Current and Future Air-Conditioning (AC) Technologies

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Content

- Current Technologies
  - Vapor Compression (Electric/Engine-Driven)
    - Ground source, air source, water source
  - Heat Activated
  - Water-source integrated heat pump (IHP)
- Future Technologies
  - Vapor Compression using alternative lower GWP refrigerants
  - Separate Sensible and Latent Cooling Systems
  - Personal Cooling Systems
  - Non-Vapor Compression Technologies
- U.S. R&D Roadmap for HVAC Technologies

Current – Electric Vapor Compression (VC)

- Air cooled/air source – residential buildings
  - Mini-split ACs:
    - Rated Seasonal Performance Factors (SPF): 4.10‡ to ~7.3 for 2.6-5.3 kW
    - Available up to 14 kW
  - Central ACs:
    - Rated SPF range: 4.10‡ to ~7.6 for 5.3-8.8 kW;
    - Available up to ~18 kW

- Commercial buildings – rooftop ACs
  - Rated integrated cooling SPF range;
    - 2.8 to 6.2 (available models in 20 - 55 kW capacity range, R410A)
    - 6.7 to 7.0 (in development; lower-GWP refrigerant)

‡ US min

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Current – Engine Driven (VC)

- Commercial
  - Packaged
    - ~40 kW; COP_{gas} 1.1 (@ 35C)
    - 12 kW water heating (heat recovery)
    - http://iceghp.com/gas_heat_pump/11-ton-gas-heat-pump/
  - Multizone
    - 30-70 kW; COP_{gas} ~1.0 (@ 35C)
    - Up to 33 indoor air handlers
- Residential
  - Variable speed (VS); cooling or cooling + water heating (WH)
  - Cooling only
    - 10 kW; COP_{gas} ~1.3 (@ 35C)
    - 10 kW; COP_{gas} ~0.7 (@ 52C)
  - Cooling + WH
    - 10 kW + 4.5 kW; COP_{gas} ~1.7 (@ 35C)
    - 10 kW; + 9 kW; COP_{gas} ~1.2 (@ 52C)

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Current – Heat Activated Technologies

- US manufactured systems
  - ThermoSorber™ (Energy Concepts)
    - 52-1055 kW cooling or refrigeration
    - 137-1406 kW water heating
    - Industrial applications
    - Waste heat source
  - HeliSorber™ (Energy Concepts)
    - 88 kW cooling
    - 176 kW water heating
    - Solar thermal source
    - 2 kW electricity input
    - Simultaneous WH and AC applications

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Current – Heat Activated Technologies

EU manufactured systems

Company (country)	Product name	Tech-nology	Working pair	Cooling capacity	COP	Dimensions (L x D x H)
InvenSor (D)	LTC 7	ADsorption	water/zeolith	7 kW	0.54	0.65 x 1.30 x 1.65 m
SorTech (D)	ACS 08	ADsorption	water/silica gel	8 kW	0.60	0.79 x 1.06 x 0.94 m
InvenSor (D)	HTC 10	ADsorption	water/zeolith	10 kW	0.50	0.65 x 1.30 x 1.65 m
ClimateWell (S)	ClimateWell 10	ABsorption	water/lithium chloride	10 kW	0.68	1.21 x 0.81 x 1.69 m
SolarNext (D)	chillii® PSC12	ABsorption	ammonia/water	12 kW	0.62	0.80 x 0.60 x 2.20 m
EAW (D)	Wegracal SE 15	ABsorption	water/lithium bromide	15 kW	0.71	1.75 x 0.76 x 1.75 m
SorTech (D)	ASC 15	ADsorption	water/silica gel	15 kW	0.60	0.79 x 1.34 x 1.39 m
ClimateWell (S)	ClimateWell 20	ABsorption	water/lithium chloride	20 kW	0.68	1.21 x 0.81 x 1.94 m
Solarice (D)	AAC 25	ABsorption	ammonia/water	25 kW	0.50	1.40 x 1.40 x 2.00 m
EAW (D)	Wegracal SE 30	ABsorption	water/lithium bromide	30 kW	0.75	2.14 x 0.97 x 1.98 m
Solarice (D)	AAC 40	ABsorption	ammonia/water	40 kW	0.75	1.40 x 1.40 x 2.00 m
AGO (D)	congelo 50	ABsorption	ammonia/water	50 kW	0.55	2.35 x 1.65 x 2.63 m
EAW (D)	Wegracal SE 50	ABsorption	water/lithium bromide	54 kW	0.75	2.95 x 1.10 x 2.31 m

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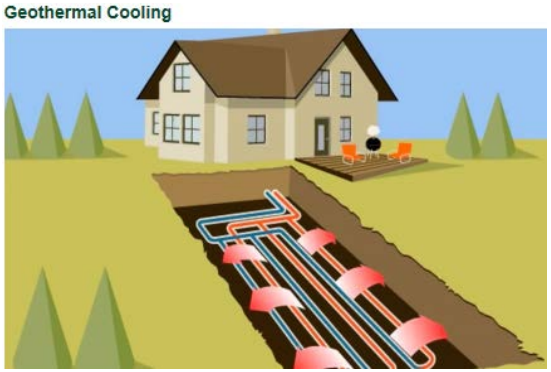
Current – Electric Vapor Compression (VC)

- Water cooled/water source (geothermal)
  - Rated cooling COP range (ISO 13285-1):
    - 4.10 to 13.2 (for 3.5-14 kW capacity; ground loop)
    - 4.10 to 18.8 (for 3.5-14 kW capacity; groundwater)

Water-to-air heat pump unit



Ground loop

- Most recent development – integrated heat pump (IHP) systems

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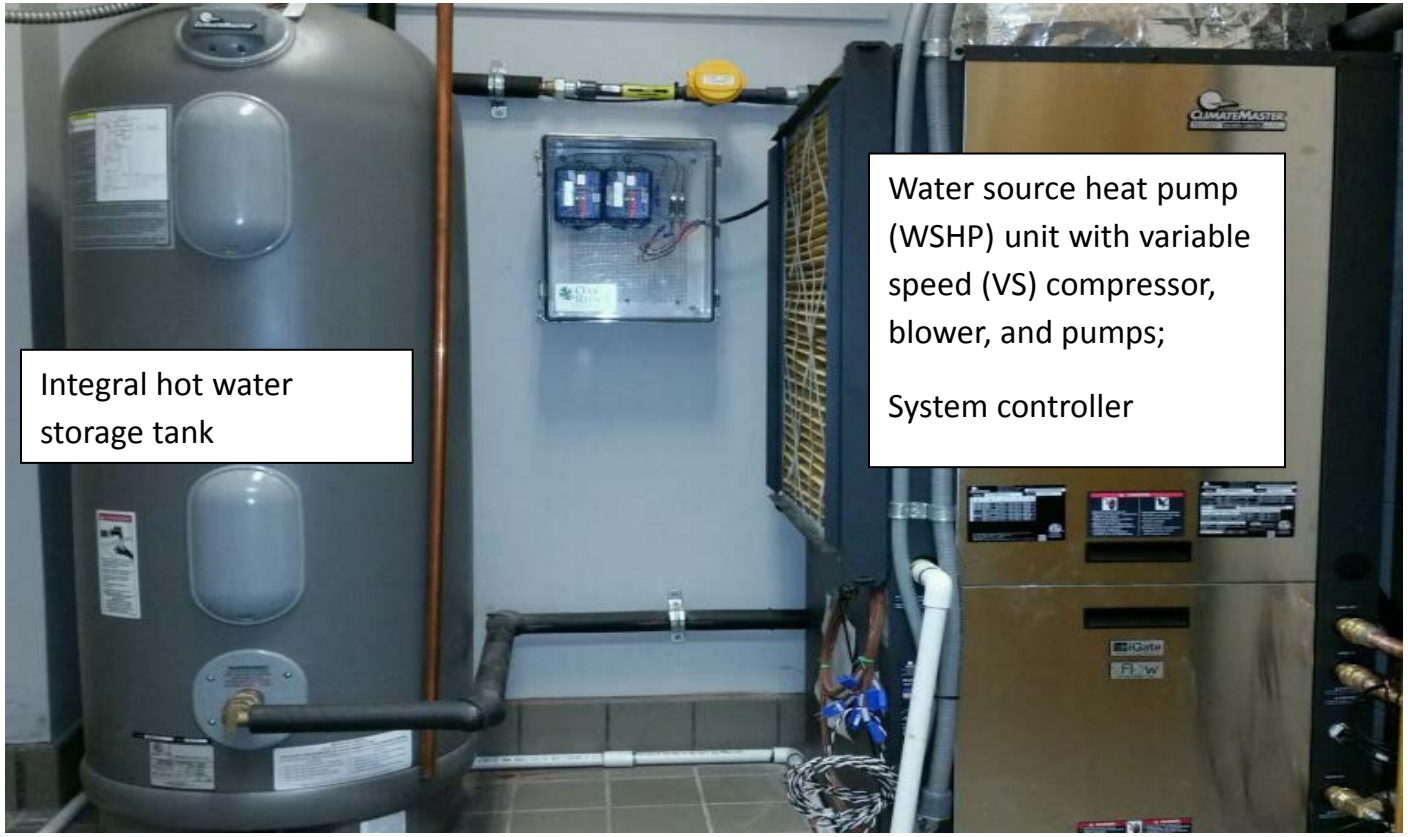
Current – water (or ground) source IHP



Field Test system installation (ground loop) in commercial kitchen facility

Four operating modes: AC, space heating, WH, AC+WH

VS cooling capacity ranges – 2.5-9 or 5.0-18 kW

Rated cooling COPs – 6.3 (max speed), 13.2 (min speed)

Measured seasonal COPs; 7.8 for AC, 3.6 for WH

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Alternative Lower GWP Refrigerants

- Effort to further mitigate the environmental impact of refrigerants used in vapor compression systems:
  - First generation “CFC” – potent ozone depleting potential (ODP) and global warming potential (GWP)
  - Second generation “HCFC” – has measurable ODP (however significantly less than CFC) but potent GWP
  - Third generation “HFC” no ODP but potent GWP
  - Fourth generation “HFC/HFO” blends no to extremely low ODP moderate to low GWP

Class	Refrigerant	ODP	GWP	Safety class
CFC	R-12	0,73	10 200	A1
HCFC	R-22	0,034	1 760	A1
HFC	R-410A	0	1 924	A1
HFC/HFO	DR-55	0	676	A2L

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Major Research Thrusts in Alternative Refrigerants

- AHRI Alternative Refrigerant Evaluation Program (AHRI AREP)
  - Engaged international HVAC&R manufacturers, Research Organizations, and Academia
  - Completed 2 phases of research campaigns and published results at: http://www.ahrinet.org/site/514/Resources/Research/AHRI-Low-GWP-Alternative-Refrigerants-Evaluation-Program
  - Held 2 conferences/meetings to discuss results
- Promoting Low-GWP Refrigerants for the Air-Conditioning Sectors in High-Ambient-Temperature Countries (PRAHA)
- Egyptian Program for Promoting Low-GWP Refrigerants' Alternative (EGYPRA)
- ORNL High Ambient Temperature (HAT) Research campaign

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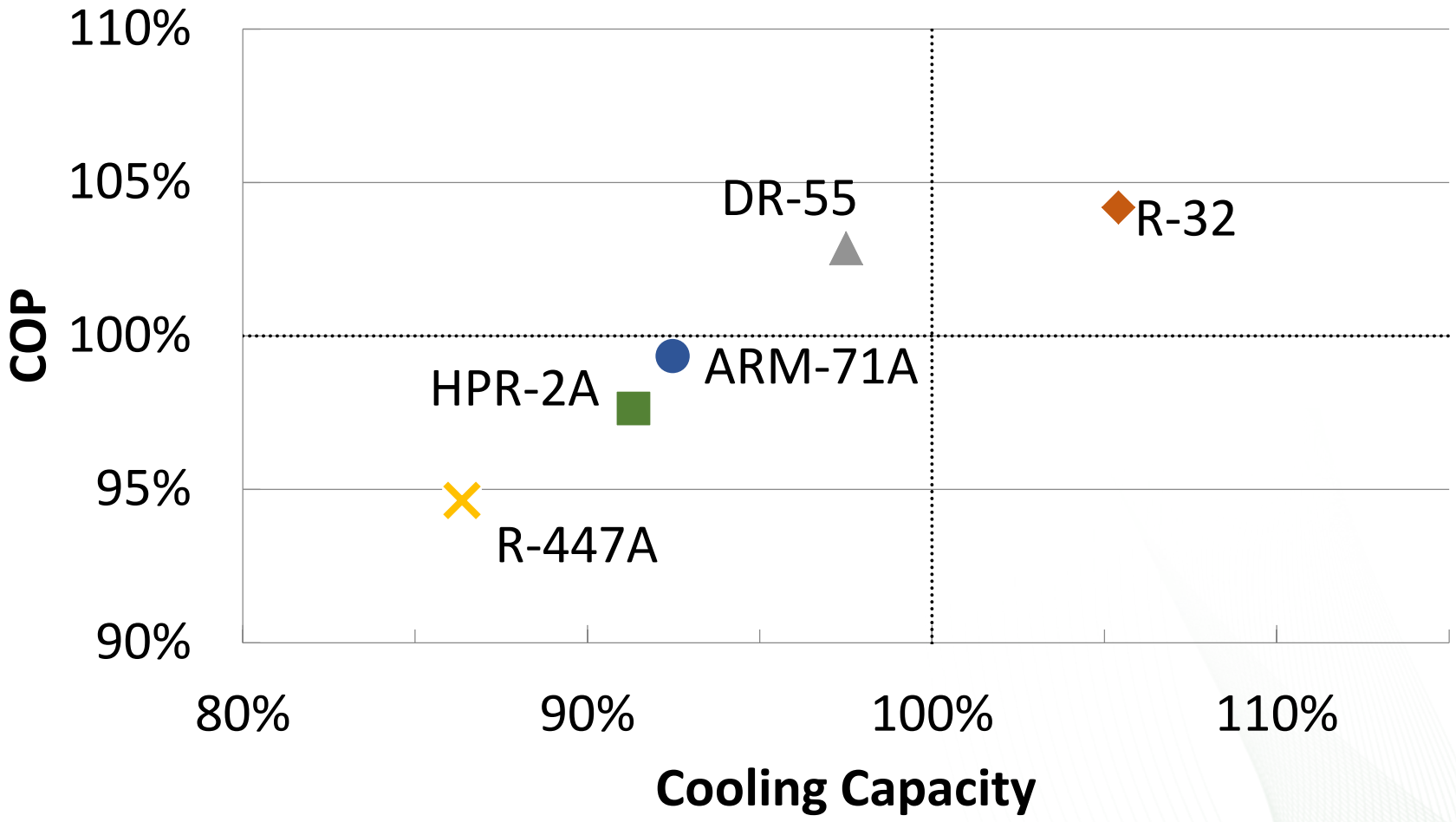
ORNL HAT Evaluation Campaign: Performance Relative to R-410A at 35C outdoor temperature Conditions



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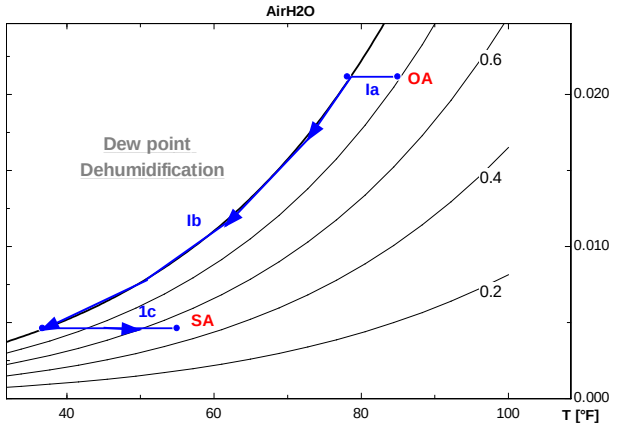
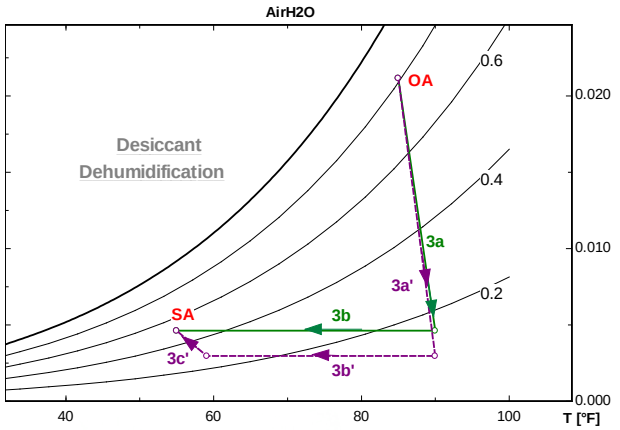
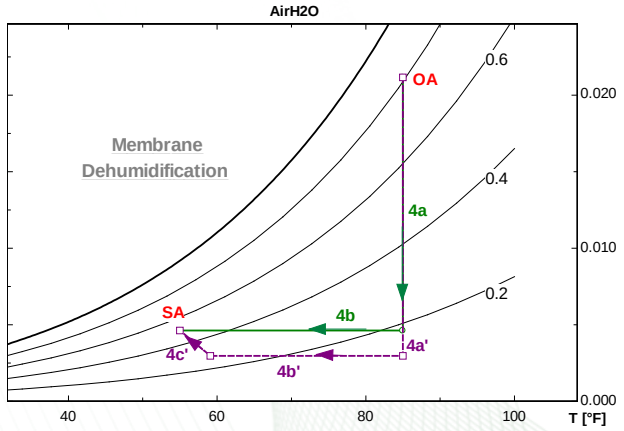
Separate Sensible and Latent Cooling Systems

- Suitable for humid environments or locations with high latent loads
- Moisture removal:
  - Desiccant dehumidification releases heat during the moisture adsorption (sensible heating) and requires regeneration energy (thermal)
  - Membrane dehumidification is an isothermal dehumidification – requires continuous vacuum for operation
- Sensible Cooling: operate a vapor compression system at higher evaporating temperature
- Energy savings: no reheat, higher T_{evap}







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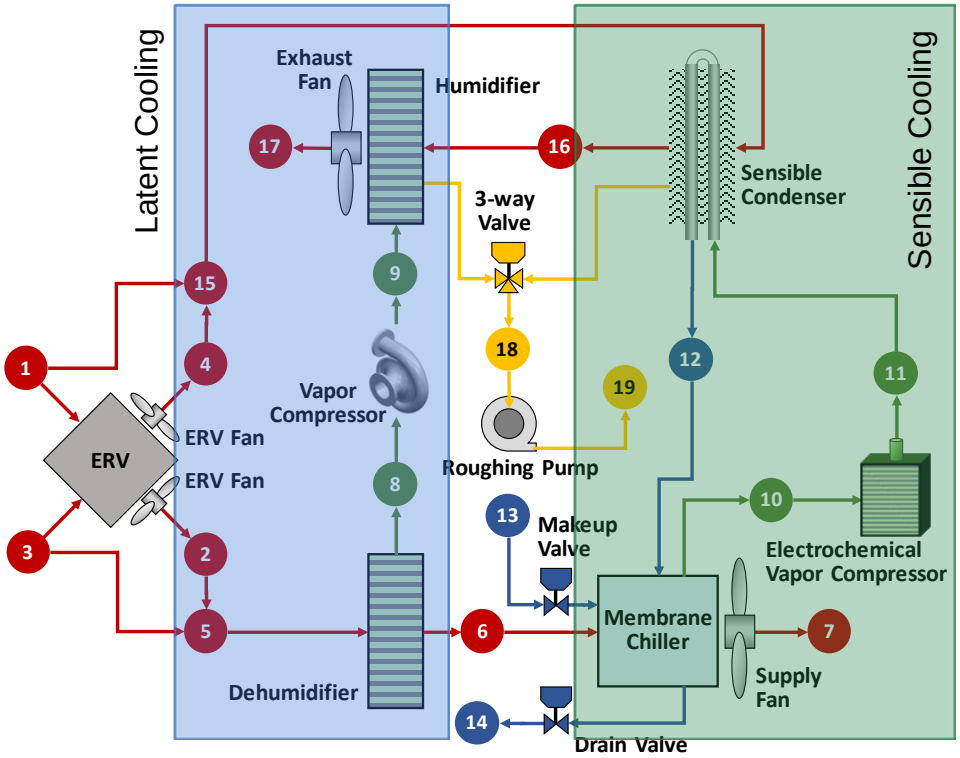
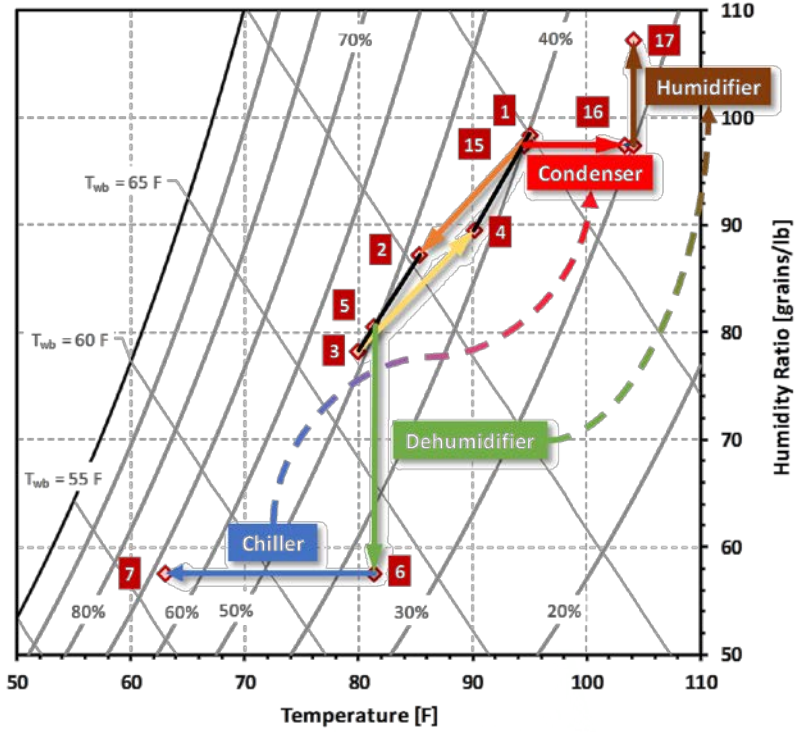
NanoAir™: An Opportunity

System Architecture

Unique and efficient

- **Patented system (US #9,283,518)**
  - No fluorocarbon refrigerants
  - Independent humidity & temperature control
  - Up to 50% energy savings compared to minimum efficiency standard





1	Outside Air	11	Compressed Water Vapor
2	ERV Supply Air	12	Condensate
3	Return Air	13	Makeup Water
4	ERV Exhaust Air	14	Drain
5	Mixed Return Air	15	Mixed Outside Air
6	Dehumidified Air	16	Heated Outside Air
7	Conditioned Supply Air	17	Humid Exhaust Air
8	Water Vapor	18	Non-Condensable Gases
9	Compressed Water Vapor	19	Ambient Air
10	Water Vapor		

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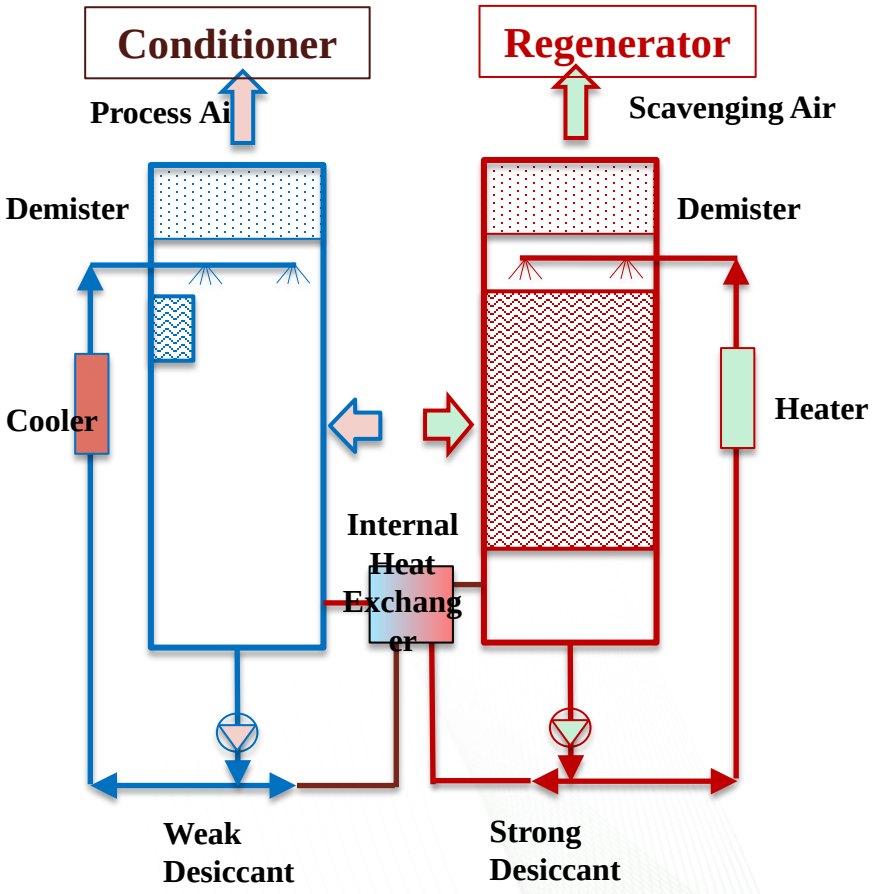
Separate Sensible and Latent Cooling – Electrochemical Compression, Xergy

- Sensible cooling using electrochemical compressor with integrated metal hydrides
- Latent cooling using desiccant dehumidification
  - Condenser heat used to regenerate ionic liquid
  - Ionic Liquid designed to have maximum absorption/desorption with lowest required regeneration temperature



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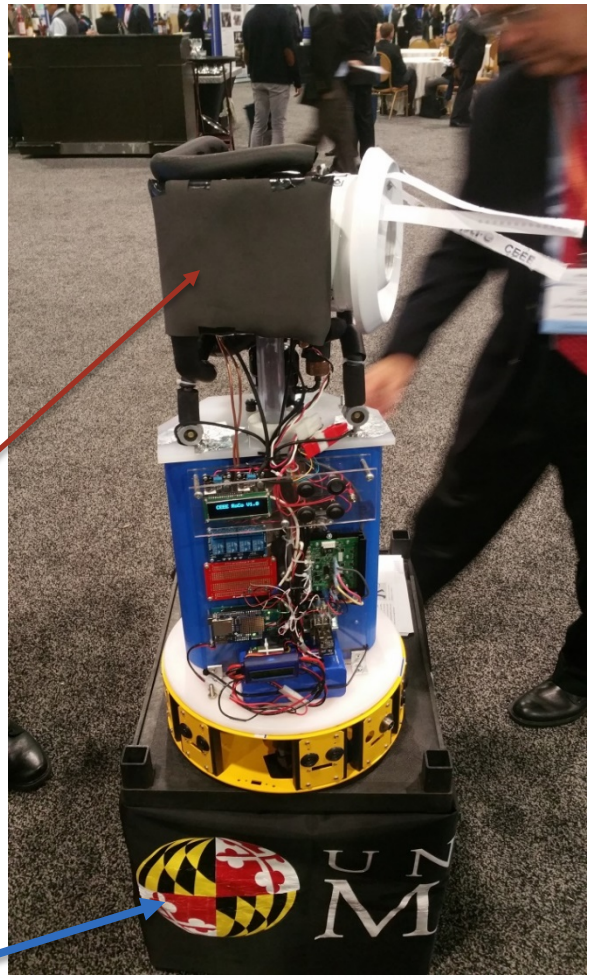
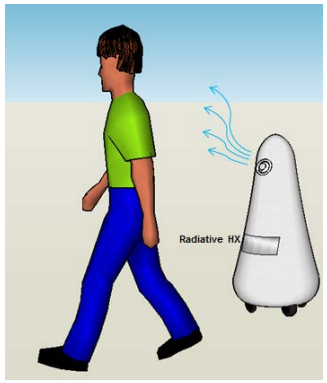
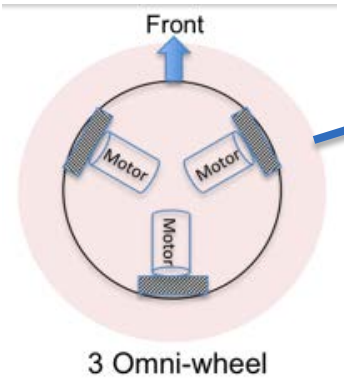
Personal Cooling Systems

- Objective: develop localized cooling systems
  - Enable relaxation of general indoor temperature settings: reduce building load and HVAC energy use
  - Improve occupant comfort
- Low cost phase change component
  - Compressed graphite and paraffin
- System design developed and prototypes assembled
  - Working toward minimizing system cost







3 Omni-wheel

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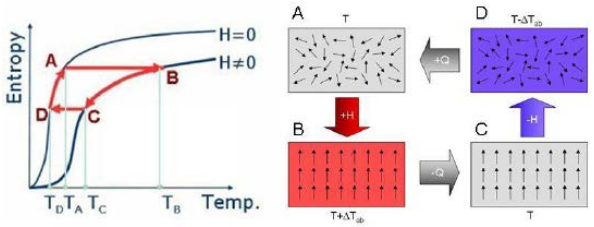
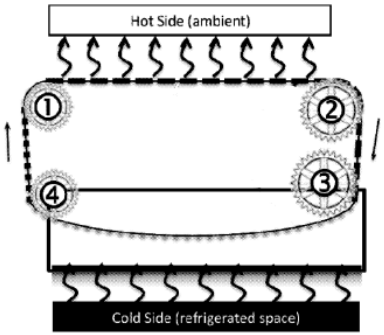
Alternative HVAC Technologies

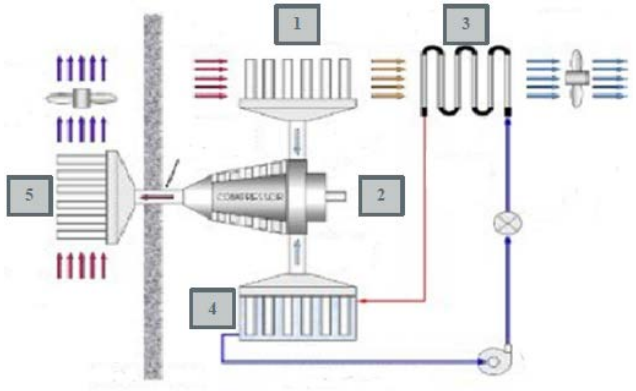
- Navigant performed assessment of alternative technologies for DOE in 2014*
- Objectives:
  - Identify most promising future technology options for RD&D efforts
  - Ranked options based on energy savings potential, development status, other criteria



Magnetic cooling system



Thermoelastic cooling system



Membrane cooling system

* http://energy.gov/sites/prod/files/2014/03/f12/Non-Vapor%20Compression%20HVAC%20Report.pdf
"Energy Savings Potential and RD&D Opportunities for Non-Vapor-Compression HVAC Technologies," Goetzler, W., R. Zogg, J. Young, and C. Johnson (Navigant Consulting), March 2014.

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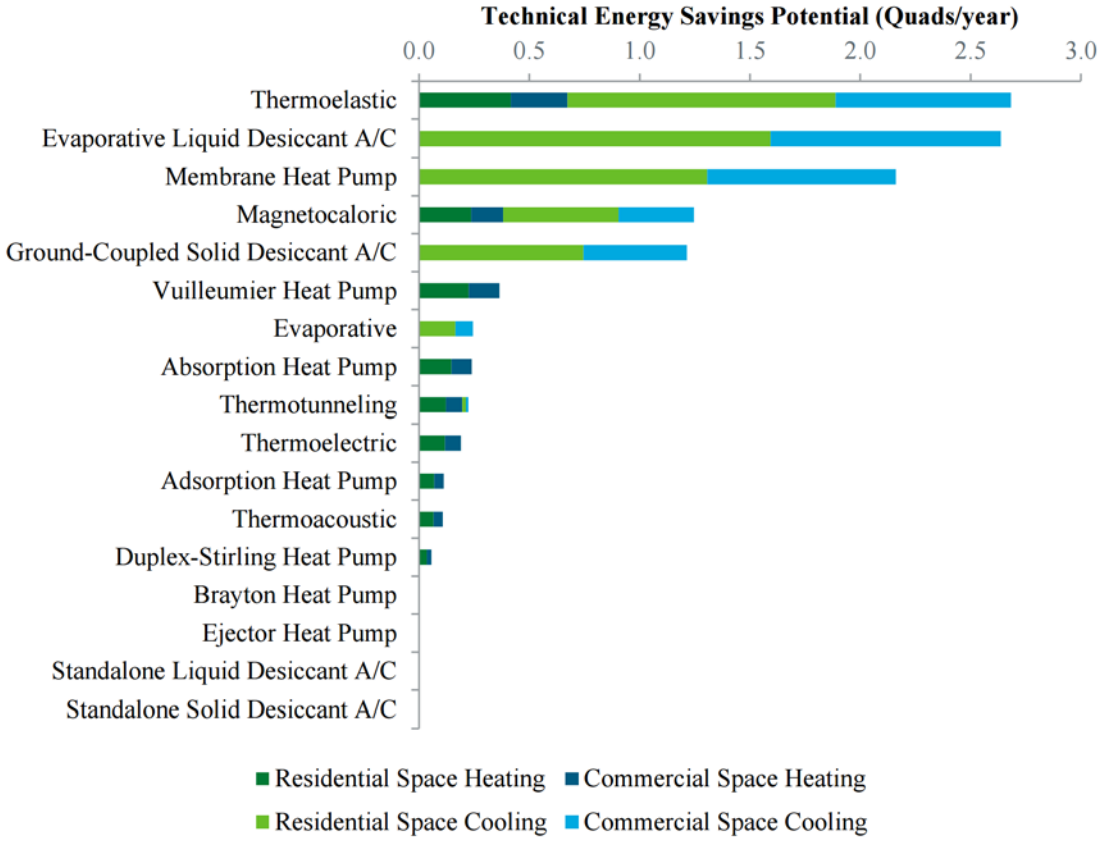
Alternative HVAC Technologies – Energy Savings potential



1 Quad = 1.055 EJ

* http://energy.gov/sites/prod/files/2014/03/f12/Non-Vapor%20Compression%20HVAC%20Report.pdf

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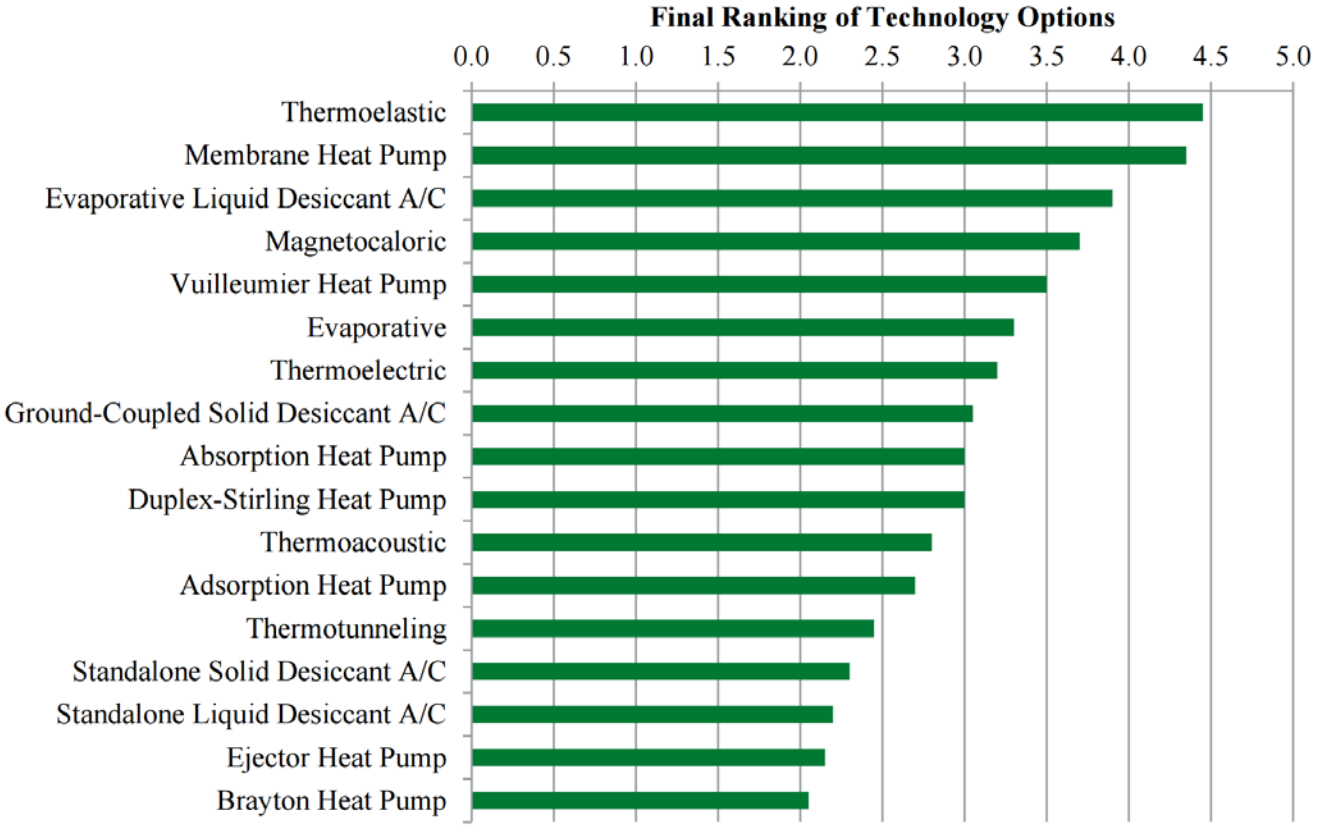
Alternative HVAC Technologies – Priority Rankings



* http://energy.gov/sites/prod/files/2014/03/f12/Non-Vapor%20Compression%20HVAC%20Report.pdf

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Alternative HVAC Technologies – Development Status

Technology	Description	Commercialization Timeline
Absorption / Adsorption	Sorption heat pumps use thermal energy (e.g., natural gas, solar) to drive the cyclical interaction between specialized working fluids or materials. Note – commercially available for large capacity and specialty applications.	Near-Term (2017-2019)
Magnetocaloric	Magnetocaloric cooling systems provide space cooling by exposing specialized magnetocaloric materials to a strong magnetic field.	Medium-Term (2019-2023)
Thermoelastic	Thermoelastic cooling systems stress and release unique shape-memory alloys to provide space cooling.	Long-Term (2023→)
Membrane	Membrane cooling systems provide space cooling and dehumidification by transferring moisture across specialized membranes using vacuum chambers.	Long-Term (2023→)
Electrochemical	Electrochemical compression uses specialized membranes and water working fluid to replace electrically driven mechanical compressors for A/C systems.	Long-Term (2023→)
Electrocaloric	Electrocaloric cooling system provides space cooling by applying an electrical field to a specialized electrocaloric material.	Long-Term (2023→)

Source: "*The Future of Low-GWP Air Conditioning for Buildings.*" Goetzler, W., M. Guernsey, J. Young, and J. Fuhrman (Navigant Consulting); and O. A. Abdelaziz (ORNL). June 2016

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U.S. DOE Research & Development Roadmap for HVAC Technologies

- Enable renewable microgrid integration by developing DC-powered HVAC system (no inverter losses)
- Enable climate specific HVAC solutions:
  - Separate sensible and latent cooling systems
  - Cold climate heat pumps
- Develop advanced compression technologies (electrochemical compressors)
- Seasonal energy storage systems

http://energy.gov/sites/prod/files/2014/12/f19/Research%20and%20Development%20Roadmap%20for%20Emerging%20HVAC%20Technologies.pdf

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U.S. DOE Research & Development Roadmap for HVAC Technologies

- Reduce the cost of sorption systems: new working fluid pairs, miniature heat exchangers, improved materials
- Develop mixed-mode AC systems to maximize energy savings associated with natural ventilation
- Improve ground-source heat pump (GHP) cost effectiveness
- Develop alternative lower emission HVAC systems
- Develop solid-state (caloric) cooling systems
  - CaloriCool™

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Enabling Research and Development Initiatives

- Proper system commissioning and installation
- Transactive HVAC management (Smart Grid)
- Low-cost sensors and controls; open source automation systems
- Standard methods for DAS
- Demonstrate renewable-integrated district CCHP
- Building metric (energy, health, etc.)
- Energy recovery: buildings with simultaneous heating and cooling loads
- Simplified energy analysis tools for homeowners
- Lessons learned repository for high performance buildings database

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Discussion

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