Sustainable Applications that Work - AEDGs to Net-Zero Energy Buildings

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November 16, 2017

Sustainable Applications that Work - AEDGs to Net-Zero Energy Buildings

A Sustainable Future is no longer just a topic for discussion but rather a serious global concern. It is now time for definitive technical guidance, innovative engineering applications and leading-edge research to be initiated as the principal focus of a global technical organization…….

ASHRAE

Why Should Architects and Engineers be Concerned?

- Buildings consume:
  - 40% of all energy used and 70% of electrical energy use
  - 17% of all fresh water
  - 25% of wood produced

- Buildings produce 33% of CO_2 emissions

- Buildings generate 30% of waste in landfills

Thermodynamics and the Destruction of Resources

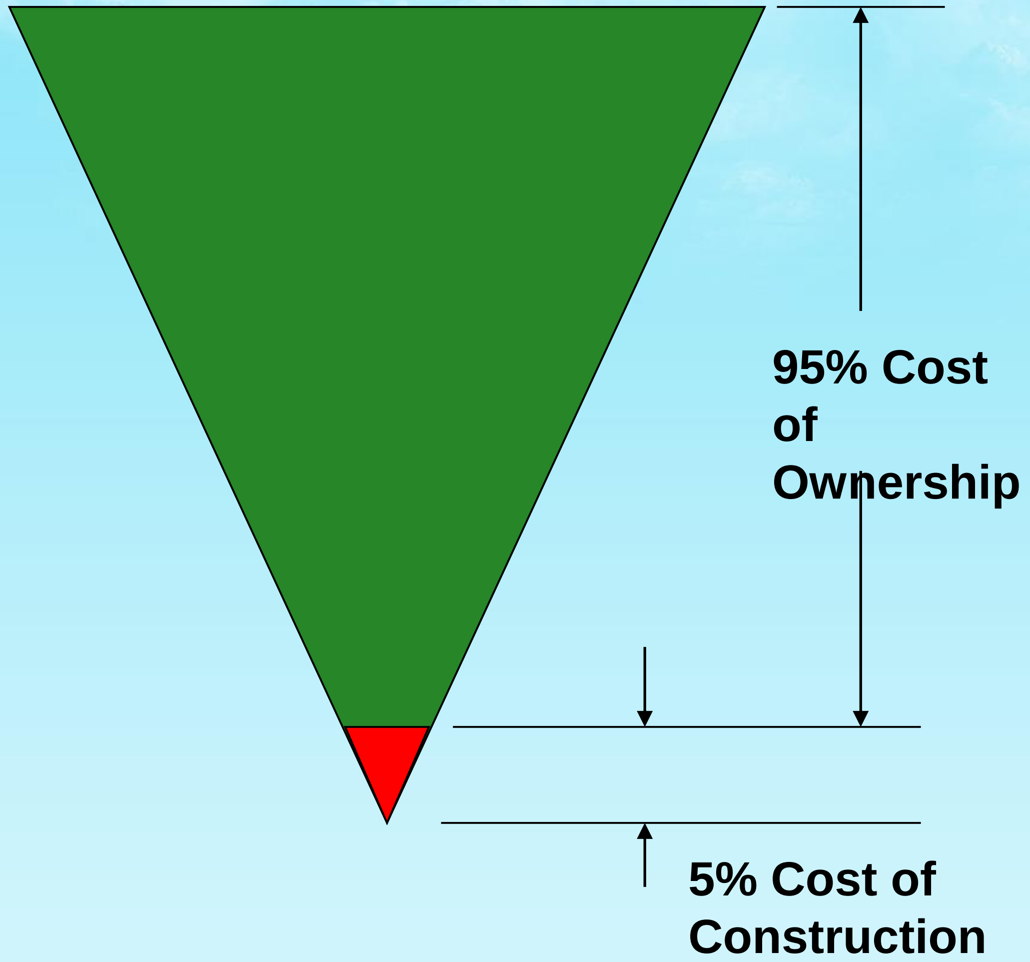
by Bakshi, Gutowski & Sekulic

- 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.

Existing Commercial Buildings

- New Buildings Globally = 2% of Building Programs
- 86% of Annual Building Construction Expenditures Relate to Building Renovations
- Even with Commissioned Buildings, their Performance Deteriorates after 3 years by 30%
- ASHRAE Research has shown that the “potential” for reduction of a building’s energy use is between 10% and 40% simply by changing operational strategies
- 70% - 80% of Buildings in 2030 exist <u>today</u>
- Over next 30 years, 150 billion sq.ft. of existing buildings will be renovated

Fundamental Truth – Cost of Ownership



AEDGs to Net-Zero Energy Buildings

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

STANDARD

ASHRAE®

ANSI/ASHRAE Standard 55-2013
(Supersedes ANSI/ASHRAE Standard 55-2010)
Includes ANSI/ASHRAE addenda listed in Appendix M

Thermal Environmental Conditions for Human Occupancy

See Appendix M for approval dates by the ASHRAE Standards Committee, the ASHRAE Board of Directors, and the American National Standards Institute.

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 ISSN 1041-2336

Approved American National Standard
ANSI

STANDARD

ASHRAE

ANSI/ASHRAE Standard 62.1-2010
(Supersedes ANSI/ASHRAE Standard 62.1-2007)
Includes ANSI/ASHRAE addenda listed in Appendix J

Ventilation for Acceptable Indoor Air Quality

See Appendix J for approval dates by the ASHRAE Standards Committee, the ASHRAE Board of Directors, and the American National Standards Institute.

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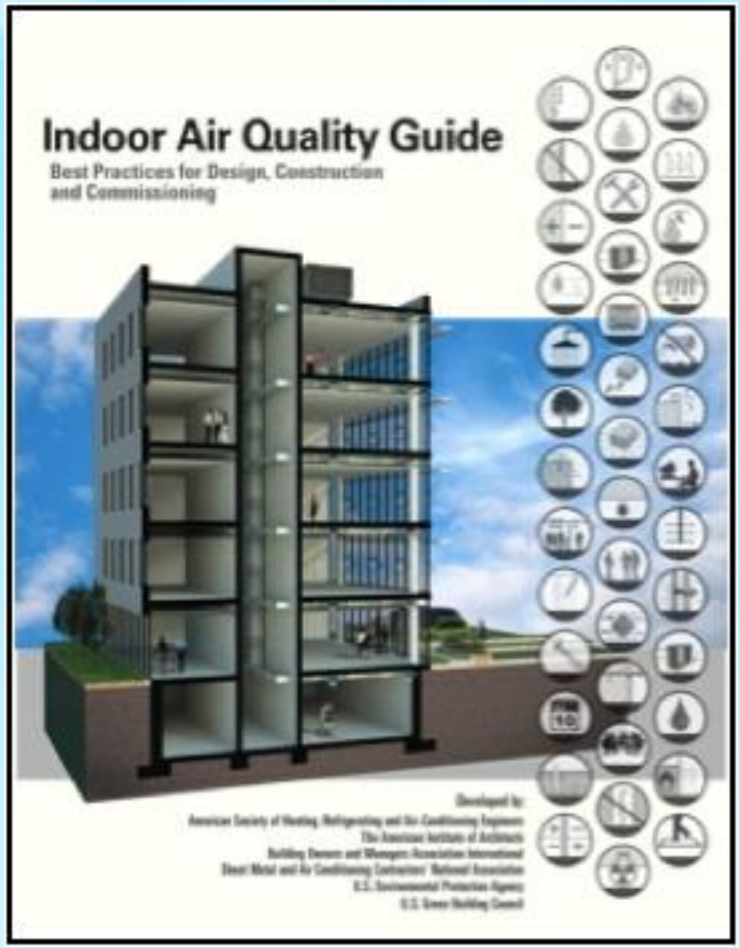
Approved American National Standard

ANSI

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



STANDARD

ANSI/ASHRAE/IES Standard 90.1-2010
(Supersedes ANSI/ASHRAE/IESNA Standard 90.1-2007)
Includes ANSI/ASHRAE/IES Addenda listed in Appendix F

Energy Standard for Buildings Except Low-Rise Residential Buildings

I-P Edition

See Appendix F for approval dates by the ASHRAE Standards Committee, the ASHRAE Board of Directors, the IES Board of Directors, and the American National Standards Institute.

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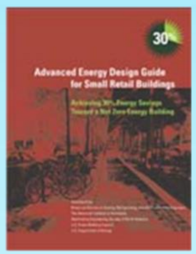
Advance Energy Design Guides

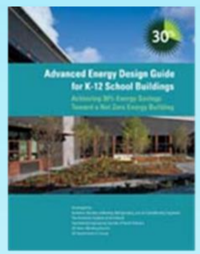
- Eleven guides published and available for download: www.ashrae.org/freeaedg
- Circulation is 600,000+ copies

30%

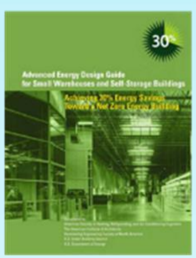
Small Office



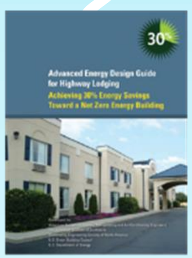
Small Retail



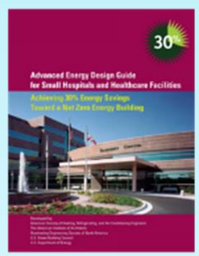
K-12 School



Warehouse

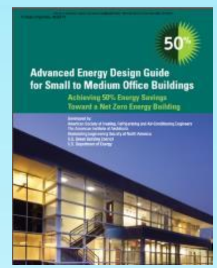


Highway Lodging

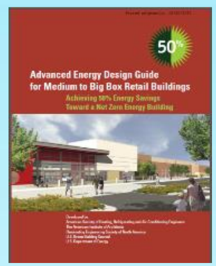


Small Hospital

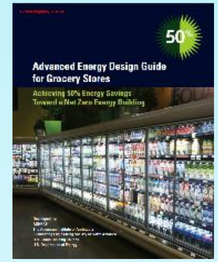
50%



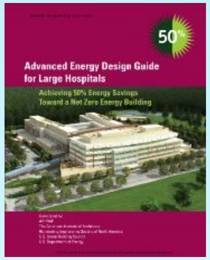
Office



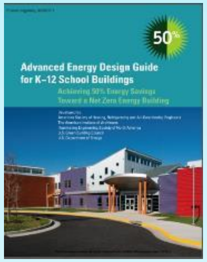
Med-Big Box Retail



Grocery Stores



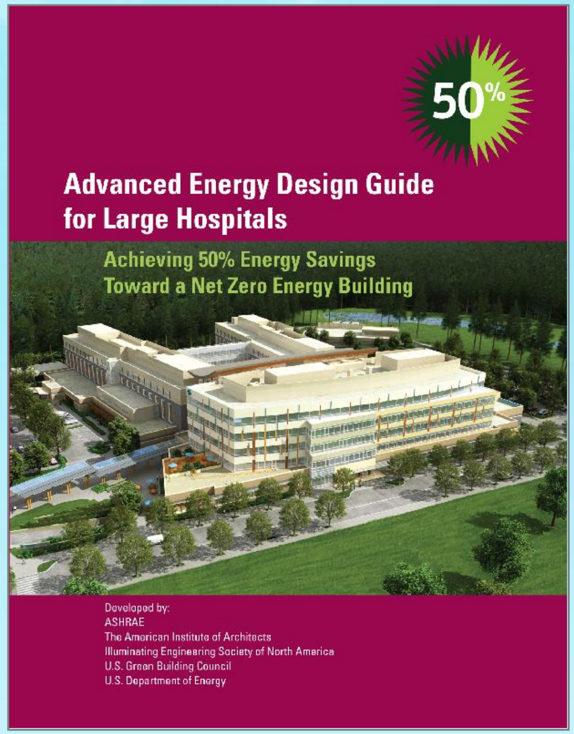
Hospitals

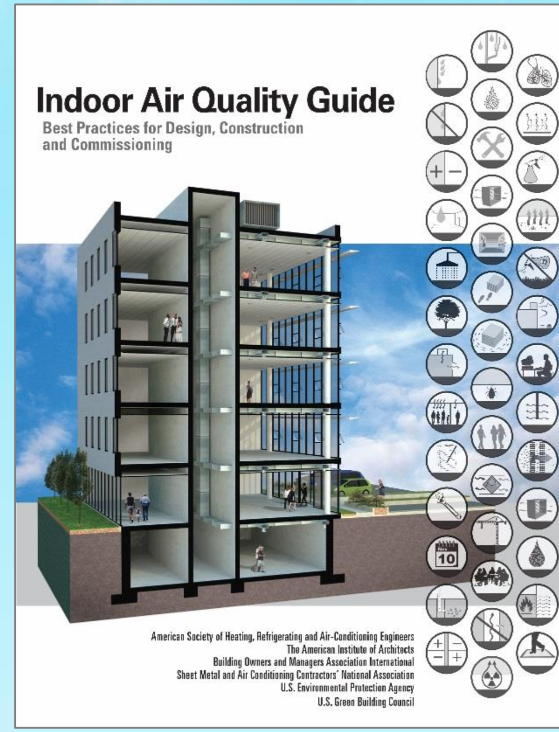


K12 Schools

"FREE" Related ASHRAE bEQ Publications

- **AEDG;** Advanced Energy Design Guides
- **IAQG;** Indoor Air Quality Guide--





www.techstreet.com/ashrae

Advance Energy Design Guides

Achieving Zero Energy

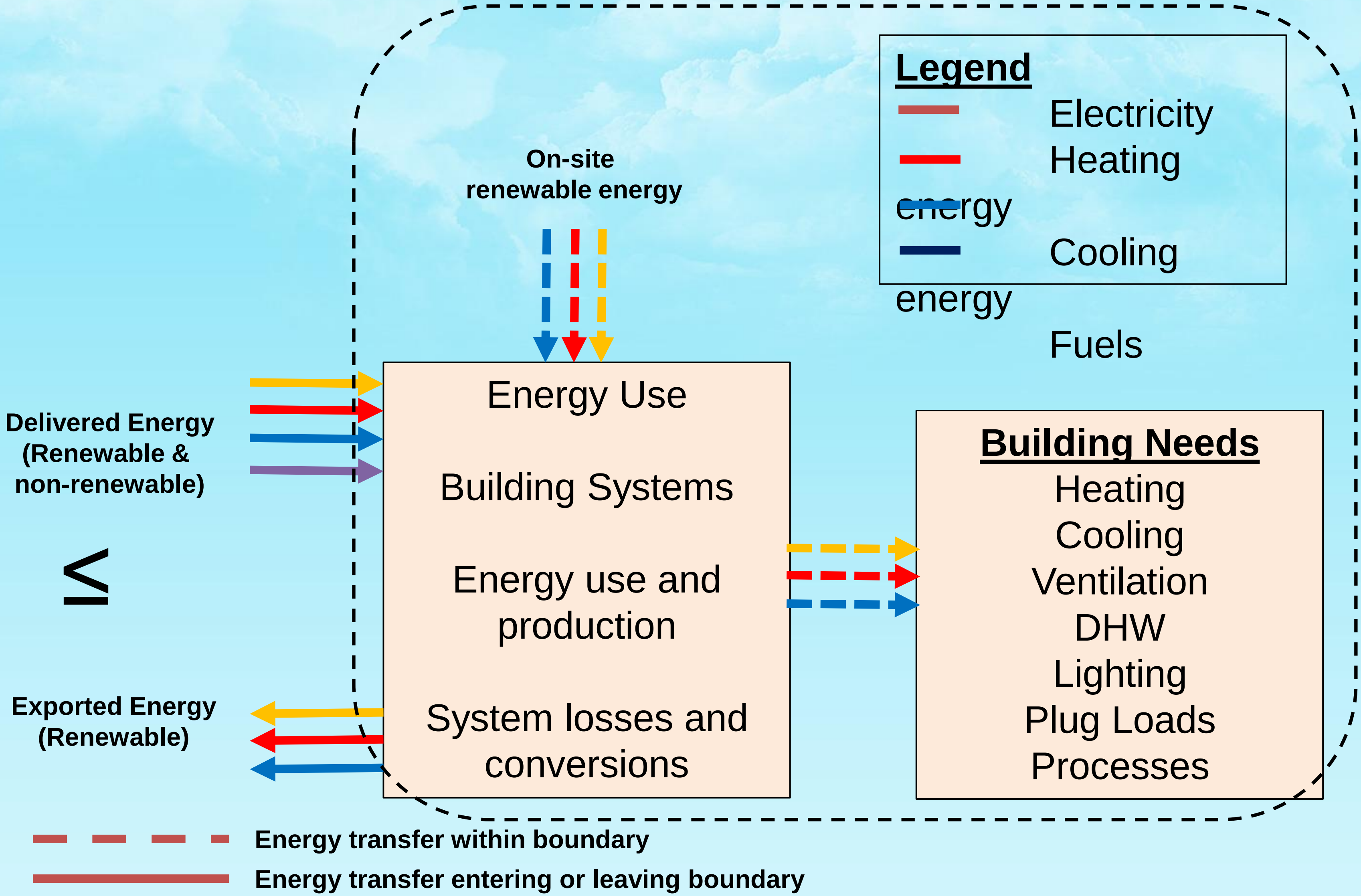
- New Series of Advanced Energy Design Guides for Zero Energy Buildings
- First volume of the new series addresses K12 Schools
- Following previous procedure, all recommendations vetted by extensive energy modeling and review by building type experts
- Available for download late fall, 2017 www.ashrae.org/freeaedg

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

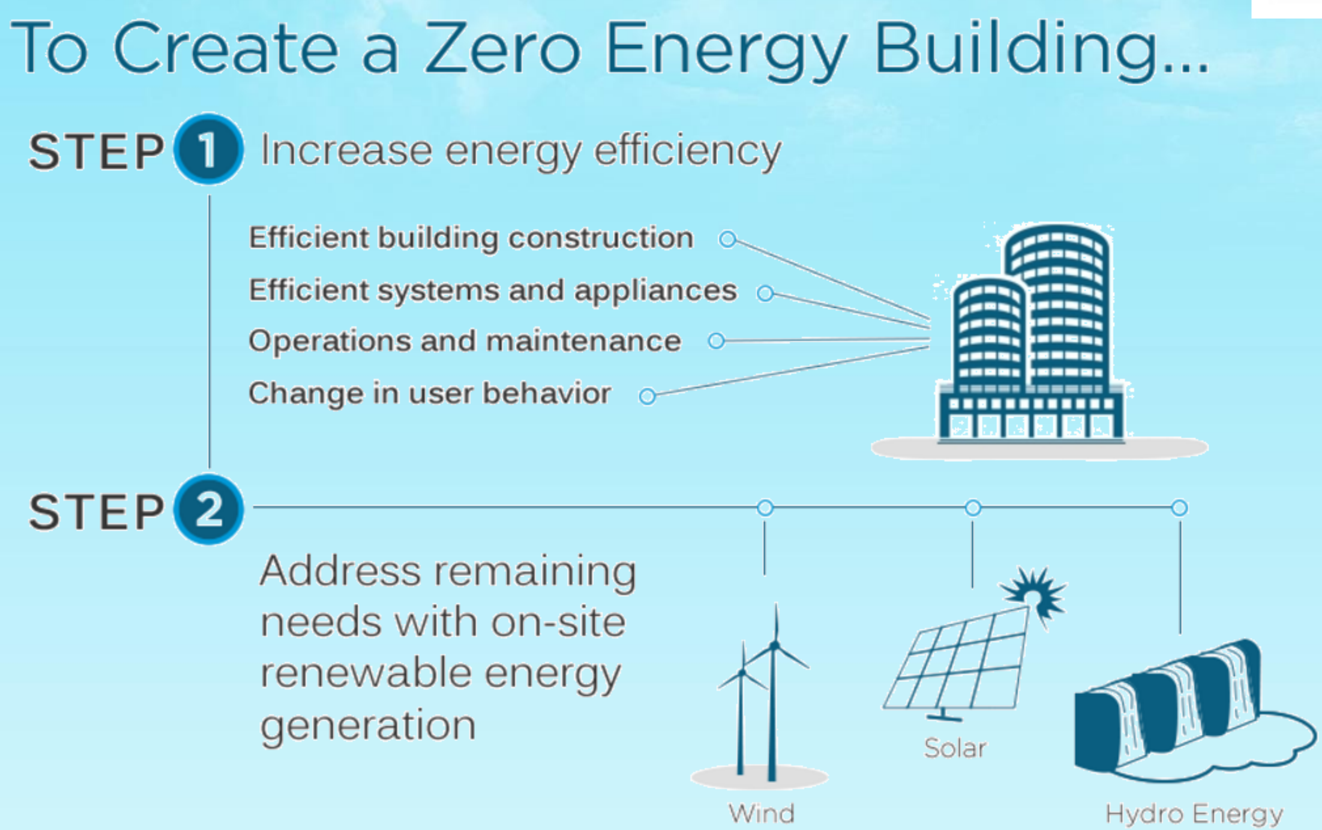


Source: A Common Definition for Zero Energy Buildings

ZE AEDG Goals

- Demonstrate that zero energy schools are attainable
- Provide direction for designing and constructing ZE schools 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

High Performance Learning Environments

- Indoor air quality
- Thermal comfort
- Acoustic comfort
- Visual comfort and daylighting
- Technology
- Adaptability
- Curriculum

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
Daylighting (DL)	18	Daylighting and view impact on student performance
Electric lighting (EL)	32	Light-emitting Diode (LED)/Solid-State Lighting (SSL), Control strategies
Plug load management (PL)	7	Policy, controls, monitor usage
Kitchen equipment (KE)	22	Menu design, efficiency equipment, controls
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

AEDGs to Net-Zero Energy Buildings

"Remember Today…For it's the Beginning of Your Forever" Dante (Inferno)

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

<u>Energy Efficiency</u>

- 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

Energy Efficiency

- 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

Zero Energy School (ZES)

- **DOE Definition for AEDG** = An energy-efficient building where, on a source energy basis, the actual annual delivered energy is <u>less than or equal </u>to the on-site renewable exported energy.
- 90% Technical Review Draft (ASHRAE, AIA, IESNA, USGBC & DOE), May 8, 2017, 216+ pages
- **Table of Contents**

Zero Energy School (ZES)

Chapter 4 – Building Performance Simulation

Chapter 5 – How-to Strategies (Envelope, Daylighting, Electric Lighting, Plug & Power Distr., Kitchen Equipment, Service Water Htg, HVAC Systems & Equipment & Renewable Energy)

Appendix A – Envelope Thermal Performance Factor

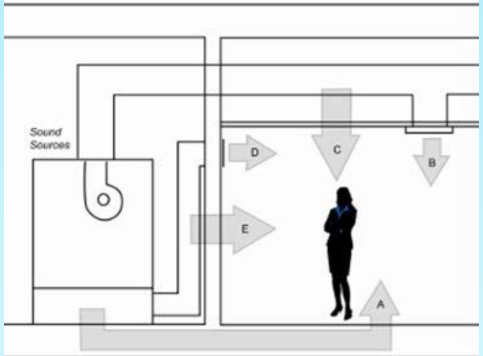
Appendix B – International Climatic Zone Definitions

GOAL OF GUIDE = Provide direction & recommendations to achieve a zero energy building…. there is no reference point, zero is an absolute energy target.

Strategy Examples

HVAC

- System choices
  (not only ones that will work)
  - Water and ground source heat pumps with DOAS
  - VRF heat pump with DOAS
  - Chillers with air handlers and DOAS
- Efficiencies: Meet or exceed ASHRAE 189.1-2017
- Comply with ASHRAE Standard 15
  (Safety with respect to refrigerant)
- Demand control ventilation (DCV)
- Acoustic analysis



Path A: Structure-borne path through floor
Path B: Airborne path through supply air system
Path C: Duct breakout from supply air duct
Path D: Airborne path through return air system
Path E: Airborne path through mechanical equipment room wall

ANSI/ASHRAE/USGBC/IES Standard 189.1-2011
(Supersedes ANSI/ASHRAE/USGBC/IES Standard 189.1-2009)

Standard for the Design of High-Performance Green Buildings

Except Low-Rise Residential Buildings

IgCC
SAFE & SUSTAINABLE BY THE BOOK

A Compliance Option of the International Green Construction Code™

See Appendix I for approval dates by the ASHRAE Standards Committee, the ASHRAE Board of Directors, the U.S. Green Building Council, the Illuminating Engineering Society of North America, and the American National Standards Institute.

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ISSN 1041-2336

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

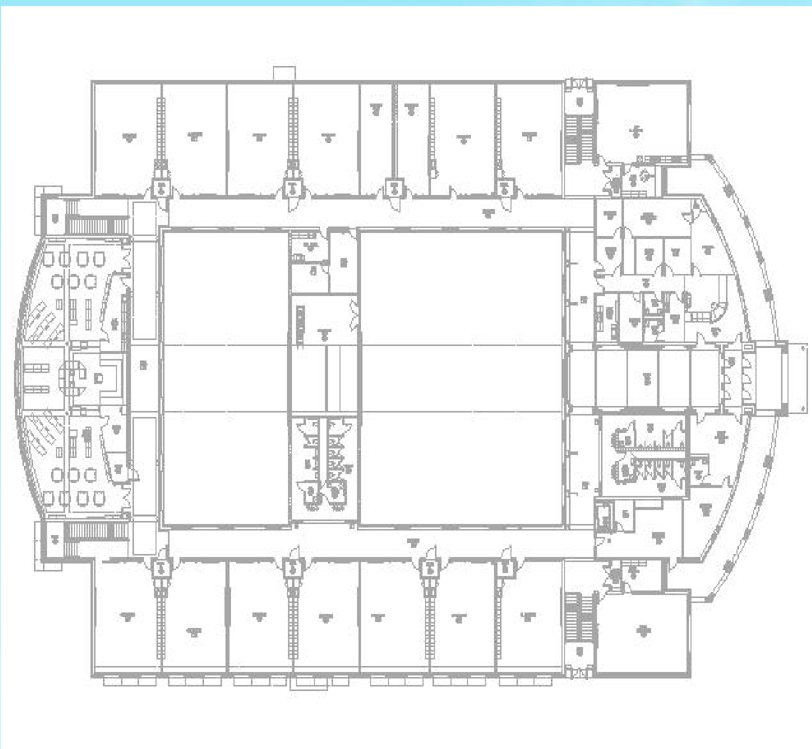
Net-Zero Richardsville Elementary School
Bowling Green, Kentucky

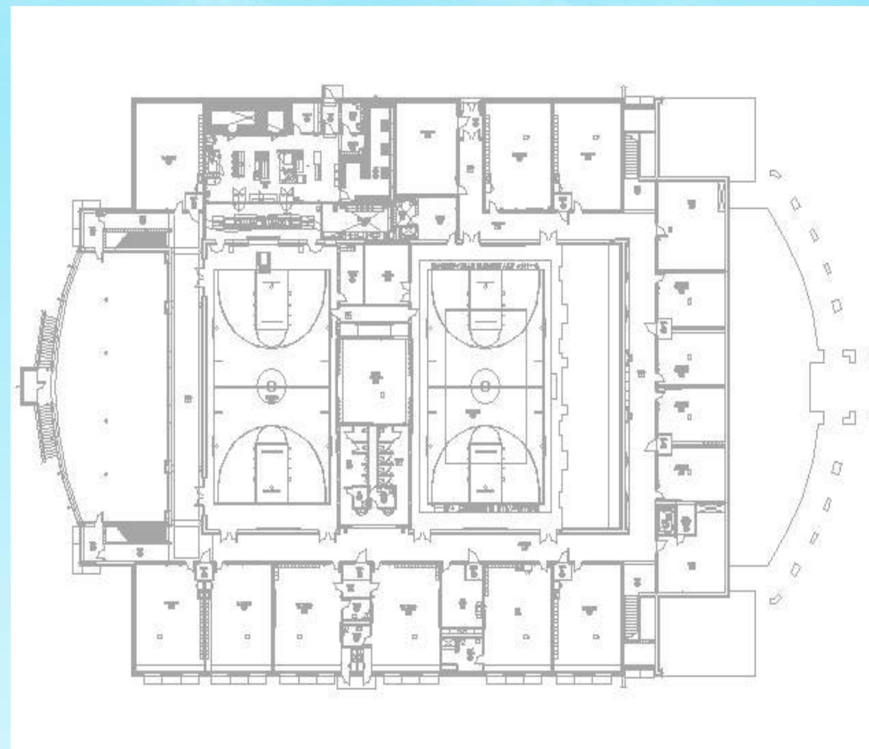
NZEB STRATEGIES

- Daylighting – Combination of Glazing + Solatubes
- Lighting Power Density = 0.68 W/ft2
- 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

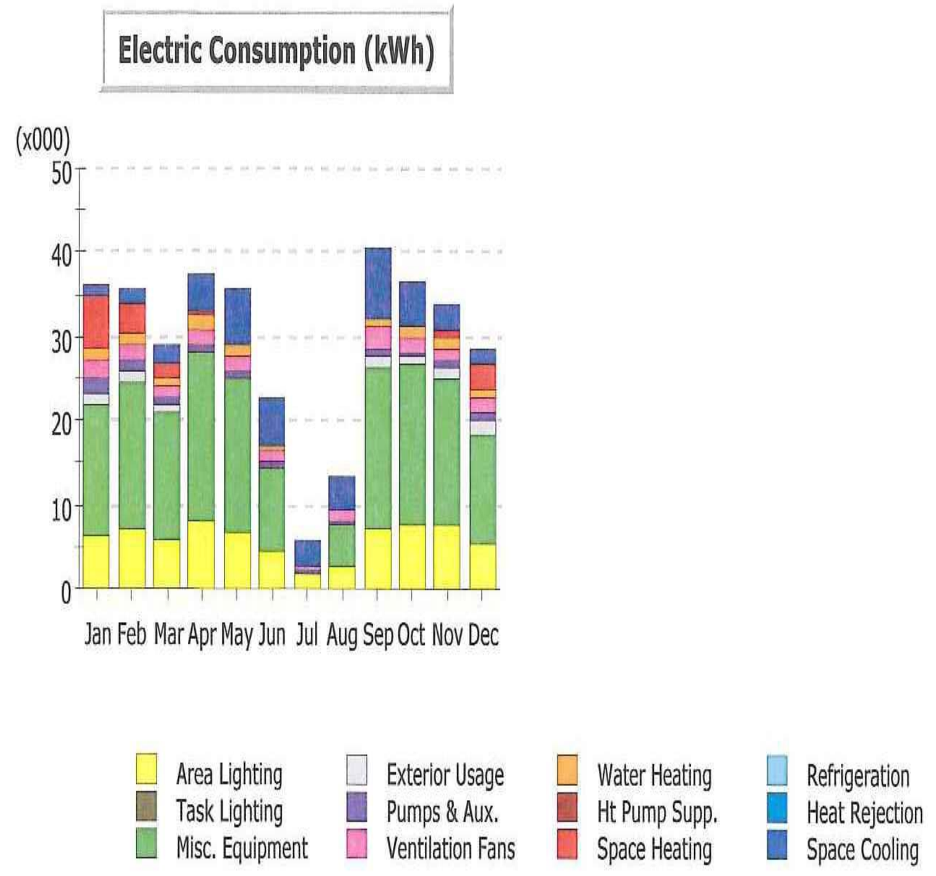




Main Level

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 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

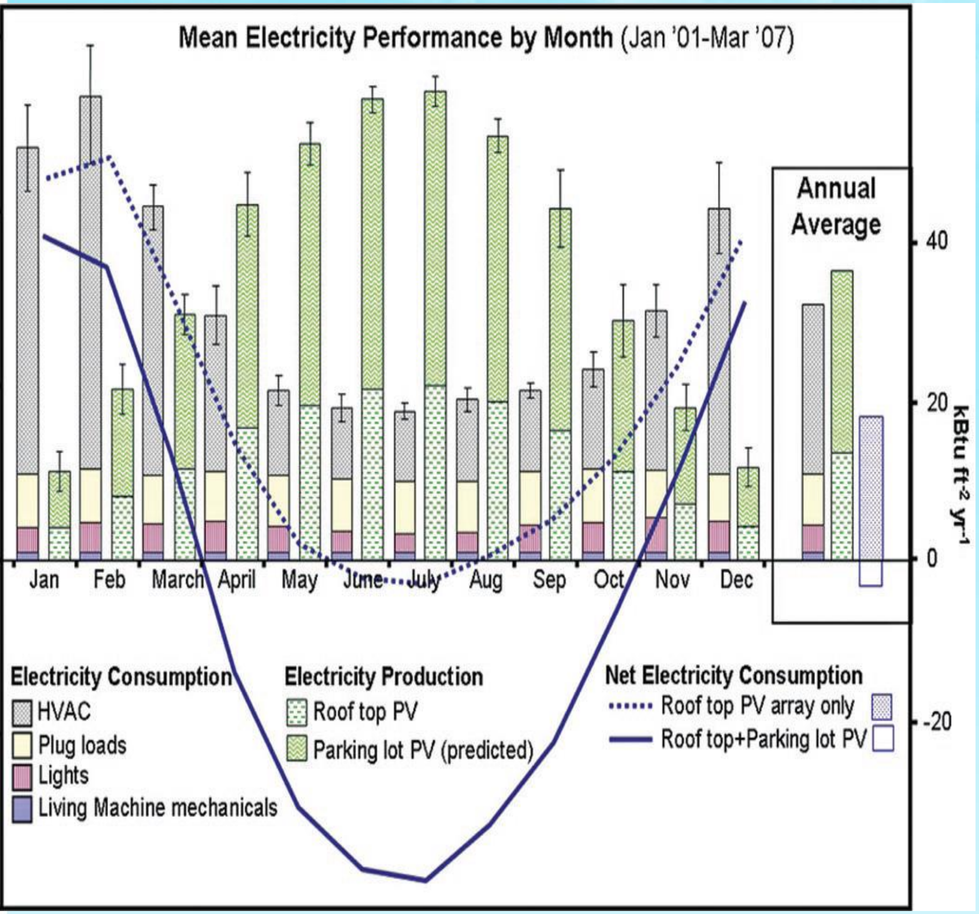
- LPD = 0.9 W/SF
- Clerestories, light-colored surfaces and interior windows for daylighting use
- Geothermal-WSHP System for heating & cooling
- Radiant floor heating in atrium
- 60 kW PV (roof) and 100 kW PV (building's parking lot cover)
- On-site wastewater treatment plant for building waste water

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

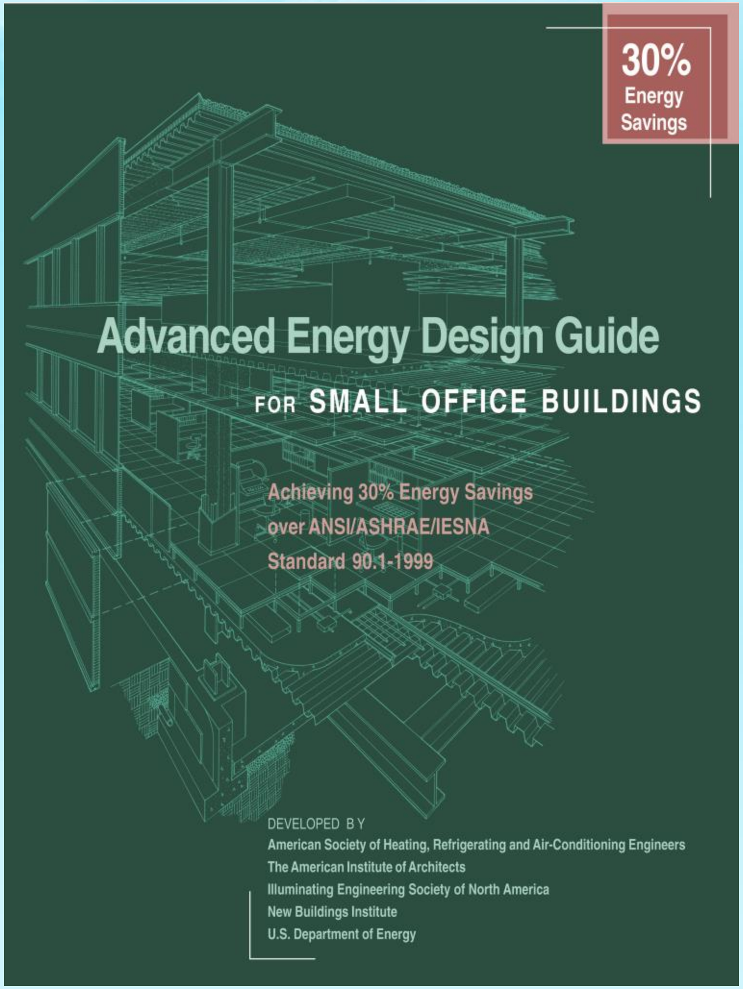
Net-Zero Lewis Center for Environmental Studies – Oberlin College



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)

Advanced Energy Design Guidance



From Brownfield to Sustainability Showcase

Chicago Center for Green Technology

Building Information

- 34,000 Sq. Ft.
- Multi-use Bldg. on a Brownfield Site
- Rooftop Garden & Rainwater Harvesting
- Recharging Stations in Garage
- Offices, Education Facility, High-tech Factory, Interpretive Center & “Garden in the City”

Mechanical Systems

- 6 Air-to-Water HPs (45 Ton)
- DOAS w/Energy Recovery
- O/A Control = Occupancy Sensors
- Geo Field = 28 – 200’ Bores
- Back-up = Boilers & CTs
- DDC w/Lighting Occupancy, CO2 Monitoring & Elec. Demand Control

Energy Efficiency

- Bldg Envelope – Highly Insulated, Low-e Glazing w/shading
- Daylighting & Electronic Dimmable Ballasts (25% Savings)
- Run-Around Heat Recovery Loop
- Geo-HVAC System
- EMS Control of All Systems

Indoor Air Quality

- Natural Ventilation (Op. Windows & Mult. Exh. Fans)
- Displacement Ventilation
- High Efficiency Filtration
- No- & Low-VOC Materials
- CO_2, Temperature & Humidity Levels Monitored w/EMS
- No Occupant Complaints

Innovation

- Geo-HVAC System w/Redundant Components
- Displacement Ventilation
- UAD & Underground Ductwork
- PV Panels – External Shading devices (71KW of 100 KW Demand)
- Occupancy Control & Load Shedding = Min. Peak Demand
- Water Saving Technologies

Innovation

- Rainwater Storage – Irrigation
- Low-flow Toilets & Showers
- Site Run-off to Landscape
- No CFCs or HCFCs in Materials
- Elevators – Canola Oil in Hydraulics
- Geo-HVAC – Propylene Glycol
- Garden Roof – Reduces Heat Island Effect & Cleans O/A

Operation & Management

- All Components Serviceable & Located Inside Bldg.
- Low Maintenance or Simple Maintenance Components
- Commissioning Plan Ensured Correct Installation
- Maintenance Staff Training
- Post Commissioning & Op. Proc. Verification

Net-Zero IDeAS Z^2 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
- Z^2 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 Z² 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 Z^2 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 Z^2 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

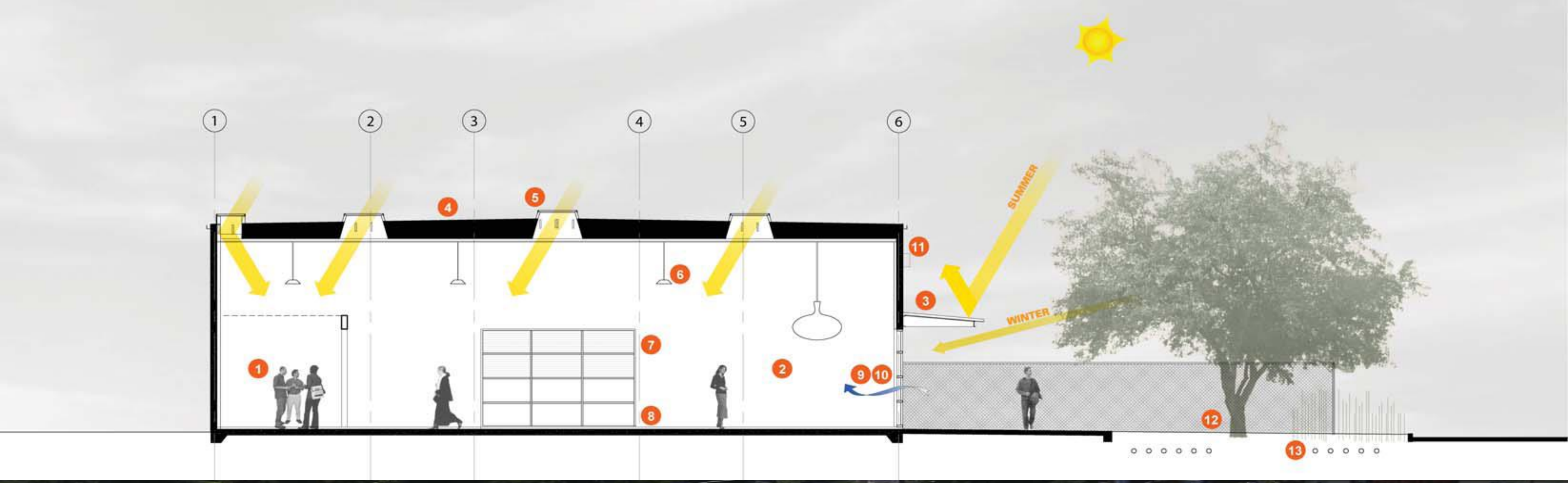
- Utility Incentives & Rebates + Tax Credits + State/Federal Incentive Programs and PV Production = 7.6 Year Payback
- Plumbing Fixtures →Ultra Water Efficient
- Bioswale (Rain Collector) Replaced Large Parking Lot & Reduced Heat Island Effect →Recharges Water Table
- Façade of Original Bldg – Reused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

Net-Zero IDeAS Z^2 Design Facility

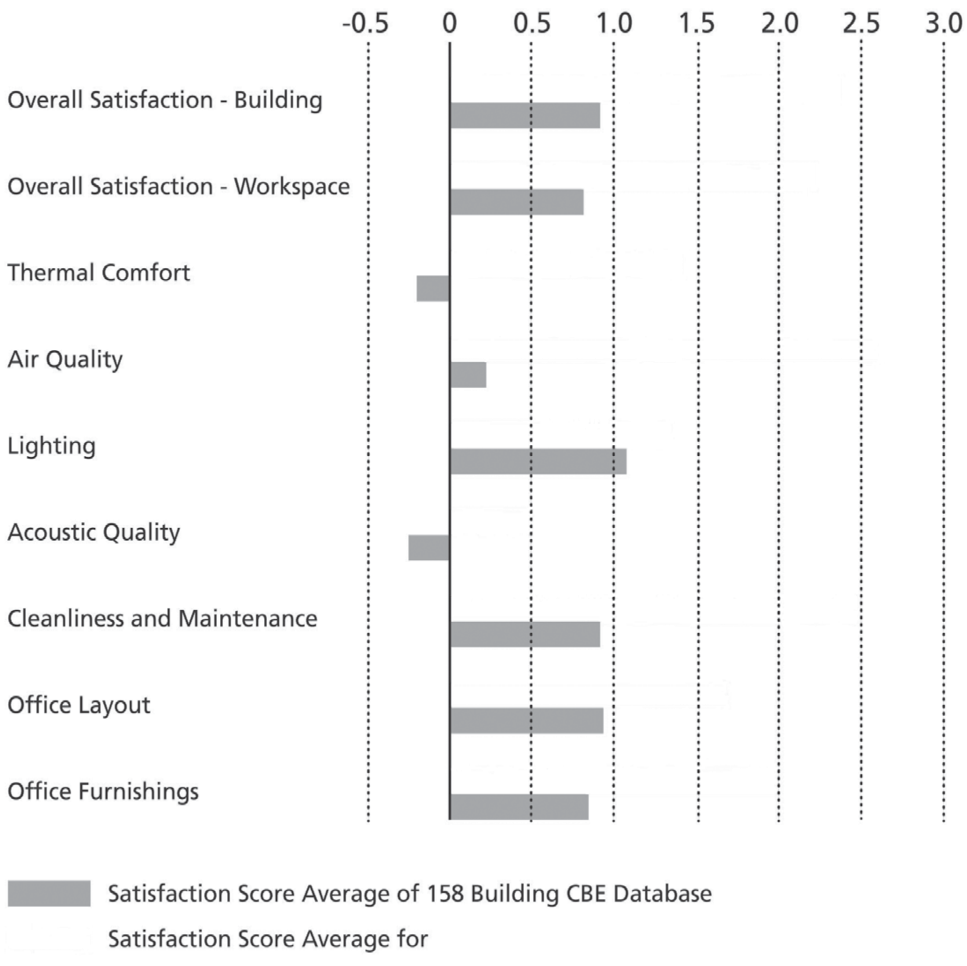
LESSONS LEARNED

- Reduce energy level <u>before</u> 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 Z² Design Facility



Net-Zero IDeAS Z² 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 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

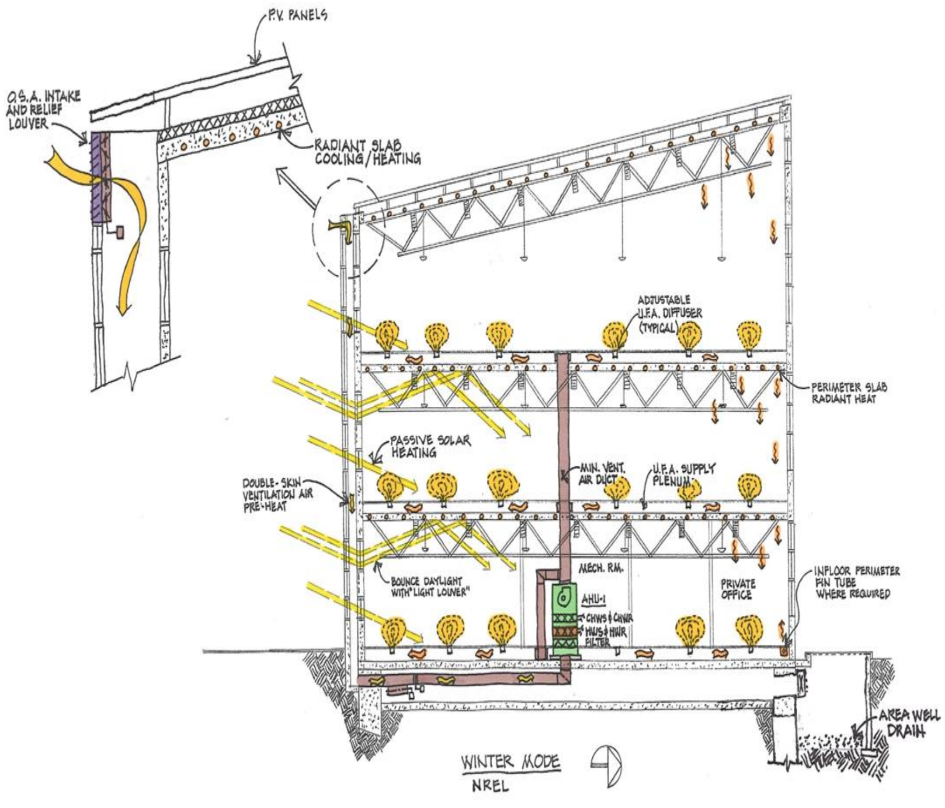
- Portion of hot water heating by woodchip biomass boiler
- Photovoltaic arrays on building roofs and Visitor’s Parking Lot →NREL to have Power Purchase Agreement from a 3rd party vendor
- Use of ‘Lightlouver’ – a light bouncing device to augment daylighting

Net-Zero NREL Administration Building

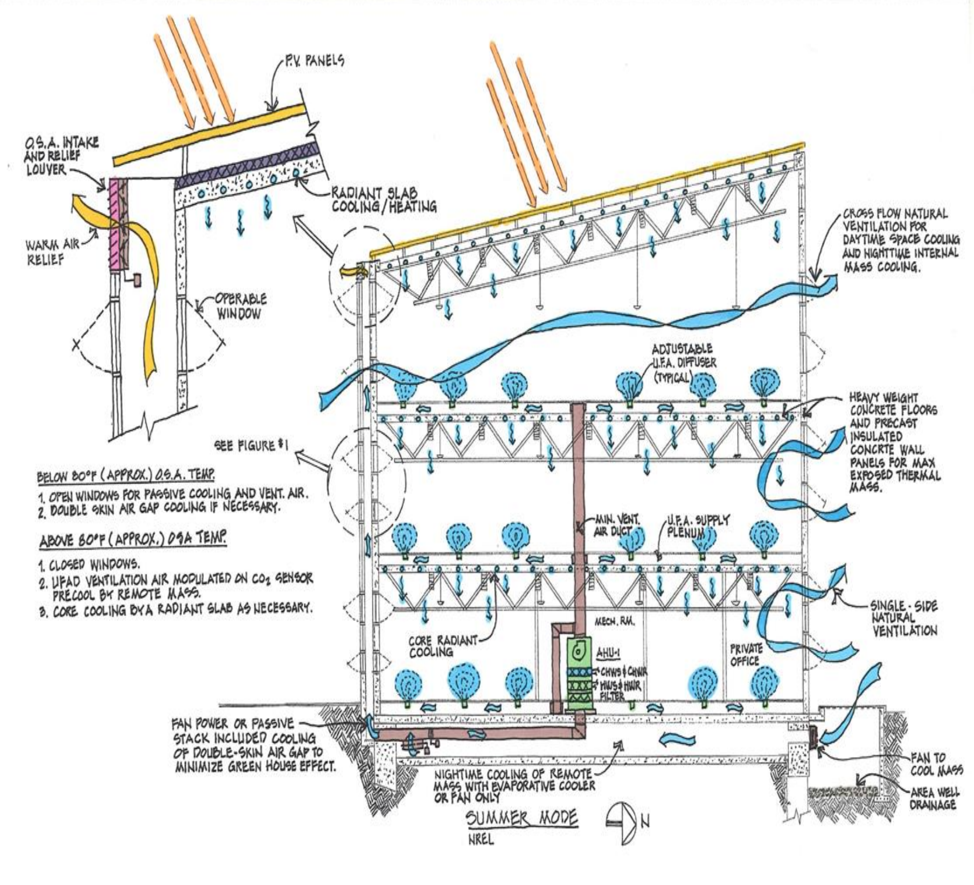
LESSONS LEARNED

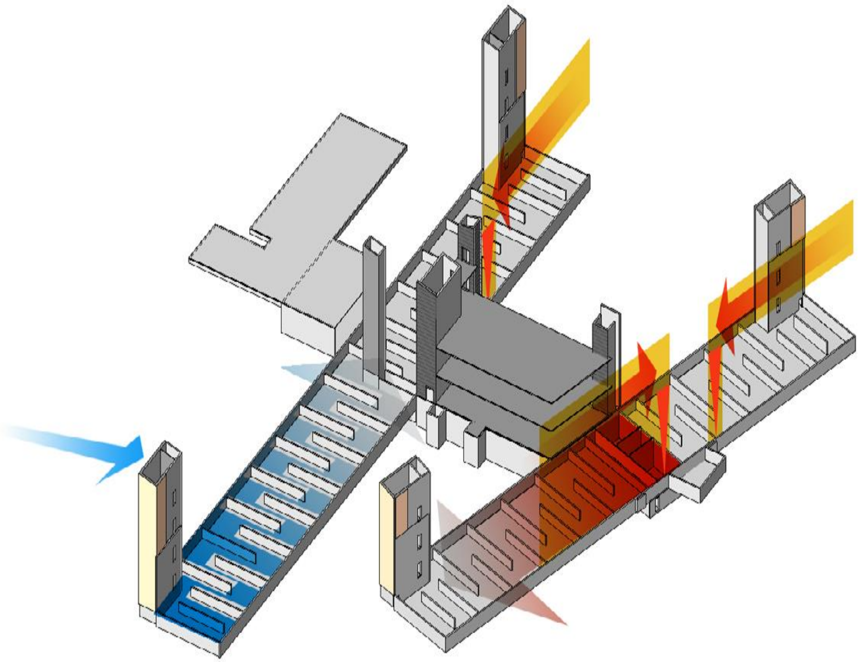
- Energy loads dominated by “plug loads” and other internal loads (server rooms/data center)
- Simple solutions are the “best” (e.g. transpired collectors vs double-skin south façade for solar control & passive heat collection)

Net-Zero NREL Administration Building

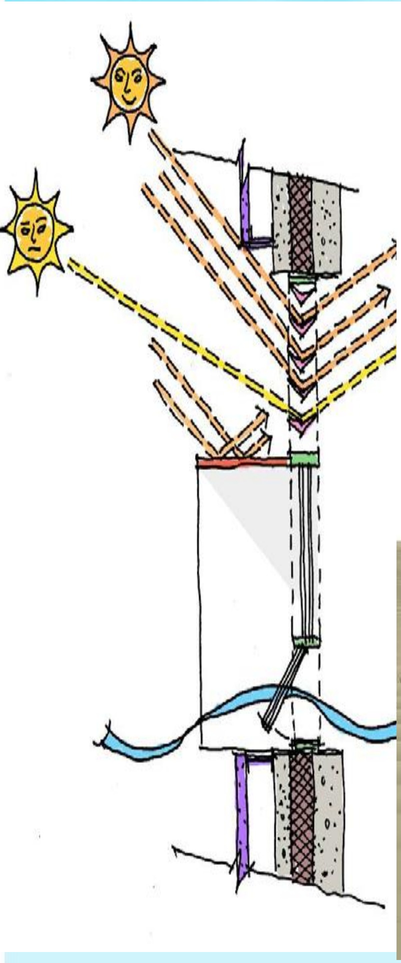


Net-Zero NREL Administration Building





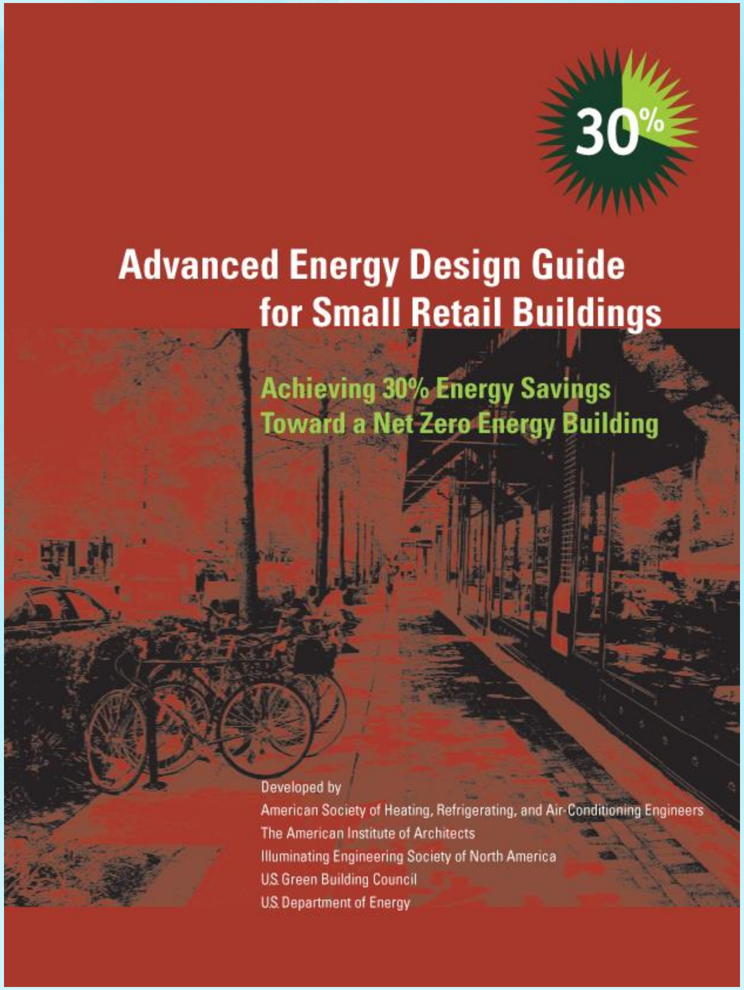
Net-Zero NREL Administration Building



Measured Energy Use

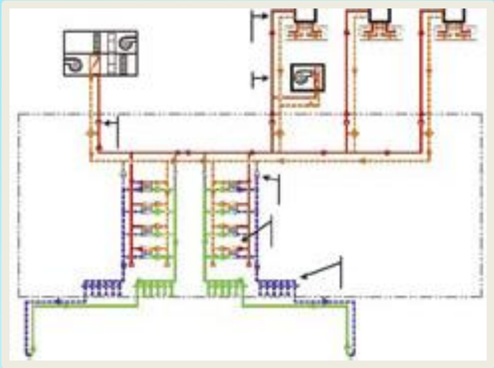
- Annual Energy Consumption = 2,001,240 kWh/yr = 9.18 kWh/SF-yr
- Renewable Annual Energy Supply = 2,001,240 kWh/yr = 9.18 kWh/SF-yr
- Net Energy Use = 0 kWh/yr (Excess sold to 3rd party)

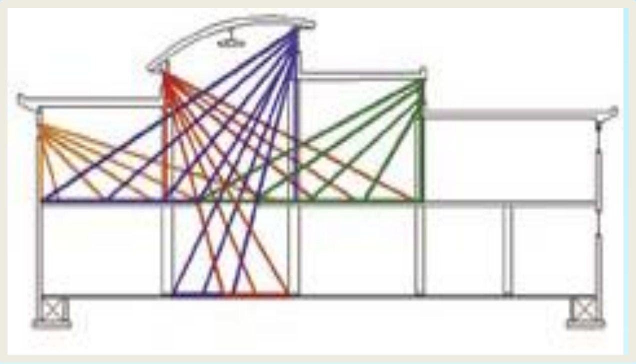
Advanced Energy Design Guidance



Creating Synergies for Sustainable Design

Mountain Equipment Coop





Creating Synergies for Sustainable Design

- Geo-exchange system using ground-source heat pumps
- Radiant slabs for heating and cooling
- Combination hybrid ventilation system
- Dedicated outdoor air unit
- High performance envelope
- Natural lighting
- Thermal energy storage with night pre-cooling and –heating
- Heat recovery from exhausted air

Creating Synergies for Sustainable Design

- Rain water harvesting
- Building
  - * 45,000 Sq. Ft.
  - * 2-Story, Open Space Retail
  - * Office Spaces
  - * Storage Areas
  - * Small Coffee Shop

  - * Target = 50% Savings of Energy over Code

Creating Synergies for Sustainable Design

Geothermal System

- 12 – 575 foot deep wells
- Eight water-to-water HPs
- Heating & Cooling Systems = Radiant Slabs
- Parallel Pumps for Natural Slab Cooling with well water
- Minimized Metallic Duct Material

Creating Synergies for Sustainable Design

Hybrid & Dedicated Ventilation

- Hybrid – Underground Tunnels
  - * Fans, Filters & Perimeter Supply
  - * Vertical Ventilation Shafts
  - * Roof Peak Exhaust Vents
  - * 50,000 CFM
- Dedicated – Heat or Dehumidify
  - * Energy Recovery Unit
  - * 6,000 CFM
- CO2 Sensors in Bldg Exhaust

Creating Synergies for Sustainable Design

Natural Lighting

- 2nd Floor Retail Areas

  * Roof Monitor & Clearstory Windows

  * Sensors Control Artificial Lighting

  * Total Installed Lighting = 1.3 W/Sq.Ft. (90.1 = 1.9 W/SF)

  * ½ Year's Lighting Energy

Creating Synergies for Sustainable Design

Building Envelope

- Walls = R35 (90.1 = R11)
- Roof = R40 (90.1 = R16)
- Windows = High Performance Double-Glazed, Low-e, U-factor = 0.3
- Window Shading
- Low or No-VOC Materials
- Flooring = Bare Concrete w/Protective Finish

Creating Synergies for Sustainable Design

Operation & Maintenance

- Automatic Switching Between Heating & Cooling Modes, Hybrid & DOAS Systems, Natural & Geo-Based HVAC System Operation
- System Weather Forecast Input
- Remote Monitor of Performance
- All Units Easily Accessed
- No Water or Mold Problems

Creating Synergies for Sustainable Design

Environmental Impact

- HPs → R-407c (HFC & 0 ODP)
- Bldg Reduced Emissions = 400 Tons/yr CO_2
- Water-Conserving Plumbing System
- Roof Water → Toilets & Irrigation
- Domestic Water Savings = 300,000 Gal/yr
- 67% of Construction Wastes Recycled

Net-Zero Kitsap SEED Commercialization Center

PROJECT DESCRIPTION

- 23,018 SF of commercial, retail and light manufacturing facility
- 2 Buildings one 2-story (17,773 SF) and one 1-story (6,245 SF)

NZEB STRATEGIES

- Passive solar orientation
- Natural ventilation w/energy recovery

Net-Zero Kitsap SEED Commercialization Center

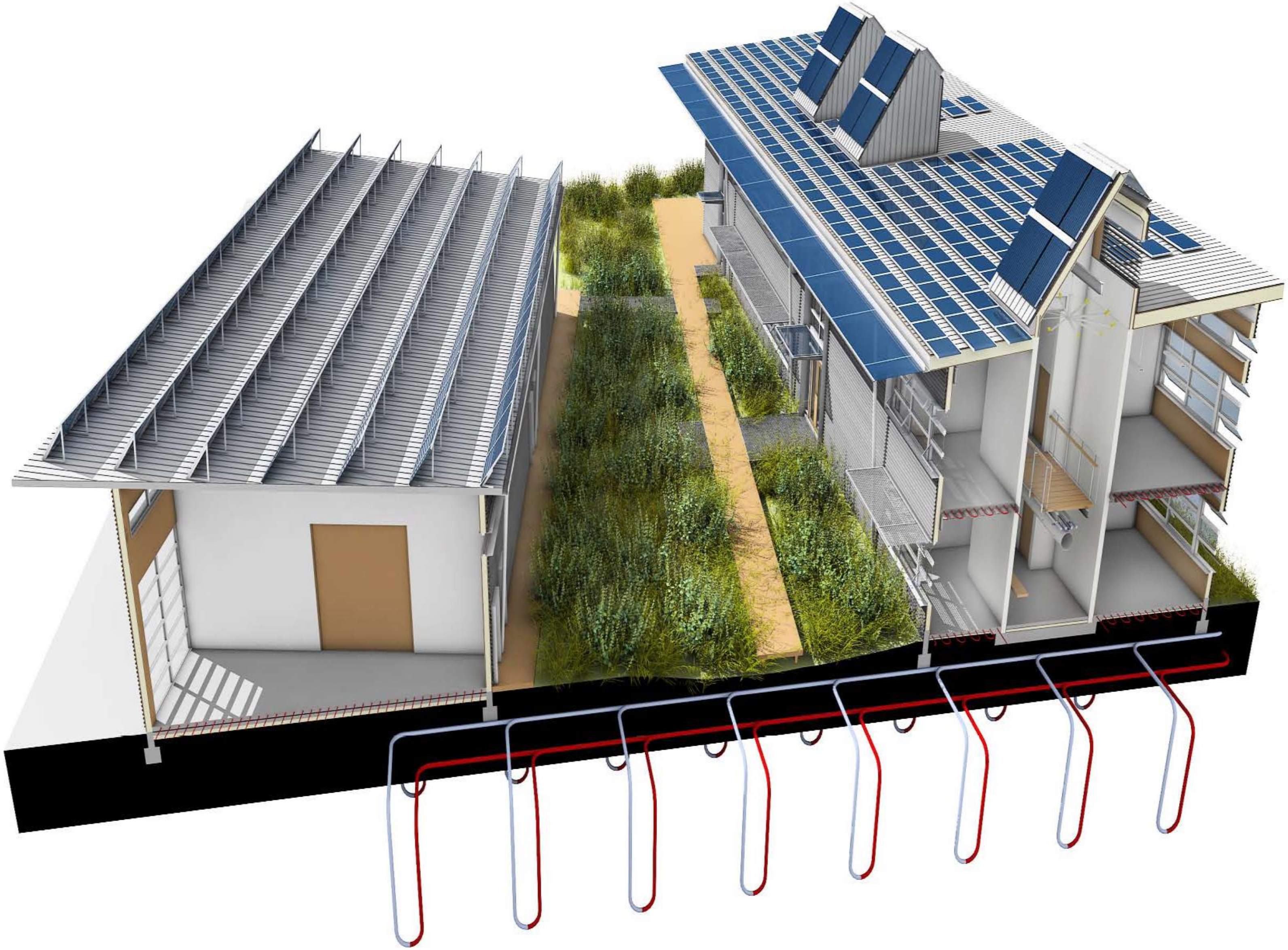
NZEB STRATEGIES

- High thermal mass shear walls create natural daylight wells & ventilation stacks
- Structural insulated panels for walls & roof
- Geothermal-based HVAC System
- Solar thermal DWH System
- Energy Efficient Lighting
- Photovoltaic energy generation

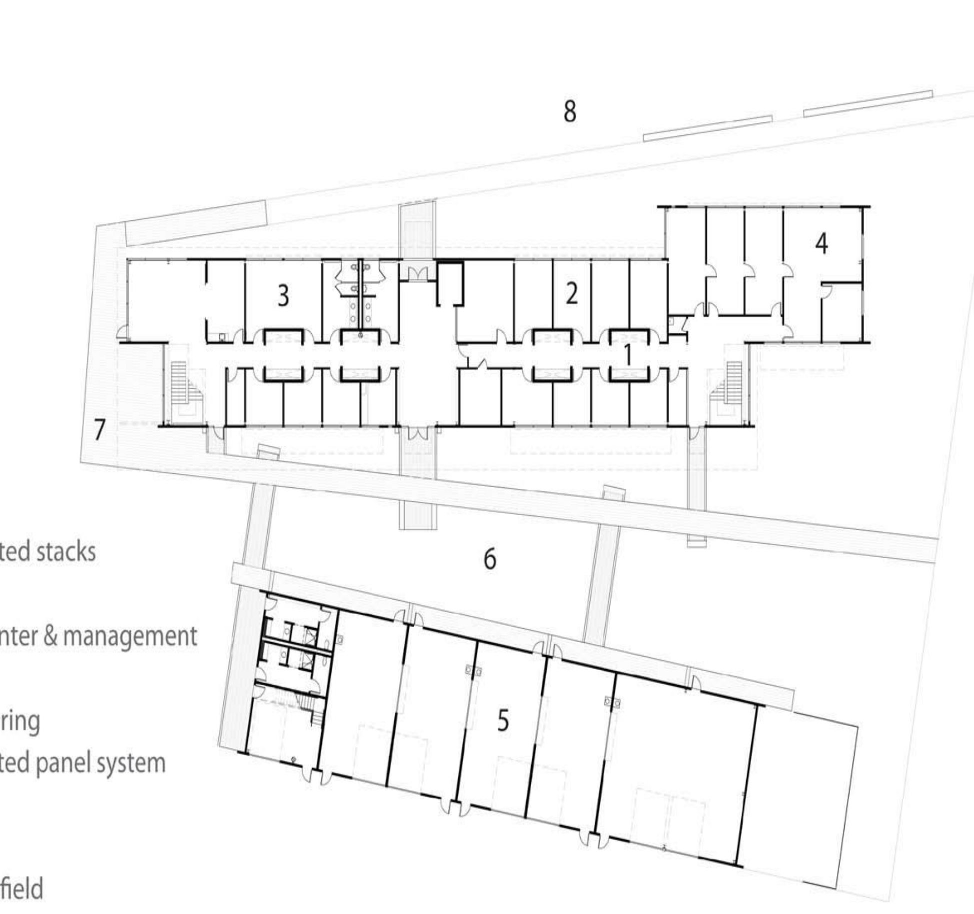
Net-Zero Kitsap SEED Commercialization Center

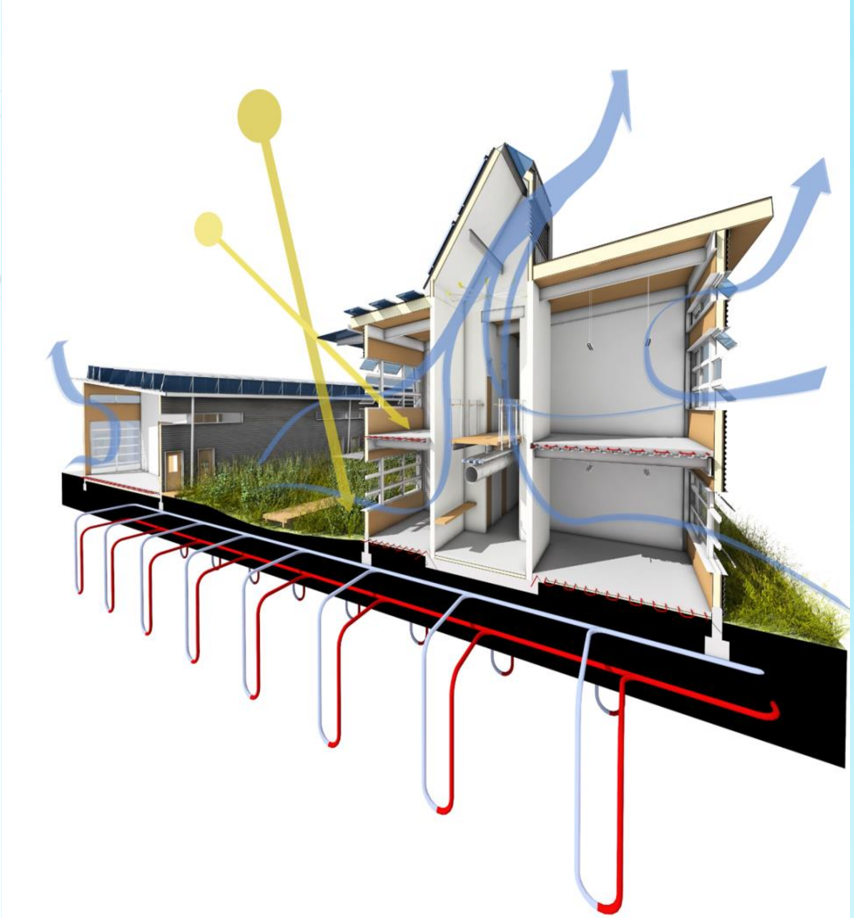
LESSONS LEARNED

- Conservation 1st then PV generation sizing
- Make building design ready for future PV and/or solar thermal wind (1st cost factors)
- Two stories and higher become challenging
- Traditional design & conservation methods may make “break-thru” ideas difficult to consider

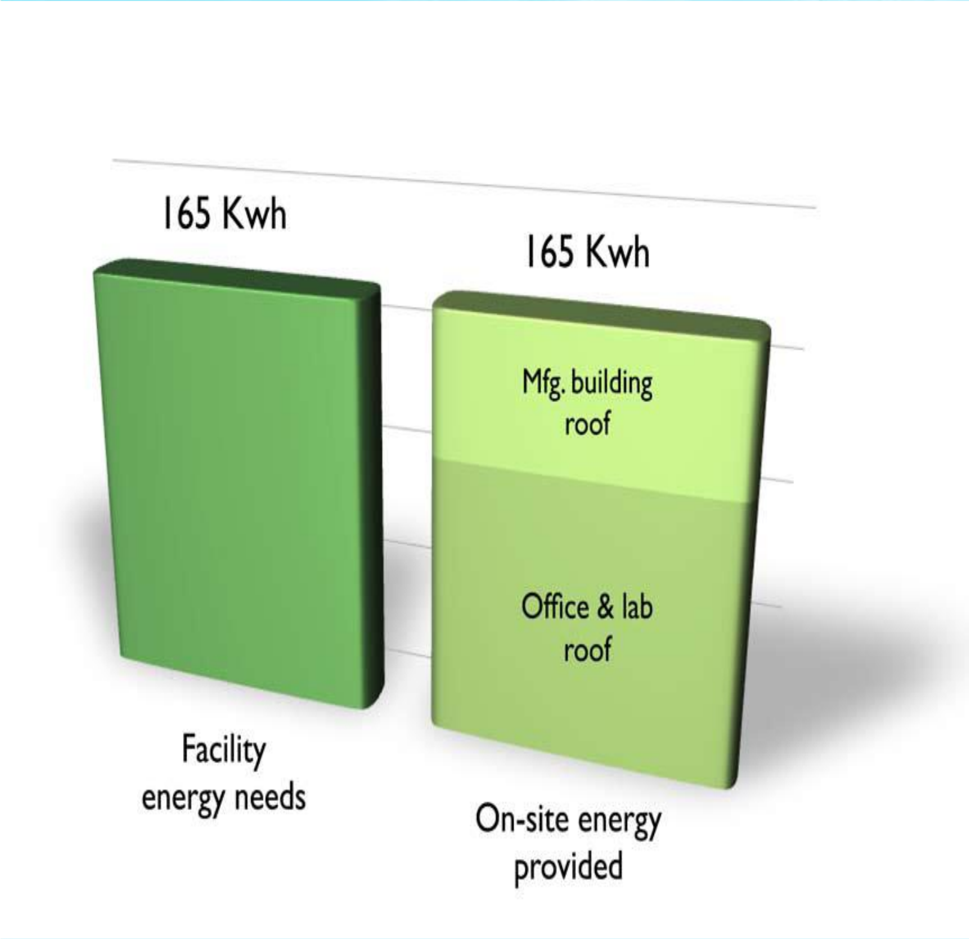


Net-Zero Kitsap SEED Commercialization Center





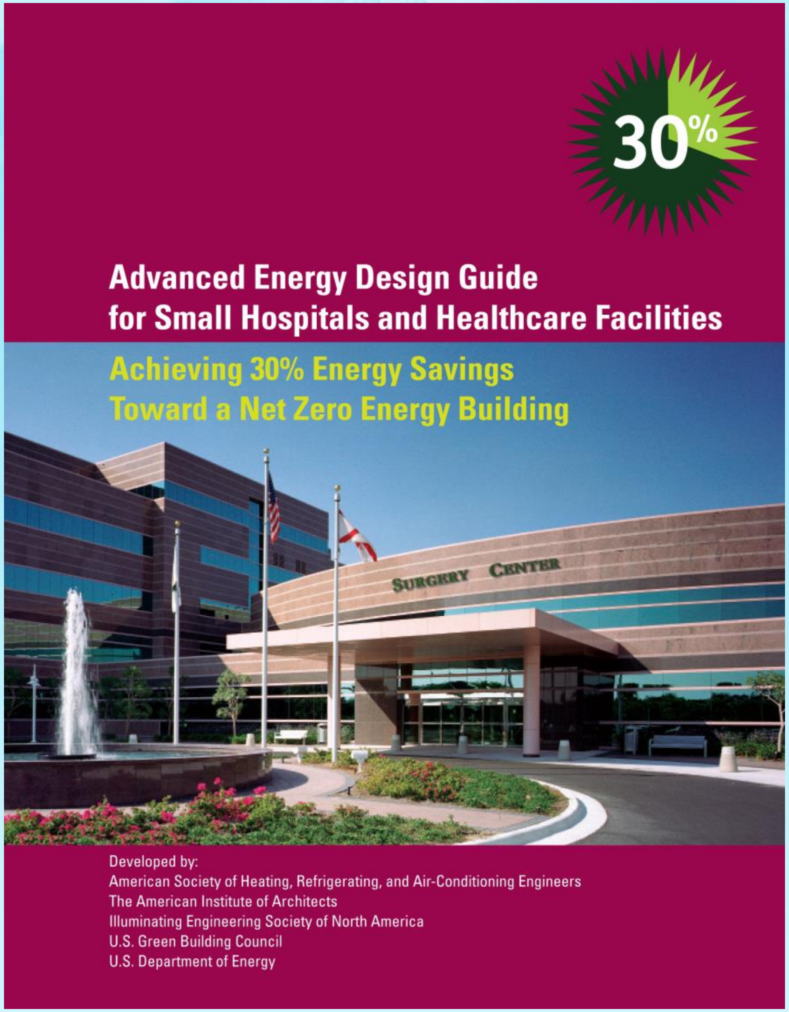
Net-Zero Kitsap SEED Commercialization Center



Measured Energy Use

- Annual Energy Consumption = 165,724 kWh/yr
  = 6.9 kWh/SF-yr
- Renewable Annual Energy Supply = 165,724 kWh/yr
  = 6.9 kWh/SF-yr
- Net Energy Use = 0 kWh/yr

Advanced Energy Design Guidance



Major Energy Uses in a Large Hos

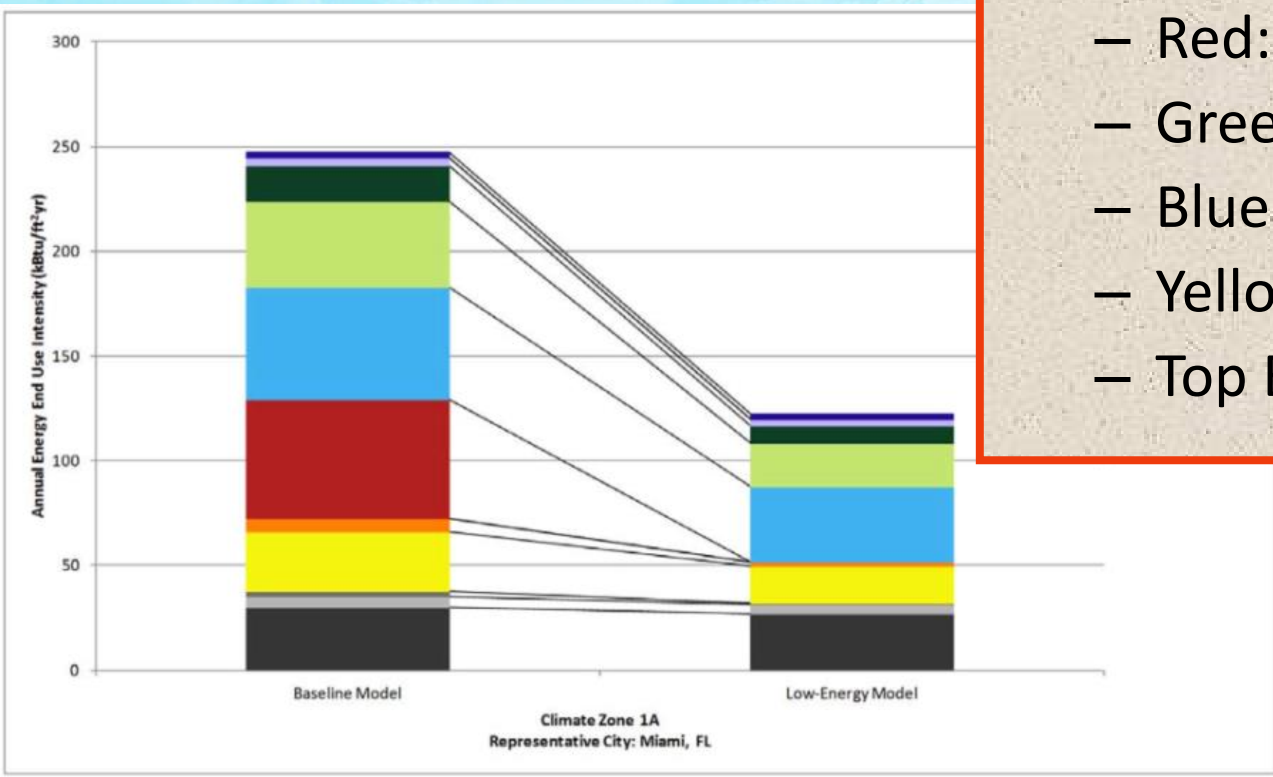


Figure 3-1 Comparison of Baseline to Prescriptive 50% AEDG Solution Showing Breakdown of Energy Savings Components

- 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 B (dry zones) = 60% sensible effectiveness 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

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 ΔTs of at least 14°F.

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

Source: 50% AEDG for Large Hospitals from ASHRAE

Aggressively Address Reheat

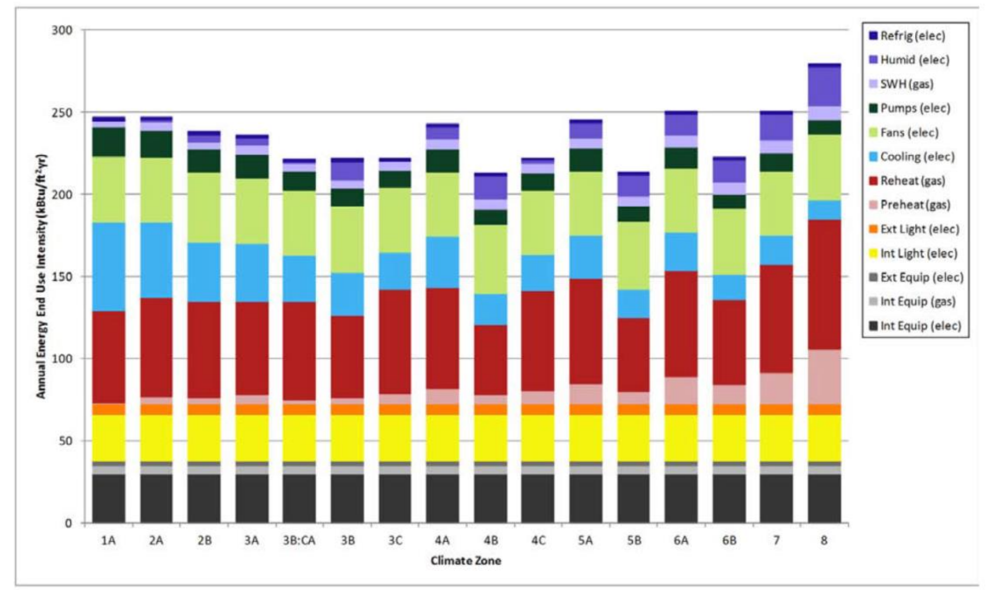
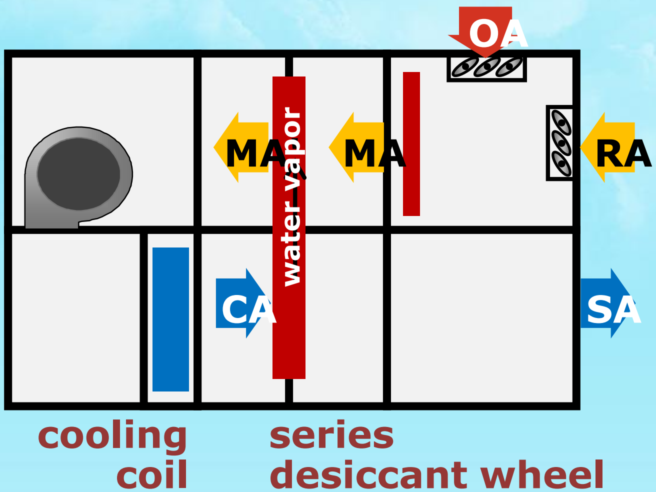


Figure 3-18 Reheat Energy (in Red) Compared to other Energy Uses in Healthcare Facilities

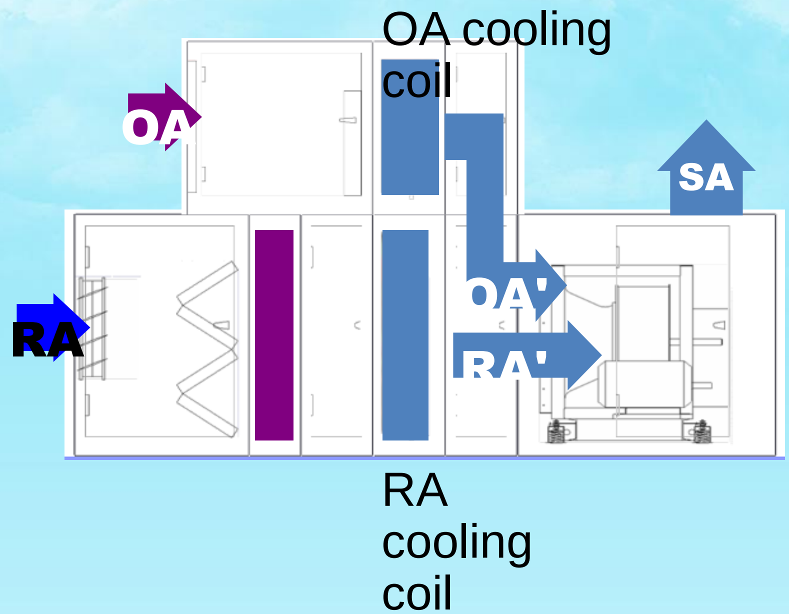
- Supply dry air to OR
- Recover heat from chilled water system

Source: 50% AEDG Large Hospitals from ASHRAE

Aggressively Address Reheat



<u>Series desiccant wheel</u>
Provide low humidity levels in the OR while minimizing reheat energy



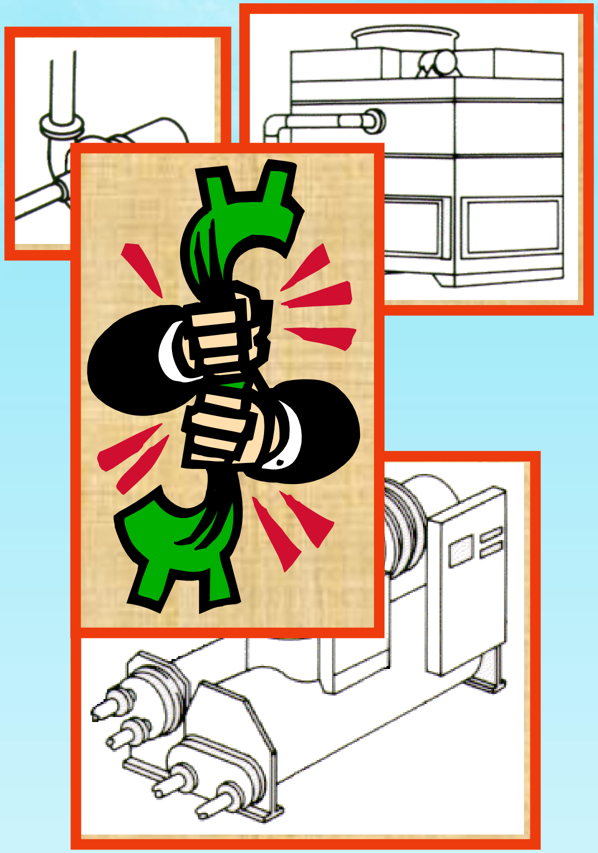
<u>Dual-Path Air Handler</u>
Treat outdoor air separately

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

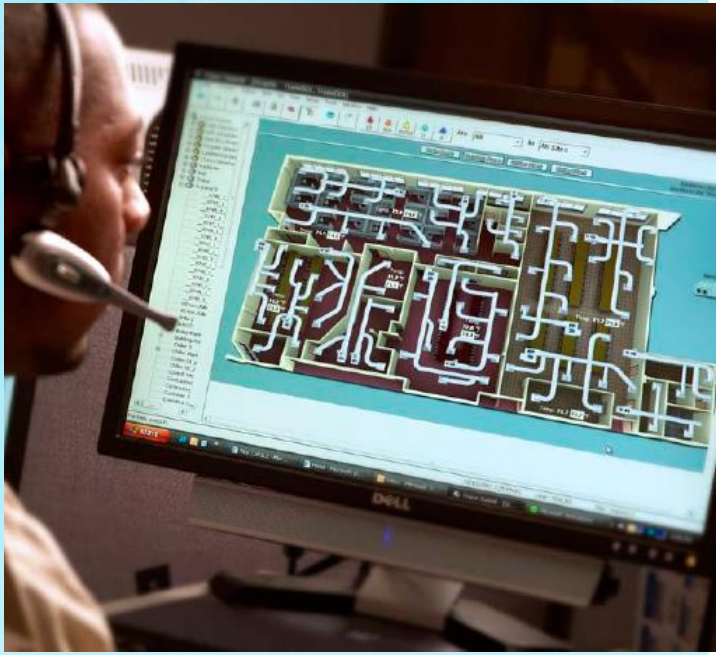
- Reduce flow rates
  - Smaller pumps, pipes, and cooling towers
  - Lower operating costs
- Variable primary flow
  - Fewer pumps
  - Lower operating costs
- Heat recovery chillers
  - Properly sized and located



High-Performance VAV System

Optimized VAV system controls

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



Honoré-Mercier Hospital

Honoré-Mercier Hospital

- Building Information

  *   135,000 SF Renovation + 90,000
      SF New Construction

  *   300 Beds; Emergency, ICU, ORs,
      Labs, Nuclear Meds, Imaging,
      Oncology, Sterilization, Food
      Services, Clinics & Pharmacy

  *   Decontamination (Aspergillus) of Entire
  Facility

Honoré-Mercier Hospital

- Building Energy Efficiency Measures

  * Enthalpy Wheels & Run-around Coils in Exhaust Air

  * Low Temp Heating Loop

  * Dual Duct System

  * Heat Recovery Chillers

  * Heat Pumps

  * High Efficiency Boilers

  * Efficient Lighting Systems

Honoré-Mercier Hospital

- Building Challenges

  * Constant Negative Pressure in Contaminated Areas

  * External Areas (Walls)-Negative Pressure; Internal Areas-Positive Pressure→Use of Press. Sensors & Constant Monitoring

Honoré-Mercier Hospital

- Operational Results

  * 43% Reduction in Energy Use

  * Annual Cost Savings = $921,855

  * Net Payback = 3.8 years

  * GHG Reduction = 3,576 Tons/yr

Sobey's Warehouse

- 147,000 Sq.Ft. Total =

  - 120,000 Sq.Ft. Refrigerated Warehouse (4° C)

  - 5,300 Sq.Ft. Office Space (Hydronic Radiant Floor Heating; Fan-Coils Cooling)

  - 20,700 Sq.Ft. Common Spaces (Cafeteria, Multi-use Space, Locker Room, Workshop & Mechanical Room) →(Hydronic Radiant Floor Heating; Fan-Coils Cooling)

Sobey’s Warehouse

Building Operations’ Strategies

- Refrigerated Warehouse cooled with ammonia central chiller & glycol secondary distribution fluid system
- Most building heating is provided by heat recovery from the chiller condensers
- Daylighting & occupancy sensors’ control lighting levels in warehouse & offices

Sobey's Warehouse

Energy Efficiency

- All building insulation levels exceed 90.1

  - Warehouse = R-30 walls; R-40 roof

  - Offices/Common Spaces = R-20 walls; R-30 roof
- Roof Sections – Warehouse (Reflective White); Office/Common Spaces (Green Roof)
- Warehouse Lighting – T5HO w/infrared motion detectors; Offices – T5 w/motion detectors

Sobey's Warehouse

Energy Efficiency

- Radiant Floor Heating – Heat recovered from condensers or gas boilers (free cooling)
- Cooling – Ammonia Chillers with different compression ratios for Warehouse (-11°C) and Offices (2°C)

  - Whse can operate in free cooling when outside Temps are bellow -12°C (Chillers use thermosiphon principle)

Sobey's Warehouse

Energy Efficiency

- Controls – O/A with CO_2 sensors; Temperatures with occupancy schedules
- Battery Charger – charging efficiency = 92% (versus standard 80%)

Sobey's Warehouse

Indoor Air Quality & Thermal Comfort

- DOAS Ventilation System controlled with CO_2 Sensors + Energy Recovery = Reduced O/A amounts (0.015 cfm/SF overall vs 0.06 cfm/SF in whse & 0.12 cfm/SF in shipping/receiving)
- High Ventilation Effectiveness (> 0.9)
- Ventilated Warehouse →Increased IEQ as compared to 5 comparable sized area warehouses of owner

Sobey's Warehouse

Operation and Maintenance

- All refrigeration and heating systems are centralized (safer for employees)
- All water & glycol loops have balancing valves
- All lighting control is centralized

Sobey's Warehouse

Cost Effectiveness

- Energy Savings = $144,896/year (energy consumption is 62% lower than code requirements)
- Efficiency Measures cost $1 Million more than a standard building
- Simple Payback – 6.9 years
- ROI for Efficiency Measures investment < 3 years W/O utility subsidies

Sobey's Warehouse

Environmental Impact

- Ammonia – Zero ODP & Zero GWP
- All plumbing fixtures = low flow; urinals = water free; water closets = dual flush
- Stormwater → Constructed Wetland retention reservoir
- Overflow → Pumped to Wetland retention
- Sanitary Waste → Septic System to Reed Field (no waste water returned to city)

Net-Zero Exploratorium at Pier 15 + 17

PROJECT DESCRIPTION

- 190,000SF combination of public plaza, exhibit spaces – interior & exterior, residential, commercial and science discovery areas.

NZEB STRATEGIES

- Exceed code requirements by a minimum of 40%
- Bay water cooling system + WSHP System

Net-Zero Exploratorium at Pier 15 + 17

NZEB STRATEGIES

- Radiant heating and cooling system
- $T_{ChW} \geq 2°F$ above indoor air $T_{Dew\ Point}$
- Mixed-mode Ventilation System – O/A ERV & mechanical conditioning
- Control of "plug loads" w/dedicated circuits & electric panels (for monitoring purposes)

Net-Zero Exploratorium at Pier 15 + 17

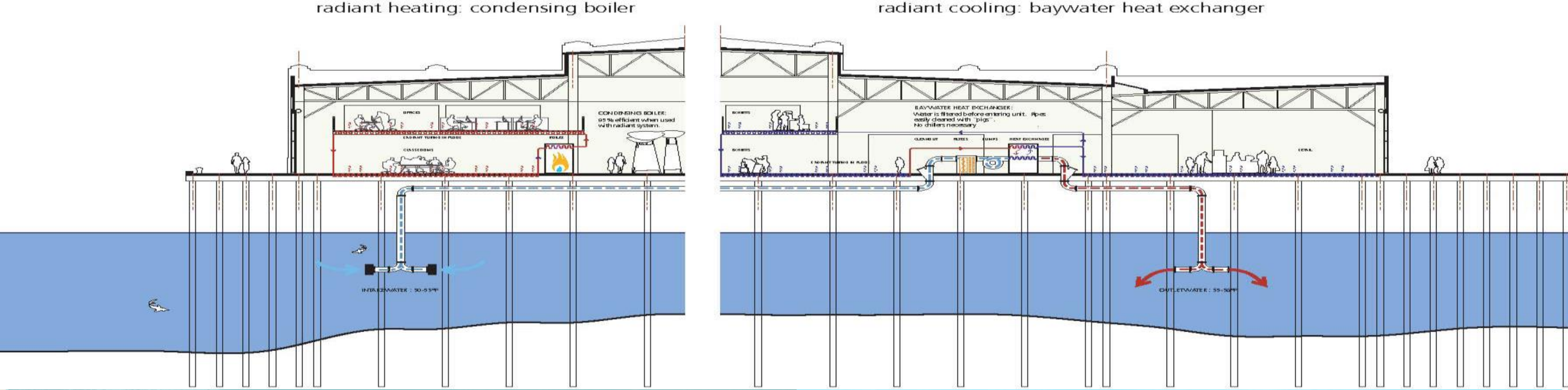
LESSONS LEARNED

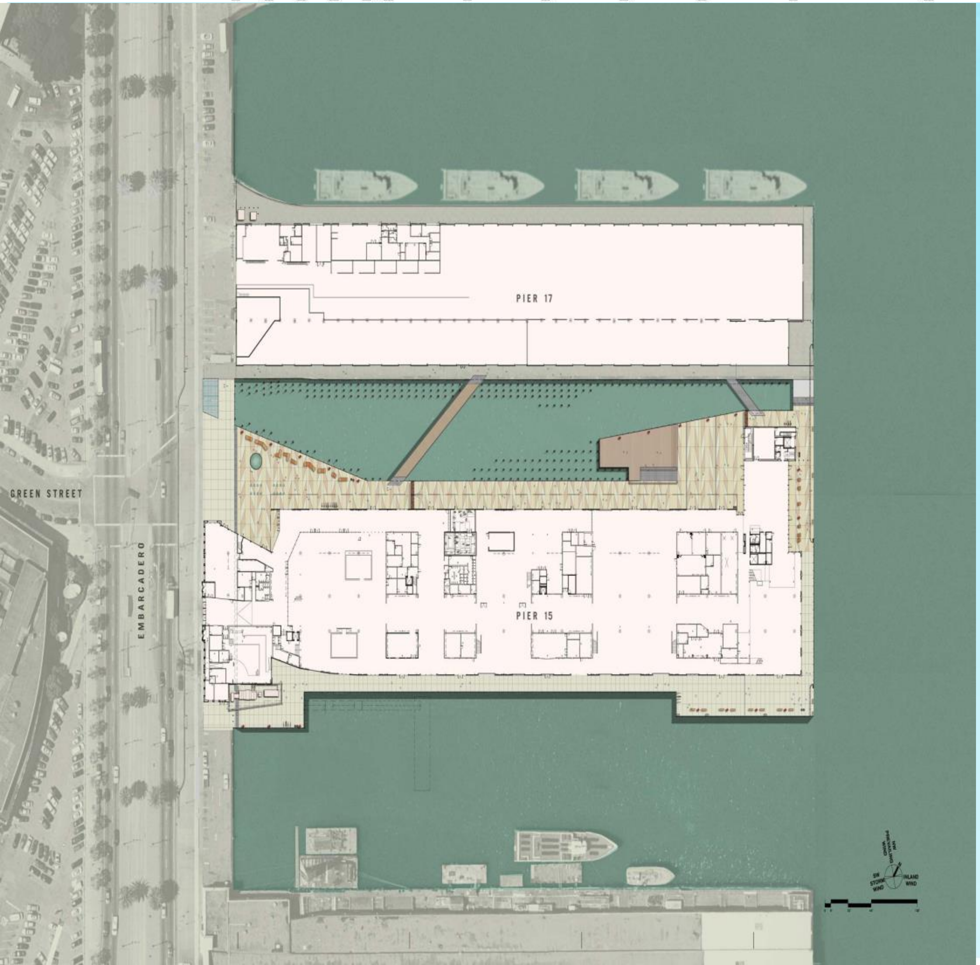
- Organizational buy-in is necessary in order to –

  ¤ Create a “centralized” plug load philosophy & procurement process

  ¤ Have periodic analysis and review of operations

  ¤ Ensure periodic maintenance of all systems





Measured Energy Use

- Annual Energy Consumption = 2,139,400 kWh/yr
  = 11.26 kWh/SF-yr
- Renewable Annual Energy Supply = 2,139,400 kWh/yr
  = 11.26 kWh/SF-yr
- Net Energy Use = 0

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.

Technical (Testing-Based) Commissioning Provides -

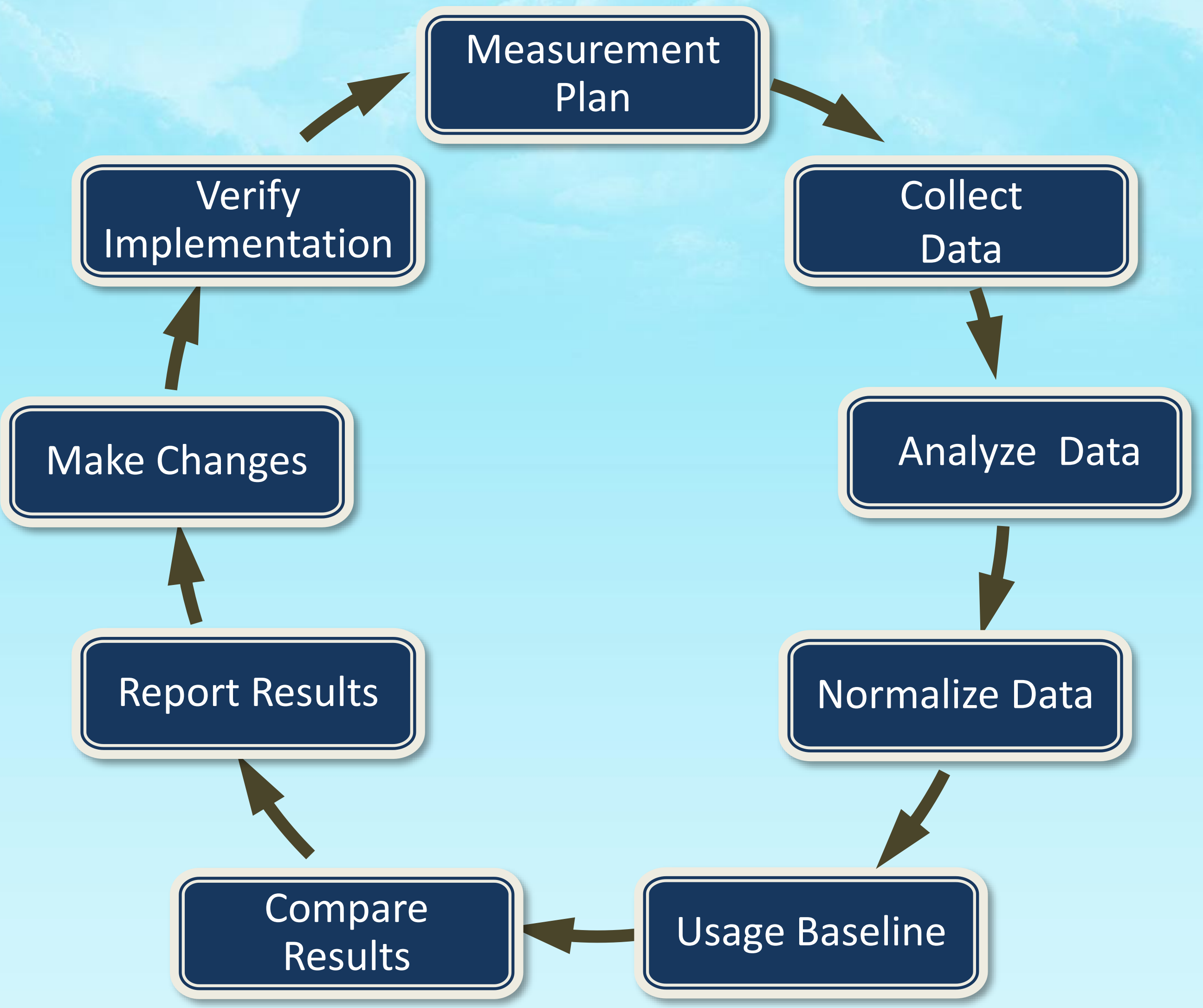
- **Improved Comfort Levels**
  - Temperature
  - Humidity
  - Sound & Vibration
  - Suitable Lighting Levels
  - Reduction of Daylight Glare
- **Improved Indoor Air Quality**
  - Ventilation Rate
  - CO_2 control
- **Reduced Utility Expense (Efficient Operations)**
  - Improved Electrical Energy Usage
  - Improved Gas Energy Usage
  - Improved Water Usage

Validation of Commissioning

- First Party (1st) Validation = A firm or individual verifying the project tasks is the same firm or individual performing the tasks.
- Second Party (2nd) Validation = The firm or individual verifying the project tasks is under the control of the firm that performed the tasks.
- Third Party (3rd) Validation = The firm verifying the project tasks is not associated with or under the control of the firm performing or designing the tasks.

Continuous Performance Verification

Continuous Performance Verification

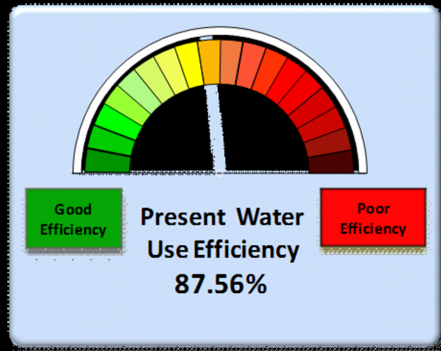


Continuous Performance Verification

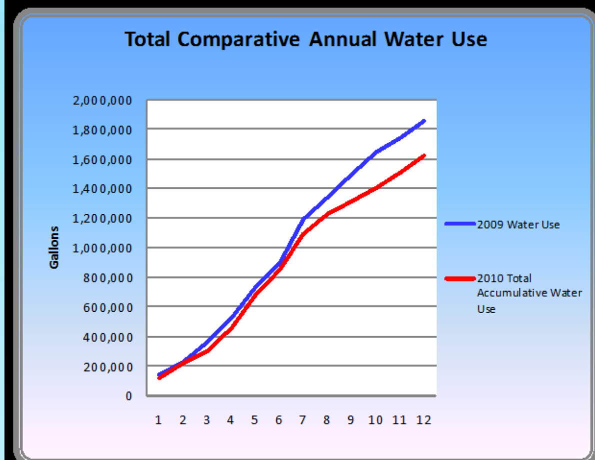
- **What is Measured?**
  - **Energy Usage both in KWH and $**
  - **Gas Usage both in Therms and $**
  - **Water Usage both in Gallons and $**
  - **Purchased Energy both in BTUH and $**
  - **Occupant Comfort or Building Performance**
    - **Annual Occupant Survey**
    - **Monitor Maintenance Management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

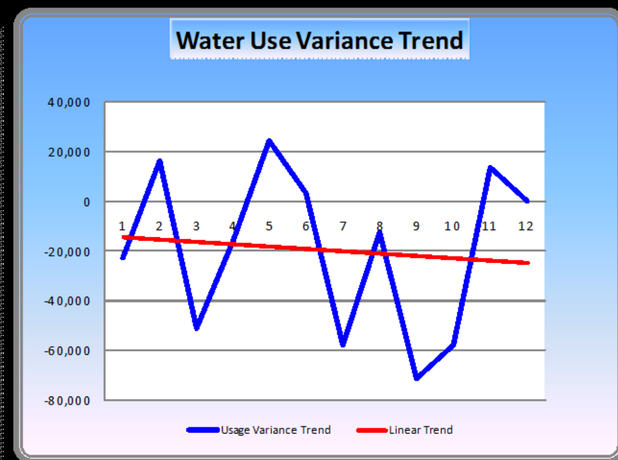
Water Use Charts for: Tester Products

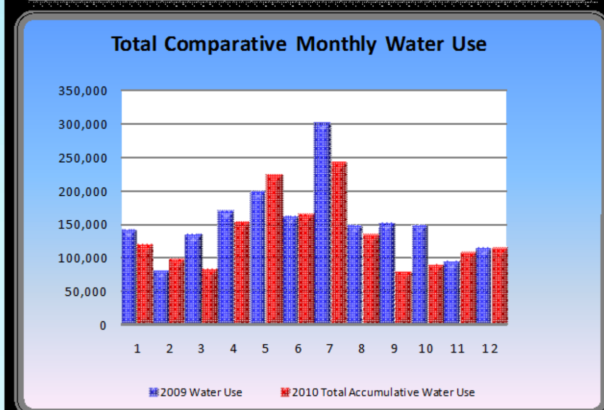
Date: 12/31/2010

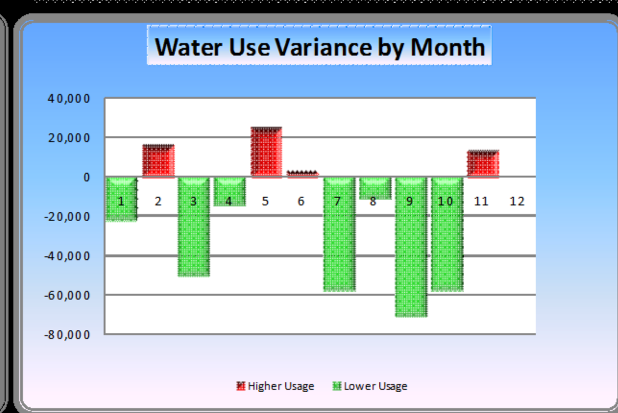


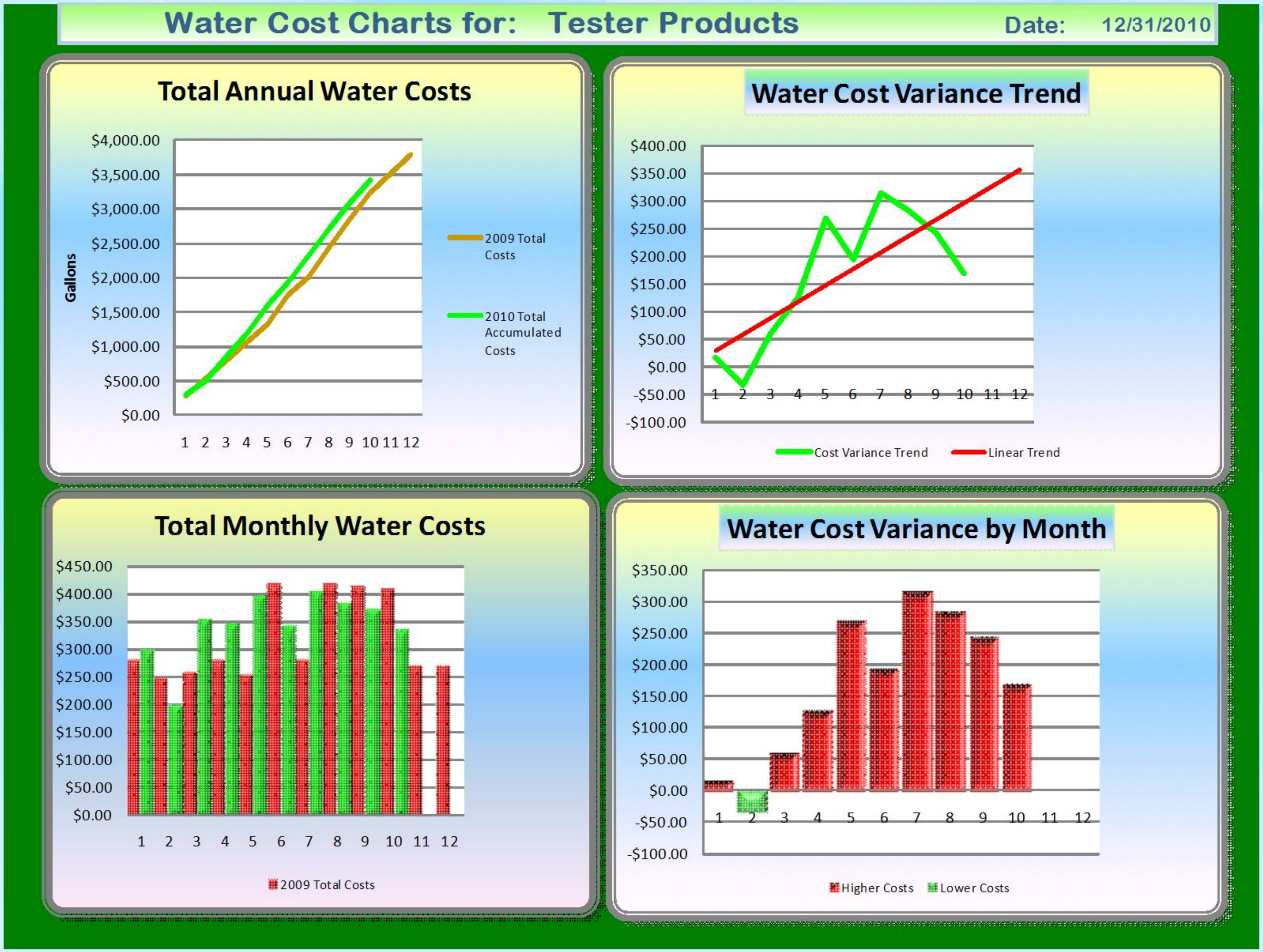
	Current Year	Prior Year	Variance
Square Feet	100,000	100,000	0
WUI Gal / Square Foot	16.25	18.56	-2.31
$ / Square Foot	$0.071	$0.067	$0.003










Water Cost Charts for: Tester Products
Date: 12/31/2010
Total Annual Water Costs
Gallons
$4,000.00
$3,500.00
$3,000.00
$2,500.00
$2,000.00
$1,500.00
$1,000.00
$500.00
$0.00
1 2 3 4 5 6 7 8 9 10 11 12
2009 Total Costs
2010 Total Accumulated Costs
Water Cost Variance Trend
$400.00
$350.00
$300.00
$250.00
$200.00
$150.00
$100.00
$50.00
$0.00
-$50.00
-$100.00
1 2 3 4 5 6 7 8 9 10 11 12
Cost Variance Trend
Linear Trend
Total Monthly Water Costs
$450.00
$400.00
$350.00
$300.00
$250.00
$200.00
$150.00
$100.00
$50.00
$0.00
1 2 3 4 5 6 7 8 9 10 11 12
2009 Total Costs
Water Cost Variance by Month
$350.00
$300.00
$250.00
$200.00
$150.00
$100.00
$50.00
$0.00
-$50.00
-$100.00
1 2 3 4 5 6 7 8 9 10 11 12
Higher Costs
Lower Costs

Your Role, Your Duty and Your Responsibility

*"Don't be put off by people who know what is not possible. Do what **needs to be done**, and then check to see if it was impossible <u>only after</u> you are done."*

Paul Hawken

University of Portland Graduation Address

May 2009

Your Role, Your Duty and Your Responsibility

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- The "Global Ponzi Scheme" – Lester Brown

  "*We are stealing from the future, selling it in the present and calling it Gross Domestic Product*"

HOW ABOUT YOU?....It's never too late to be what you might have been. (George Elliot)