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STAENGL ENGINEERING

Deep dive into carbon impacts of mechanical system choices for passive house buildings

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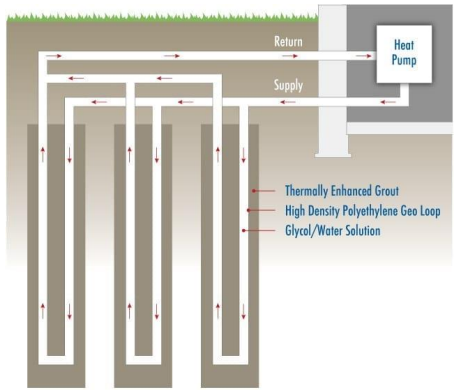
Don't lose sight of the 50,000 ft view: ***Where and What*** you build is the most important. Will it be loved? Will the space created by it be loved?

Learning Objective: Compare the Carbon Impacts of different HVAC, Dehumidification and Hot Water System Choices

- Passive House Multifamily Building is currently under construction
- IES VE used to energy model all HVAC cases against each other.
  - All systems use a **20 year** analysis time period for energy and refrigerant
  - The building has 45 apartments, 133 people, and 57,500 sq ft
- Hot water modeled with spreadsheets
  - 20 gallons per person per day *(note this is different than the 6.6 gpd in the PHIUS guidebook)*
- Equipment, piping, ductwork and accessories accounted for in the weight of each system and a simplified ***1 to 9 lbs CO2e / lb of equipment**** *depending on complexity* used to arrive at the embodied carbon of the systems. **** This is a very difficult number to attain and verify.***
- Refrigerants impacts are quantified using a leakage model and GWP20

Heating and Cooling Investigation

VRF……Mini Split……..……..Geothermal…….All-in-one (Ephoca)



Heating and Cooling: VRF (Variable Refrigerant Flow) * *Installed System*

HC1

Pieces of Equipment

- Mitsubishi VRF
- 47x vertical ducted indoor units
- 11x other indoor units
- 2x twelve-ton VRF outdoor units
- 1x fourteen-ton VRF outdoor units
- 10x branch controllers
- 58x Small ERVs (Panasonic FV-10VEC2)
- Refrigerant Piping
- Conditioning and Ventilation D
  Room-by-room

Critical Statistics

- 11,900 lbs of equipment
- 1130 lbs of refrigerant piping
- 20,726 lbs of ductwork and accessories
- 214 lbs of R-410A Refrigerant
- ***Leak Rate: 6%***
- ***EUI: 6.29 kBTU/sqft/yr***

Heating and Cooling: Mini Splits

HC2

Pieces of Equipment

- Mitsubishi Mini-Splits
- 47x vertical ducted indoor units
- 11x other indoor units
- 58x mini-split outdoor units
- 58x Small ERVs (Panasonic FV-10VEC2)
- Refrigerant Piping
- Conditioning and Ventilation Ductwork Room-by-room

Critical Statistics

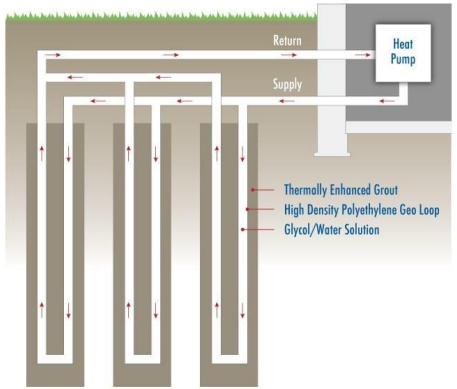
- 15,500 lbs of equipment
- 792 lbs of refrigerant piping
- 20,726 lbs of ductwork and accessories
- 121 lbs of R-410A Refrigerant
- ***Leak Rate: 5%***
- ***EUI: 8.12 kBTU/sqft/yr***

Heating and Cooling: Geothermal

HC3

Pieces of Equipment

- 47x ducted water-to-air heat pumps (waterfurnace)
- 11x console water-to-air heat pumps (waterfurnace)
- 2x circulation pumps
- 28x three hundred foot wells
- 58x Small ERVs (Panasonic FV-10VEC2)
- Conditioning and Ventilation Ductwork Room-by-room



Critical Statistics

- 9,520 lbs of equipment
- 19,900 lbs of water piping
- 20,726 lbs of ductwork and accessories
- 89 lbs of R-410A Refrigerant
- ***Leak Rate: 3%***
- ***EUI: 5.09 kBTU/sqft/yr***

Heating and Cooling: All-in-One (Ephoca)

HC4

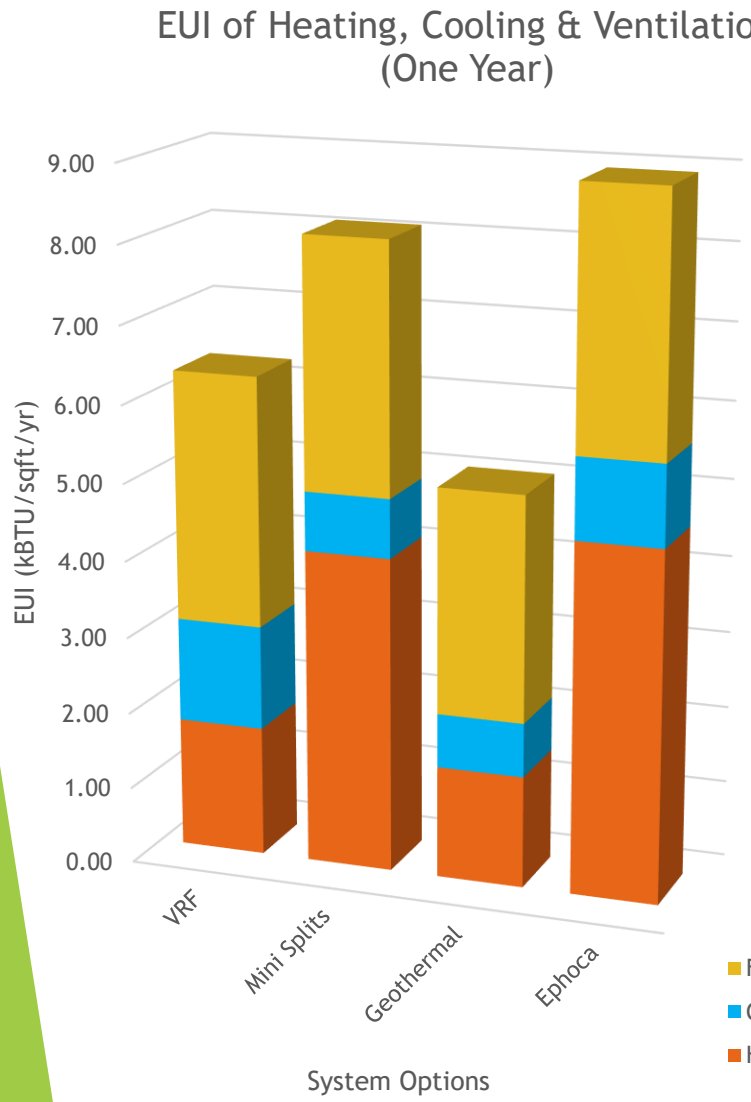
Pieces of Equipment

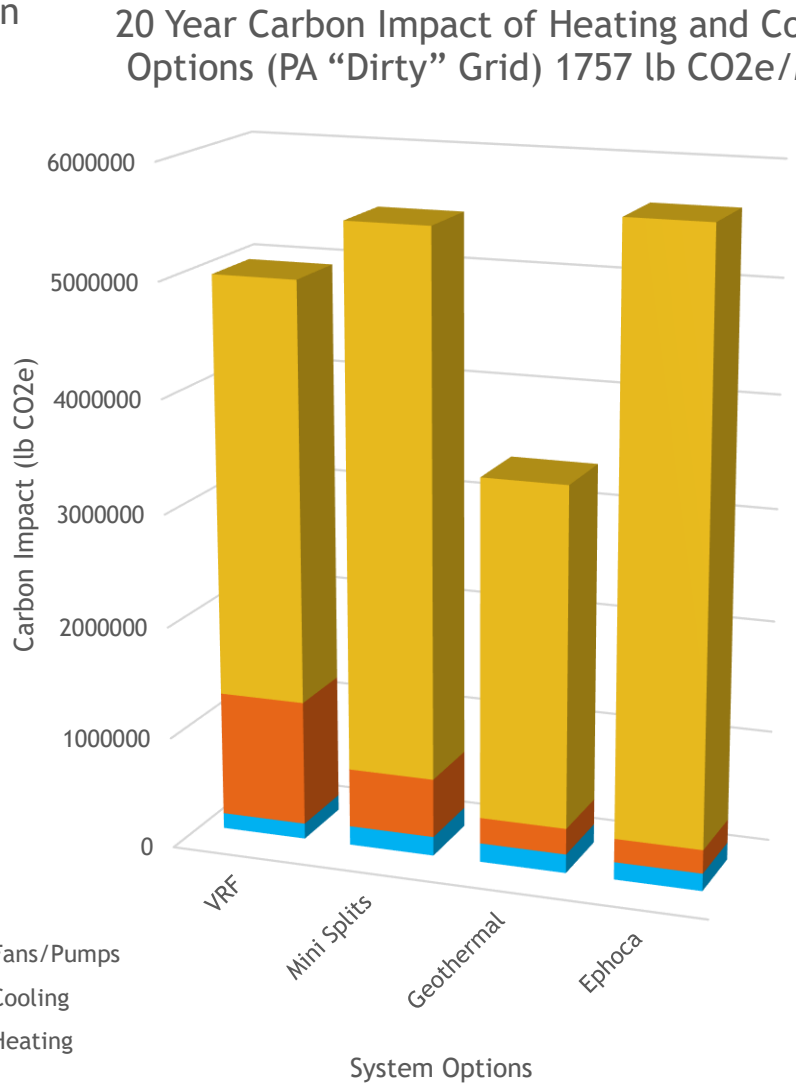
- 47x vertical ephoca heat pump/ERVs
- 11x horizontal ephoca heat pump/ERVs
- Conditioning and Ventilation Ductwork Room-by-room

Critical Statistics

- 15,237 lbs of equipment
- ***0 lbs of refrigerant piping***
- 12,250 lbs of ductwork and accessories
- 81 lbs of R-410A Refrigerant
- ***Leak Rate: 3%***
- ***EUI: 8.95 kBTU/sqft/yr***

Heating and Cooling Investigation Results





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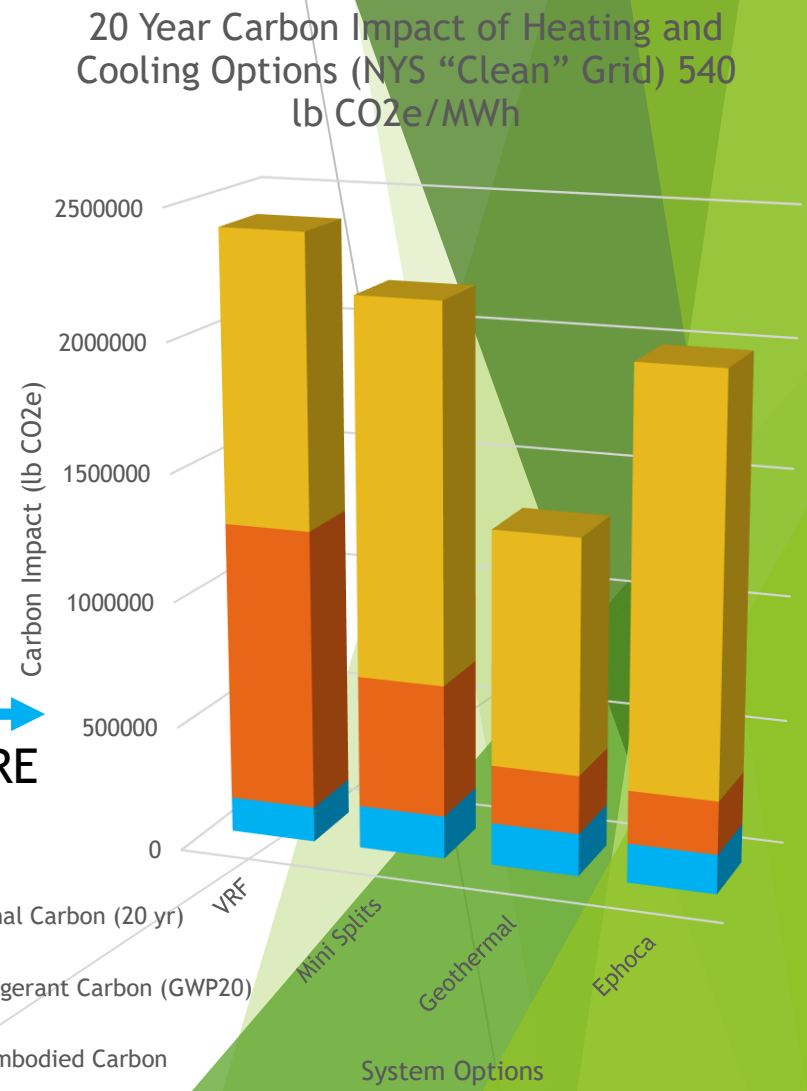
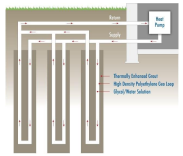


Heating and Cooling Investigation Takeaways

- As the electrical grid gets cleaner (renewables added) the carbon impact of refrigerant becomes more pronounced as the impact of operational energy carbon is reduced.



- Geothermal is a clear winner in both operational and refrigerant carbon savings, however ***Geothermal wells are the trickiest system to get correct, you MUST have a rockstar geothermal well installer or do not consider it.***

- VRF and to a lesser degree mini-split heat pumps use a lot of refrigerant and are prone to leaks due to the large amount of field-installed piping. Even though the energy use is lower than other systems, the amount of refrigerant cancels out the carbon benefit.

- All-in-one systems like ephoca are compelling mainly due to their reduced system complexity and reduced refrigerant charge, even though they do use a little more energy
- VRF was chosen for the building many years ago due to limited roof space for mini splits, the site was too challenging for geothermal, and ephoca did not exist yet.

Dehumidification Investigation

Packaged DOAS……Split DOAS…Packaged Geothermal…Split Geothermal…Wall Dehumidifiers

Dehumidification: Packaged DOAS (Trane) * *Installed System*

DH1

Pieces of Equipment

- Subtract the 58x Small ERVs from the H/C analysis (Panasonic FV-10VEC2)
- Add Ventilation Ductwork From Rooftop to rooms
- Add a ten-ton Trane Horizon Dedicated Outside Air System

Critical Statistics

- 825 lbs of added equipment
- 20,726 lbs of added ductwork and accessories
- 35.6 lbs of R-410A Refrigerant
- ***Leak Rate: 3%***
- ***EUI: 1.58 kBTU/sqft/yr***

Dehumidification: Packaged DOAS (Swegon/Mitsubishi VRF)

DH2

Pieces of Equipment

- Subtract the 58x Small ERVs from the H/C analysis (Panasonic FV-10VEC2)
- Add Ventilation Ductwork From Rooftop to rooms
- Add a ten-ton VRF outdoor unit
- Add a Swegon Gold RX DOAS

Critical Statistics

- 90 lbs of subtracted equipment
- 16 lbs of refrigerant piping
- 20,726 lbs of added ductwork and accessories
- 39 lbs of R-410A Refrigerant
- ***Leak Rate: 5%***
- ***EUI: 1.35 kBTU/sqft/yr***

Dehumidification: Packaged Geothermal DOAS (Waterfurnace)

DH3

Pieces of Equipment

- Subtract the 58x Small ERVs from the H/C analysis (Panasonic FV-10VEC2)
- Add Ventilation Ductwork From Rooftop to rooms
- Add a ten-ton Waterfurnace Versatec 500
- 5x three hundred foot wells

Critical Statistics

- 380 lbs of subtracted equipment
- 20,726 lbs of added ductwork and accessories
- 13 lbs of R-410A Refrigerant
- ***Leak Rate: 3%***
- ***EUI: 1.06 kBTU/sqft/yr***

Dehumidification: Split Geothermal DOAS (Swegon/Waterfurnace Hydronic)

DH4

Pieces of Equipment

- Subtract the 58x Small ERVs from the H/C analysis (Panasonic FV-10VEC2)
- Add Ventilation Ductwork From Rooftop to rooms
- Add a ten-ton water-to-water heat pump
- Add a Swegon Gold RX DOAS
- 5x three hundred foot wells

Critical Statistics

- 795 lbs of subtracted equipment
- 20 lbs of water piping
- 20,726 lbs of added ductwork and accessories
- 4 lbs of R-410A Refrigerant
- ***Leak Rate: 3%***
- ***EUI: 0.90 kBTU/sqft/yr***

Dehumidification: Wall Mounted Dehumidifiers

DH5

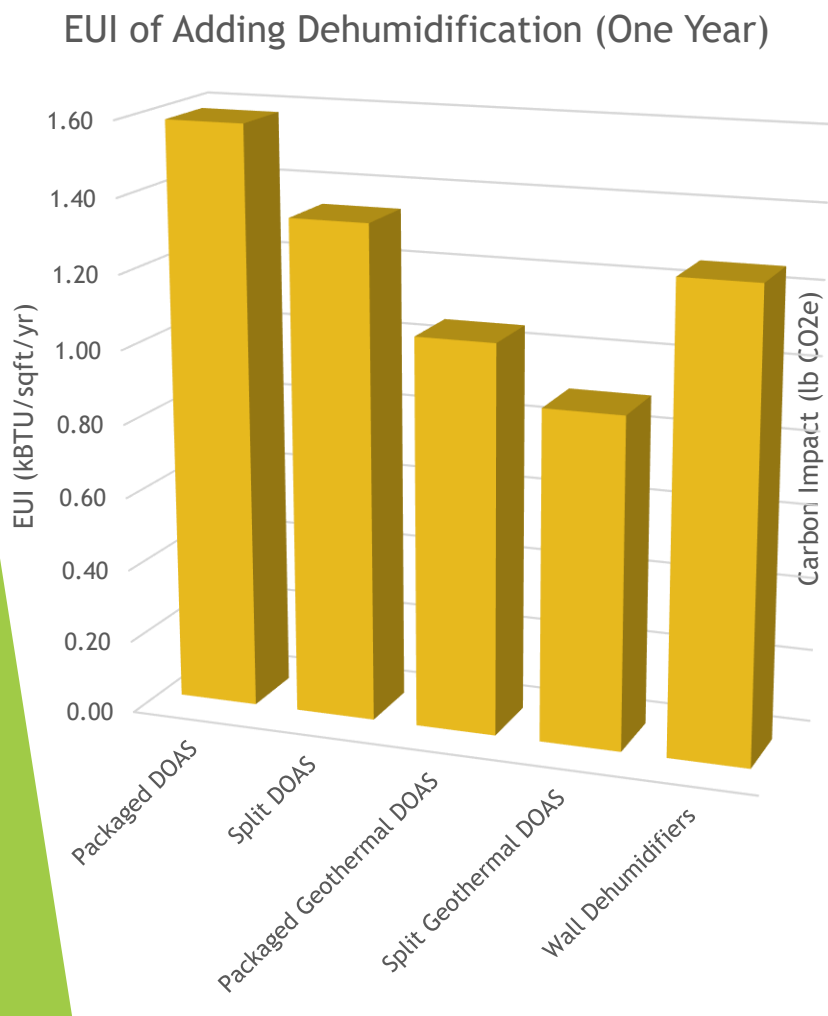
Pieces of Equipment

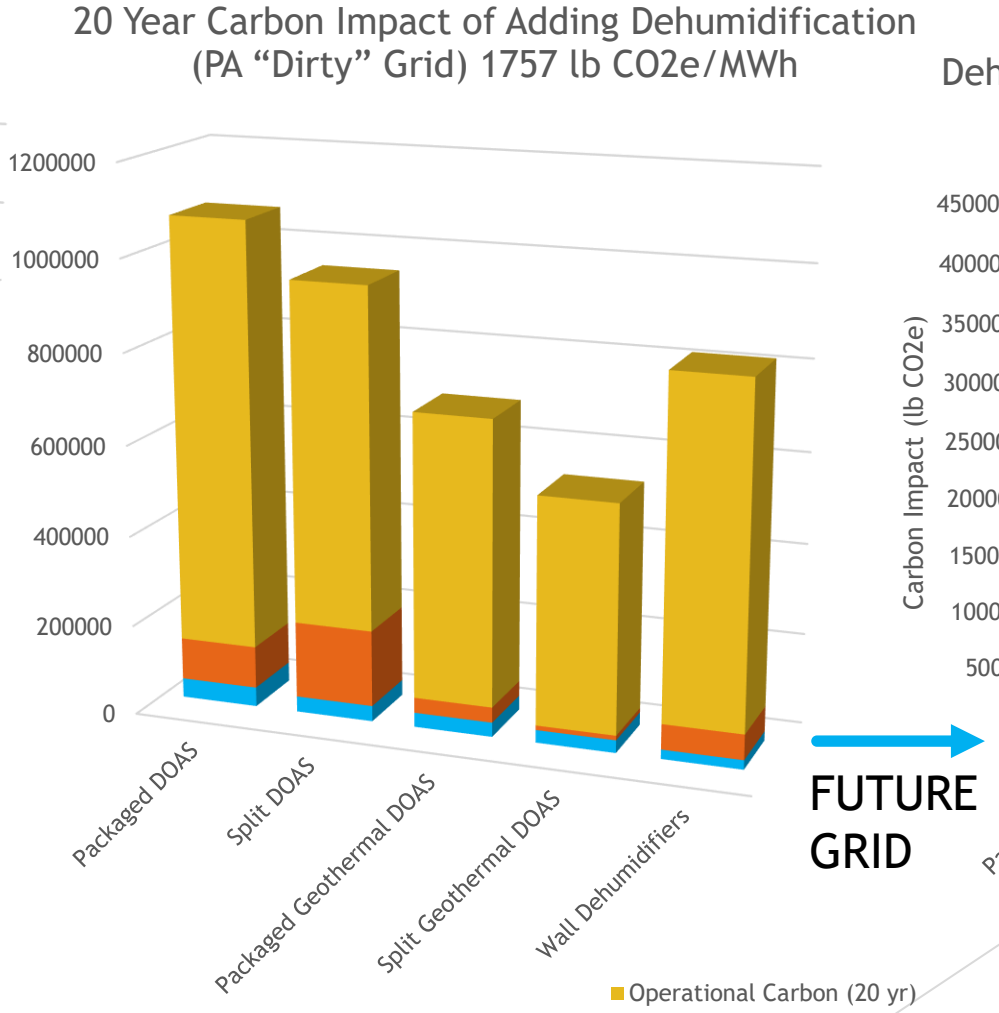
- Add 58x wall mounted dehumidifiers (Innovative Dehumidifer IW-25-4)

Critical Statistics

- 2262 lbs of added equipment
- 168 lbs of condensate piping
- 24.3 lbs of R-134A Refrigerant
- ***Leak Rate: 3%***
- ***EUI: 1.26 kBTU/sqft/yr***

Dehumidification Investigation Results





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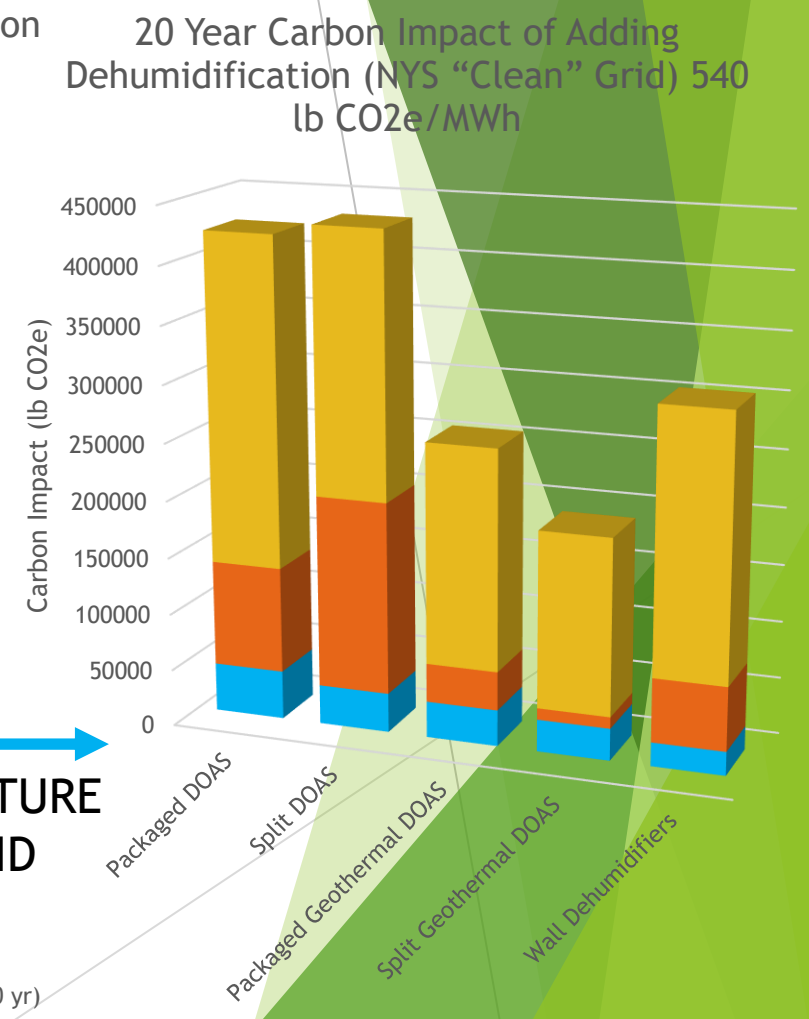
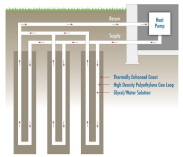


Dehumidification Investigation Takeaways

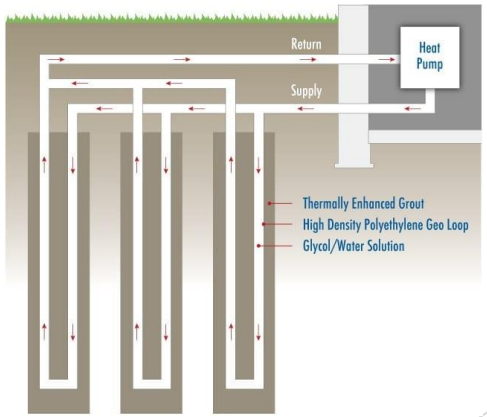


- As the electrical grid gets cleaner (renewables added) the carbon impact of refrigerant becomes more pronounced as the impact of operational energy carbon is reduced.
- Geothermal is again a clear winner in both operational and refrigerant carbon savings but again, ***Geothermal wells are the trickiest system to get correct, you MUST have a rockstar geothermal well installer or do not consider it.***
- The energy efficiency gains of using a high performance ERV like swegon is somewhat counteracted by the fact that a VRF conditioning system is required to add dehumidification to the unit, which is more prone to refrigerant leaks than a packaged alternative.
- All-in-one systems like ephoca require wall mounted dehumidifiers in many climate areas; wall mounted dehumidifiers are also easy to install.
- Rooftop DOAS systems require a lot of extra ductwork over using wall mounted dehumidifiers.
- A packaged DOAS was chosen for the building many years ago due to first cost, the site was too challenging for geothermal, and ephoca did not exist yet.

Heat Pump Domestic Hot Water Investigation

Distributed Tanks…Central CO2 with HP/EL recirc…Central Geothermal…Central VRF

SAN CO_2



Hot Water: Distributed Tanks (Rheem) * *Installed System*

WH1

Pieces of Equipment

- 28x 80 gallon tank type heat pump hot water heaters
- 28x expansion tanks

Critical Statistics

- 7094 lbs of equipment
- 3600 lbs of condensate piping and ductwork
- 25.2 lbs of R-134A Refrigerant
- ***Leak Rate: 3%***
- ***EUI: 3.23 kBTU/sqft/yr***

Hot Water: Central *CO2 with HP Recirc (Swegon + Rheem)*

WH2

Pieces of Equipment

- 7x CO2 heat pump hot water heaters
- 8x 120-gallon hot water storage tanks
- 1x expansion tank
- 3x heat pumps to handle recirculation losses
- 1x recirculation pump

SAN CO_2

Critical Statistics

- 4370 lbs of equipment
- 4470 lbs of hot water piping
- 3 lbs of R-134A Refrigerant
- 21 lbs of CO2 refrigerant
- ***Leak Rate: 3%***
- ***EUI: 2.96 kBTU/sqft/yr (Primary)***
- ***EUI: 0.14 kBTU/sqft/yr (Recirc)***

Hot Water: Central *CO2 with Electric Recirc (Swegon)*

WH2A

Pieces of Equipment

- 7x CO2 heat pump hot water heaters
- 8x 120-gallon hot water storage tanks
- 1x expansion tank
- 1x electric resistance tank to handle recirculation losses
- 1x recirculation pump

Critical Statistics

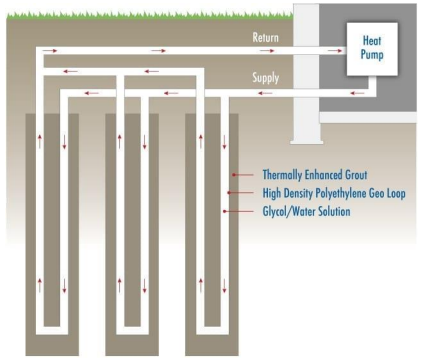
- 3882 lbs of equipment
- 4470 lbs of hot water piping
- 21 lbs of CO2 refrigerant
- ***Leak Rate: 3%***
- ***EUI: 2.96 kBTU/sqft/yr (Primary)***
- ***EUI: 0.51 kBTU/sqft/yr (Recirc)***

Hot Water: Central *Geothermal*

WH3

Pieces of Equipment

- 1x nine-ton Water-to-water heat pump (Waterfurnace NEW)
- 8x 120-gallon hot water storage tanks
- 1x expansion tank
- 1x recirculation pump
- 2x equipment pumps
- 4x three-hundred-foot wells



Critical Statistics

- 2832 lbs of equipment
- 7194 lbs of hot water and geothermal piping
- 4 lbs of R-134A refrigerant
- ***Leak Rate: 3%***
- ***EUI: 3.05 kBTU/sqft/yr (Primary)***
- ***EUI: 0.29 kBTU/sqft/yr (Recirc)***

Hot Water: Central *VRF*

WH4

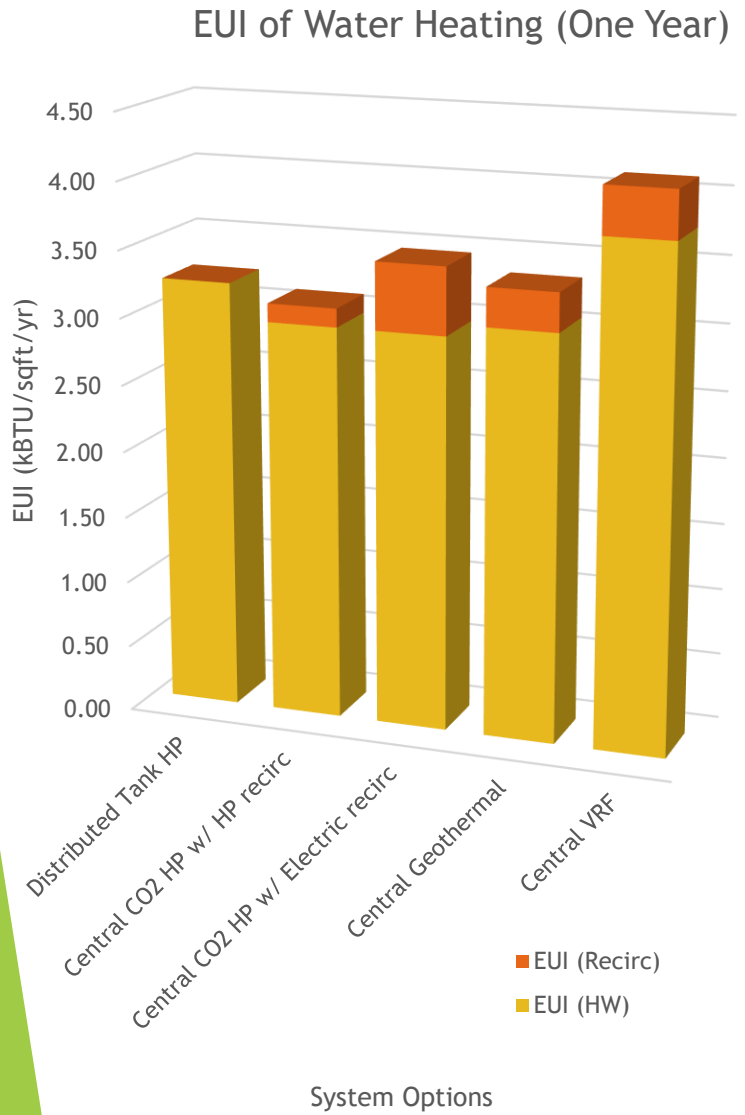
Pieces of Equipment

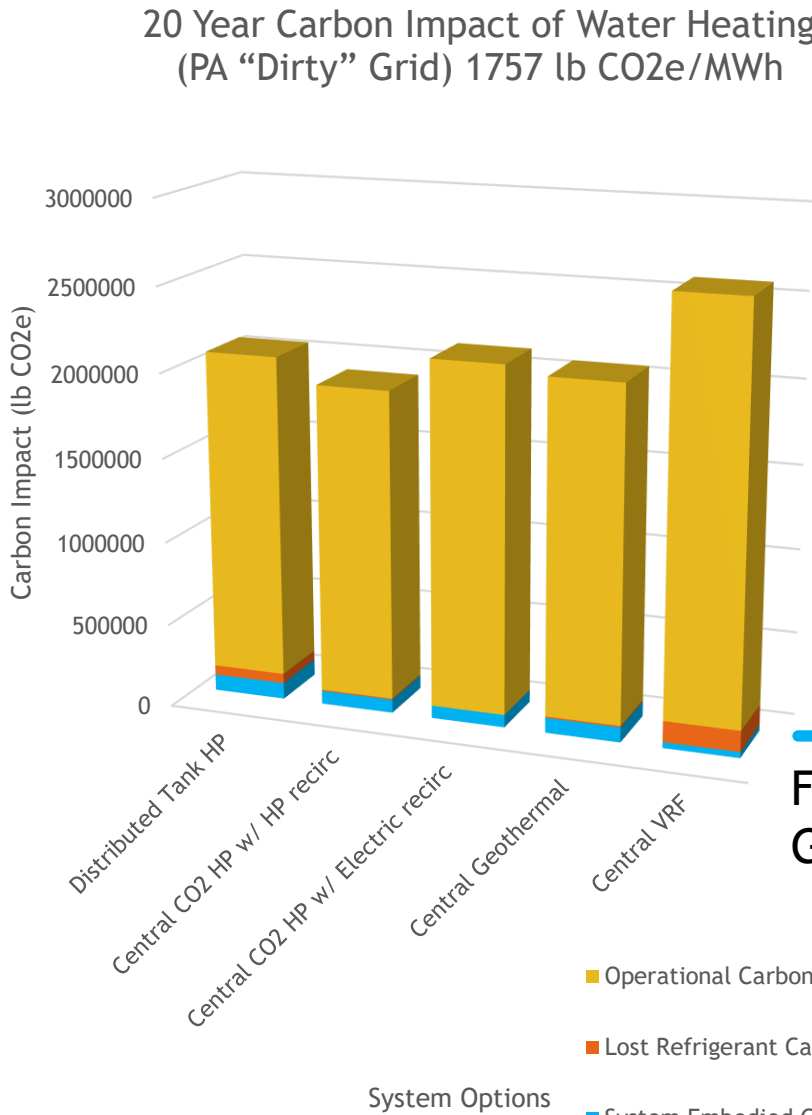
- 1x ten-ton VRF outdoor Unit (LG)
- 2x hydro-kit refrigerant-to-water heat pump (LG)
- 8x 120-gallon hot water storage tanks
- 1x expansion tank
- 1x recirculation pump
- 2x equipment pumps

Critical Statistics

- 3917 lbs of equipment
- 4523 lbs of hot water piping
- 19.8 lbs of R-410A refrigerant
- 9.9 lbs of R-134A refrigerant
- ***Leak Rate: 6% VRF / 3% Hydro Kit***
- ***EUI: 3.76 kBTU/sqft/yr (Primary)***
- ***EUI: 0.36 kBTU/sqft/yr (Recirc)***

Heat Pump Domestic Hot Water Results (20 gpd)





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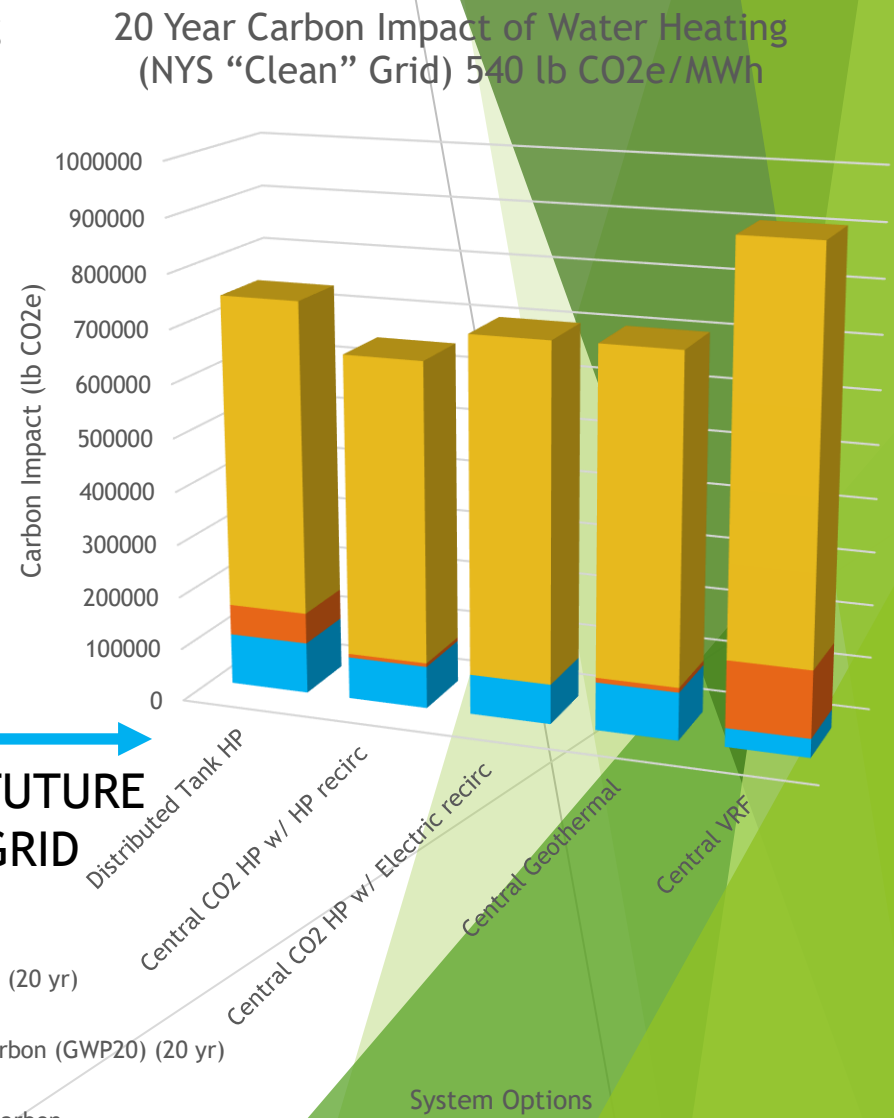
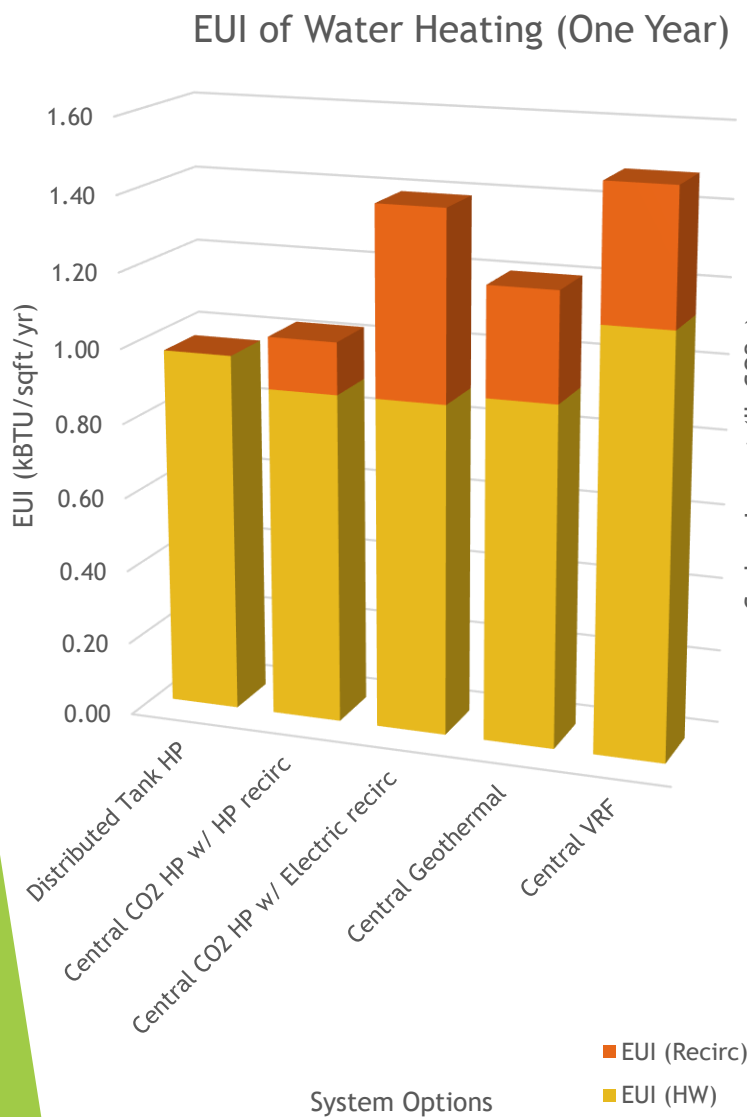
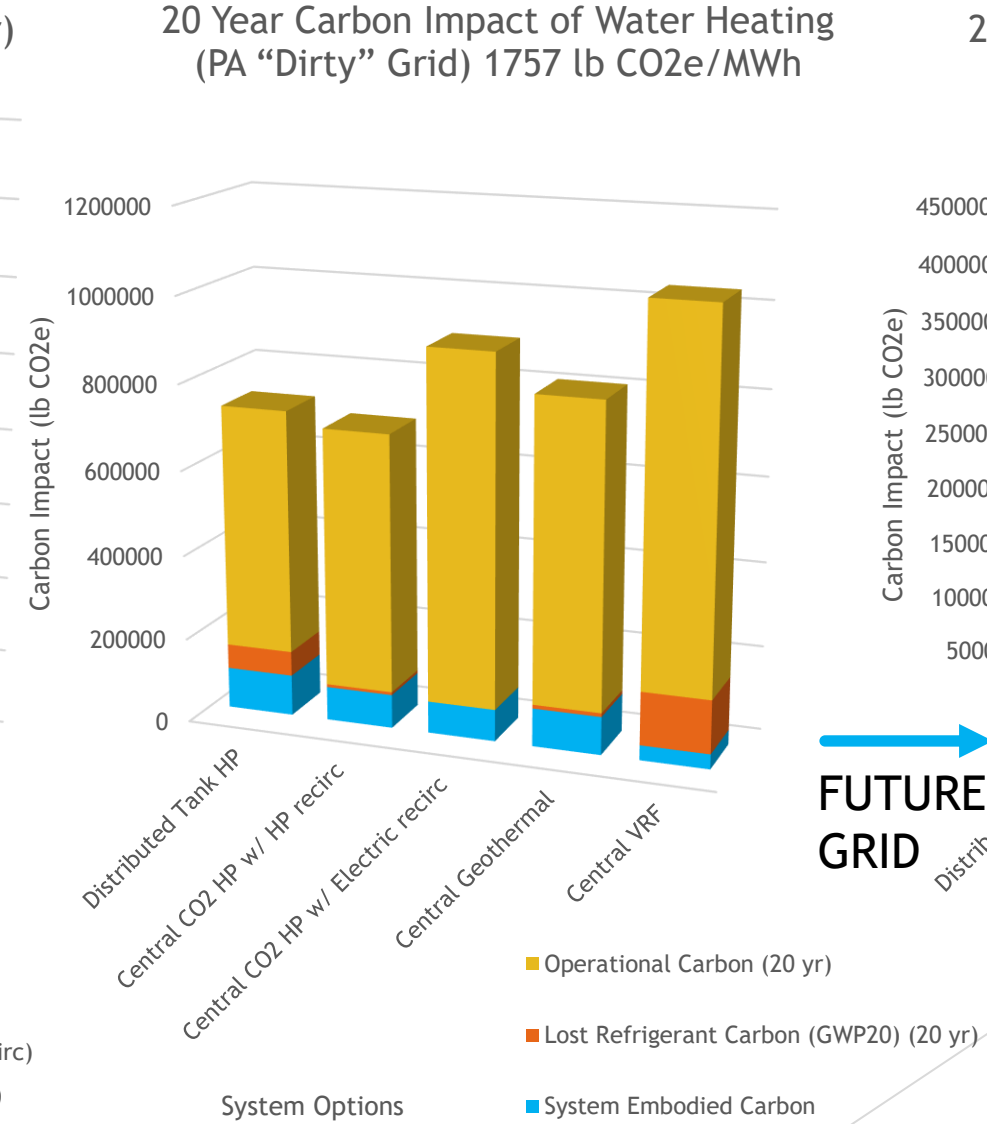


Heat Pump Domestic Hot Water Results (6.6 gpd)





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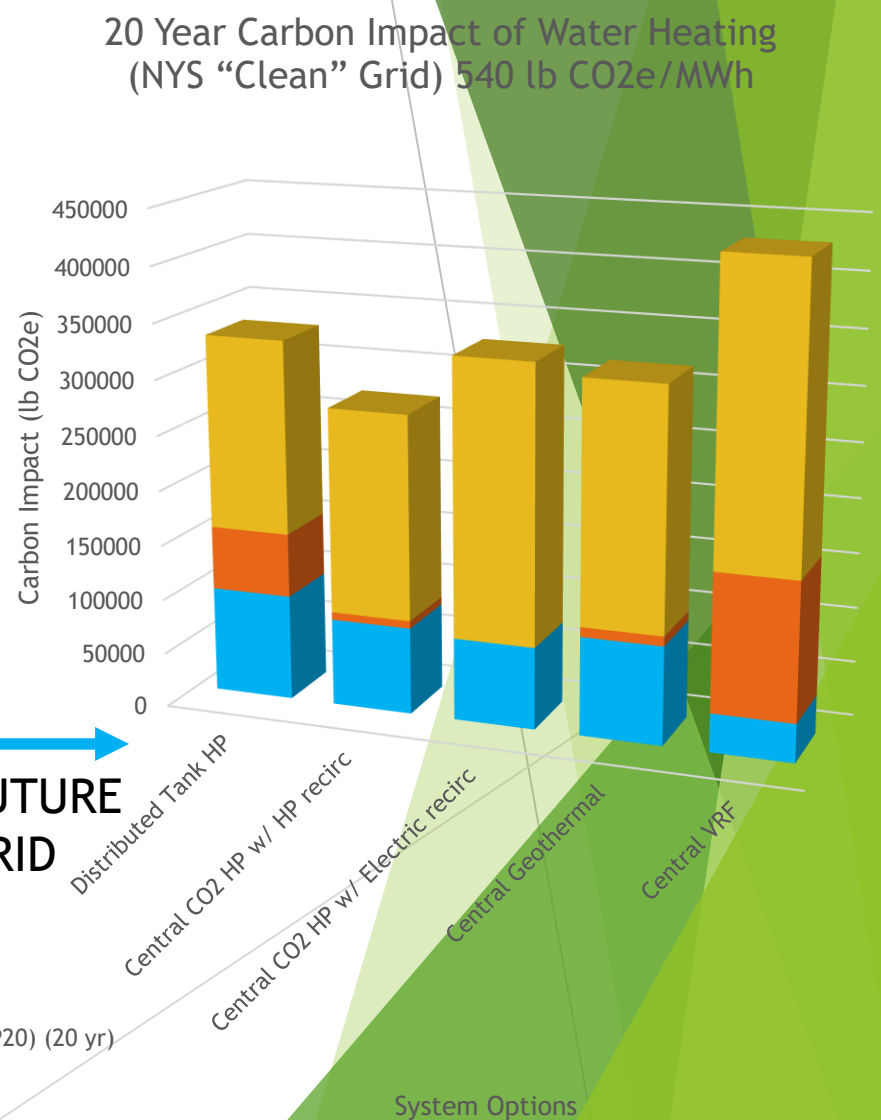

Heat Pump Domestic Hot Water Investigation Takeaways

- As the electrical grid gets cleaner (renewables added) the carbon impact of refrigerant becomes more pronounced as the impact of operational energy carbon is reduced.
- All heat pump hot water systems analyzed have very good performance and relatively low embodied and refrigerant impacts

- VRF hot water is the most complex, uses the most energy, and contains more refrigerant than all other systems, but doesn't require freeze protection like the CO2 options.

- Central CO2 heat pumps require freeze protection as domestic water is on the roof.
- Geothermal hot water systems must be considered and analyzed carefully as they shift the yearly energy balance of the wells. You can end up cooling the ground too much in cold climates

- A distributed tank heat pump system was chosen for the building many years ago because there was space for the heat pumps in the building and Sanden CO2 was at the early adopter phase. VRF was not considered due to limited manufacturers importing hydronic .