Getting from AEDGs to Zero Energy Buildings

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Learning Objectives

► What is an Advanced Energy Design Guide?
► Which building types are the 50% AEDGs available for?
► What is a net-zero energy building?
► Are there real net-zero energy buildings today and how are they performing?
► Which technologies does it take to get to net-zero energy?
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Approved for 1 LU/HSW by AIA, course CRAWLEY06

Getting from AEDGs to Zero Energy Buildings

By Drury B. Crawley

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Course ID: 0920010370
Buildings energy use worldwide

U.S. Buildings Energy Use

Commercial Buildings Energy End-Uses 2017

Other Uses, 34.1%
First Steps Towards Zero Energy:

Advanced Energy Design Guides (AEDGs)

AEDGs? 50%?

Advanced Energy Design Guide (AEDG):

- Multiple ways, but **not the only ways** to build energy-efficient buildings that use significantly less energy than a code-minimum building (ASHRAE/IESNA Standard 90.1-2004)
- Six original guides targeted 30% energy savings: Small Office, Small Retail, K-12 Schools, Small Warehouse, Small hotel, and Small Hospital
- Five 50% guides completed – halfway towards a net-zero energy building
AEDG Development

- Collaboration among four organizations
- DOE provided research funding for national labs and technical reports
- Volunteer effort (2250 - 5000 hours each guide)
- Two Peer Reviews
- Educational guidance – not a Standard

Focus

- New Non-residential Construction
- Also applicable to:
  - Complete/Major Renovations
  - Building Additions
  - Remodeling/Modernization Projects
  - Systems Upgrades
- AEDG requirements include Opaque Envelope, Fenestration, Daylighting, Lighting, HVAC, SWH, Plug, Kitchen Equipment, Quality Assurance – Cx, M&V, benchmarking
- Includes Additional Bonus Savings
AEDG for Small to Medium Office Buildings: 50% Savings

World Climate Zones -- Standard 169-2013 Addenda A
Recommendations Tables

Medium Office with Radiant System
50% AEDGs Available

- Small to Medium Offices
- K-12 Schools
- Medium to Big Box Retail
- Large Hospitals
- Grocery Stores

All the AEDGs available as free download from: [www.ashrae.org/aedg](http://www.ashrae.org/aedg)

Technical support documents describing process and results are available here: [www.ashrae.org/technical-resources/aedgs/50-aedg-technical-support-documents](http://www.ashrae.org/technical-resources/aedgs/50-aedg-technical-support-documents)

Beginning in 2018: Zero Energy AEDGs

- Demonstrate that zero energy buildings are attainable
- Provide direction for designing and constructing in all climate zones
- Offer methodology for achieving energy goals that are:
  - Financially feasible
  - Operationally workable
  - Readily achievable
  - Measurable goals
- Coming in 2020 – Multifamily Buildings
Keys to Getting to Zero

- High Performance Learning Environments
- Collaboration and iteration
- Engage with all the stakeholders – teachers, community, school district, parents, facility managers and elected officials
- Set Energy Targets
- Simulate/Model/Commission/Measure/Verify

Zero Energy AEDG Summary

- Zero energy buildings are achievable and affordable
- Provide enhanced learning environment
- Engages community
- Commitment of all stakeholders critical
- Teamwork and iteration necessary
Increased Stringency in Energy Efficiency and Green Standards

Can we get to Net Zero Energy Buildings?
What is an Zero Energy Building (ZEB)?

- 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.

Boundaries

- Building and its site
- Campus: set of closely related buildings
- Community of buildings
- Portfolio of buildings (single owner, different locations)
Technical Potential

- Assessment of the Technical Potential Achieving Net Zero-Energy Buildings Commercial Sector
  www.nrel.gov/docs/fy08osti/41957.pdf

- Methodology for Analyzing the Technical Potential for Energy Performance Across the Commercial Sector
  www.nrel.gov/docs/fy08osti/41956.pdf

- ASHRAE Research Project 1651-RP (completed updated this analysis for ASHRAE energy standards development; savings of >45% over 90.1-2010. Report free for members:

ZEB Characteristics

Number of floors impacts ability to reach ZEB goal

- Roof area
- Daylighting
Energy Efficiency

Need 60% to 70% decrease in energy consumption of commercial buildings in order for renewables to supply the balance.

Great Potential in Commercial Buildings

What we’ve proven we can do
Low Energy Buildings

Where we are today
90 (152) existing commercial buildings

Where we would be if all buildings were built to current code
70.7 (80) new building base scenario

Where we could be with current technologies
49.3 (60) Max. Tech energy efficient scenario

Add renewables and we are almost to net-zero
12.1 (15) Max. Tech energy efficient scenario w/ PV
Great Potential: Real ZEB Commercial Buildings

<table>
<thead>
<tr>
<th>Building</th>
<th>Location</th>
<th>Floor Area, ft² (m²)</th>
<th>Annual Purchased Energy kBtu/ft²-y (MJ/m²-y)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aldo Leopold Legacy Center</td>
<td>Baraboo, WI</td>
<td>11,300 (1050)</td>
<td>-2.02 (-24.9)</td>
</tr>
<tr>
<td>Audubon Center at Debs Park</td>
<td>Los Angeles, CA</td>
<td>5,020 (465)</td>
<td></td>
</tr>
<tr>
<td>Challengers Tennis Club</td>
<td>Los Angeles, CA</td>
<td>3,500 (325)</td>
<td>-0.096 (-1.09)</td>
</tr>
<tr>
<td>Environmental Tech. Center, Sonoma State</td>
<td>Rohnert Park, CA</td>
<td>2,200 (205)</td>
<td>-1.47 (-16.69)</td>
</tr>
<tr>
<td>Hawaii Gateway Energy Center</td>
<td>Kailua-Kona, HI</td>
<td>3,600 (335)</td>
<td>-3.46 (-39.29)</td>
</tr>
<tr>
<td>IDeAs Z2 Design Facility</td>
<td>San Jose, CA</td>
<td>6,560 (610)</td>
<td>-0.00032 (-0.00039)</td>
</tr>
<tr>
<td>Oberlin College Lewis Center</td>
<td>Oberlin, OH</td>
<td>13,600 (1263)</td>
<td>-4.23 (-48.036)</td>
</tr>
<tr>
<td>Science House</td>
<td>St. Paul, MN</td>
<td>1,530 (145)</td>
<td>0</td>
</tr>
</tbody>
</table>

High-Performance Buildings Database

First Database with Net-Zero Energy Buildings
## System Details

<table>
<thead>
<tr>
<th>Building</th>
<th>Building Use</th>
<th>PV System Size, kW</th>
<th>% Savings w/o PV</th>
<th>Floors</th>
<th>HVAC System Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aldo Leopold</td>
<td>Commercial office</td>
<td>406</td>
<td>70%</td>
<td>1</td>
<td>GSHP; Radiant Slab; Earth-Tube; Natural Ventilation</td>
</tr>
<tr>
<td>Audubon Center</td>
<td>Recreation; Park</td>
<td>25</td>
<td>-</td>
<td>1</td>
<td>Solar Hot Water; Absorption Chiller; Natural Ventilation</td>
</tr>
<tr>
<td>Challengers Tennis Club</td>
<td>Recreation</td>
<td>6</td>
<td>60%</td>
<td>2</td>
<td>Natural Ventilation</td>
</tr>
<tr>
<td>Environmental Tech., Center, Sonoma State</td>
<td>Higher education: Laboratory</td>
<td>3</td>
<td>80%</td>
<td>1</td>
<td>Natural Ventilation; Passive Solar Heating; Thermal Mass; Radiant Heating</td>
</tr>
<tr>
<td>Hawaii Gateway</td>
<td>Commercial office</td>
<td>20</td>
<td>80%</td>
<td>1</td>
<td>Natural Ventilation; Cold Sea Water to Cool Air</td>
</tr>
<tr>
<td>IDeAs 22</td>
<td>Commercial office</td>
<td>30</td>
<td>60%</td>
<td>2</td>
<td>GSHP; Radiant Slab</td>
</tr>
<tr>
<td>Oberlin College</td>
<td>Higher education: Library; Assembly</td>
<td>160</td>
<td>54%</td>
<td>2</td>
<td>GSHP; Radiant Slab</td>
</tr>
<tr>
<td>Science House</td>
<td>Interpretive Center</td>
<td>8.8</td>
<td>60%</td>
<td>1</td>
<td>GSHP; Natural Ventilation; Passive Solar Heating</td>
</tr>
</tbody>
</table>
NIST Net-Zero Energy Residential Test Facility

- Test facility designed to be 60% more efficient than homes built to current standards
- Operating at net-zero energy for first three years of operation
- Photovoltaic and solar thermal panels provide power and hot water
- Efficient systems
- Super insulated
- Typical layout of local homes
- USGBC LEED Platinum

Floor plans
Technologies Being Tested
- Photovoltaic power
- Thermal solar
- Heat pump water heater
- Super insulated walls, roof, floors, windows, foundation
- Heat recovery ventilator
- Building envelope air tightness
- IAQ/VOCs
- Dedicated outside air
- Decoupled dehumidification
- High efficiency appliances (washer, dryer, cooktop, dishwasher)
- Multiple geothermal heat exchangers installed: vertical borehole, horizontal u-tube, horizontal slinky configurations
- Long-term net-zero energy impacts

Previous year measured energy use
Large Zero Energy Building!

Department of Energy
National Renewable Energy Lab
Research Support Facilities (RSF)

Objectives

- Critical
  - Health and Life Safety
  - LEED Platinum
  - Energy Star

- Goal
  - 220,000 ft² (20,000 m²)
  - 800 people
  - 35 kBTU/ft²-y (400 MJ/m²-y)
  - 100 kW data center
  - Flexible
  - BIM / energy model
  - Complete in 2010

- Stretch
  - Net zero energy
  - Most energy efficient building in world
  - LEED Platinum Plus
  - ASHRAE 90.1 + 50%
### Energy Modeling

**NREL RSF Energy Use Breakdown**

<table>
<thead>
<tr>
<th>Energy End-Use</th>
<th>kBtu/ft²·y</th>
<th>MJ/m²·y</th>
</tr>
</thead>
<tbody>
<tr>
<td>Space Heating</td>
<td>8.58</td>
<td>97.44</td>
</tr>
<tr>
<td>Space Cooling</td>
<td>0.85</td>
<td>9.66</td>
</tr>
<tr>
<td>Pumps</td>
<td>0.48</td>
<td>5.46</td>
</tr>
<tr>
<td>Ventilation Fans</td>
<td>1.88</td>
<td>21.35</td>
</tr>
<tr>
<td>Domestic Hot Water</td>
<td>0.90</td>
<td>10.22</td>
</tr>
<tr>
<td>Exterior Lights</td>
<td>0.12</td>
<td>1.36</td>
</tr>
<tr>
<td>Lights</td>
<td>2.07</td>
<td>23.51</td>
</tr>
<tr>
<td>Office Plug Loads</td>
<td>7.87</td>
<td>90.34</td>
</tr>
<tr>
<td>Task Lights</td>
<td>0.10</td>
<td>1.14</td>
</tr>
<tr>
<td>Data Center Power</td>
<td>12.11</td>
<td>137.53</td>
</tr>
<tr>
<td>Data Center Cooling</td>
<td>0.02</td>
<td>0.23</td>
</tr>
<tr>
<td>Data Center Fans</td>
<td>0.20</td>
<td>2.27</td>
</tr>
</tbody>
</table>
Technologies to Get to Zero?

- Modularity
- Massing (long axis E-W)
- Double skin
- Daylighting – Shading
- Natural Ventilation
- Thermal labyrinth
- Data center heat recovery
- Data center cooling
- PV

What did they achieve?

- LEED Platinum 58 of 69 LEED-NC points
- Operating at net zero-energy including and site mounted PV (since July 2011)
- Energy use: 35.4 kBTU/ft²-y (400 MJ/m²-y) vs predicted 35.1 kBTU/ft²-y
- Peak plug loads of 0.35 W/ft² (3.7 W/m²) vs predicted 0.55 W/ft² (6 W/m²)
- 100% of workstations are daylit
- Peak LPD of 0.3 W/ft² (3.2 W/m²)
- Work space for 800 staff, 220,000 ft² (20,000 m²)
- [www.nrel.gov/about/sustainable-buildings.html](http://www.nrel.gov/about/sustainable-buildings.html)
And in 2011, A New Wing for RSF

Objectives
- 27 kBtu/ft²-y (300 MJ/m²-y)
- 50% energy cost savings
- Assured performance with incentives

Results
- 20 kBtu/ft²-y (230 MJ/m²-y) measured
- 17% more efficient than RSF
- 5% capital cost savings
- 500 more staff
- 140,000 ft² (13,000 m²)
  for total of 360,000 ft² (33,500 m²)

Walgreens
Evanston, Illinois
Walgreens Objectives

- First net-zero energy retail store in the US
- LEED Platinum
- Living Building Challenge Net Zero Certification
- Open in 14 months – design and construction

What Technologies Did They Use?

- Ultra-high-efficiency mechanical and refrigeration system
- CO₂ refrigerant
- Geothermal heat pump
- All LED lighting – 0.9 W/ft² (10 W/m²)
- Daylighting, with 5 zones
- Natural ventilation with operable windows
- Building automation
- 850 solar panels (220,000 kWh annually)
- Two wind turbines
How did they do?

- 40% less energy than conventional store
- Model for future stores and remodels
- First year they were 15% short – corrective actions made

Bullit Center
Seattle, Washington
Bullit Center Objectives

- Greenest building in the world
- Meet all requirements of the Living Building Challenge:
  - Net-zero energy
  - Net-zero water
  - Non-toxic materials
  - Increased functional ecosystem area
  - Enhance human health
  - Contribute to social equity
  - Emphasize beauty
- Integrated Building Design
- Living laboratory
What Features Did They Incorporate?

- EUI of 16 kBtu/ft²-y (180 MJ/m²-y)
- Triple-glazed, low-e, operable windows (natural ventilation)
- Daylighting for all occupants
- Rainwater harvesting, vortex, ceramic filters (reverse osmosis) and UV treatment for potable water
- Composting toilets
- Durability – structure designed for 250-year life
- Local and safe materials
- Ground-source heating pump
- Solar canopy (242 kW) covers roof and provides overhangs
Radiant Heating

What did they achieve?

- Living Building Challenge Certified
- LEED Platinum
- Operating at net-zero energy and water
Case studies of zero energy buildings worldwide

- More than 40 zero energy buildings with detailed technical information and data on energy performance
- Non-residential buildings
- Residential buildings
NZEB Worldwide

batchgeo.com/map/net-zero-energy-buildings

IEA BCS Annex 52, 2013

Online Case Study Library

www.worldgbc.org/case-study-library
Many new ZEBs and ZECs!

Growth in Zero Energy

But don’t ZEBs cost a lot more?

Sustainable Cities and Society
Volume 45, February 2019, Pages 324-334

Does zero energy building cost more? – An empirical comparison of the construction costs for zero energy education building in United States

Ming Hu

So, are these Tomorrow’s Buildings?

Probably More Like NREL RSF
And these NZE Buildings

Or this building in Brazil
Summary

- Today’s energy standards are pushing buildings to use 60% less energy than 40 years ago.

- Beyond those energy standards and codes:
  - Possible today to cost-effectively construct residential and non-residential buildings that use substantially less energy.
  - Guidelines exist to help designers those savings another 50% and now for schools... ZEB!

- Low and net zero energy buildings are being constructed and operated today worldwide.

No Single Metric Tells the Building Performance Story

- Energy
- Demand
- Cost
- Water
- IEQ
- Carbon

- Business
  (sales, student, occupied room, business unit: barrel of beer, case of wine)
50% AEDGs Available

- Small to Medium Offices
- K-12 Schools
- Medium to Big Box Retail
- Large Hospitals
- Grocery Stores

- All the AEDGs available as free PDF download from: www.ashrae.org/aedg

- Technical support documents describing the process and results are available here: www.ashrae.org/technical-resources/aedgs/50-aedg-technical-support-documents

Zero Energy AEDGs

- K-12 Schools
- Small/Medium Office Buildings

- Coming in 2020 – Multifamily Buildings
Thank you!

Questions?

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GBCI Approved | 1 CE Hour | 0920010370
AIA Approved | 1 LU/HSW | CRAWLEY06

https://climate.onebuilding.org
NIST Net-Zero Energy Residential Test Facility

- [https://www.nist.gov/el/net-zero-energy-residential-test-facility](https://www.nist.gov/el/net-zero-energy-residential-test-facility)
- Documentation, plans, technical specifications
- Data, research reports, annual energy use and production

IEA Annex Case studies of zero energy buildings worldwide

- Case studies:
More on the NZEB NREL Research Support Facility

- NREL RSF web site:
  www.nrel.gov/about/sustainable-buildings.html

- The Design-Build Process for the Research Support Facility
  www.nrel.gov/docs/fy12osti/51387.pdf

- Reducing Data Center Loads for a Large-Scale, Net Zero Office Building
  www.nrel.gov/docs/fy12osti/52786.pdf