What is Needed for 50% Approach for Zero Net Energy Use

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Learning Objectives

- What has been done to achieve a 50 % reduction in building energy use
- What is needed to achieve a 50 % reduction using today's technologies
- Why an integrated design process is essential to achieving a low energy building

Background

- Advanced Energy Design Guides (AEDGs)
  - Guides for 30 % energy reduction in buildings
- Scoping Committee:
  - Develop background for 50 % energy reduction
  - Document existing energy efficient buildings
  - Determine energy measures for different classes of buildings in different climates

Issues

- Are significant energy reductions in buildings possible?
- Are the reductions in <u>source</u> or <u>site</u> energy?
- What is the baseline for energy use?
- What are the availability, acceptability, and cost of proposed measures?

Is a Net Zero Energy Building Possible?

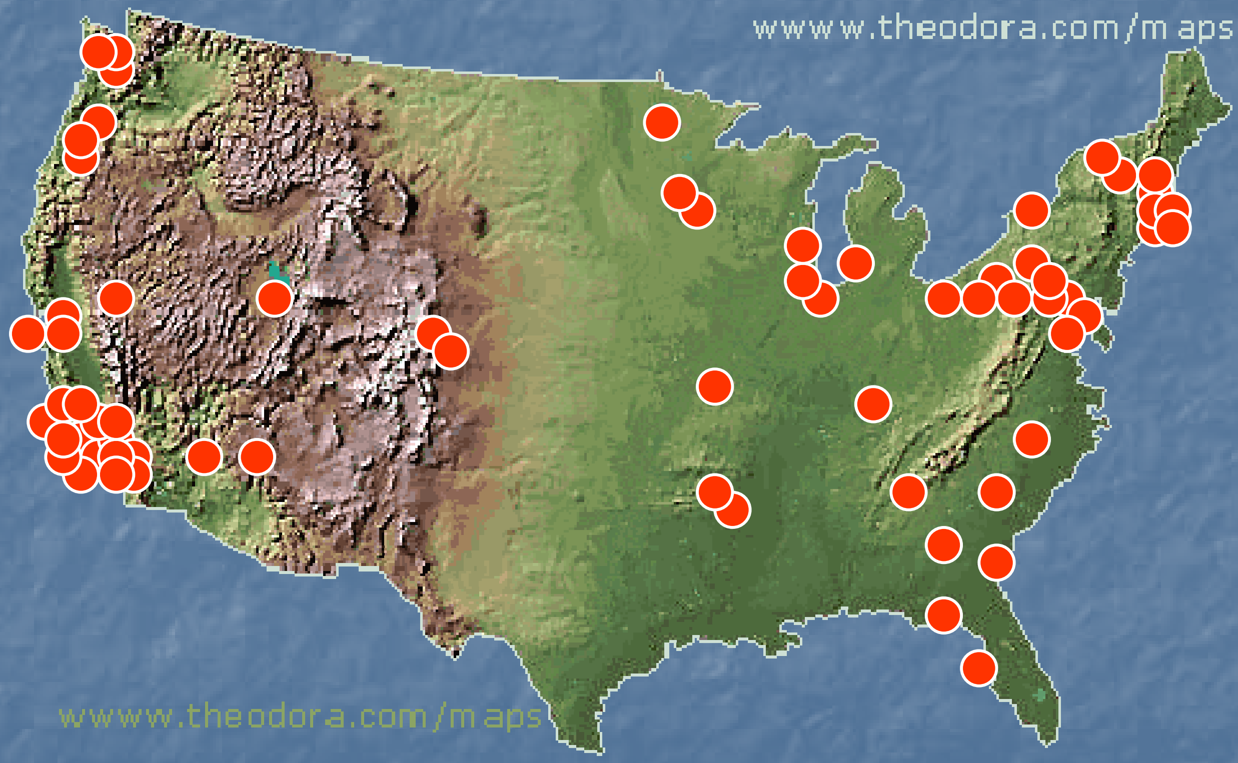
- Modeling:
  - NREL study - 5000 models for all building types based on the 1999 CBECS data set
- Actual buildings
  - Case Studies of low energy buildings (GT50)
  - ASHRAE, AIA, USGBC, and EPACT 50

Results of NREL Study

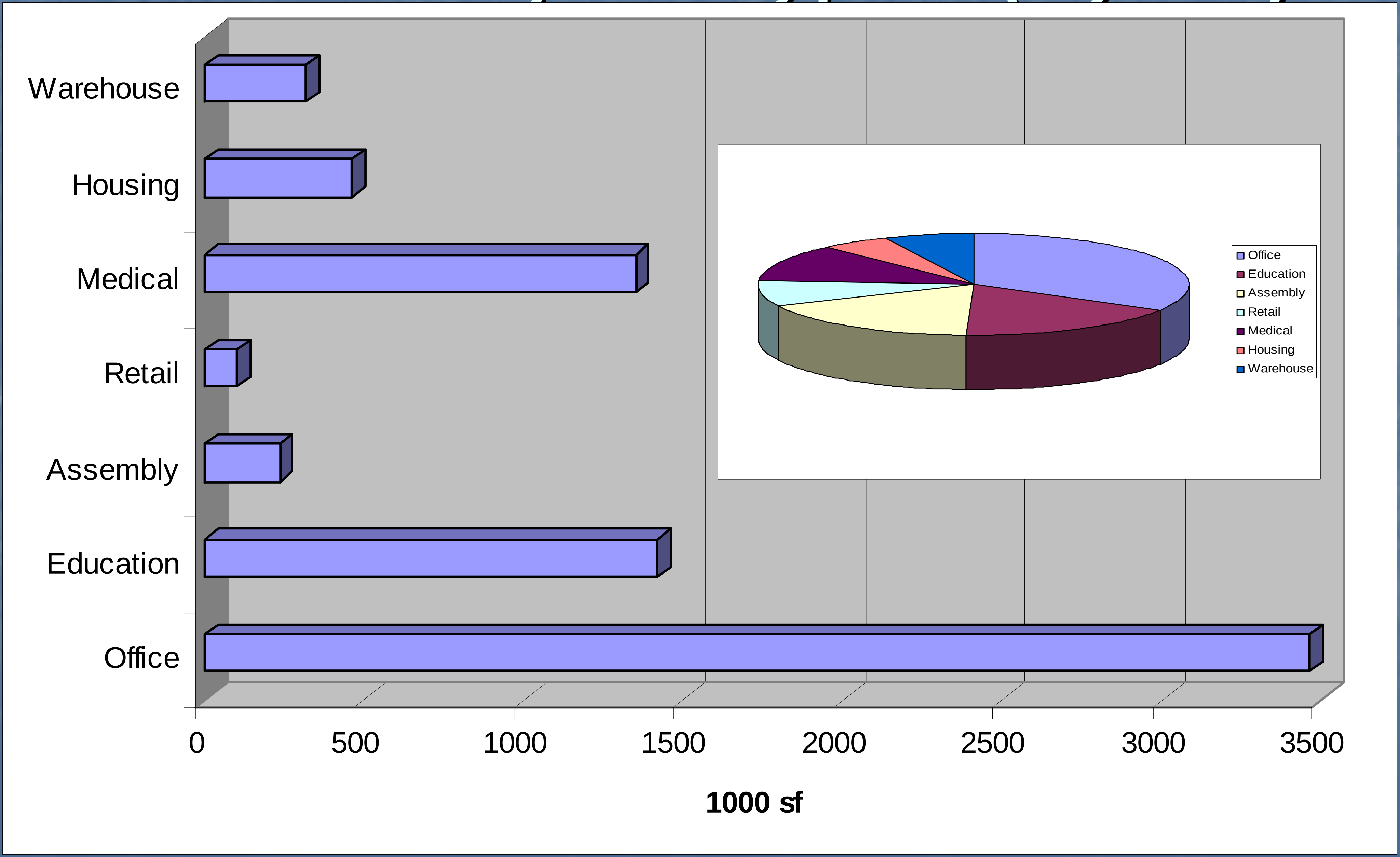
- Average site energy reductions:
  - 44 % with PV
  - 82 % with aggressive strategies and PV
- Greatest aggregate reductions for offices, warehouses, and educational facilities
- Lowest aggregate reductions for health care, malls, and laboratories
- Heating climates are more difficult than cooling climates

The 100 Best Performing Buildings in the Country
(New Buildings Institute)

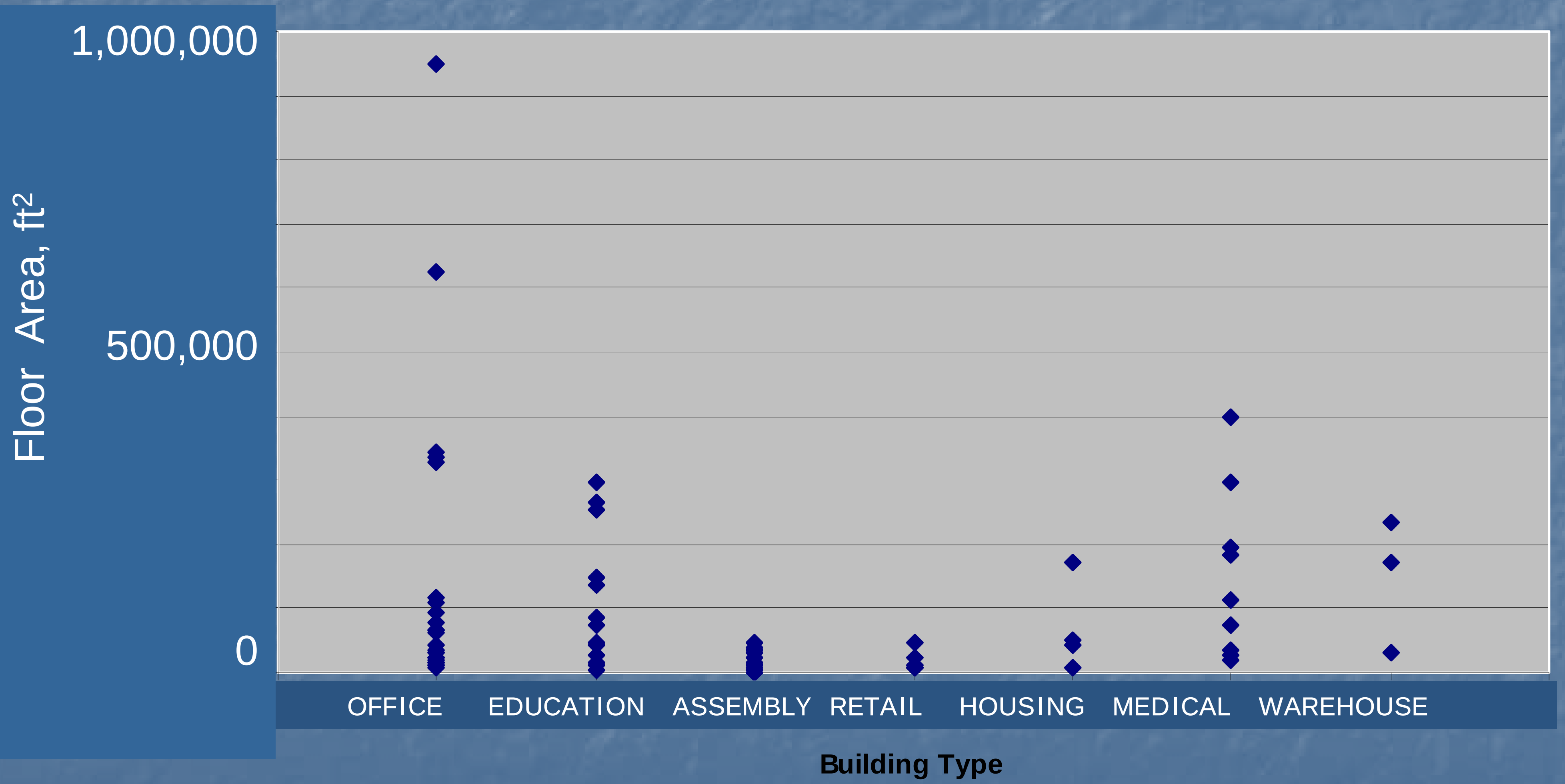
GT50 Project Distribution



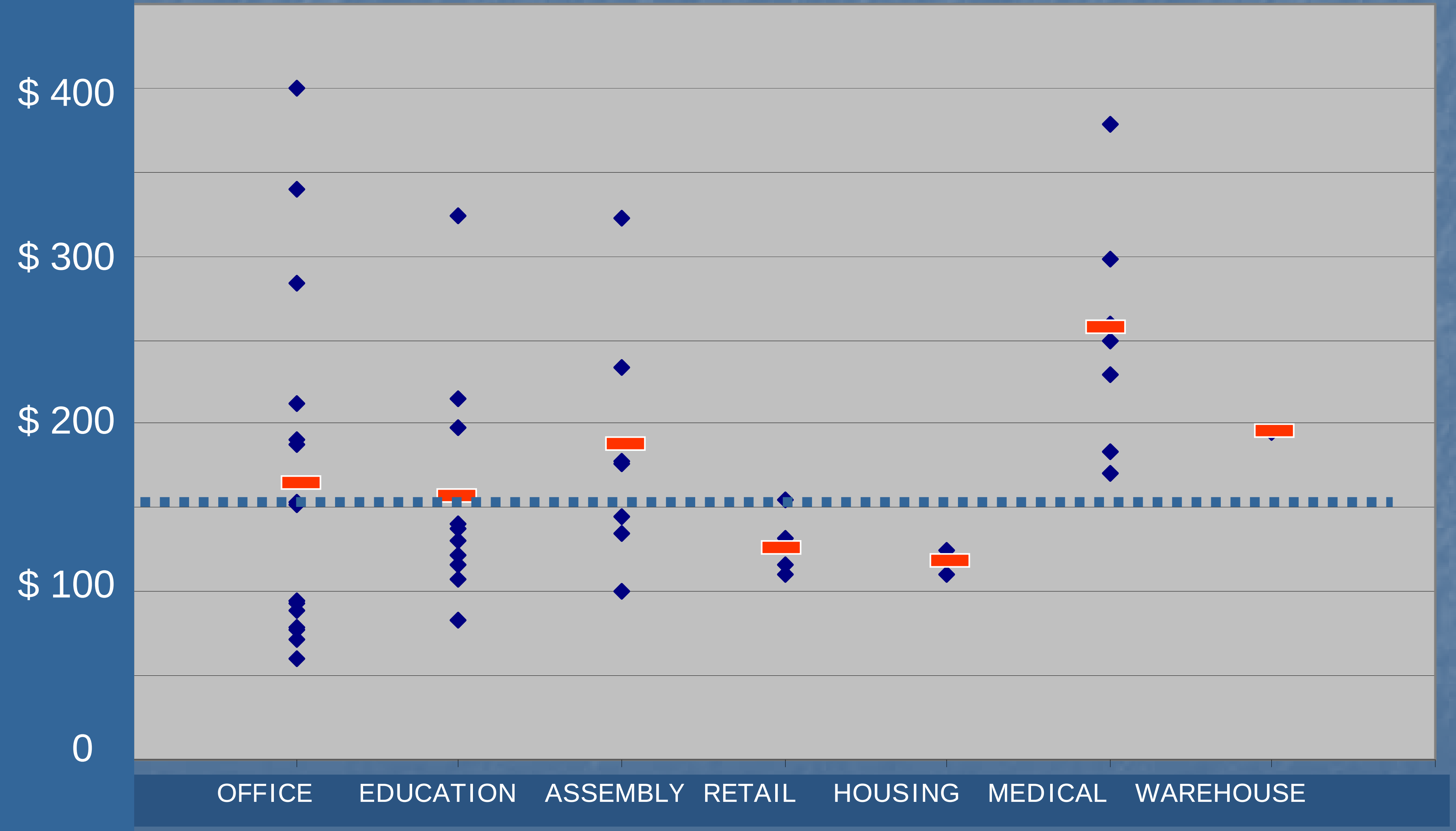
GT50 Project Types (by SF)



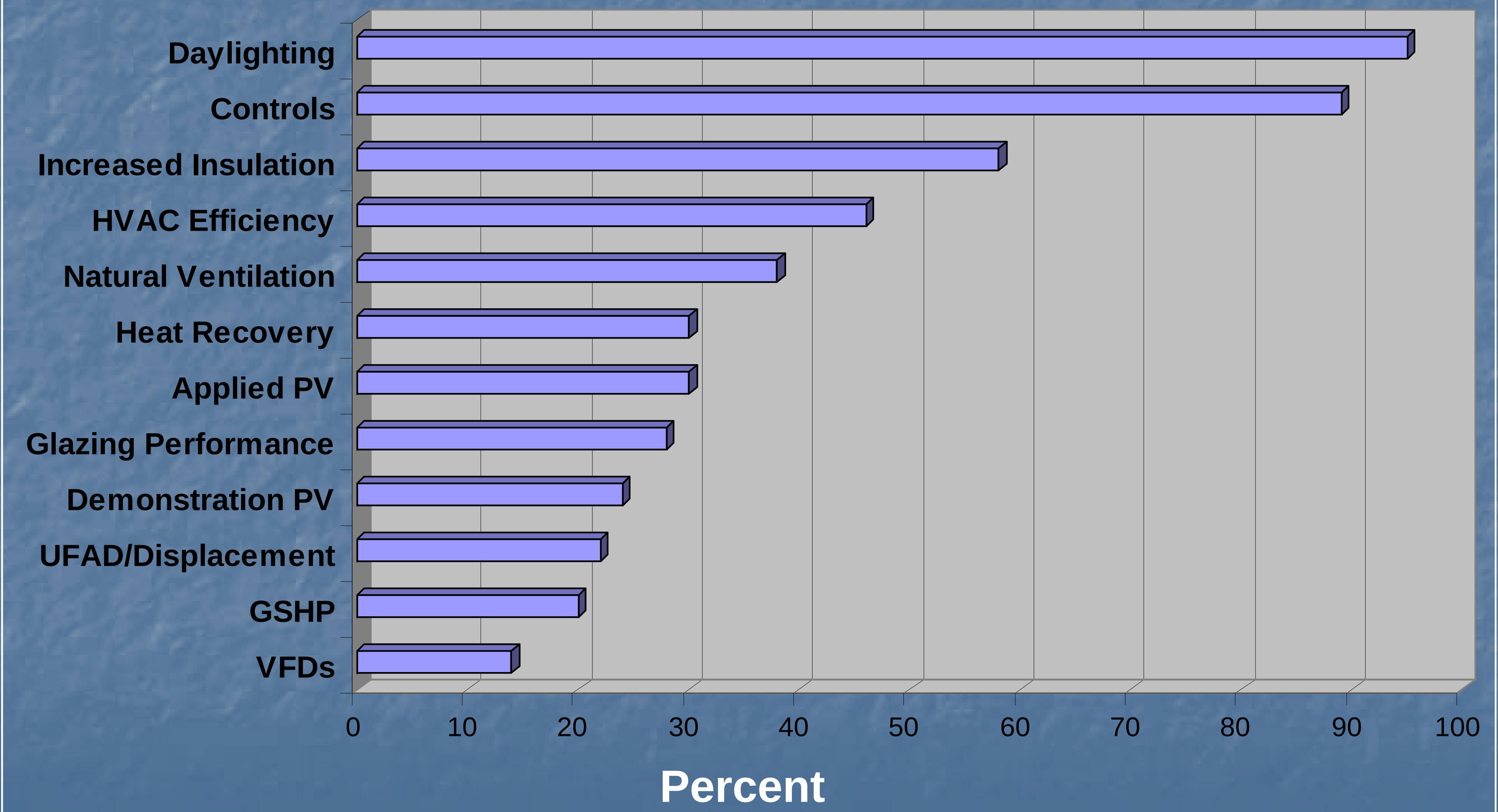
Distribution by Size



Cost per Square Foot



Technologies in GT50



Cambria Office Building

- [x] Daylighting
- [x] Controls
- [x] Increased Insulation
- [ ] HVAC Efficiency
- [ ] Natural Ventilation
- [x] Heat Recovery
- [x] Applied PV
- [x] Glazing Performance
- [ ] Demonstration PV
- [x] UFAD
- [x] GSHP
- [ ] VFD
- [x] Other Elements

- 36, 000 sf Office, State Agency
- Ebensburg, Pennsylvania
- Construction cost: $103/sf
- Completed: 2000

Clackamas High School

- [x] Daylighting
- [x] Controls
- [x] Increased Insulation
- [x] HVAC Efficiency
- [x] Natural Ventilation
- [ ] Heat Recovery
- [ ] Applied PV
- [x] Glazing Performance
- [x] Demonstration PV
- [ ] UFAD
- [ ] GSHP
- [x] VFD
- [x] Other Elements

- 265,000 sf
- Clackamas, Oregon (2002)
- $117/sf (excluding land)
- Energy savings $69,000/yr (+40% over ASHRAE)

Artists for Humanity Epicenter

- [x] Daylighting
- [x] Controls
- [x] Increased Insulation
- [ ] HVAC Efficiency
- [x] Natural Ventilation
- [x] Heat Recovery
- [x] Applied PV
- [x] Glazing Performance
- [ ] Demonstration PV
- [x] UFAD
- [x] GSHP
- [x] VFD
- [ ] Other Elements

- Boston, MA
- LEED Platinum
- Completed in 2004
- $208/sf, including PV
- 23,500 sf Assembly, etc.

Lillis Business Complex

- [x] Daylighting
- [x] Controls
- [ ] Increased Insulation
- [ ] HVAC Efficiency
- [x] Natural Ventilation
- [ ] Heat Recovery
- [x] Applied PV
- [x] Glazing Performance
- [ ] Demonstration PV
- [ ] UFAD
- [ ] GSHP
- [ ] VFD
- [x] Other Elements

- Business School, U of Oregon
- Completed September 2003
- LEED Silver
- 137,346 sf, at $217/sf
- 41% better than ASHRAE

Case Studies

IEUA Hdqtrs.
66% over
T-24
Platinum

Clearview Court.
100% PV
gas microturbine w/HR

NRDC Hdqtrs.
55% over
T-24
Platinum

Existing Low Energy Buildings

- 50% energy savings are possible throughout the US climate for all building classes
- Relatively few buildings compared to existing stock
- Design savings do not necessarily mean reduced energy use
- Monitored performance and focus on O&M yields energy savings

Selection of Measures for 50 % Reduction

- Available now or within the next five years.
- Not “sole source” but available from more than one vendor
- Expected to provide the same amenities at a cost equal to or lower than current practice.
- Yield significant reductions in energy use
- Not equally applicable in all climates and for all building types

Measures to achieve 50 % Approach to Net Zero Energy Use

- Envelope and Lighting Measures
  - Insulation
  - Fenestration
  - Lighting
  - Integration of daylighting with high efficiency lighting
- HVAC Distribution Systems
  - Parasitics losses
  - Ventilation
  - Natural Ventilation
  - Distribution of heating and cooling to spaces
  - Thermal Storage

Measures to achieve 50 % Approach to Net Zero Energy Use

- HVAC Primary Systems
  - Water loop heat pumps
  - Variable capacity equipment
  - Evaporative Cooling
  - Desiccant dehumidification and cooling
- Renewable Energy Electric and Thermal Systems
  - Photovoltaic systems
  - Solar water heating
- Integrated Design methodology

Envelope Measures

- "Good Design Practice" envelope recommendations (*The Advanced Energy Design Guides, 2004 - 2007*):
  - Insulation thickness levels depending on climate and building class
  - Continuous insulation and avoiding thermal bridging
  - Maximum ratio of glazing to opaque wall area

Creating Zero Energy Windows

Energy Losers --> Net Energy Suppliers

- Heating season
  - Need very low U but moderate solar gain
- Cooling season
  - Reduce heat losses (U) so that ambient solar energy balances or exceeds loss
  - Reduce cooling loads with very low SHGF
  - Static control -> dynamic control
- All seasons
  - Replace electric lighting with daylight

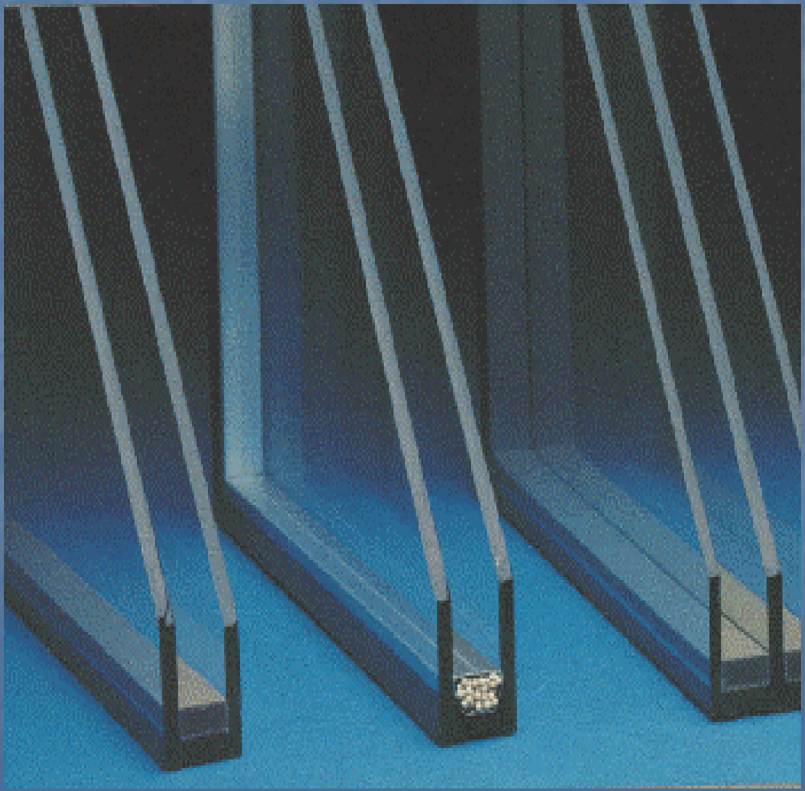
Zero Energy Window Objective

Long Term Target: U-Factor < 0.1 Btu/(hr-ft^2-°F)

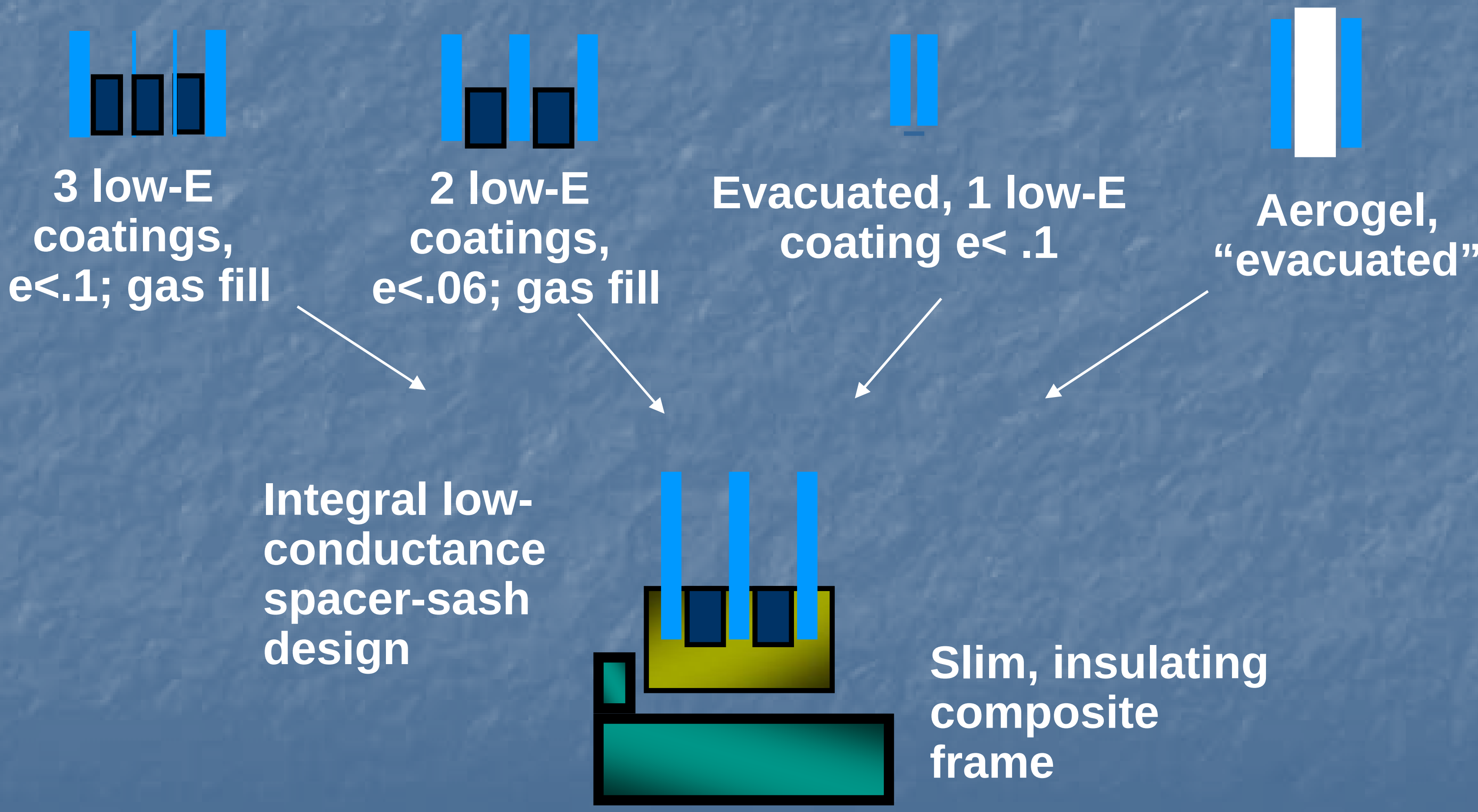
Nearer Term Objective: .15 Btu/(hr-ft^2-°F)

Starting Point:

- Low-Emissivity Coatings
- Low Conductance Gas Fills
- "Warm edge" low conductance spacers
- Insulated Frame Systems

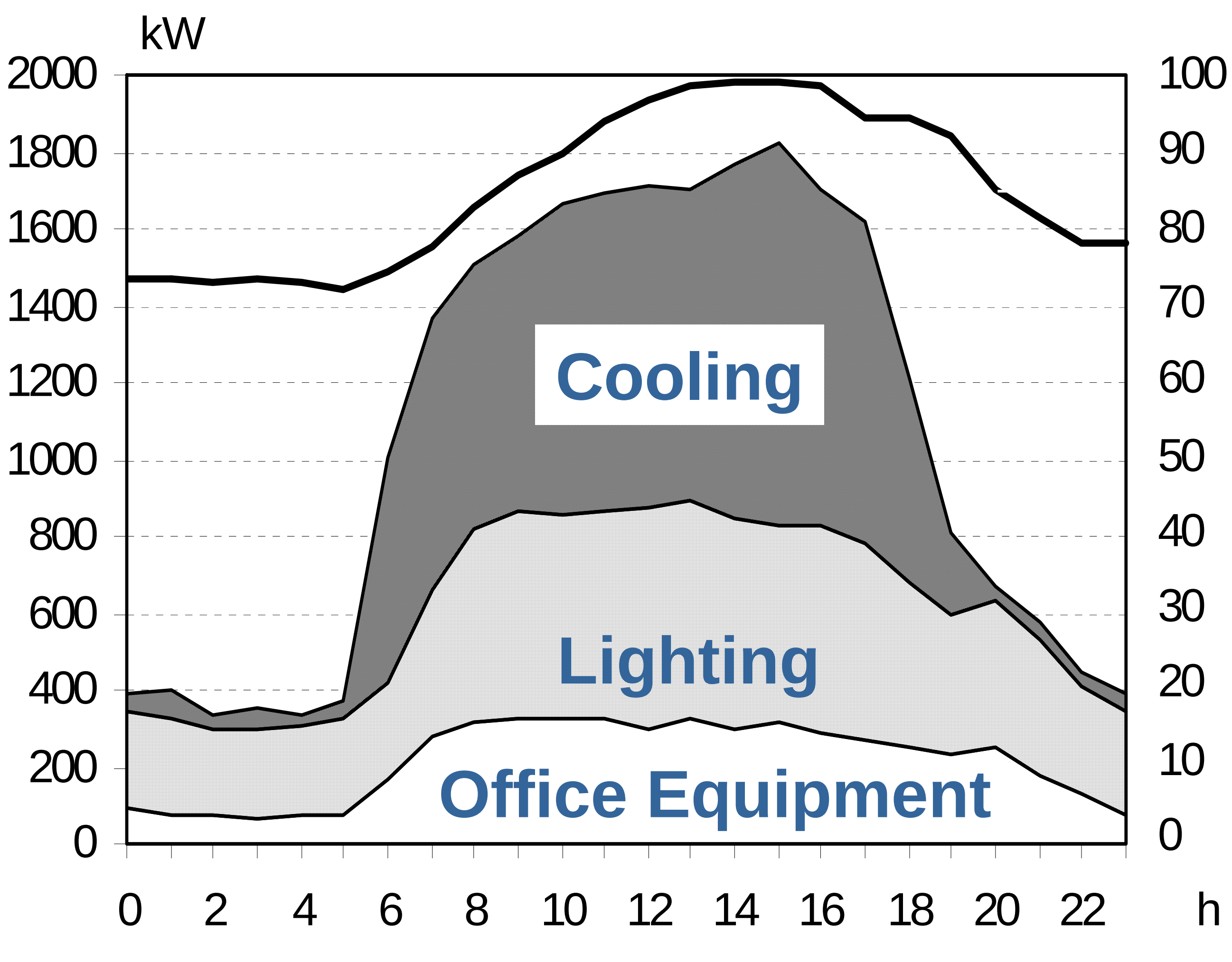


Potential Solutions for U < 0.15



Lighting Demand Issues

Electric Demand



Outside Temp

Typical Hot Summer Day

Office Building Hourly Electric Load

Better Lighting

- Recent progress made due to reducing "lighting power density", Watts/sq.ft
  - Less efficient sources replaced with more efficient:
    - Incandescent (17 lumens/W) --> Fluorescent (90 l/w)
  - Improved light distribution from sources:
    - Inefficient fixture with more optically efficient fixture

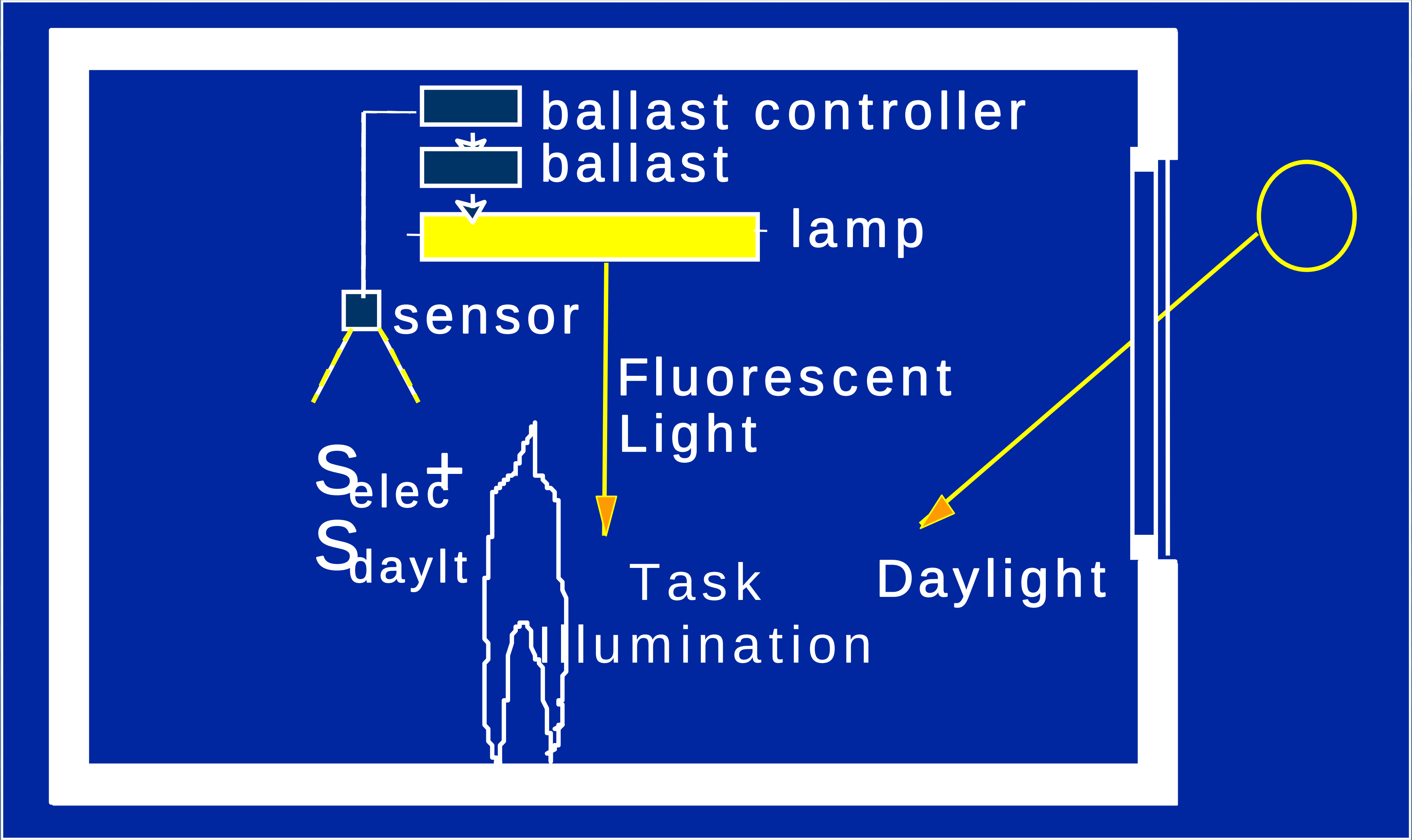
Next Generation

- More efficient lamps and fixtures suited to specific tasks
- Lighting design and operation that:
  - Separates task lighting from ambient lighting
  - Varies with task
  - Varies with location
  - Varies with user
  - Varies with time
  - Addresses perception in the space rather than easily measurable engineering units (lux or footcandles)

Lighting Controls

- Occupancy controls well accepted
- Conventional lighting controls need further improvement
  - Improved photocell sensors
  - Controls capable of exploiting many control strategies
  - Modular integration of occupant and photo-sensing controls
  - Lighting control integrated with variable transmittance windows (automated blinds, electrochromic glazing)

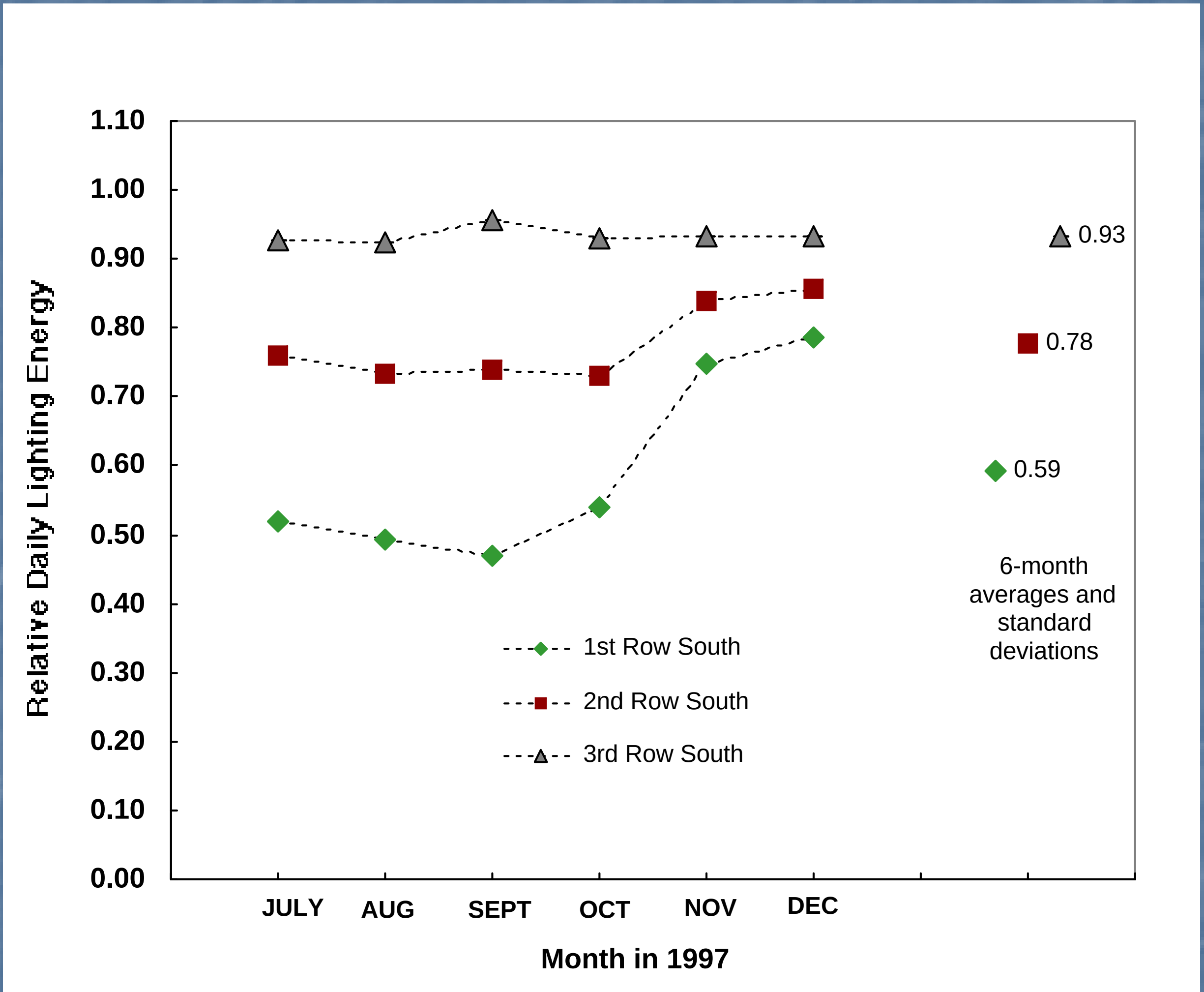
The Challenge of Daylight Control



Daylighting vs. Cooling/Glare

- Key design issue is control
  - Separate heat and light
  - Separate light and view
  - Dynamically control light/solar transmission
  - Integrate daylight, glare, and electric light
  - Manage peak electric load as well as energy
- Aesthetic and “human side” of daylight
  - Must control glare and thermal comfort
  - Manual vs automatic controls

Daylighting Energy Savings (South)

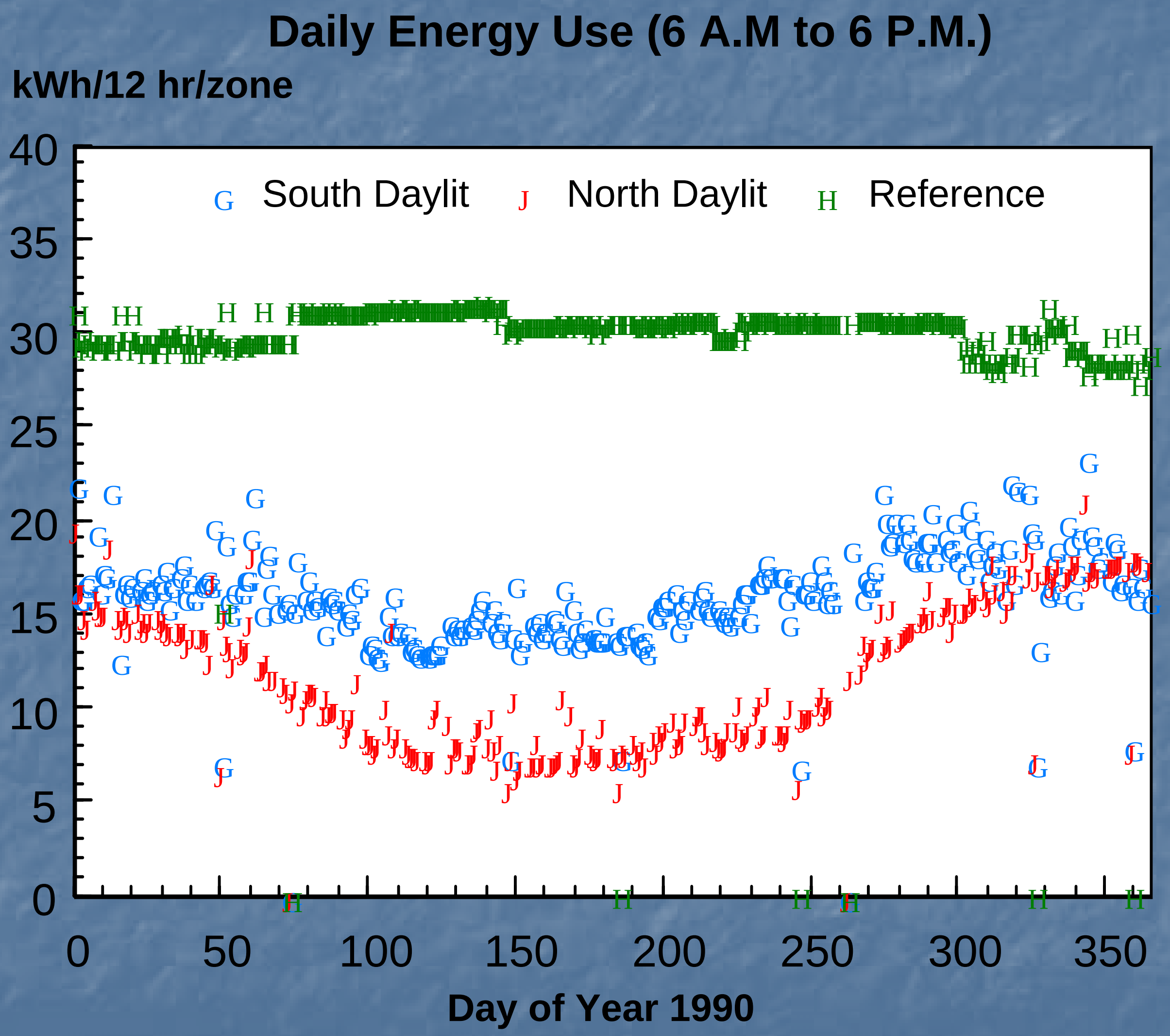


Relative lighting energy consumed by each row of lights on South side of third floor for six months in 1997

The row of lights nearest the window are dimmed more than the second row of lights

Annual savings:
First row: 41%
Second row: 22%

Good Lighting Controls Work



Data from advanced lighting controls demonstration in Emeryville, CA (1990)

Lessons:
Its not just the lighting controls…
Need smart shades

Lightshelves: UK and US

BRE Building, UK

SMUD Building, CA

Automated Shading NY Times Testbed

Motorized, automated shades; active sensor-based control of position; addresses glare and cooling

Shades deployed to lower edge of upper exterior shading rods

Façade Layers

External layer: Fixed
-- Shading, light diffusion

Glazing layer: Fixed
-- Low-E, spectrally selective
- thermal control
- solar gain control

-- Frit - solar, glare control

Internal layer: Dynamic
-- Motorized Shade system
-- Solar control
-- Glare control

Façade Layers: Floor to Floor

floor to desk
desk to head
head to ceiling
plenum

HVAC Primary Systems

- Water loop heat pumps
- Variable capacity equipment
- Evaporative Cooling
- Desiccant dehumidification and cooling

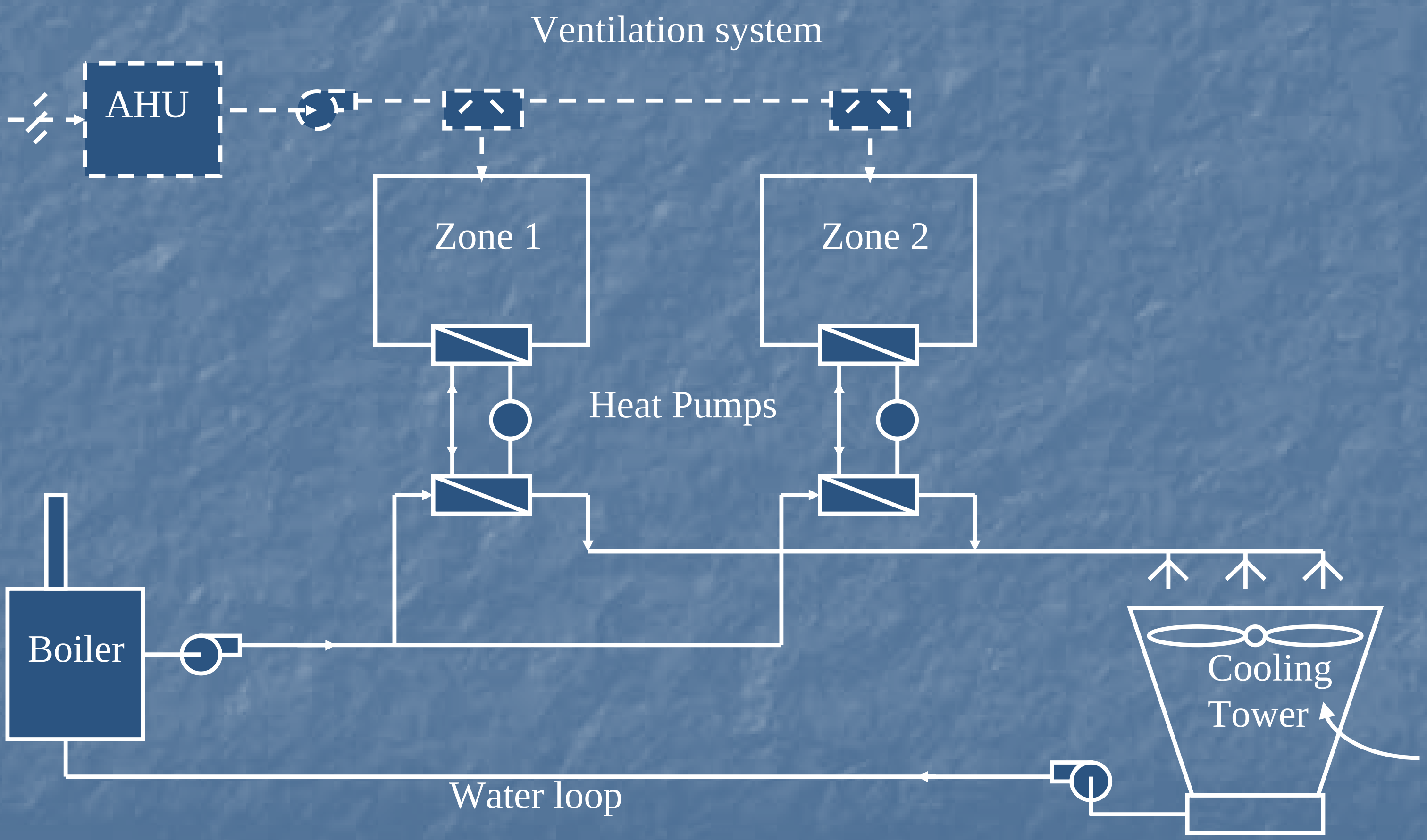
Distribution of Heat and Cooling inside a Building

- Energy consumed by fluid transport (fans and pumps) in a typical air distribution system is normally about 15 % of the HVAC energy use.
- Transport energy using water is less than that using air
- Possible to separate cooling and dehumidification functions

Transporting 100 Tons 100 Feet

Transport Medium	Conduit Size	Required Power	Heat Penalty
40,000 cfm Hi. Vel. Air	**44" Duct**	2.2 kW × 2 for S&R	0.63 Tons × 2 for S&R
40,000 cfm Lo. Vel. Air	**54" Duct**	0.75 kW × 2 for S&R	0.21 Tons × 2 for S&R
240 gpm chilled wtr.	**4 in. pipe**	0.29 kW × 2 for S&R	0.08 Tons × 2 for S&R
150A/460 VAC-3 ph.	**3-00AWG 0.365" x 3**	0.3 kW	0.08 Tons

Water Loop Heat Pumps



Ground Source Heat Pumps

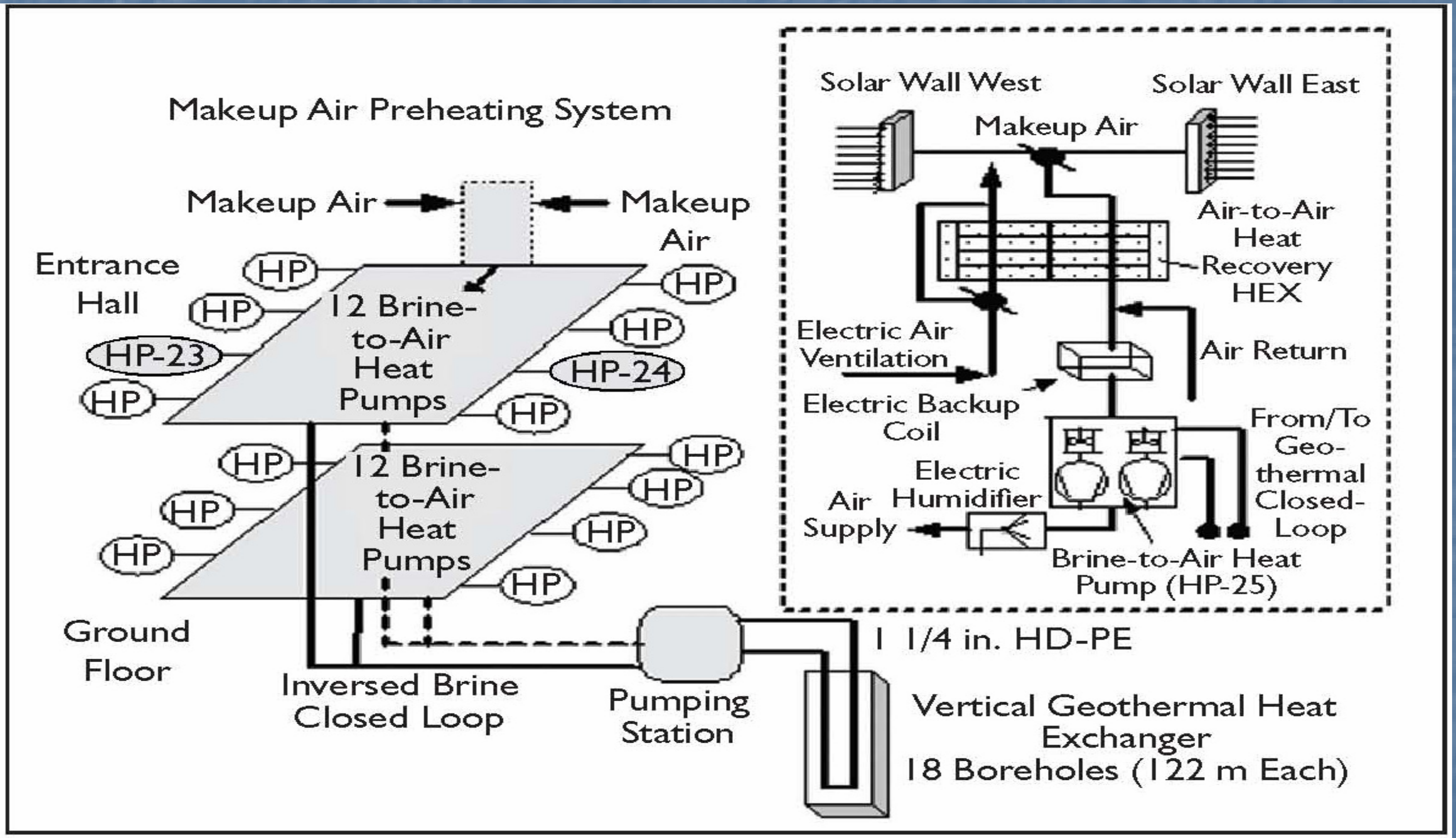


Figure 4: Configuration of the simple GSHP system with vertical ground heat exchanger.

Variable Frequency and Multi-staged Drives

- Achieve 10 – 30 % energy reductions for
  - Chillers
  - Chilled water circulation pumps
  - Condenser tower fans
  - Condenser water pumps
  - Supply and return fans

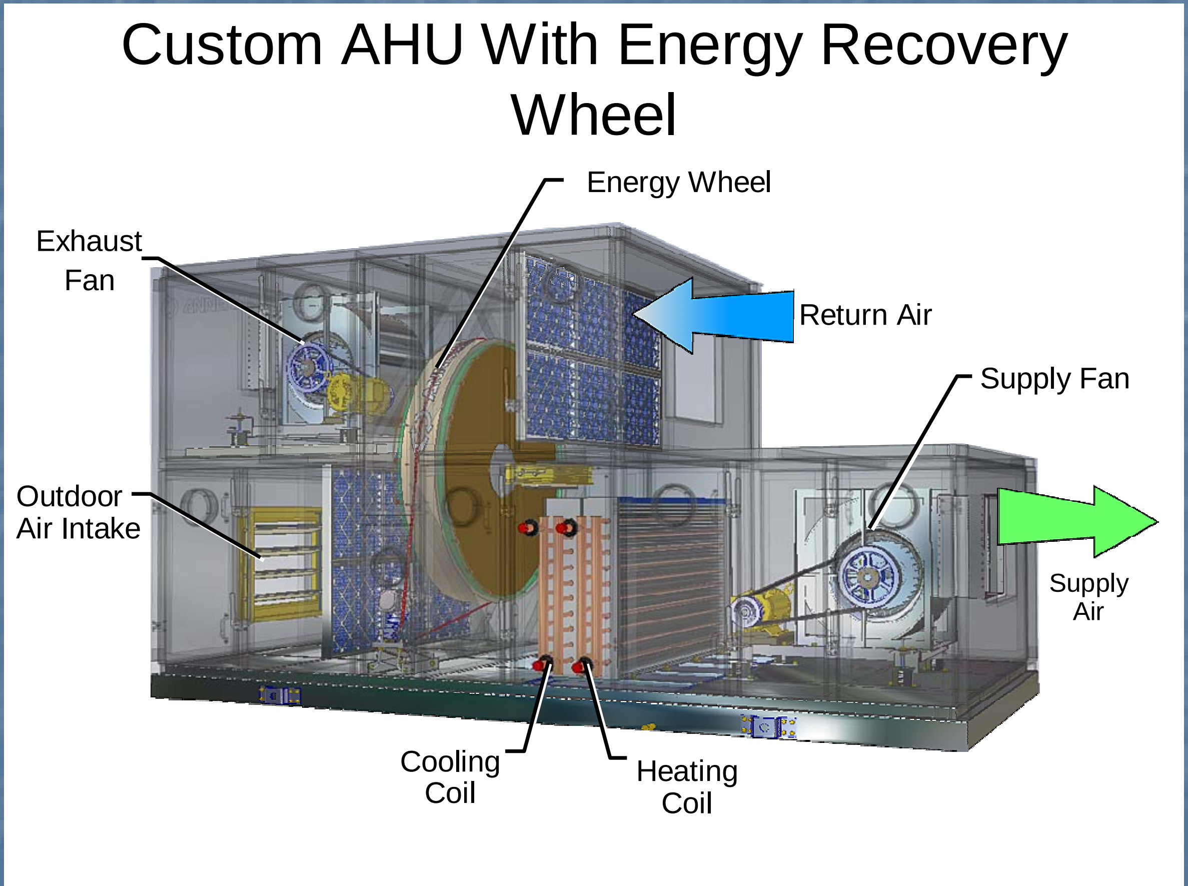
Case-specific Technologies

- Evaporative devices
  - Single and two-stage evaporative coolers
  - Evaporative condensers
- Desiccant devices
  - Liquid desiccants
  - Solid desiccants

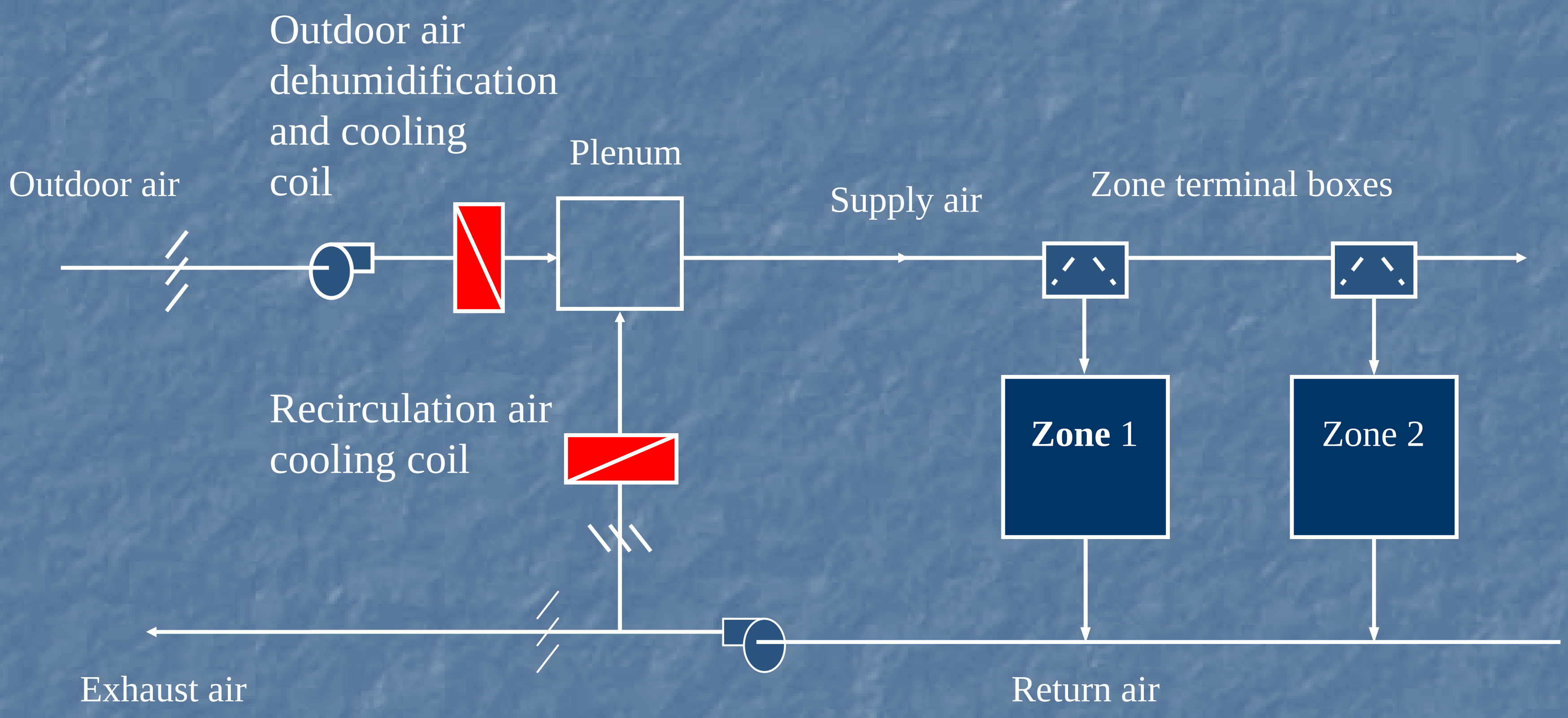
Ventilation Systems

- Heat and energy recovery systems
- Dedicated outdoor air systems (DOAS)
- Natural ventilation
- Parasitic losses

HRVs and ERVs

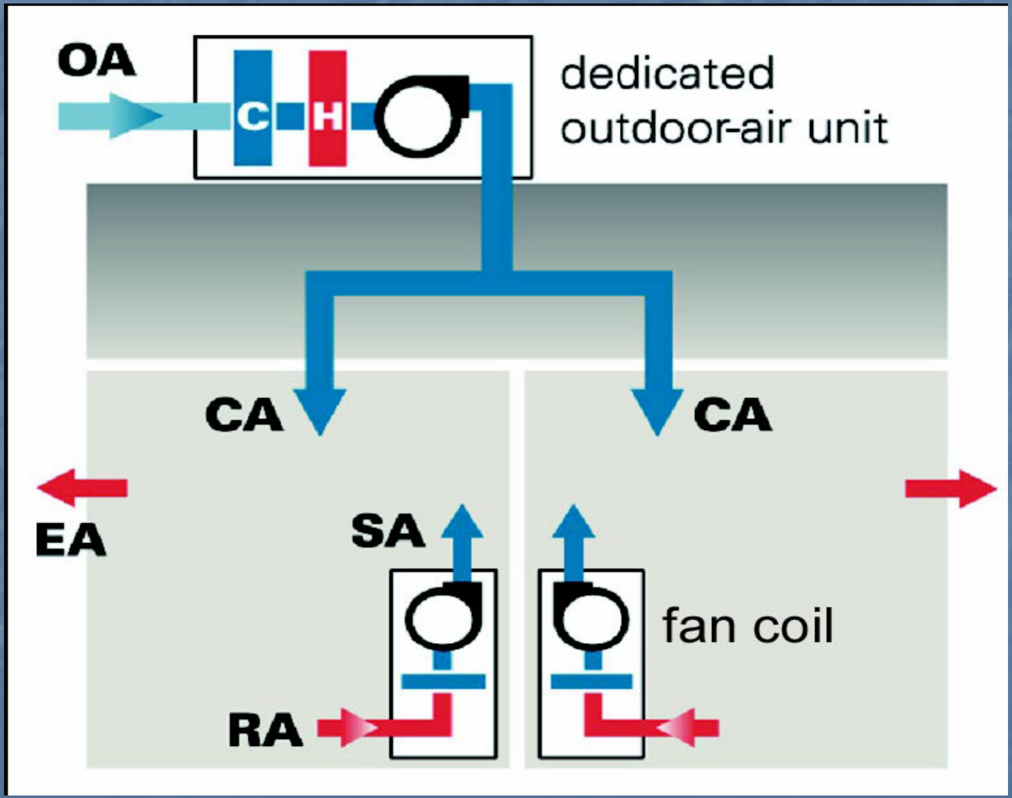


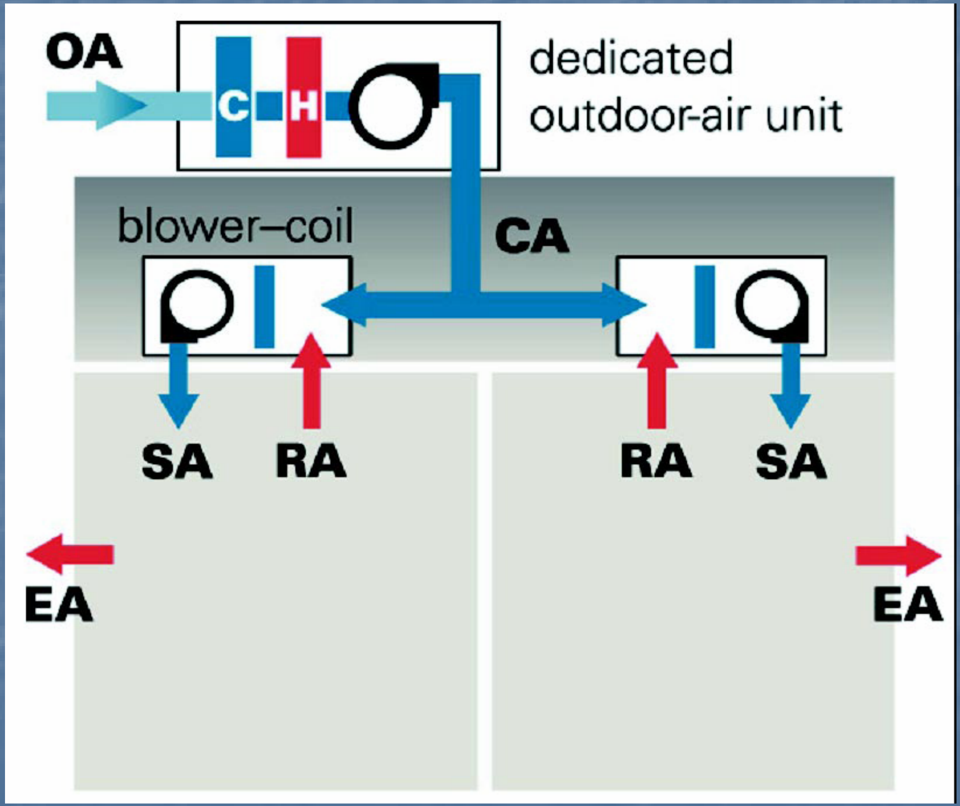
DOAS



Outdoor air
dehumidification
and cooling
coil
Plenum
Outdoor air
Supply air
Zone terminal boxes
Recirculation air
cooling coil
Zone 1
Zone 2
Exhaust air
Return air

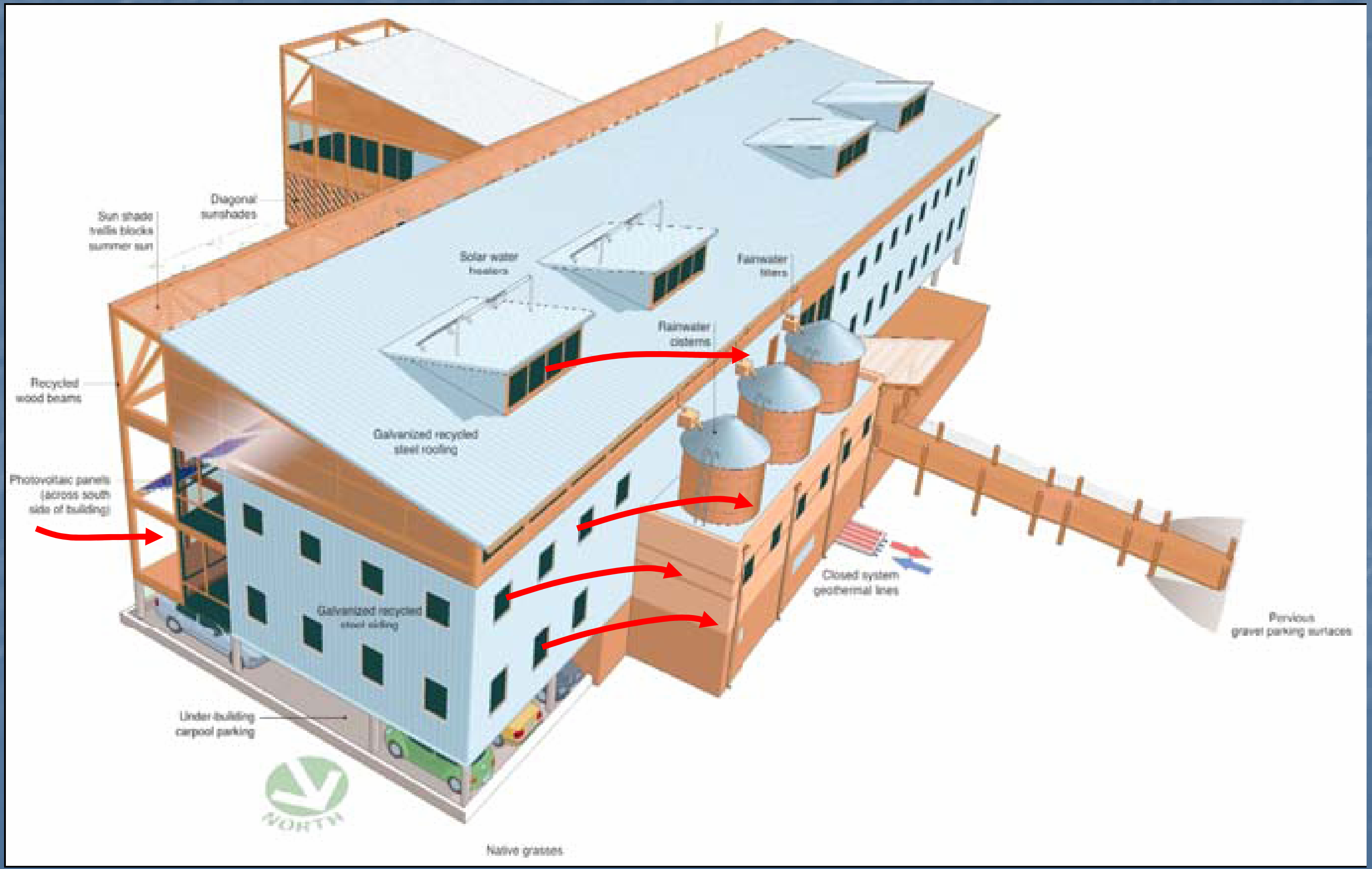
DOAS Configurations





Mixed Mode Natural Ventilation

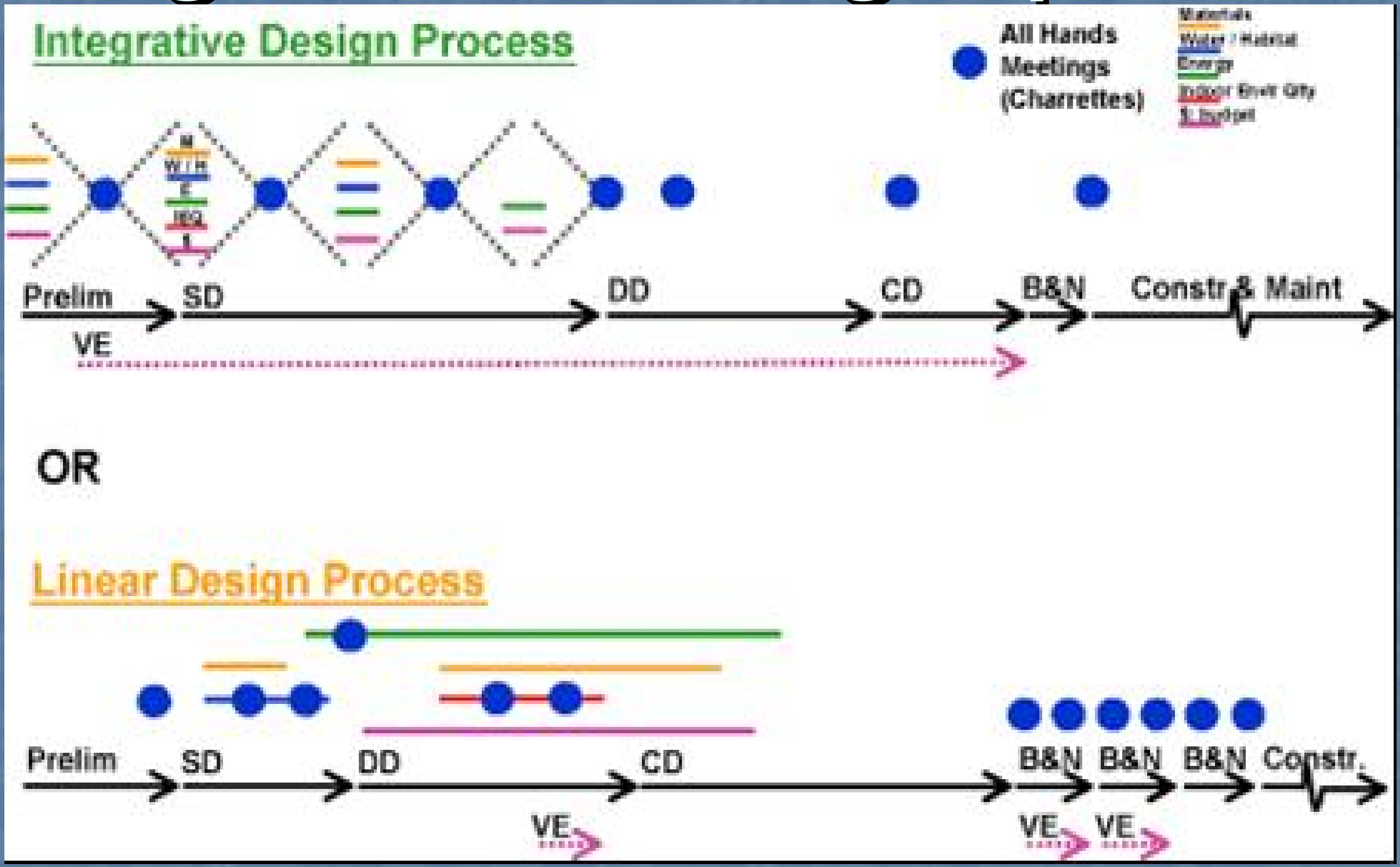
Chesapeake Bay Environmental Center



Air Distribution Design Issues

- Duct shape as large and round as possible
- Smooth ducts – minimize flex duct
- Minimize area changes and bends
- Elbows – use turning vanes
- Filters – as much flow area as possible
- Sealed and insulated ductwork
- Reduce static pressure (0.5 in water)

Integrated design process



Legend: ***SD: Schematic Design;, DD: Design Development; CD: Construction Documentation; B&N: Bidding & Negotiation; VE: Value Engineering***

Lessons Learned about Integrated Design Process

- Owners are the motivation for low-energy buildings
- Need measurable energy saving goals at the onset
- Many decisions are not motivated by cost.
- Today’s technologies change how buildings perform.
- Whole-building design approach lowers energy use and cost.
- Low-energy buildings do not always operate as designed.
- Monitoring leads to better management and improved performance

Conclusions

- It is possible to achieve a 50 % reduction in building energy use
- It is feasible to achieve a 50 % reduction using technologies available today
- Increased design costs result in lower energy costs
- An integrated design process is essential

THANK YOU

This concludes the ASHRAE & AIA Continuing Education Systems Program

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Questions or Comments??

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