# FROM AEDGs TO NET-ZERO (& BEYOND) BUILDINGS
# LONDON-WINDSOR ONTARIO
# NOVEMBER 29, 2021

.

**“Live as if you were to die tomorrow. Learn as if you were to live forever.”**

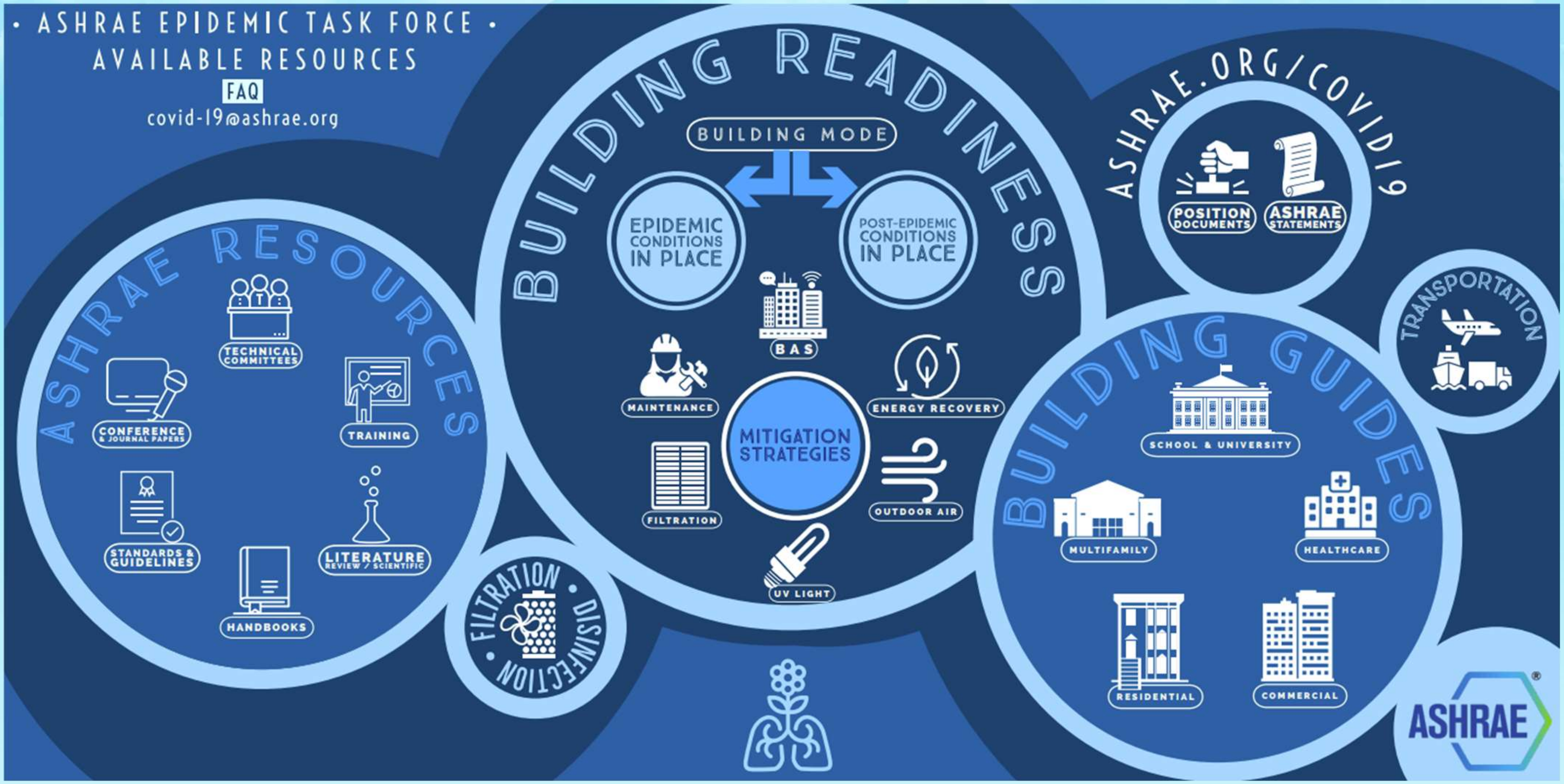
**Mahatama Gandhi**

# ASHRAE Epidemic Task Force

- Formed in March 2020 by direction of ASHRAE BOD to Environmental Health Committee
- Scope
  - Short term guidance
  - Re-opening/2nd wave guidance
  - Future directions
    - Research
    - Standards
    - Education
- 26 members
  - 22 volunteers
  - 4 ASHRAE staff
- Functions as a steering committee
- 15 teams with over 150 members
- Guidance
- Q&A
- Meetings and presentations
- Educational programs

# ASHRAE Epidemic Task Force Teams

- Communications
- Developing economies
- External partnerships
- Literature review
- Science applications
- Research
- Filtration and disinfection
- Building readiness
- Healthcare (including long-term care)
- Residential
- Commercial/retail
- Schools
- Laboratories
- Industrial
- Transportation




ashrae.org/covid1
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# ASHRAE'S COVID-19 GUIDANCE

- Principles and Hierarchy
  - **DO NO HARM**
  - Increase O/A  Amount to Building and Spaces
  - Increase Filtration Efficiency to MERV 13 or better (if possible)
  - Install air cleaning and disinfection technologies (such as Ultraviolet Germicidal Irradiation (UVGI)
  - Supplement existing systems that cannot be modified or upgraded  with –
    - Portable HEPA filtration Units
    - Upper Room & Portable UVGI

# ASHRAE'S Mitigation Strategies

- Outside Air Ventilation
  - Increase Quantity (if possible)
- Filtration Levels (MERV Rating) in Systems
  - Increase to MERV 13 or 14
  - Consider Portable MERV Filtration
- Ultraviolet Energy Strategy
  - UVGI in Duct
- System Operation Hours
  - Pre-flush (Recommended) & Post-flush (Optional)
- BAS Capabilities
  - Temperature & Relative Humidity (RH) Control
  - Monitoring and Alarms

## “BUILDINGS ARE FOR PEOPLE”

- People are the most valuable & expensive part of a building
- 1:10:100: 1000 Rule (Order of Magnitude)
  - $1 of design cost
  - $10 of construction cost
  - $100 of operating cost (energy, water,…)
  - $1000 of occupant cost (salary, benefits…)
- Indoor Environmental Quality (IEQ) affects
  - Safety (chronic & acute toxicity)
  - Comfort (IAQ, comfort, lighting & acoustics)
  - Productivity/Learning
  - Health – Allergies/asthma, cardiopulmonary disease, infectious diseases

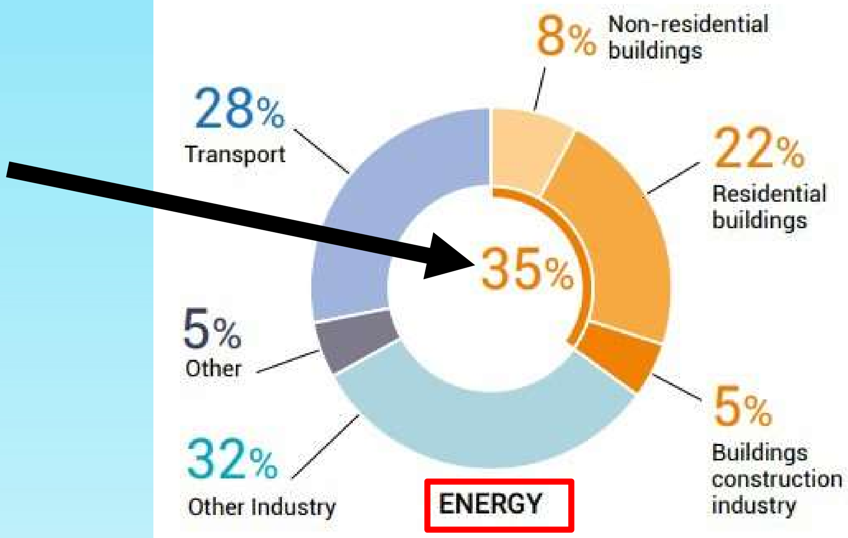
# Thermodynamics and the Destruction of Resources

by Bakshi, Gutowski & Sekulic

- The 1st and 2nd Laws of Thermodynamics should also be called the 1st and 2nd Laws of Economics.
- 1st Law – If we could create useful energy, we could have superabundant sources and sinks, no depletion, no pollution, and more of everything we wanted (direct abolition of scarcity).
- 2nd Law – Rules out abolishment of scarcity because we can't achieve perfect recycling of our sources.
- Attention to the thermodynamic constraints on the economy, indeed to the entropic nature of the economic process, is now critical.

# Do buildings make a difference?

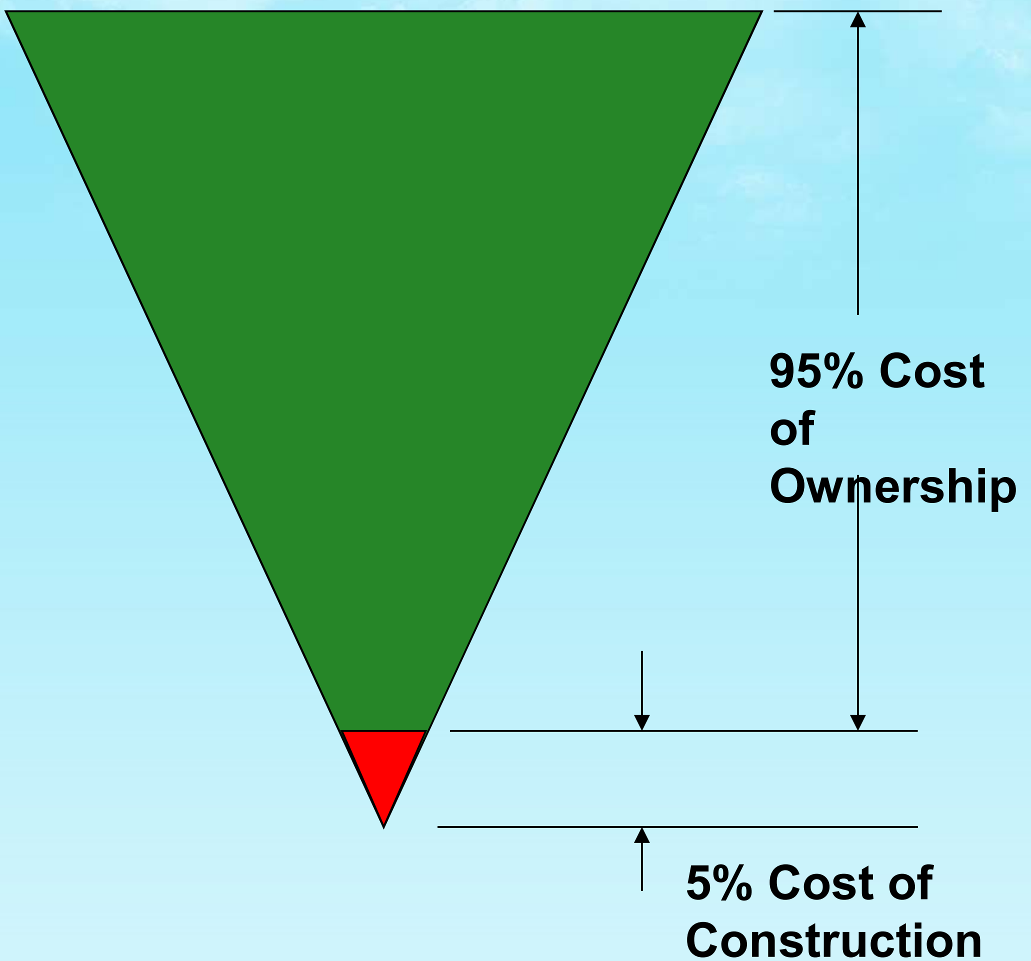
Global share of buildings and construction final energy and emissions, 2019




Notes: Buildings construction industry is the portion (estimated) of overall industry devoted to manufacturing building construction materials such as steel, cement and glass. Indirect emissions are emissions from power generation for electricity and commercial heat.

Sources: (IEA 2020d; IEA 2020b).  Adapted from "IEA World Energy Statistics and Balances" and "Energy Technology Perspectives".

# Fundamental Truth – Cost of Ownership



# Optimization for 21$^{st}$ Century Design Sequence

**Rocky Mountain Institute**

(Suggested Design Steps)

1. Expand comfort considerations – radiant temperatures, turbulent air movement, ventilative chairs, etc…

2. Reduce unwanted heat gains/losses of space

3. Exploit passive cooling (ventilative, radiative, ground-coupling, etc…)

4 Utilize non-refrigerative alternative cooling (evaporative, desiccant, absorption and hybrids)

5. **Choose efficient HVAC components** (normal starting point)

# Advance Energy Design Guides

- Eleven guides published and available for download: www.ashrae.org/freeaedg
- Circulation is 600,000+ copies

# Prescriptive Recommendations

- Envelope (30% & 50%)
  - Roof
  - Walls
  - Floors
  - Slabs
  - Doors
  - Vestibules(50%)
  - Vertical Fenestration
  - Interior Finishes
- Interior Lighting – Two options-30%
  - Multiple options-50%
- HVAC
  - DX -30%
  - WSHP-30%
  - GSHP-50%
  - Unit Ventilator and Chiller-30%
  - Fancoil & Chiller-30% & 50%
  - Package Rooftop VAV-30%
  - VAV and Chiller-30% & 50%
  - Ventilation Systems-30% & 50%

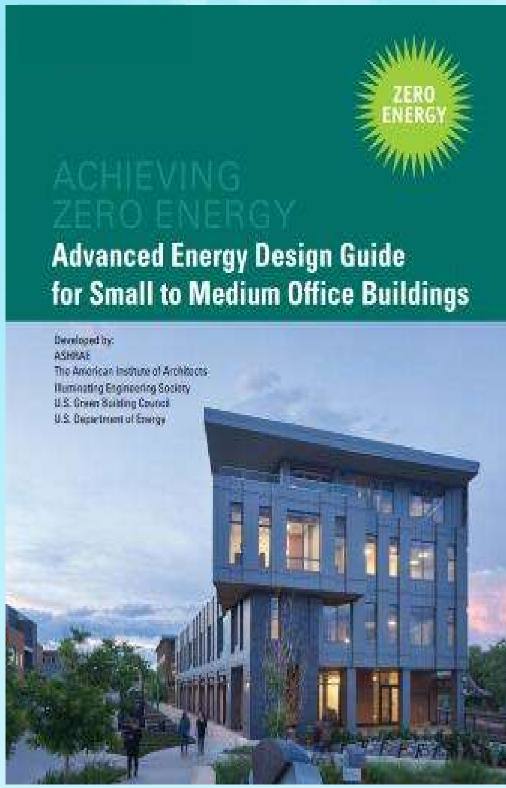
# Prescriptive Recommendations

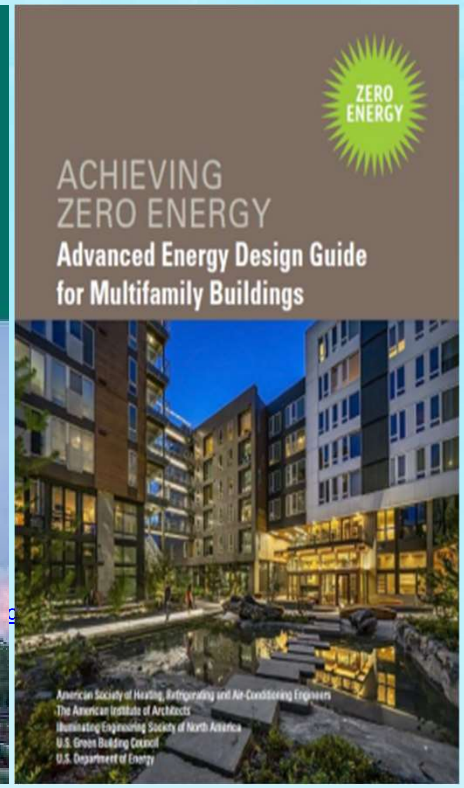
- HVAC
  - Ducts & Dampers-30% & 50%
  - M&V/Benchmarking-50%
- Exterior Lighting-50%
- Equipment Choices-50%
  - Computers
  - Vending Machines
- Controls/Programs-50%
  - Power/outlet controls
- Service Water Heating
  - 30% & 50%
- Kitchen Equipment-50%

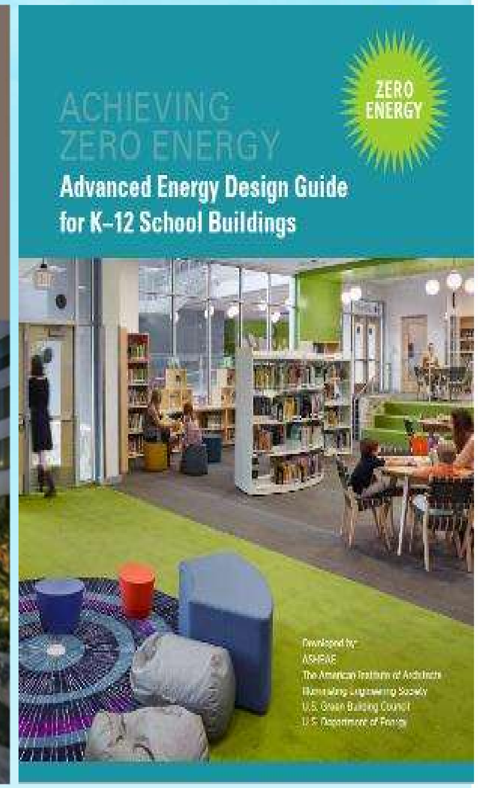
# Zero Energy Trends

Resources:
*Advanced Energy Design Guide for Achieving Zero Energy*

- Design guidance by building type and climate zone
    - Supported by case studies and energy modeling
- Developed by leading industry experts
- Looked to for beyond energy code

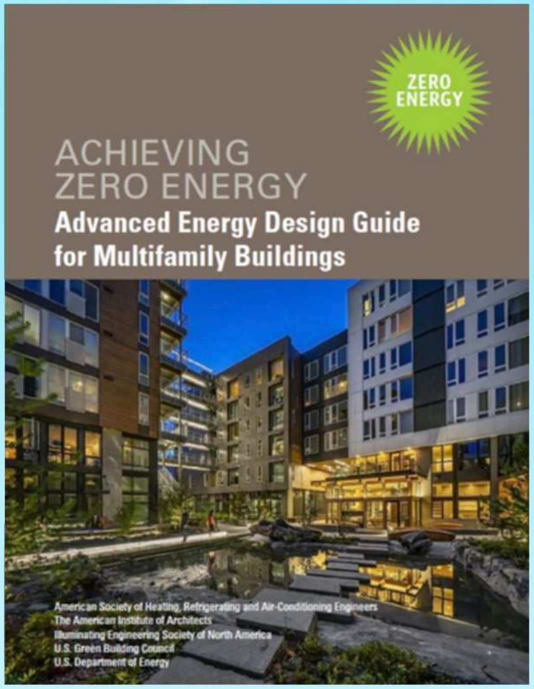


# Advanced Energy Design Guides

- Definitions and process
- Solution sets by climate zone; mix of **prescriptive** and **performance-based** approaches
- Guidance on specific strategies, whole-building integration approaches, additional considerations when using new technologies in field
- Recommended energy targets
- Examples of buildings with performance data showing that techniques work and that targets are achievable



# How-To Strategies

| Strategy Type | #Tips | Examples |
|---|---|---|
| Building and site planning (BP) | 23 | Site selection and building orientation |
| Envelope (EN) | 64 | Air leakage control, thermal mass, insulation levels |
| Daylighting (DL) | 18 | Daylighting and view impact on occupants/residents |
| Electric lighting (EL) | 32 | Light-emitting Diode (LED)/Solid-State Lighting (SSL), Control strategies |
| Plug load management (PL) | 7 | Policy, controls, monitor usage |
| Service water heating (WH) | 8 | Efficiency, controls, heat recovery |
| HVAC (HV) | 37 | Distributed generation, system selection, DCV |
| Renewable energy (RE) | 12 | Sizing, storage, metering, rates |

# Indoor Air Quality Guide
# Best Practices for Design, Constr. & Commissioning

# Indoor Air Quality Guide
# Best Practices for Design, Construction & Commissioning
# Document Objective

- **Describes design and construction strategies to improve IAQ relative to current practice and minimum codes & standards.**
- **Beyond Standard 62.1!!!**
- **Transform mid-range of practice** into better practice; not targeting the least or most sophisticated
- **Facilitate O&M** through informed design decisions.
- **Make application easier and more likely**: tabulated recommendations, sample details, great graphics
- Help to define good IAQ practice **for use in green and sustainable building programs**.

# FROM AEDGs TO NET-ZERO (& BEYOND) BUILDINGS

“*We are confronted with insurmountable opportunities*”……Pogo

# Advance Energy Design Guides

**Achieving Zero Energy**

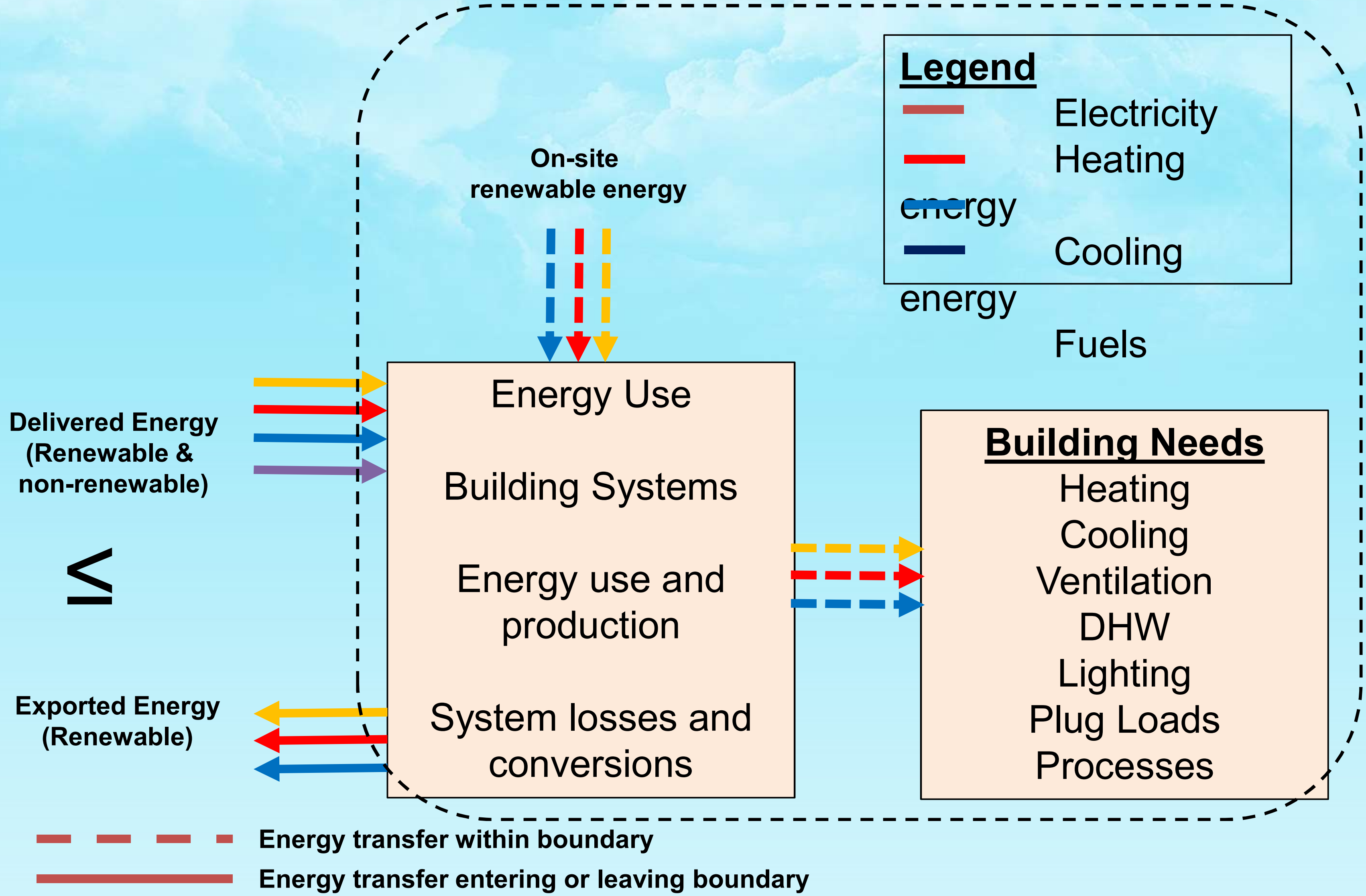
- New Series of Advanced Energy Design Guides for Zero Energy Buildings
- First volumes of the new series addresses K12 Schools, Small to Medium Office Buildings & Multi-Family Dwellings
- Following previous procedure, all recommendations vetted by extensive energy modeling and review by building type experts
- AEDG K-12 & S-M Office Bldgs Available for download
- AEDG Commercial Buildings Available for download www.ashrae.org/freeaedg

# Zero Energy Definition

*"An energy-efficient building where, on a source energy basis, the actual annual delivered energy is less than or equal to the on-site renewable exported energy."*

***The DOE definition provides a standard accounting method for zero energy using nationwide average source energy conversion factors…**

# Energy Balance Boundary

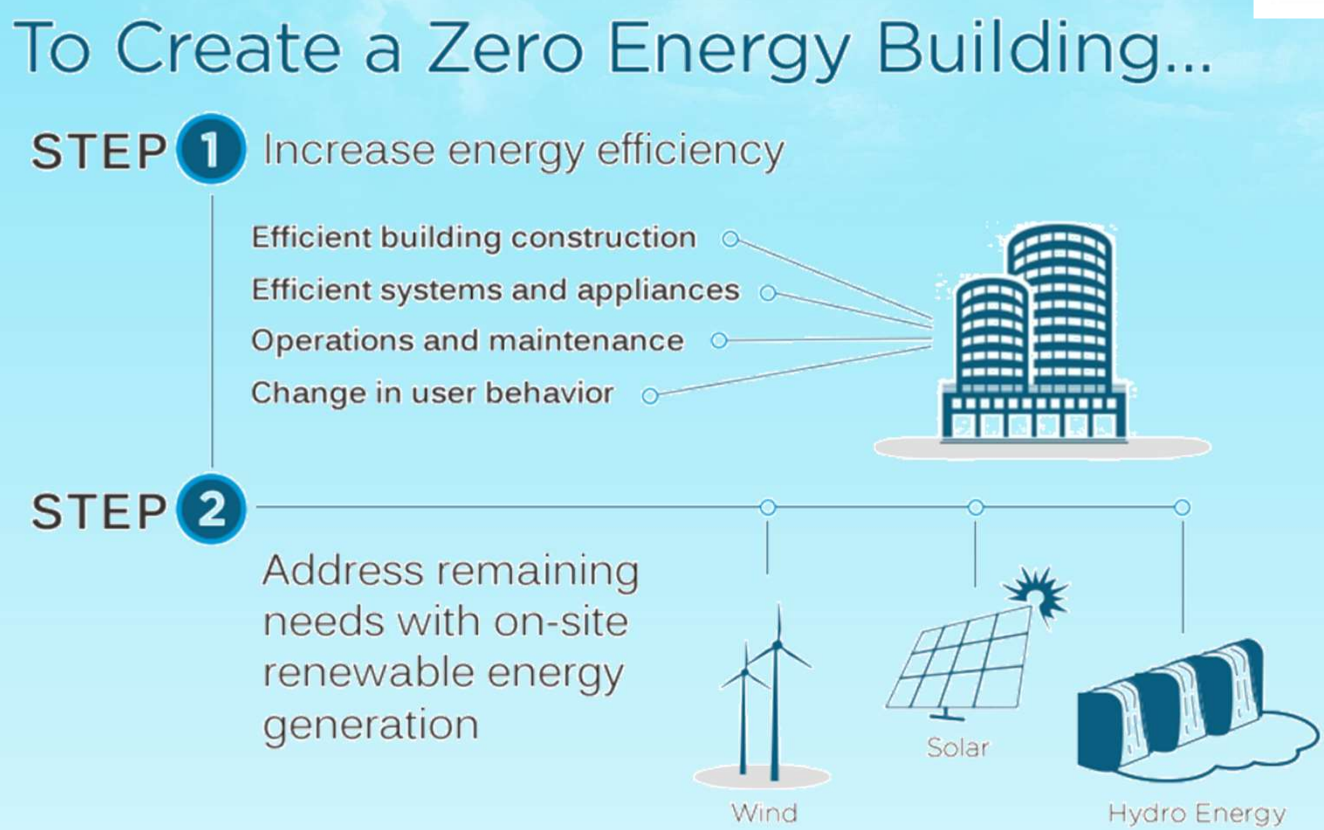



*Source: A Common Definition for Zero Energy Buildings*

# ZE AEDG Goals

- Demonstrate that zero energy buildings are attainable
- Provide direction for designing and constructing ZE buildings in all climate zones
- Offer methodology for achieving energy goals that are:
  - Financially feasible
  - Operationally workable
  - Readily achievable
- Measurable goals

# ZERO ENERGY BUILDINGS




**Optimization of EUI reduction through efficiency and PV system capacity**

# ASHRAE Task Force on Building Decarbonization (TFBD)

# ASHRAE Task Force for Building Decarbonization (TFBD)

**Formation of the Task Force for Building Decarbonization**

- Initiative of ASHRAE President and President-Elect
- 15 members
- Nine working groups with over 100 international volunteers

**Realization** that our successful **initiatives in building energy efficiency** should be **expanded to building decarbonization**

# ASHRAE Task Force for Building Decarbonization (TFBD)

## TFBD Working Groups

- Research/Knowledge Hub
- Operation Carbon
- Embodied Carbon
- Carbon Sequestration on Building Sites
- Building-Grid Intersection
- Building Performance Standards
- Standards and Codes
- Appliance and Equipment Standards
- Training and Education

Contact: Alice Yates, AYates@ashrae.org

# What is Building Decarbonization?

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- The reduction or elimination of greenhouse gas emissions using the standard metric of carbon dioxide

- Three pillars
  - Energy efficiency
  - Switching to cleaner energy sources
  - Shifting to electricity produced with low-carbon energy sources

## Why is it important to ASHRAE?

- Direct building $CO_2$ emissions need to be cut in half by 2030 to achieve net zero carbon building stock by 2050
- Of those who have submitted Nationally Determined Contributions (NDCs), 136 countries mention buildings, 53 countries mention building energy efficiency, and only 38 specifically call out building energy codes
- ASHRAE has an international presence – Chapters in over 130 countries
- ASHRAE is the standards authority for energy usage and efficiency in buildings

## How is the Task Force going to accomplish this?

- Public Policy Issues Brief (PPIB) that describes ASHRAE's role in building decarbonization has already been developed
- Established Position Document and nine Working Groups
- Each autonomous WG will identify key areas of concern to address
- Each WG will deliver recommendations and practices for industry stakeholders
- Website established to disseminate the information

# ASHRAE Task Force on Building Decarbonization
# Website Information

- https://www.ashrae.org/about/ashrae-task-force-for-building-decarbonization

# R.J Klarchek Information Commons Bldg

- 70,500 sq.ft. 4-Story 24/7 Digital Library
- Double-skin West Curtain Wall; Single-skin East Curtain Wall
- Classrooms in "Bookends"
- Partitioned Group Study Areas – Center
- Ground Floor Café
- Vegetative Roof

- Hillside, IL
- Loyola University
- Indoor Experience ≈ Being Outdoors on a Beautiful Day

# R.J Klarchek Information Commons Bldg

**Energy Efficiency**

- Dual Temp Radiant Ceiling – PEX Tubing
- Ducted Underfloor Air System – Ventilation & Supplement Radiant Cooling
- Radiant Cooling – Return Water from Central Chiller Plant
- Natural Ventilation & Hybrid Operation Modes – Automatic Operable Windows; Motorized Awning Windows → Indoor Temps ≈ ½ Degree of Outdoor Temps; Hybrid Op = Natural Ventilation + Radiant Cooling

# R.J Klarchek Information Commons Bldg

**Energy Efficiency**

- Automated Motorized Shading – Control of Venetian Blinds per Angle of Sun & Internal Roll-up Blinds (East Side) for Max Solar Heat Gain

- Heat Recovery & Dehumidification – Heating Mode AHUs Function as DOAS w/Heat Recovery; Cooling Mode AHUs/VAV Boxes Controlled by CO2 Levels & Temp Over-ride (Chilled Ceiling Can't Meet Sensible Loads); AHUs Dehumidify w/Run-around Coils

# R.J Klarchek Information Commons Bldg

## <u>Energy Efficiency</u>

- Daylight Harvesting – Daylighting Control Maintains 35 fc → 50 fc w/Continuous Ltg Dimming/Adjustment per Space Conditions
- Control Sequence – Detailed Sequences of HVAC & Smoke Evac Systems + Complete Weather Station (light levels, wind, $T_{DP}$, $T_{DB}$ & Precipitation)
- Large Ceiling Mass – Stores Night Harvested “Coolness” (Hybrid Ventilation)

# R.J Klarchek Information Commons Bldg

## Indoor Air Quality

- Demand Controlled Ventilation via Under Floor Air Distr. System w/High Induction Swirl Diffusers
- VAV Box Control Maintains $CO_2 \leq 1{,}000$ ppm
- Zone Air Distribution Effectiveness = 1.0 (Table 6.2 of Std 62.1)

# R.J Klarchek Information Commons Bldg

## Maintenance & Operation

- Accessible Raised Floor – All Open Areas
- 3rd Party Commissioning Process
- Continuous Monitoring of Bldg Systems' Operations & Alterations (as necessary)
- Problematic Operations Discovered & Resolved by Staff
- Sub-meters on ChW, Dual-temp Water & Electricity→Plug Loads Larger Than Expected

# R.J Klarchek Information Commons Bldg

## Cost Effectiveness

- Low-flow Fixtures (1/8 gpm) = Reduced Waste
- Dual Flush Toilets
- Green Roof Area = Additional Insulation, Temp Control, Reduced Storm Water Runoff & Absorption of Solar Energy
- Actual Bldg Performance →46% Better than ASHRAE 90.1-1999 (84 kBTU/SF/yr of which Plug Loads = 24 kBTU/SF/yr)
- Bldg → Most Popular on Campus

# Net-Zero NREL Administration Building

## PROJECT DESCRIPTION

- 218,000 SF that includes one 3-story and one 4-story office wing
- Building Occupancy = 780

## NZEB STRATEGIES

- Cross Ventilation Strategies
- Hydronic radiant slab heating and cooling
- DOAS in a displacement ventilation configuration

# Net-Zero NREL Administration Building

## NZEB STRATEGIES

- Ventilation air preheat w/collectors on S-face of buildings
- Remote mass thermal storage (heat & coolth)
- Evaporative cooling for data center w/heat recovery
- Daylight harvesting + window shading
- Thermally massive exterior wall assemblies

# Net-Zero NREL Administration Building

## NZEB STRATEGIES

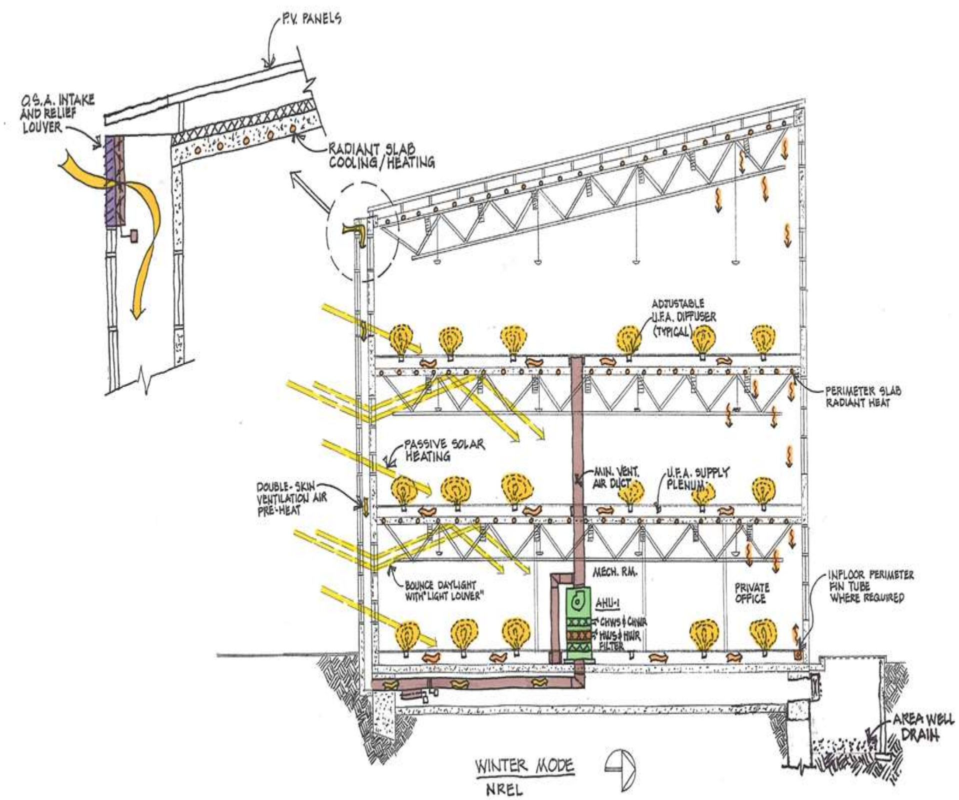
- Portion of hot water heating by woodchip biomass boiler
- Photovoltaic arrays on building roofs and Visitor's Parking Lot →NREL to have Power Purchase Agreement from a 3rd party vendor
- Use of 'Lightlouver' – a light bouncing device to augment daylighting

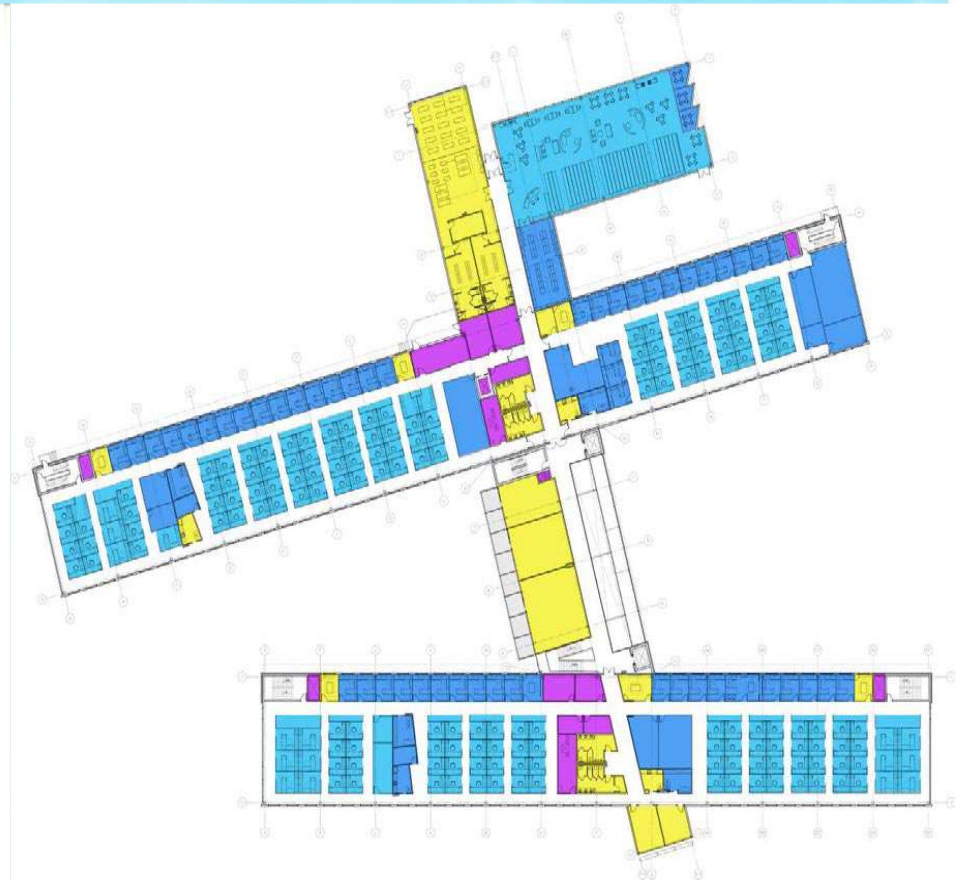
# Net-Zero NREL Administration Building

## LESSONS LEARNED

- Energy loads dominated by “plug loads” and other internal loads (server rooms/data center)
- Simple solutions are the “best” (e.g. transpired collectors vs double-skin south façade for solar control & passive heat collection)

# Net-Zero NREL Administration Building



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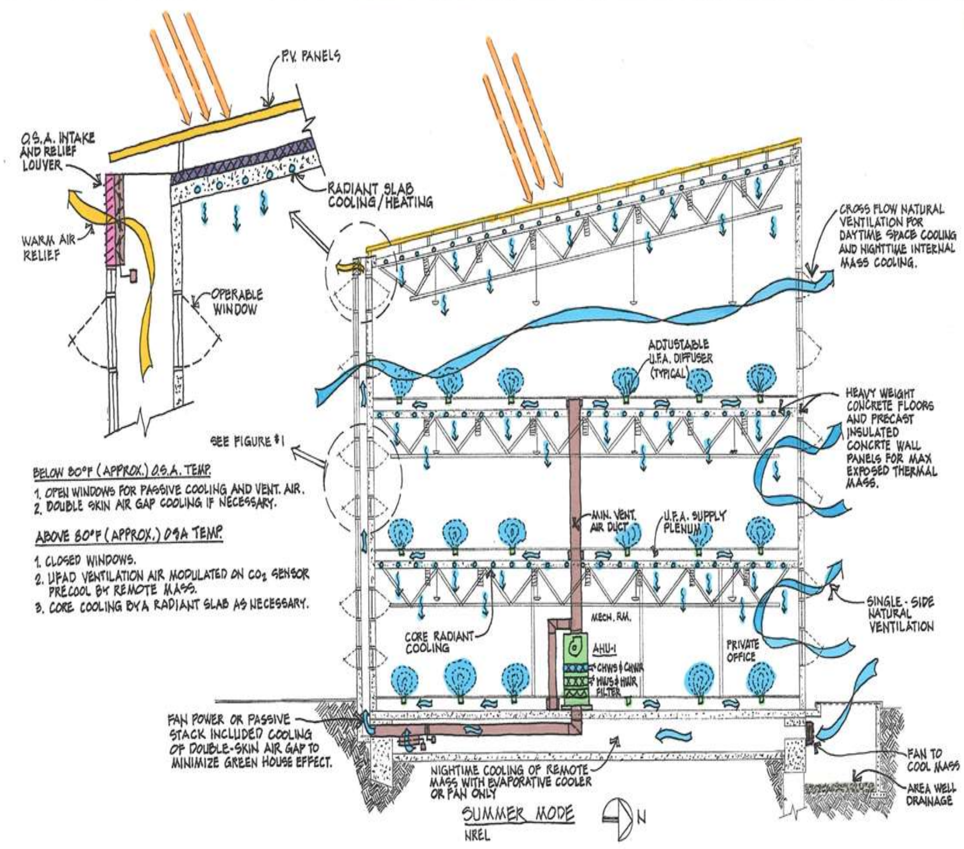


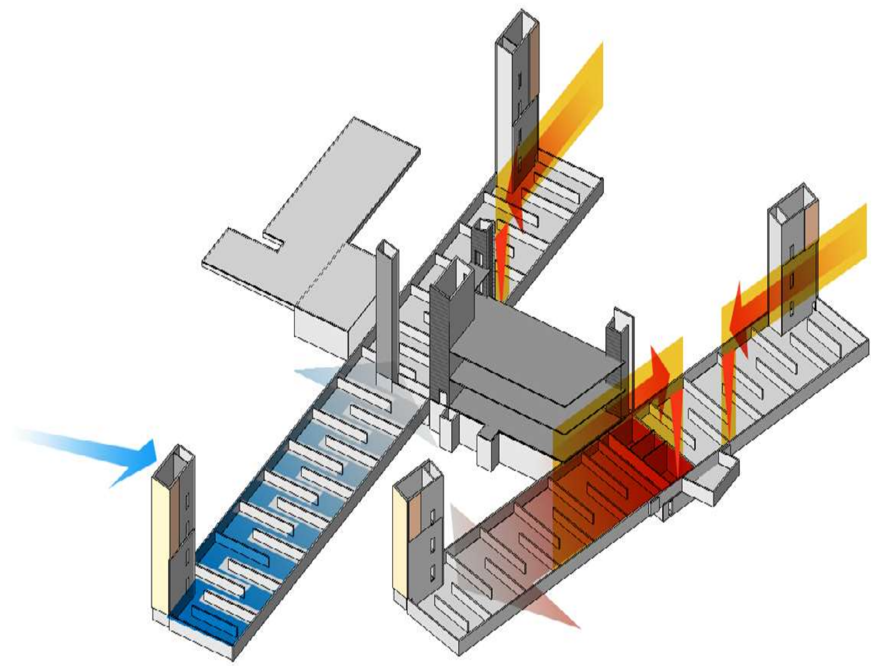

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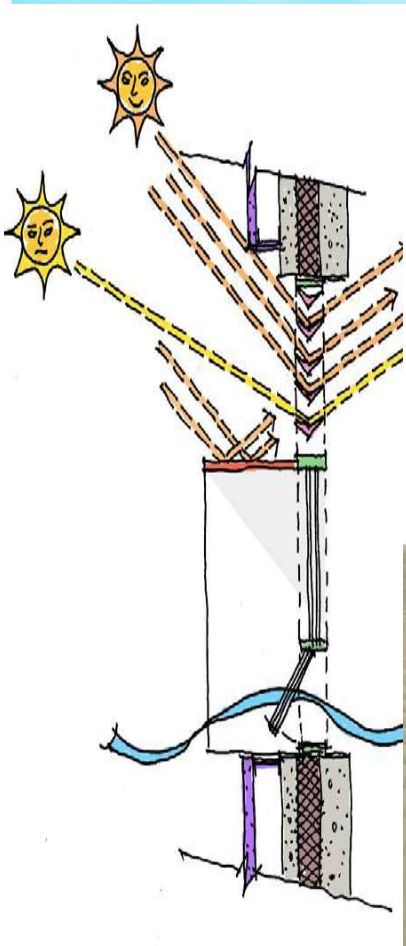
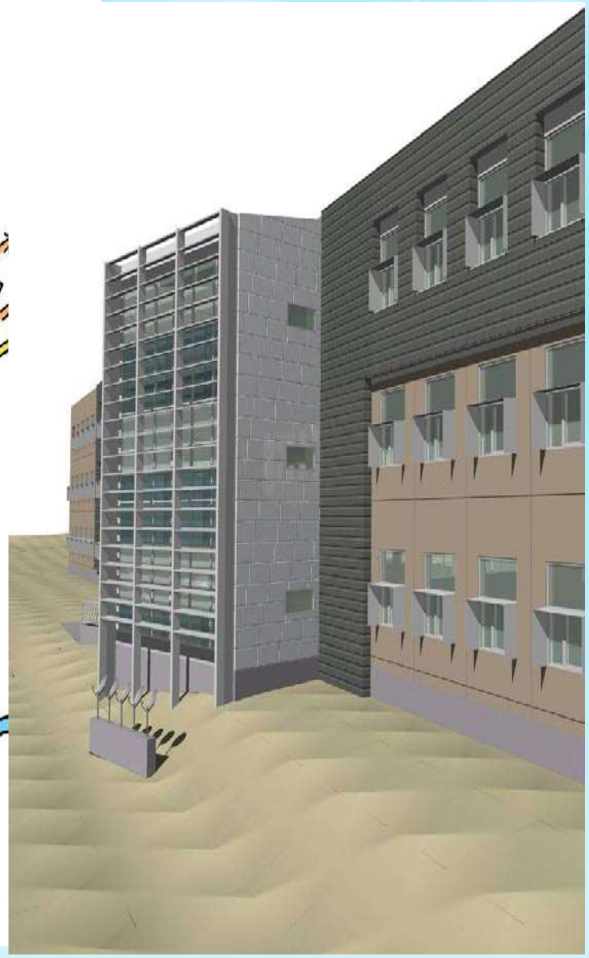




**Measured Energy Use**

- Annual Energy Consumption
  = 2,001,240 kWh/yr
  = 9.18 kWh/SF-yr
- Renewable Annual Energy Supply = 2,001,240 kWh/yr
  = 9.18 kWh/SF-yr
- Net Energy Use = 0 kWh/yr
  (Excess sold to 3rd party)

# Net-Zero Richardsville Elementary School
## Bowling Green, Kentucky

### PROJECT DESCRIPTION

- 72,300 sq.ft. facility for 500 elementary school students
- 2-story facility with initial goal of annual consumption of 18 kBtu/sf-year

### NZEB STRATEGIES

- Geothermal HVAC System using dual compressor WSHP units
- Ventilation w/100% O/A, variable volume, heat recovery unit; Use of $CO_2$ Sensors/continuous testing of IAQ
- Thermal envelope – ICF wall construction

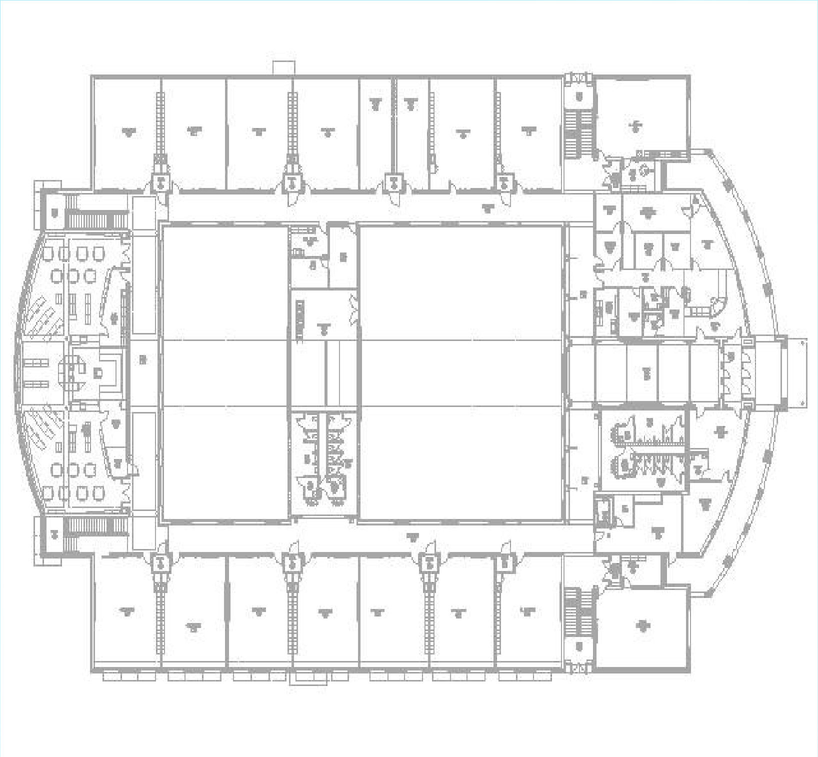
# Net-Zero Richardsville Elementary School
## Bowling Green, Kentucky

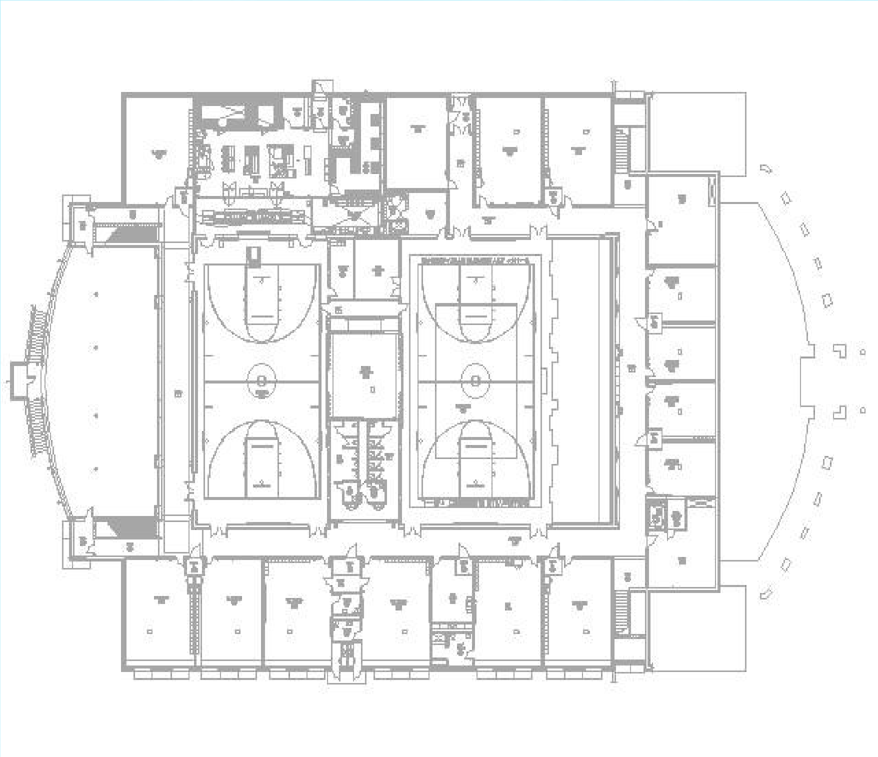
### NZEB STRATEGIES

- Daylighting – Combination of Glazing + Solatubes
- Lighting Power Density = 0.68 $W/ft^2$
- Kitchen – Type II hoods installed – reduced exhaust air requirements; most efficient cooking equipment installed
- Computers – Fist wireless school in KY (all laptops)
- Power Generation – 208 KW of roof mounted thin film solar photovoltaics and 140 KW of mono-crystalline photovoltaic panels

### LESSONS LEARNED

- Energy reduction opportunities – Kitchen power, Computers & Ventilation system/control

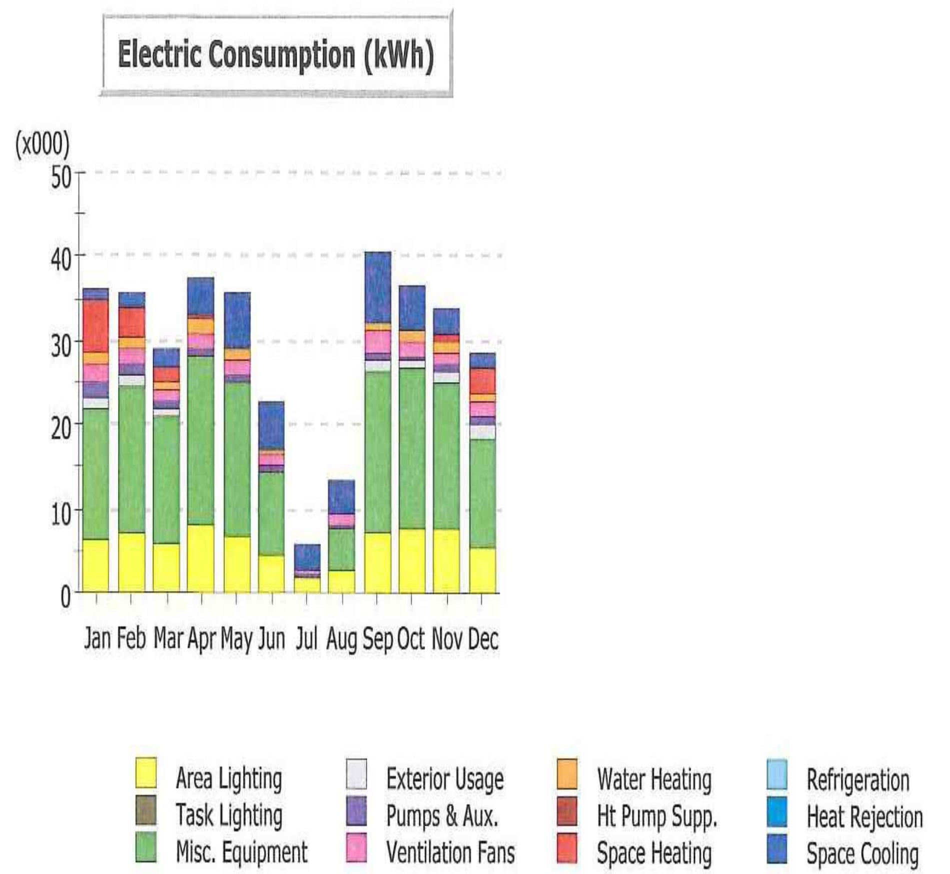




Main Level

Lower Level

# Net-Zero Richardsville Elementary School
## Bowling Green, Kentucky




**Measured Energy Use**

- Annual Energy Consumption = 357,000 kWh/yr
- Renewable Annual Energy Supply = 366,000 kWh/yr
- Net Energy Use = (9,000 kWh/yr)

# Net-Zero IDeAS Z² Design Facility

**PROJECT DESCRIPTION**

- 7,200 sq.ft. Gross Area
- Commercial Office Space for Electrical Consulting Engineering Firm
- 3,100 sq.ft. 1-story Open Studio Space
- 4,100 sq.ft. 2-story Office Section
- Z² Design Goals:

1. Net-zero Energy
2. Zero $CO_2$ Emissions


- Oakland, CA
- Model Showed 60% Reduction from ASHRAE 90.1-1999
- PV Produced More than Consumed (2009)

## Net-Zero IDeAS $Z^2$ Design Facility

### NZEB STRATEGIES

- Slab Radiant Tubing – Heating & Cooling
- Ground-source Heat Pumps →Chilled Water & Space Heating Water
- Natural Ventilation – O/A Temps fall within Acceptable Range
- Natural Daylighting
- East Electrochromic Window Wall – No Moving Parts
- R-19 (Walls); R-30 (Roof)

# Net-Zero IDeAS $Z^2$ Design Facility

## NZEB STRATEGIES

- 30 kW Building Integrated PV (BIPV) System →56 MWh/yr (100% of Bldg's Energy Requirement)
- BIPV = White Roof Membrane Integrated PV Monocrystalline Solar Cells
- 2nd BIPV = Sunshade @ Main Entrance
- High Efficiency Interior & Exterior Ltg
- Occupancy Sensors – Lighting and Workspace Appliances & Task Lights

# Net-Zero IDeAS Z² Design Facility

## NZEB STRATEGIES

- Office Spaces @ 0.15 cfm/sf (62.1 = 0.13 cfm/sf)
- DOAS = 100% O/A to all spaces
- AHUs →MERV 13 Filters
- Displacement Ventilation →Assists Radiant Htg & Clg
- Natural Ventilation – Operable Windows & Large Swing-open Patio Style Doors
- IEQ Bldg Survey→90%+ Satisfaction

# Net-Zero IDeAS Z² Design Facility

## NZEB STRATEGIES

- Building Management DDC System – Automatically Makes Operational Mode Changes
- Monitor of Actual Energy Consumption – Circuit-by-Circuit Basis; Weather Data from PV →Fine Tune Systems' Efficiencies
- Drought Tolerance Plants – Reduce Irrigation Requirements & Maintenance

# Net-Zero IDeAS Z² Design Facility

## NZEB STRATEGIES

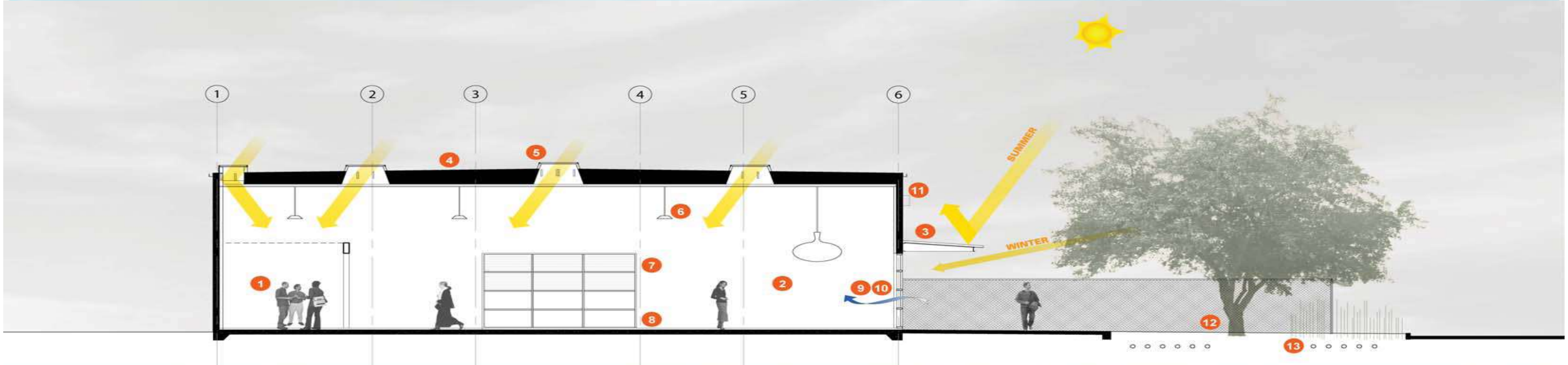
- Utility Incentives & Rebates + Tax Credits + State/Federal Incentive Programs and PV Production = 7.6 Year Payback
- Plumbing Fixtures →Ultra Water Efficient
- Bioswale (Rain Collector) Replaced Large Parking Lot & Reduced Heat Island Effect →Recharges Water Table
- Façade of Original Bldg – Reused in Courtyard

# Net-Zero IDeAS Z² Design Facility

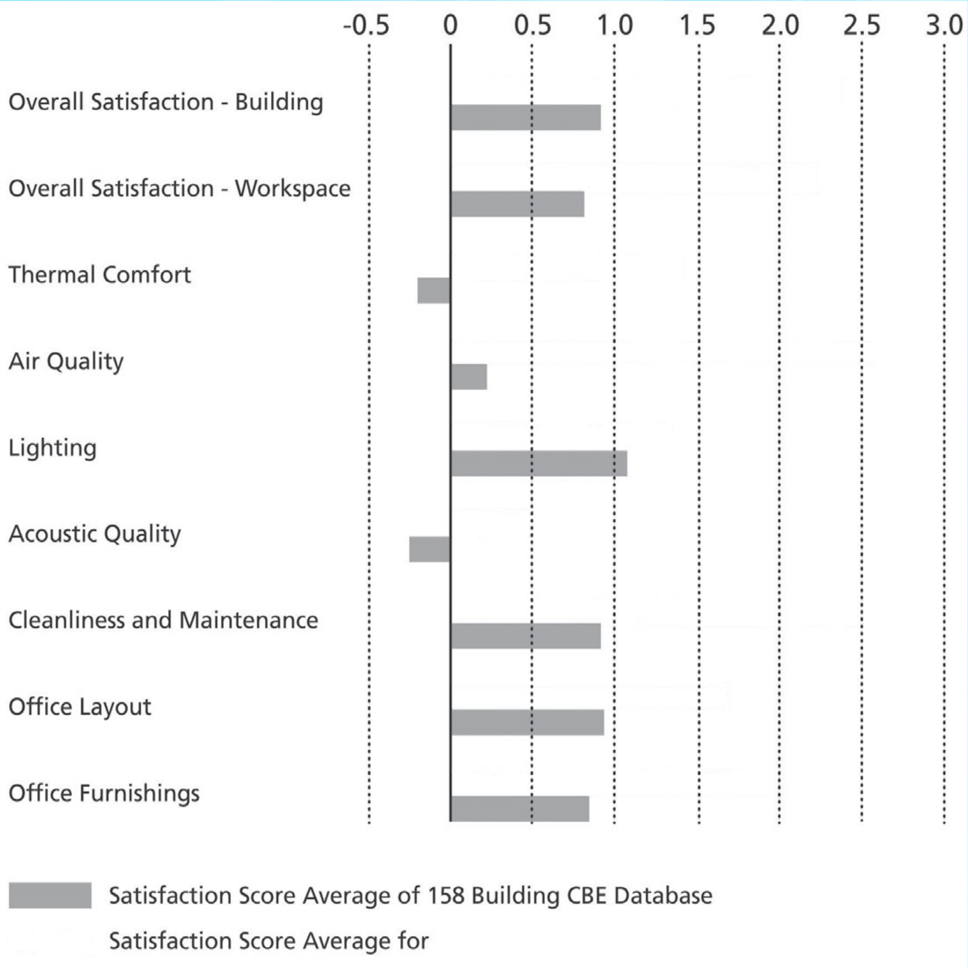
## LESSONS LEARNED

- Reduce energy level before adding renewable energy sources
- New technologies can/will fail initially
- Radiant heating and cooling + natural ventilation provide low energy consumption & exceptional comfort levels

# Net-Zero IDeAS $Z^2$ Design Facility




# Net-Zero IDeAS $Z^2$ Design Facility




## Measured Energy Use

- Annual Energy Consumption = 54,948 kWh/yr

  = 8.38 kWh/SF-yr

- Renewable Annual Energy Supply = 44,063 kWh/yr

  = 6.72 kWh/SF-yr

- Net Energy Use = 10,885 kWh/yr

  = 1.66 kWh/SF-yr

# Net-Zero Lewis Center for Environmental Studies – Oberlin College

## PROJECT DESCRIPTION

- 13,600 sq.ft.; 1 ½ floors of classrooms, office spaces, small auditorium, library and resource center
- Goal of being a net energy exporter within 10 years

## NZEB STRATEGIES

- R-13 (walls & floors), R-30 (roof) insulation levels & earth berm of north wall
- Double & Triple-paned argon-filled, low-e windows
- All areas daylight (except auditorium) – photoelectric daylight sensors

# Net-Zero Lewis Center for Environmental Studies – Oberlin College

**NZEB STRATEGIES**

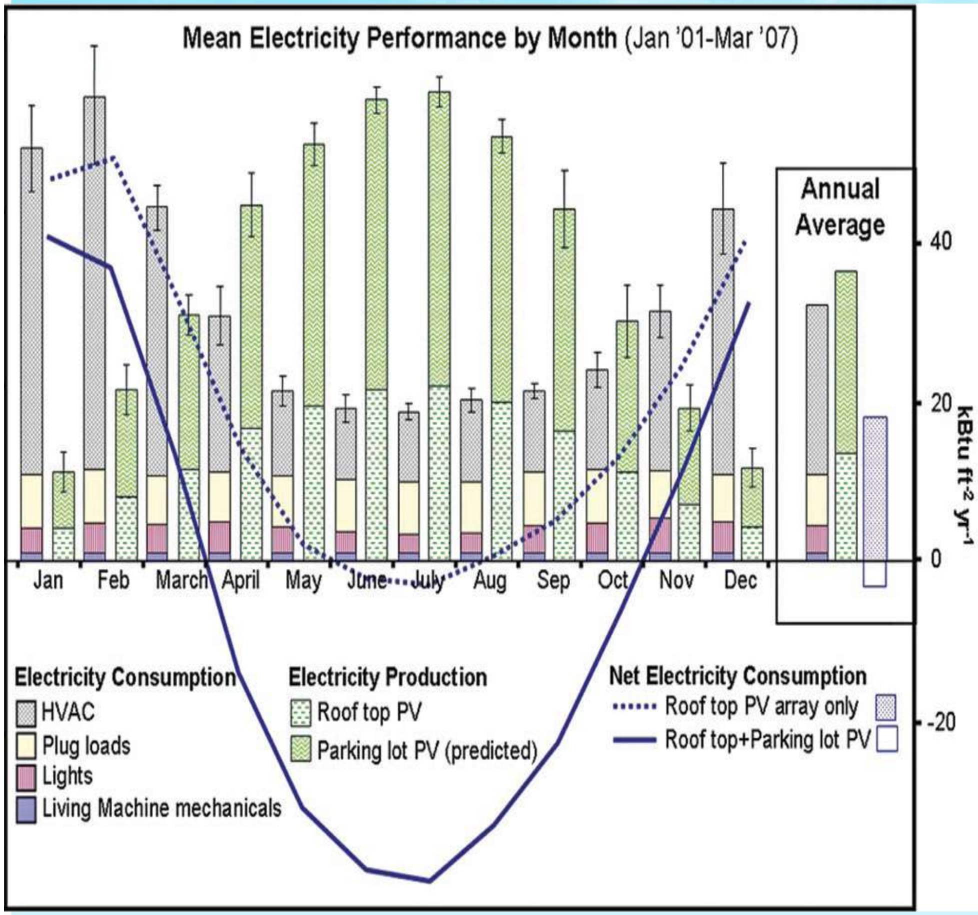
- LPD = 0.9 W/SF
- Clerestories, light-colored surfaces and interior windows for daylighting use
- Geothermal-WSHP System for heating & cooling
- Radiant floor heating in atrium
- 60 kW PV (roof) and 100 kW PV (building's parking lot cover)
- On-site wastewater treatment plant for building waste water

# Net-Zero Lewis Center for Environmental Studies – Oberlin College

## LESSONS LEARNED

- Better control algorithms needed to meet net-zero energy goal
- End use monitoring needed to fine tune energy systems and provide feedback – dedicated data acquisition system monitors, displays and archives the performance data

# Net-Zero Lewis Center for Environmental Studies – Oberlin College




## Measured Energy Use

- Annual Energy Consumption = 127,840 kWh/yr
- Renewable Annual Energy Supply = 145,520 kWh/yr
- Net Energy Use = (17,680 kWh/yr)

# Net-Zero Gebhard- Mueller School

## Riss, Germany

## PROJECT DESCRIPTION

- 120,560 Business School facility for 1,650 students and 100 teachers
- Target of 10 Kwh/sf-yr (60% lower than German code requirements)

## NZEB STRATEGIES

- Groundwater well plant for heat pumps serving the radiant heating and cooling systems
- $CO_2$ sensors for outside air control

# Net-Zero Gebhard- Mueller School

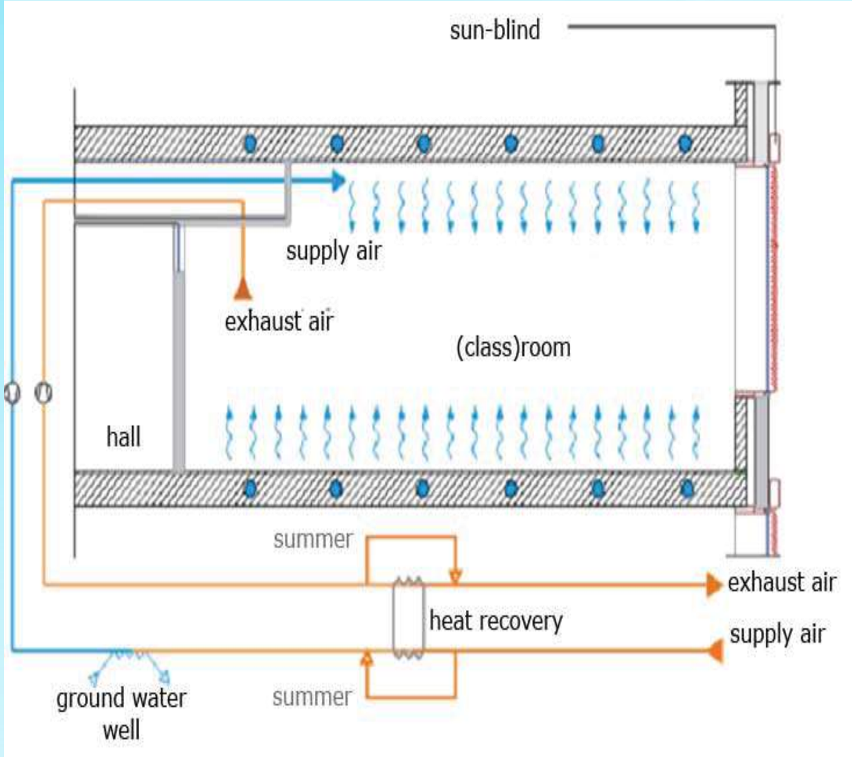
## Riss, Germany

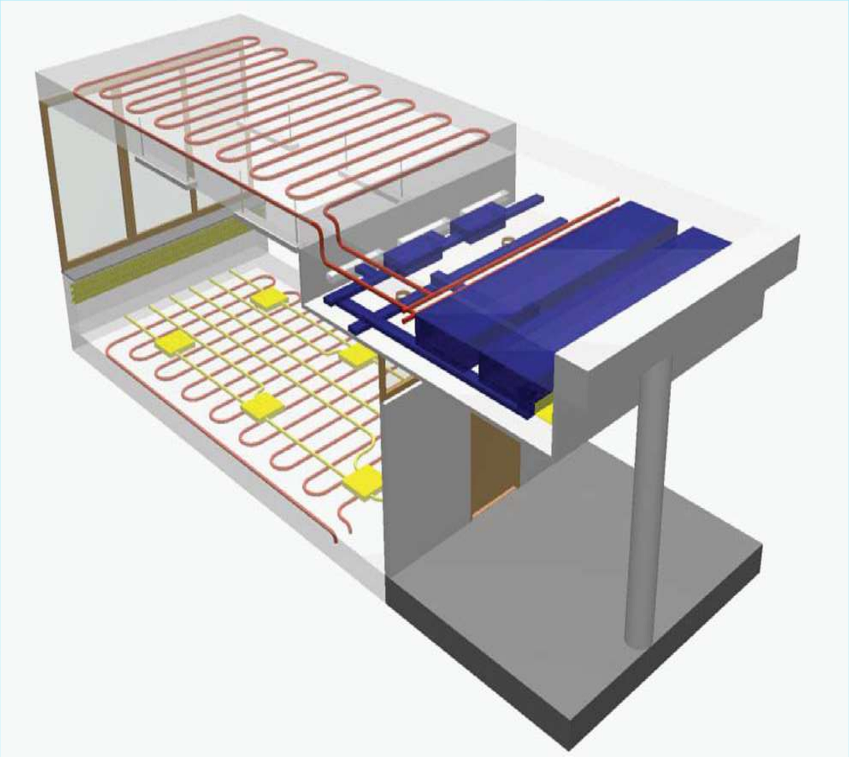
### NZEB STRATEGIES

- AHUs equipped with energy recovery systems
- Automatic control of lighting systems with daylighting & occupancy schedules
- Continuous performance monitoring of systems

### LESSONS LEARNED

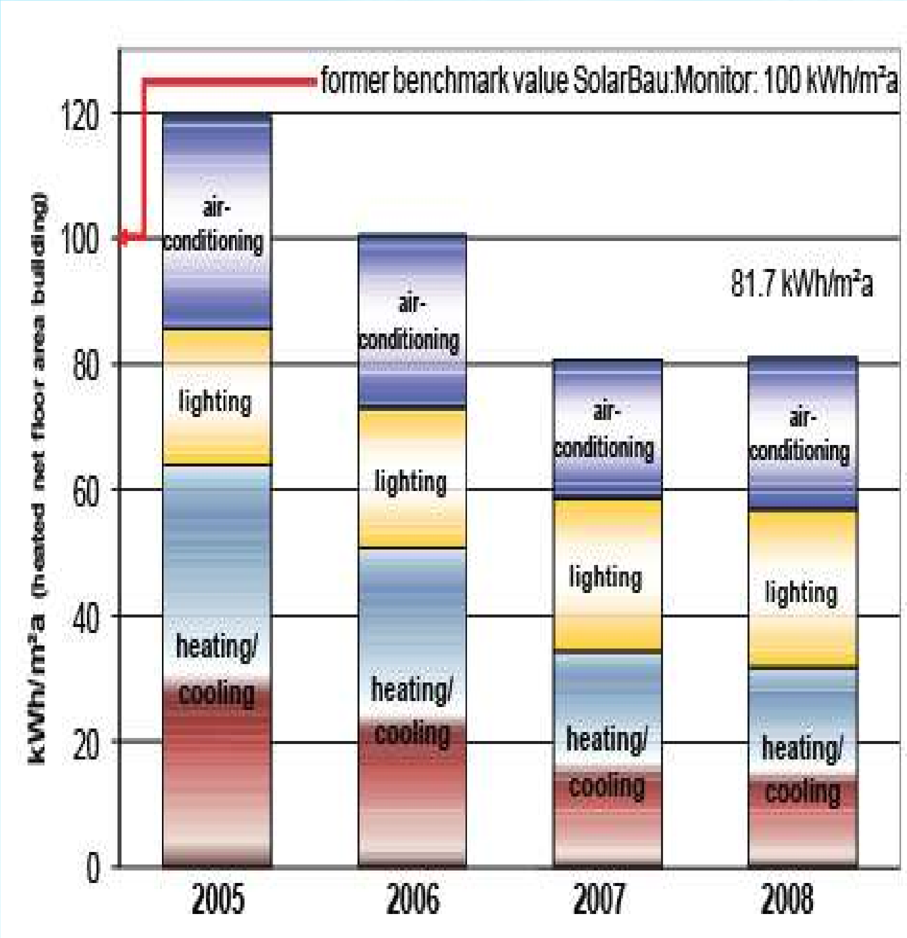
- Integrated design is <u>crucial</u> for a low-energy bldg.
- Design on ½ of success story – Commissioning, User Training of Systems & Performance Monitoring provides operation optimization


sun-blind
supply air
exhaust air
(class)room
hall
summer
exhaust air
heat recovery
supply air
ground water
well
summer



# Net-Zero Gebhard- Mueller School

## Riss, Germany




### Measured Energy Use

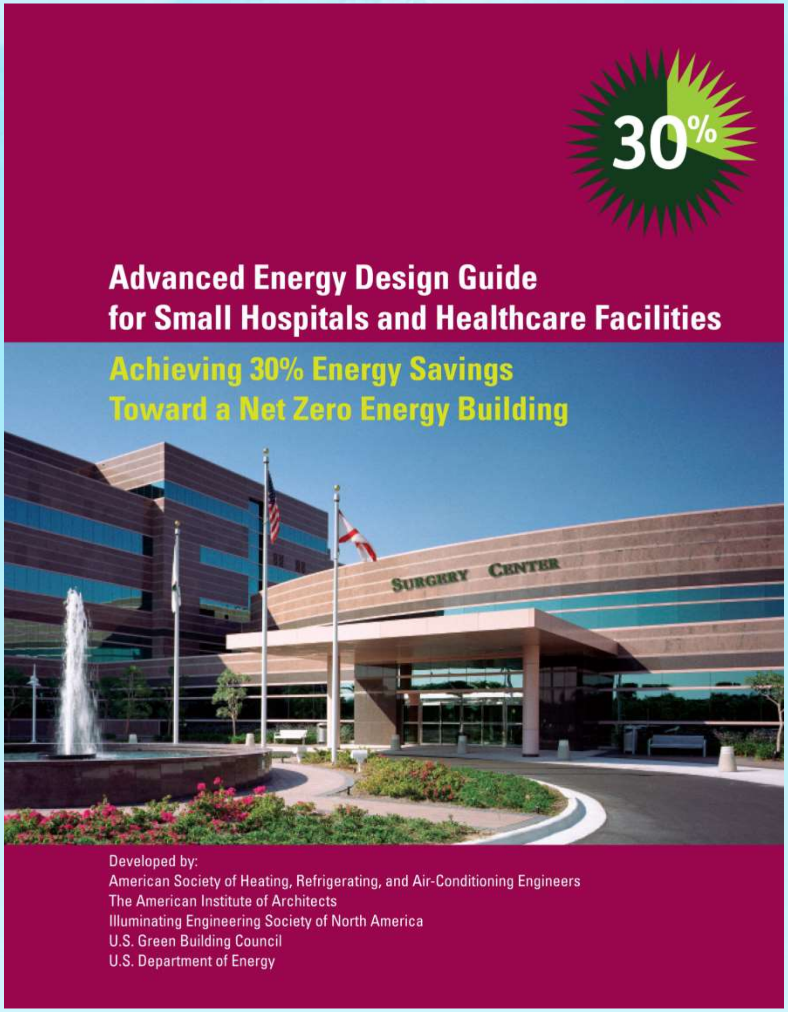
- Annual Energy Consumption = 482,240 kWh/yr

  = 4.0 kWh/SF-year

- Annual Energy Consumption w/o Plug Loads = 289,344 kWh/yr

  = 2.4 kWh/SF-year

# Advanced Energy Design Guidance



# Major Energy Uses in a Large Hospital

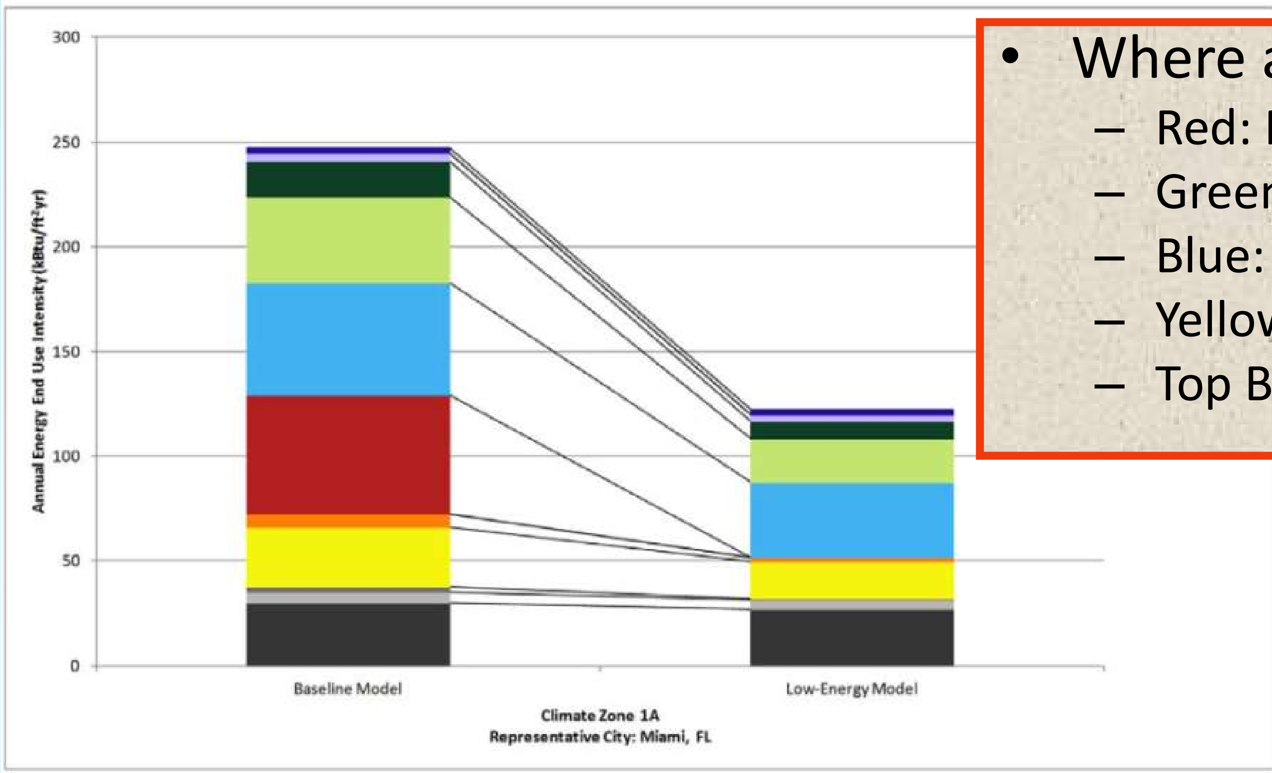



**Figure 3-1 Comparison of Baseline to Prescriptive 50% AEDG Solution Showing Breakdown of Energy Savings Components**

- Where are the savings?
  - Red: Reheat
  - Green: Fans
  - Blue: Cooling
  - Yellow: Interior lights
  - Top Black: Pumps

**Source: 50% AEDG Large Hospitals from ASHRAE**

# How-To Tips

| | | | | | |
|---|---|---|---|---|---|
| HVAC | Nonsurgery | Fan-coil system with DOAS | Water-cooled chiller | 6.5 COP | HV8, 35 |
| | | | Water-circulation pumps | VFD and NEMA premium | HV35 |
| | | | Cooling towers | VFD on tower fans | HV37 |
| | | | Boiler efficiency | 90% $E_c$ | HV8 |
| | | | Maximum fan power | 0.4 W/cfm | HV21–22, 24 |
| | | | FCU fans | Multiple speed | HV5 |
| | | | Exhaust-air energy recovery in DOAS | A (humid zones) = 60% total effectiveness<br>B (dry zones) = 60% sensible effectiveness<br>C (marine zones) = 60% total effectiveness | HV9, 15–16 |
| | | | DOAS ventilation control | DCV with VFD | HV10–11 |

*HV5* ***Fan-Coils w***

In fan-coil sy
factory desig
and possibly
Fan coils
corridor (or some other noncritical space), or in a closet adjacent to the space (see the WSHP figure in HV2 as an example). However, the equipment should be located to meet the acoustic goals of the space; this may require that the fan coils be located outside of the space while also attempting to minimize fan power, ducting, and wiring. Fan coils should be equipped with a variable-speed fan to automatically enable VAV operation and enhance motor efficiency.

All the fan coils are connected to a common water distribution system. Cooling is provided

The cooling equipment, heating equipment, and fans should meet or exceed the efficiency levels listed in the recommendation tables in Chapter 4 or listed in this chapter (HV8). The cooling equipment should also meet or exceed the part-load efficiency level, where shown. Performance requirements for ducted fan coils are (1) 0.30 W/cfm design supply air to a space with VAV operation and (2) coil chilled-water $\Delta T$s of at least 14°F.

**Source: 50% AEDG for Large Hospitals from ASHRAE**

# Aggressively Address Reheat

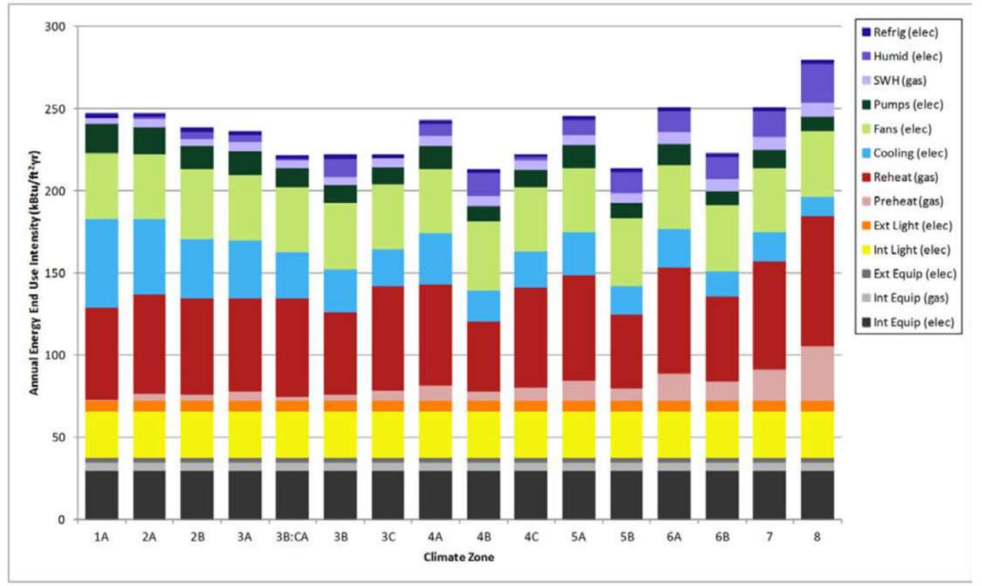
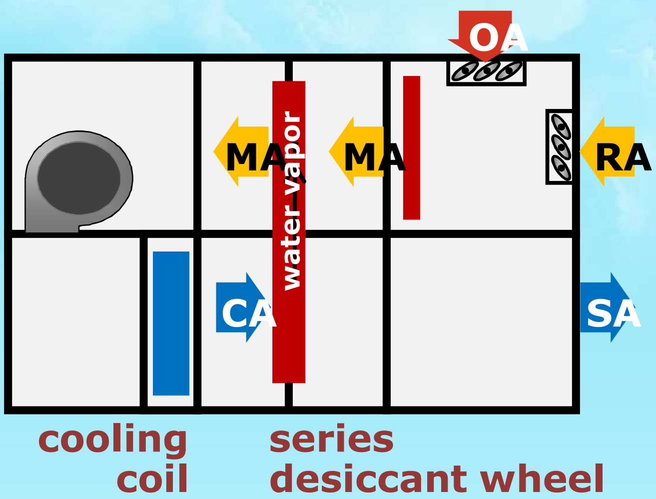



**Figure 3-18 Reheat Energy (in Red) Compared to other Energy Uses in Healthcare Facilities**

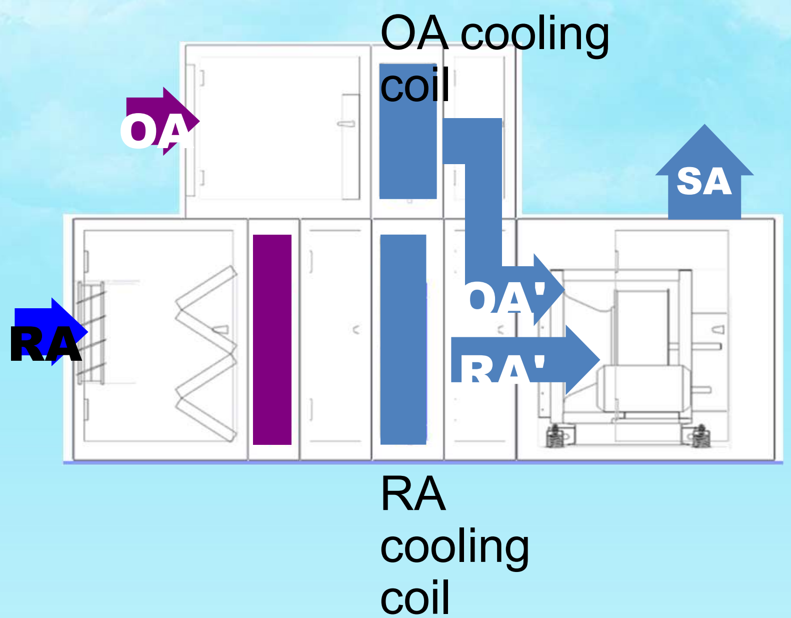
- Supply dry air to OR
- Recover heat from chilled water system

**Source: 50% AEDG Large Hospitals from ASHRAE**

# Aggressively Address Reheat




**Series desiccant wheel**
**Provide low humidity levels in the OR while minimizing reheat energy**




**Dual-Path Air Handler**
**Treat outdoor air separately**

# 50% AEDG for Large Hospitals
# WSHPs with DOAS

- WSHPs with two-stage or variable-speed compressors and variable-speed fans
  - ≥ 4 tons, but encouraged for smaller units also
  - Cooling: 17.6 EER (part load), 15.0 EER (full load)
  - Heating: 5.7 COP (part load), 5.0 COP (full load)
- Dedicated OA system
  - Deliver air cold when possible
  - Exhaust-air energy recovery (60% effective)
  - Demand-controlled ventilation

# 50% AEDG for Large Hospitals
# Fan-Coils with DOAS

- Multiple-speed or variable-speed fans
- Chiller plant
  - Chiller: 6.50 COP (0.54 kW/ton)
  - 15°F chilled water ΔT
  - 14°F condenser water ΔT
  - Variable-speed cooling tower fans
  - Control to minimize chiller + tower energy
- Dedicated OA system
  - Deliver air cold when possible
  - Exhaust-air energy recovery (60% effective)
  - Demand-controlled ventilation

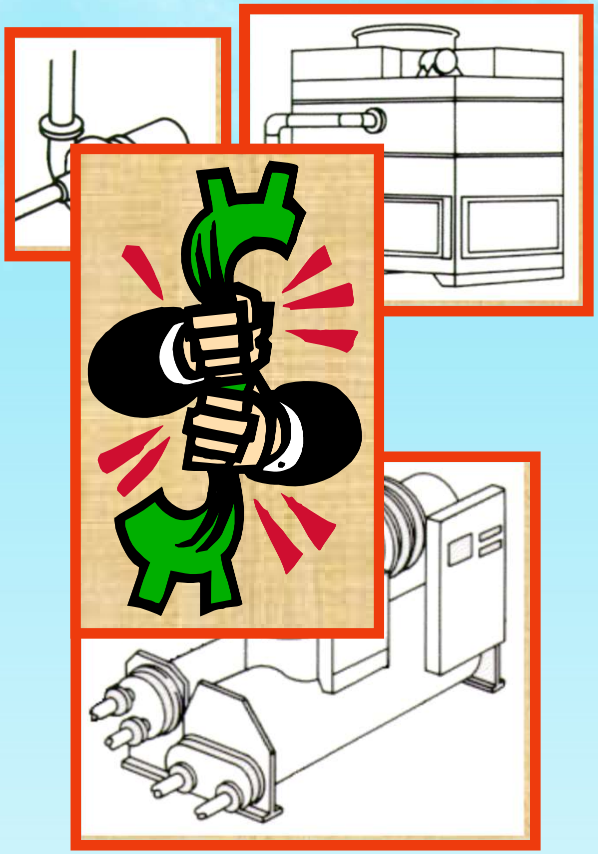
## 50% AEDG for Large Hospitals

# Chilled-Water VAV System

- Separate treatment of OA
  - Exhaust-air energy recovery (60% effective)
  - Demand-controlled ventilation
- Chiller plant
  - Water-cooled heat recovery chiller: 4.55 COP
  - Water-cooled cooling-only chiller: 6.50 COP
  - 15°F chilled water ΔT
  - 14°F condenser water ΔT
  - Variable-speed cooling tower fans
  - Control to minimize chiller + tower energy

# Reduce Mechanical Installed and Operating Costs

- Reduce flow rates
  - Smaller pumps, pipes, and cooling towers
  - Lower operating costs
- Variable primary flow
  - Fewer pumps
  - Lower operating costs
- Heat recovery chillers
  - Properly sized and located



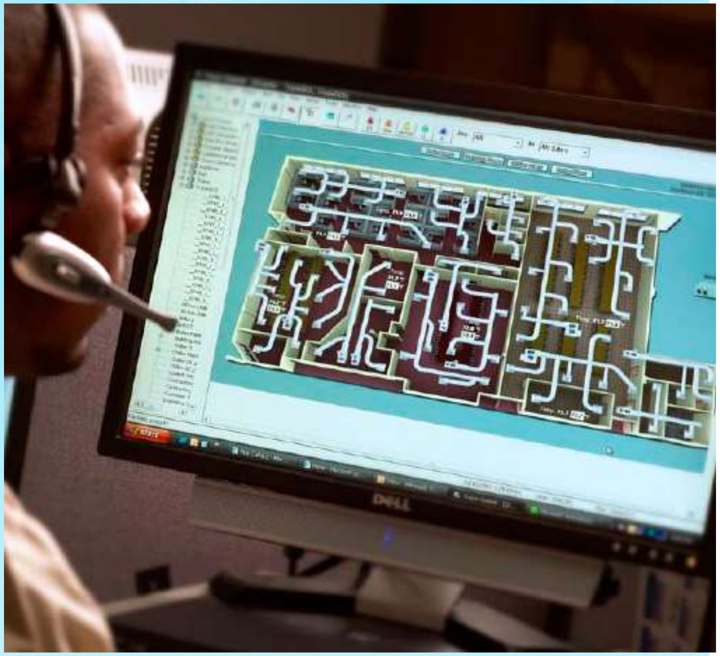
# Avoid Overventilation

- Sensing technologies
  - $CO_2$ sensors in densely occupied spaces
  - Occupancy sensors where population variation is minimal
  - Time-of-day for zones that are sparsely occupied or predicted occupancy patterns
- Std 170
  - *“Reduce airflow rates during unoccupied hours in surgery rooms and other spaces with minimum air-change requirements”*
  - Maintain pressurization requirements

# High-Performance VAV System

**Optimized VAV system controls**

- Optimal start/stop
- Fan-pressure optimization
- Supply-air-temperature reset
- Ventilation optimization (including demand-controlled ventilation)



# Guide Contents—Case Studies

<u>Great River Medical Center</u>

- West Burlington, Iowa
- 700,000 $ft^2$
- 190 inpatient beds, 8 operating rooms
- Two 99,000-$ft^2$ medical office buildings
- Heated and cooled with one of the largest lake-coupled geothermal system in the United States
  - 1800 tons of cooling
  - 85-mile long piping system
  - 800 heat pumps
- 96 kBtu/$ft^2$·yr whole-building energy use intensity
  - Average hospital is at about 240 kBtu/$ft^2$·yr
- $0.94/$ft^2$·yr in utility costs
  - Average hospital is at about $2.39/$ft^2$·yr

# Unique AEDG & Net-Zero Applications

## AEDG APPLICATIONS

- 100 Howe Building – Corporate Call Center
- Oracle Data Center
- Dallas Semiconductor Manufacturing Complex
- cGMP Cell Therapy Facility – Northwestern Univ.

## NET-ZERO APPLICATIONS

- Marin County K-8 Day School
- Packard Foundation Office Complex
- CSIRO Energy Center
- Cellophane House

# ZEB Technology Pathways for Commercial Buildings

## Design Process Pathways

| | CODE | 30% Savings | 50% Savings | 70% Savings | 100% Savings |
|---|---|---|---|---|---|
| Design Guidance | 90.1 | 30% AEDGs | 50% AEDGs w/perform. optimization | Optimization Tools for Guidance | Optimization Tools incl'g renewable energy sources |
| Integrated Building Design | NONE | Suggested | Rec. to direct integrated design | Use of optimization tools for site specific designs | Fully integrated energy efficiency & optimization |

# ZEB Technology Pathways for Commercial Buildings

## Technology Pathways

| | CODE | 30% Savings | 50% Savings | 70% Savings | 100% Savings |
|---|---|---|---|---|---|
| Roofs | R-15→R-25 | R-15→R-30 | R-20→R-35 | R-25→R-45 | R-25→R-45 |
| Walls | R-2→R-15 | R-2→R-15 | R-10→R-30 | R-19→R-35 | R-19→R-35 |
| Windows | 90.1 | U-0.5→U-O.33 SHGC:0.45→0.25 Vt/SHGC: 1 | U-0.4→U-0.2 SHGC:0.45→0.25 Vt/SHGC: 2 | U-0.3→U-0.13 SHGC:0.5→0.25 Vt/SHGC: 2.5 | U-O.3→U-0.13 SHGC:0.5→0.25 Vt/SCHGC: 2.5 |
| Daylighting | None Spec'd | None Spec'd | 35% + daylight energy reduct | 60% + daylgt energy red. | 80% + daylgt energy red. |

# ZEB Technology Pathways for Commercial Buildings

## Technology Pathways

| | CODE | 30% Savings | 50% Savings | 70% Savings | 100% Savings |
|---|---|---|---|---|---|
| Lighting | 90.1 | 10% LPD reduct. MLPW > 70 | 20% LPD red. MLPW> 80 | 30% LPD reduct. MLPW> 90 | 50% LPD reduct. MLPW>120 |
| HVAC | 90.1 | 0—30% incr in efficiency | 30% incr eff w/climatic-specif secndry HVAC sys | 50% incr eff w/clim spec secndry HVAC sys | 50% incr in ttl HVAC eff w/clim spec HVAC sys |
| Outdoor Air | 90.1 | ERVs, DCV & econ on small HVAC | Reduc energy 50% assoc w/OA | Reduc energy 75% assoc w/OA | (Same as 70%) |
| Plug & Process | No change | Energy Star appliances | 10% peak red. & 30% nighttime red | 15% peak & 40% night reductions | 25% peak & 60% night reductions |

# ZEB Technology Pathways for Commercial Buildings

## Technology Pathways

| | CODE | 30% Savings | 50% Savings | 70% Savings | 100% Savings |
|---|---|---|---|---|---|
| Service Water Heating | 80% Et | 90% Et | 90% Et | 95% Et | 95% Et |
| Energy Storage | None | None | None | Create load factor of 50%+ | Create loaf factor of 75%+ |

Technology Pathways Table Notes:

Vt/SHGC = Ratio of Visible Transmittance to Solar Heat Gain Coefficient

MLPW = Mean Lumens per Watt lighting system (bulb, ballast system efficacy)

Renewables Table Wind Speed Classifications for U.S.

http://www.eere.energy.gov/windandhydro/windpoweringamerica/pdfs/wind_maps/us_windmap.pdf

# ZEB Technology Pathways for Commercial Buildings

## Renewables

| | CODE | 30% Savings | 50% Savings | 70% Savings | 100% Savings |
|---|---|---|---|---|---|
| PV | None | None | 0%→20% Bldg load | 20%→75% Bldg load | 75%+ Bldg load |
| Solar Hot Water | None | None | Solar Fraction = 0.5 (year around HW) | Solar Factor = 0.75 (yr around HW) | Solar Factor = 0.75 (HW) & 0.5 (rad. htg) |
| Site Wind | None | None | 0→10% Bldg load (wind class >4) | 20%+ Bldg load (wind class>4) | 30%+ Bldg load (wind class>3) |
| Site Biomass | None | None | None | 50%+ HW & space htg | 80%+ HW & space htg |
| Off Site Purchases | None | None | None | None | Meet bal of loads after renewables |

# ZEB Technology Pathways for Commercial Buildings

## General Notes for All Tables:

- For each level of savings, not every technology must be applied or is needed for every building in every climate. The pathways represent a range of performance likely to be needed across climate zones. Building and site-specific optimization tools can be used to determine the most cost-effective combination of pathways needed to reach energy savings goals.
- Daylight Lighting Reduction: Percent reduction in annual lighting energy measured from sunrise to sunset. Includes the concept of “Daylighting Saturation Percent,” which is the percentage of occupied hours times the percentage of floor area that is fully daylit. “Fully daylit” is defined as daylighting that provides a minimum illuminance, but not more than a maximum illuminance (typically 400 footcandles). This metric includes the controls and related hardware necessary to achieve the savings from daylighting.

# ZEB Technology Pathways for Commercial Buildings

## General Notes for All Tables:

- 30% savings data based on 30% AEDGs.
- 50% savings data based on 50% grocery and medium box TSDs, experience with 50% designs from case studies, and Greensburg examples.
- 70% savings data based on expected diminishing returns for each technology pathway based on 50% design optimizations.
- 100% savings data based on ongoing ZEB research and attempting various ZEB designs at NREL's new office building (RSF), Greensburg School analysis (ZEB goal), and ZEB case study database portal.
- HVAC system efficiencies include all primary and secondary systems needed to provide heat/cold to the occupants. Includes compressors, supply fans, condenser fan and pumps, primary pumps, controls, dampers, etc., and includes controls to make systems operate to full operating potential.
- Plug loads include traditional plug loads, elevators, transformers, and all other equipment that is not directly tied to lighting or HVAC. Efficiency gains could include DC power distribution.

# Continuous Performance Verification

# What is Building Performance?

- **Building meets the owners needs (OPR)**
- **IEQ Performance**
  - Occupant Comfort, temp & humidity
  - Indoor Air Quality
  - Space Lighting Level and Quality
  - Space Acoustic Quality
- **Energy and Water Use**
  - Meets projected usage values
  - Meets selected baselines

# Continuous Performance Verification

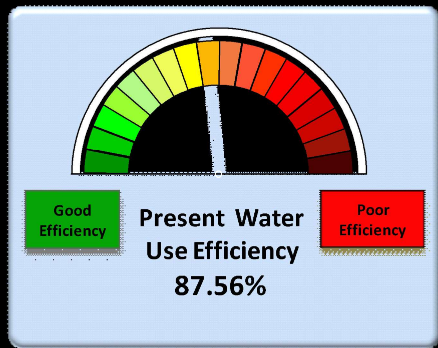
- **What is Measured?**
  - **Energy Usage both in KWH and $**
  - **Gas Usage both in Therms and $**
  - **Water Usage both in Gallons and $**
  - **Purchased Energy both in BTUH and $**
  - **Occupant Comfort or Building Performance**
    - **Annual Occupant Survey**
    - **Monitor Maintenance Management System**
    - **Dashboards of Building Systems' Performance**



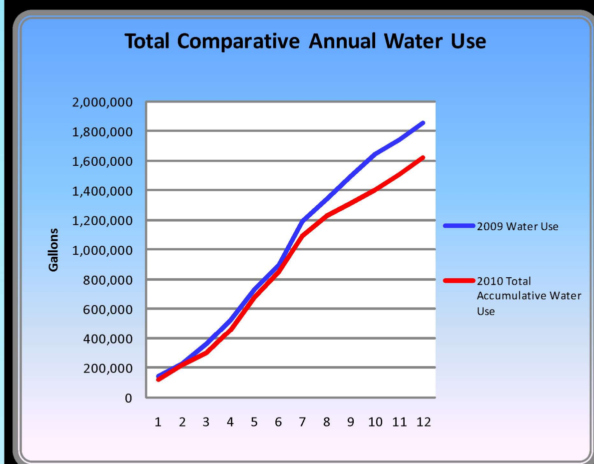
NEBB

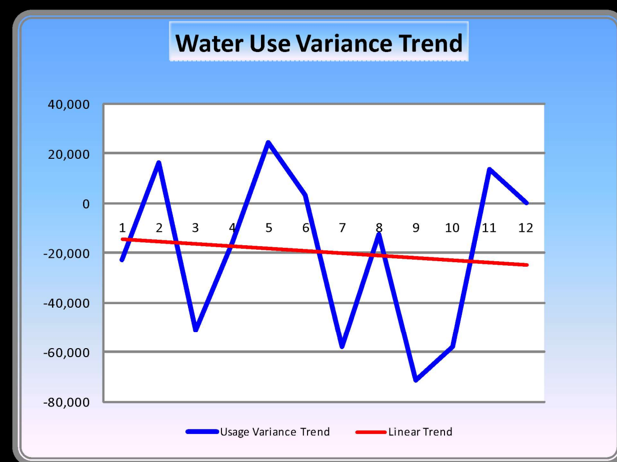
# Water Use Charts for: Tester Products

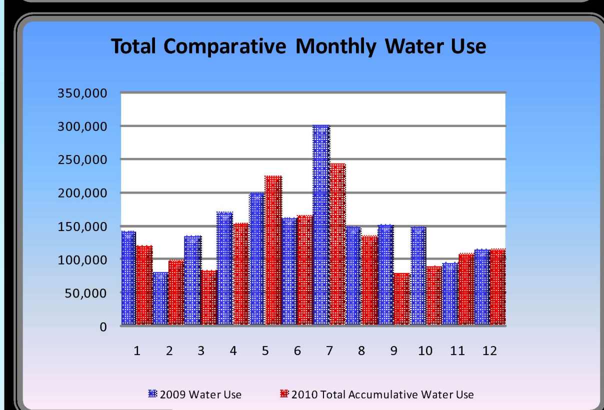
Date: 12/31/2010

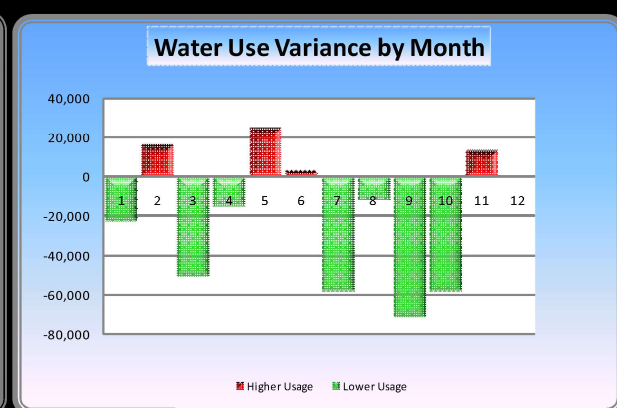



| | Current Year | Prior Year | Variance |
|---|---|---|---|
| Square Feet | 100,000 | 100,000 | 0 |
| WUI Gal / Square Foot | 16.25 | 18.56 | -2.31 |
| $ / Square Foot | $0.071 | $0.067 | $0.003 |



# Your Role, Your Duty and Your Responsibility

- *"Don't ask yourself 'what the world needs', ask yourself what makes you come alive. And then go do that. Because what the world needs are people (engineers) who have come alive!"*

**Howard Thurman**

**"Do Not Be Embarrassed by Your Failures, Learn From Them and Start Again"**

**Sir Richard Branson**