Getting from AEDGs to Zero Energy Buildings

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ASHRAE Iowa Chapter

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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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Getting from AEDGs to Zero Energy Buildings

By Drury B. Crawley

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General CE hours

LEED GREEN ASSOCIATE

LEED AP BD+C

LEED AP HOMES

LEED AP ID+C

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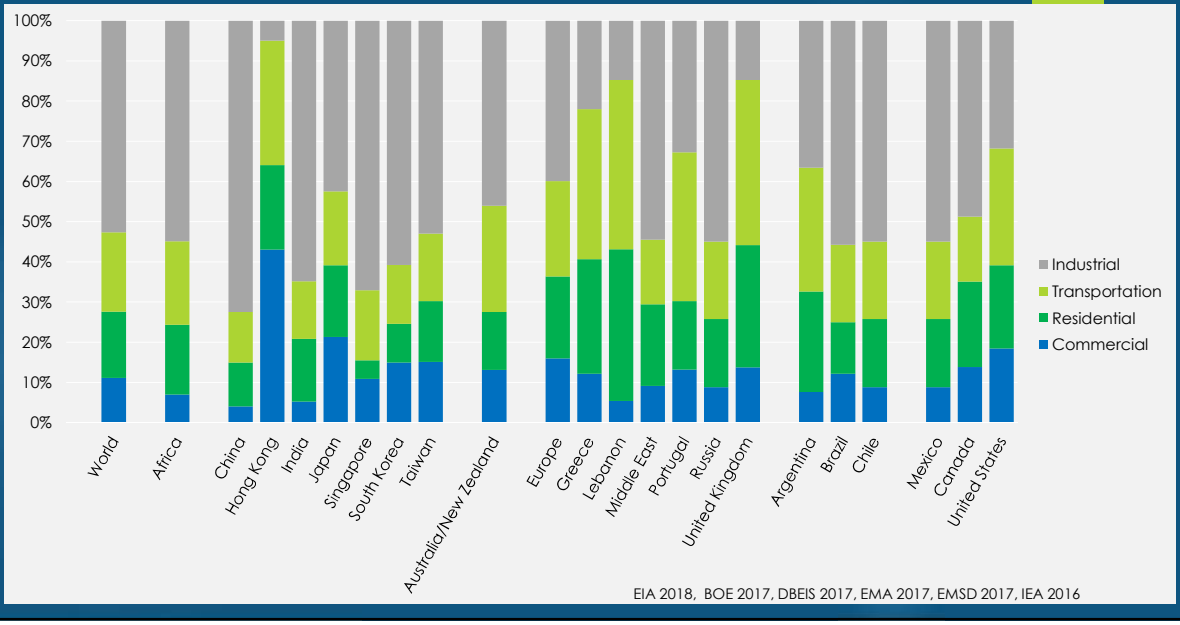
Buildings energy use worldwide



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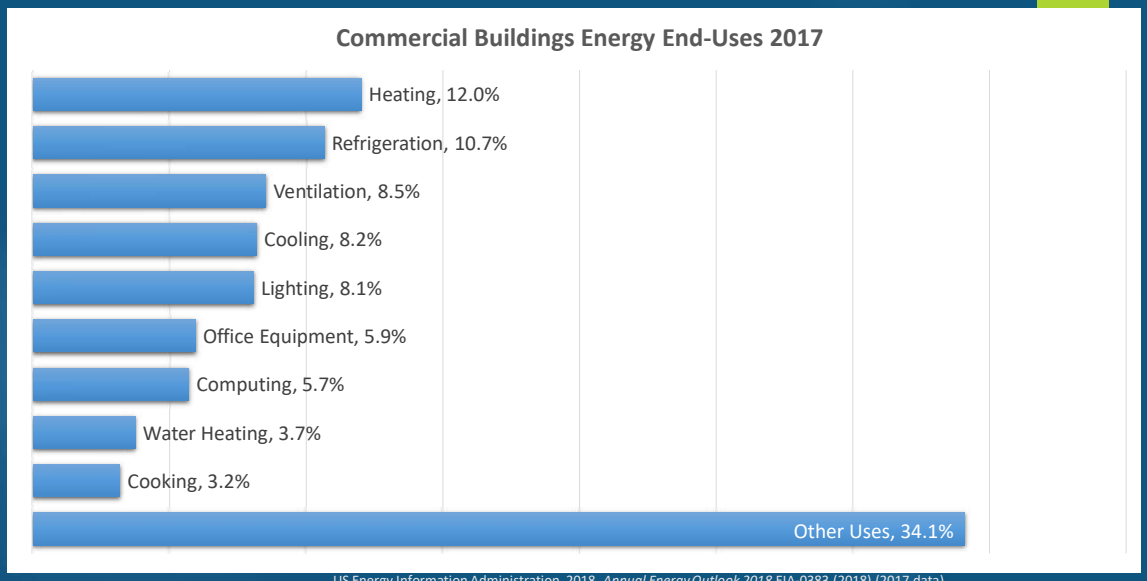
U.S. Buildings Energy Use



US Energy Information Administration. 2018. *Annual Energy Outlook 2018* EIA-0383 (2018) (2017 data)

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First Steps Towards Zero Energy:

Advanced Energy Design Guides (AEDGs)

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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

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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

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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

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AEDG for Small to Medium Office Buildings: 50% Savings

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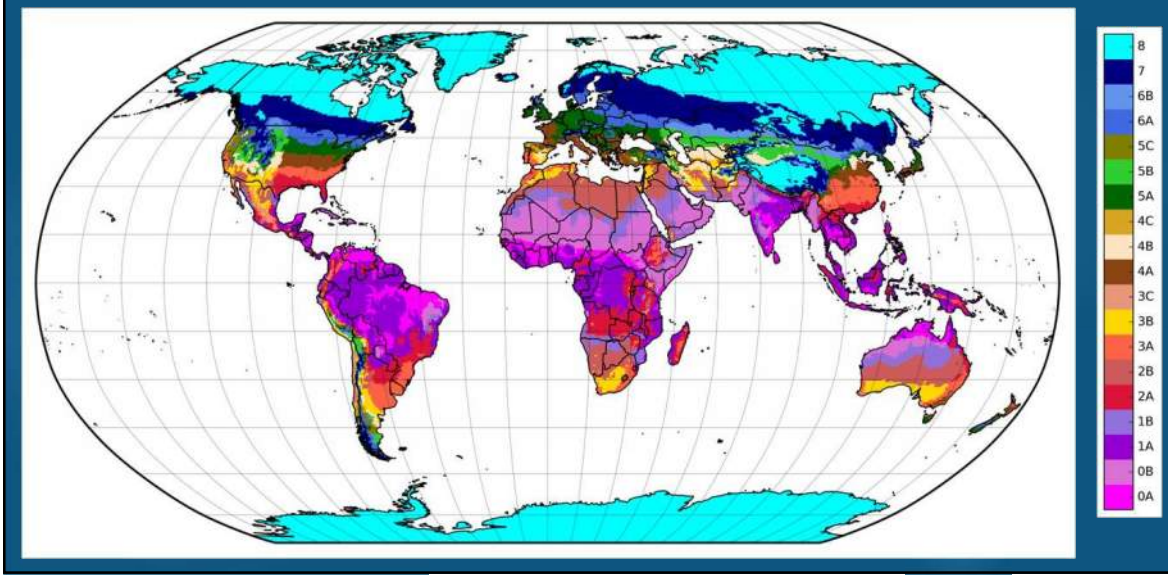
World Climate Zones -- Standard 169-2013 Addenda A



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Recommendations Tables

Climate Zone 5 Recommendation Table for Small to Medium Office Buildings

	Item	Component	Recommendation	How-To Tips	✓
Envelope	Roofs	Insulation entirely above deck	R-30.0 c.i.	EN2, 17, 19, 21–22	
		Attic and other	R-49.0	EN3, 17, 19, 20–21	
		Metal building	R-19.0 + R-11.0 l.s	EN4, 17, 19, 21	
		SRI	No recommendation	None	
	Walls	Mass (HC > 7 Btu/ft²)	R-13.3 c.i.	EN6, 17, 19, 21	
		Steel framed	R-13.0 + R-13.0 c.i.	EN6, 17, 19, 21	
		Wood framed and other	R-13.0 + R-19.0 c.i.	EN7, 17, 19, 21	
		Metal building	R-0.0 + R-19.0 c.i.	EN8, 17, 19, 21	
		Below grade walls	R-7.5 c.i.	EN9, 17, 19, 21–22	
	Floors	Mass	R-14.6 c.i.	EN10, 17, 19, 21	
		Steel joist	R-30.0	EN11, 17, 19, 21	
		Wood framed and other	R-30.0	EN11, 17, 19, 21	
	Slabs	Unheated	R-15.0 for 24 in.	EN12, 14, 17, 19, 21–22	
		Heated	R-20.0 for 24 in.	EN13–14, 17, 19, 21–22	
	Doors	Swinging	U-0.50	EN15, 17–18	
		Nonswinging	U-0.50	EN16–17	
	Vestibules	At building entrance	Yes	EN18	
	Continuous Air Barriers	Continuous air barrier	Entire building envelope	EN17	
	Vertical Fenestration	WWR	20% to 40%	EN25; DL6	
		Window orientation	Area of W and E windows each less than area of S windows (N in southern hemisphere)	EN30–31	
		Exterior sun control (S, E, and W only)	PF-0.5	EN26	
		Thermal transmittance	Nonmetal framing windows = U-0.35 Metal framing windows = U-0.50	EN23–25	
		SHGC	Nonmetal framing windows = 0.25 Metal framing windows = 0.38	EN24, 32–33, DL12	
Daylighting & Lighting	Daylighting	Light-to-solar-gain ratio	Minimum VT/SHGC = 1.10	EN34–42	
		Vertical fenestration EA	0.12	DL7–11	
	Interior Finishes	Interior surface average reflectance	Ceilings = 80% Wall surfaces = 70% Open office partitions = 50%	DL14–15; EL4	
		Open office partitions parallel to window walls	Total partition height = 39 in. maximum - or - Partition above desk height = min 50% translucent	DL4, 10; EL2, 4	
	Interior Lighting	LPD	0.75 W/ft²	DL1–5; EL2–3, 5, 12–19	
		24-hour lighting LPD	0.075 W/ft²	EL20	
		Light source lamp efficacy (mean LPW)	T8 and T5 lamps ≥ 2 ft = 92 T8 and T5 lamps ≤ 2 ft = 85 All other > 50	EL5–8	
		Ballasts	4 ft T8 lamp nondimming applications = NEMA Premium instant start 4 ft T8 lamp dimming applications = NEMA Premium program start Fluorescent and HID sources = electronic	EL9	
		Controls for daylight harvesting in open offices — locate on N and S sides of bldg	Dim all general fluorescent lights within primary and secondary daylight zones of open offices	DL16–20; EL1, 11	
		Automatic controls	Auto ON to 50% = private offices, conference and meeting rooms, lounge and break rooms, copy rooms, storage rooms Auto ON occupancy sensors = restrooms, electrical/mechanical rooms, open and private office task lighting Time switch control = all other spaces	DL13; EL1, 5, 9–10	

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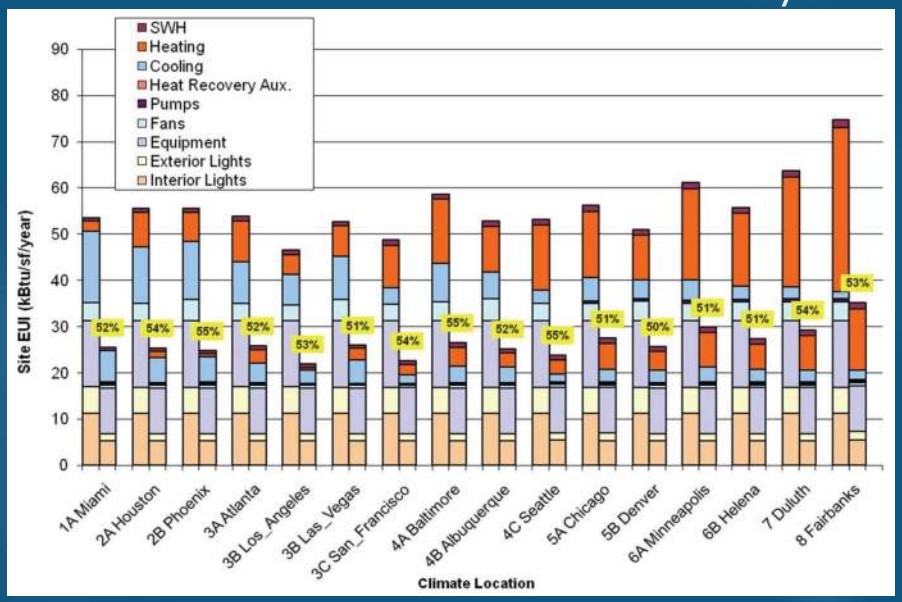
Medium Office with Radiant System



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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

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

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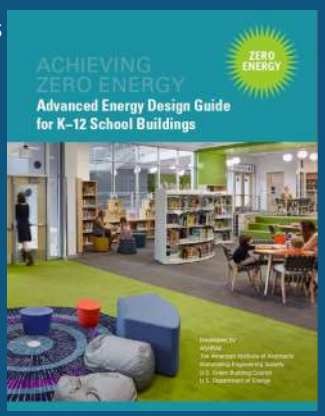
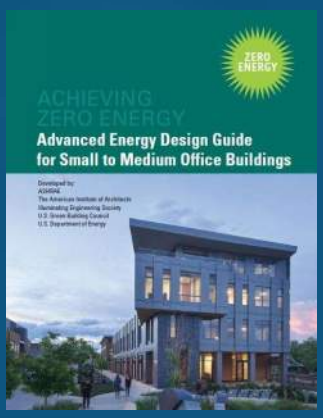
Beginning in 2018: Zero Energy AEDGs

- 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





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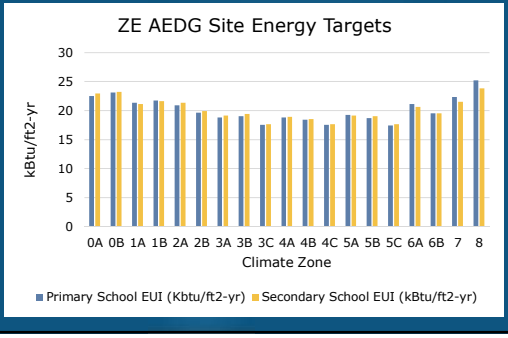
Keys to Getting to Zero

- 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



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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

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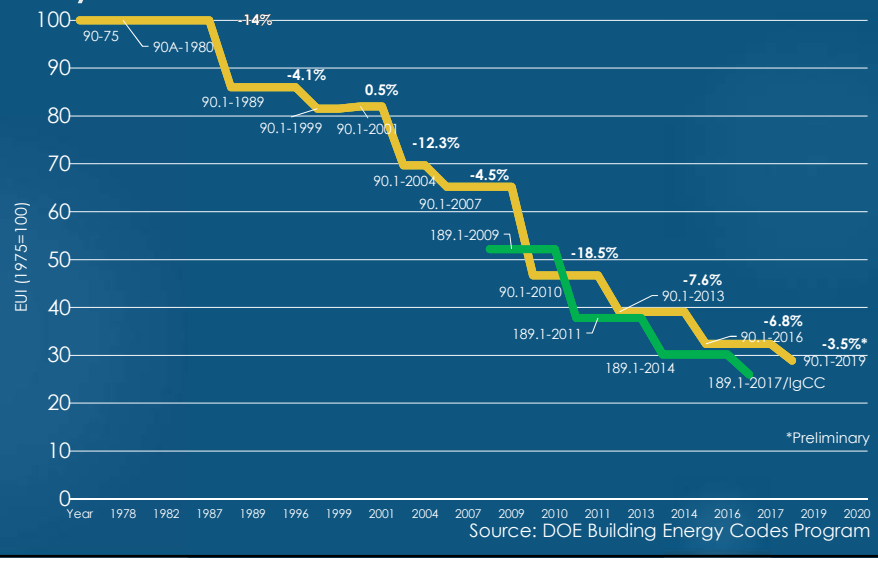
Increased Stringency in Energy Efficiency and Green Standards



Source: DOE Building Energy Codes Program

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Can we get to Net Zero Energy Buildings?

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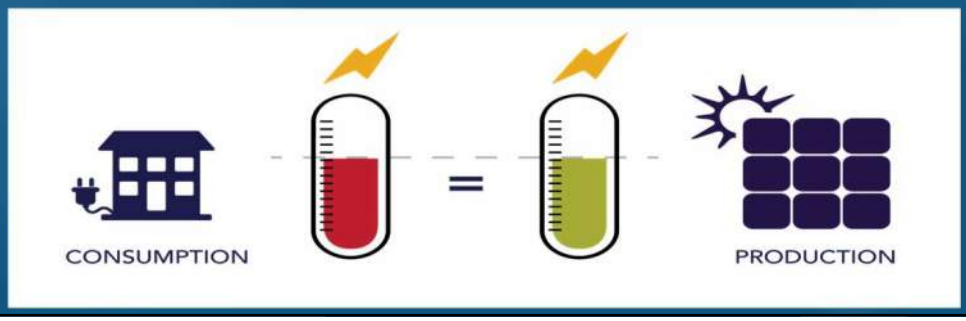
What is an Zero Energy Building (ZEB)?

- 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.



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Boundaries

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

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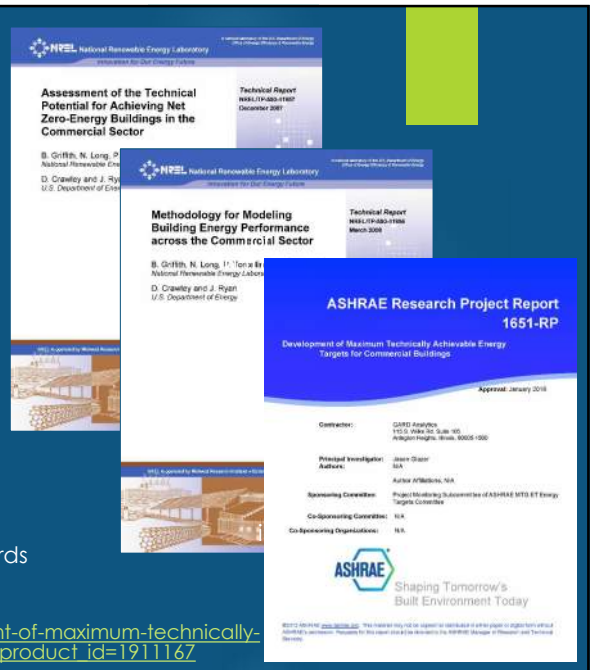
Technical Potential



- 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:

  www.techstreet.com/standards/rp-1651-development-of-maximum-technically-achievable-energy-targets-for-commercial-buildings?product_id=1911167

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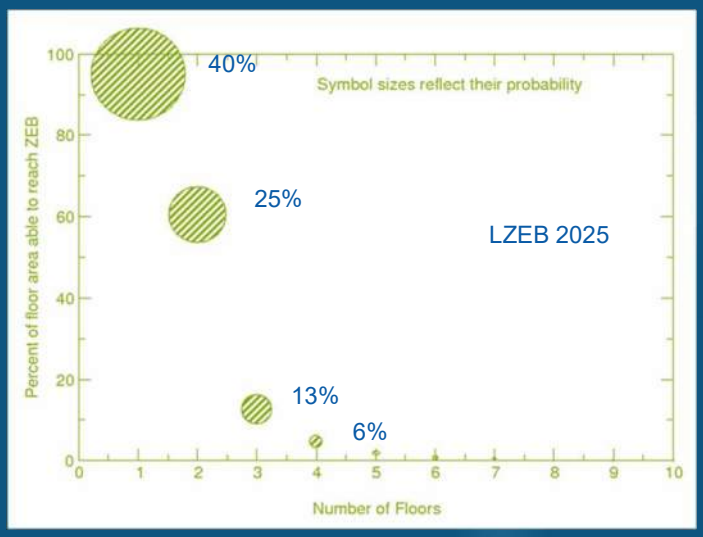
ZEB Characteristics

Number of floors impacts ability to reach ZEB goal

- Roof area
- Daylighting



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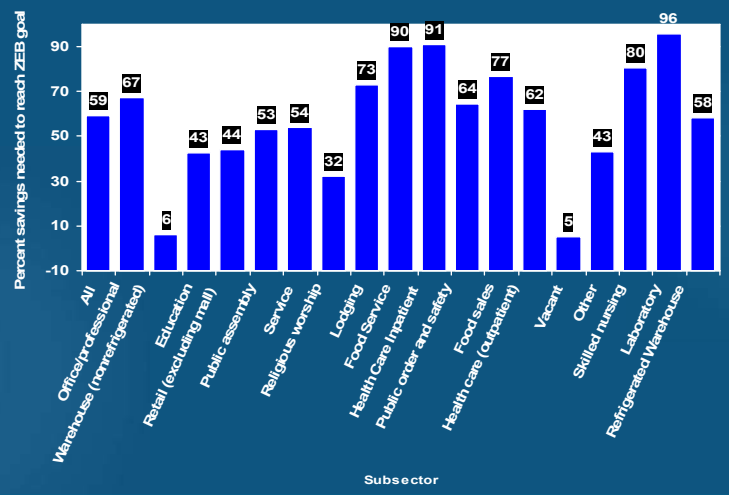
Energy Efficiency



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

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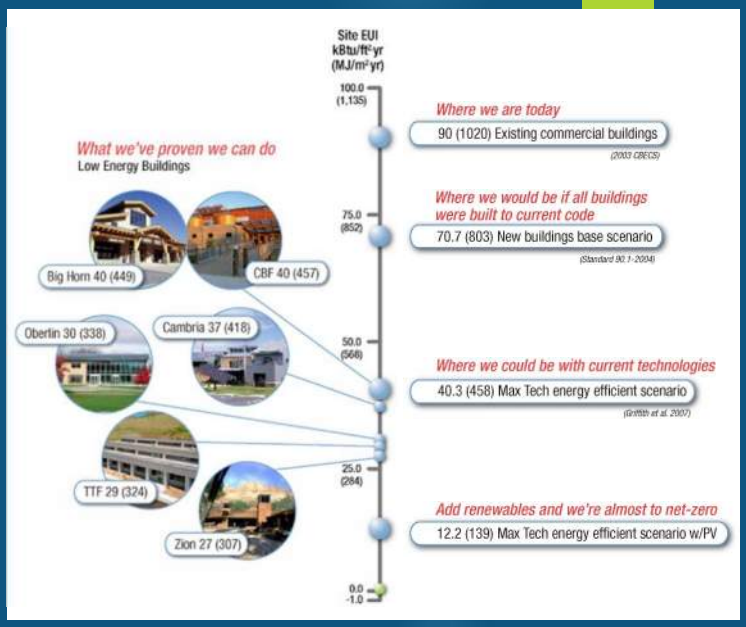
Great Potential in Commercial Buildings



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Great Potential: Real ZEB Commercial Buildings

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High-Performance Buildings Database

First Database with Net-Zero Energy Buildings

Building	Location	Floor Area, ft² (m²)	Annual Purchased Energy, kBtu/ft²-y (MJ/m²-y)
Aldo Leopold Legacy Center	Baraboo, WI	11,300 (1050)	-2.02 (-24.9)
Audubon Center at Debs Park	Los Angeles, CA	5,020 (465)	
Challengers Tennis Club	Los Angeles, CA	3,500 (325)	-0.096 (-1.09)
Environmental Tech. Center, Sonoma State	Rohnert Park, CA	2,200 (205)	-1.47 (-16.69)
Hawaii Gateway Energy Center	Kailua-Kona, HI	3,600 (335)	-3.46 (-39.29)
IDeAs Z2 Design Facility	San Jose, CA	6,560 (610)	-0.00052 (-0.0059)
Oberlin College Lewis Center	Oberlin, OH	13,600 (1265)	-4.23 (-48.036)
Science House	St. Paul, MN	1,530 (145)	0

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System Details

Building	Building Use	PV System Size, kW	% Savings w/o PV	Floors	HVAC System Type
Aldo Leopold	Commercial office	406	70%	1	GSHP; Radiant Slab; Earth-Tube; Natural Ventilation
Audubon Center	Recreation; Park	25	-	1	Solar Hot Water; Absorption Chiller; Natural Ventilation
Challengers Tennis Club	Recreation	6	60%	2	Natural Ventilation
Environmental Tech. Center, Sonoma State	Higher education; Laboratory	3	80%	1	Natural Ventilation; Passive Solar Heating/Cooling; Thermal Mass; Radiant Heating
Hawaii Gateway	Commercial office	20	80%	1	Natural Ventilation; Cold Sea Water to Cool Air
IDeAs Z2	Commercial office	30	60%	2	GSHP; Radiant Slab
Oberlin College	Higher education; Library; Assembly	160	54%	2	GSHP; Radiant Slab
Science House	Interpretive Center	8.8	60%	1	GSHP; Natural Ventilation; Passive Solar Heating

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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

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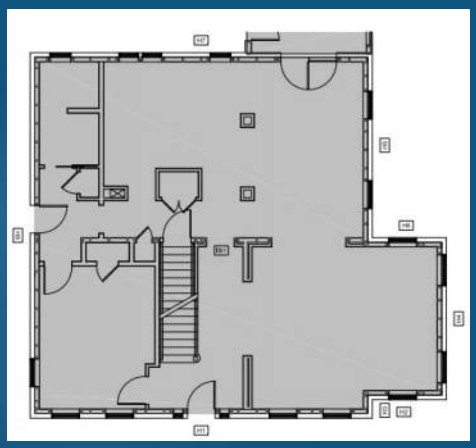
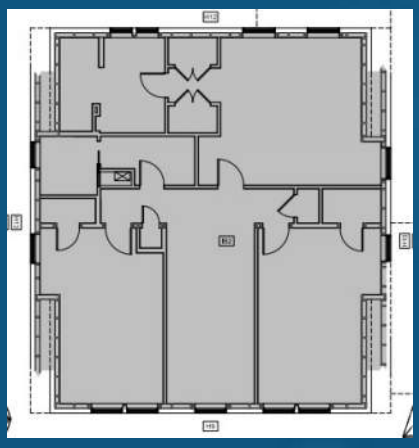
Floor plans





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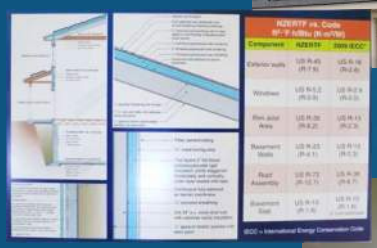
Technologies Being Tested

- 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



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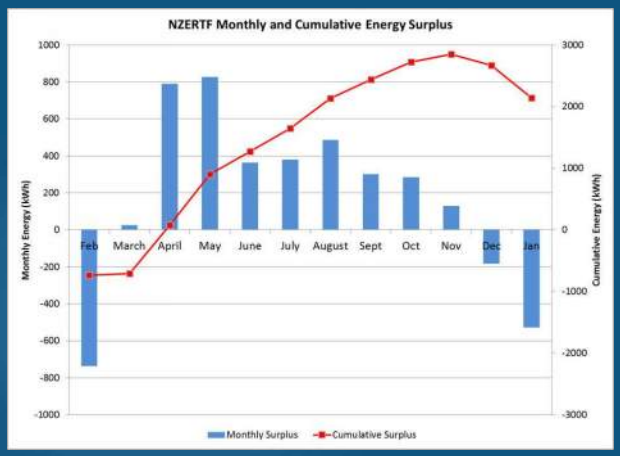
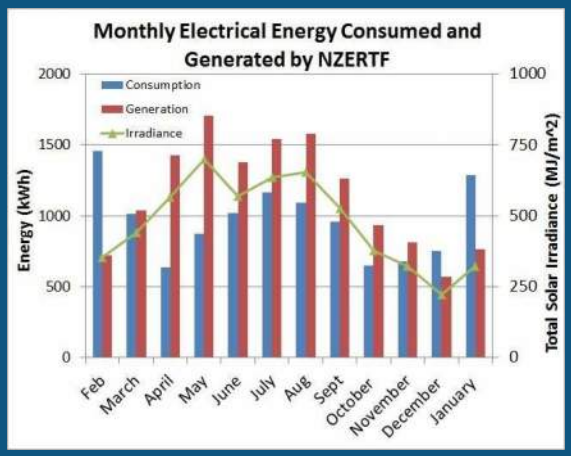
Previous year measured energy use





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Large Zero Energy Building!

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Objectives

- Critical
  - Health and Life Safety
  - LEED Platinum
  - Energy Star
- Goal
  - 220,000 ft^2 (20,000 m^2)
  - 800 people
  - 35 kBtu/ft^2-y (400 MJ/m^2-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%**

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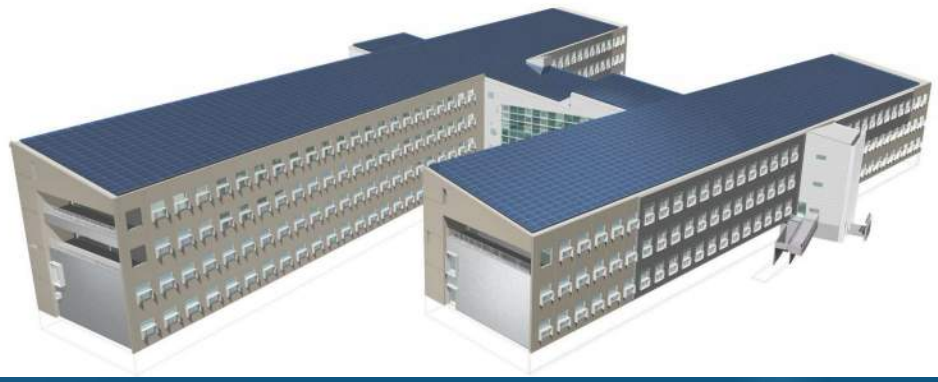
Massing



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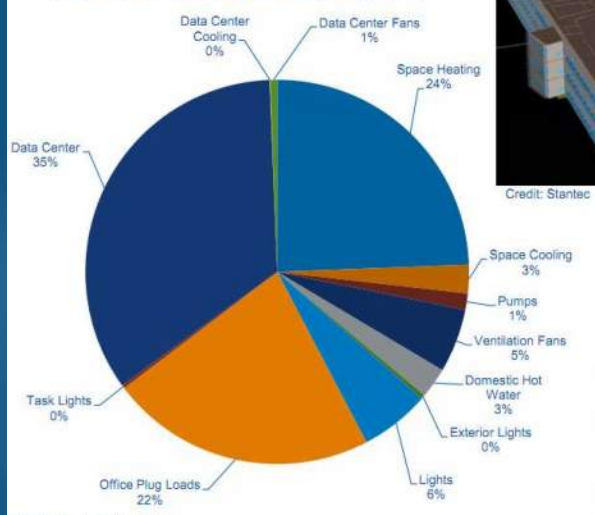
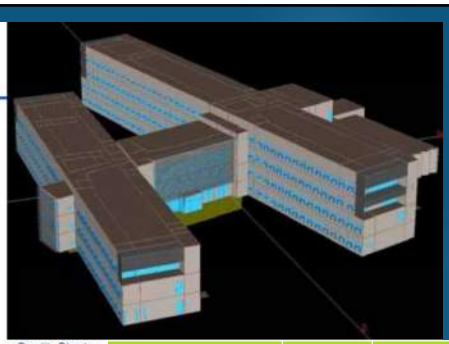
Energy Modeling

NREL RSF Energy Use Breakdown



Credit: Chad Lobato/NREL



Credit: Stantec

Energy End-Use	kBtu/ft²-y	MJ/m²-y
Space Heating	8.58	97.44
Space Cooling	0.85	9.65
Pumps	0.48	5.45
Ventilation Fans	1.88	21.35
Domestic Hot Water	0.90	10.22
Exterior Lights	0.12	1.36
Lights	2.07	23.51
Office Plug Loads	7.87	89.36
Task Lights	0.10	1.14
Data Center Power	12.11	137.53
Data Center Cooling	0.02	0.23
Data Center Fans	0.20	2.27

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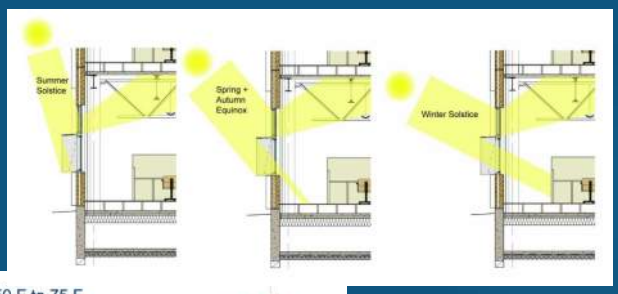
Technologies to Get to Zero?

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



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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/ft^2-y (400 MJ/m^2-y) vs predicted 35.1 kBtu/ft^2-y
- Peak plug loads of 0.35 W/ft^2 (3.7 W/m^2) vs predicted 0.55 W/ft^2 (6 W/m^2)
- 100% of workstations are daylit
- Peak LPD of 0.3 W/ft^2 (3.2 W/m^2)
- Work space for 800 staff, 220,000 ft^2 (20,000 m^2)
- www.nrel.gov/about/sustainable-buildings.html

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And in 2011, A New Wing for RSF

Objectives

- 27 kBtu/ft^2-y (300 MJ/m^2-y)
- 50% energy cost savings
- Assured performance with incentives

Results

- 20 kBtu/ft^2-y (230 MJ/m^2-y) measured
- 17% more efficient than RSF
- 5% capital cost savings
- 500 more staff
- 140,000 ft^2 (13,000 m^2) for total of 360,000 ft^2 (33,500 m^2)

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Walgreens Evanston, Illinois

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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

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What Technologies Did They Use?

- Ultra-high-efficiency mechanical and refrigeration system
- CO_2 refrigerant
- Geothermal heat pump
- All LED lighting – 0.9 W/ft^2 (10 W/m^2)
- Daylighting, with 5 zones
- Natural ventilation with operable windows
- Building automation
- 850 solar panels (220,000 kWh annually)
- Two wind turbines

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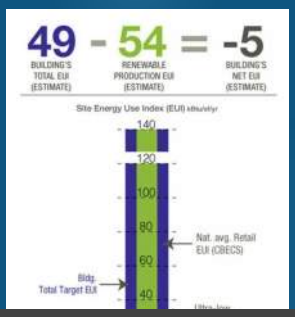
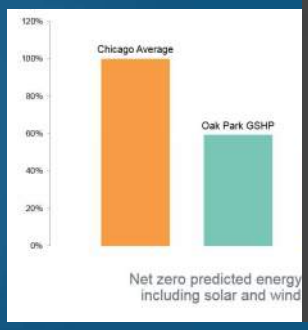
How did they do?

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





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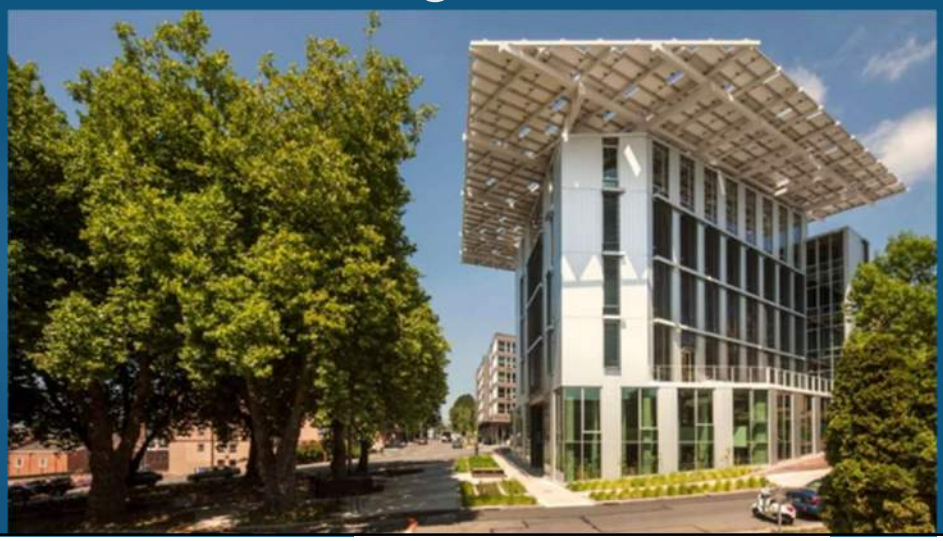
Bullit Center
Seattle, Washington



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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

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What Features Did They Incorporate?

- EUI of 16 kBtu/ft^2-y (180 MJ/m^2-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

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Radiant Heating

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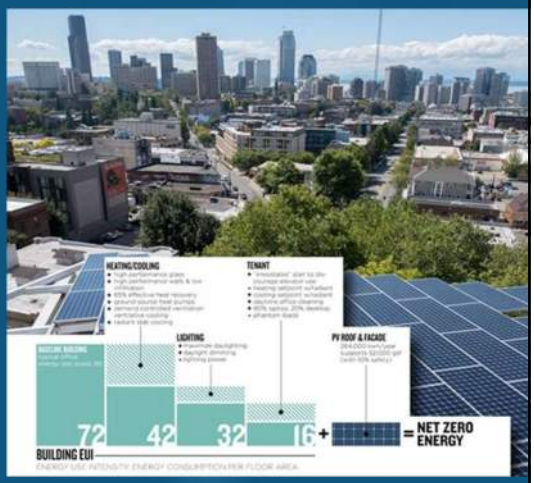
What did they achieve?

- Living Building Challenge Certified
- LEED Platinum
- Operating at net-zero energy and water



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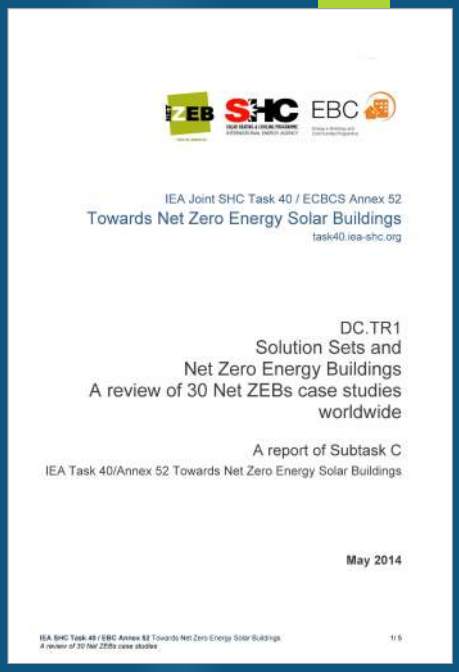
Case studies of zero energy buildings worldwide

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



IEA Joint SHC Task 40 / ECBCS Annex 52

Towards Net Zero Energy Solar Buildings

task40.iea-shc.org

DC.TR1
Solution Sets and
Net Zero Energy Buildings
A review of 30 Net ZEBs case studies
worldwide

A report of Subtask C

IEA Task 40/Annex 52 Towards Net Zero Energy Solar Buildings

May 2014

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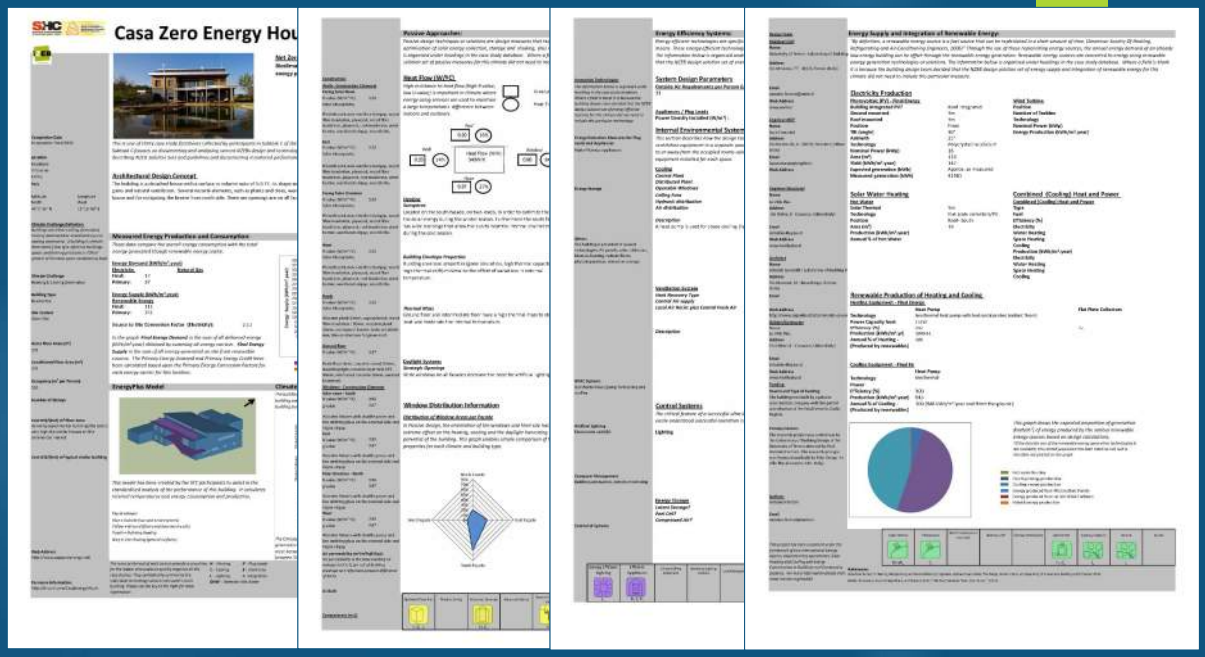

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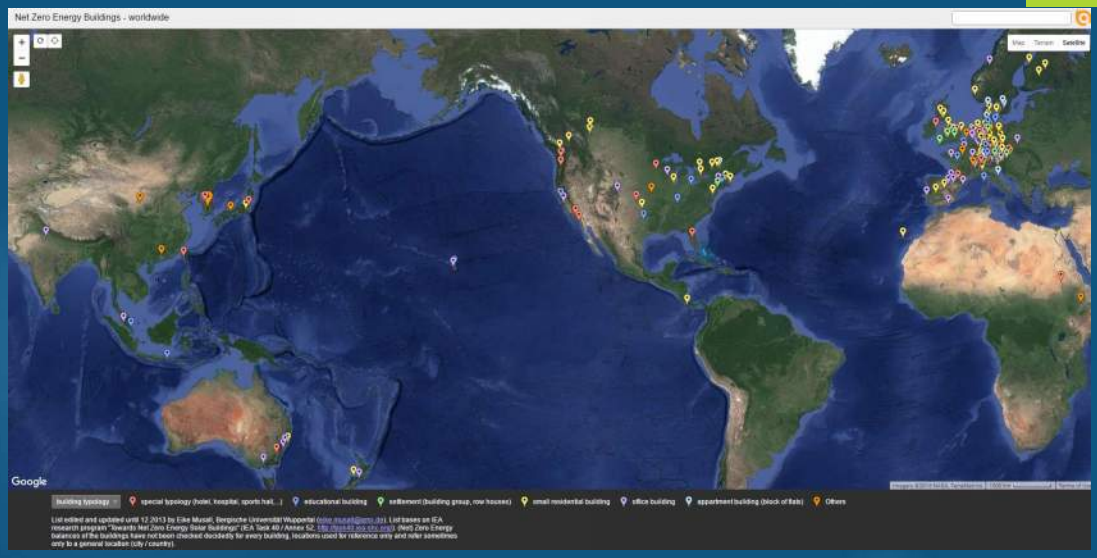
NZEB Worldwide



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

IEA BCS Annex 52, 2013

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WORLD GREEN BUILDING COUNCIL

Online Case Study Library

www.worldgbc.org/case-study-library

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Building type

- Academic
- Commercial
- Healthcare
- Industrial
- Other
- Residential (single)
- Residential (multi-unit)
- Retail

Sustainability focus

- Health & wellbeing
- Net zero carbon
- Industry game-changers
- Commitment signatories

Certification/Rating

- FITWEL
- IGBC Health and Wellbeing
- RESET
- Sustainability Certificate (Health Element)
- WELL Building Standard
- Alliance-HQE E+C-
- Brasil GBC Zero Energy Standard
- CaGBC Zero Carbon Standard
- DGNB Climate Positive
- GBCA Green Star Carbon Neutral
- GBCSA Net Zero / Net Positive Carbon
- Indian GBC Net Zero Energy
- LEED Zero
- Sweden GBC NollCO2
- ILFI Living Building Challenge
- ILFI Zero Energy
- ILFI Zero Carbon

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Many new ZEBs and ZECs!

New Buildings Institute. 2018. Getting to Zero Status Update and List of Zero Energy Projects, Vancouver, WA. newbuildings.org/wp-content/uploads/2018/01/GTZ_StatusUpdate_ZE_BuildingList_2018.pdf

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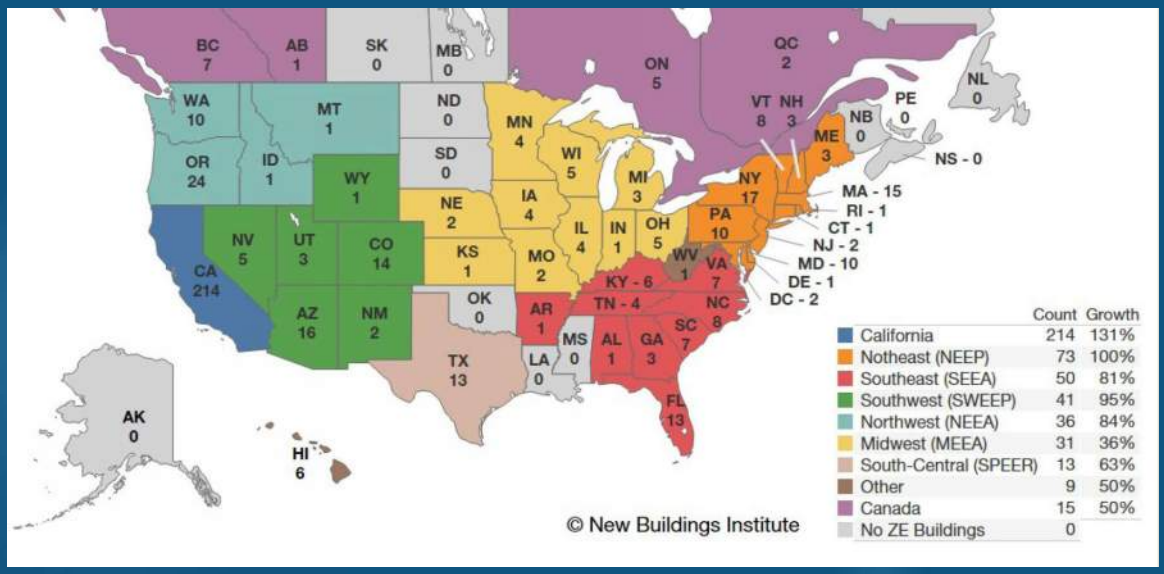
Growth in Zero Energy



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But don't ZEBs cost a lot more?

https://www.sciencedirect.com/science/article/pii/S221067071831237X

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So, are these Tomorrow's Buildings?

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Probably More Like NREL RSF

78

And these NZE Buildings

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Or this building in Brazil

sustentabilidade

HAUS

Paraná chega a 5 empreendimentos autossuficientes em energia e lidera ranking nacional

Com certificação da sede da empresa de engenharia Petinelli, o estado concentra cinco dos sete empreendimentos autossuficientes em energia e certificados no Brasil

Curitiba é autossuficiente em energia e colocou o Paraná como o estado com o maior número de certificações. Fotos: Divulgação

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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

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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)

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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

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Zero Energy AEDGs

- K-12 Schools
- Small/Medium Office Buildings

- Coming in 2020 – Multifamily Buildings

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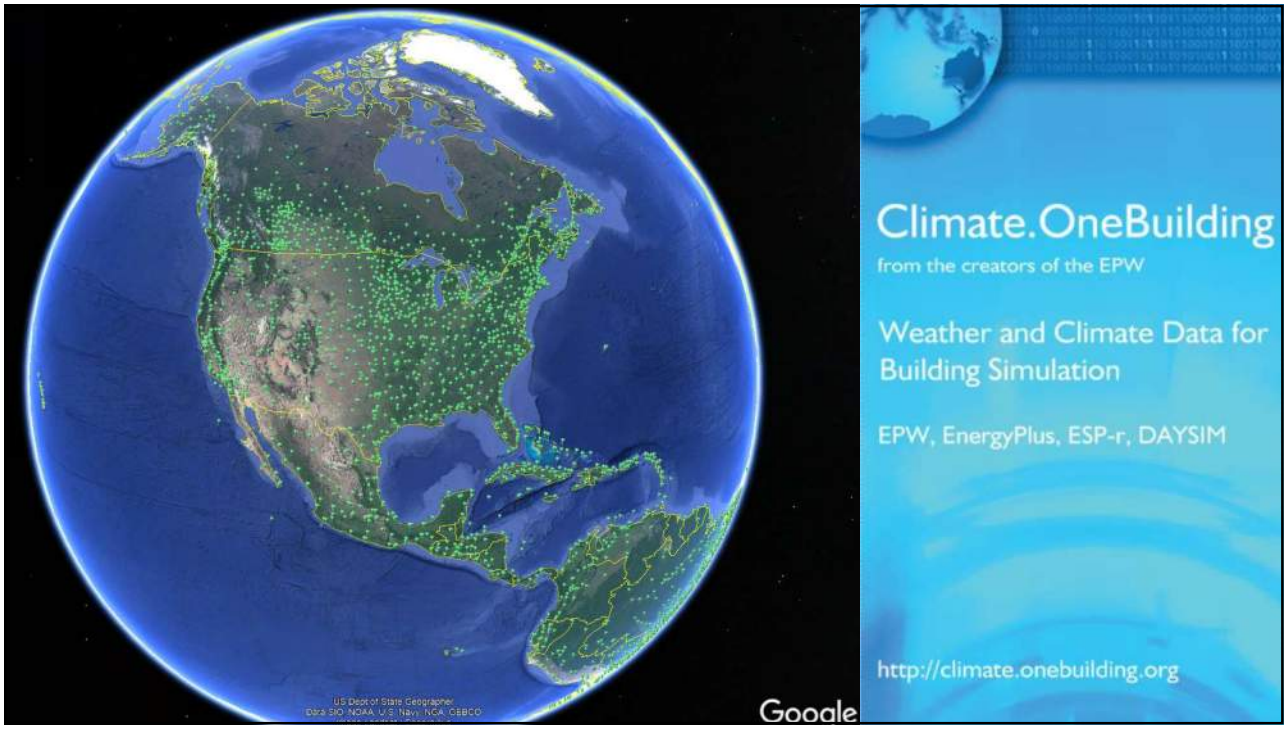

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Thank you!

Questions?

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AIA Approved | 1 LU/HSW | CRAWLEY06

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NIST 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

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IEA Annex Case studies of zero energy buildings worldwide

- Case studies:
- www.iea-ebc.org/projects/project?AnnexID=52

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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

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