HVAC Solutions for ZNE Buildings

Kent Peterson
P2S Engineering, Inc.

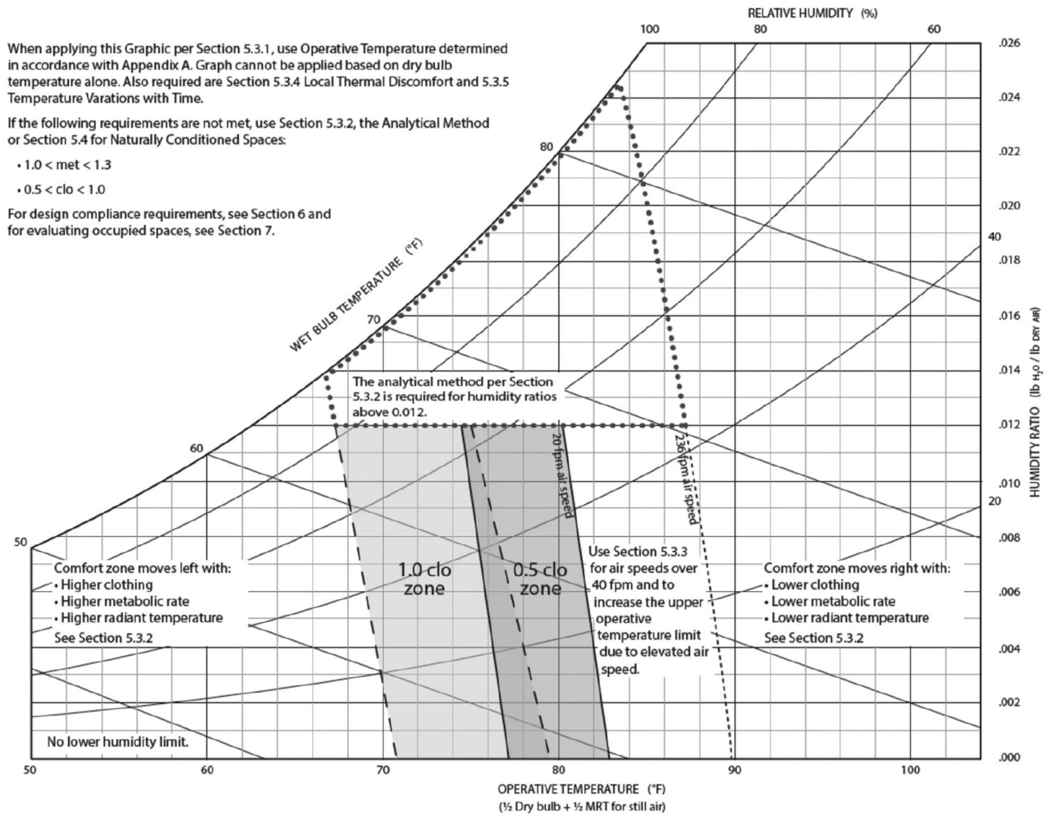
Meeting the Challenge of Zero Net Energy Nonresidential Buildings by 2030

Presentation Outline

- Thermal Comfort
- Case Studies
- HVAC Systems
- Control Systems
- Cost Effectiveness
- Future Trends
- Challenges

Thermal Comfort

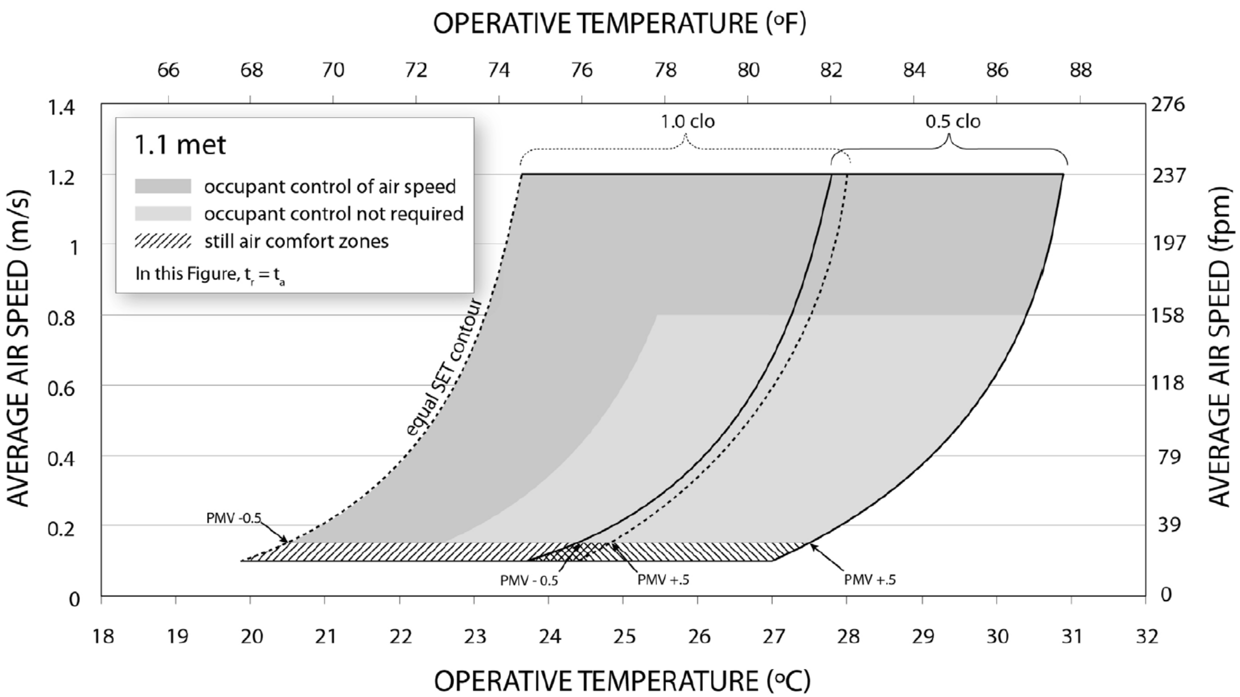
ASHRAE Summer and Winter Comfort Zones



ASHRAE 55-2013 Figure 5.3.1.1

Acceptable ranges of operative temperature and humidity for average air speed (V_a) for the 1.0 and 0.5 clo clothing during primary sedentary activity
(1.0 ≤ met < 1.3)
(0.5 < clo < 1.0)
(dewpoint ≤ 62.2°F)

ASHRAE Summer and Winter Comfort Zones

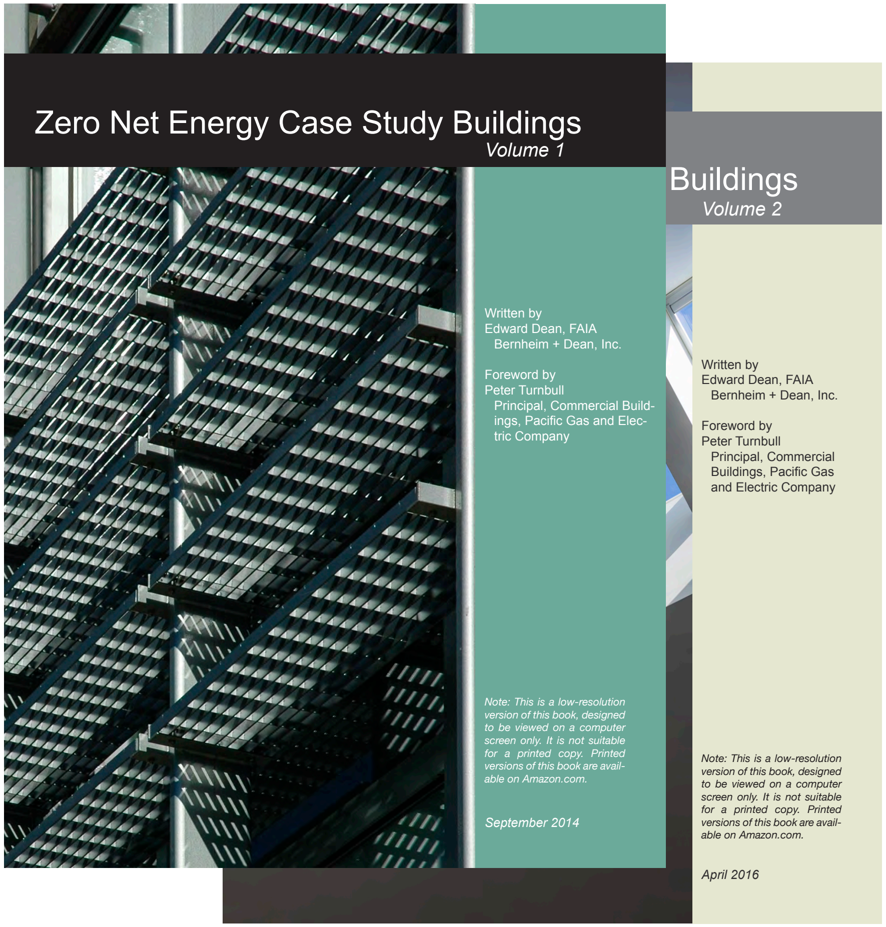


ASHRAE 55-2013 Figure 5.3.3A

Acceptable ranges of operative temperature (t_o) and average air speed (V_a) for the 1.0 and 0.5 clo comfort zone presented in Figure 5.3.1.1, at humidity ratio 0.010

Case Studies

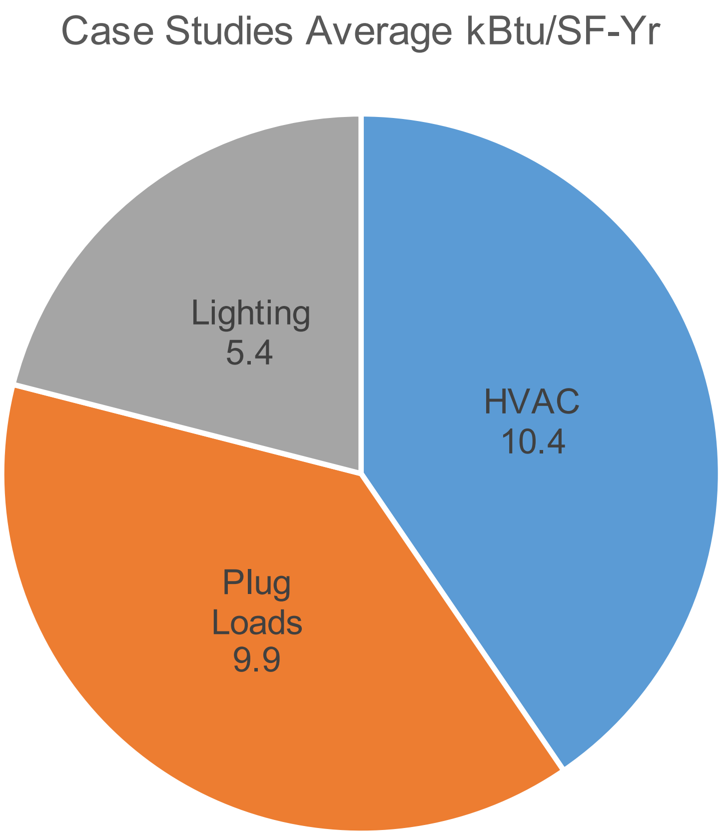
Learning from Case Studies



Eleven Zero Net Energy Case Studies

- Natural ventilation & night purge
- Ceiling fans
- Radiant heating & cooling
- High efficiency heat pumps
- DOAS
- Variable refrigerant flow
- Indirect evaporative cooling
- High efficiency VAV

High Level Energy Budgeting



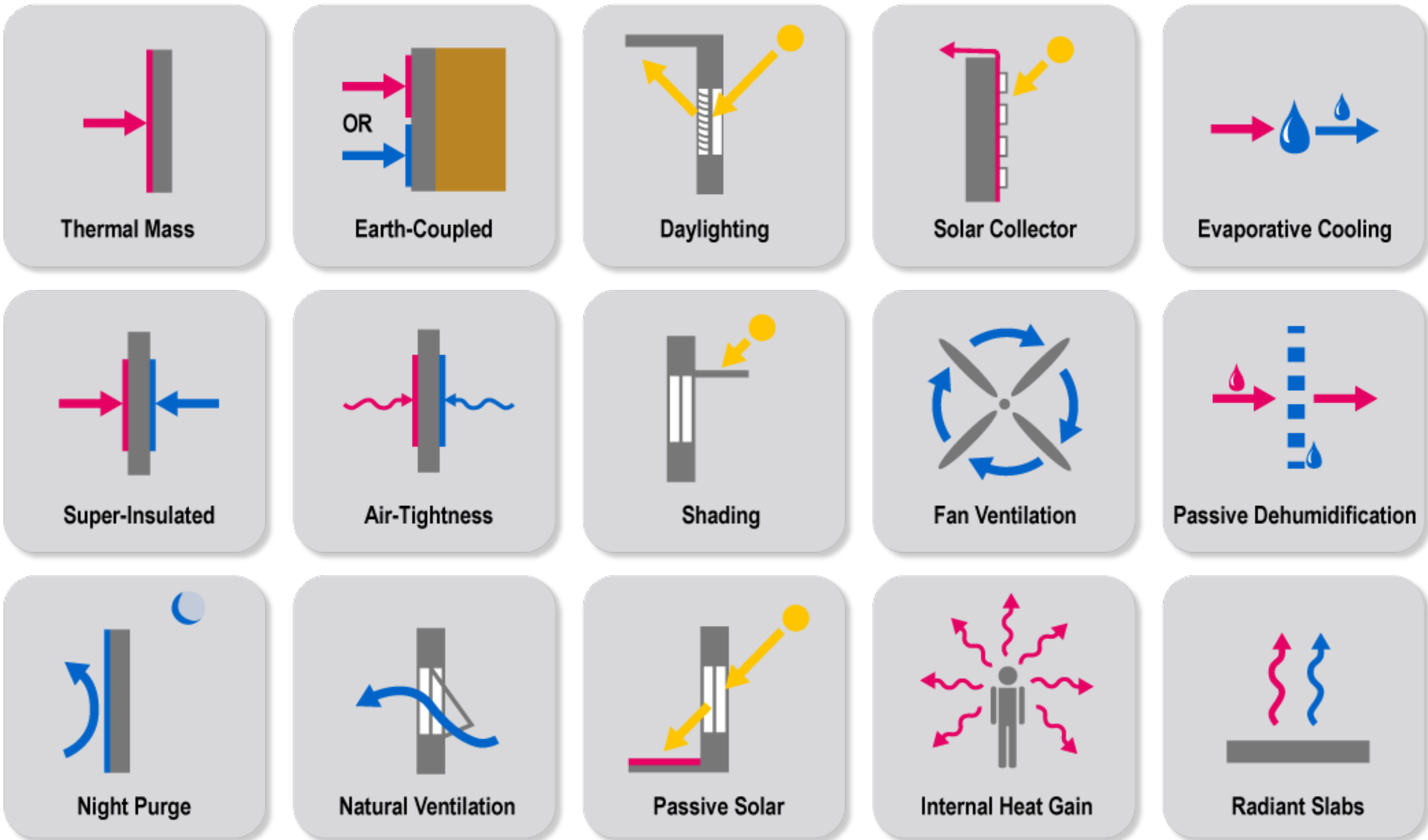
- Measured Total EUI (kBtu/SF-yr)
  - 13.5 to 51.5, 26.6 average
- Measured HVAC EUI
  - 2.4 to 18.1, 10.4 average
- Measured Plug Load EUI
  - 4.8 to 24.2, 9.9 average
- Measured Lighting EUI
  - 1.8 to 11.5, 5.4 average

HVAC Systems

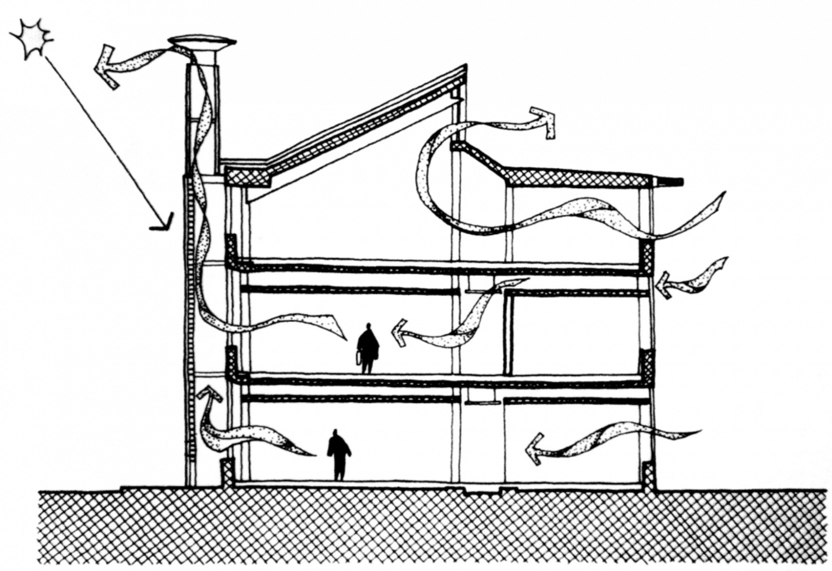
High Level HVAC Strategies

- Understand annual climate conditions
- Expand thermal comfort zone
- Reduce loads
- Utilize passive strategies first
- Minimize waste heat
- Minimize fan energy
- Decouple air system cooling and ventilation
- Utilize high efficiency equipment

Passive Design Strategies – Consider the Whole Building



Natural Ventilation & Night Purge



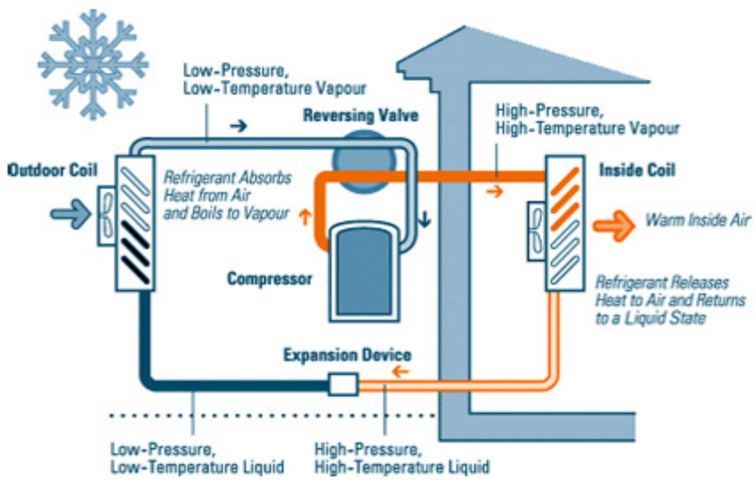
- Stack effect (buoyancy)
- Wind driven (Bernoulli's Principle)
- Night purge to precool thermal mass when cooling is required the next day

Ceiling Fans

- Gentle air movement expands the thermal comfort zone
- Automatic vs manual control
- Standard 55 allows average 1.2 m/s air speed with local fan speed control

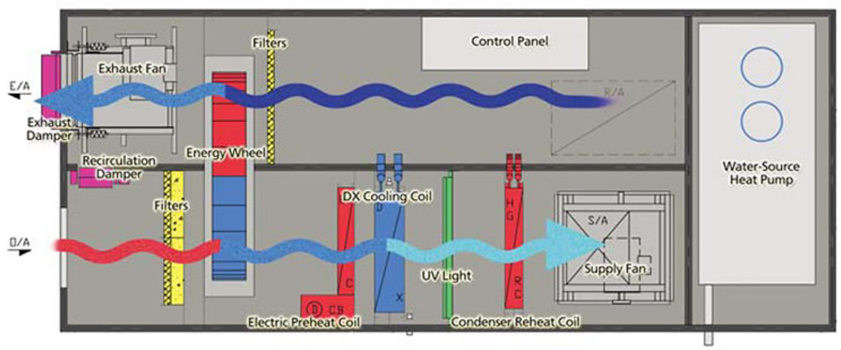
Radiant Heating and Cooling

- Allows larger space deadband
- Cooling typically limited to 5W/SF
- In slab installation can be competitive to VAV
- 20-30% savings vs VAV



- Manifold systems advantageous when simultaneous heating and cooling in different zones
- Types
  - Geothermal
  - Water-source
  - Air-to-air
  - Water-to-water

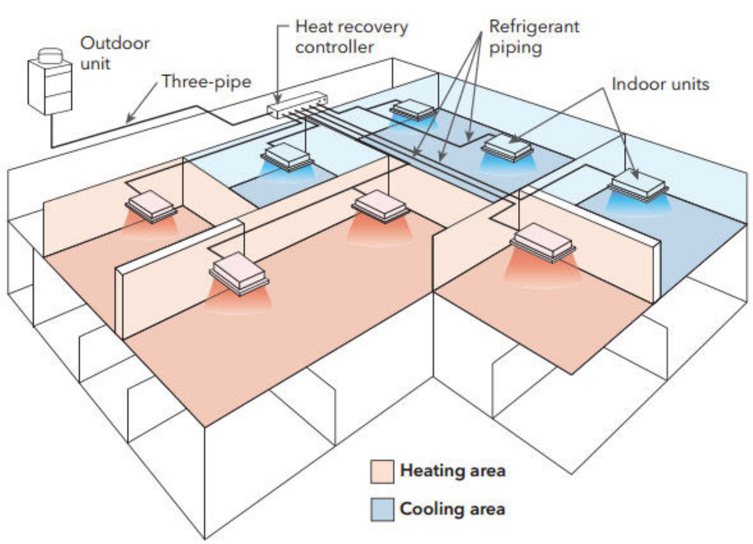
Dedicated Outside Air Systems



Outside air AHU(s) ducted to each zone with zonal system for space sensible cooling/heating

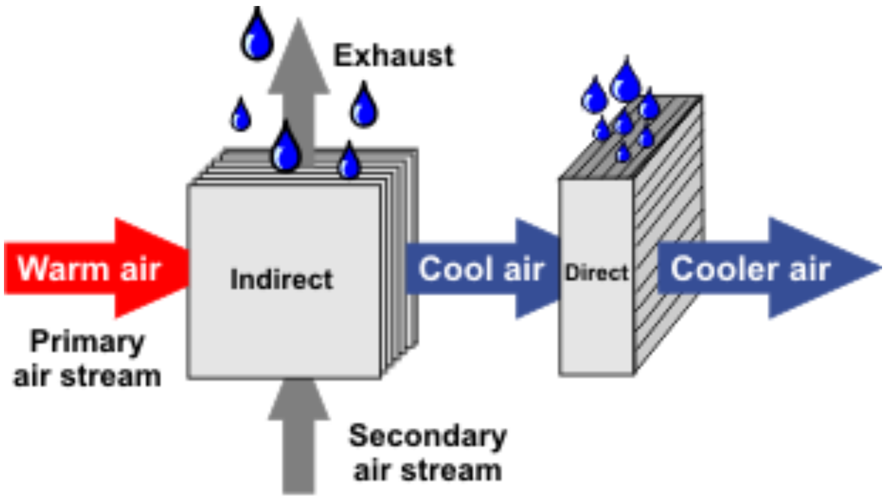
- Supply OSA cold without reheat except with high latent loads
- Use heat recovery per 90.1
- Reset supply air temperature based on zone feedback
- Use CO_2 sensors in densely occupied spaces
- Less ceiling space and fan energy if zone sensible is radiant

Variable Refrigerant Flow



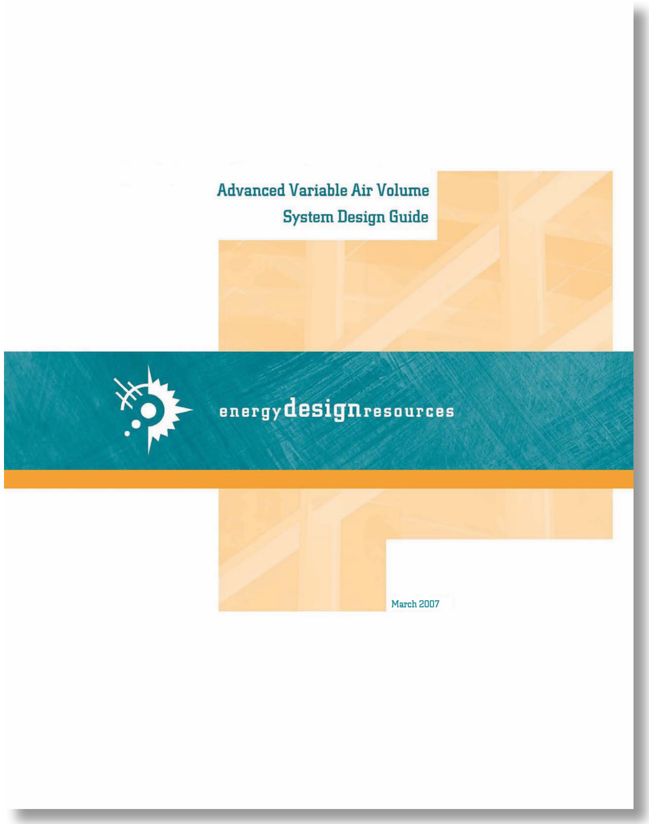
- High part load efficiency when compared to conventional DX
- Reduces ductwork
- Heat recovery allows simultaneous heating and cooling in different zones
- Refrigerant concentrations must meet CMC 1102.2

Indirect/Direct Evaporative Cooling



- 50-90% more efficient than compressors depending on climate
- CFC & HFC free cooling
- 50% less water than electric cooling with power plant
- Lower initial cost

High Performance Variable Air Volume Systems

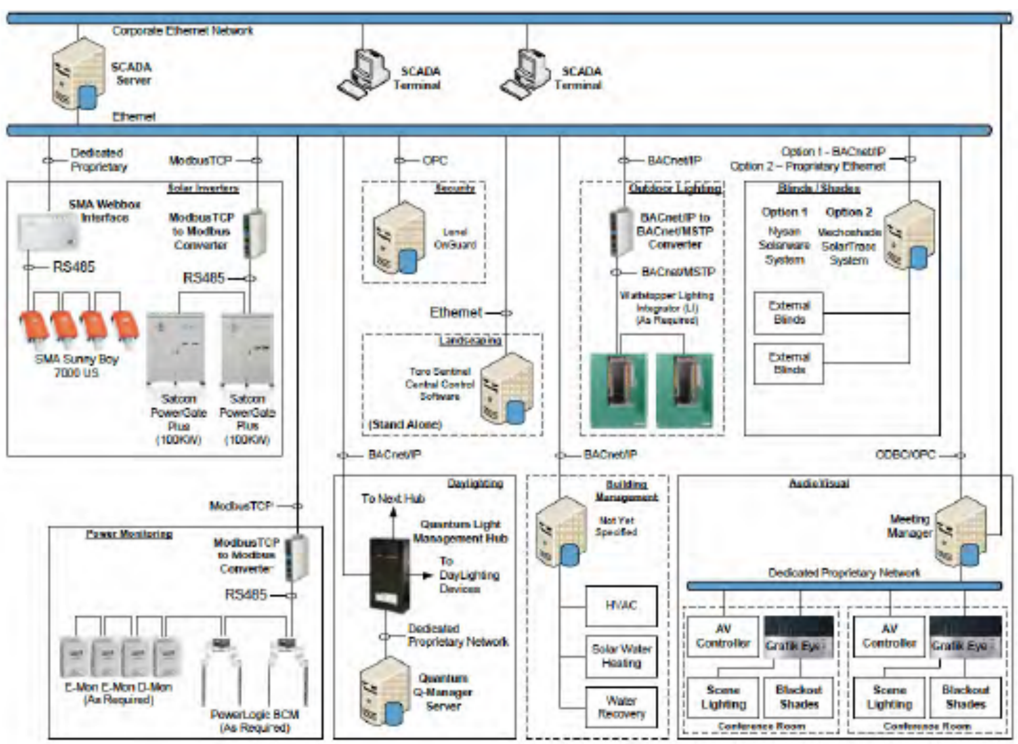


- Low pressure drop design
- Fan pressure optimization
- Airside economizer
- Supply air temperature reset
- Zone level DCV
- More difficult to use with passive strategies

References
Murphy, J. *High-Performance VAV Systems*, ASHRAE Journal, October 2011
Low Pressure Drop HVAC Design for Laboratories, Labs21

Control Systems

Control Systems

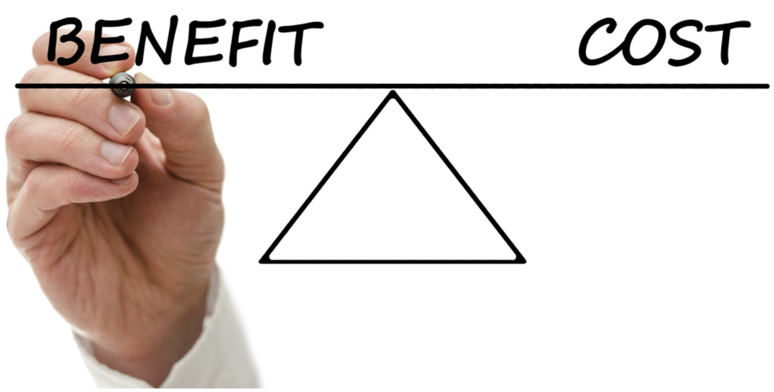


Packard Foundation Headquarters Building

- Importance of master control system for various control systems
- Engage systems integrator during design
- Passive systems must work with HVAC systems
- Collect and display energy performance data

Cost Effectiveness

Understanding Cost Effectiveness



- Understand impacts on other disciplines when reviewing costs
  - Building enclosure (height, size)
  - Mechanical shafts
  - Electrical
- Annual hours of mechanical operation can be significantly lower with passive technologies

Future Trends

Future Trends in HVAC

- More informed passive design
- Thermally driven air conditioners
- More IEC technology
- More radiant
- Smarter controls and IoT
- COP, EER, SEER, IEER & CEF

Challenges

Challenges Moving Forward

- Roadblocks to ALL buildings
- Growing “Intelligence”
- Improve analytical tools
- Educating owners, operators, architects and engineers
- Design & construction processes
- Utilities and rate structures


Do not underestimate the power of imagination