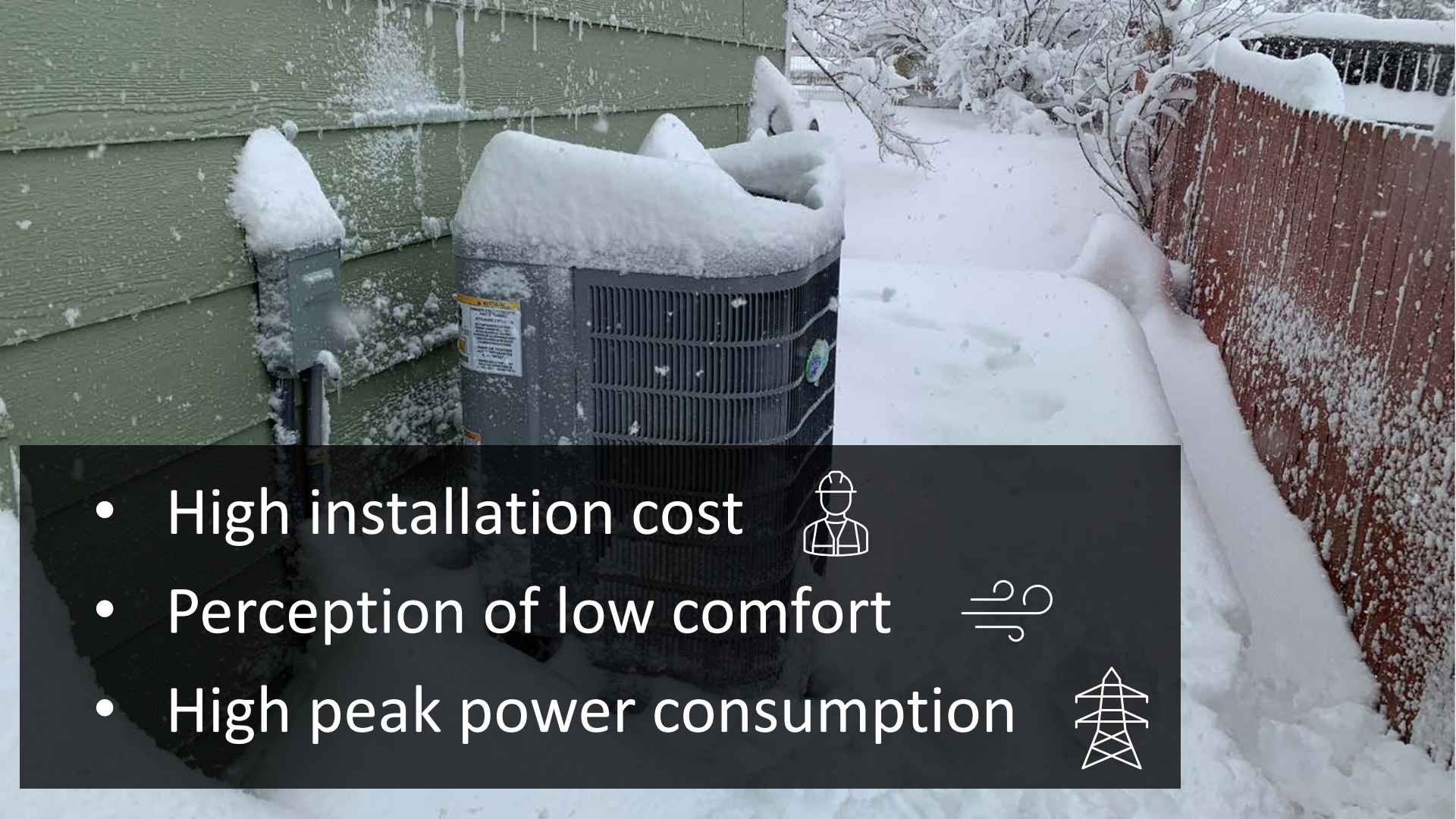
Novel Modular Residential CCHP for Space Conditioning and Water Heating

ACEEE Hot Air Forum

Juan Catano

March 5, 2024


What are the biggest challenges facing HP today?

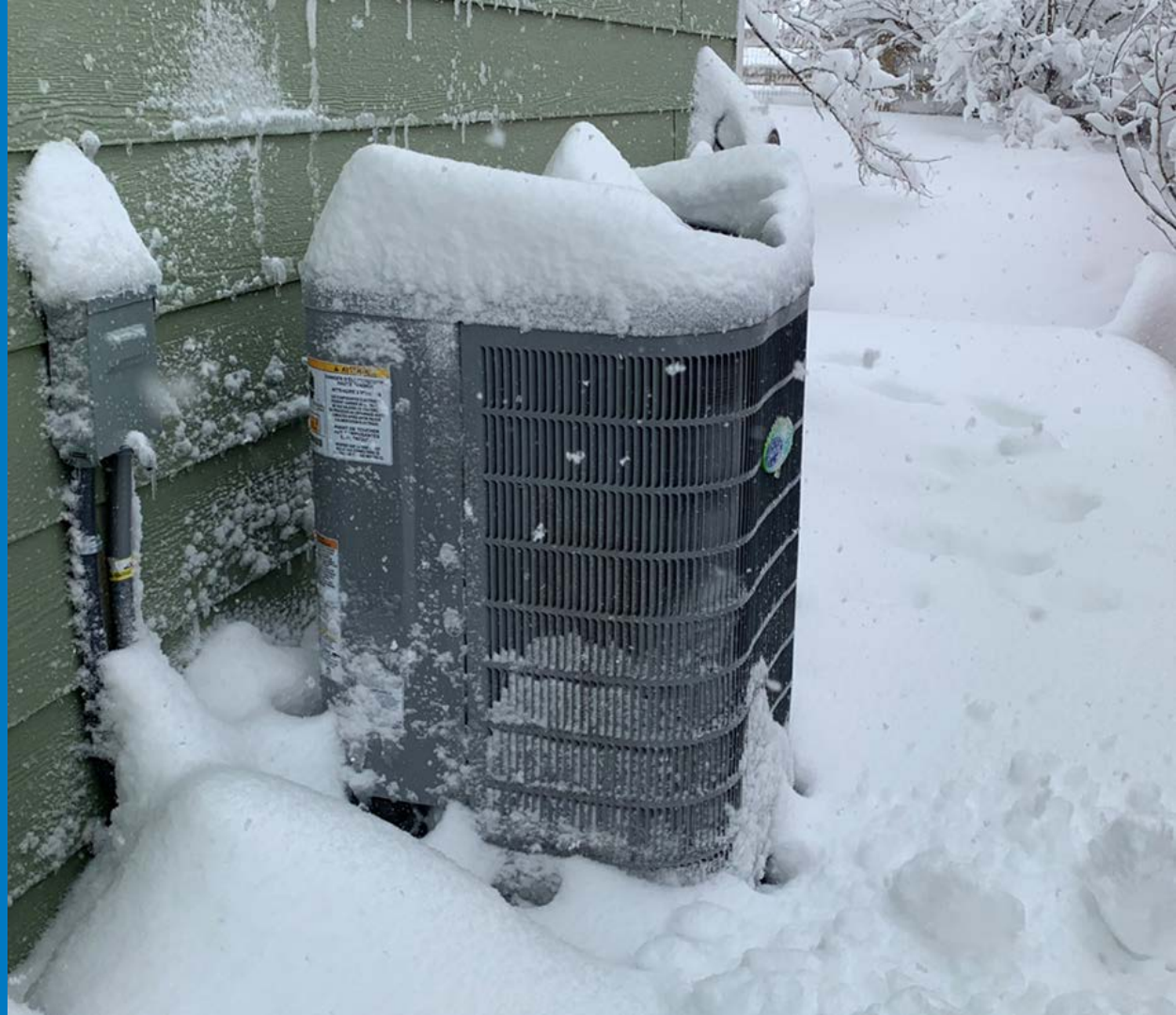

• High installation cost
• Perception of low comfort
• High peak power consumption

High installation cost:

- Shortage of skilled labor
- Potential house upgrades:
  - Electric panel
  - Ducts

Perception of low comfort:

- Conditioned space is cooled during defrost cycles
- Lower capacity at lower T_{amb}



High peak power consumption:

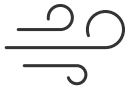
- Probable higher electric bills
- Added load to the electric grid

What are we doing to address these challenges?

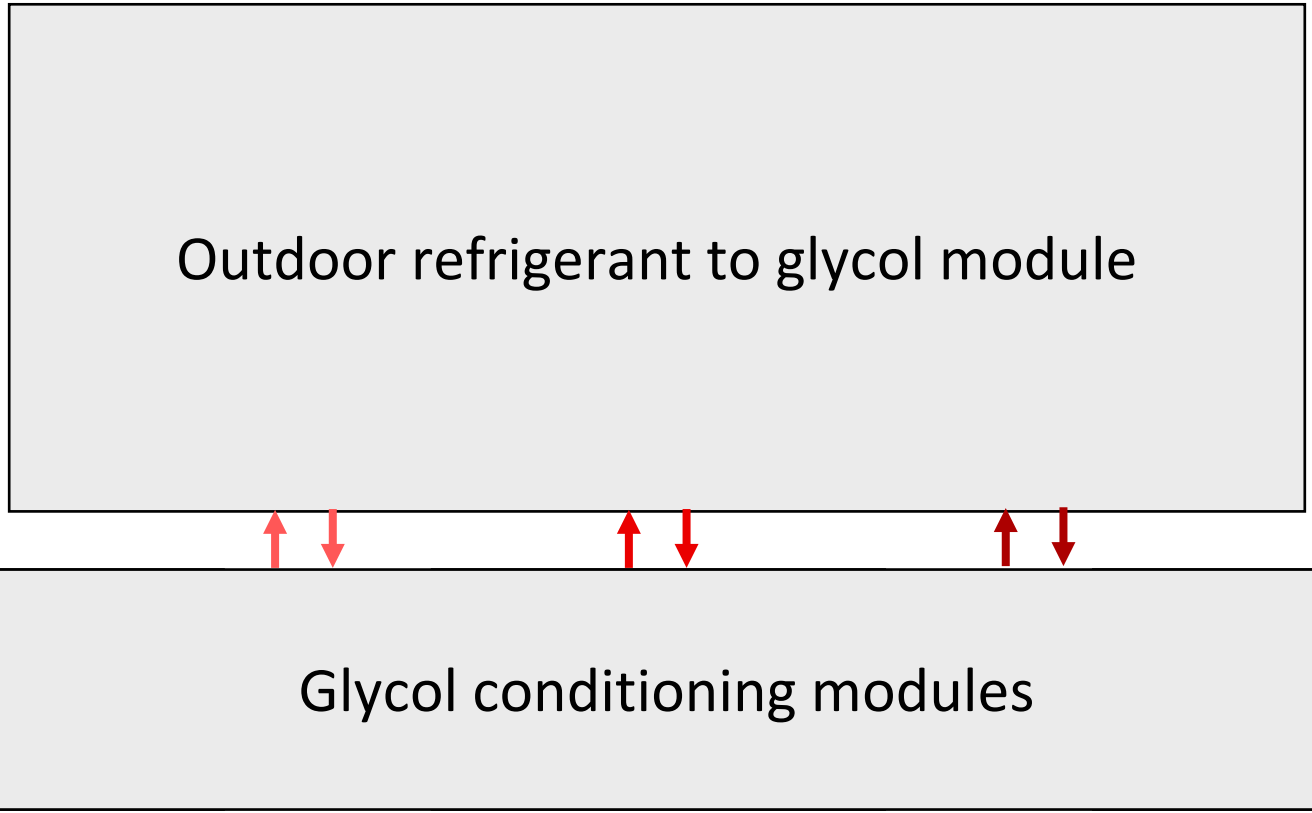
Develop a Modular CCHP for Space Conditioning and Water Heating

Compared to a typical residential heat pump:

- **Installation:** A **40%** reduction **in cost** and **50%** reduction in **time**
- **4-hour peak-load reduction**: **50%** in summer; **40%** in winter
- **Electricity use: 25%** reduction including TES charging
- **Payback period: 2-3 years** with TOU pricing
  - A **TES module** cost of less than **$40/kWh$_{th}$**, (including connecting hardware)

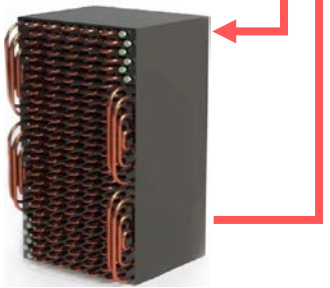

Modular CCHP for Space Conditioning and Water Heating

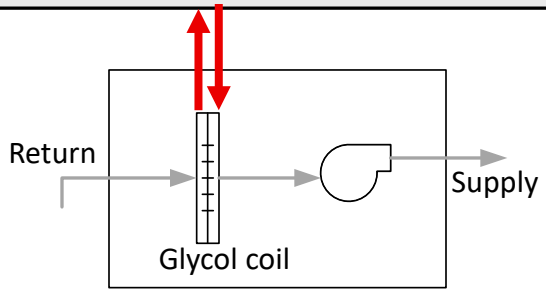


Conditioning Modules

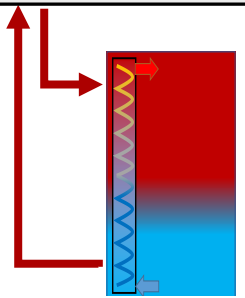
Outdoor refrigerant/glycol module

Thermal energy storage module



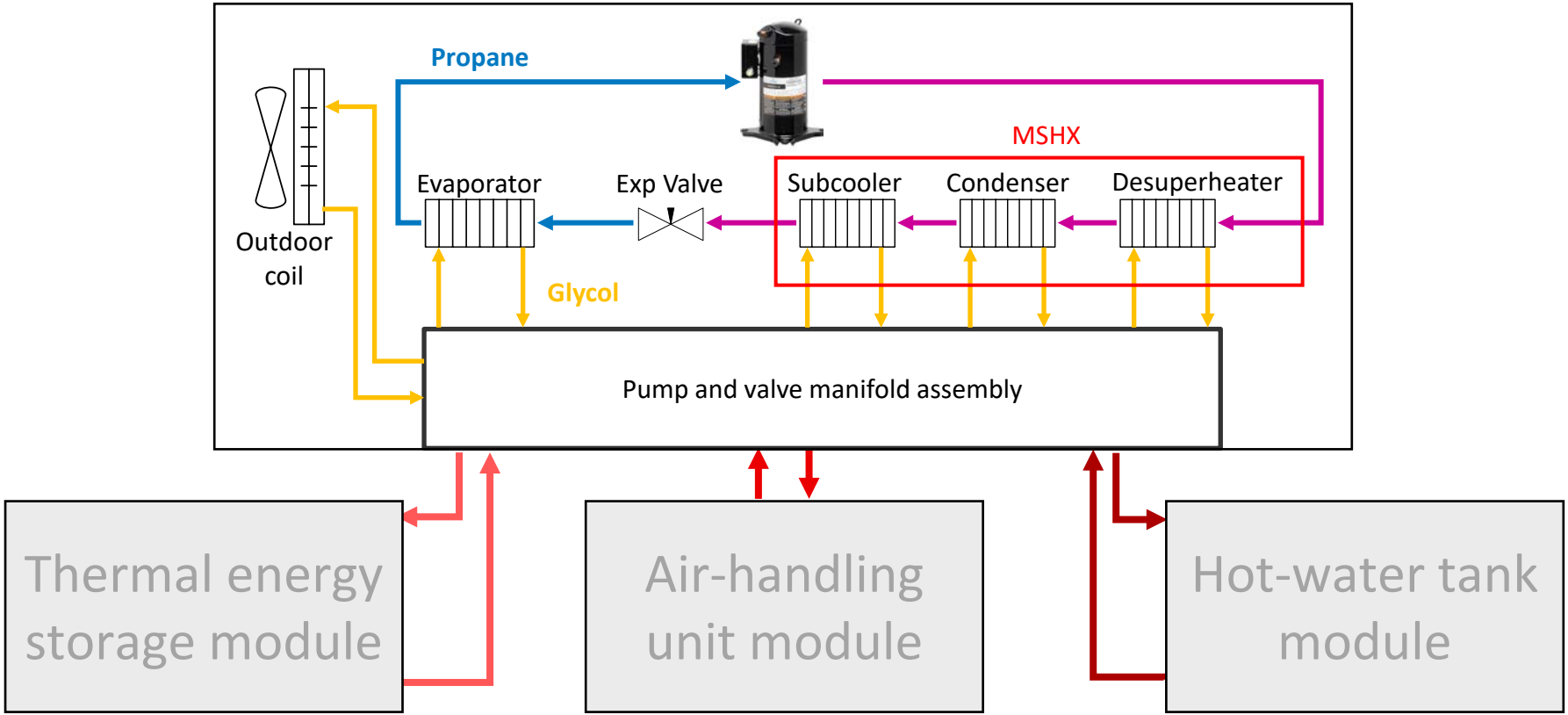


Air-handling unit module

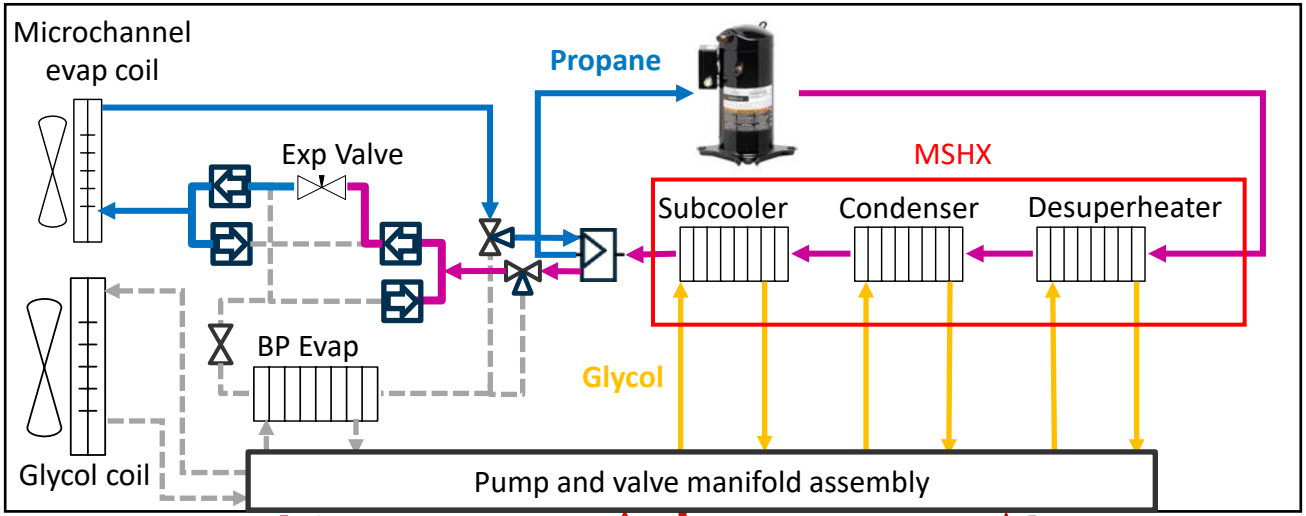


Hot-water tank module

Outdoor Refrigerant/Glycol Module: Config 1 (Basic)



Outdoor Refrigerant/Glycol Module: Config 2 (Cold Climate)



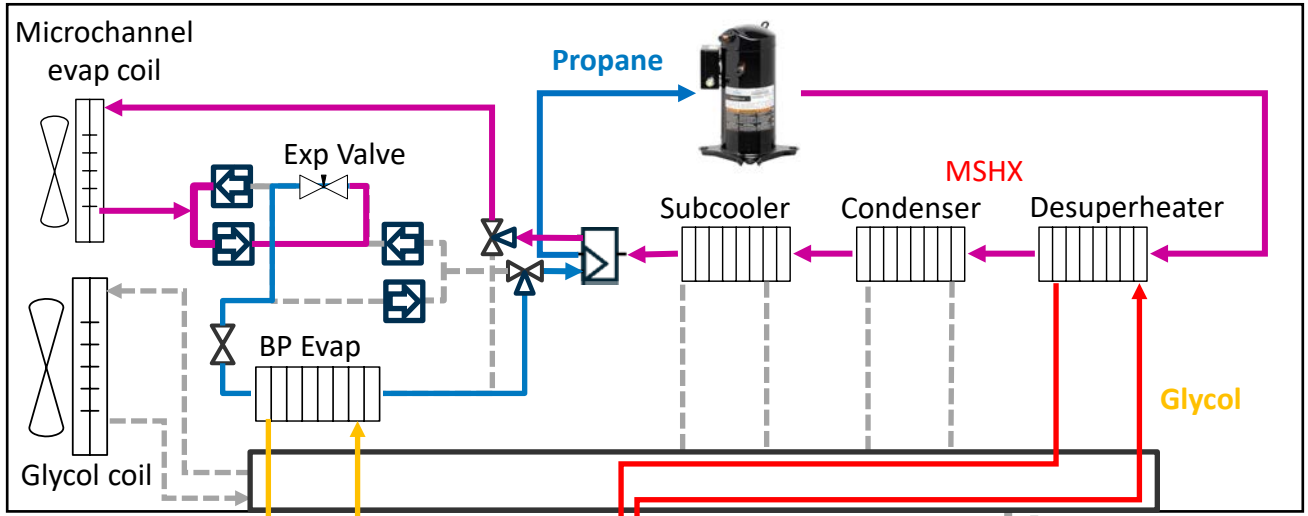
Thermal energy storage module

Air-handling unit module

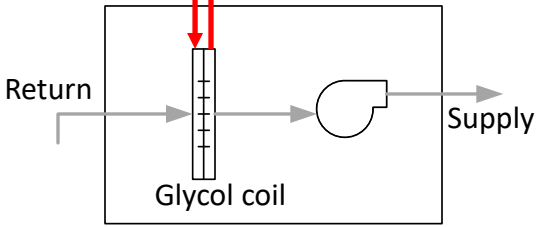
Hot-water tank module

Novel Operating Modes

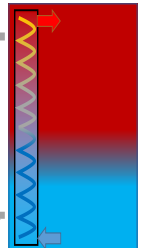
Defrost Cycle with Space Heating



Thermal energy storage module

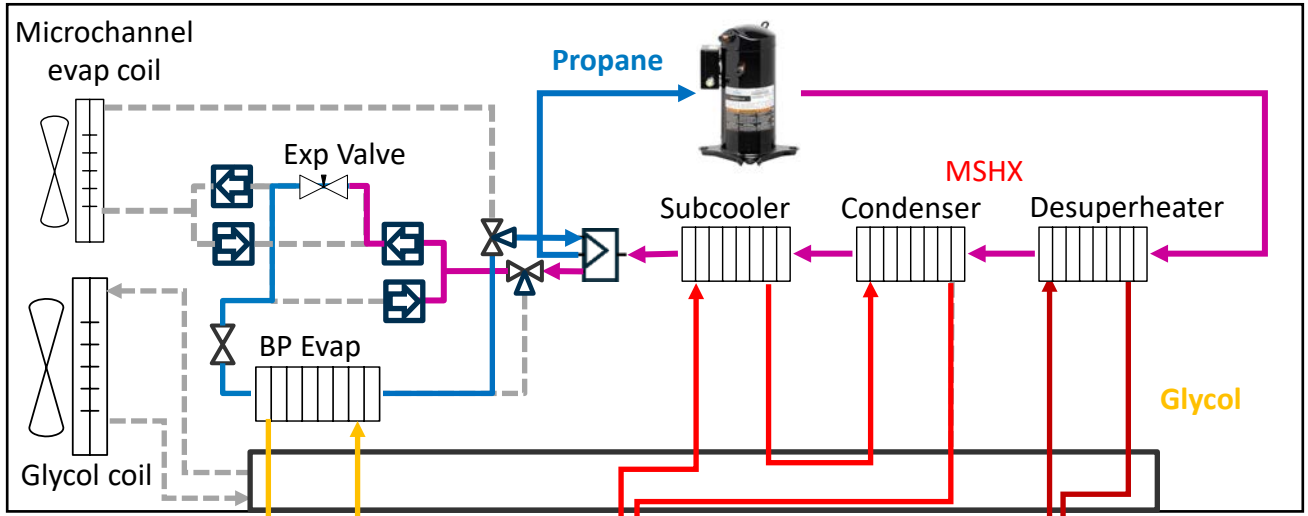


Air-handling unit module

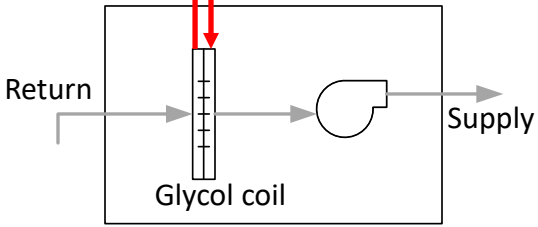


Hot-water tank module

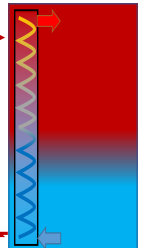
Space and Water Heating with TES discharge



Thermal energy storage module

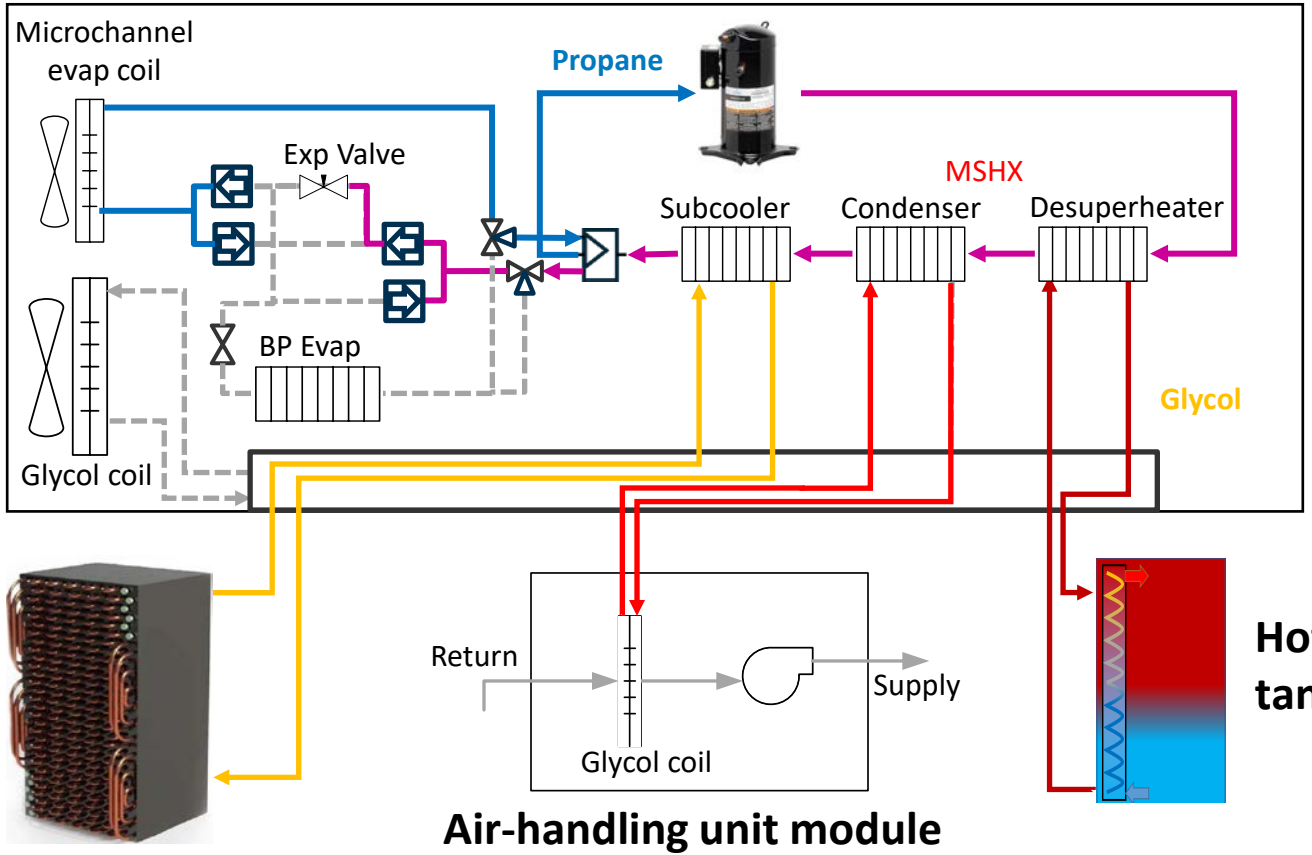


Air-handling unit module



Hot-water tank module

Space and Water Heating with TES charge



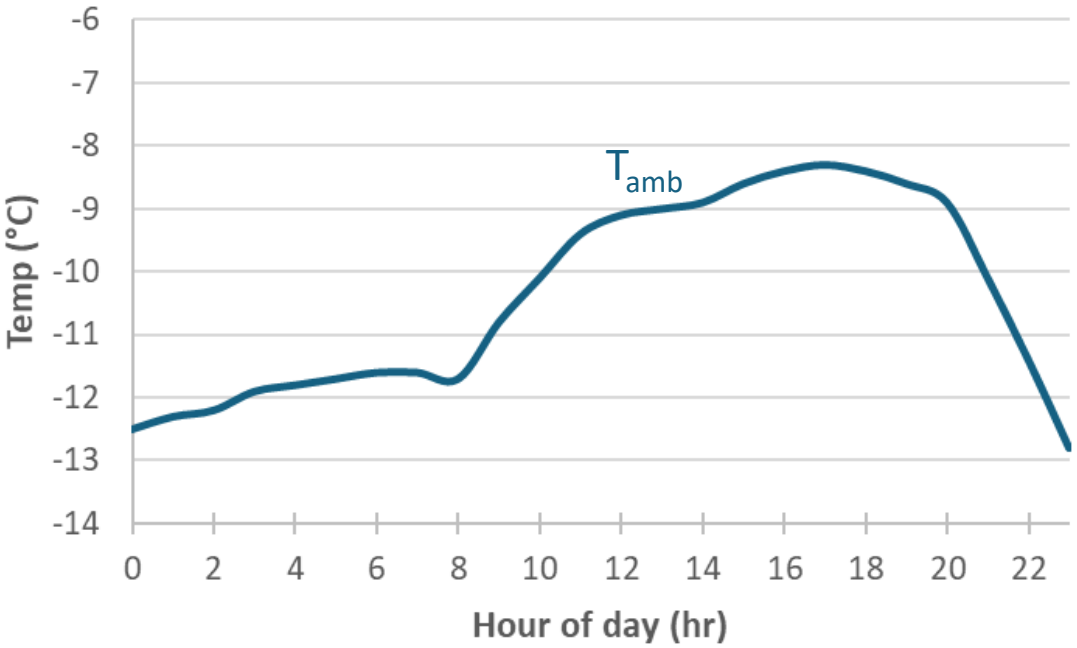
Thermal energy storage module

Air-handling unit module

Hot-water tank module

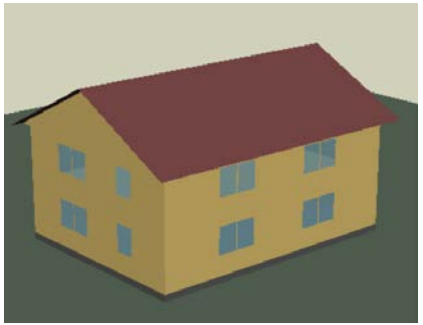
Winter Day Simulations

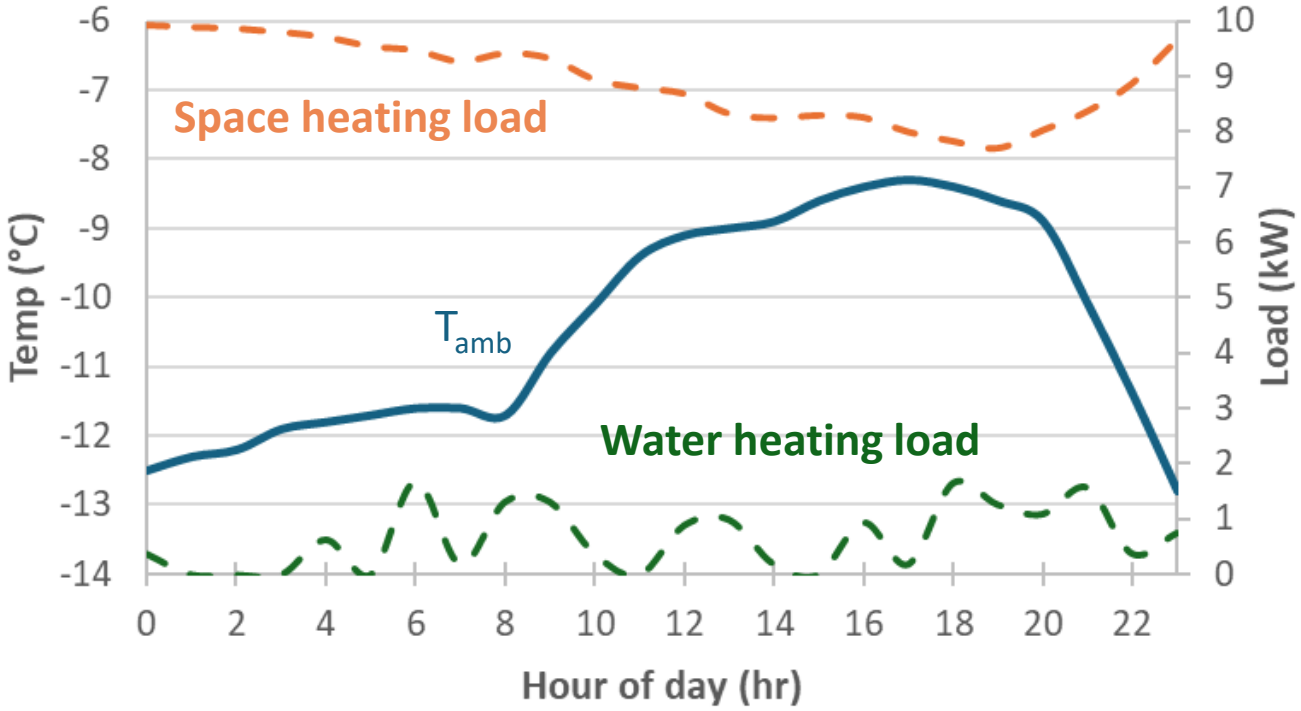
Winter Day in Minnesota



*Typical meteorological year 3 (TMY3) data (single winter day)

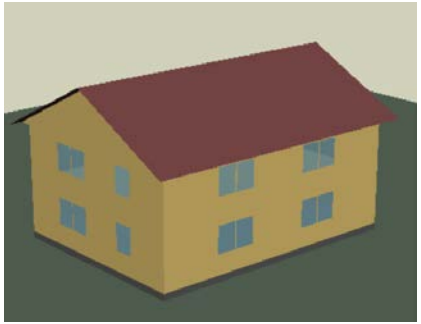
Winter Day in Minnesota: Loads





*BEopt (Building Energy Optimization Tool) software simulation data

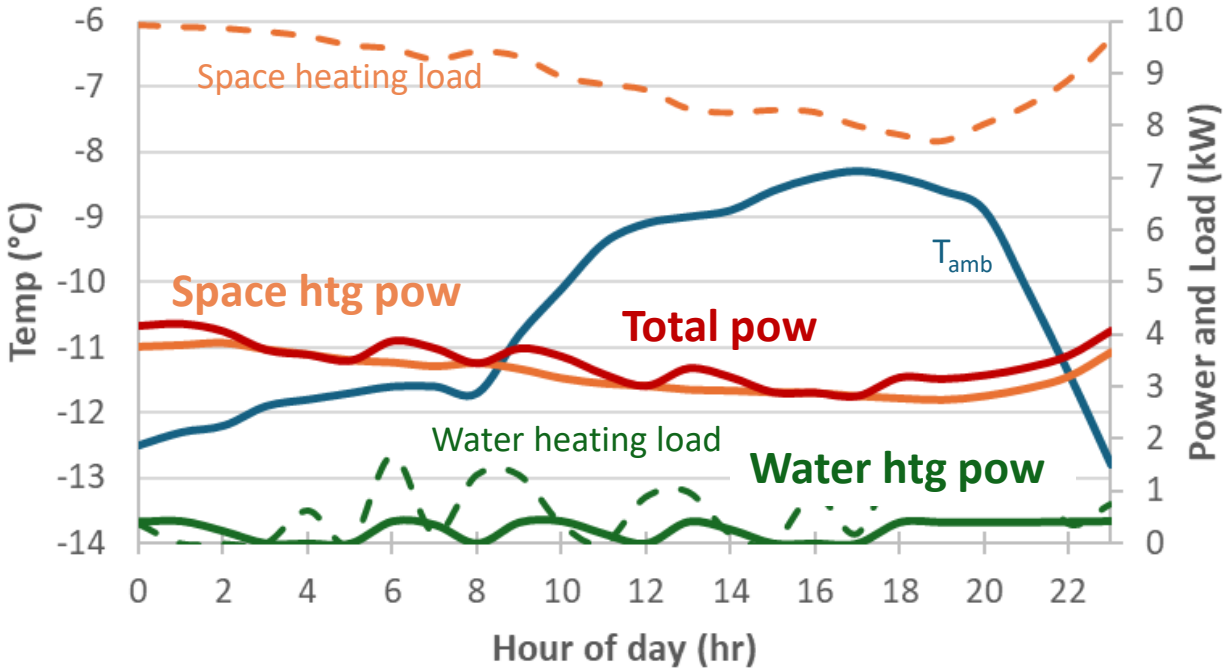
Winter Day in Minnesota: Baseline System



	Space heating	Water heating
Baseline	ASHP **HSPF 9.2**, Variable speed, Sized for max load	HPWH **UEF: 3.5**, 80-gal tank

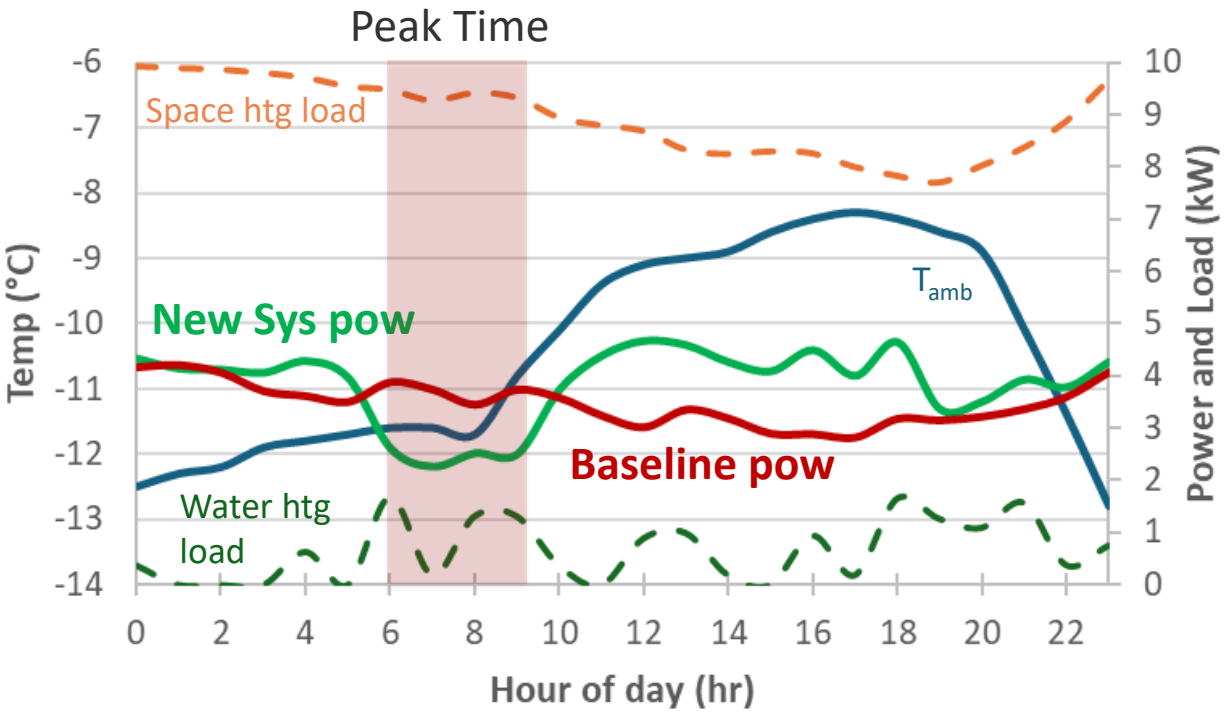
Baseline System Results

	Peak Time Pow (kW)	Total Energy (kWh)
Baseline	**3.9**	**83.6**



New System Reduces Power Consumption during Peak Time by 33%

	Peak Time Pow (kW)	Total Energy (kWh)
Baseline	3.9	83.6
New Sys	2.6	91.7

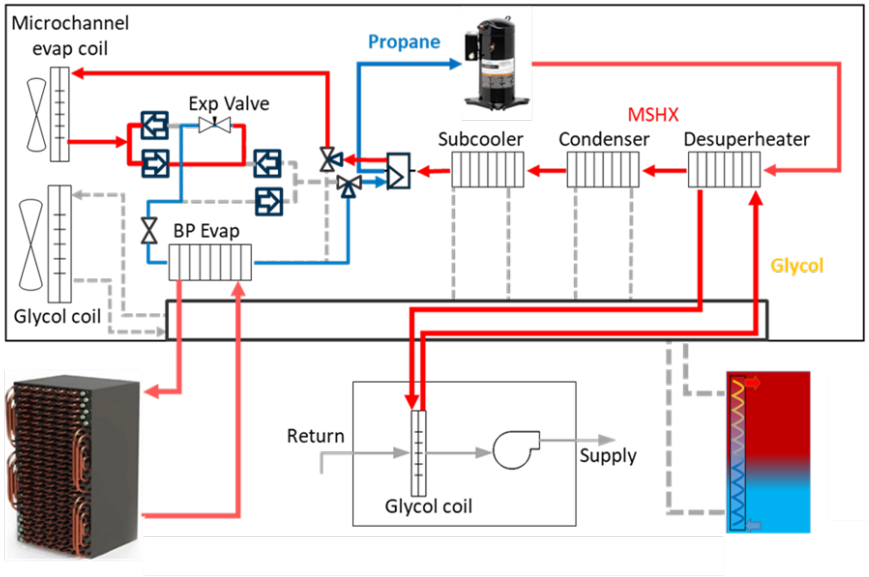


PRELIMINARY RESULTS

Conclusions and Future Work

Conclusions:

- Space conditioning and water heating cold-climate HP that can:
  - **Heat during defrost cycles**
  - **Reduce peak power all year**



Future Work

- **System Optimization:**
    - Control algorithms
    - Modules design
- **Build and test prototype**
- **Evaluate installation time and cost**

Thank you

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NREL/PR-5500-93436

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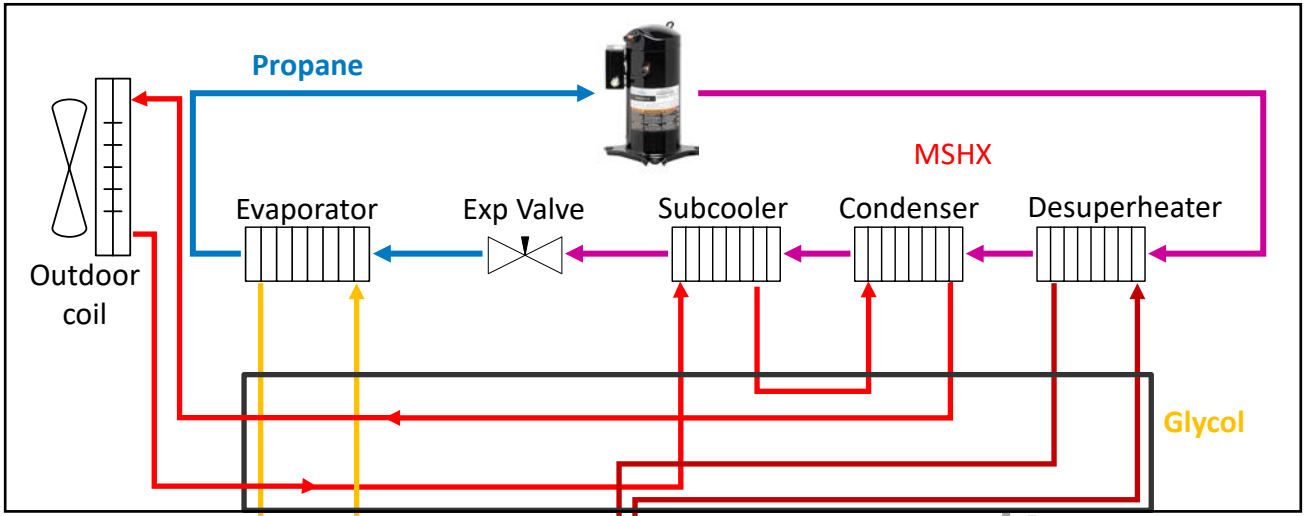
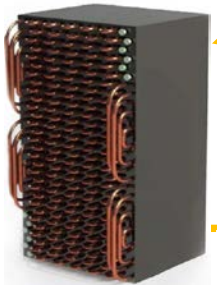
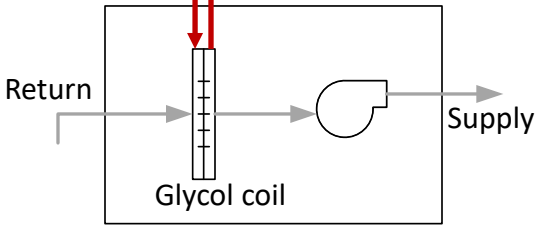
1a) Defrost Cycle with Space Heating

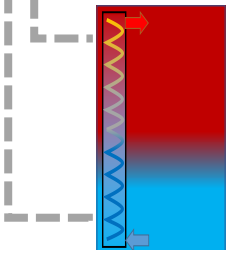


Thermal energy storage module



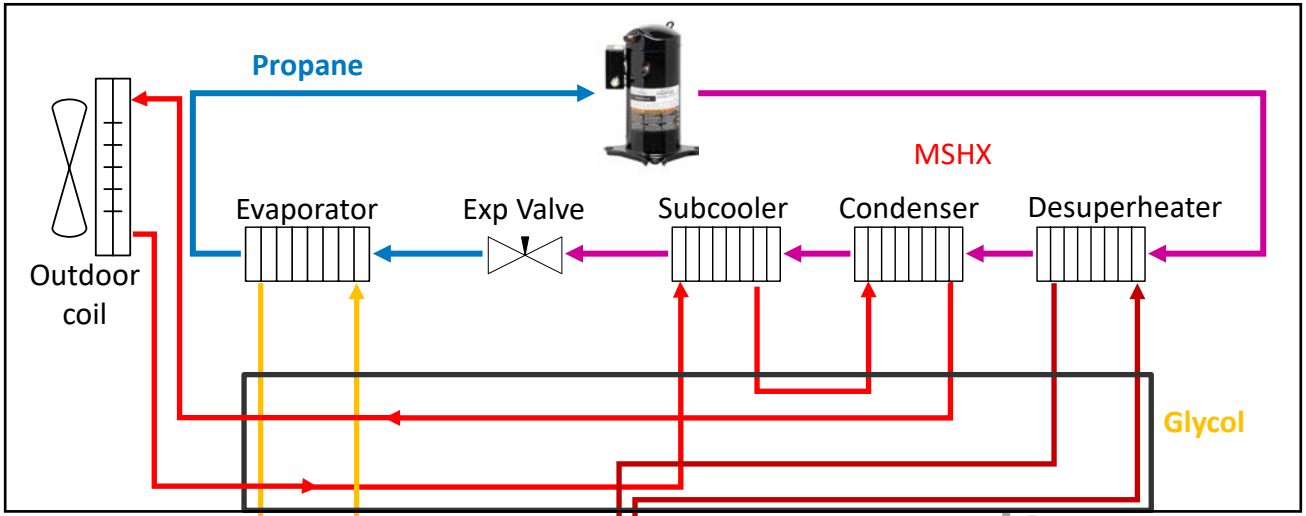


Air-handling unit module

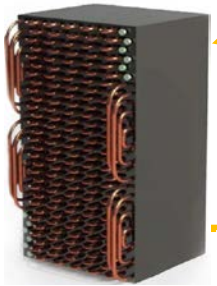


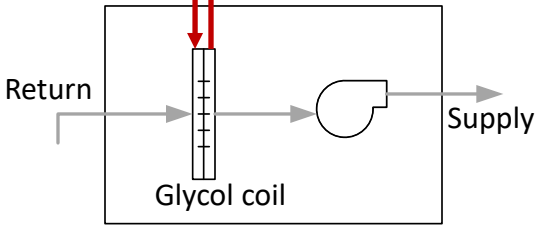
Hot-water tank module

Dual Fuel

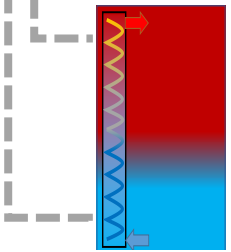


Thermal energy storage module



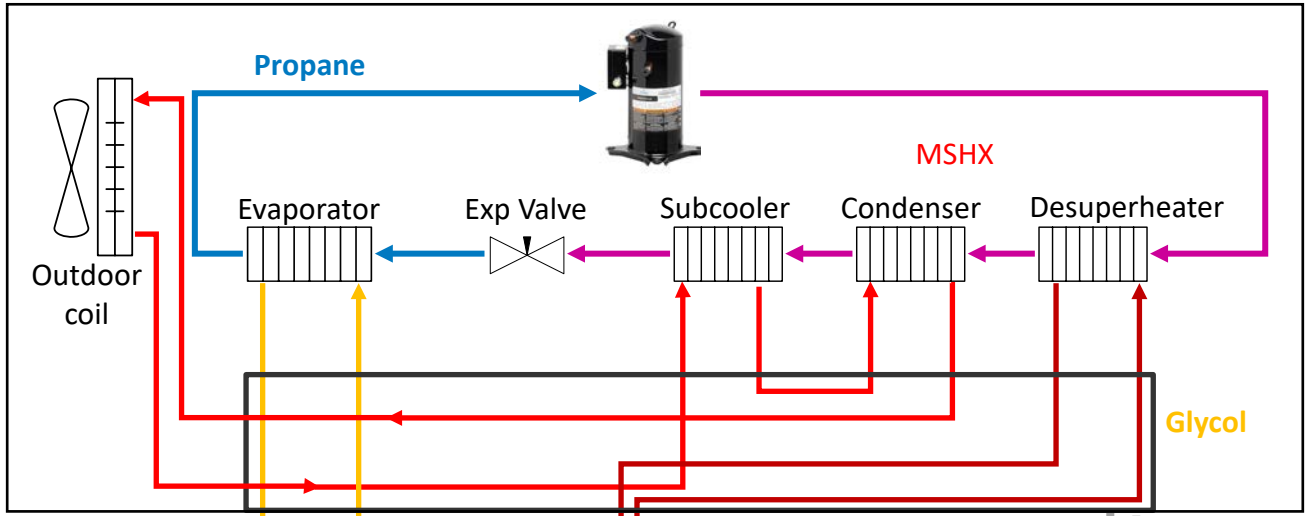


Air-handling unit module

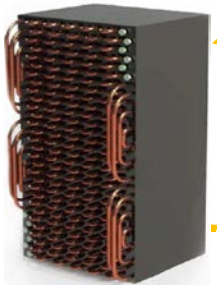


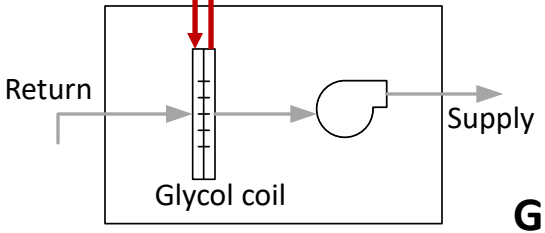
Hot-water tank **w. gas water heater** module

Dual Fuel



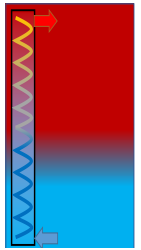
Thermal energy storage module





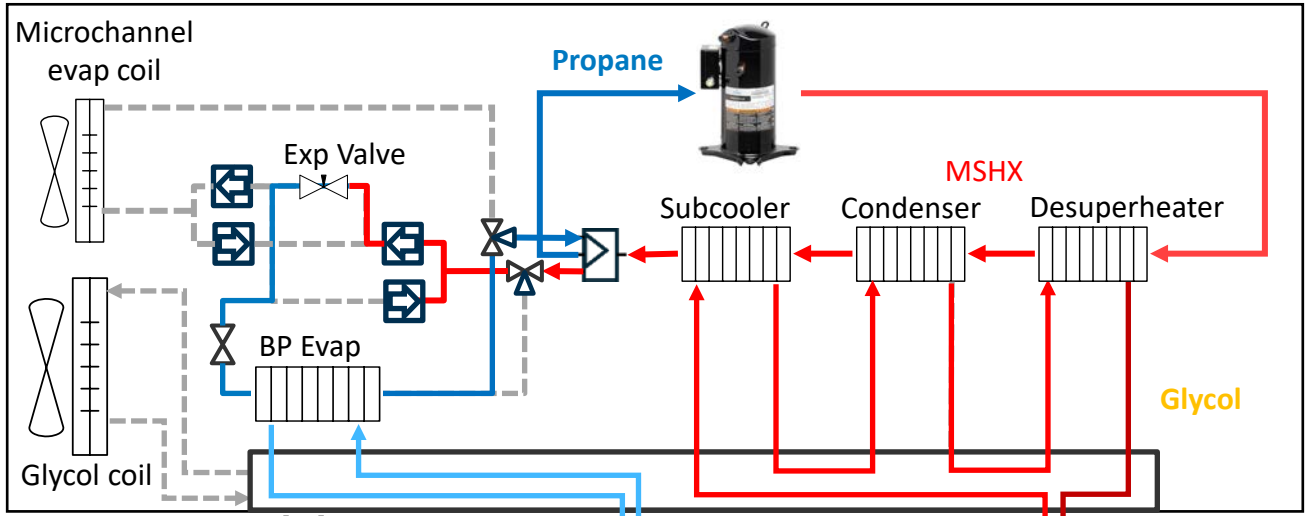
Air-handling unit

Gas tankless water heater

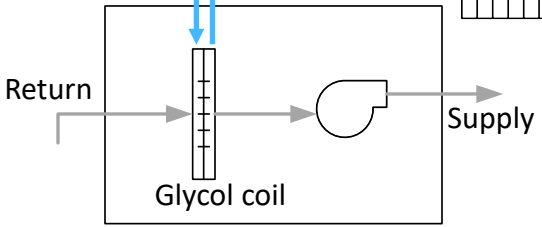


Hot-water tank module

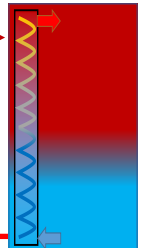
4a) Space Cooling and Water Heating



Thermal energy storage module

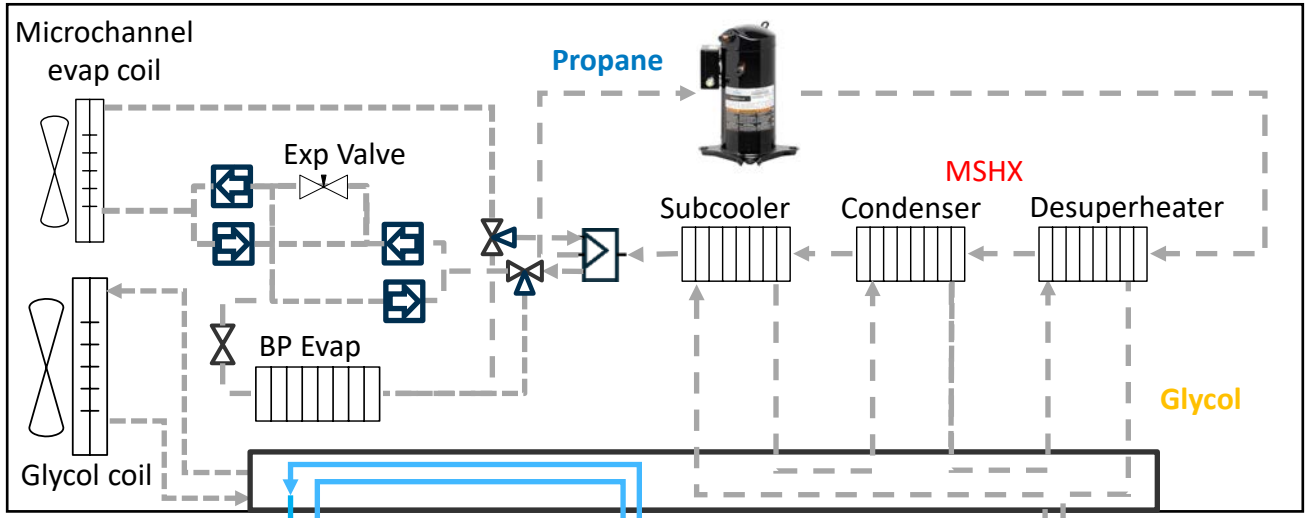


Air-handling unit module

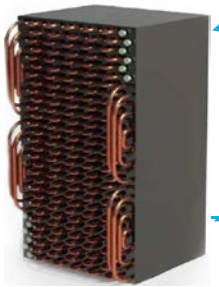


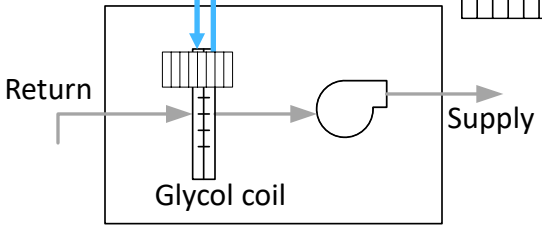
Hot-water tank module

4a) Space Cooling w. TES Discharge

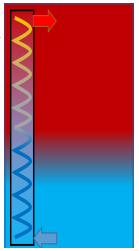


Thermal energy storage module



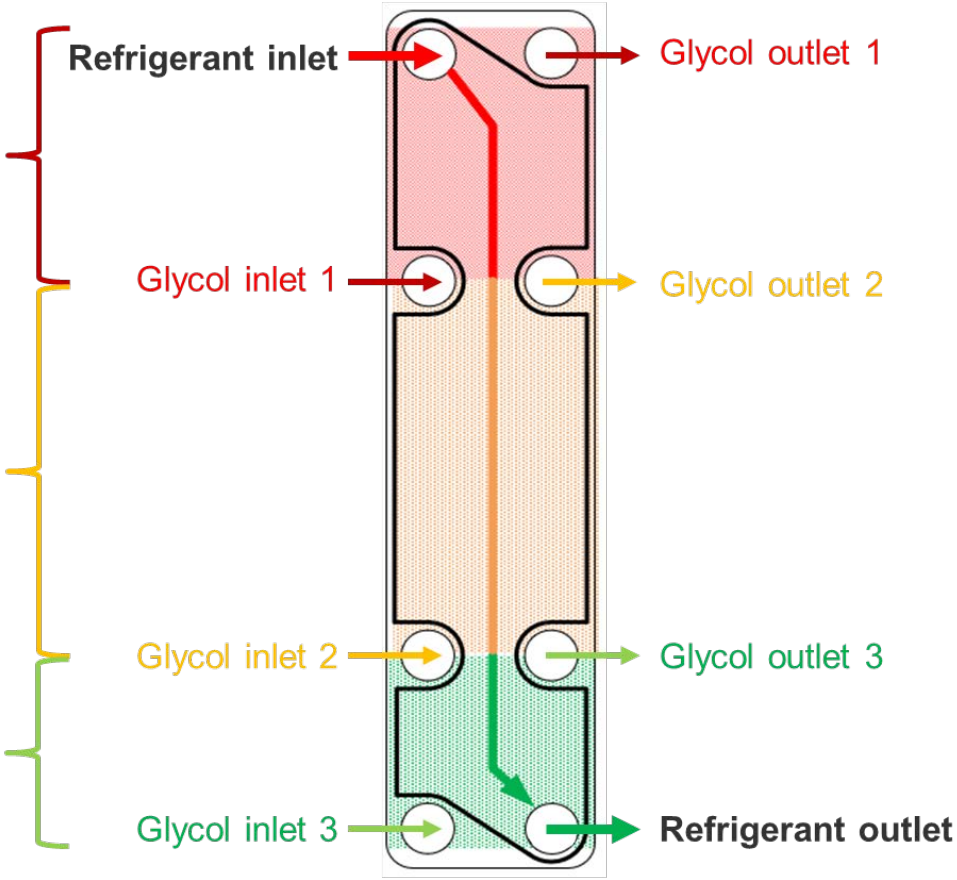


Air-handling unit module



Hot-water tank module

Multi-section HX



Multi-section HX