
Getting to Zero-Energy Buildings: AEDGs to ZEBs

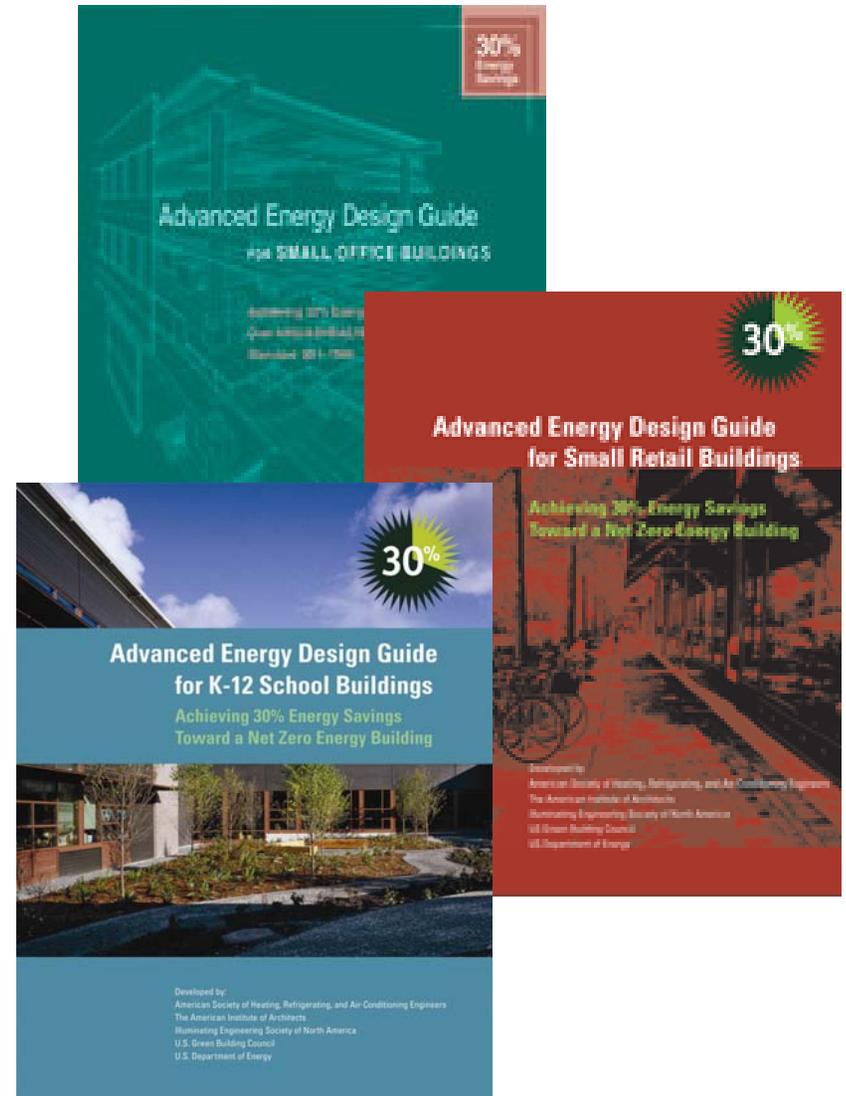
Drury B Crawley
U S Department of Energy



Energy Efficiency and Renewable Energy

30% Advanced Energy Design Guides

- ASHRAE, IESNA, AIA, USGBC, and DOE developing series of energy design guides for achieving 30% lower energy than 90.1
- Prescriptive tabular approach
- Small office guide published 2005, retail guide in late 2006, and K-12 schools in early 2008.
- **LEED points without simulation!**
- Warehouse guide released in April 2008, followed by highway lodging and healthcare guides in late 2009.
- www.ashrae.org/aedg



Development Objectives

- Provide a way, but not the only way to achieve 30% energy savings relative to 90.1-1999
- Provide recommendations (prescriptive measures) and design strategies (“how to implement” tips)
- Energy savings as the independent variable - Use of practical, off-the-shelf technology
- Provide user-friendly document targeting contractors, design/build firms and designers involved in smaller buildings (< 20K ft²)
- LEED points: 4 E&A credits

Recommendation Tables

Climate Zone 5 Recommendation Table

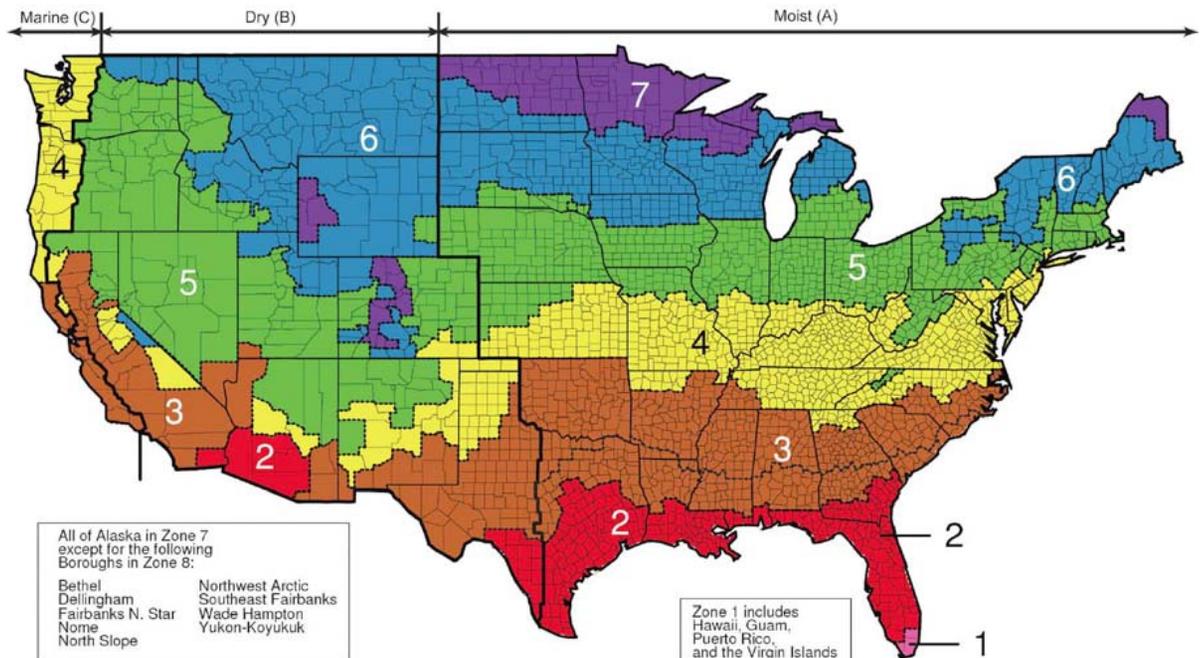
Item	Component	Recommendation	How-to's in Chapter 4
Roof	Insulation entirely above deck	R-20 c.i.	EN2, 17, 20-21
	Metal building	R-13 + R-19	EN3, 17, 20-21
	Attic and other	R-38	EN4, 17-18, 20-21
	Single rafter	R-38 + R-5 c.i.	EN5, 17, 20-21
	Surface reflectance/emittance	No recommendation	
Walls	Mass (HC > 7 Btu/ft ²)	R-11.4 c.i.	EN6, 17, 20-21
	Metal building	R-13 + R-13	EN7, 17, 20-21
	Steel framed	R-13 + R-7.5 c.i.	EN8, 17, 20-21
	Wood framed and other	R-13 + R-3.8 c.i.	EN9, 17, 20-21
	Below-grade walls	R-7.5 c.i.	EN10, 17, 20-21
Floors	Mass	R-10.4 c.i.	EN11, 17, 20-21
	Steel framed	R-30	EN12, 17, 20-21
Slabs	Wood framed and other	R-30	EN12, 17, 20-21
	Unheated	No recommendation	EN17, 19-21
Doors	Heated	R-10 for 36 in.	EN14, 17, 19-21
	Swinging	U-0.70	EN15, 20-21
Vertical Glazing	Non-swinging	U-0.50	EN16, 20-21
	Window to wall ratio (WWR)	20% to 40% maximum	EN23, 36-37
	Thermal transmittance	U-0.42	EN25, 31
	Solar heat gain coefficient (SHGC)	N, S, E, W - 0.46 N only - 0.46	EN27-28
	Window orientation	$(A_{N1} \cdot SHGC_{N1} + A_{S1} \cdot SHGC_{S1}) > (A_{N2} \cdot SHGC_{N2} + A_{W2} \cdot SHGC_{W2})$	A_{N1} - Window area for orientation x EN26-32
Skylights	Exterior sun control (S, E, W only)	Projection factor 0.5	EN24, 28, 30, 36, 40, 42 DL5-6
	Maximum percent of roof area	3%	DL5-7, DL8, DL13
	Thermal transmittance	U-0.69	DL7, DL8, DL13
Interior Lighting	Solar heat gain coefficient (SHGC)	0.39	DL8, DL13
	Lighting power density (LPD)	0.9 W/ft ²	EL1-2, 4, 8, 10-16
	Light source (linear fluorescent)	90 mean lumens/watt	EL4, 9, 17
	Ballast	Electronic ballast	EL4
	Dimming controls for daylight harvesting for WWR 25% or higher	Dim fixtures within 12 ft of N/S window wall or within 8 ft of skylight edge	DL1, 9-11, EL6-7
	Occupancy controls	Auto-off all unoccupied rooms	DL2, EL5, 6
	Interior room surface reflectances	80%+ on ceilings, 70%+ on walls and vertical partitions	DL3-4, EL3
HVAC	Air conditioner (0-65 KBtuh)	13.0 SEER	HV1-2, 4, 6, 12, 16-17, 20
	Air conditioner (>65-135 KBtuh)	11.0 EER/11.4 IPLV	HV1-2, 4, 6, 12, 16-17, 20
	Air conditioner (>135-240 KBtuh)	10.8 EER/11.2 IPLV	HV1-2, 4, 6, 12, 16-17, 20
	Air conditioner (>240 KBtuh)	10.0 EER/10.4 IPLV	HV1-2, 4, 6, 12, 16-17, 20
	Gas furnace (0-225 KBtuh - SP)	80% AFUE or E_f	HV1-2, 6, 16, 20
	Gas furnace (0-225 KBtuh - Split)	90% AFUE or E_f	HV1-2, 6, 16, 20
	Gas furnace (>225 KBtuh)	80% E_f	HV1-2, 6, 16, 20
	Heat pump (0-65 KBtuh)	13.0 SEER/7.7 HSPF	HV1-2, 4, 6, 12, 16-17, 20
	Heat pump (>65-135 KBtuh)	10.6 EER/11.0 IPLV/3.2 COP	HV1-2, 4, 6, 12, 16-17, 20
	Heat pump (>135 KBtuh)	10.1 EER/11.0 IPLV/3.1 COP	HV1-2, 4, 6, 12, 16-17, 20
Economizer	Air conditioners & heat pumps - SP	Cooling capacity > 54 KBtuh	HV23
Ventilation	Outdoor air damper	Motorized control	HV7-8
	Demand control	CO ₂ sensors	HV7, 22
Ducts	Friction rate	0.08 in. w.c./100 feet	HV9, 18
	Sealing	Seal class B	HV11
	Location	Interior only	HV9
	Insulation level	R-6	HV10
Service Water Heating	Gas storage	90% E_f	WH1-4
	Gas instantaneous	0.81 EF or 81% E_f	WH1-4
	Electric storage 12 kW	EF > 0.99 - 0.0012xVolume	WH1-4
	Pipe insulation (d<1½ in./ d≥1½ in.)	1 in./ 1½ in.	WH6

Note: If the table contains "No recommendation" for a component, the user must meet the more stringent of either Standard 90.1 or the local code requirements in order to reach the 30% savings target.

- Energy-saving recommendations for each climate zone on **single page**
- Tables color-coded to maps
- Prescriptive recommendations identify energy savings without costly calculations
- References to “how-to” section

What the Design Guides Provide

- Explains integrated design
 - Checklists
 - Suggested targets
- Savings by climate zone
 - 8 climate zones
 - Prescriptive path
 - *No modeling required*
 - Helps earn CHP, LEED, or other credits



How Do I Get the Advanced Energy Design Guides?

- Free download at ashrae.org/freeaedg
 - 50,000 downloads already
- ASHRAE sent out 15,000 free hard copies to U S school districts



What's Next for the AEDGs?

Additional Advanced Energy Design Guides Planned or in Process

- **30% for Highway Lodging (due early 2009)**
- **30% for Healthcare (due spring 2009)**
- **30% for Existing Buildings (2008, 2009)**

- **50% and Beyond towards Net Zero Energy Buildings (2009→)**



Real Low-Energy Buildings

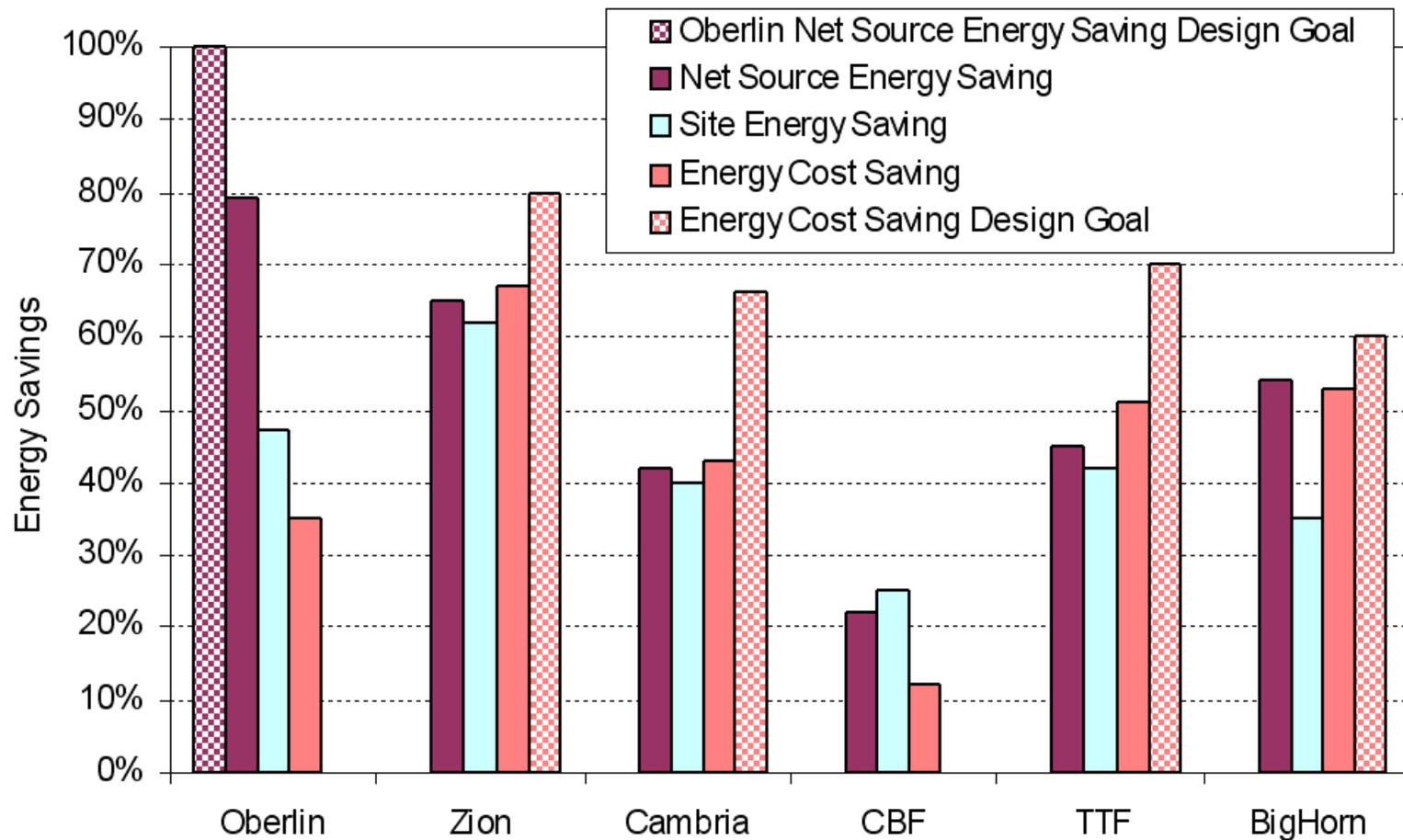
Case Study Buildings

- Oberlin College Lewis Center
 - Oberlin, Ohio
 - goal: zero net site energy use (79%)
- Zion Visitor Center
 - Springdale, UT
 - goal: 70% energy cost savings (65%)
- Cambria Office Building
 - Ebensburg, PA
 - goal: 66% energy cost savings (43%)
- Chesapeake Bay Foundation (CBF)
 - Annapolis, MD
 - goal: LEED 1.0 Platinum Rating (25%)
- Thermal Test Facility (TTF)
 - Golden, CO
 - goal: 70% energy savings (51%)
- BigHorn Home Improvement
 - Silverthorne, CO
 - goal: 60% energy cost savings (53%)



Results

Measured Energy Savings vs. Design Goals

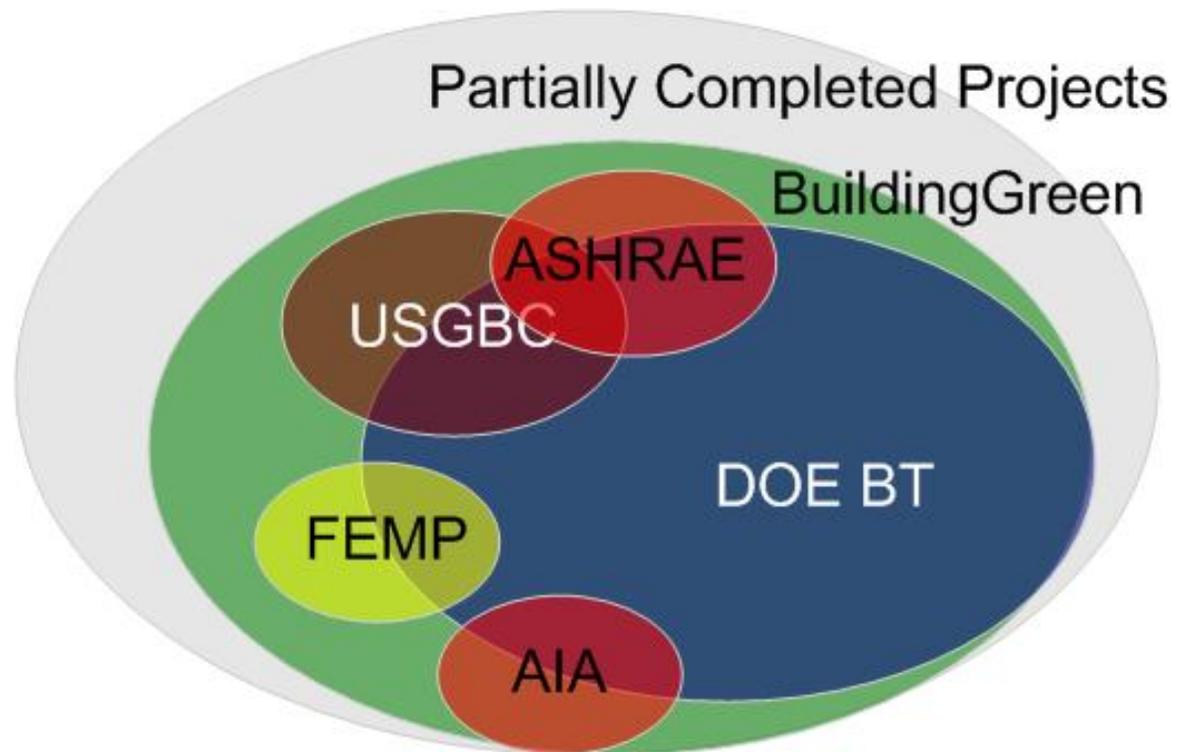




Database of Information on High Performance Buildings

High-Performance Buildings Database

- Share successes and lessons learned about projects
- Public database
- www.highperformancebuildings.gov



Database Partners

- USGBC
- Federal Energy Management Program
 - New Federal buildings must be entered by Executive Order 14123
- AIA Top Ten Winners
- USGBC LEED™ case studies
- Massachusetts Technology Collaborative
- Efficiency Vermont
- USGBC Cascadia Chapter
- Department of Energy
- ASHRAE/IESNA/AIA Advanced Energy Design Guide case studies
- New Buildings Institute (links data from Getting to 50 database)

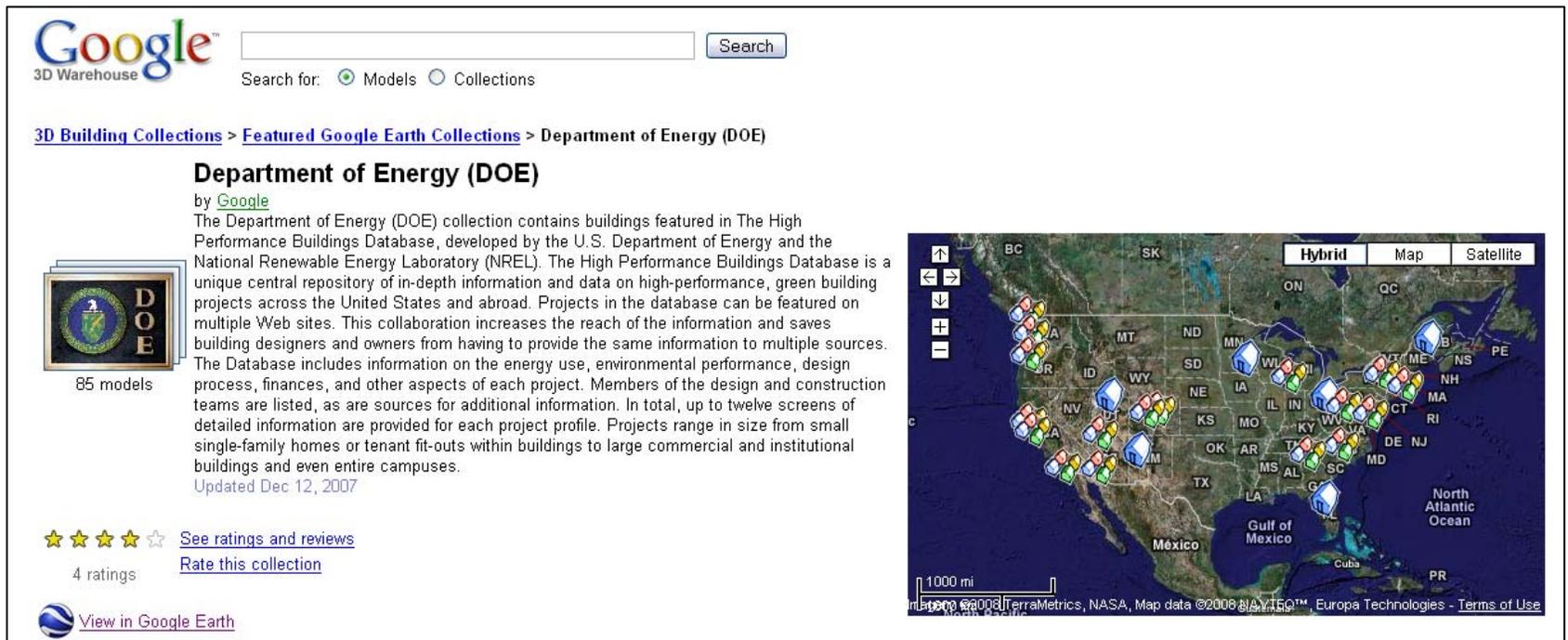
- We know of others that are linking the data
- 3-D models (SketchUp) available for many of the buildings in a new Google Earth layer

Google Earth Layer for High Performance Buildings

- Lives on Google Server
- Can “fly” to any of the featured High Performance Buildings
- Displays buildings in 3D with textures
 - Models can be downloaded into Google SketchUp (not full geometry!)
- Links to HPB Database to show detailed information of building

DOE Building Collections in Google 3D Warehouse

- Provides enhanced display of High Performance Buildings
- Currently contains 85 models (in SketchUp)
- Linked to the HPB Database for additional information



The screenshot displays the Google 3D Warehouse search results for the Department of Energy (DOE) collection. At the top, the Google logo and search bar are visible, with the search term set to "Models". Below the search bar, the breadcrumb navigation shows "3D Building Collections > Featured Google Earth Collections > Department of Energy (DOE)".

The main heading is "Department of Energy (DOE)" by Google. A small thumbnail image of the DOE logo is shown next to the text "85 models". The description states: "The Department of Energy (DOE) collection contains buildings featured in The High Performance Buildings Database, developed by the U.S. Department of Energy and the National Renewable Energy Laboratory (NREL). The High Performance Buildings Database is a unique central repository of in-depth information and data on high-performance, green building projects across the United States and abroad. Projects in the database can be featured on multiple Web sites. This collaboration increases the reach of the information and saves building designers and owners from having to provide the same information to multiple sources. The Database includes information on the energy use, environmental performance, design process, finances, and other aspects of each project. Members of the design and construction teams are listed, as are sources for additional information. In total, up to twelve screens of detailed information are provided for each project profile. Projects range in size from small single-family homes or tenant fit-outs within buildings to large commercial and institutional buildings and even entire campuses." The collection was updated on Dec 12, 2007.

Below the description, there are four stars and a link to "See ratings and reviews", and a link to "Rate this collection". At the bottom left, there is a "View in Google Earth" button. On the right side of the page, there is a map of the United States with numerous colored pins indicating the locations of the buildings in the collection. The map includes a scale bar for 1000 miles and a copyright notice for 2008.

DOE Building Collections in Google 3D Warehouse (cont)

Review building information online

Models in Department of Energy (DOE)

Results 37 - 48 of about 85 (0.1 seconds)

Sorted by date [Sort by rating](#) [Sort by popularity](#)



[Zion Visitors Center](#)
by [Google](#)
As a primary component of the...
[View in Google Earth](#)



[ECHO](#)
by [Google](#)
In October 2003, ECHO at the...
[View in Google Earth](#)



[Ridgehaven Office Building](#)
by [Google](#)
★ ★ ★ ★ ★ (1 rating)
The Ridgehaven Building is a...
[View in Google Earth](#)



[Quabbin Education Support Center](#)
by [Google](#)
The new administrative...
[View in Google Earth](#)



[PNC Firstside Center](#)
by [Google](#)
PNC Firstside Center was...
[View in Google Earth](#)



[Pierce County Environmental Services](#)
by [Google](#)
The Pierce County...
[View in Google Earth](#)



[NREL Wind Site Entrance Building](#)
by [Google](#)
This building serves as a...
[View in Google Earth](#)



[NREL Thermal Test Facility](#)
by [Google](#)
Completed in August of 1996,...
[View in Google Earth](#)



[NREL Solar Energy Research Facility](#)
by [Google](#)
When it was designed in 1992,...
[View in Google Earth](#)



[NREL Science and Technology Facility](#)
by [Google](#)
The Science and Technology...
[View in Google Earth](#)



[Norm Thompson Corporate Headquarters](#)
by [Google](#)
The Norm Thompson...
[View in Google Earth](#)



[NAVFAC Building 33](#)
by [Google](#)
Building 33 is located in the...
[View in Google Earth](#)

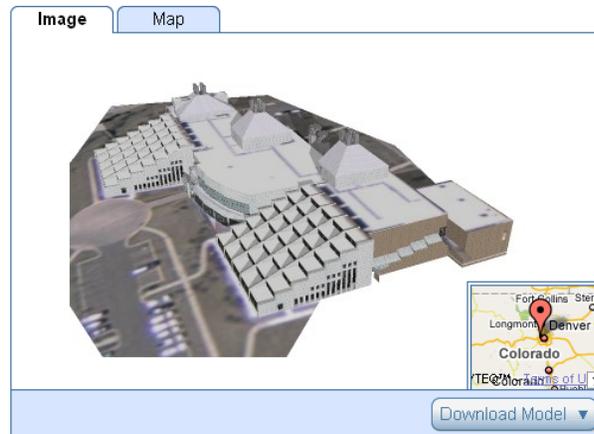


Result Page: [Previous](#) [1](#) [2](#) [3](#) [4](#) [5](#) [6](#) [7](#) [8](#) [Next](#)

DOE Building Collections in Google 3D Warehouse (cont)

Detailed view contains link to HPB database

NREL Solar Energy Research Facility by Google



☆☆☆☆☆ [Rate this model](#)

No ratings

When it was designed in 1992, SERF's annual energy costs were predicted to be 30% lower than a 10CFR435 (federal) reference case. Today (based on data collected in 2002), its energy use is still very close to the 1992 predicted levels. The building has experienced an increase in both occupants and equipment, causing an increase in energy use. However, this was more or less negated through smart retrofits and changes in controls so that the building still operates using approximately 30% less energy than the reference case. The project's long axis faces a few degrees east of due south to capitalize on sunlight for heating and daylighting. This design allows extensive daylighting in the office. Other environmental features include energy-efficient lighting, direct evaporative cooling, a heat recovery system to pre-condition incoming fresh air, over-sized cooling towers to provide indirect evaporative cooling, window glazing and automatic controls, and a Trombe wall.

<http://www.eere.energy.gov/femp/highperformance/overview.cfm?ProjectID=198>

Related Items

Collections containing this model:



[Department of Energy](#)

More models by [Google](#):



[Management Building at Georgia Tech](#)

Model complexity [What's this?](#)



Tags

[energy efficient](#), [department of energy](#), [DOE](#), [Integrated team](#), [Design charrette](#), [Simulation](#), [Performance measurement and verification](#), [Open space preservation](#), [Wildlife habitat](#), [Indigenous vegetation](#), [Drought-tolerant landscaping](#), [Massing and orientation](#), [Insulation levels](#), [Glazing](#), [Passive solar](#), [HVAC](#), [Lighting control and daylight harvesting](#), [Efficient lighting](#), [On-site renewable electricity](#), [Adaptable design](#), [Recycled materials](#), [Occupant recycling](#), [Daylighting](#), [Natural ventilation](#), [Ventilation effectiveness](#), [Moisture control](#), [Thermal comfort](#), [Noise control](#), [Indoor air quality monitoring](#)

Google Earth Layer

Display detailed information
on the featured buildings



High Performance Buildings

NREL Solar Energy Research Facility

- Location: Golden, CO
- Annual Purchased Energy: 359 kBtu/ft²
- Building type(s): Laboratory
- New construction
- 115,000 sq. feet (10,700 sq. meters)
- Project scope: 3-story building
- Suburban setting
- Completed October 1993



[Read the full in-depth case study from the Department of Energy](#)

This case study is also available at
[BuildingGreen.com](#) [High Performance Federal Buildings](#)

Photo credit: Warren Greer

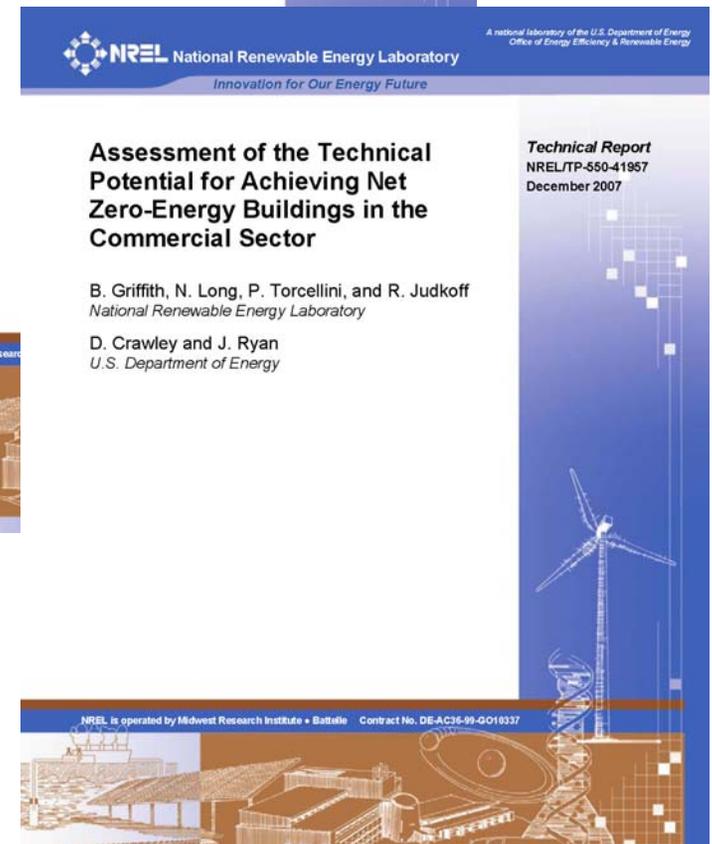
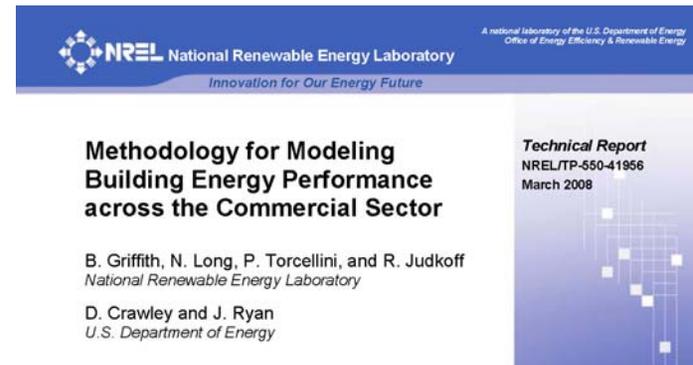


[View 3D model in Google Earth](#)

Can We Get to Zero-Energy?

Assessment of Technical Potential

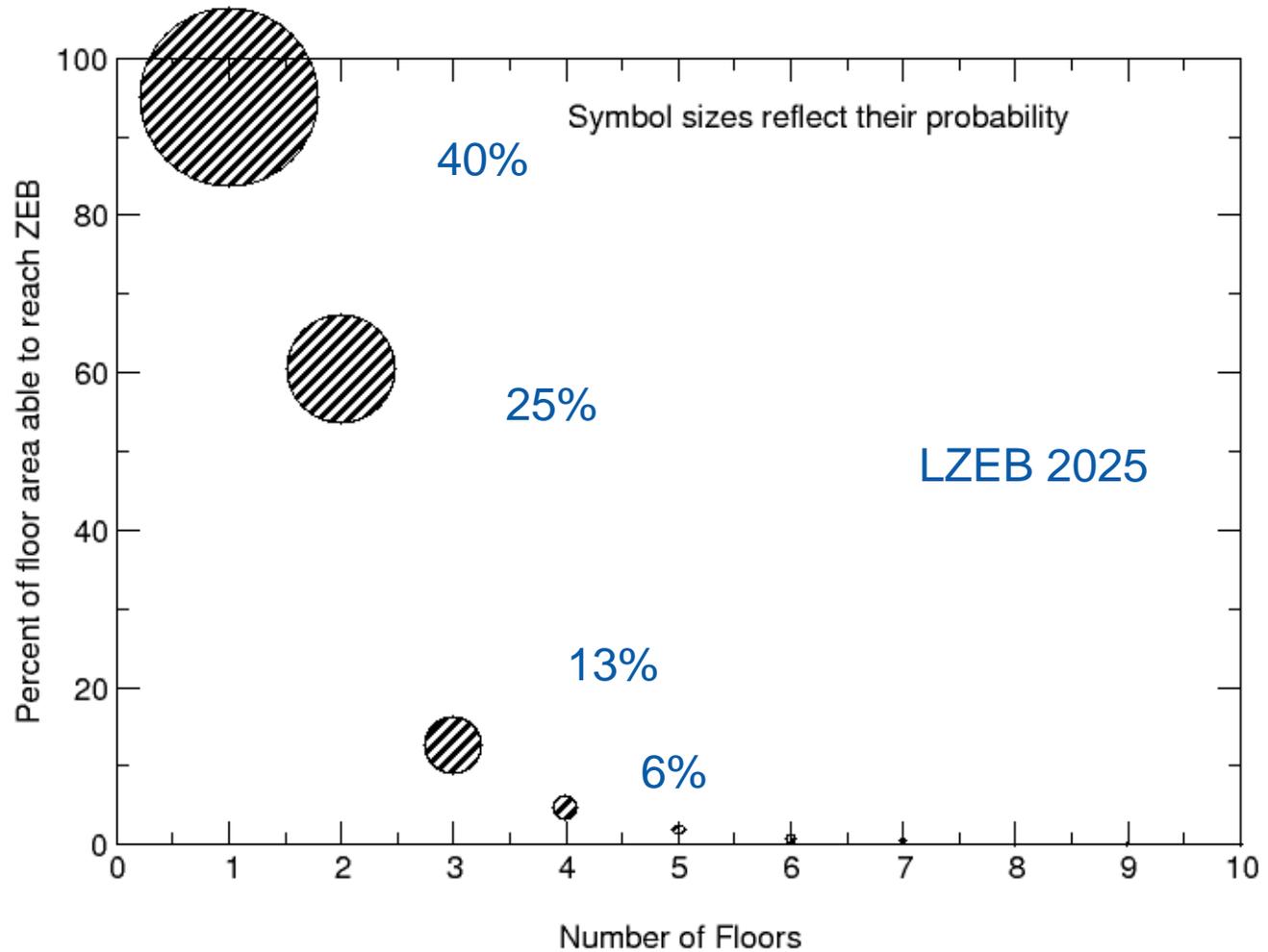
- *Assessment of the Technical Potential for Achieving Net Zero-Energy Buildings in the Commercial Sector*
<http://www.nrel.gov/docs/fy08osti/41957.pdf>
- *Methodology for Analyzing the Technical Potential for Energy Performance Across the Commercial Sector*
<http://www.nrel.gov/docs/fy08osti/41956.pdf>
- **Scenario Analysis Using EnergyPlus Models for 4,820 Samples**
 - Forward modeling allows modeling “what if” scenarios
 - Annual, 15-minute modeling with historical weather files for 2003
 - Detail developed from probability, literature, engineering design, codes, and standards.



ZEB Characteristics

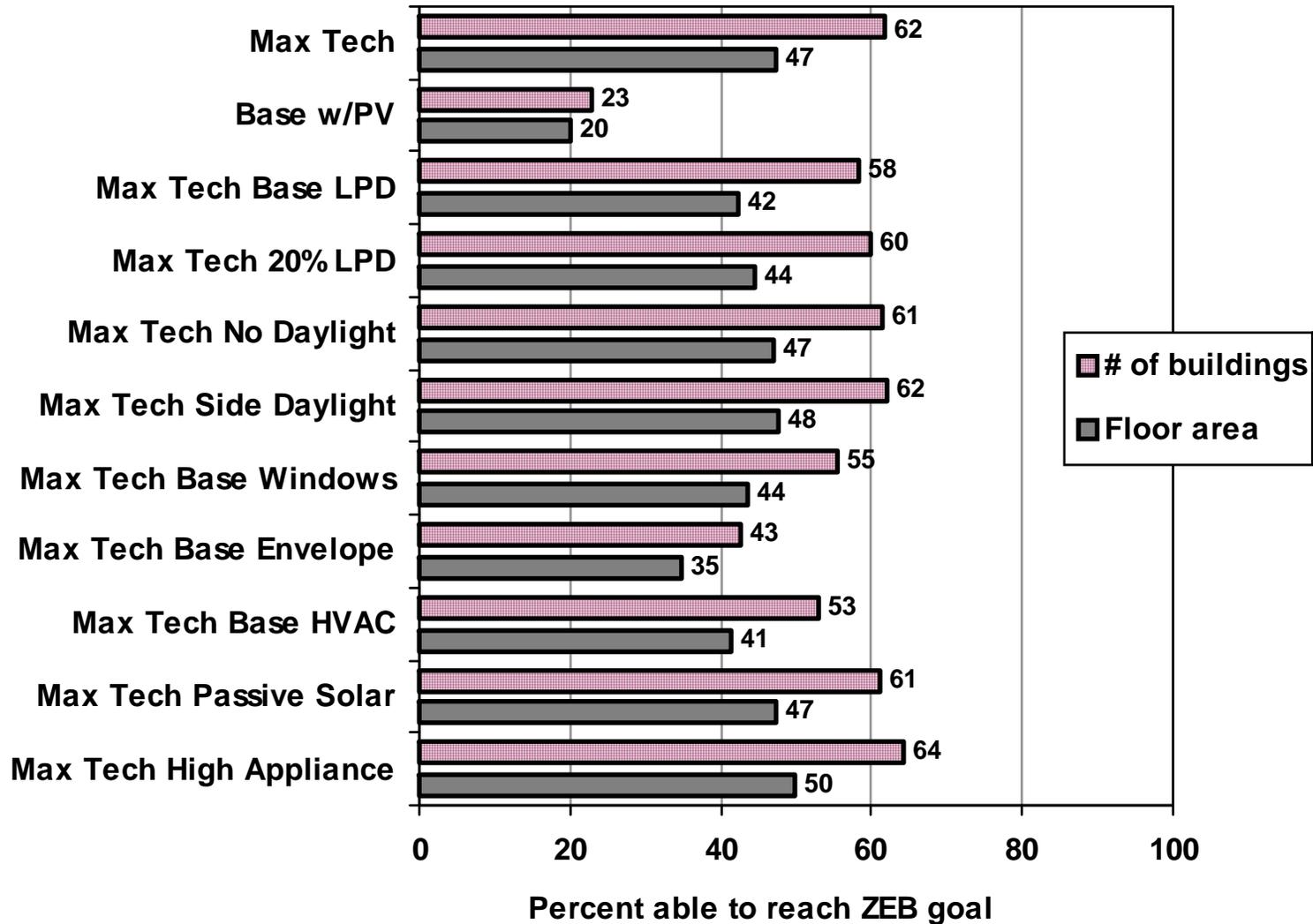
Number of floors impacts ability to reach ZEB goal

- Roof area
- Daylighting



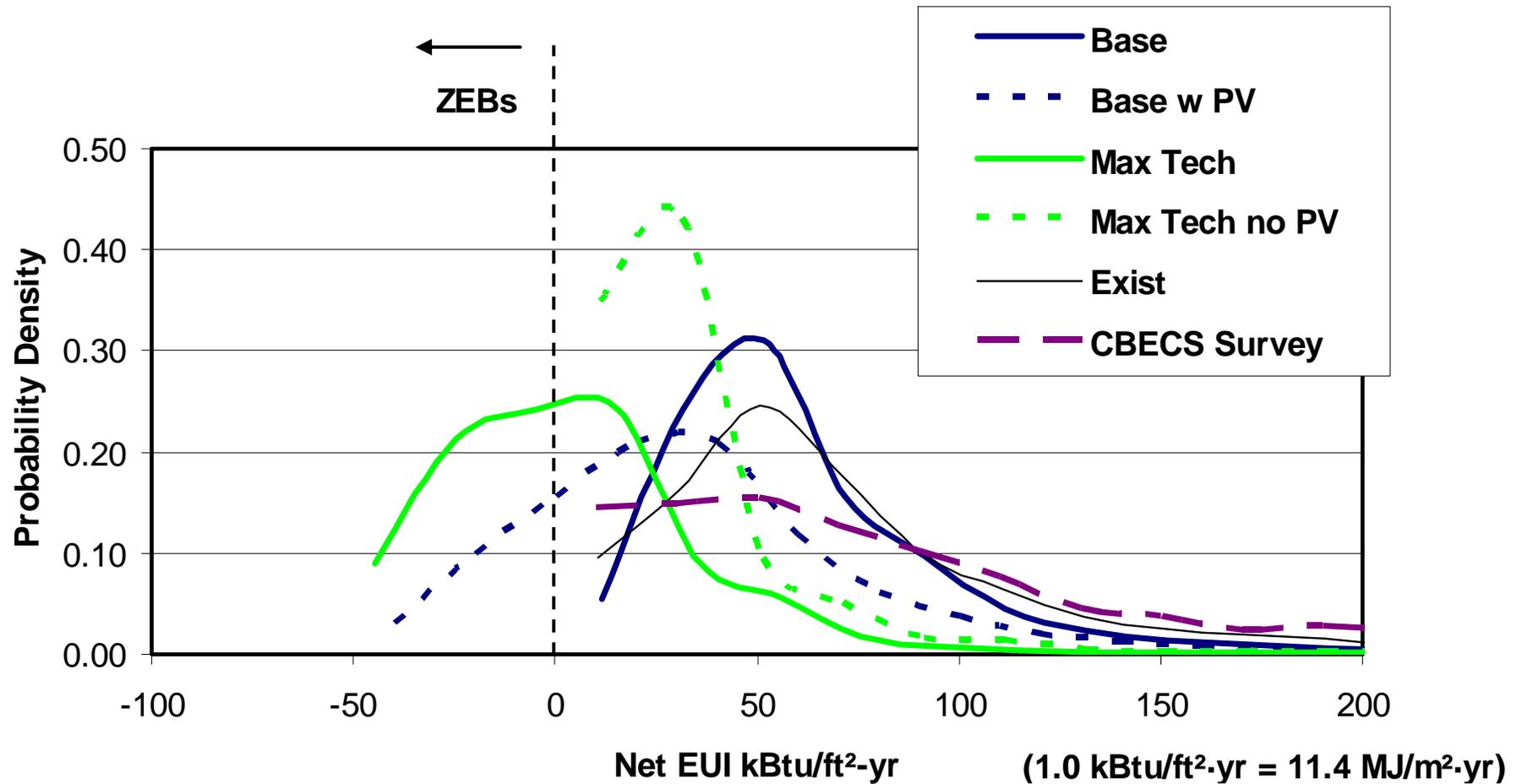
Results

Percent of Commercial Sector That Can Reach ZEB



Results

Net-EUI Distributions from ZEB Assessment



Target EUIs for 30% Savings

- Developed targets by climate zone and principal building activity
- Cited in DOE order 430.2B (Feb. 27, 2008) for federal buildings

Table 1. Target Energy Use Intensities¹ for 30% savings relative to ANSI/ASHRAE/IESNA Standard 90.1-2004² by Subsector and Climate Zone³: IP Units kBtu/ft²-yr

Subsectors	Climate Zones															
	All	1A	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	6A	6B	7	8
All	49	56	47	51	54	40	44	49	39	39	52	45	53	51	52	52
Office/professional	40	39	42	45	37	32	31	42	41	37	42	33	43	43	47	47
Nonrefrigerated warehouse	29	19	21	21	26	21	21	29	35	21	33	35	35	33	32	32
Education	36	36	34	40	29	29	38	42	24	30	37	31	42	45	45	45
Retail (except malls)	47	47	46	46	44	38	38	48	40	40	51	50	53	64	70	70
Public assembly	43	46	46	46	50	37	37	38	33	54	48	35	46	36	49	49
Service	58	58	55	55	42	44	44	55	36	36	64	53	72	60	76	76
Religious worship	31	28	28	28	20	21	21	31	41	41	36	24	40	27	31	31
Lodging	38	45	36	36	37	28	28	40	43	43	39	36	42	45	44	44
Food services	248	248	248	248	266	262	262	257	257	257	235	198	239	239	248	248
Inpatient health care	77	75	75	75	83	69	68	74	74	74	81	74	79	81	81	81
Public order and safety	47	38	38	38	47	47	47	42	42	42	55	54	51	61	61	61
Food sales	127	140	140	140	133	105	105	132	132	132	121	127	146	146	127	127
Outpatient health care	53	53	56	56	45	55	55	46	46	46	63	53	57	55	75	75
Vacant	21	21	16	16	21	14	14	29	29	29	15	15	28	28	28	28
Other	40	51	51	51	40	40	40	40	40	40	43	43	44	44	44	44
Skilled nursing	92	92	92	92	79	72	72	102	102	102	99	74	93	93	93	93
Laboratory	226	226	226	226	226	258	258	191	191	191	219	219	226	226	226	226
Refrigerated warehouse	60	60	60	60	60	60	60	62	60	60	60	60	60	60	60	60

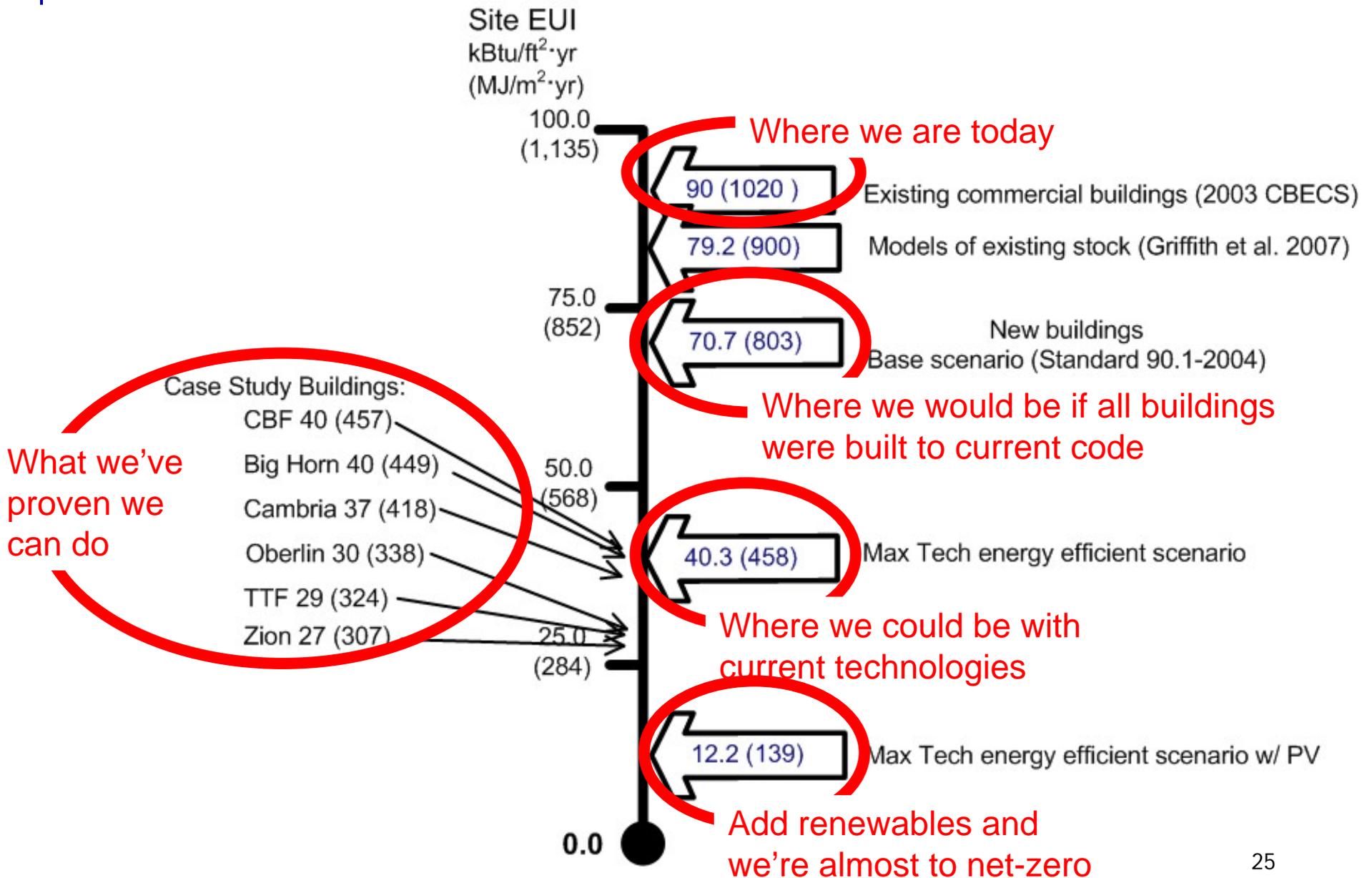
¹ EUIs are site (delivered) energy use for the whole building.

² 30% Targets were developed from modeling results for Standard 90.1-2004 multiplied by 0.7 (listed in Table 2).

³ Climate zones are defined in ANSI/ASHRAE Standard 169-2006.

http://buildings.energy.gov/highperformance/pdfs/energy_use_intensity_targets.pdf

Great Potential for Commercial Building Energy Efficiency



More information

- Office of Building Technologies
buildings.energy.gov
- EnergyPlus
www.energyplus.gov
- High Performance Buildings
www.highperformancebuildings.gov

'Every building is a forecast. Every
forecast is wrong.'

Steward Brand