ASHRAE Region VI CRC
Track III: Session 3
Ventilation Energy Recovery

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Learning Objectives

- Understand how ventilation heat recovery systems work
- Identify the requirements for ventilation heat recovering as defined by ASHRAE 90.1
- Recognize typical situations that lead to cost-effective applications of ventilation heat recovery

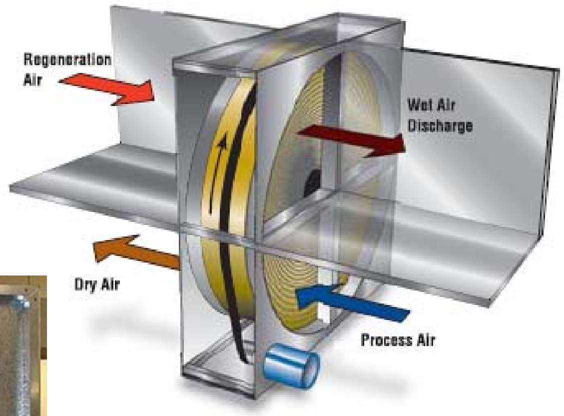
Agenda

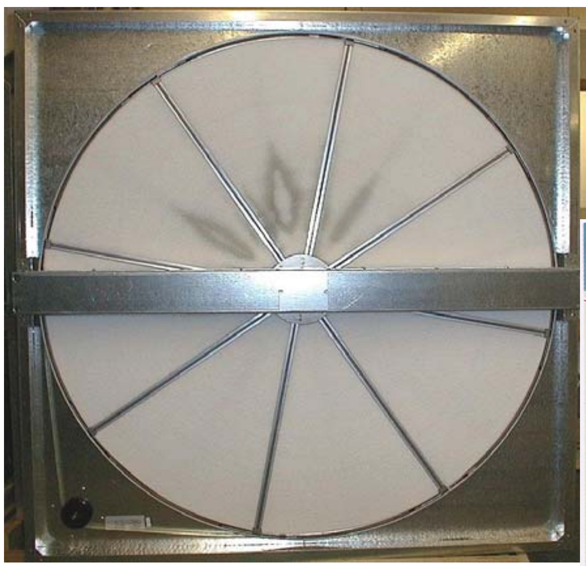
- Energy Recovery Types
- Standard 90.1 Requirements
- Costs & Benefits
- Typical Application Schematics & Control Sequences

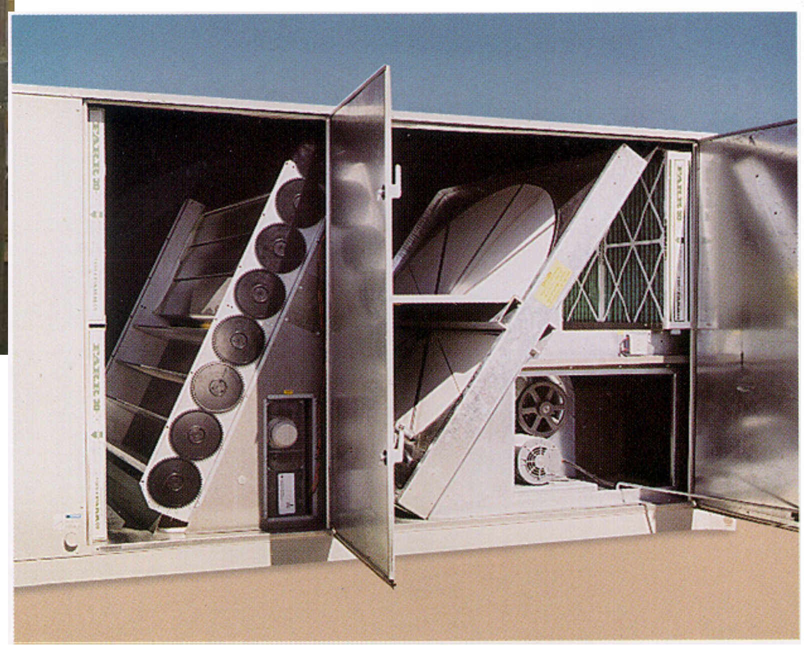
Energy Recovery Types

- **Rotary (wheel)**
  - Sensible
  - Total (Enthalpy)
- **Flat Plate**
  - Sensible
  - Total (Enthalpy)
- **Heat Pipe**
- **Run-around**

Rotary Heat Exchanger

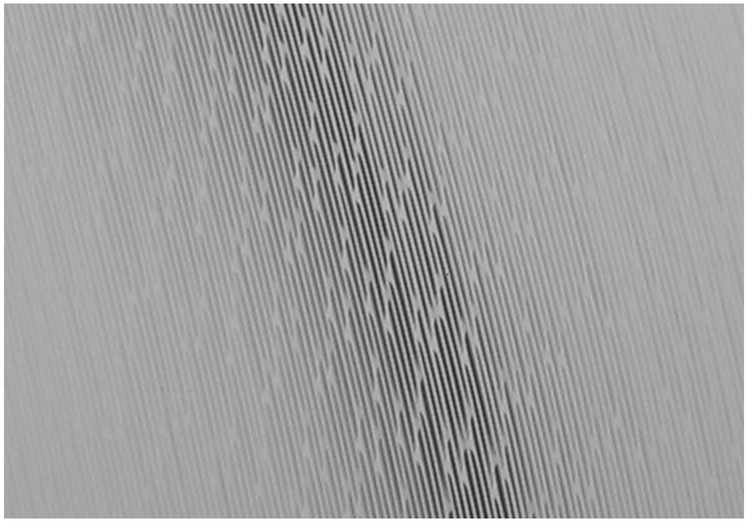


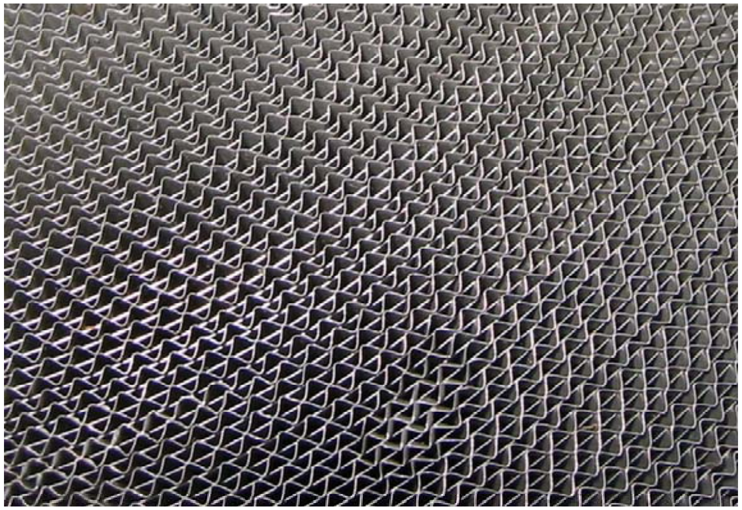




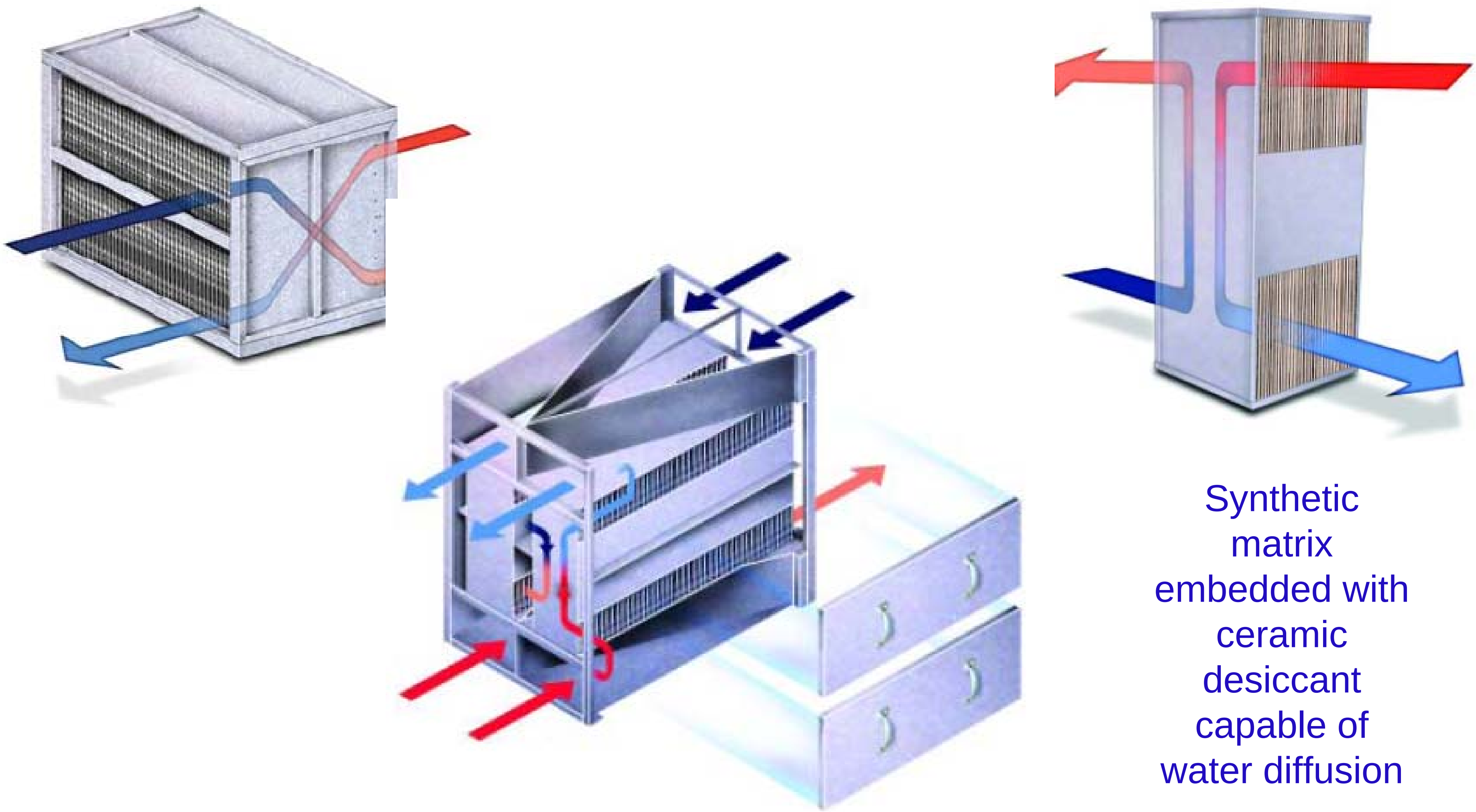
Enthalpy Wheel Desiccants

- **Lithium Chloride**
  - Salts dissolve, wash off.
- **Silica Gel**
  - Best water transfer characteristics.
- **Molecular Sieves**
  - Can be engineered to discriminate between species. Ideal for many process applications.



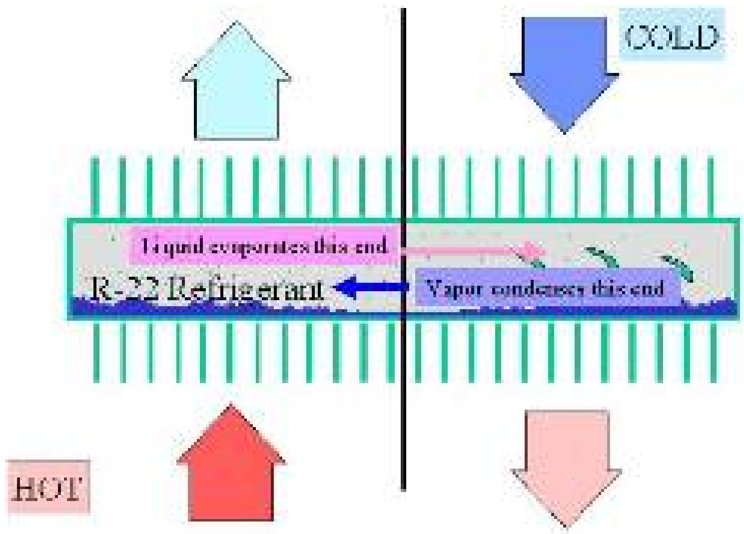


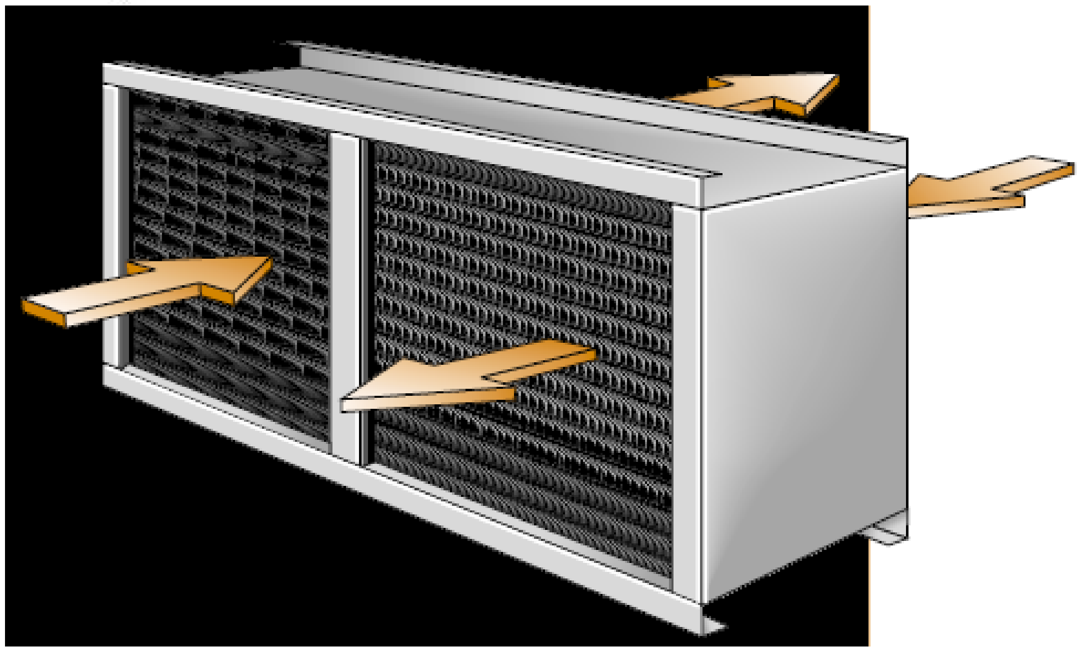
Flat Plate Heat Exchanger



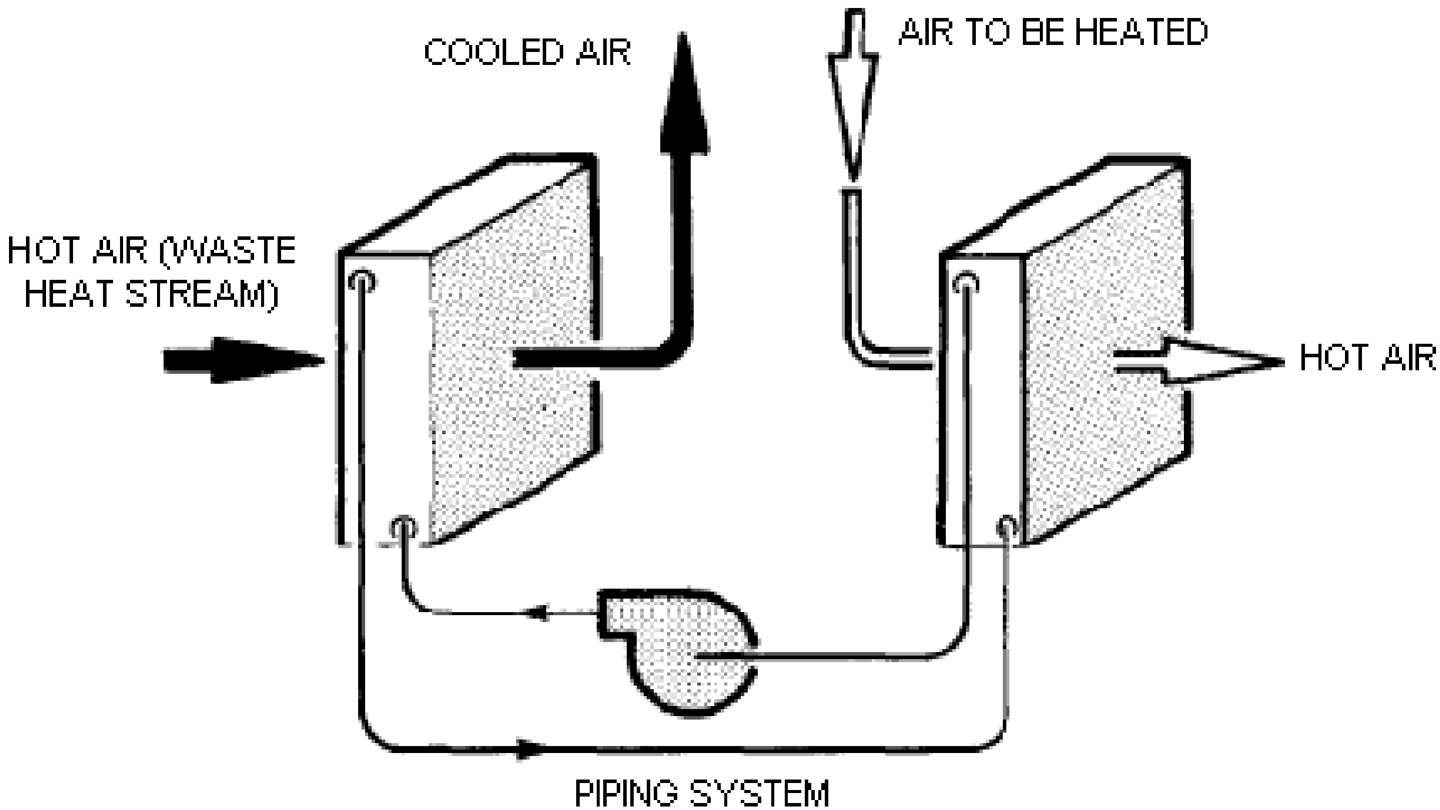
Synthetic matrix embedded with ceramic desiccant capable of water diffusion

Heat Pipe Heat Exchanger

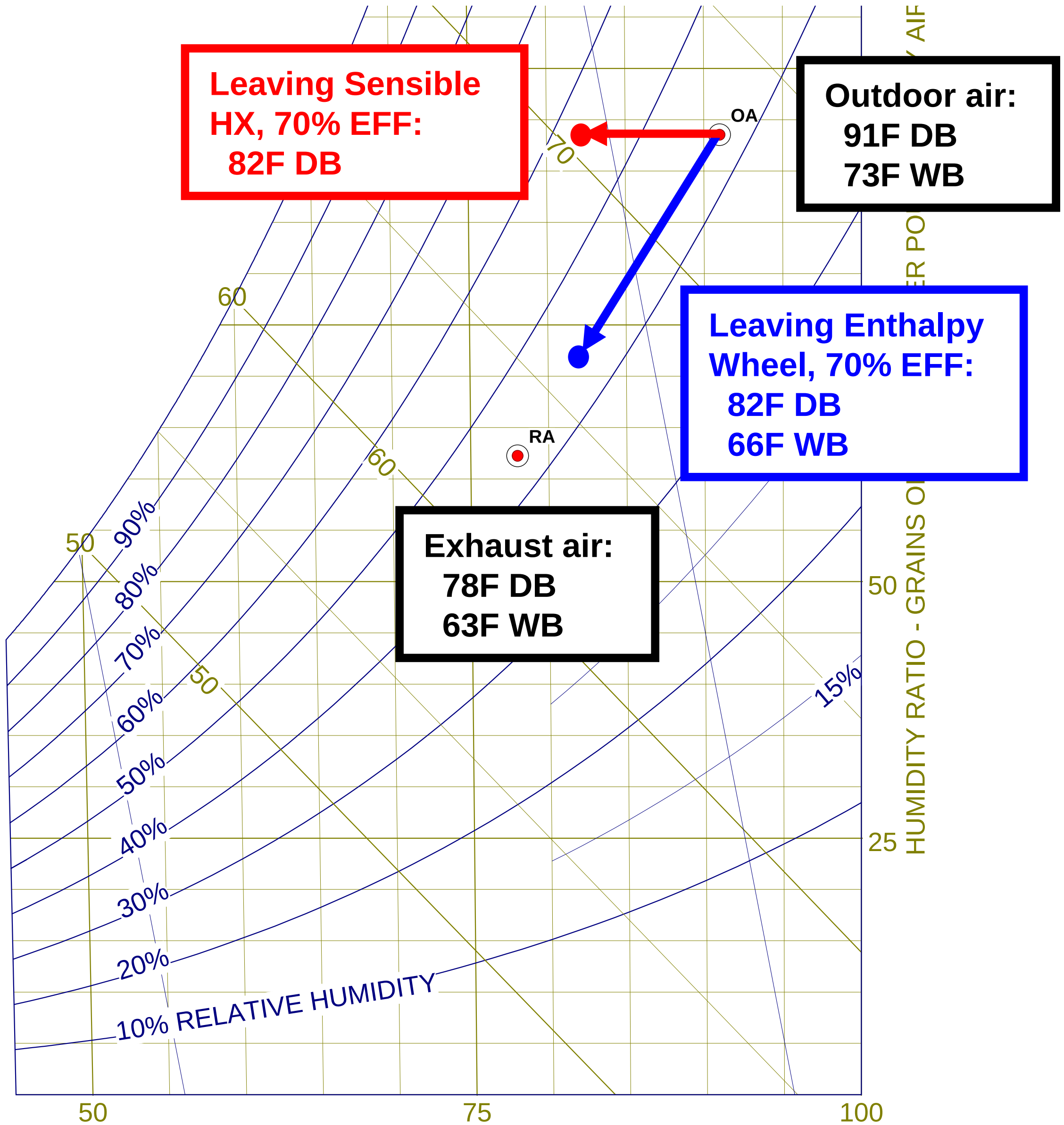




Run-Around Heat Exchanger



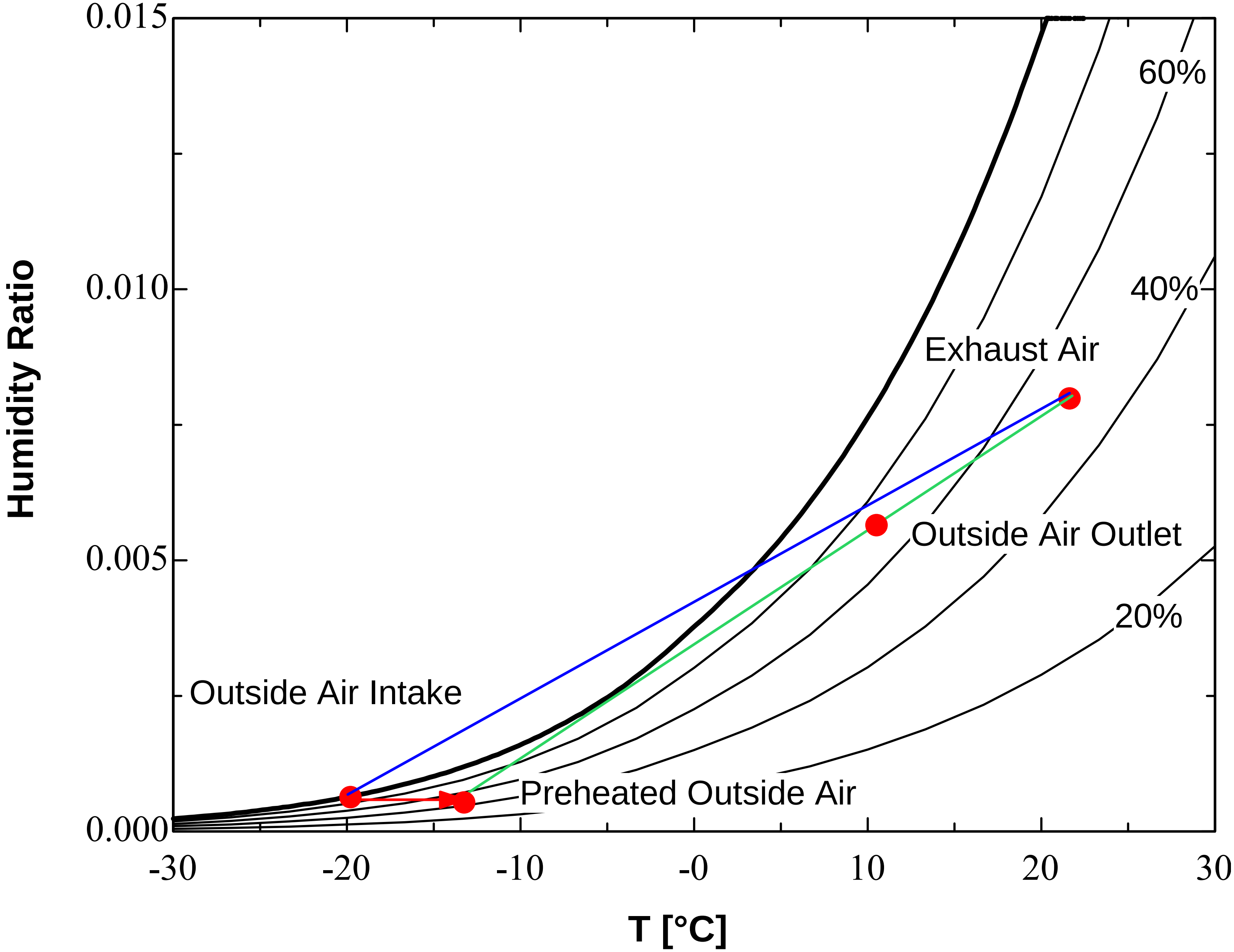
Heat Exchanger Cooling Performance



Heat Exchanger Ratings

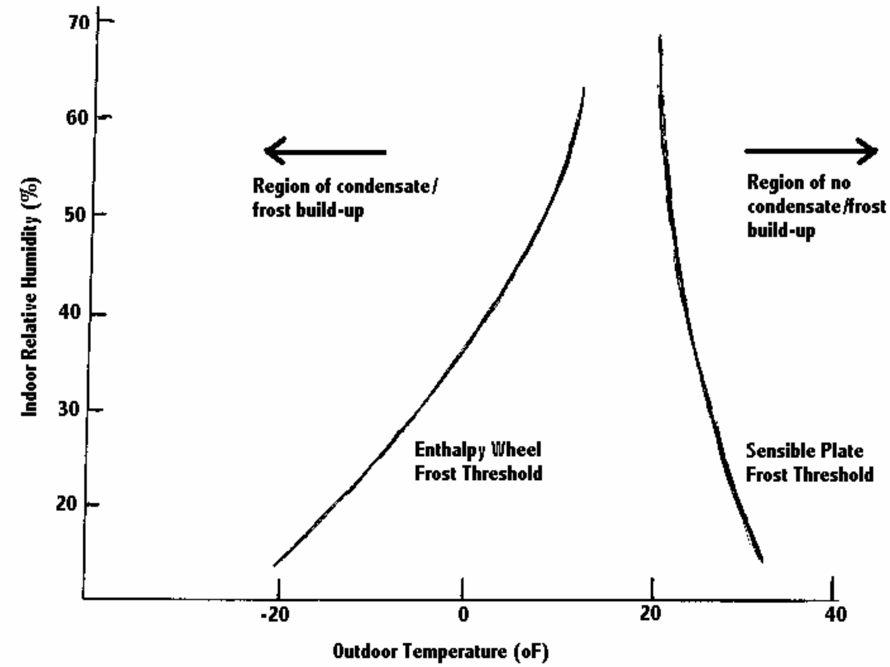
- **ARI 1060**
  - Rotary
  - Flat Plate
  - Heat Pipe
  - Non-ARI Certified language
    - "Tested in accordance with ARI 1060"
    - "Independently tested in accordance with ASHRAE Standard 84 and ARI standard 1060"
    - "Independently certified in accordance to ARI 1060"
  - ARI Certified language
    - ARI 1060 certified and listed in the ARI 1060 Directory of Certified Air-to-Air Energy Recovery Ventilation Equipment
    - No seal – not certified!
- **ARI 410**
  - Run-around coils

Freezing/Frosting



Frost Control

- Function of outdoor temperature and indoor RH
- Enthalpy wheel has the lowest frost threshold
- Pre-heat is preferred solution – maintains maximum recovery
- Usually not required in non-humidified buildings

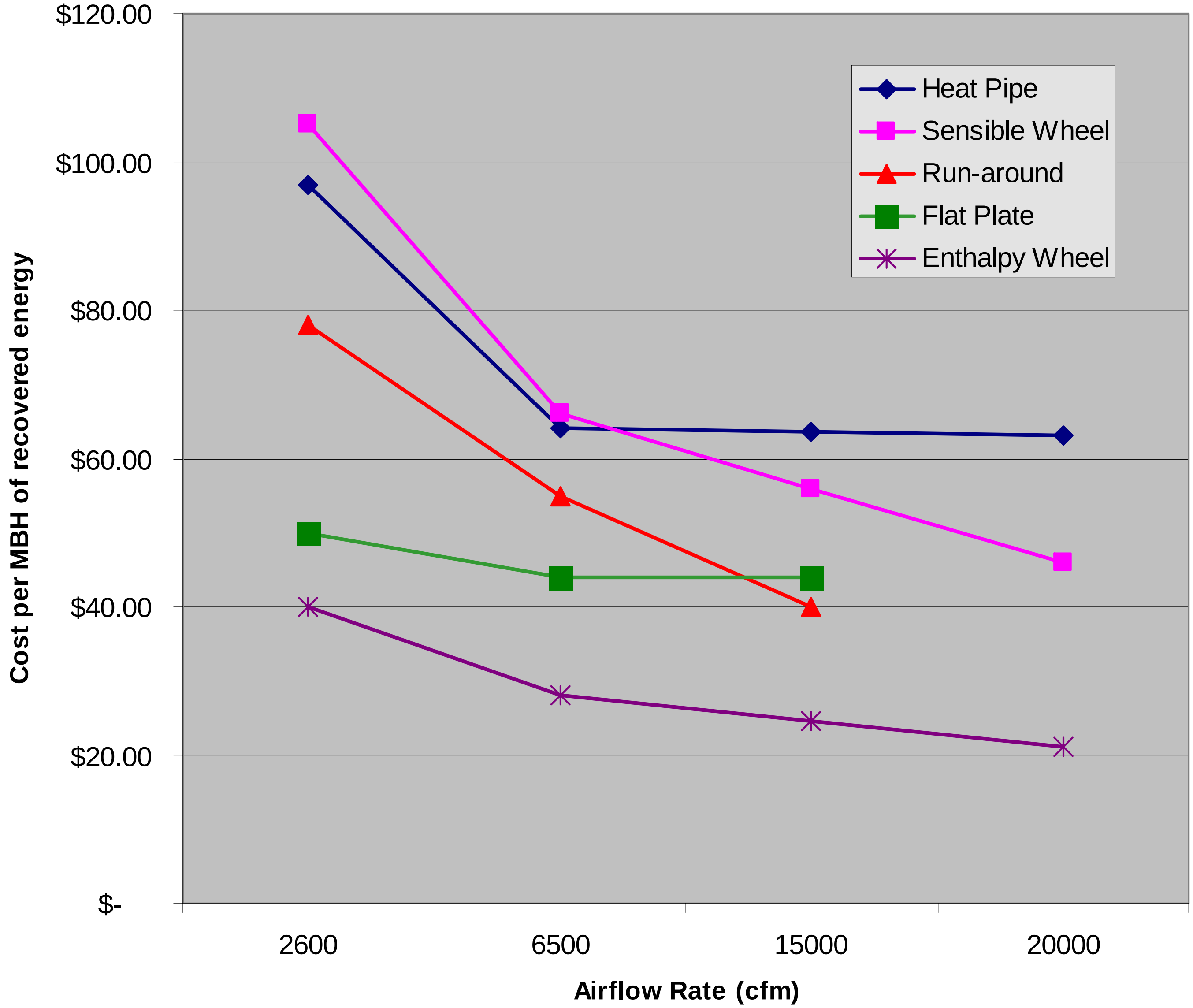


Frost Threshold Temperature (°F)				
Indoor Air RH (%)	Indoor Air Dry Bulb Temperature			
	70° F	72° F	75° F	80° F
20	-14	-13	-11	-8
30	-3	-2	-1	3
40	5	7	9	11
50	12	13	15	18
60	18	19	21	26

Comparison of HX Types

Characteristic	Rotary Wheel	Fixed Plate	Heat Pipe	Run-Around
Sensible Effectiveness (equal flow)	60%-80%	60%-70%	30%-65%	45%-65%
Total Effectiveness (equal flow)	65%-80%	45%-65%	–	–
Pressure drop (each side)	0.5 to 1.2 in.wg.	0.6 to 1.4 in.wg.	0.2 to 0.8 in.wg.	0.3 to 1.0 in.wg.
Susceptibility to frost	High (sensible) Lowest (total)	Highest (sensible) Low (total)	Modest	Modest
Cross-leakage	Modest	Slight	Slight	None
Adapted from Trane Heat Recovery Applications Manual				

Typical Cost/Performance Ratio



from Trane Heat Recovery Applications Manual, 1997

Standard 90.1 Requirements

- **Individual fan systems that have both a design supply air capacity of 5000 cfm or greater and have a minimum outdoor air supply of 70% or greater of the design supply air quantity shall have an energy recovery system with at least 50% recovery effectiveness.**
  - Provision shall be made to bypass or control the heat recovery system to permit air economizer operation
- **Note: Addendum to toughen requirements recently out for public review but not likely to be approved as written**

Standard 90.1 Exceptions

Energy Recovery not required for:

a) Laboratory systems meeting 6.5.7.2.

b) Systems serving spaces that are not cooled and that are heated to less than 60°F.

c) Systems exhausting toxic, flammable, paint, or corrosive fumes or dust.

d) Commercial kitchen hoods used for collecting and removing grease vapors and smoke.

e) Where more than 60% of the outdoor air heating energy is provided from site-recovered or site solar energy.

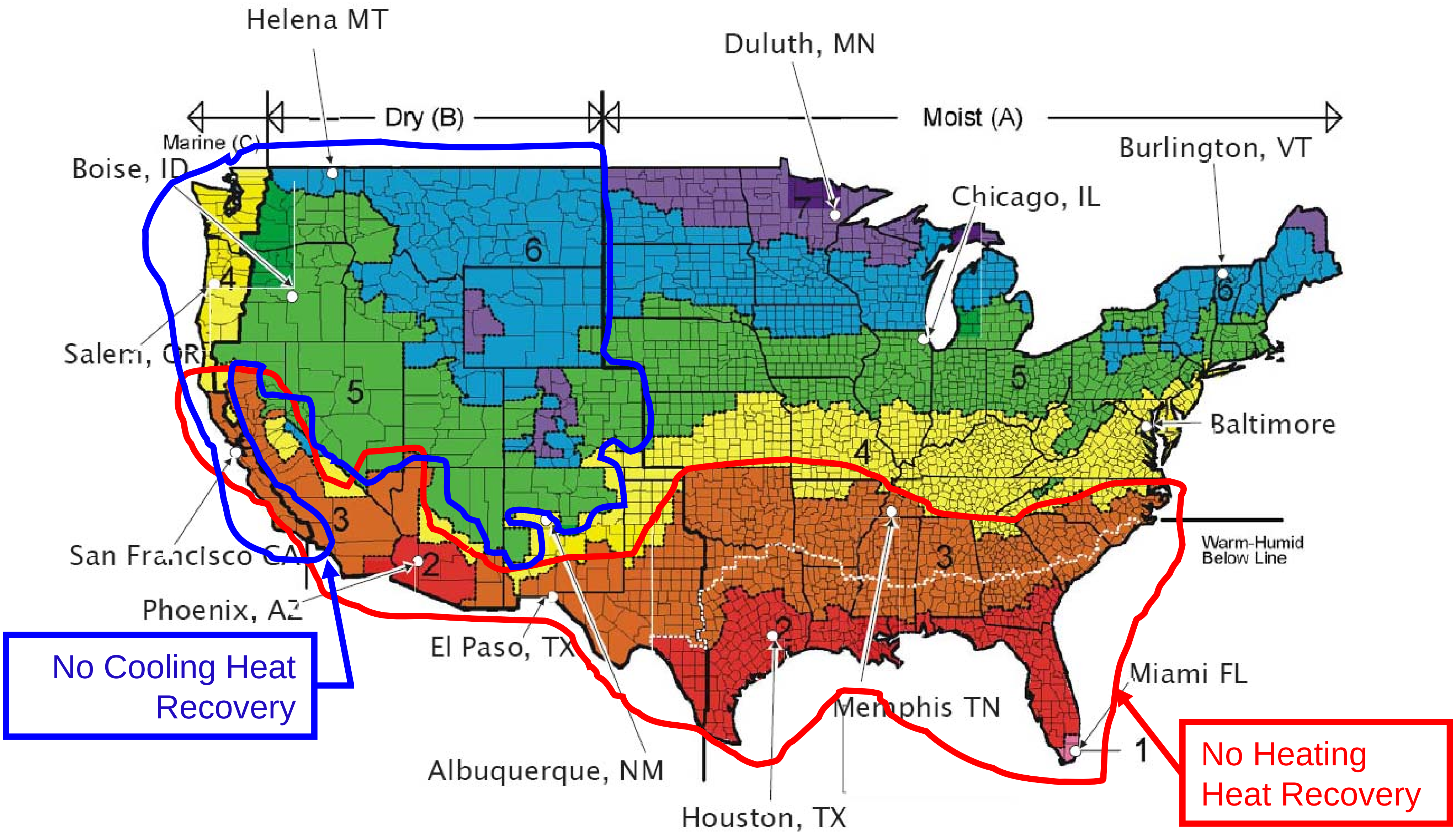
f) Heating systems in climate zones 1 through 3.

g) Cooling systems in climate zones 3c, 4c, 5b, 5c, 6b, 7, and 8.

h) Where the largest exhaust source is less than 75% of the design outdoor air flow.

i) Systems requiring dehumidification that employ energy recovery in series with the cooling coil.

ASHRAE Climate Zones



ASHRAE 90.1 vs. Actual Effectiveness

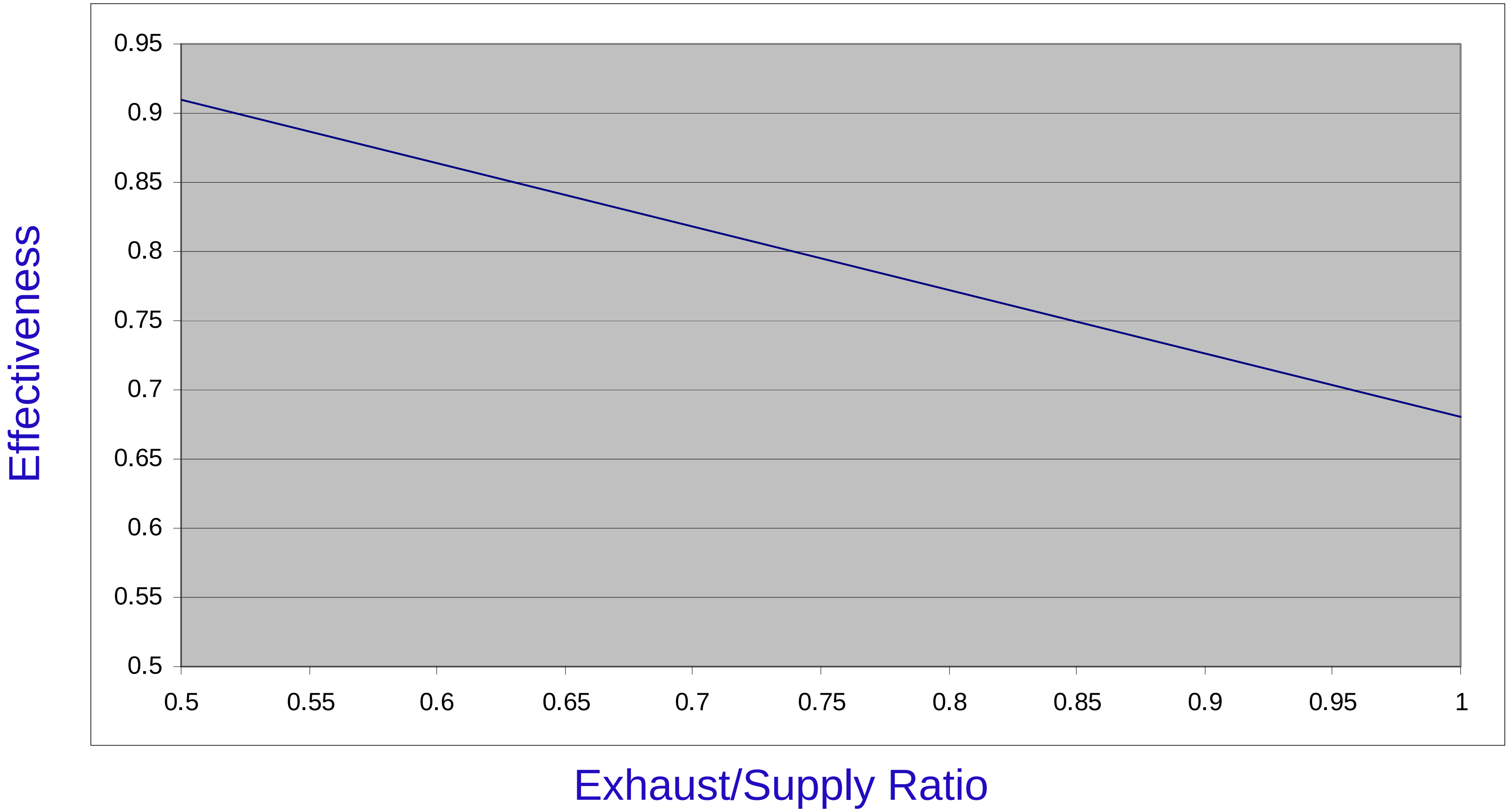
$$\varepsilon_{ARI} = \frac{\dot{m}_{oa}(h_{oaE} - h_{oaL})}{\dot{m}_{\min}(h_{oaE} - h_{raE})} = \frac{\dot{m}_{oa}(h_{oaE} - h_{oaL})}{\dot{m}_{ea}(h_{oaE} - h_{raE})}$$

$$\varepsilon_{90.1} = \frac{h_{oaE} - h_{oaL}}{h_{oaE} - h_{raE}} > 0.5$$

ASHRAE 90.1 definition basically assumes equal exhaust and outdoor airflow rates

Unbalanced Flow and Effectiveness

- Effectiveness increases with unbalanced flow, but energy recovered does not!

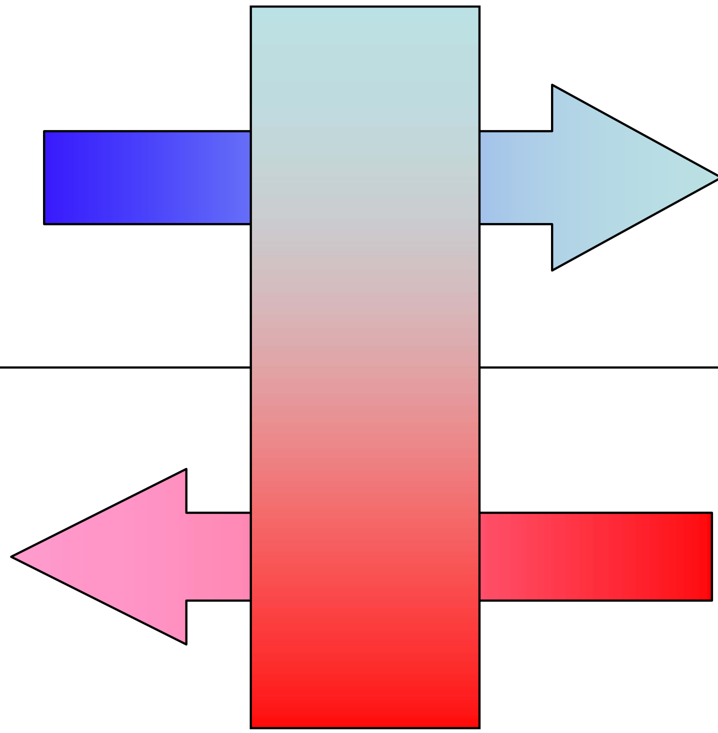


Wintertime Sensible Effectiveness

70% Sensible Effectiveness

100% Exhaust Airflow Rate

Outdoor Air:
DB: 35F
WB: 33F
h: 12.2 Btu/lb



Outdoor Air:
DB: 59.5F
WB: 46.2F
h: 18.4 Btu/lb

Exhaust Air:
DB: 45.5F
WB: 41.7F
h: 16.1 Btu/lb

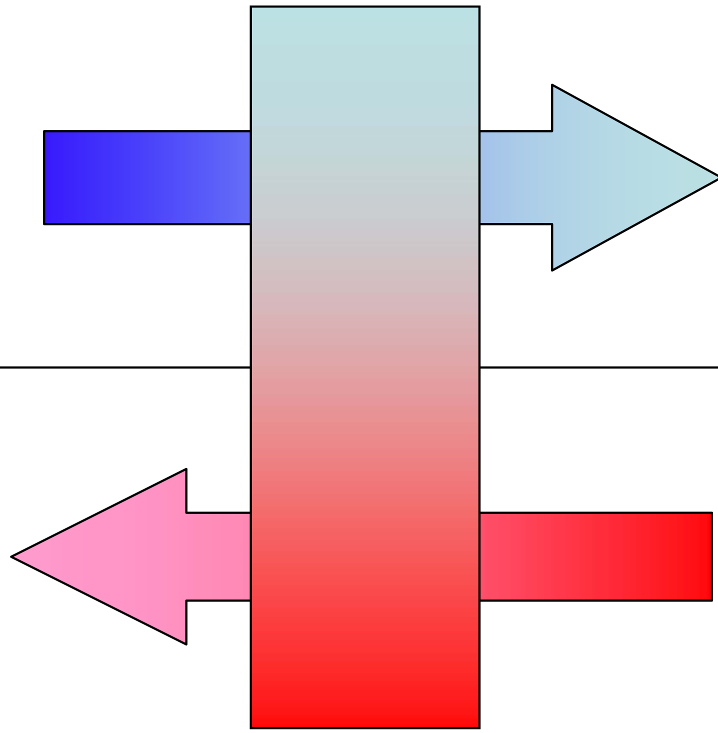
Exhaust Air:
DB: 70F
WB: 53.4F
RH: 30%
h: 30.0 Btu/lb

ASHRAE
Effectiveness: 61%

Wintertime Sensible Effectiveness

82% Sensible Effectiveness

70% Exhaust Airflow Rate



Outdoor Air:
DB: 35F
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Outdoor Air:
DB: 59.5F
WB: 46.2F
h: 18.4 Btu/lb

Exhaust Air:
DB: 45.5F
WB: 41.7F
h: 16.1 Btu/lb

Exhaust Air:
DB: 70F
WB: 53.4F
RH: 30%
h: 30.0 Btu/lb

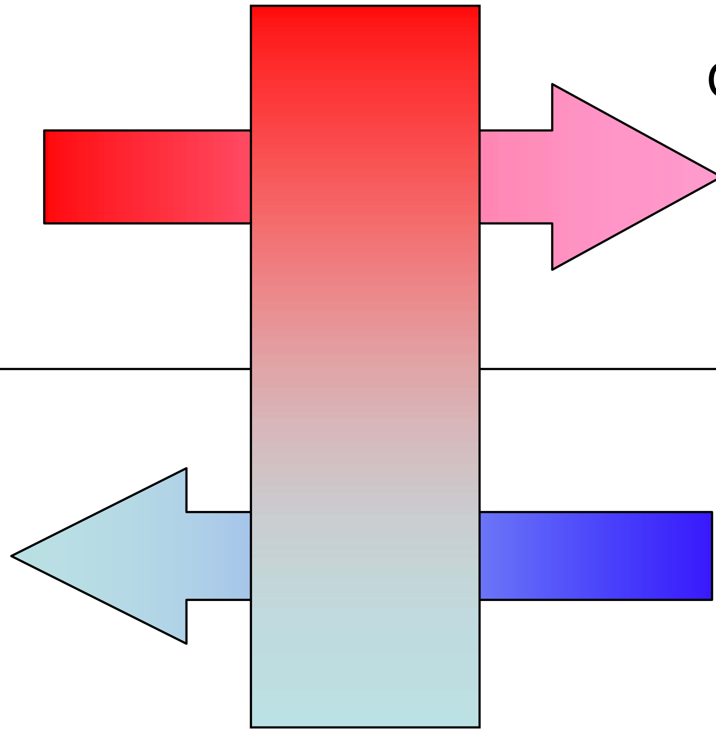
ASHRAE Effectiveness: 50%

Summertime Sensible Effectiveness

80% Sensible Effectiveness

100% Exhaust Airflow Rate

Outdoor Air:
DB: 95F
WB: 78F
h: 41.9 Btu/lb



Outdoor Air:
DB: 79F
WB: 73.6F
h: 37.6 Btu/lb

Exhaust Air:
DB: 91F
WB: 68.5F
h: 33.0 Btu/lb

Exhaust Air:
DB: 75F
WB: 63F
RH: 51%
h: 28.8 Btu/lb

ASHRAE Effectiveness: 33%

Conclusion

- **Where 90.1 requires heat recovery for cooling:**
  - Enthalpy heat exchanger required
- **Where 90.1 requires heat recovery for heating:**
  - If humidified (RH>~30%): Enthalpy heat exchanger required
  - If not humidified : Any style will work

Enthalpy Wheels

- **Advantages**
  - Somewhat self-cleaning and easy to clean
  - Low frost temperature limits
    - May eliminate preheat coil in non-humidified buildings
    - Increases heat recovered in cold weather
  - Compact
  - Highest effectiveness, sensible & total
  - Lowest cost per unit of recovered energy
  - “Free” winter humidification (recovers latent load)
- **Disadvantages**
  - Moving parts affect maintenance costs
  - Leakage and carryover between airstreams
  - Airstreams must be side-by-side (vs. run-around)

First Costs/Benefits

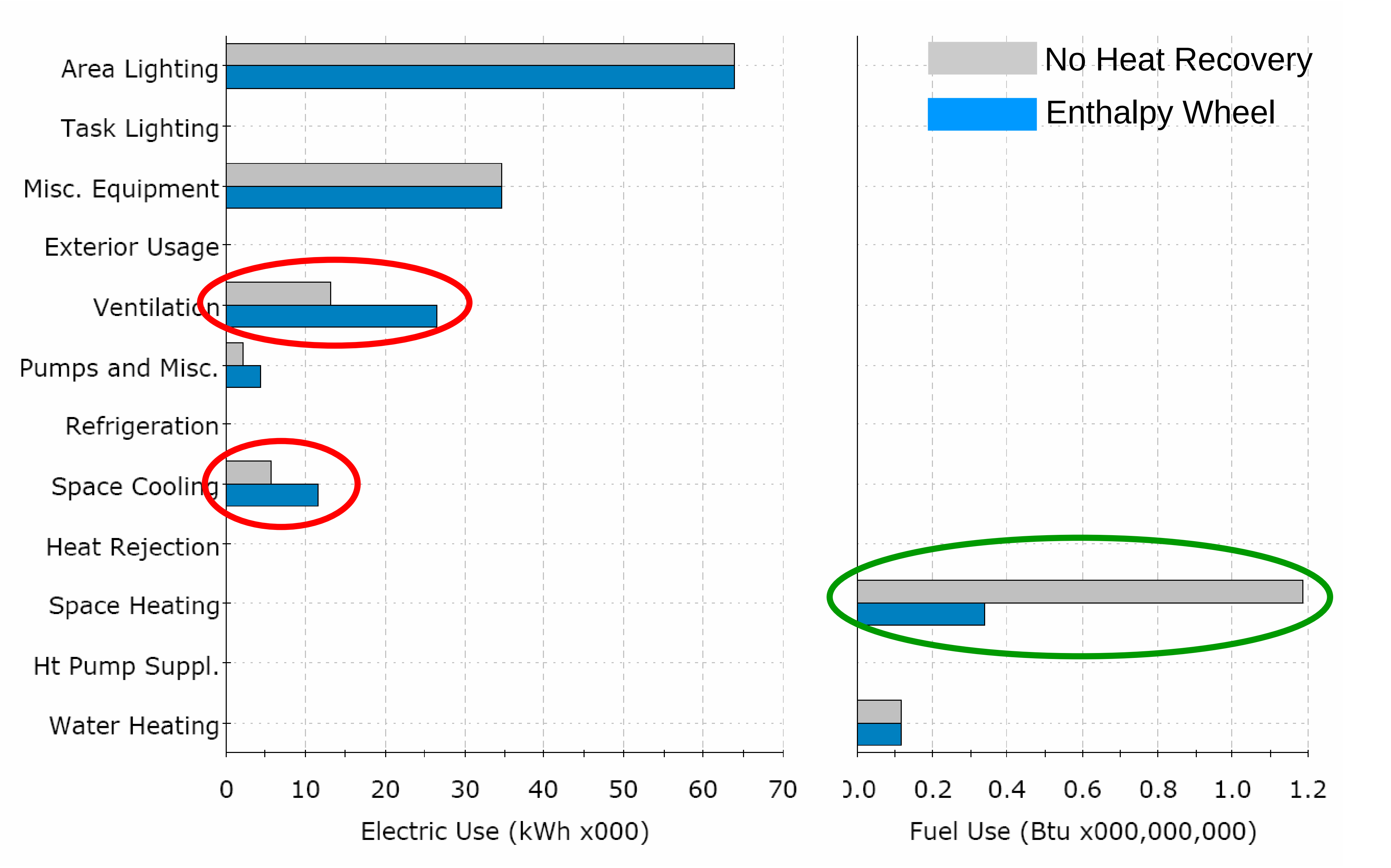
- **Costs**
  - Heat recovery device
  - Routing exhaust ducts (or run-around pipes) to intakes
  - Added fans (where applicable)
  - Increased fan motor HP of existing supply air and exhaust air fans
- **Benefits**
  - Downsizing heating/cooling systems

Operating Costs/Benefits

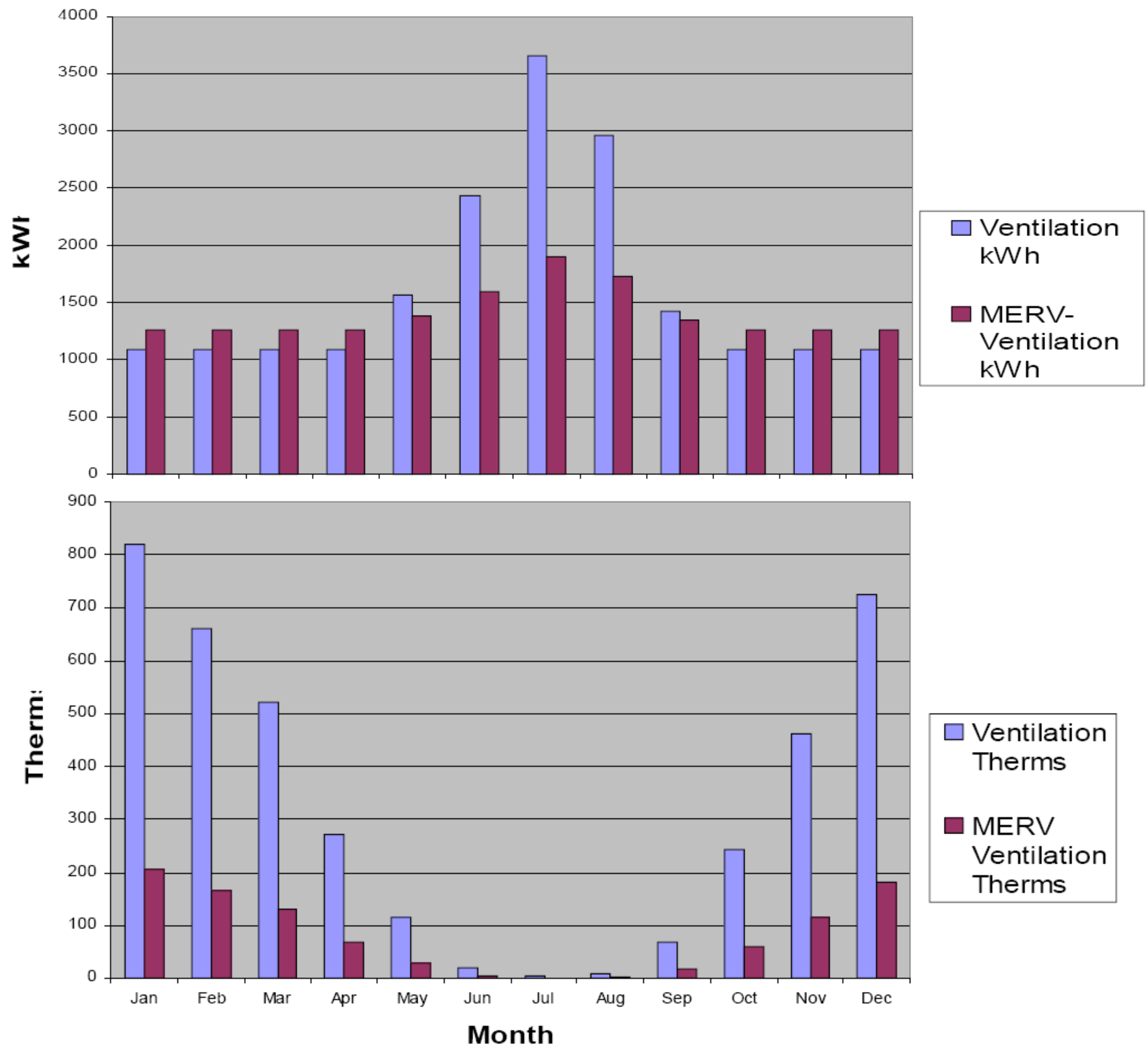
- **Costs**
  - Increased maintenance (filters, coil/core cleaning, motor, bearings)
- **Benefits**
  - Reduced cycling due to smaller AC unit size for improved temperature and humidity control
    - No real humidity benefits from moisture transfer – it is the cooling system that removes the moisture
  - Reduced cooling and heating loads
    - Offset partly by added fan energy
    - Net savings varies by application, design, and climate

Net Energy Savings

(School in Madison, WI. No summer classes)



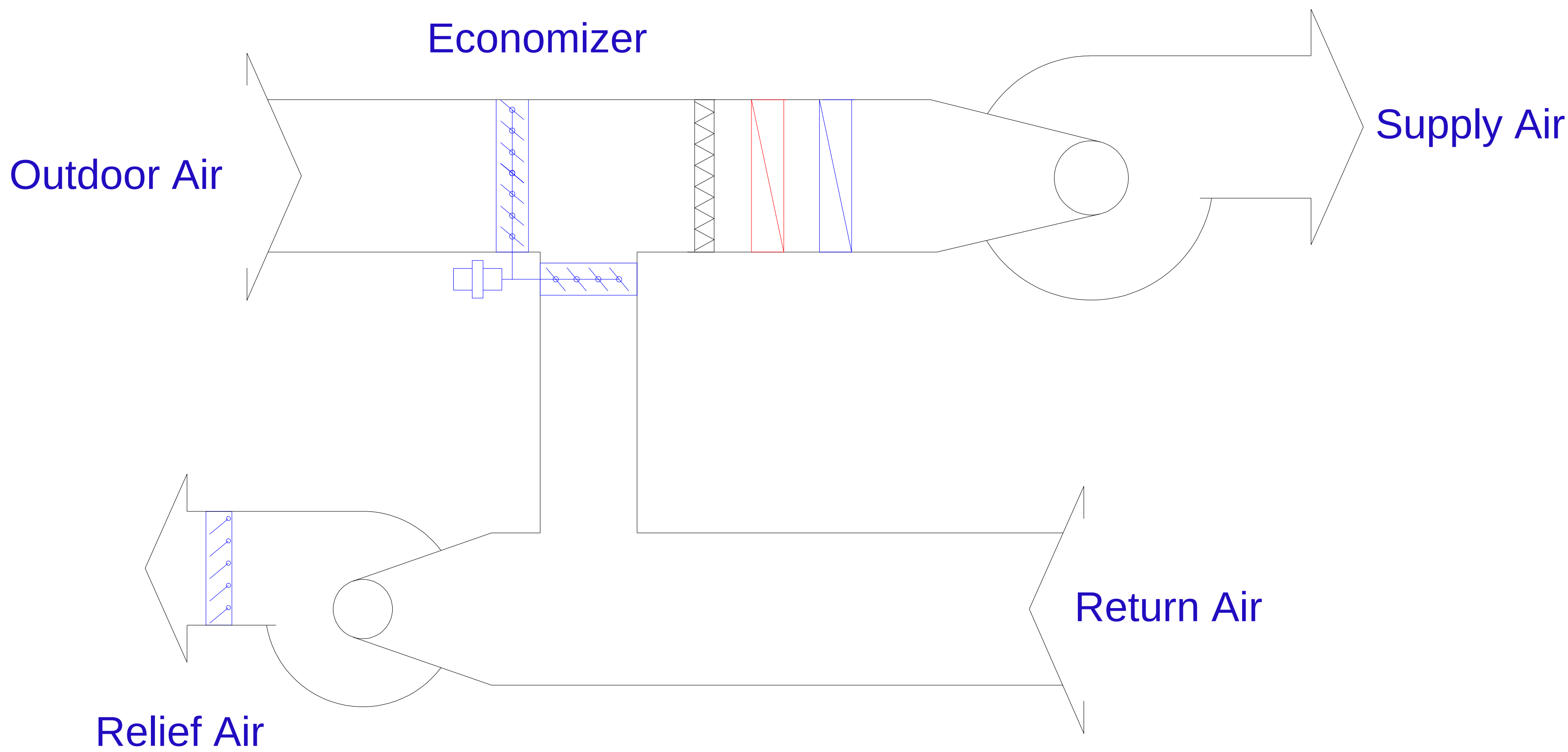
Net Energy Savings
(Big Box Department Store, Iowa)



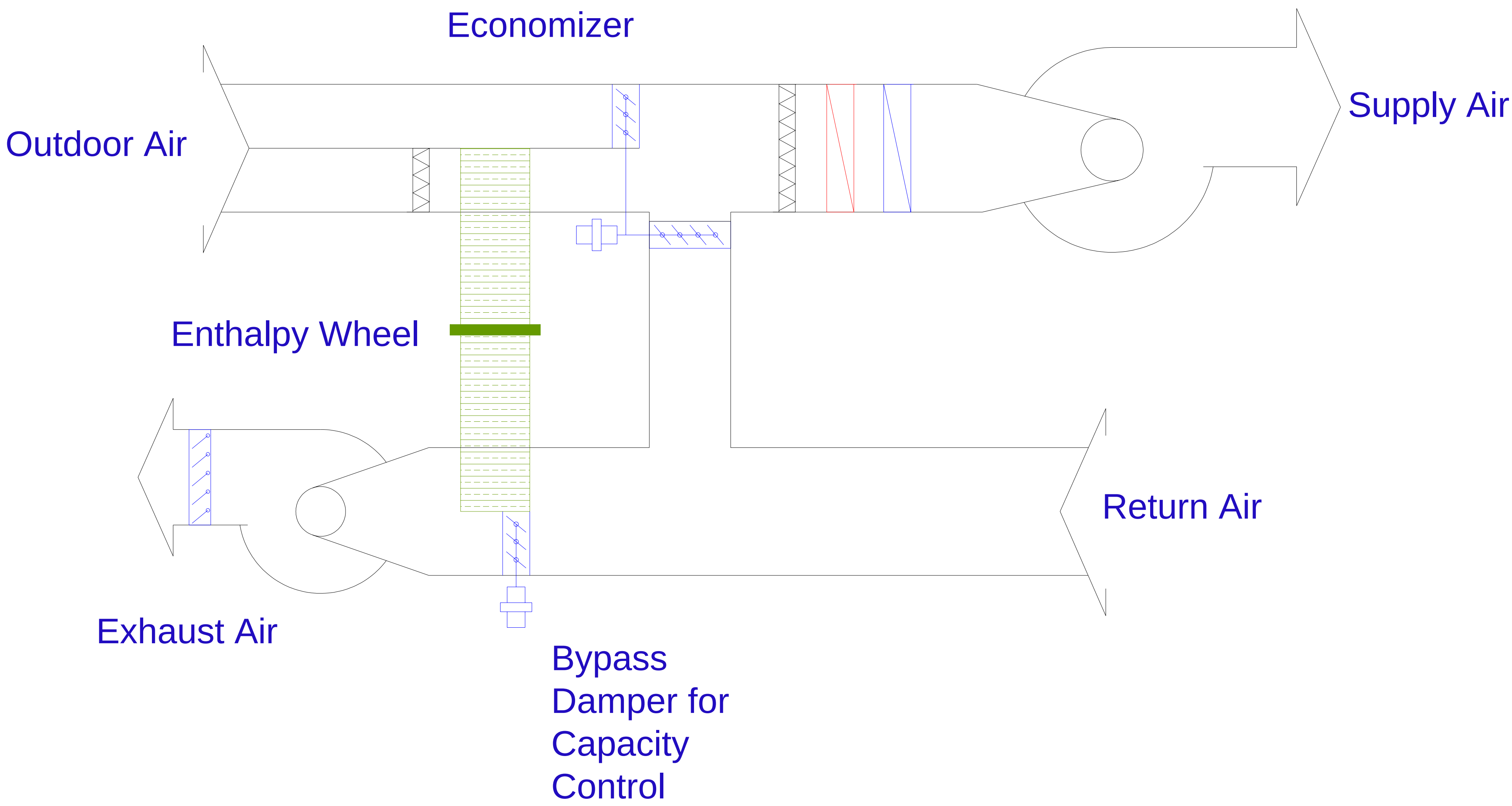
Most Cost Effective Applications

- **High outdoor air rate**
  - Densely occupied spaces
- **Excess return air that would have to be exhausted anyway to prevent over-pressurizing building**
  - Allows HR to be used without extra ductwork and without extra fan if there already is a relief fan

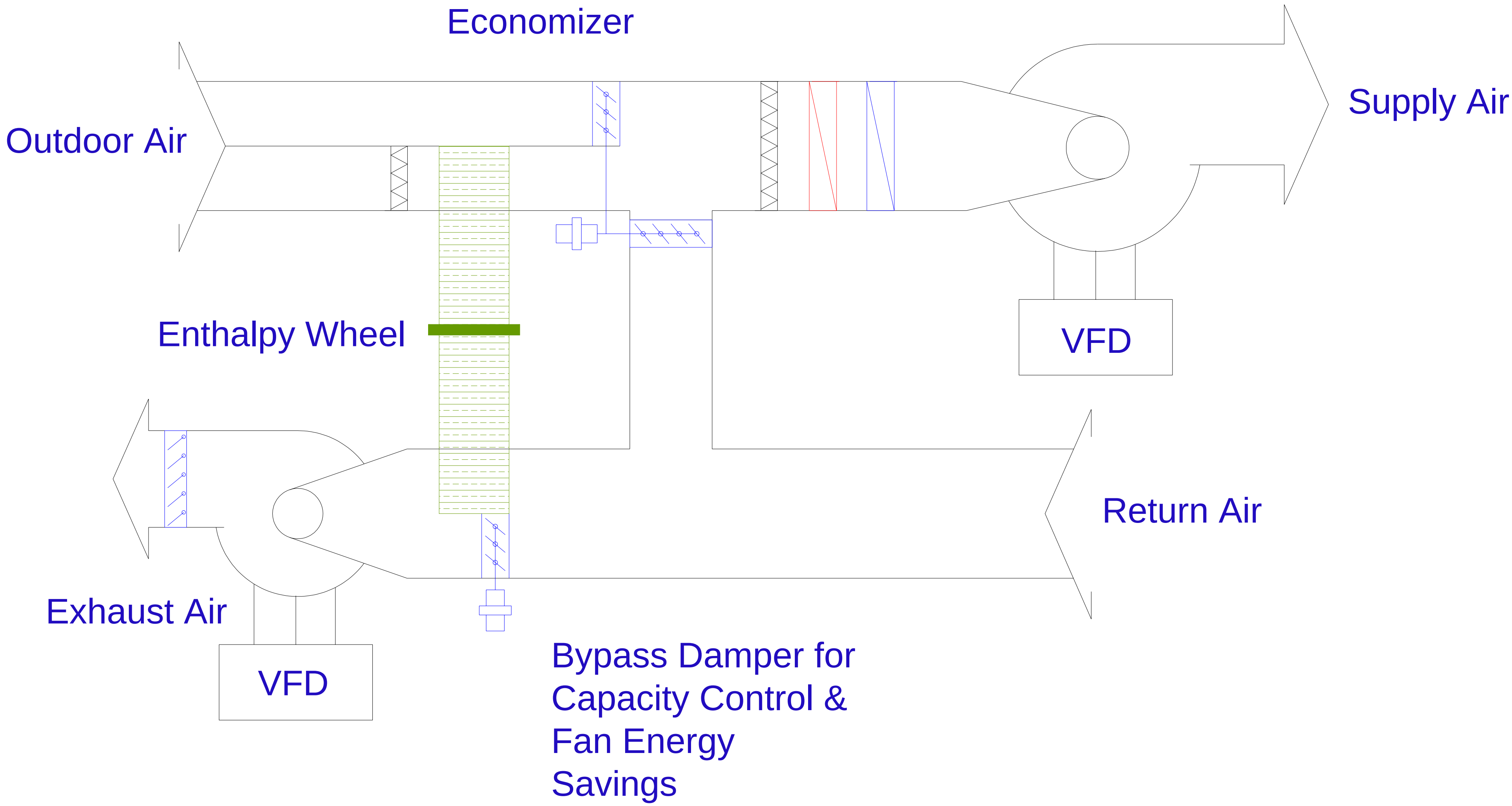
Typical Constant Volume AHU without Energy Recovery



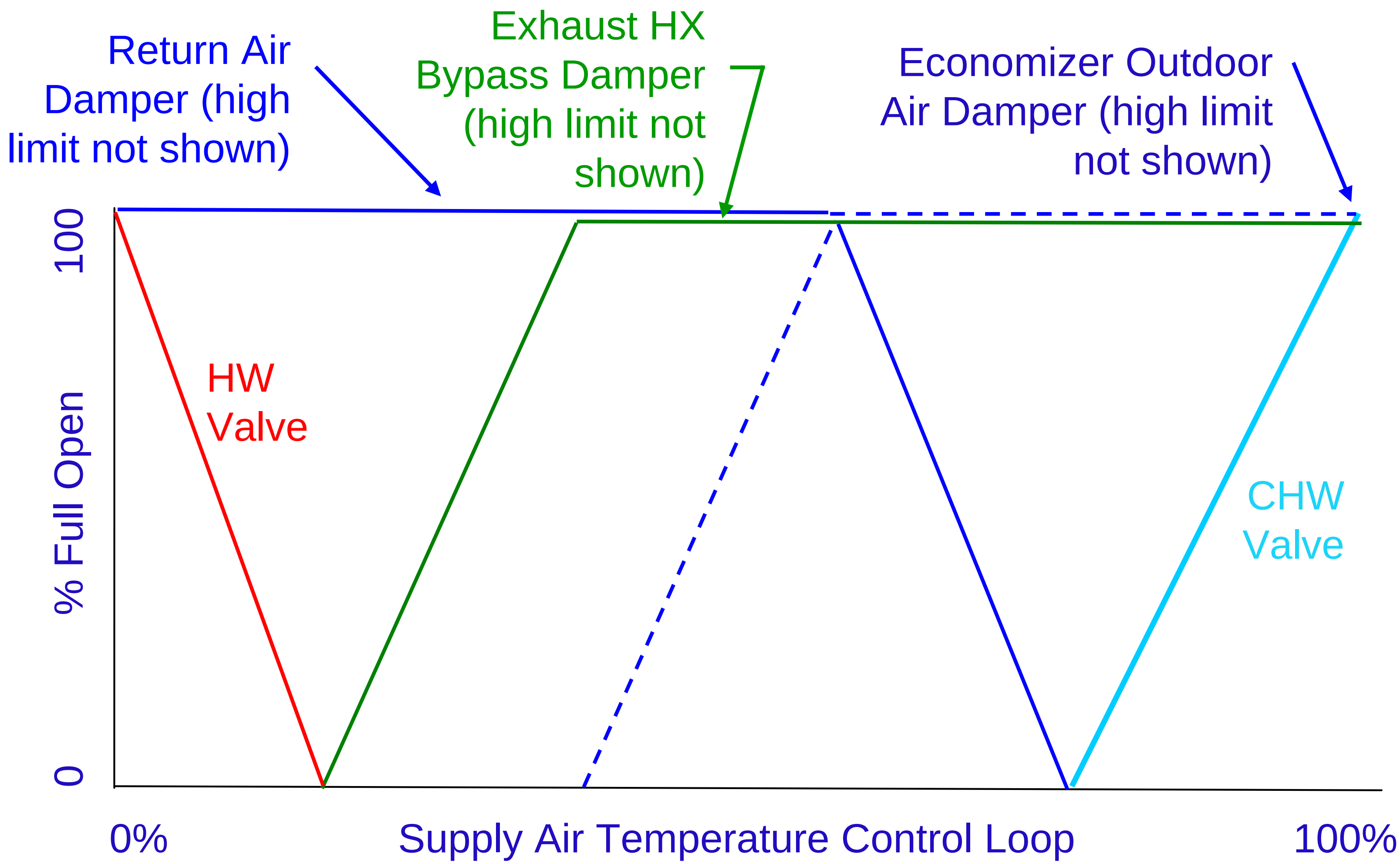
Constant Volume AHU with Energy Recovery



Variable Volume AHU with Energy Recovery & Economizer



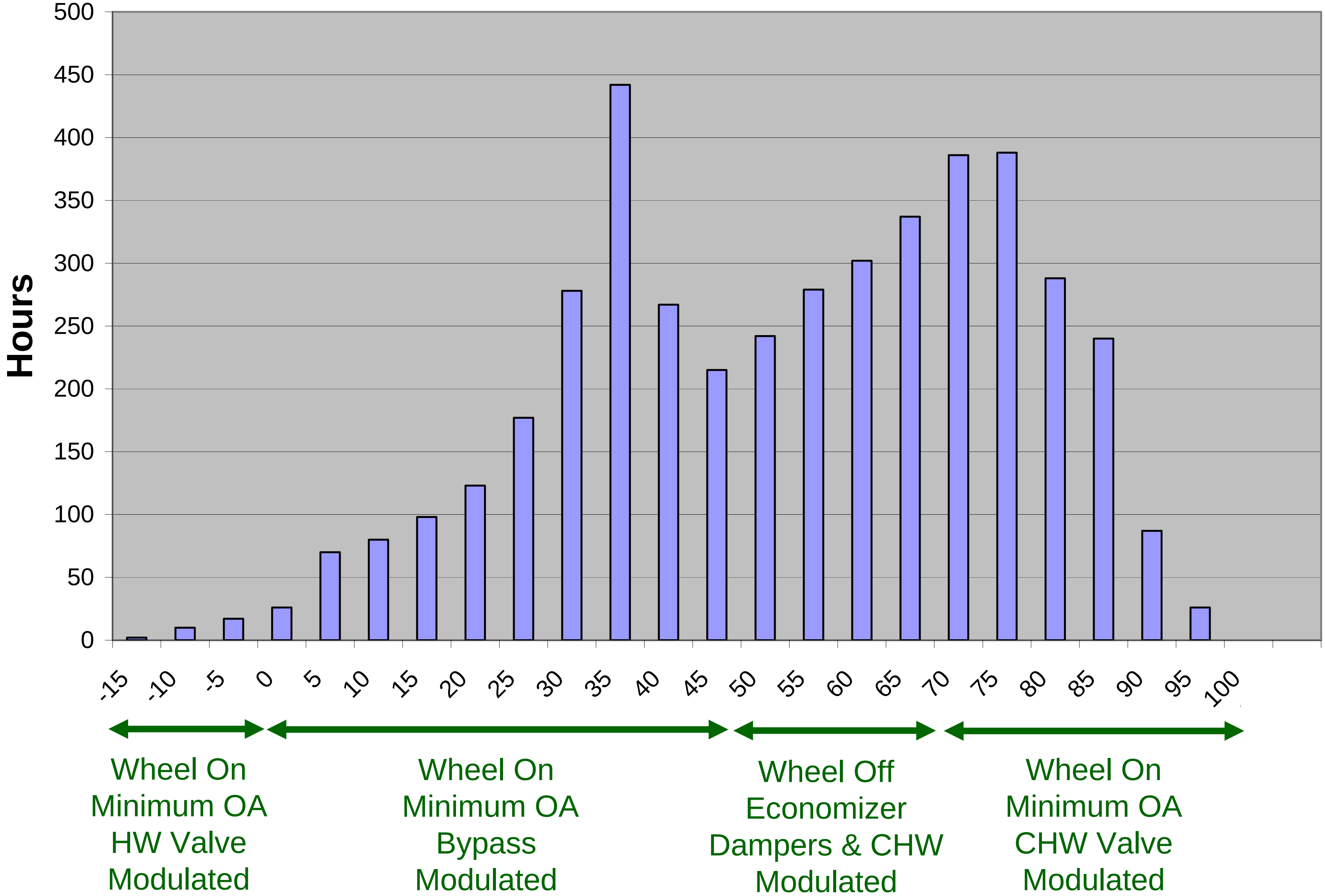
Control Logic



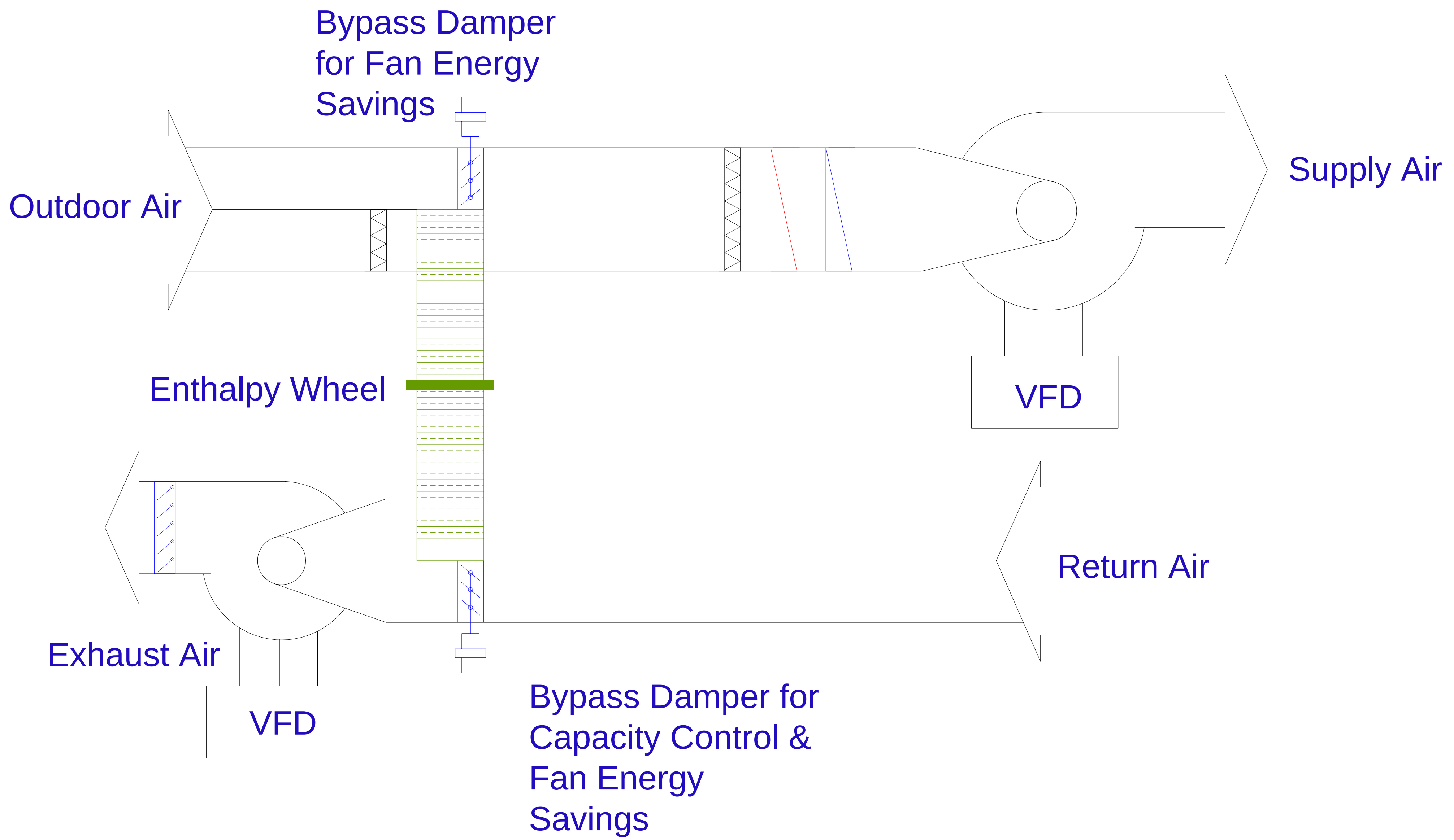
HX Wheel On when Economizer Outdoor Air Damper is closed.
Bypass & Economizer Outdoor air damper closed, Return air damper open when outdoor air enthalpy > return air enthalpy

Wheel Operation

Madison, WI, 8am-8pm, 70% min OA



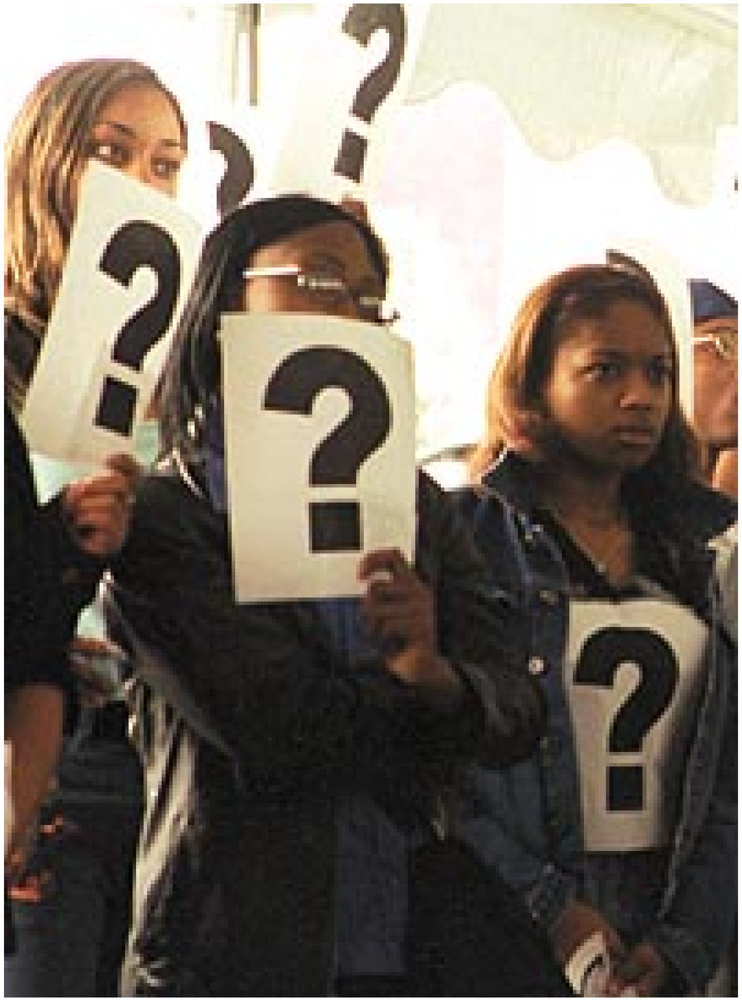
100% OA Variable Volume AHU with Energy Recovery



Summary & Tips

- **Usually the optimum Energy Recovery type is:**
  - Enthalpy Wheel in humid climates & cold climates with humidification
  - Flat Plat or Run-around for hot dry climates and no humidification
  - No heat recovery in mild climates
- **Use ARI Certified products only**
  - Ensures fair playing field, realistic load reduction estimates
- **Keep pressure drops low to minimize fan energy losses**
- **Only apply to minimum outdoor air**
  - Bypass HX for economizer outdoor air
- **Take credit for reduced loads in heating/cooling equipment sizing**
  - Necessary for cost effectiveness and control benefits
- **Determine savings using annual energy program of actual system application**
  - Manufacturer’s programs are often over-simplified and favor recovery

Questions?



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