In Search of the Magic Box: A Review of Crossover Conditioning/Ventilation/ Dehumidification Devices on the US Market

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Definition

Crossover Device:

Machine that handle space conditioning, ventilation, and dehumidification (and maybe water heating) in a single package

Nilan – Compact P

Daikin

Zehnder

Drexel und Weiss

?

?


MINOTAIR

Energie Sprong

REALIZE
RMI

“catalyzing the development of a speedy and scalable process for zero-carbon residential retrofits”

+

“REALIZE is currently seeking an **integrated set of mechanical systems** for the retrofit pilot.”

RetrofitNY
NYSERDA

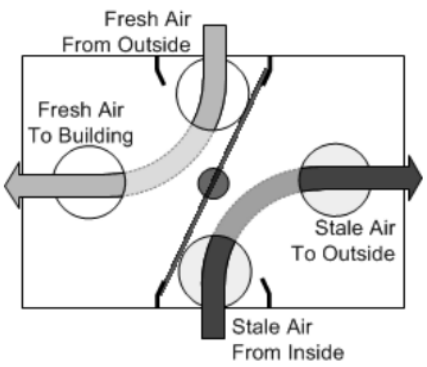
“aggressively working to help create new solutions to renovate multifamily buildings”

Energiesprong “energy pod” example

- Heat pump for space conditioning and DHW
- ERV
- PV inverter
- DHW tank

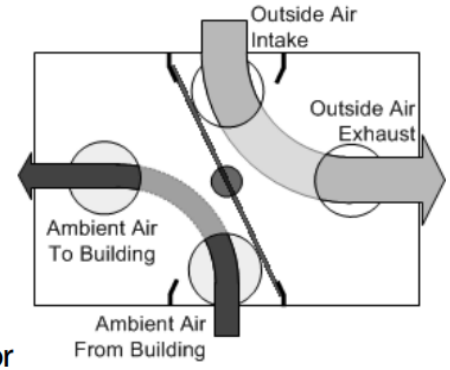
Crossover Device Description

Ventilation Mode



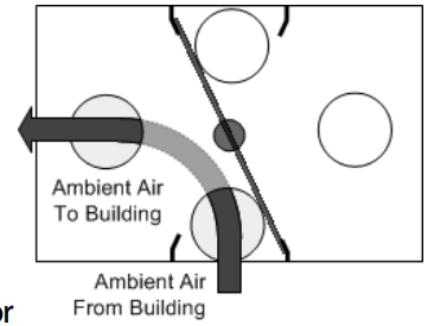
or

Recirculation Mode w/ compressor

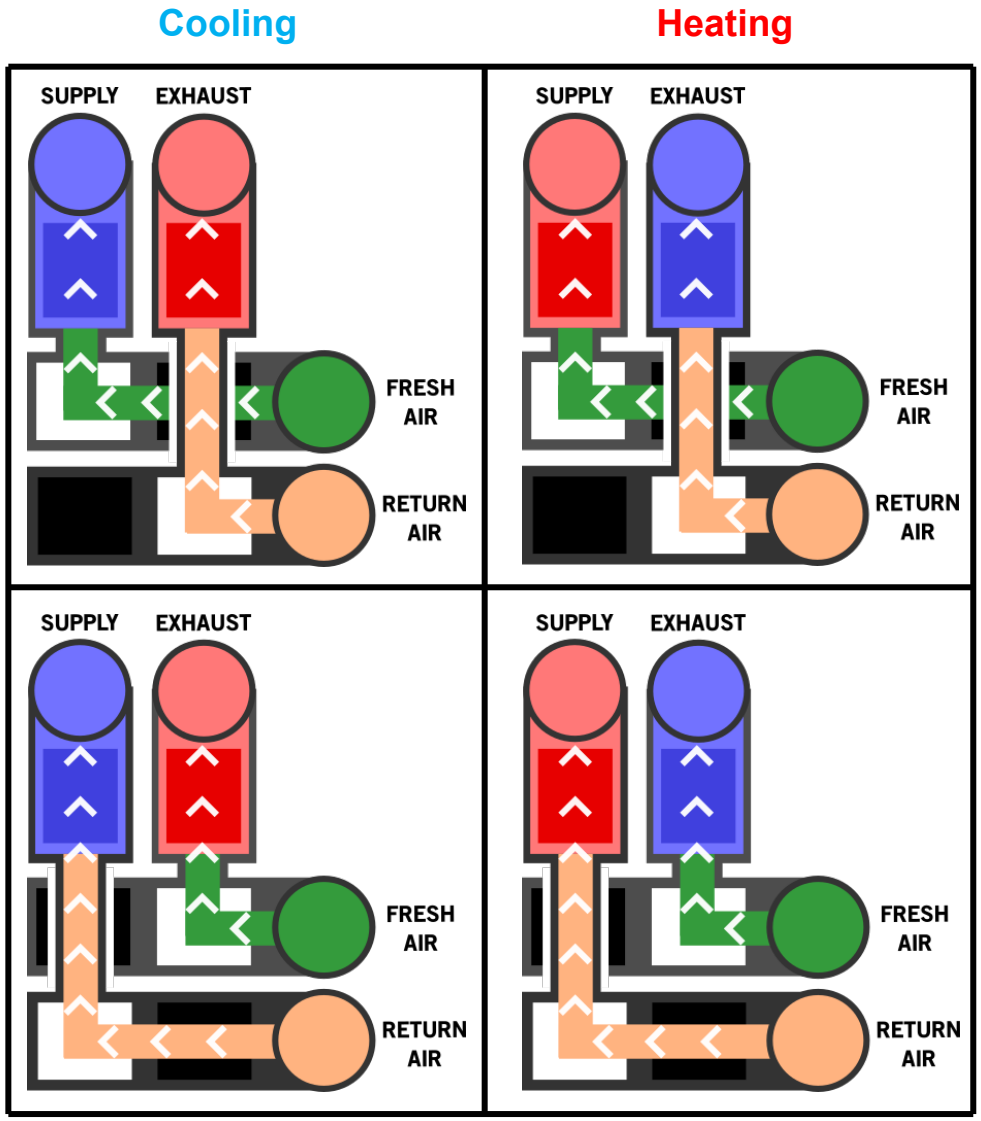


or

Recirculation Mode w/o compressor



Crossover Device Description



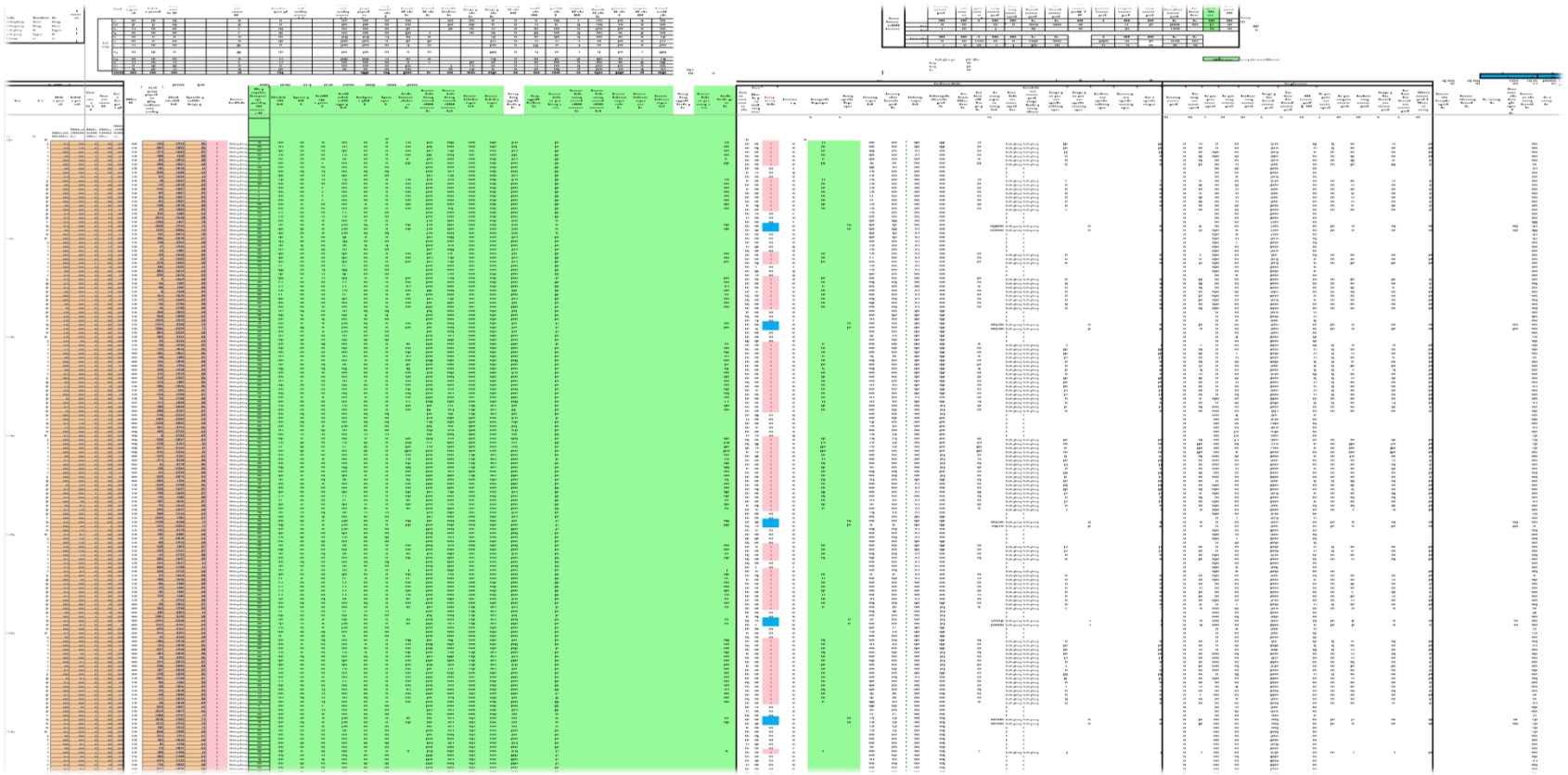
Device Details

		Minotair Pentacare-V12	Build Equinox CERV2
Unique features	Heating capacity (Btu/h)[1]	8700	4660 (recirc), 6631 (vent)
	Cooling capacity (Btu/h)[2]	11200	2230 (recirc), 5314 (vent)
	Sensible cooling capacity (Btu/h)[3]	8100	1318 (recirc), 3891 (vent)
	Nominal heating efficiency (COP),[1] recirculation mode	3.00	3.60
	Nominal cooling efficiency (COP),[2] recirculation mode	3.40	3.20
	Nominal heating efficiency (COP), ventilation mode	?	4.90
	Nominal cooling efficiency (COP), ventilation mode	?	7.60
	Dehumidification (Liters/day)	53	9.6 (recirc), 14.9 (vent)
	Compressor speed	constant	variable
	Max fresh air flow rate (cfm)	180	300
	Max recirculation air flow rate (cfm)	250	300
	Fan power (total for 2 fans) (W)	116 (180 cfm), 136 W (250 cfm)	66 (180 cfm), 150 (250 cfm)
	Compressor power (W)	725	202 (recirc), 204 (vent)
	Filtration	MERV 15 HEPA	2x MERV 13
	Maximum static pressure (inches)	1.6	0.9"SP at 150 cfm
	Connection orientation	vertical	vertical
	Dimensional orientation	horizontal	vertical
	System dimensional volume (ft3)	20	41
	System dimensional footprint (ft2)	9	7
Features in common	Heat recovery core	active heat pump	
	Modes	alternating ventilation and recirculation	
	Dehumidification	yes	
	Pollutants detected and controlled	CO2, VOCs	
	Fans	2 ECM type	
	Free cooling mode	yes	
	Optional auxiliary duct heater	up to 5 kW electric resistance	
	Warranty	5 years	

[1]at 47 F [2]at 95 DB / 75 WB outside, 80 DB / 67 WB inside [3]Assuming 250 cfm and 50 F supply

Methodology Overview

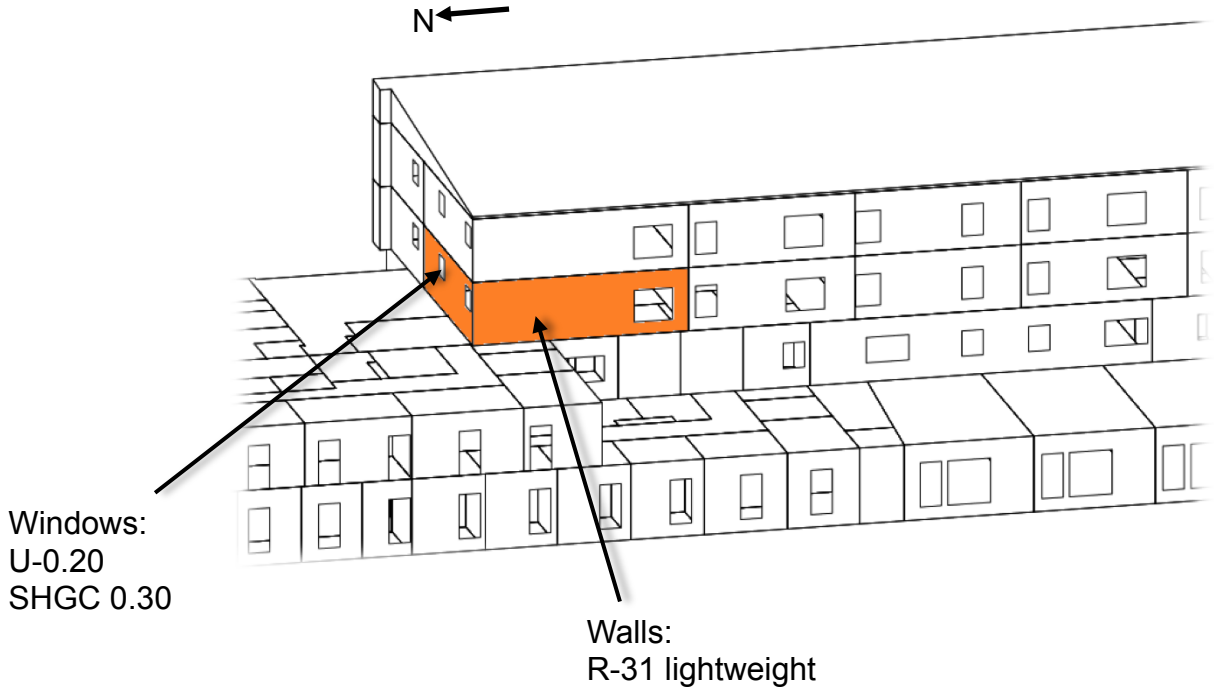
1. **Calculate hourly heating and cooling loads** for a representative apartment
2. Assume the device to have an HRV/ERV efficiency of 0.75 and **determine the associated fan and compressor energy**
3. **Calculate fan and compressor energy to meet the hourly load**.
4. Sum these values over the year to **calculate the average heating COP and cooling COP**.
5. **Calculate the average annual W/cfm** (fan power plus compressor power divided by cfm of OA that is equivalent to the required constant OA rate).

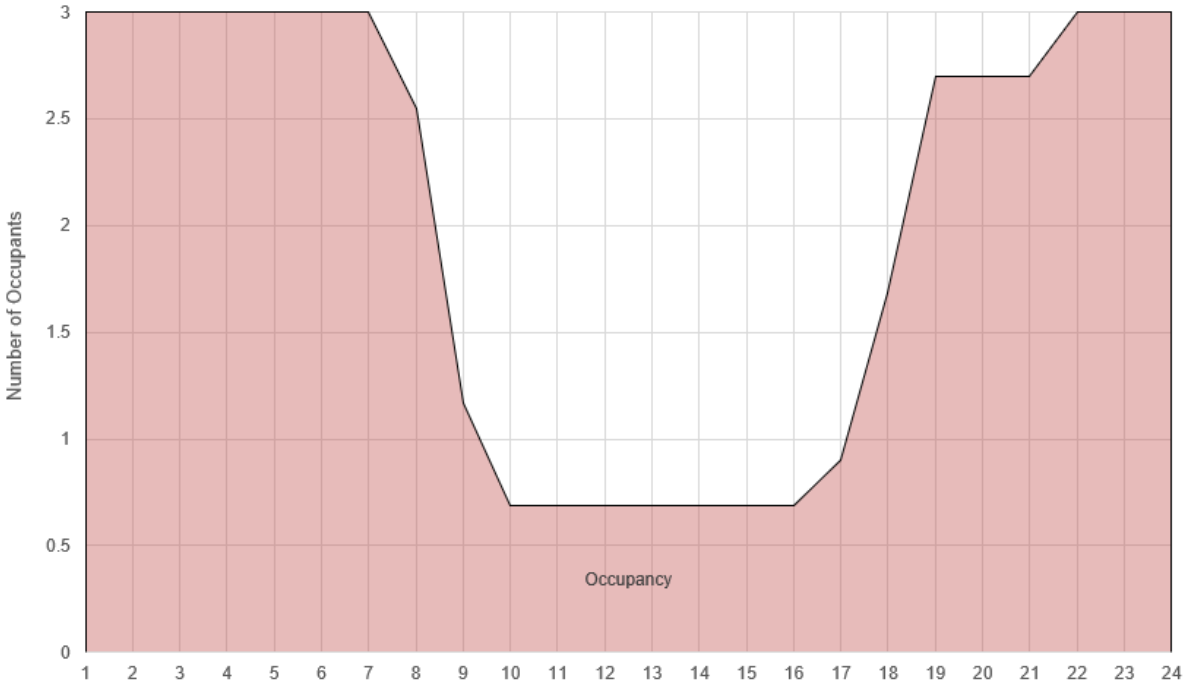


Representative Apartment

Construction types
&
space details

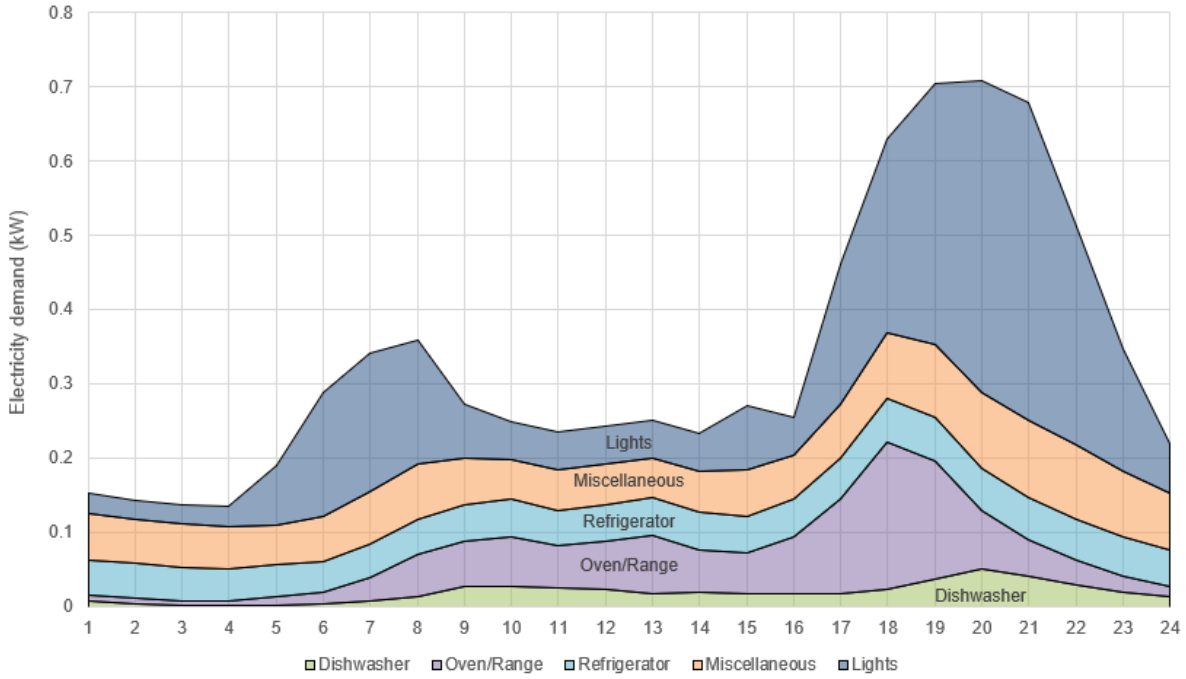
- 1,032 ft^2
- North and west exposures
- 2 bedrooms
- 1 bathroom
- 3 occupants
- 0.05 ach (at atmospheric pressure)



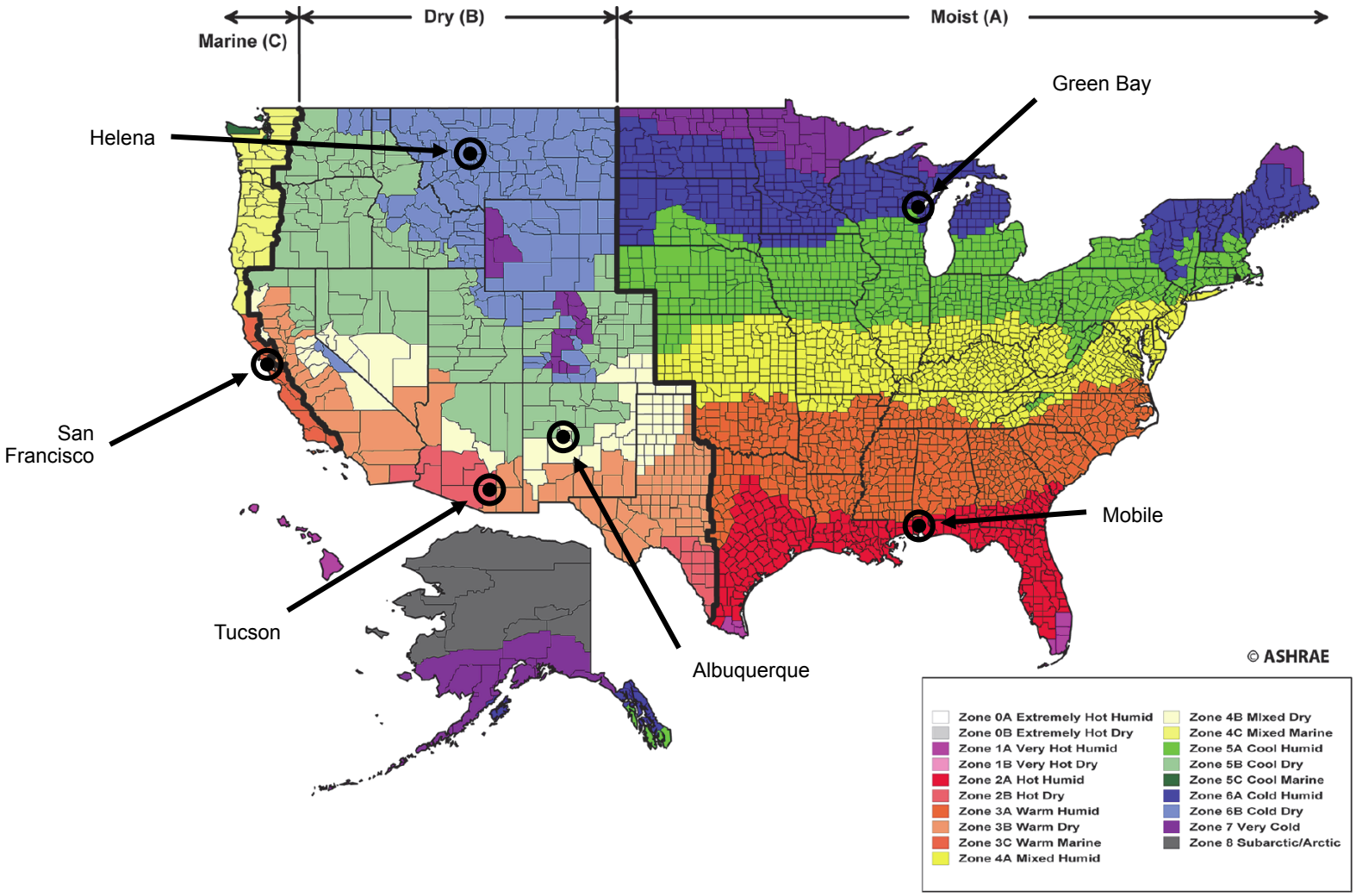


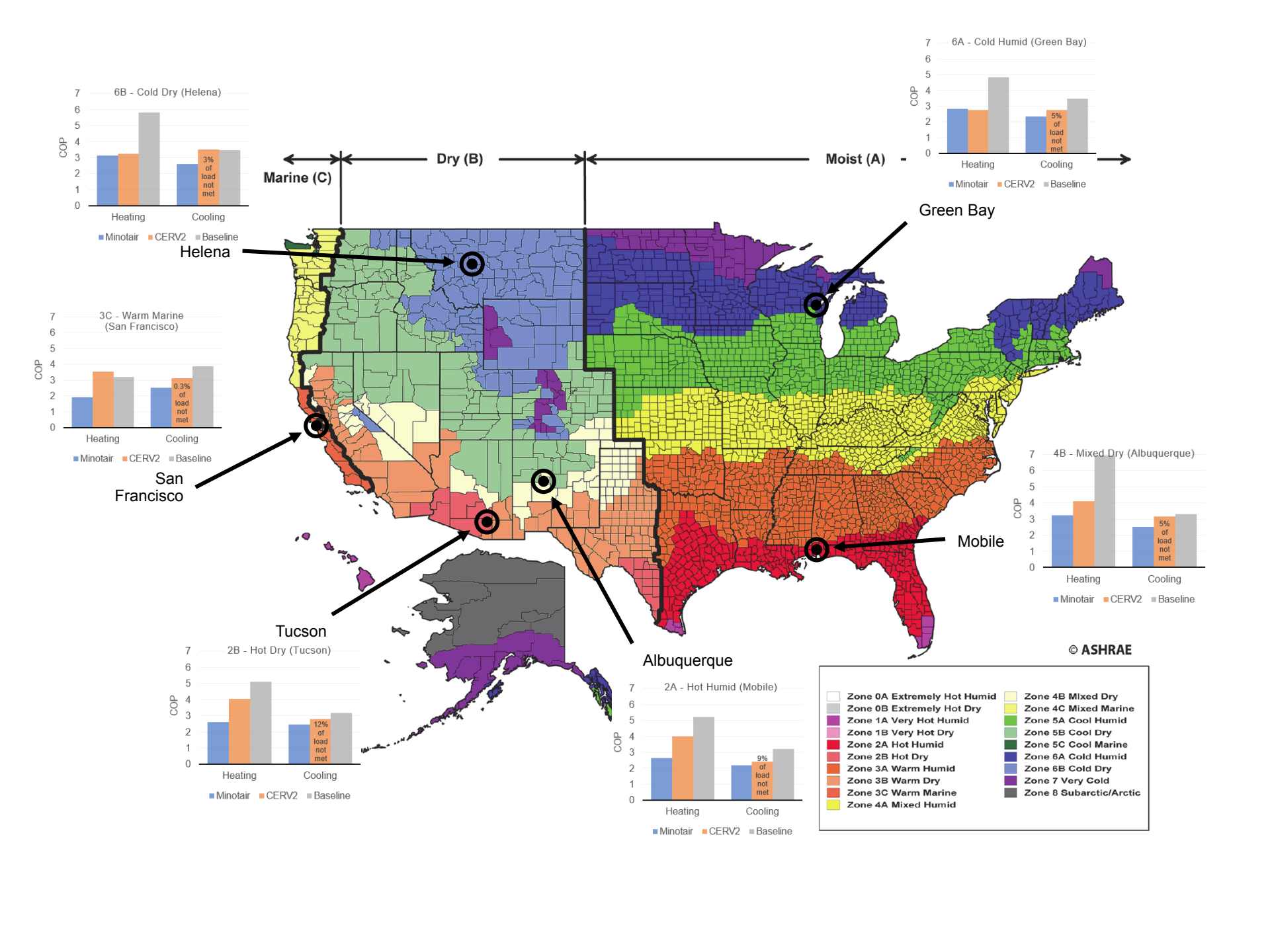
Representative Apartment Unit

daily schedules
&
peak loads



	Peak electricity consumption (Btu/h)	Peak sensible heat gain (Btu/h)	Peak latent heat gain (Btu/h)
Lights	997	997	0
Miscellaneous	517	481	0
Refrigerator	365	365	0
Oven/Range	399	160	120
Dishwasher	135	81	20


Marine (C)
Dry (B)
Moist (A)
Helena
Green Bay
San Francisco
Tucson
Albuquerque
Mobile
© ASHRAE
Zone 0A Extremely Hot Humid
Zone 0B Extremely Hot Dry
Zone 1A Very Hot Humid
Zone 1B Very Hot Dry
Zone 2A Hot Humid
Zone 2B Hot Dry
Zone 3A Warm Humid
Zone 3B Warm Dry
Zone 3C Warm Marine
Zone 4A Mixed Humid
Zone 4B Mixed Dry
Zone 4C Mixed Marine
Zone 5A Cool Humid
Zone 5B Cool Dry
Zone 5C Cool Marine
Zone 6A Cold Humid
Zone 6B Cold Dry
Zone 7 Very Cold
Zone 8 Subarctic/Arctic


6B - Cold Dry (Helena)
COP
3% of load not met
Heating
Cooling
Minotair
CERV2
Baseline
6A - Cold Humid (Green Bay)
5% of load not met
Marine (C)
Dry (B)
Moist (A)
Helena
Green Bay
3C - Warm Marine (San Francisco)
0.3% of load not met
San Francisco
Mobile
4B - Mixed Dry (Albuquerque)
5% of load not met
Tucson
2B - Hot Dry (Tucson)
12% of load not met
Albuquerque
2A - Hot Humid (Mobile)
9% of load not met
© ASHRAE
Zone 0A Extremely Hot Humid
Zone 0B Extremely Hot Dry
Zone 1A Very Hot Humid
Zone 1B Very Hot Dry
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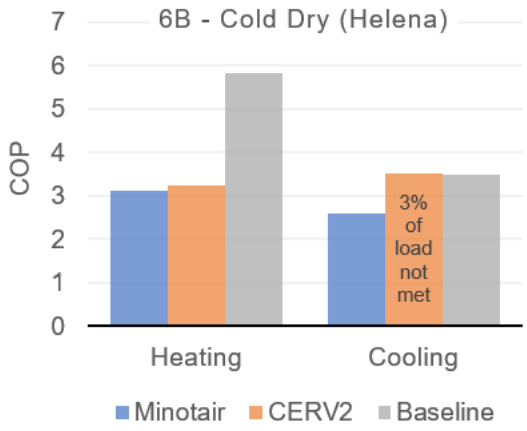
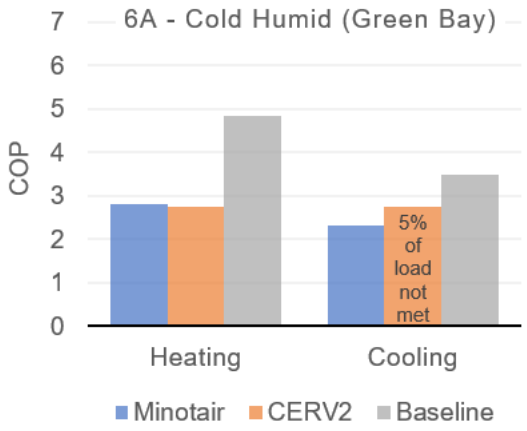
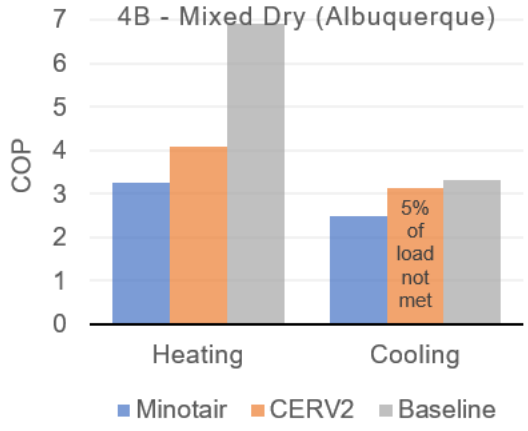
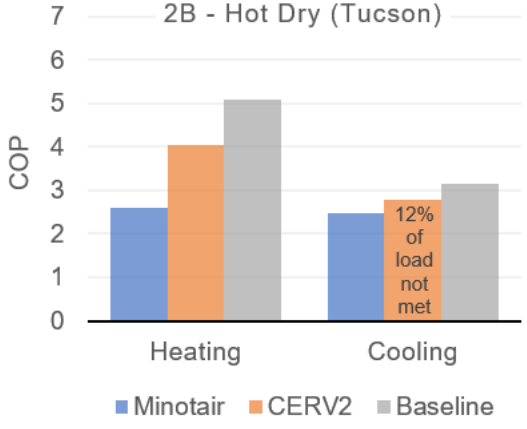
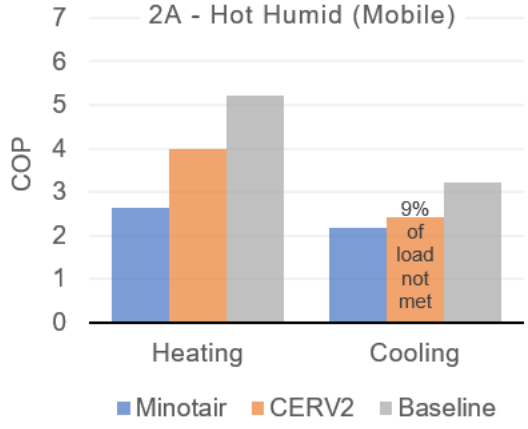
Total Annual COP

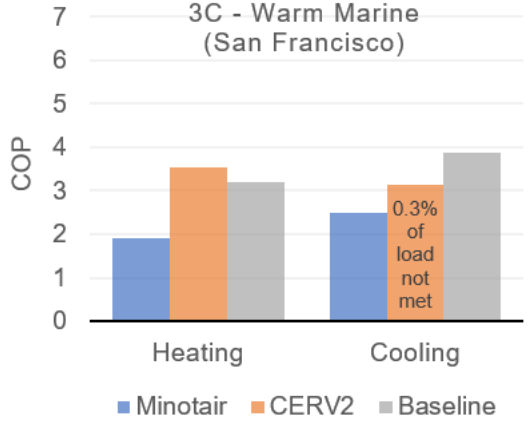




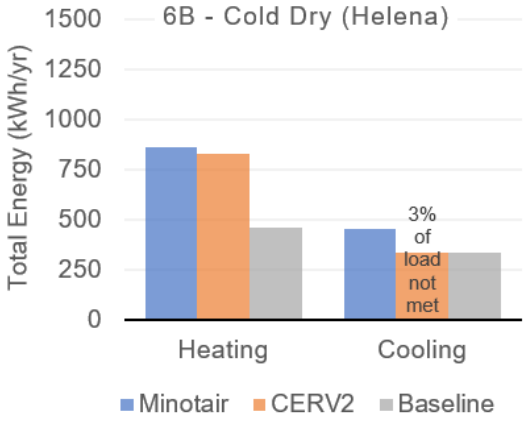


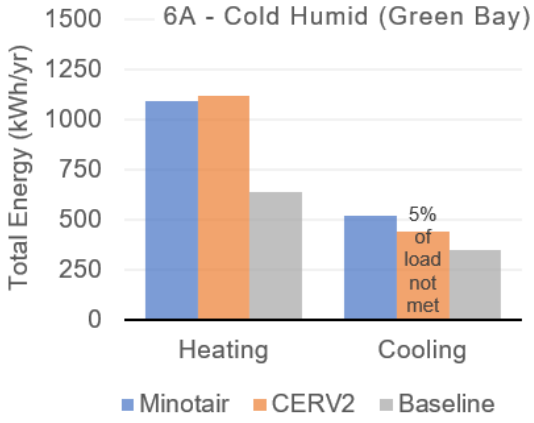


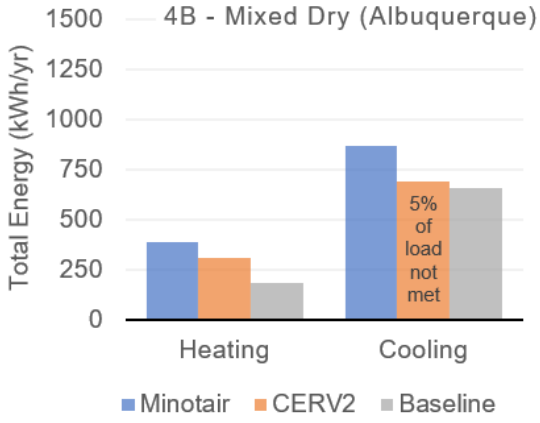


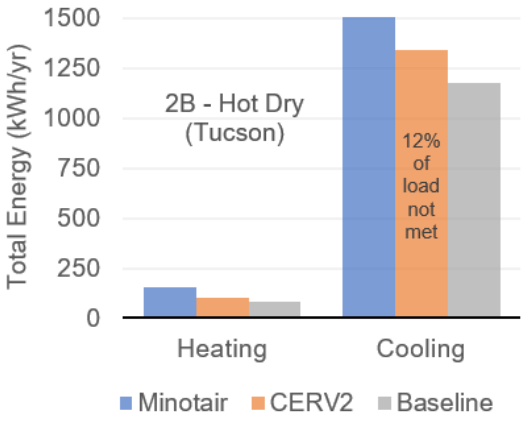


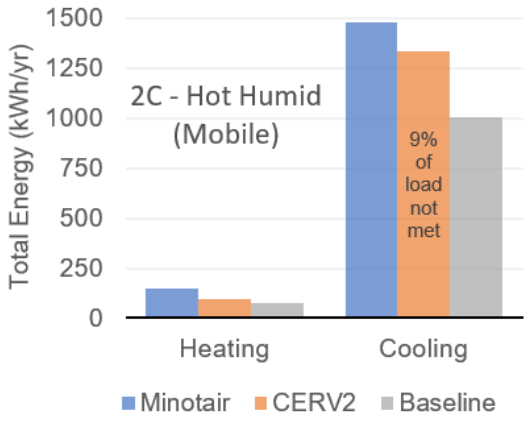
Total Annual Energy Consumption

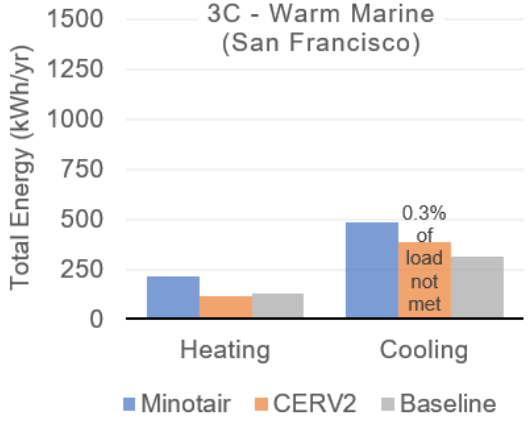












Results

		Location					
	ASHRAE Climate Zone	6B - Cold Dry	6A - Cold Humid	4B - Mixed Dry	2B - Hot Dry	2A - Hot Humid	3C - Warm Marine
Device	**WUFI Passive Entry and Annual Efficiency**	Helena, MT	Green Bay, WI	Albuquerque, NM	Tucson, AZ	Mobile, AL	San Francisco, CA
Minotair Pentacare-V12	Electric efficiency [W/cfm]	1.75	1.77	1.47	1.36	1.20	1.13
	Annual heating coefficient of performance (COP)	1.47	1.26	2.07	2.32	2.03	no heating required
	Annual cooling COP	2.70	2.39	2.62	2.62	2.28	2.51
	Combined Annual Heating COP	3.12	2.81	3.25	2.60	2.64	1.90
	Combined Annual Cooling COP	2.61	2.32	2.50	2.47	2.17	2.50
Build Equinox CERV2	Electric efficiency [W/cfm]	1.19	1.19	0.78	0.45	0.41	0.42
	Annual heating coefficient of performance (COP)	1.23	1.09	1.60	1.79	1.58	no heating required
	Annual cooling COP**	3.47	2.73	3.07	2.61	2.34	3.13
	Combined Annual Heating COP	3.25	2.75	4.09	4.03	4.00	3.54
	Combined Annual Cooling COP	3.51	2.74	3.14	2.78	2.41	3.13
Baseline: ERV + Mini-Split	Electric efficiency [W/cfm]	0.85	0.85	0.85	0.85	0.85	0.85
	Annual heating coefficient of performance (COP)	1.87	1.54	2.69	2.96	2.68	no heating required
	Annual cooling COP	3.57	3.59	3.39	3.17	3.36	3.89
	Combined Annual Heating COP	5.81	4.84	6.92	5.10	5.21	3.19
	Combined Annual Cooling COP	3.48	3.48	3.30	3.16	3.21	3.86
	**% cooling load not met by CERV2	3.1%	4.8%	5.2%	12%	9.0%	0.27%

ERV

Indoor unit

Dehumidifier

Outdoor unit

System integration and CO2 control

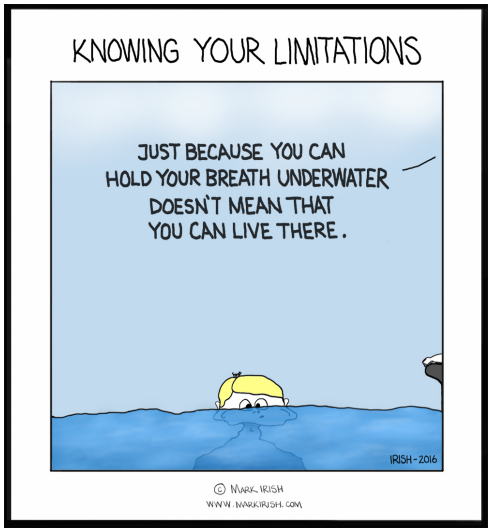
Limitations

1. Ability to provide cooling or heating in ventilation mode beyond bringing the supplied fresh air to the 75% effectiveness supply temperature that was **arbitrarily assumed for comparison's sake**

2. The COP values in the Results section also **do not include the benefits from free cooling**

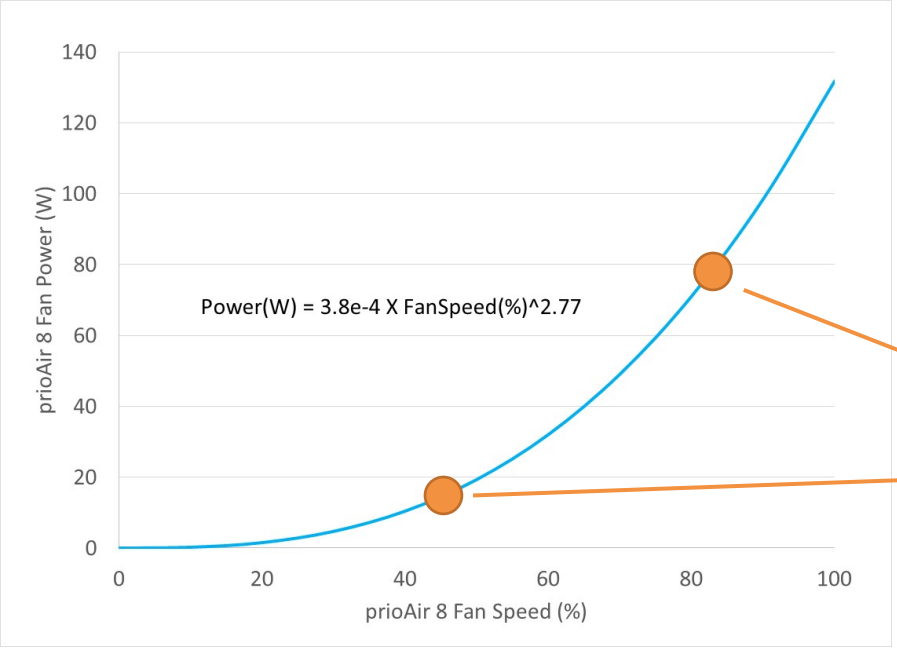
3. The calculation assumes a **constant (on/off) airflow rate** during recirculation mode

4. The calculation **does not account for CO2-controlled ventilation**.



Important Note: This analysis was done based on a combination of manufacturer-provided data (when available), publicly-available data (e.g., brochures, websites), and numerous assumptions. The results of this study represent neither actual performance of the devices nor theoretical performance of the devices. Rather, they represent only a comparison of the devices based on a large set of assumptions and using a methodology that, while not reflecting accurately the actual operation or energy consumption of the devices, allows for some measure of comparison in the WUFI Passive tool.

Fan Power as a Function of Air Flow Rate



CERV2

https://www.buildequinox.com/ → “Take Control”

https://www.buildequinox.com/ → “Take Control”

“Vermod” CERV Report

13 CERV® Homes in Vermont:
Keeping Occupants Healthy, Comfortable and Energy Efficient

The 13 Vermod-CERV homes have an annual occupancy energy usage of 3650 kWh/person.

HVAC in the Vermod study:
CERV, 1-ton cold climate heat pump, heat pump water heater

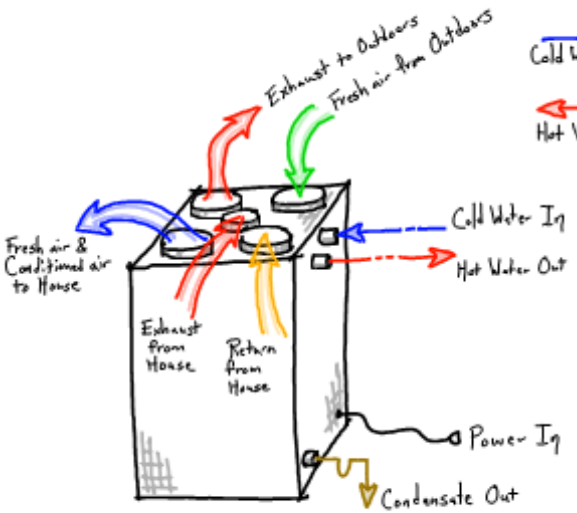
Next Steps

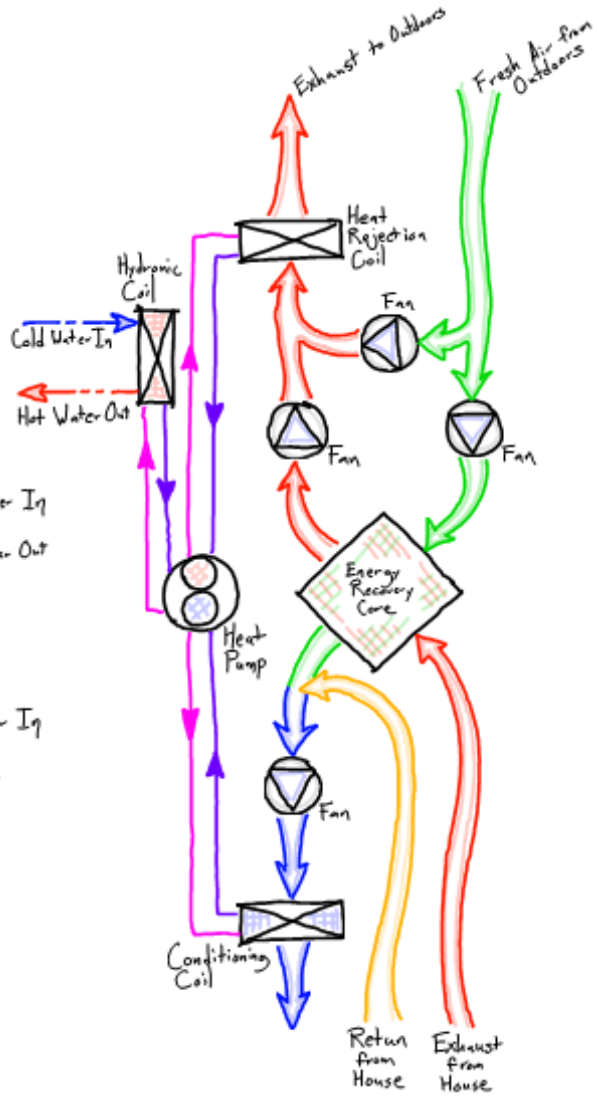
Analyze the upfront and **lifecycle cost**, including operating costs, of each option **accounting for all equipment needed to heat, cool, and manage humidity**.

Convince someone to make our pie in the sky a reality.

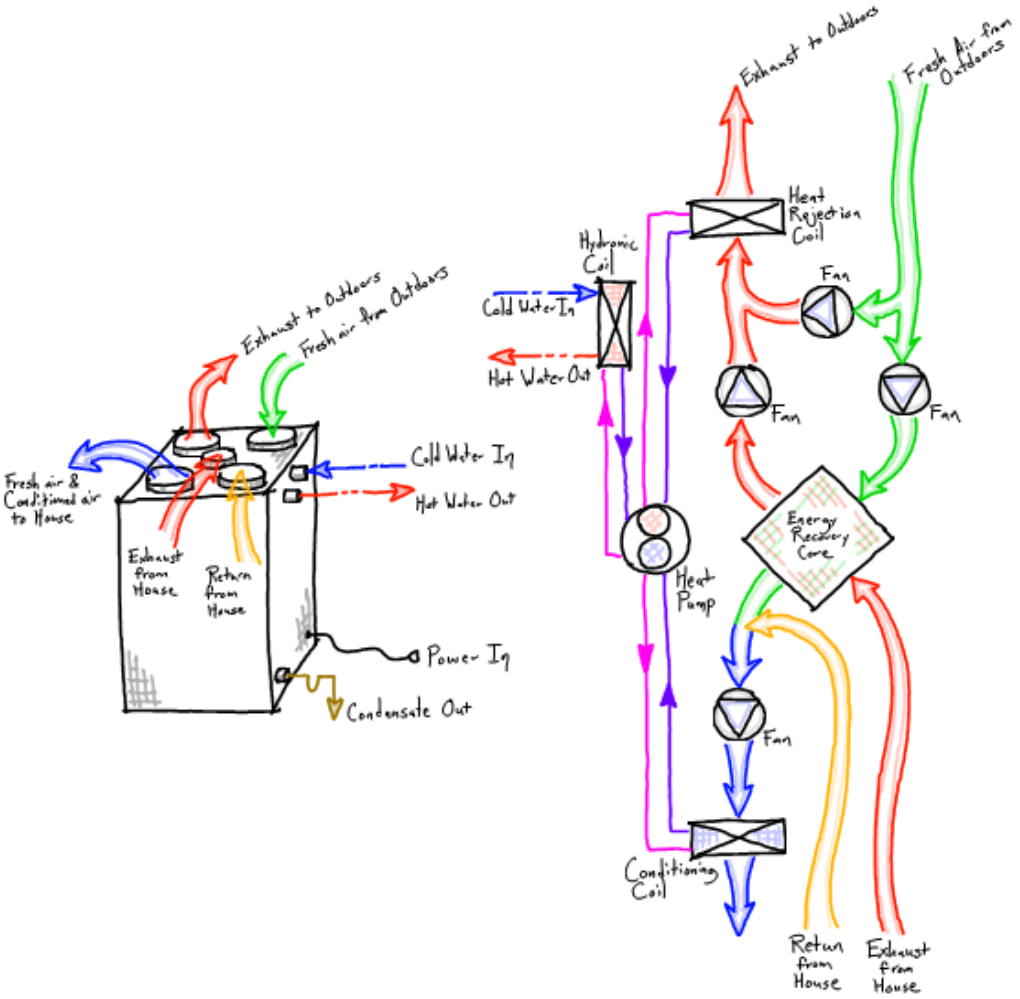
Pie in the Sky

- Ability to ventilate, exhaust, heat, cool, dehumidify, and generate hot water
- Passive ERV core
- Heat pump for additional heat recovery, domestic water heating, dehumidification, and reheat (if required)
- High COP, variable speed compressor and good fan power curve
- Natural refrigerant
- Good low-temperature performance
- Adequate capacity to handle all heating, cooling, and water heating loads
- Capable of continuous exhaust





Questions?



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Resources

Weather Files

- USA_MT_Helena.Rgnl.AP.727720_TMY3
- USA_WI_Green.Bay.726450_TMY2
- USA_NM_Albuquerque.Intl.AP.723650_TMY3
- USA_AZ_Tucson.Intl.AP.722740_TMY3
- USA_AL_Mobile-Downtown.AP.722235_TMY3
- USA_CA_San.Francisco.Intl.AP.724940_TMY3

Websites

https://www.buildequinox.com/
https://buildequinox.com/publications/
https://www.minotair.com/minotair-pentacare-v12_us/

Baseline Case:
ERV + Mini-split

Assumed indoor conditions:

Heating
68 F

Cooling
77 F dry bulb
50% RH

Assumed indoor unit fan power: 135 W

Assumed ERV efficiency: 0.85 W/cfm

Hypothetical mini-split performance used in calculations: