The Amazing Shrinking Room

HPWHs in Less-than-Ideal Spaces

Larson Energy Research

Presented by

Ben Larson

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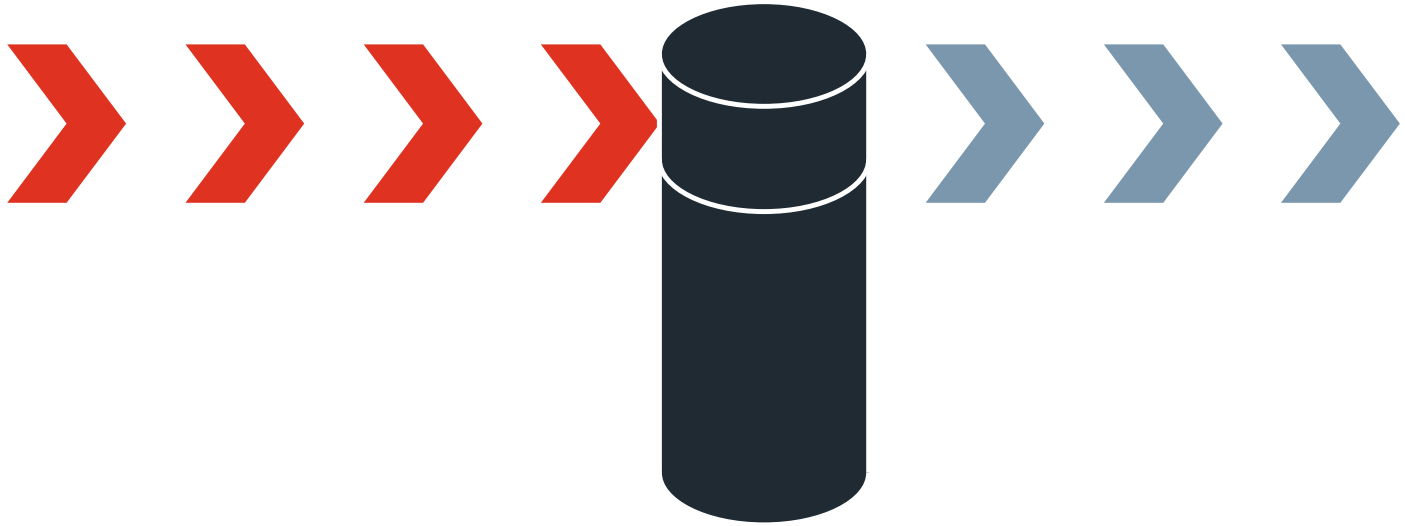
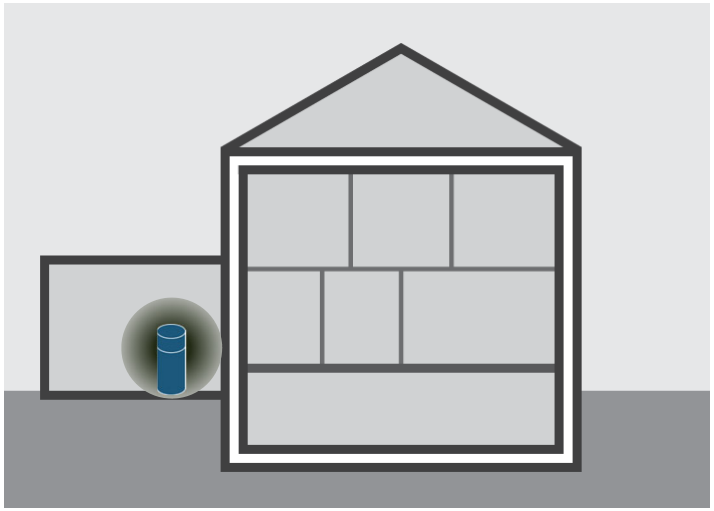
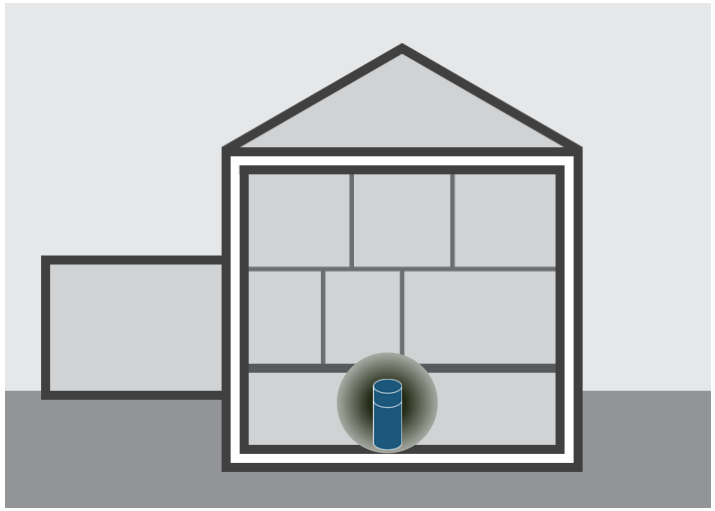
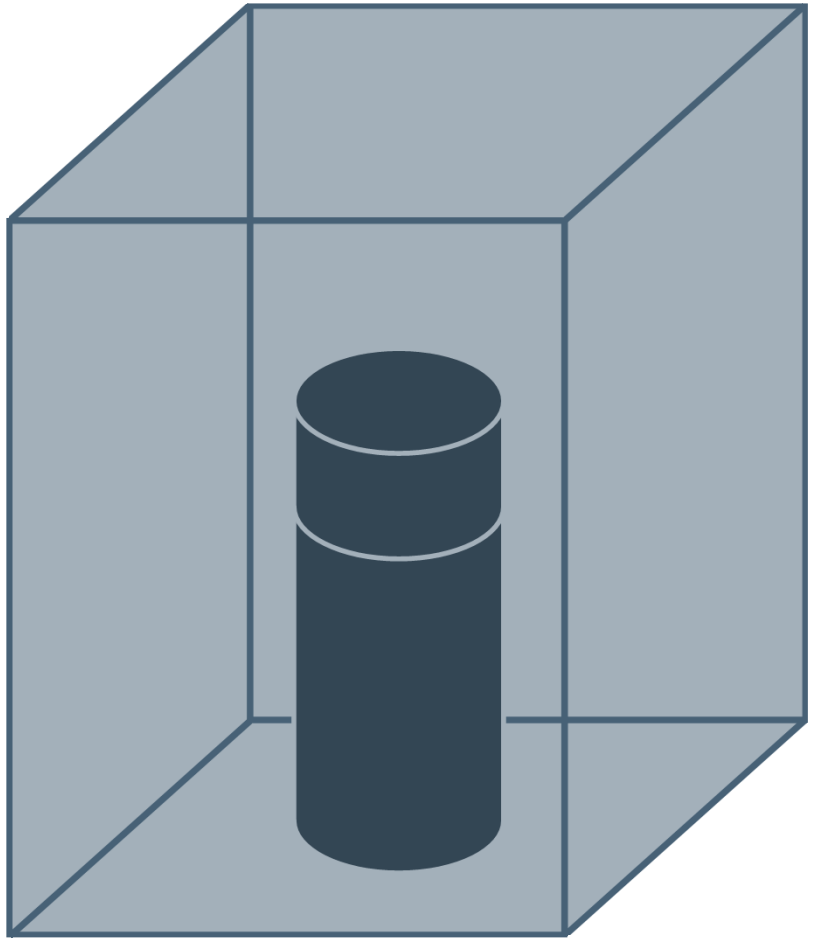
Energy Trust of Oregon

Building Energy Simulation Forum

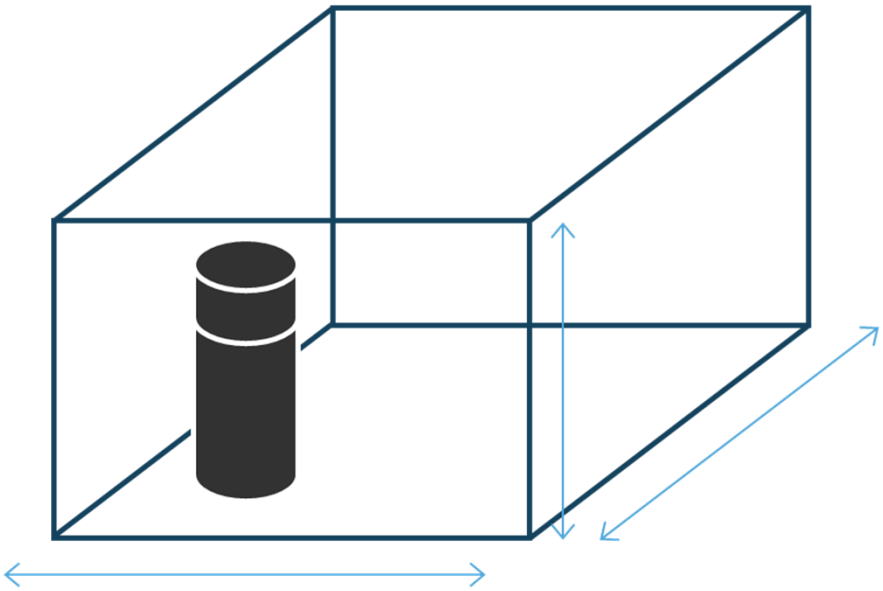




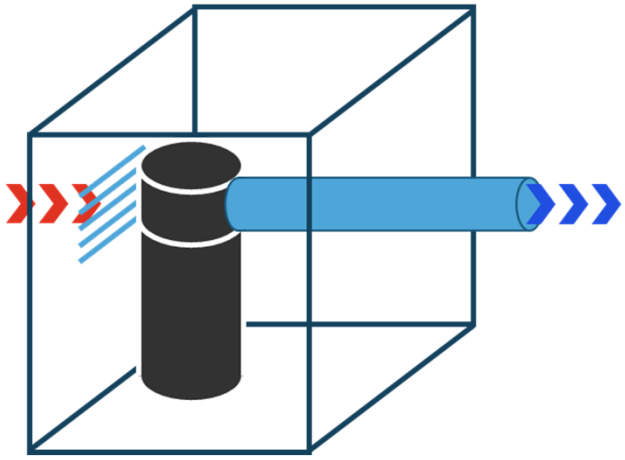




Minimum room dimensions



Ventilation



How much does room volume affect HPWH efficiency?

How effectively can efficiency be improved in a small space?


neea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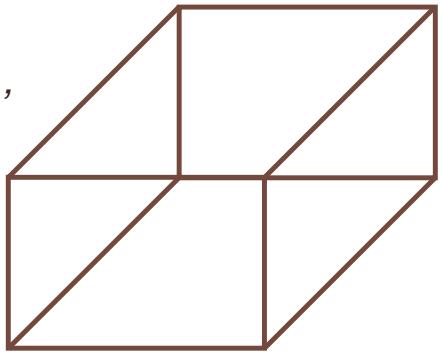
Amazing Shrinking Room

How installation room volume affects HPWH efficiency

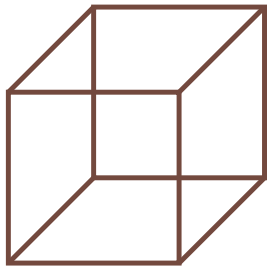
Audience Poll

What size room is large enough to be a good location for a HPWH?

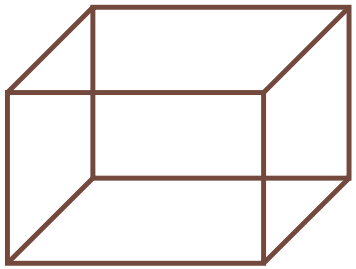
A. 192 ft^2
e.g. 12' x 16'



C. 64 ft^2
e.g. 8' x 8'



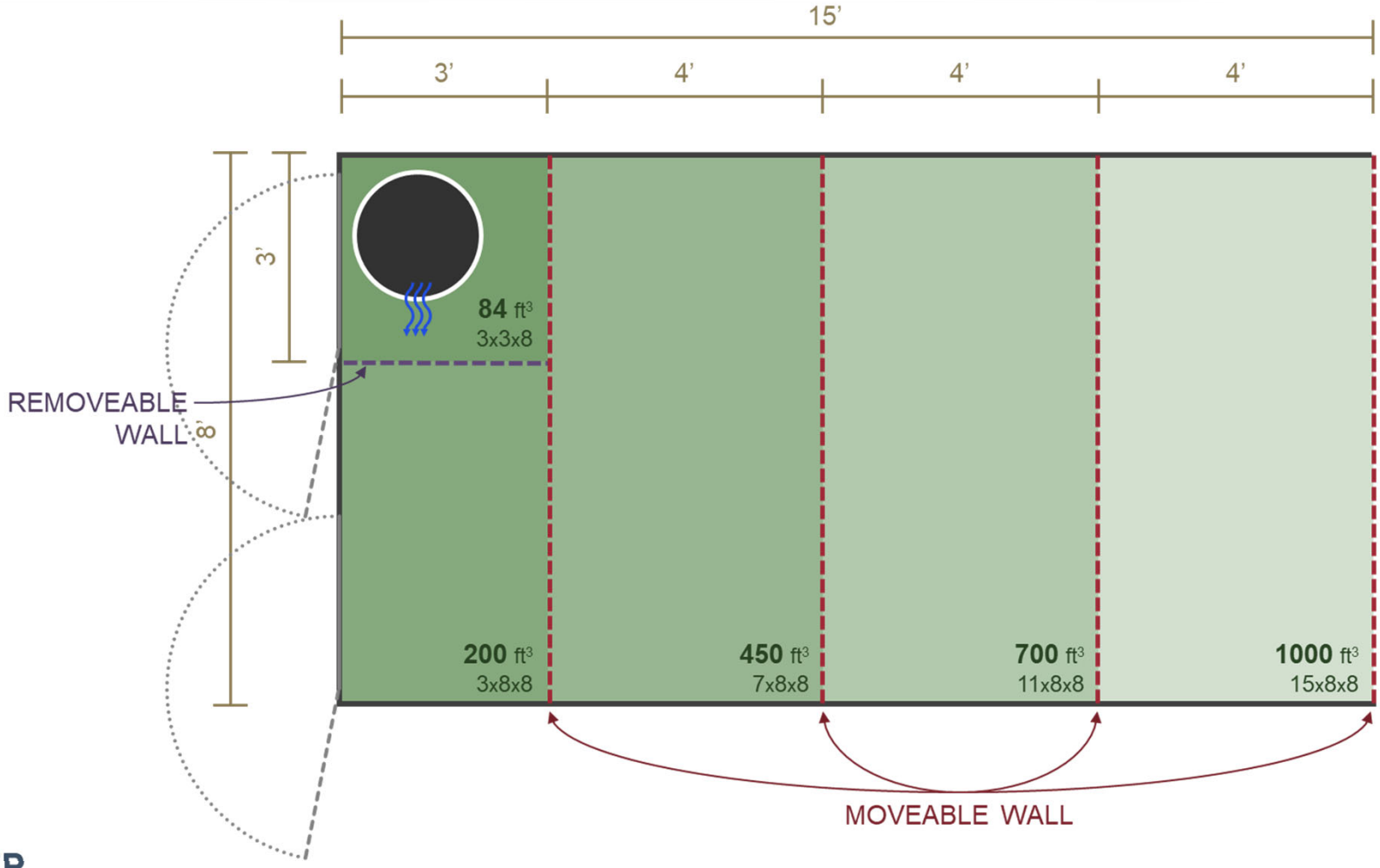
B. 96 ft^2
e.g. 8' x 12'



D. 9 ft^2
e.g. 3' x 3'

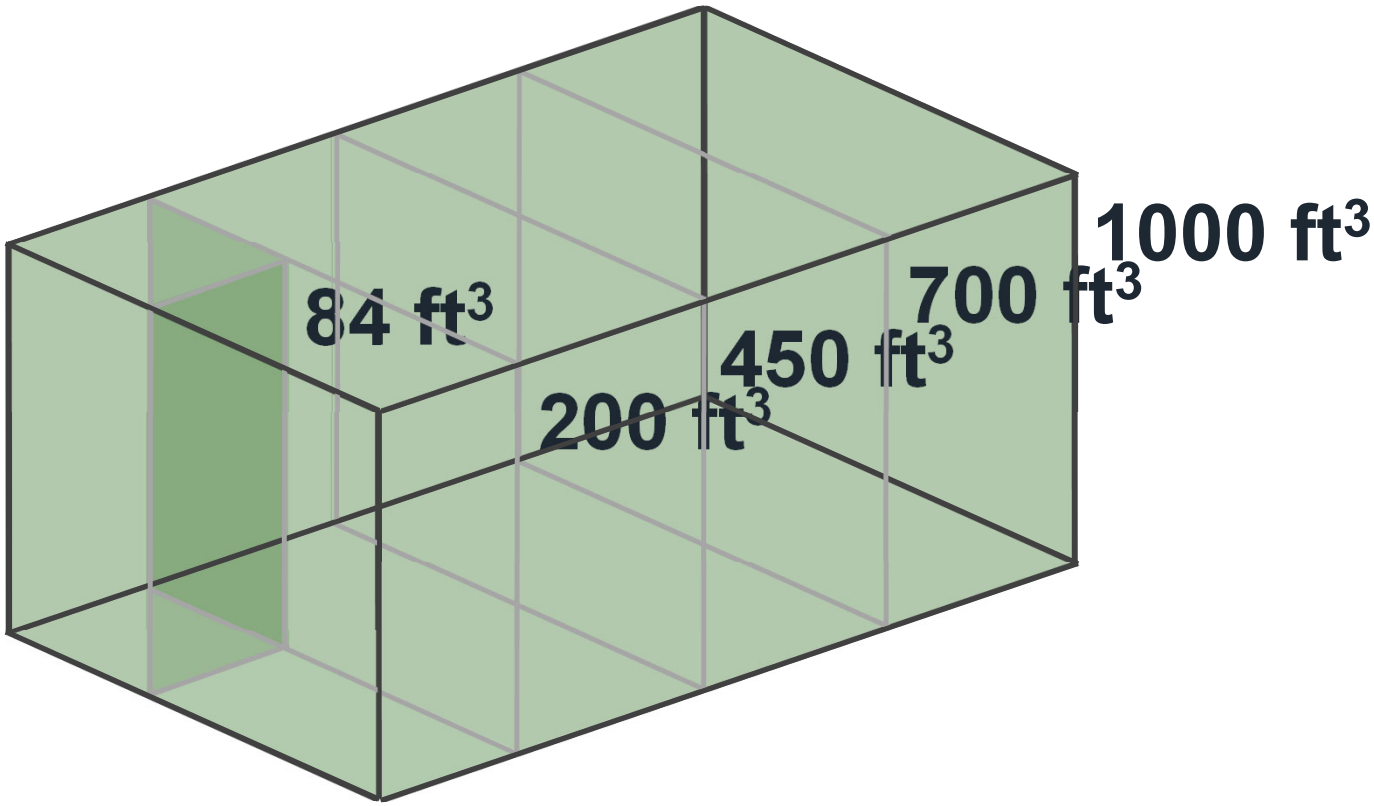
Amazing Shrinking Room

Amazing Shrinking Room

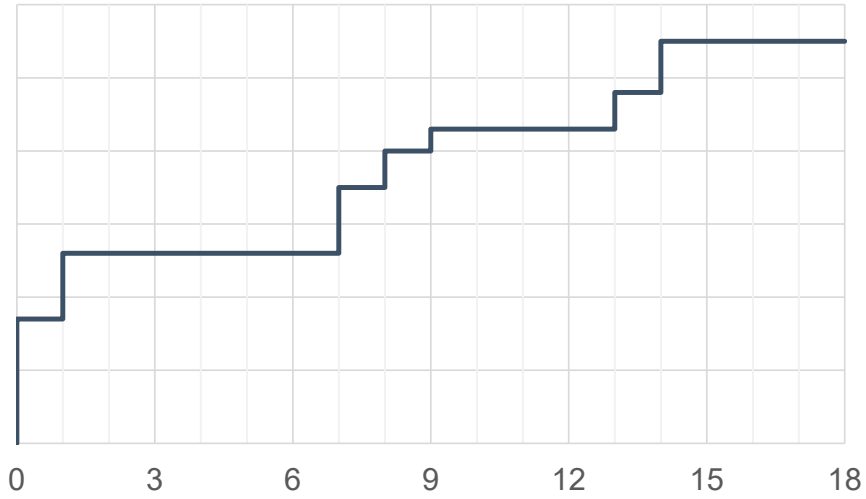


Amazing Shrinking Room

Amazing Shrinking Room



Efficiency Test Procedure

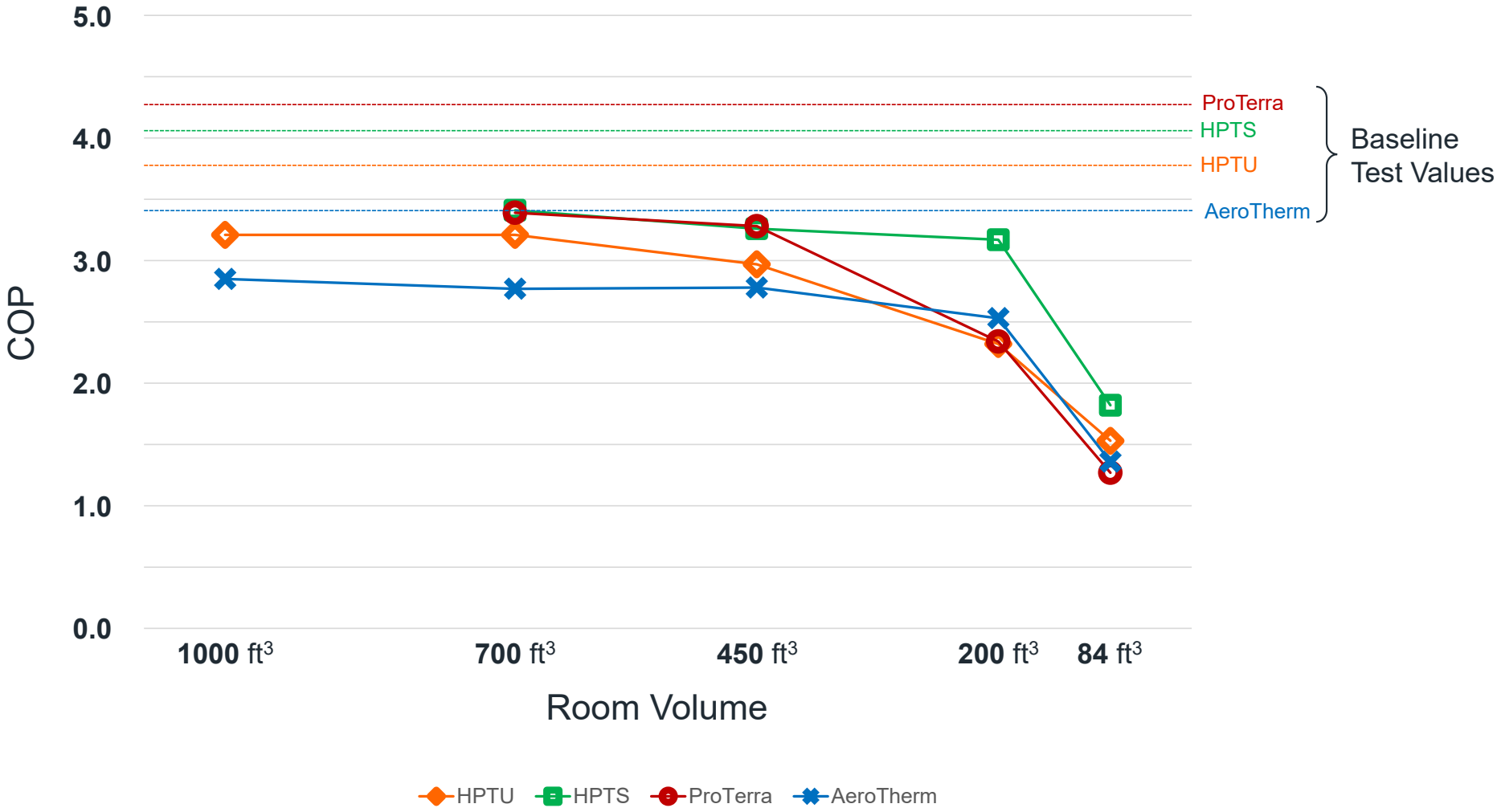


- 18-hr simulated-use test
- Ambient air temperature *not* controlled
- COP: hot water output / electrical input
- Baseline value established by running procedure with unrestricted access to room-temperature air

Water Heaters Used in Testing

	Voltex (HPTU) **A. O. Smith**	**Voltex XE** (HPTS) **A. O. Smith**	**ProTerra** **Rheem**	**AeroTherm** **Bradford White**
Model Number	HPTU-50N	HPTS-50	XE80T10H45U0	RE2H50S10-1NCTT
				
Nominal Storage	50 gal	50 gal	80 gal	50 gal
Uniform Energy Factor (UEF)	3.45	3.80	4.07	3.44
Recovery Efficiency	407%	452%	447%	406%
First Hour Rating (FHR)	66 gal *Medium-Usage*	65 gal *Medium-Usage*	87 gal *High-Usage*	65 gal *Medium-Usage*
NEEA AWHS Tier	3	4	4	4
Introduced	2016	2022	2020	2023

Amazing Shrinking Room Results

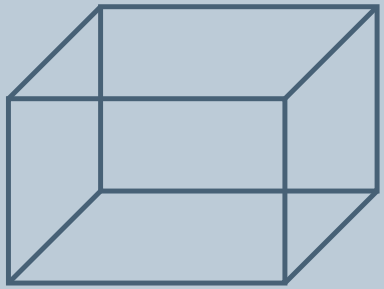


Closed-Room Volume Recommendation

New Construction
Single-Family

700 ft^3

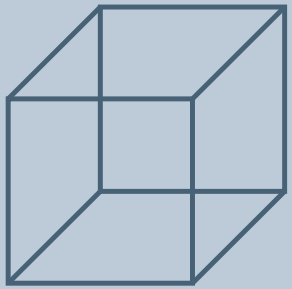
minimum



Multi-Family
or **Retrofit**

450 ft^3

minimum

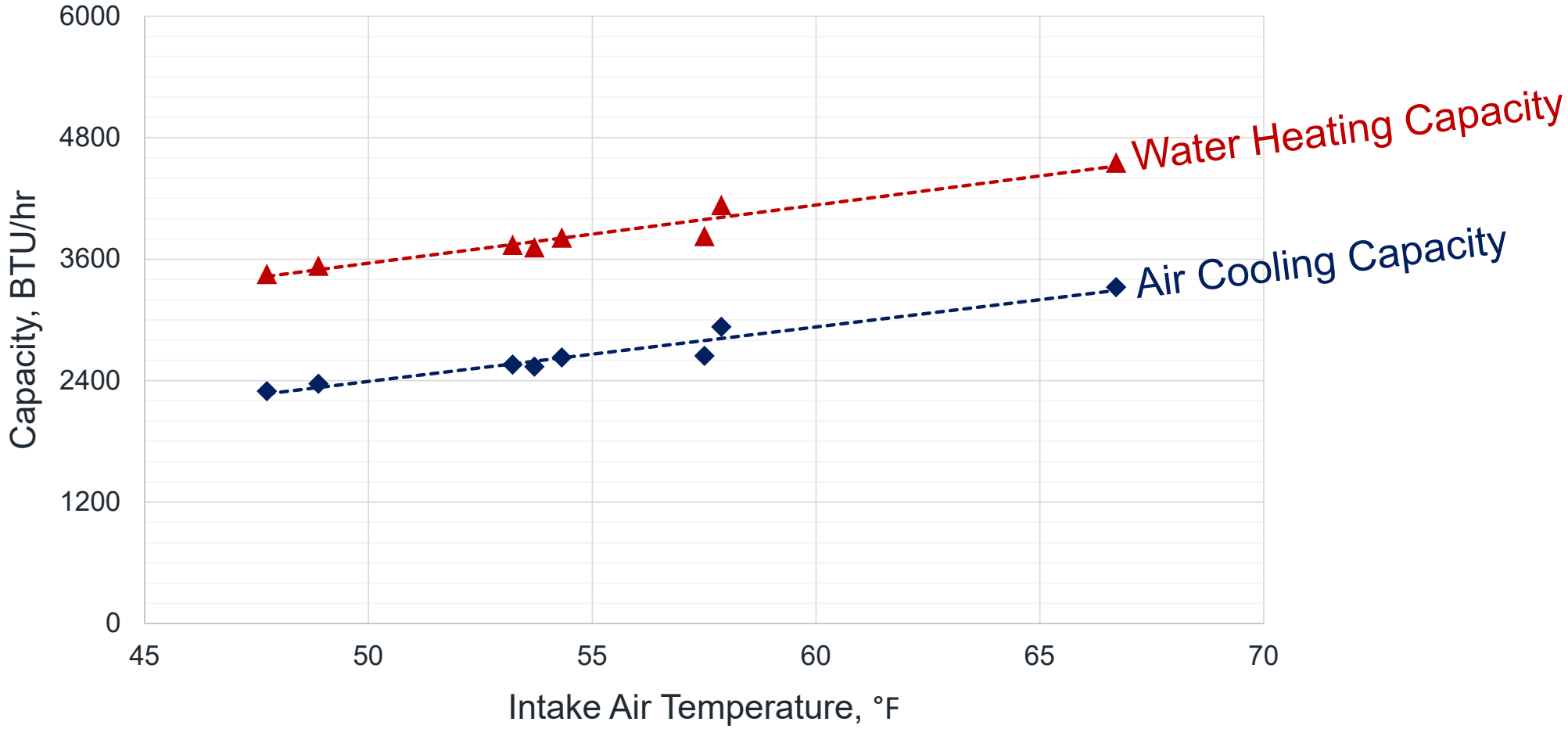


Explaining the Results

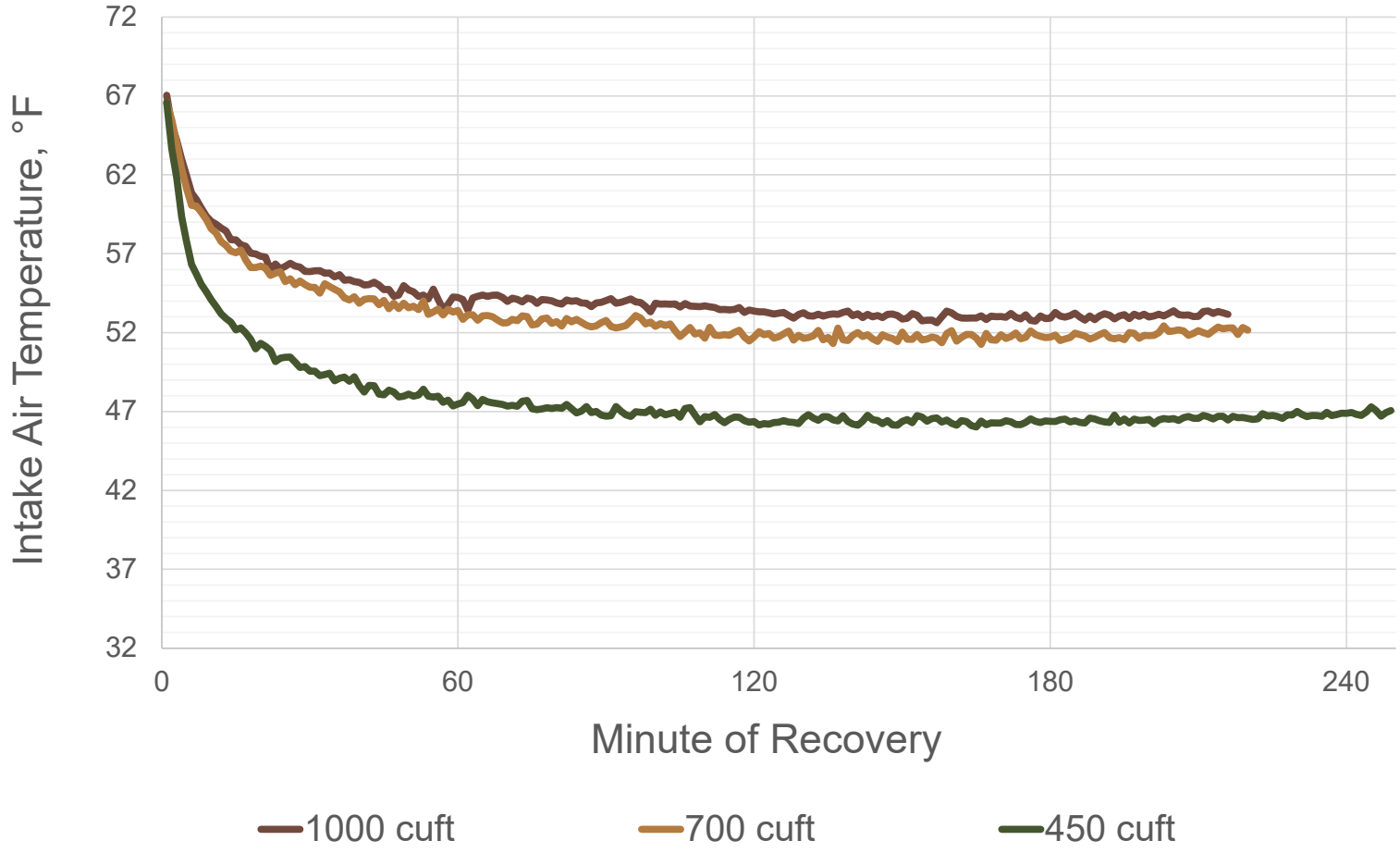
As the heat pump runs, it cools the air. Cooler air results in:

- Decreased water-heating capacity
- Decreased air-cooling capacity
- Increased heat transfer through walls
- Increased tank heat loss

Heat Pump Capacity by Intake Air Temp



Resulting Intake Air Temperature



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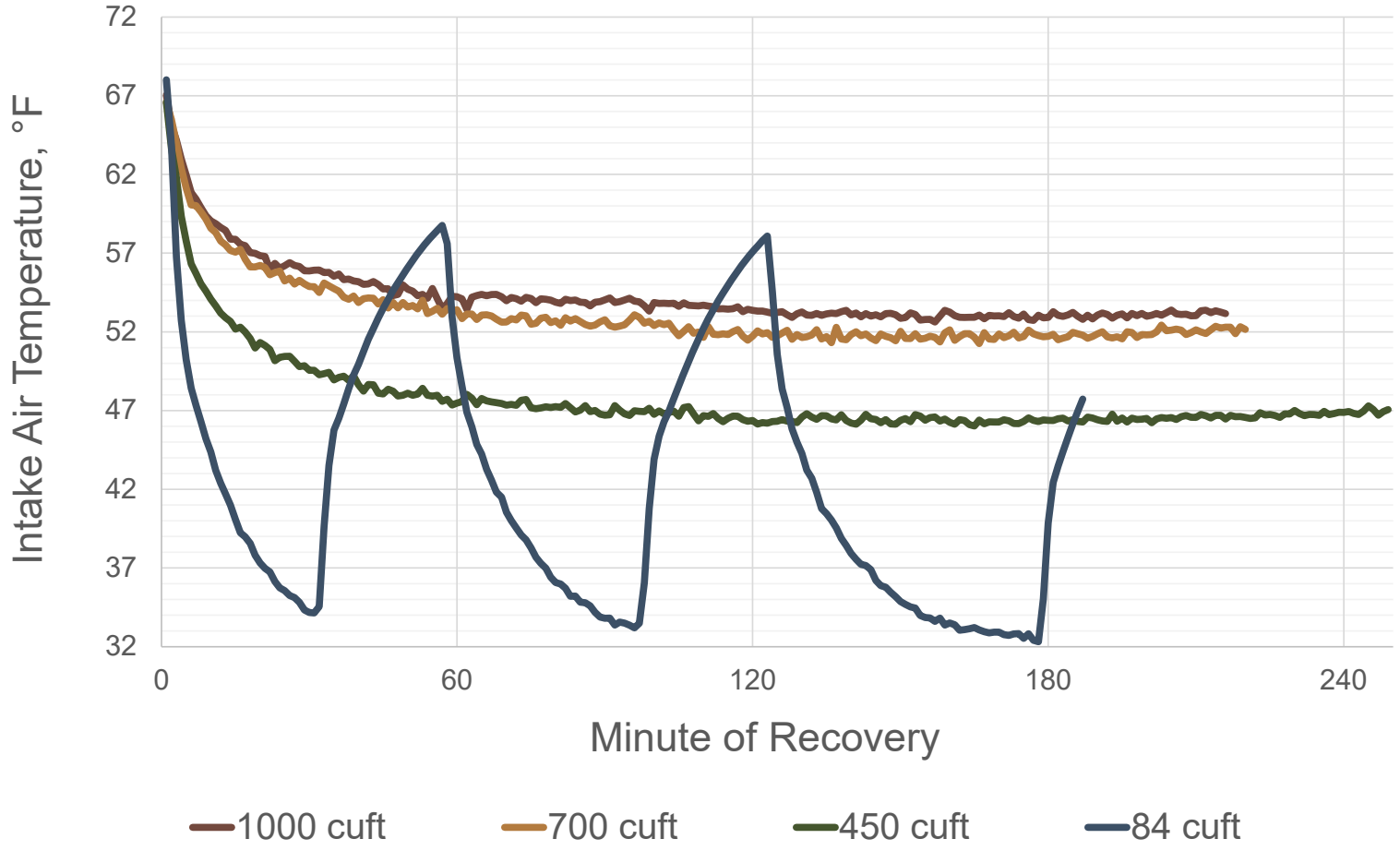


Explaining the Results

After equilibration, if air temperature is…

…**within** compressor's operating range…

Water heater can complete recovery using solely heat pump. **Efficiency will vary** with that temperature.

…**below** compressor's operating range…

Water heater will resort to ER heating, resulting in **unsatisfactory efficiency**.

Audience Poll

In a multifamily building using residential water heaters, what is the most convenient way to locate them?

A. One water heater inside each dwelling

B. Water heaters in multiple utility/mechanical closets through the structure

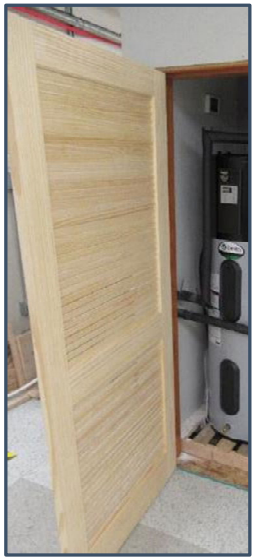
C. In a single space (basement, mechanical room, etc.) for the whole building

D. Water heaters should take up no space

Passive Ventilation

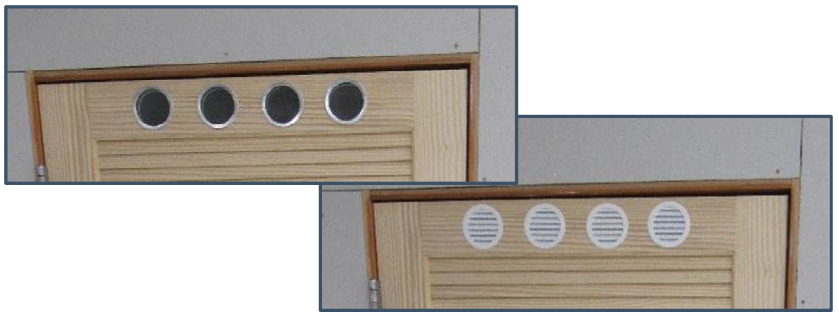
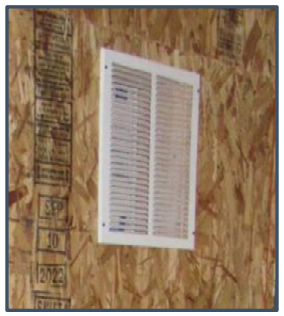
Using convection to replenish thermal resource in a small space

Passive Ventilation



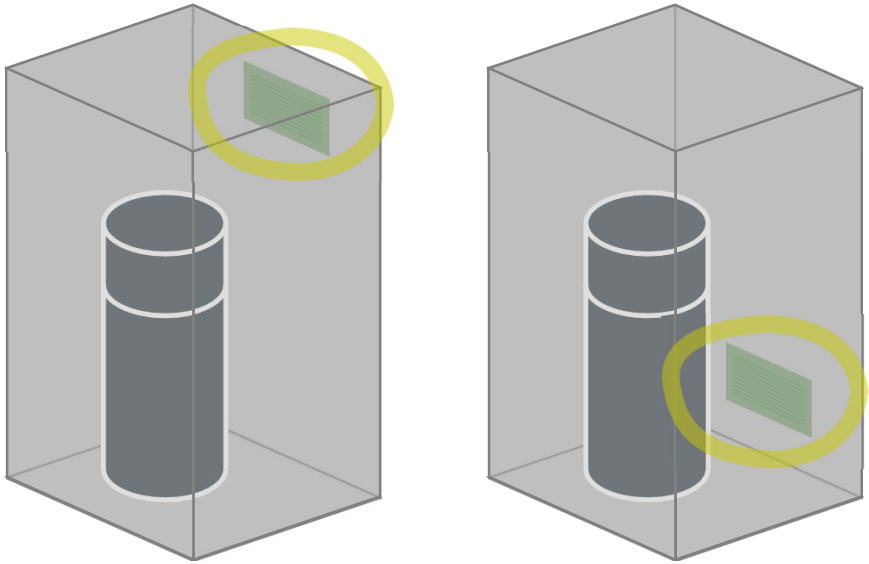




Vertical Distribution of Open Area

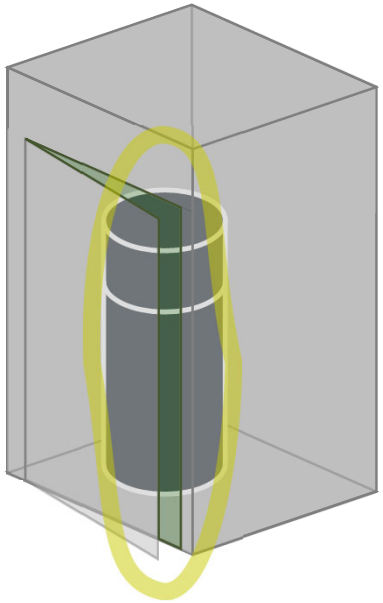
130 in^2 NFA distributed across **8** vertical in:



COP: **1.5**

Same as if no openings

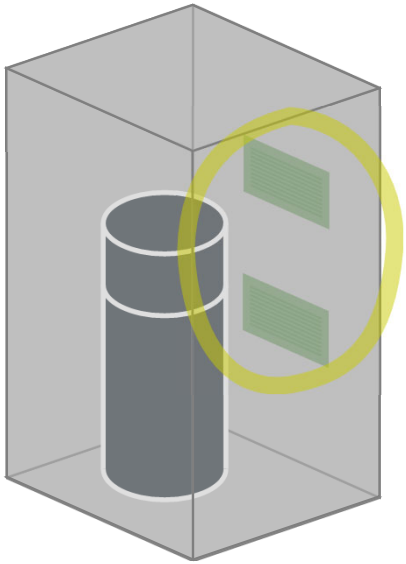
115 in^2 NFA distributed across **80** vertical in:



COP: **2.5**

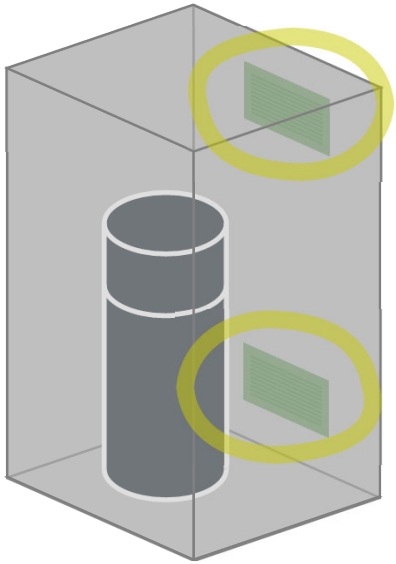
Vertical Distribution of Open Area

260 in^2 NFA divided across **32** vertical in:



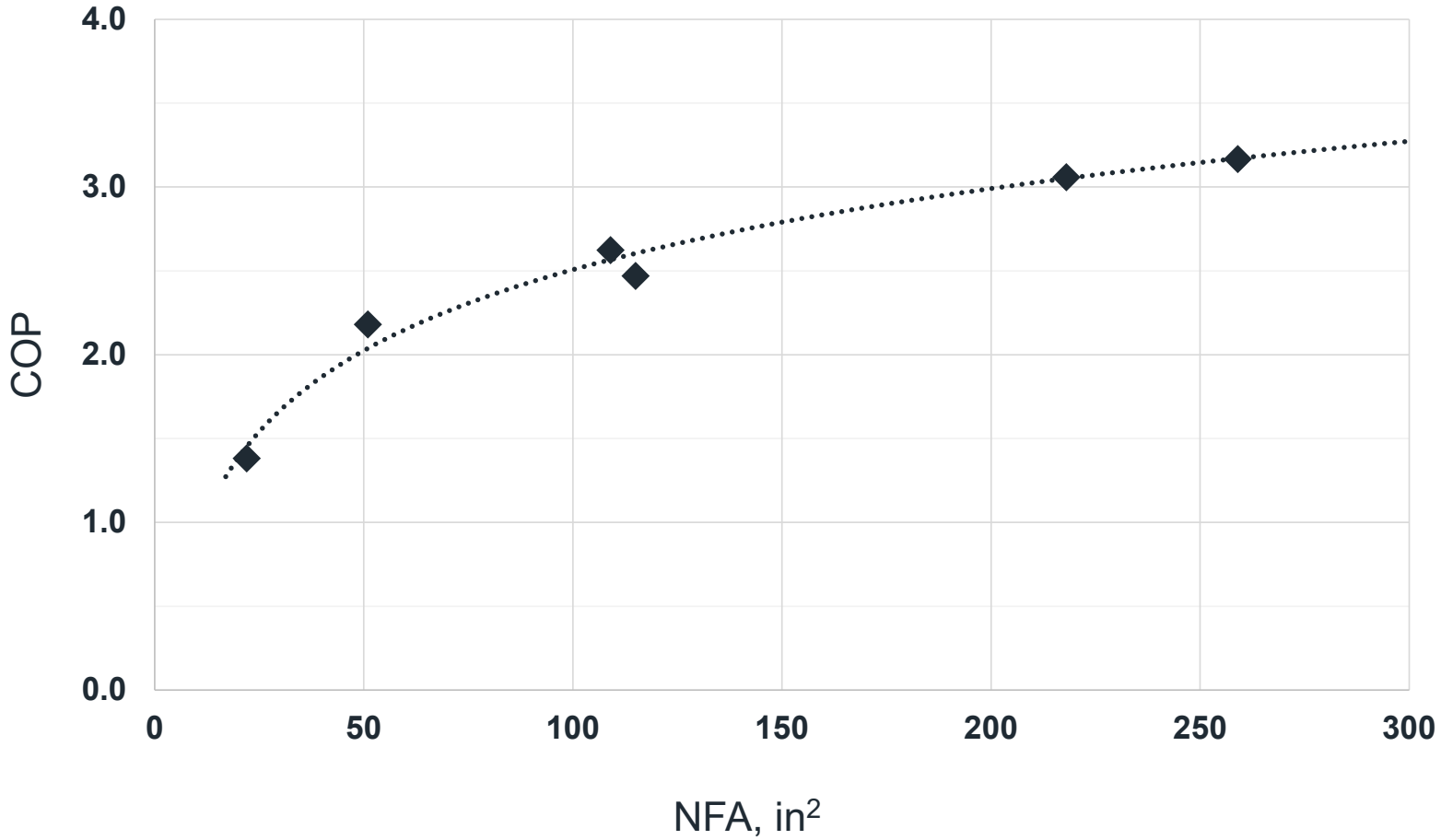
COP: **2.7**

260 in^2 NFA divided across **80** vertical in:

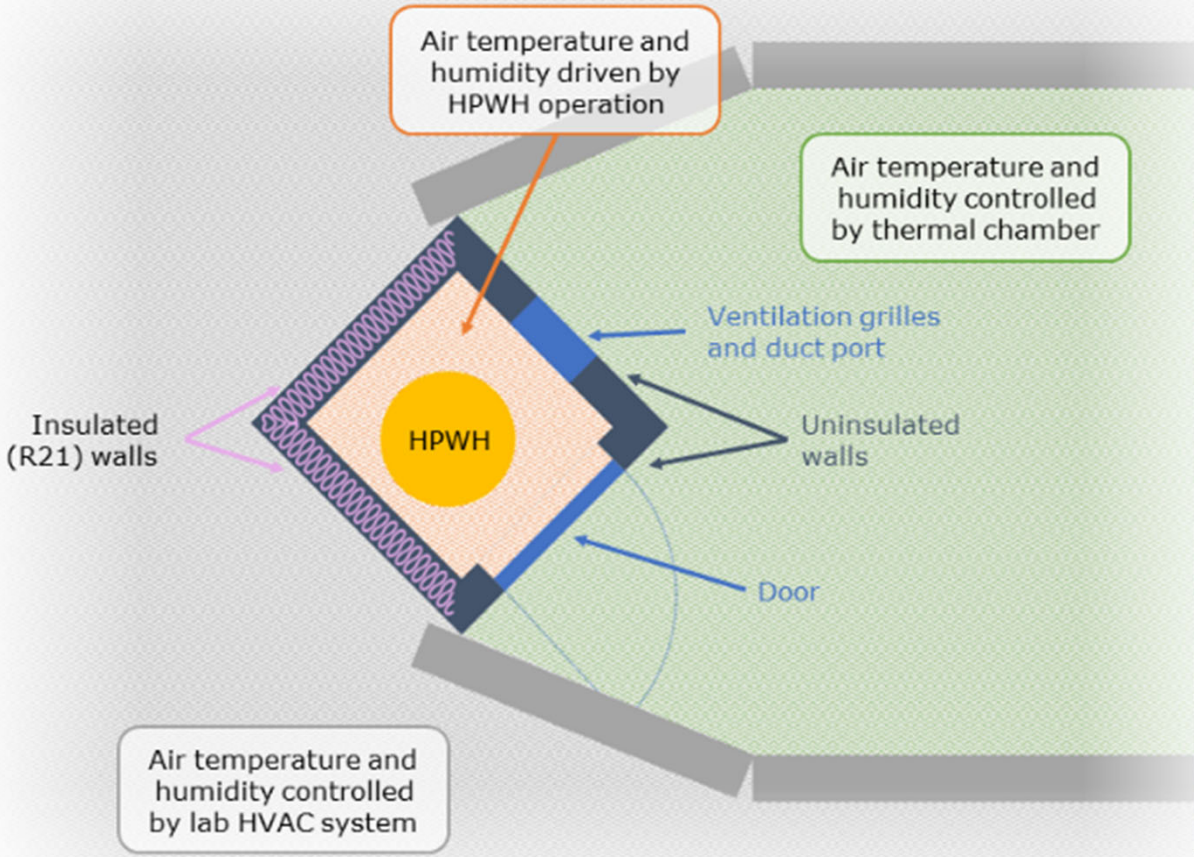


COP: **3.4**

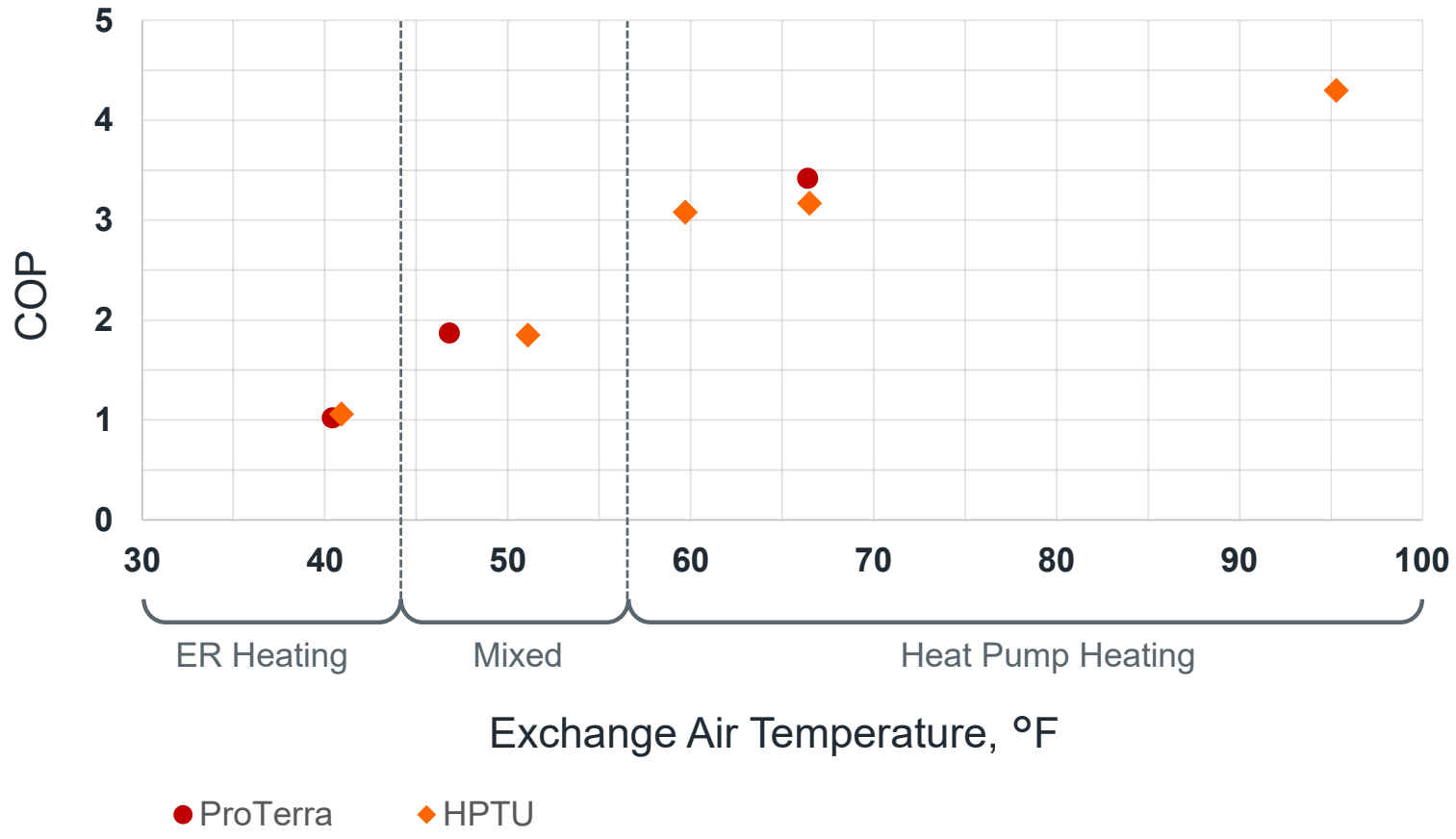
Total Net Free Area



Exchange Air Temperature

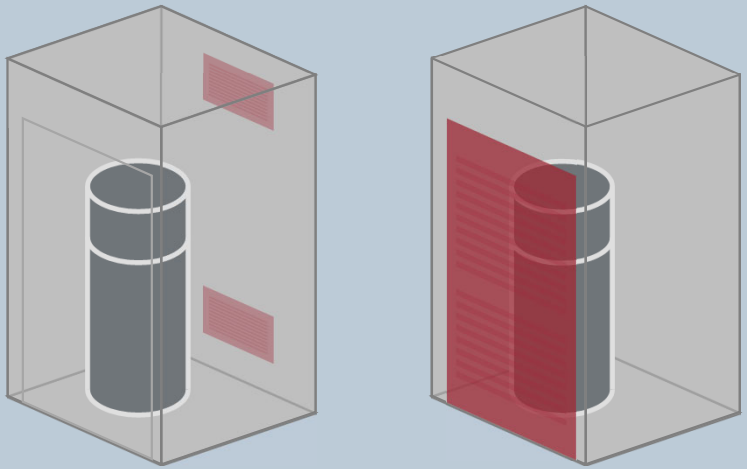


Exchange Air Temperature



Passive Ventilation Recommendation

- Provide a minimum of **300 in^2 NFA**
- Locate openings both **high and low**



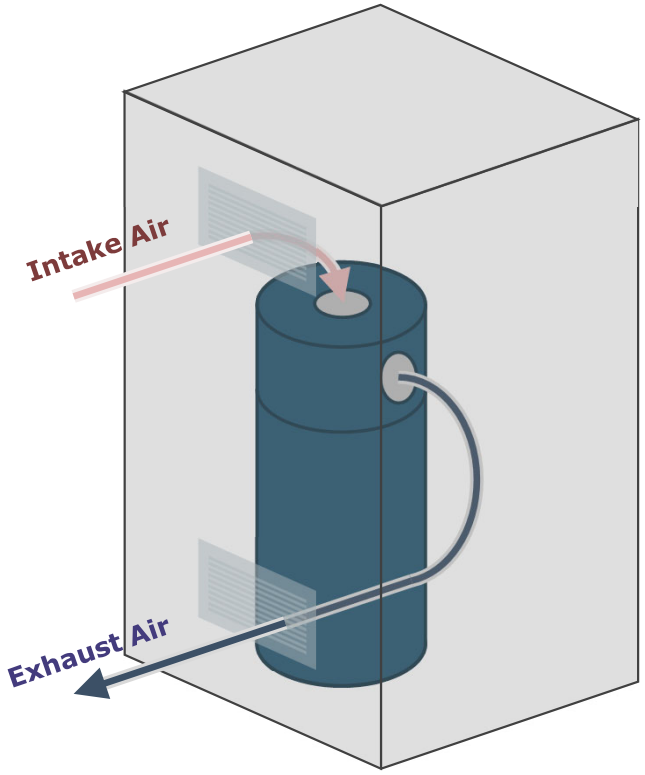
Avoid exchanging air with exterior in cooler climates.

IECC Climate Zone	
1, 2	OK
3, 4	Caution
5+	Inadvisable

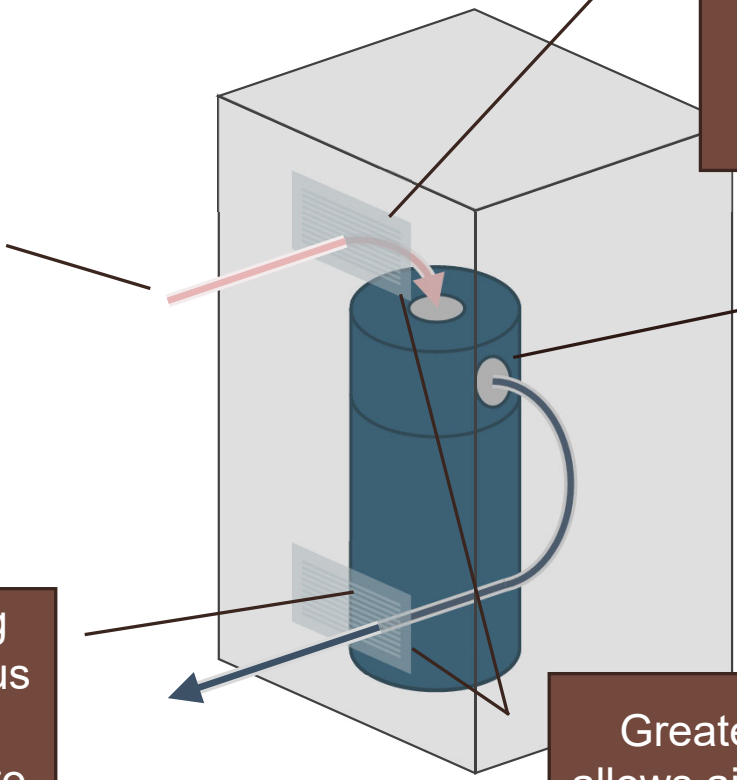
Explaining the Results

Air exchange driven by the “stack” effect

- Heat pump reduces air’s buoyancy as it extracts heat
- The cooler exhaust settles downward within the room
- Given sufficient openings, exhaust will exit the room to a space with less-dense air and new air will be drawn in from above



Factors in Passive Ventilation



Having high opening provides access to warmest exchange air and brings in air above HPWH's intake

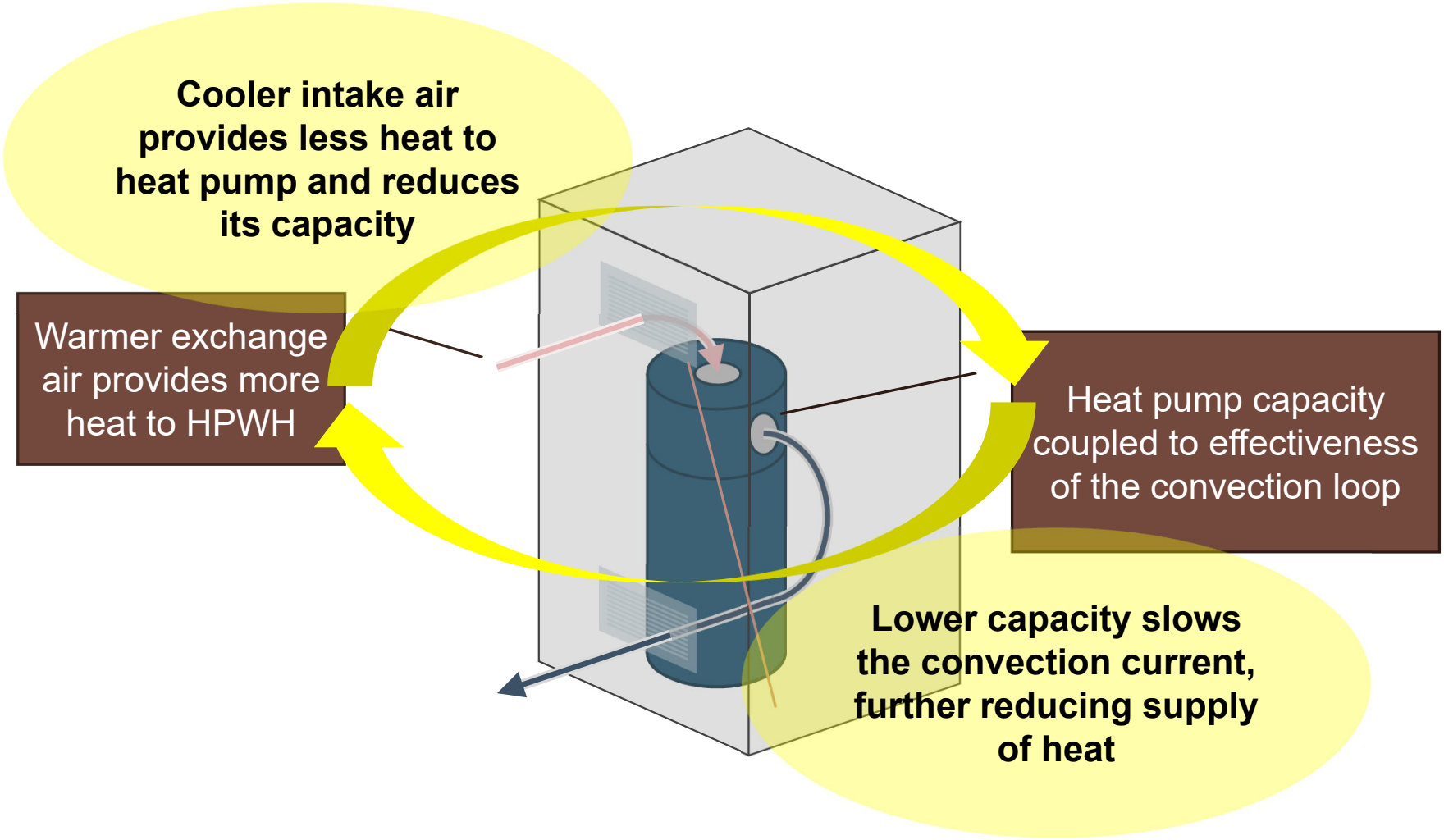
Warmer exchange air provides more heat to HPWH

Heat pump capacity coupled to effectiveness of the convection loop

Having low opening creates most vigorous convection loop allowing coldest air to escape

Greater total NFA allows air to exchange more freely

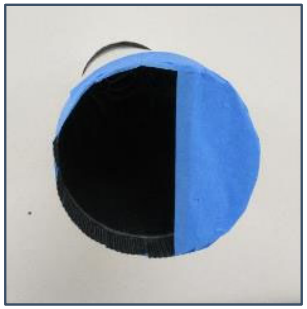
Factors in Passive Ventilation



Active Ventilation

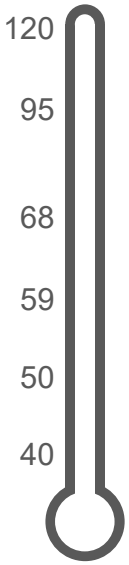
Using HPWH's evaporator fan to force exchange of air with another space

Active Ventilation



Active Ventilation

Exchange Air Source



Intake Path

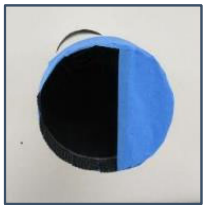
HPWH

Exhaust Path

Ducted

Directed

Various Lengths and Terminations



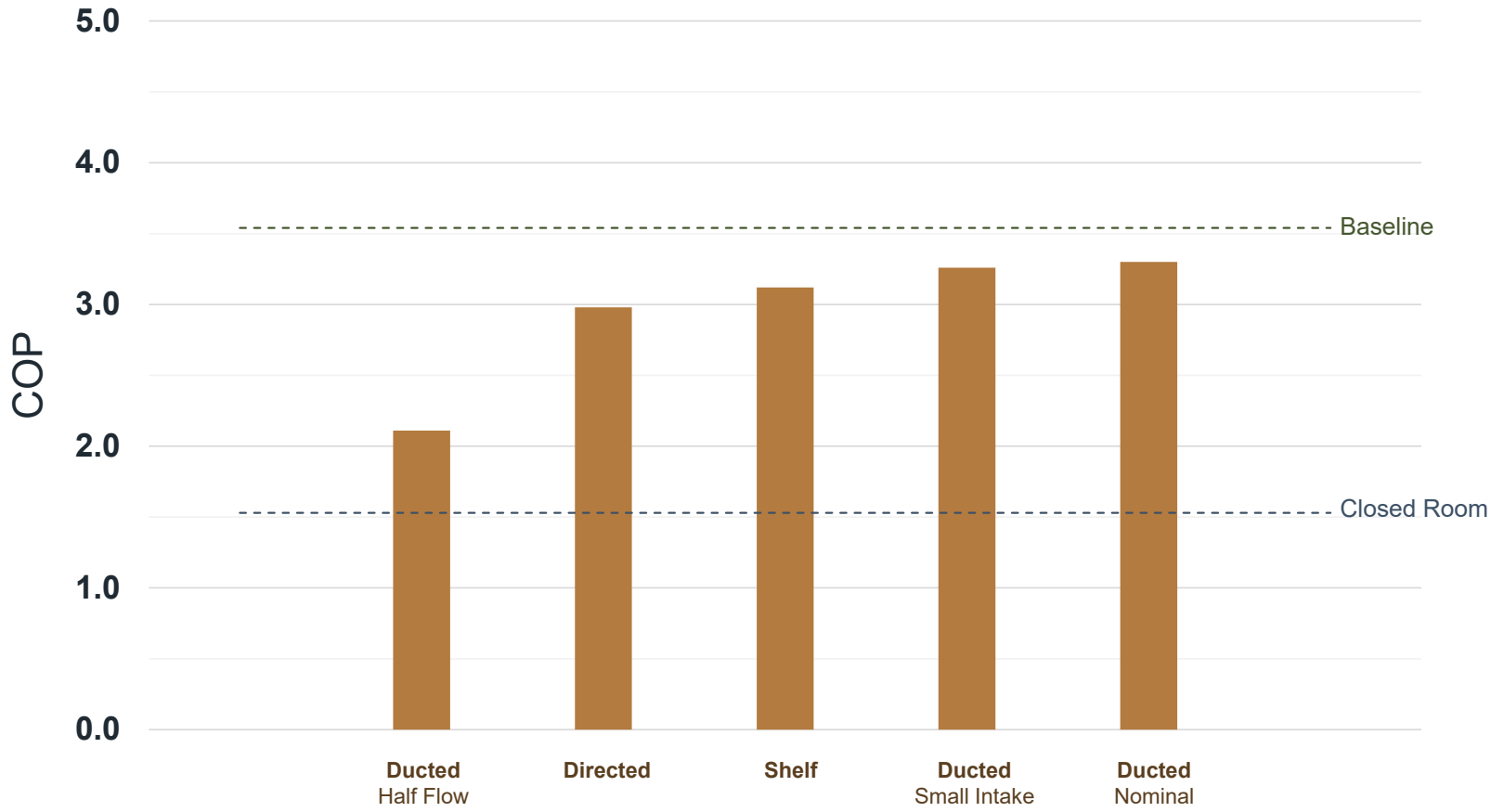
Different Diameters (4”, 8”)

and

Different types (rigid, flex)

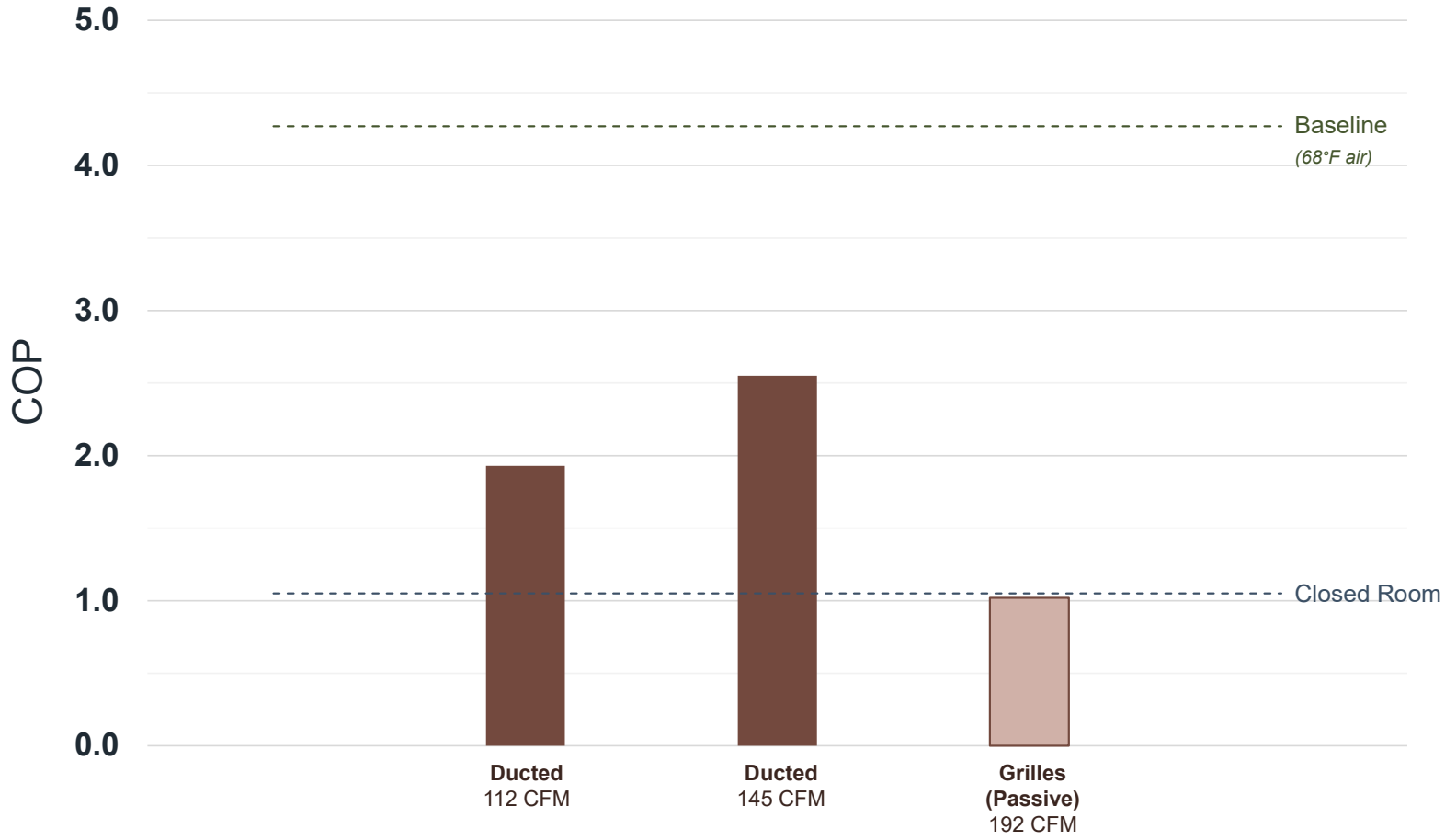
Active Ventilation Results

HPTU
68°F exchange air



Ventilation Results

ProTerra
50°F exchange air



Active Ventilation Recommendation

Maximize airflow

- Minimize duct length, elbows
- Use large-diameter, rigid ducting
- Select HPWH model with sufficient fan strength

Consider **passive** ventilation if adjacent space is reliably over 50°F

- Interior spaces
- Climate zones 1, 2

Avoid using exterior air source in cool/cold climates

- Climate zones 5+

Explaining the Results

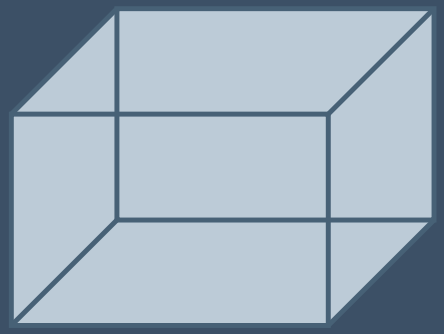
Heat pump efficiency dependent on access to heat.

- Intake air source temperature will affect efficiency
- Unlike passive, intake air source temperature will *not* affect thermal resource (exchange air) flow through HPWH closet
- For a given air temperature, the amount of heat delivered to heat pump depends on airflow rate
  - Stronger fans increase flowrate
  - Static pressure presented by duct decreases flowrate

minimum

450 ft^3

interior room



minimum

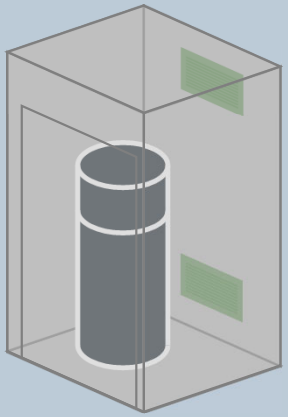
700 ft^3

interior room

Ventilate

Passive Ventilation

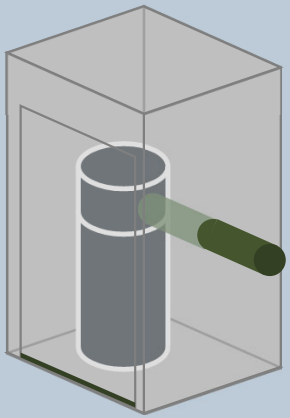
- Minimum 300 in^2 NFA
- Open area high and low



Use when there is a suitable adjacent interior space, or with outdoor air in hot climates

Active Ventilation

- Minimize static pressure
- Ensure fan is sufficient

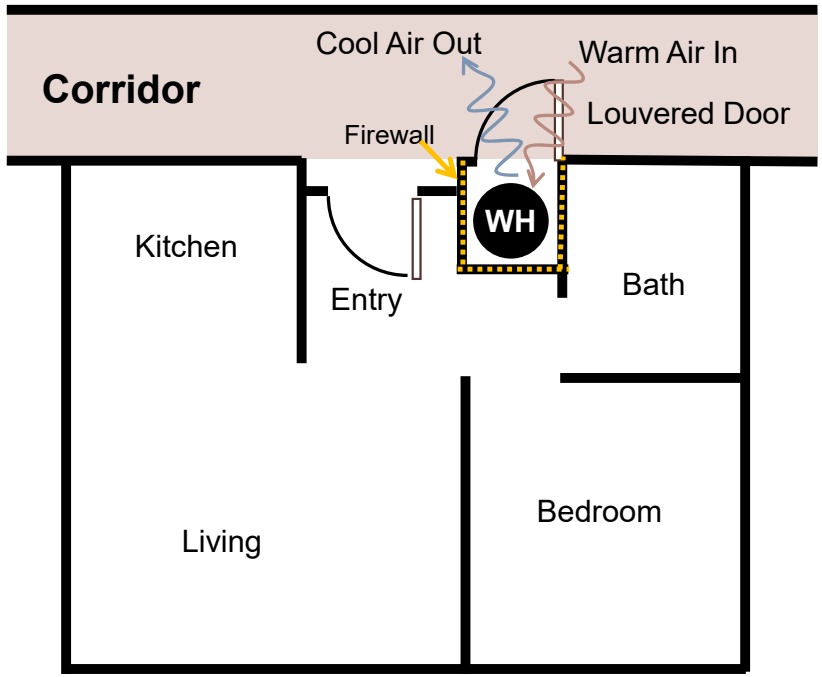


Use when exchange air source is not reliably above 50°F

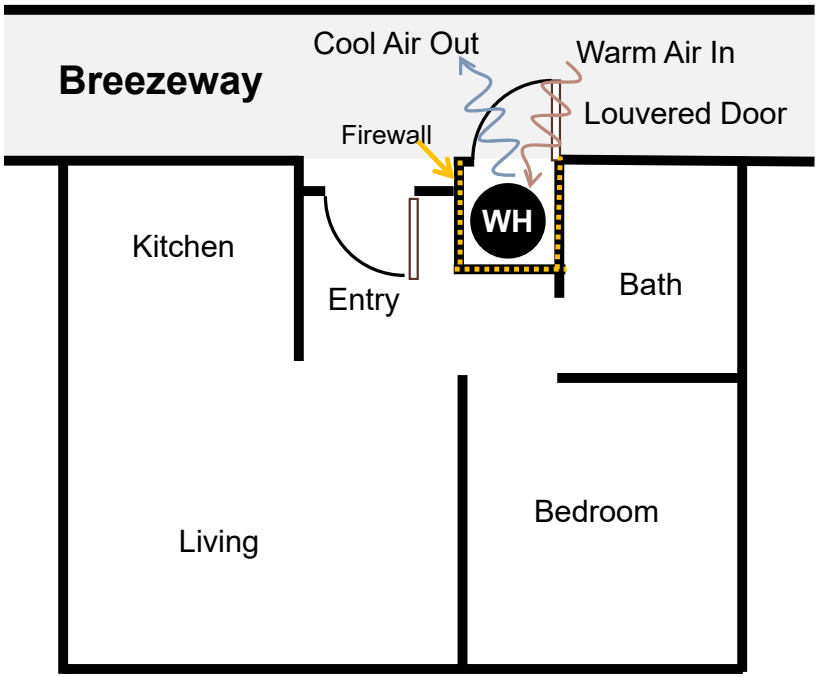
Floor Plan Examples

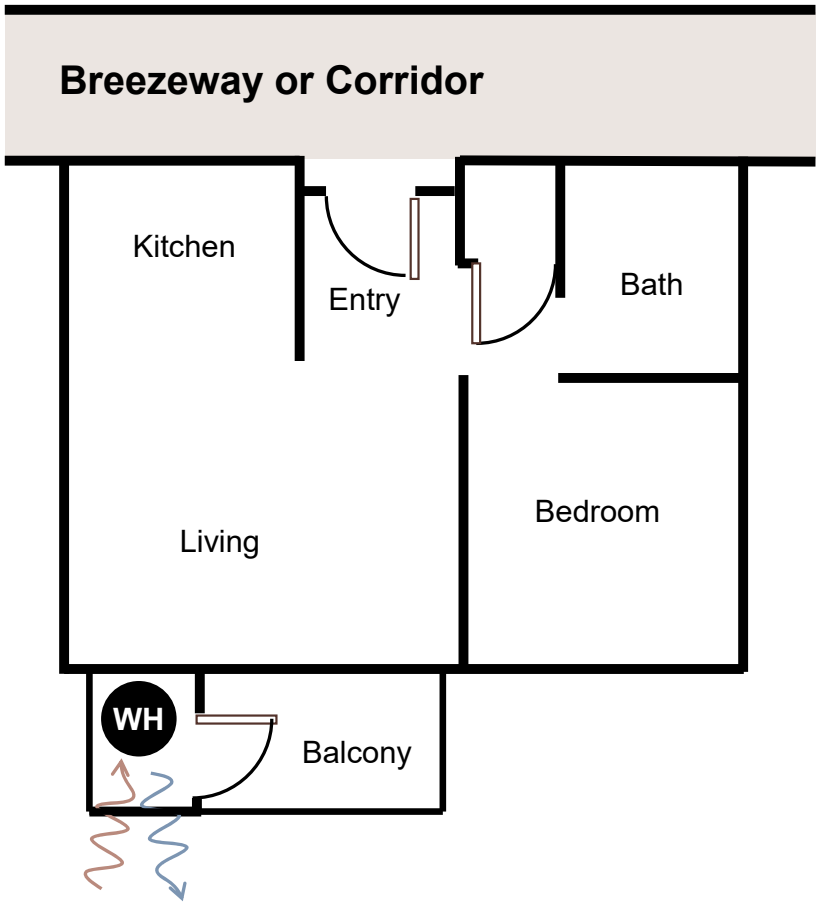
Multifamily

Corridor Closet

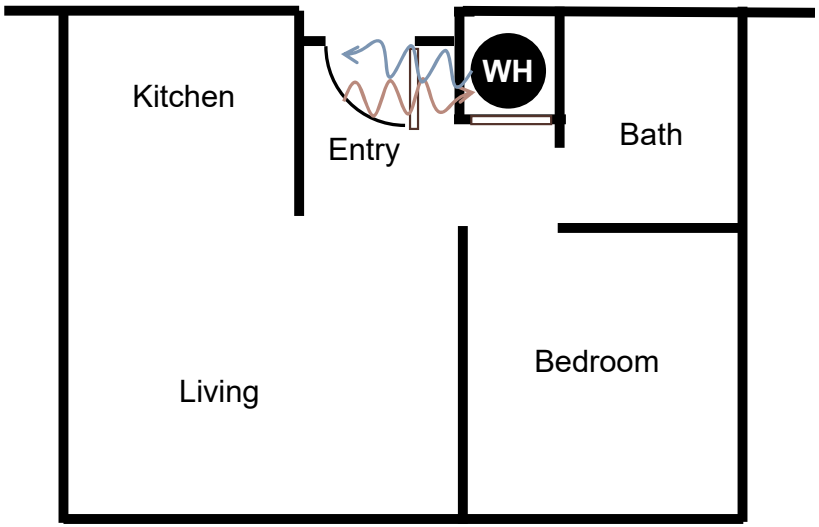


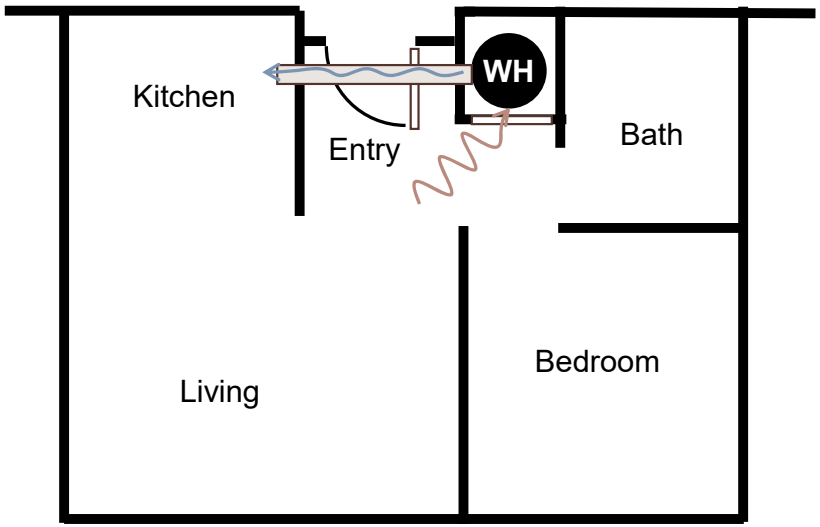
Exterior Closet Options





Interior Closet Options





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Heat Pump Water Heaters in Small Spaces Lab Testing: "The Amazing Shrinking Room"

https://neea.org/resources/heat-pump-water-heaters-in-small-spaces-lab-testing-the-amazing-shrinking-room

Laboratory Testing of Heat Pump Water Heater Performance: Impact of Airflow and Space Configurations

https://etcc-ca.com/reports/code-readiness-laboratory-testing-heat-pump-water-heater-performance-impact-airflow-and