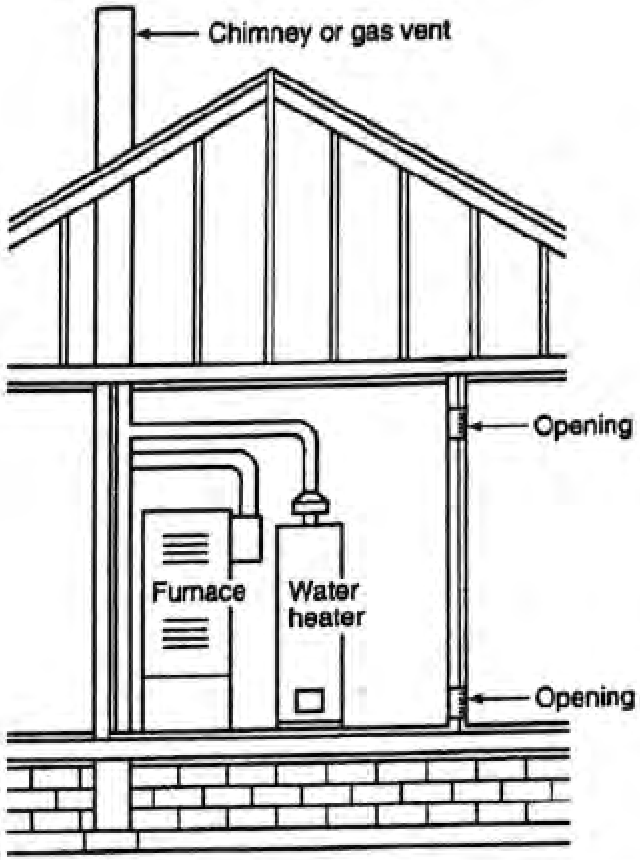


FIGURE 506.3
ALL COMBUSTION AIR FROM ADJACENT INDOOR SPACES THROUGH INDOOR COMBUSTION AIR OPENINGS
[NFPA 54: FIGURE A.9.3.2.3(1)]

Davis, California: Exterior Closet Metal Louvered Door

Davis, California: Proposed Fix

 |

Davis, California: Actual Fix

 |

San Jose: Interior along Entry Hall

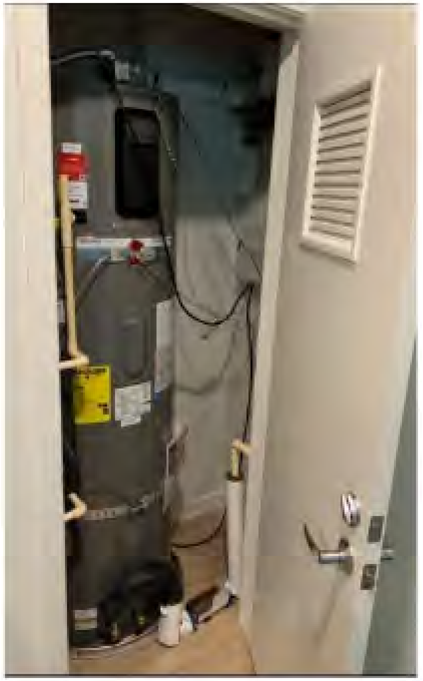
Closet volumes

- vary from ~80 -100 cubic feet.

Approximate Closet Volumes (varied)			
Depth	width	Height	Total
2.5	4	8	80
2.5	5	8	100

Air gap was about ¼ to 3/8 inch by 2 ft door

One wall in the closet is on an exterior hallway that is open to outside air. There is possibility to vent(in/out) to outdoors.



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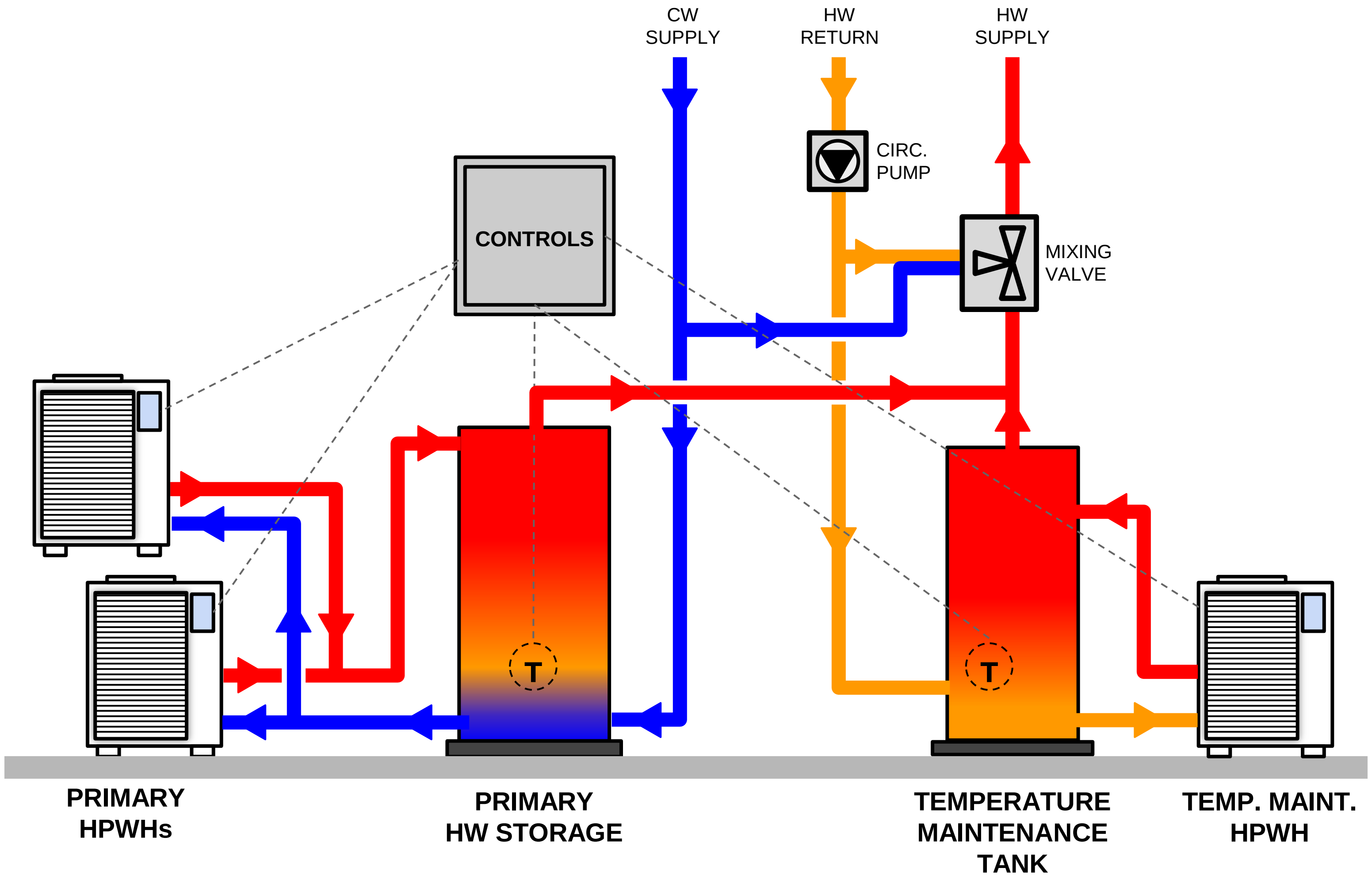
HPWH Configurations for Central Systems

ECOTOPE

Components of CHPWH System



Primary heat pump water heater (HPWH)

Primary HW storage tank

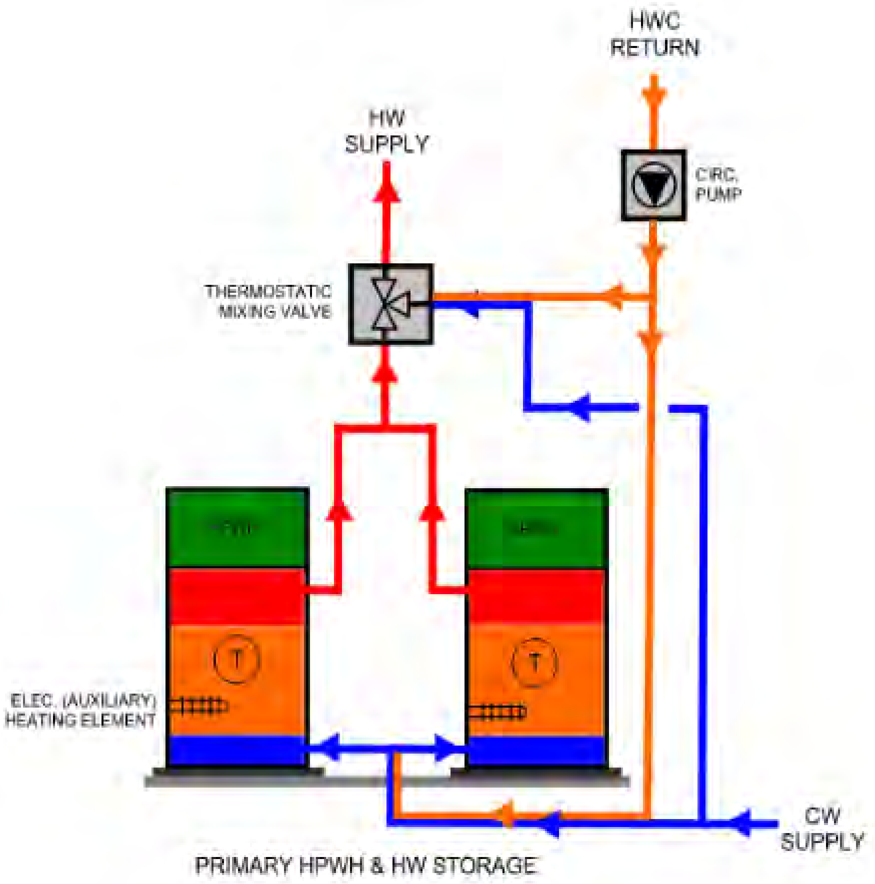
Temperature maintenance system

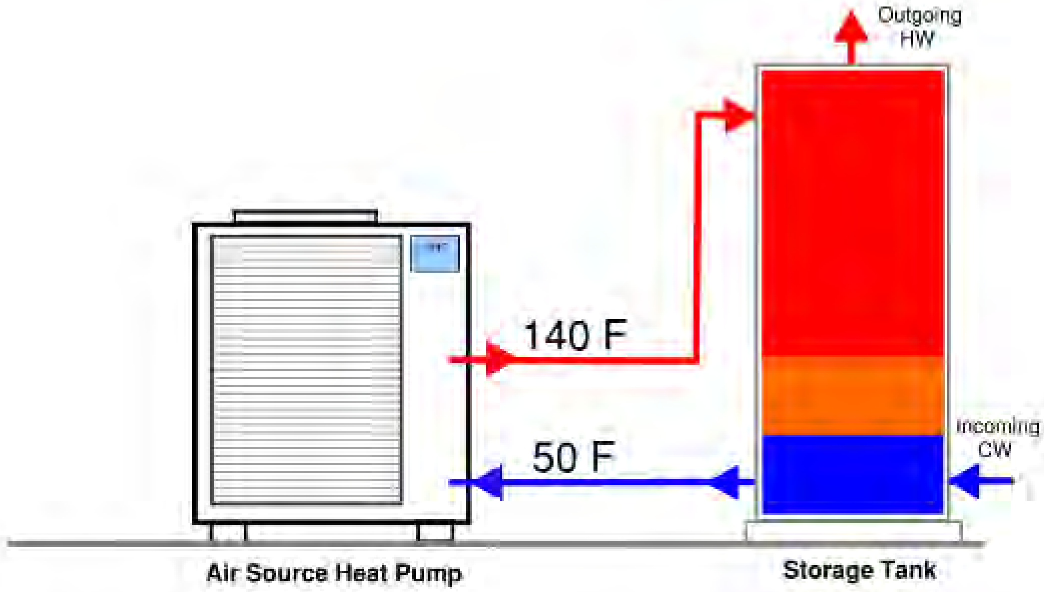
Control system

Small CHPWH Systems

- Scalable deployment
- Unitary or single pass
- Circulation system?

Small System Configuration for Multiple Apts.





Challenges and Opportunities

ECOTOPE

- Sizing
- System Component Bundles
- System Efficiency

System Capacity

55 Tons
1,000 Gallons

5 Tons
520 Gallons

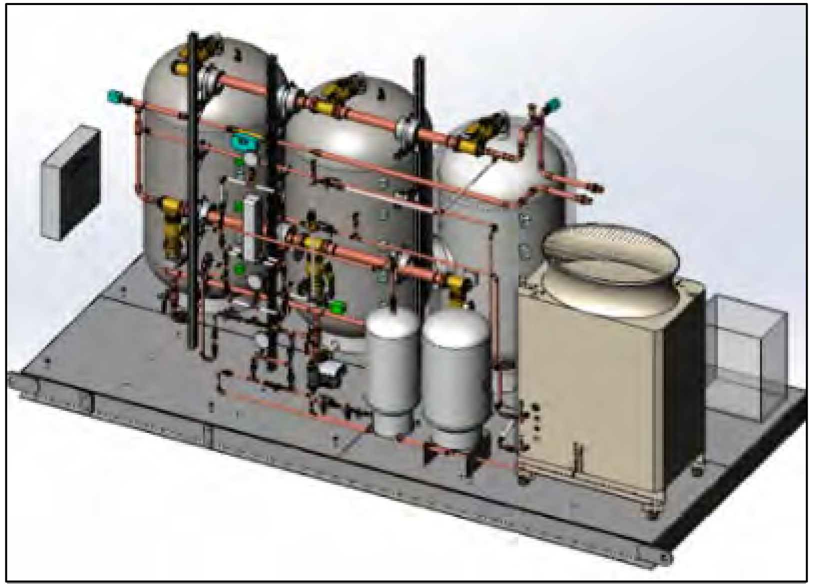
Market Delivery Models

CUSTOM ENGINEERED SYSTEM

All the pieces are separate & come from multiple distributors and/or manufacturers.

SPECIFIED BUILT-UP SYSTEM

All the pieces are separate but come from a single distributors or manufacturer.



PACKAGED/SKID

Everything is assembled & delivered in a single package.

Bayview Tower

Energy Savings

This system has seen a reduction from 230,000 to 95,000 kWh/yr and operates 3x more efficiently with a COP of 3.0

Low GWP refrigerant

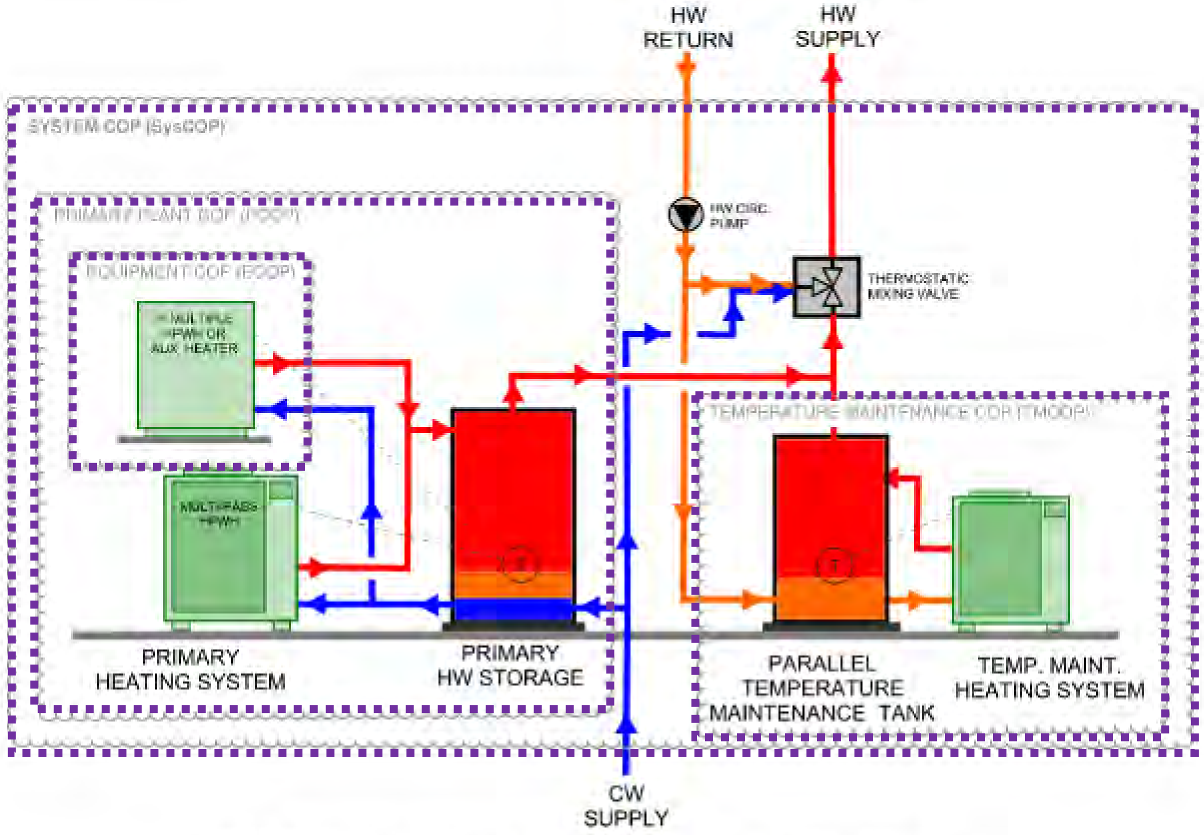
The Mitsubishi QAHV heat pump uses carbon dioxide (CO2), a natural refrigerant with a global warming potential of 1.

Cost Savings

Expected cost savings are ~$15,000/yr.

Skid-Mounted CHPWH System Delivered to Bayview Tower, Seattle

System Efficiency



COP Boundaries: SINGLE-PASS PRIMARY HPWH SYSTEM WITH PARALLEL TEMPERATURE MAINTENANCE TANK & MULTI-PASS HPWH

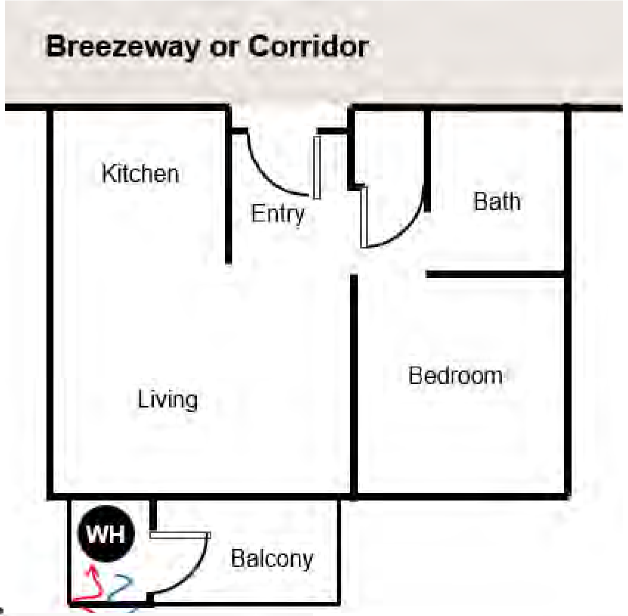
Heat Pump

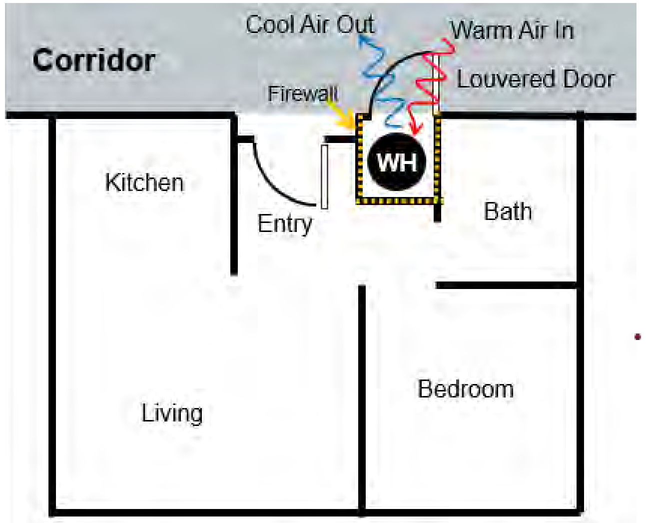
Heat Pump + Storage Tank

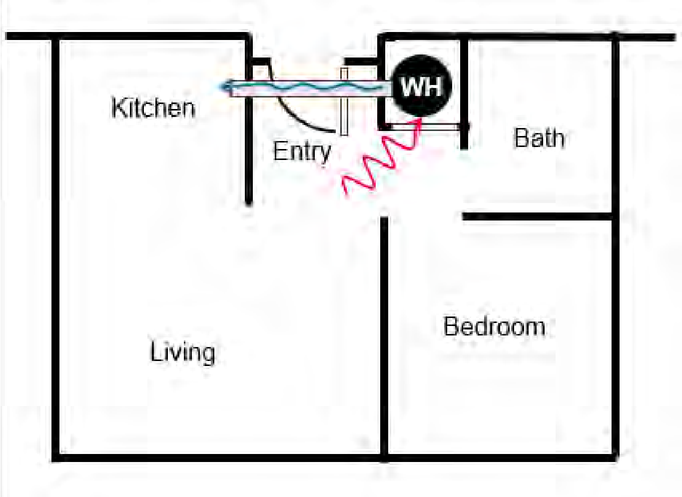
Temperature Maintenance System

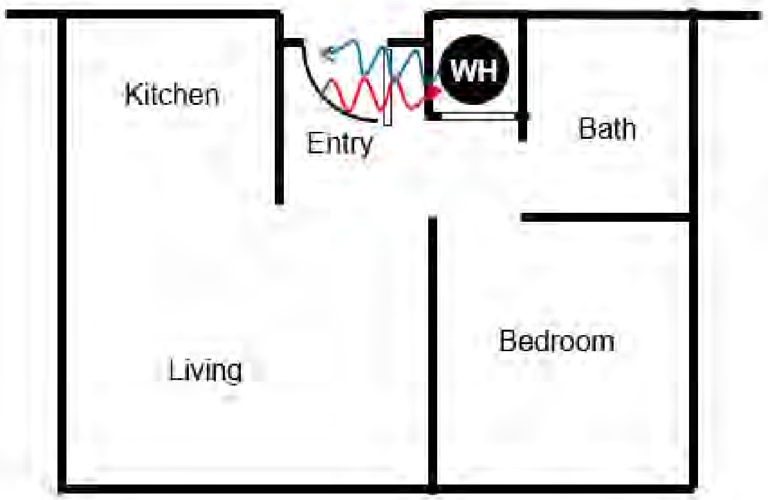
Total System COP

Examples of designs and locations in Multifamily

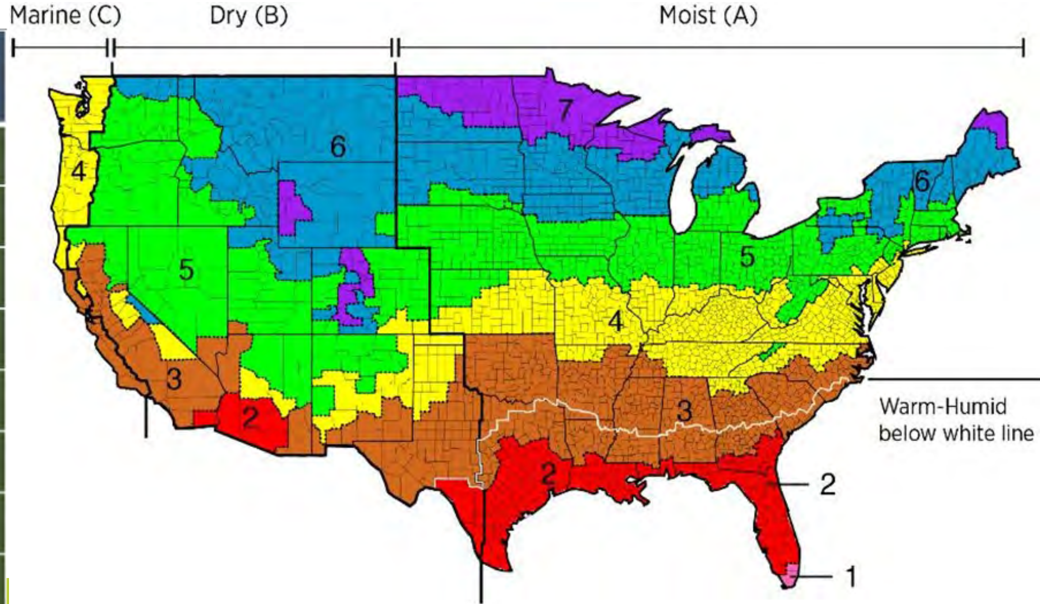








Climate Zone	Corridor Closet	Exterior Closet	Interior Closet
1			
2			
3			
4 A+B			
4 C			
5			
6			
7			




ONE BEDROOM APARTMENT HOMES
(488 SQUARE FEET)
DECK
SLIDING GLASS DOORS
BEDROOM
CLOSET
SHOWER/ BATH TUB
BATHROOM
COUNTER TOP
OVEN
SINK
KITCHEN
CLOSET
WATER HEATER
DISHWASHER
REFRIGERATOR
LIVINGROOM
ENTRANCE


Furnace & Water Heater Closet
Laundry Room W/D Hook-Ups
Entry
Kitchen
Bathroom
Closet
Linen Closet
Walk-In Closet
Dining Room
15.5' x 18.5'
Bedroom
19.5' x 18.5'
Living Room
Fireplace
Storage
Balcony
Storage


BEDROOM
CLOSET
BATH
HALL
KITCHEN
DINING ROOM
LIVING ROOM
STORAGE
PATIO


TWO BEDROOM TOWN HOMES
(960 SQUARE FEET)
ENTRY LEVEL
488 SQUARE FEET
SECOND LEVEL
488 SQUARE FEET
DECK
SLIDING GLASS DOORS
LIVINGROOM
SINK
HALF BATHROOM
TOILET
COUNTER TOP
KITCHEN
CLOSET
CLOSET
OVEN
REFRIGERATOR
STAIRS
SINK
DISHWASHER
COUNTER TOP
ENTRANCE
DECK
SLIDING GLASS DOORS
CLOSET
MASTER BEDROOM
CLOSET
SHOWER/ BATH TUB
BATHROOM
STAIRS
TOILET
SINK
GUEST BEDROOM
CLOSET