Twenty-first Century Building Design: Getting to Net-Zero Energy?

National Conference of State Legislators

Paul A. Torcellini, Ph.D., PE

June 23, 2009

www.highperformancebuildings.gov
Building Energy Use

- **Buildings**: 39%
  - **Heating**: 32%
  - **Cooling**: 10%
  - **Water Heat**: 13%
  - **Lights**: 28%
  - **Other**: 4%
- **Commercial**: 18%
  - **Heating**: 16%
  - **Cooling**: 13%
  - **Water Heat**: 7%
  - **Office Equip**: 7%
  - **Ventilation**: 7%
  - **Computers**: 3%
  - **Cooking**: 2%
  - **Refrigeration**: 4%
- **Residential**: 21%
  - **Heating**: 32%
  - **Cooling**: 10%
  - **Water Heat**: 13%
  - **Lights**: 12%
  - **Other**: 10%

Source: 2004 Buildings Energy Databook with SEDS distributed to all end-uses
Trend of Commercial Sector

Commercial Sector Energy Use is Growing at 1.6% per year
Growth is faster than energy efficiency measures
The U.S. Department of Energy’s (DOE) Building Technologies (BT) Program set a goal of creating the conditions for low- and zero-energy commercial buildings (LZEBs) to be market viable by 2025.
Preface

Remember the overall vision—reduce the impact of buildings.

Today’s building’s designs mortgage the energy future of this country.
Many Pieces

So many ways to assemble the pieces

Design is about making decisions – need motivation to make the right decisions
Setting Goals

Measurable goals are better
From bad to good…

– I want a green building
– Design a LEED <rating> building
– Design a building to use 30% less energy than ASHRAE 90.1-2004
– Design a building to use less than 30,000 BTU/sqft
– Design a [NET] ZERO ENERGY BUILDING

Influencing purchasing decision—the owner
What are [Net] Zero Energy Buildings?

Conceptually, a building that has no adverse energy [or environmental] impact [because of its operation]

ZERO is not easy to define!

– Disconnect all utility interfaces?
– Net energy transfer across boundary?
– Where is the boundary?
Definitions of NZEB’s

Net Zero Site Energy
Net Zero Source Energy
Net Zero Emissions
Net Zero Energy Cost

Boundaries and metrics
Role of Efficiency vs. Renewable
The Path to a Net Zero Building

Typical 90.1 Compliant Building

- **Source Energy Savings (%):**
  - 0%
  - 100%

- **Total Annual Costs ($/year):**
  - 0
  - 500
  - 1,000
  - 1,500
  - 2,000
  - 2,500

- **Cash Flow**
- **Lease Costs (or Finance Costs)**
- **Utility Bills**
The Path to a Net Zero Building
The Path to a Net Zero Building

![Graph showing Total Annual Costs ($/year) vs. Source Energy Savings (%)]

- **Cash flow**
- **Lease Costs (or Finance Costs)**
- **Utility bills**
The Path to a Net Zero Building

- **Total Annual Costs ($/year)**
  - Lease Costs (or Finance Costs)
  - Utility bills

- **Source Energy Savings (%)**

  - 1. Cash flow
  - 2. Lease Costs (or Finance Costs)
  - 3. Utility bills
  - 4. Source Energy Savings (%)

Data from National Renewable Energy Laboratory.
Optimization Curve

Starting Point
Cost Neutral Point
Minimum Cost Point

ZEB Not Possible
Maximum Energy Savings

~3,000 Simulations
Can We Build Zero Energy Buildings?
Where we are today

Site EUI
kBtu/ft²·yr
(MJ/m²·yr)

100.0
(1,135)

90 (1020)

79.2 (900)

75.0
(852)

70.7 (803)

Existing commercial buildings (2003 CBECs)

Models of existing stock (Griffith et al. 2007)

New buildings

Base scenario (Standard 90.1-2004)

Case Study Buildings:
CBF 40 (457)

Oberlin 30 (338)

40.3 (458)

Max Tech energy efficient scenario

(284)

12.2 (139)

Max Tech energy efficient scenario w/ PV

Where we are if all buildings were built to code

Assessment potential
Need a 60 to 70 percent decrease on the Energy Consumption in commercial buildings.

Figure 4-17 Percent savings from efficiency needed to reach ZEB
EE vs. RE

Typically less energy transfers, the better
Best to use energy produced on-site, rather than exporting to another building
Roughly 60-70 percent savings from EE with 30ish percent RE
Lewis Center for Environmental Studies

13,600 sqft classroom and offices
60 kW PV system on roof
Daylighting
Ground-source Heat Pumps
Water Treatment
Natural Ventilation
The Value of Monitoring

Oberlin Lewis Center Monthly Energy Performance
January 2000 - December 2002

Daily Average Monthly Consumption and Production (kWh/day)
End Loads

- Wastewater treatment
- Elevator
- DHW
- PV system consumption
- Emergency receptacles
- Receptacles
- Parking lot lights
- Sidewalk lights
- Emergency lights
- Auditorium lights
- Indoor room lights
- Hydronic circulation pumps 3-6
- VSD Hydronic circulation pumps 1-2
- Total Lights 13%
- Total HVAC 59%
- Total Equipment 28%
- Hydronic system electric boiler
- Auditorium heat pump
- Classroom ventilation heat pump
- Auditorium energy recovery unit
- Classroom energy recovery unit
NREL Thermal Test Facility (TTF)

10,000 sqft Laboratory and Office
Typical steel frame building
Good insulation package
Simple daylighting design
Loads Example

- Lighting: 57.0%
- Plug Loads: 22.0%
- Exterior Lights: 4.2%
- Hot Water: 1.1%
- Heating: 4.0%
- Cooling: 8.3%
- Fans/Pumps: 4.6%

Savings: 52.9%

Final Design:
- Plug Loads: 22.0%
- Exterior Lights: 4.2%
- Hot Water: 1.1%
- Heating: 4.0%
- Cooling: 1.6%
- Lighting: 12.1%
- Fans/Pumps: 1.8%

72% savings excluding plug loads and exterior lights
Zion National Park
Visitor Center
All the Pieces Fit Together

Daylighting
Operable Windows
Overhangs
Projects: Habitat for Humanity ZEB

Daily and Cumulative Net Electricity Use
February 2006 - March 2007

Daily net kWh used
(A negative number indicates net production)

Cumulative net kWh used

Blizzards
It is Really About the Details

Combinations of lots of little things that cause buildings to use energy

Conceptually, low-energy buildings can be done—fail on the details

Difference between expectations and actual operation?
Where Are the Issues?

Envelope
Windows
Lighting Systems (Including Daylighting)
Electrical Systems
Plug Loads
Photovoltaic Systems
HVAC Systems
High-Performance Buildings Database

Share successes and lessons learned about projects
Public database
Actual Energy Information
FEMP, USGBC, AIA, DOE all have “front ends”
A special section for ZEB’s.
www.highperformancebuildings.gov
Ending Thoughts…

Zero takes a coordinated effort with the architect and the engineering.

The little things make the difference in getting to zero (as you get to zero, little is significant).

The owner needs to set measurable goals and communicate these goals to the design team.

The solution is not bigger supplies.
Questions?

www.highperformancebuildings.gov