Energy Efficient Design

Rachel Wagner, Wagner Zaun Architecture

U.S. DOE
Energy Codes 2008
Conference
23 July 2008
St. Paul, MN

This presentation is protected by US and International copyright laws.
Reproduction, distribution, display and use of the presentation
without written permission of the speaker is prohibited. ©

Wagner Zaun
Architecture

Presentation Outline

- Buildings and Energy: Background and Context
- Where and How Residential Buildings Use Energy
- Building Energy Codes: Why and How?
- Defining Energy Efficiency
- Building with Regard to Energy Efficiency
- Recommendations for Policy and Practice

Buildings and Energy

- Building operation accounts for almost 40% of all energy use in the U.S. and almost 40% of all CO2 emissions.

- Commercial Sector: 18%
- Residential Sector: 21%
- Industrial Sector: 28%
- Transportation Sector: 33%

Source: U.S. Energy Information Administration www.eia.doe.gov

Buildings, Energy, and CO2

- CO2 emissions from energy use are rising, most notably from the use of coal and natural gas.
- Residential energy-related CO2 emissions grew 4.4% in 2006-2007, more than any other sector
- The largest growth in energy-related CO2 emissions in homes is for electricity use.
- CO2 emissions from petroleum use fell in 2007.

Source: U.S. Energy Information Administration www.eia.doe.gov

Energy Use: Residential Buildings

- 85% of all energy use in the U.S. comes from non-renewable fossil fuels
- In the residential sector, about 95% of all energy use comes from non-renewable fossil fuels
  - Electricity
  - Natural Gas
  - Fuel Oil
  - Propane

Source: U.S. Energy Information Administration www.eia.doe.gov

Where do houses use energy?

- More than 50% is used for space heating and air conditioning combined
- In cold climates (like MN), more than 60% is used for space heating alone
- About 16% is used for water heating
- About 4-5% is used for refrigeration
- About 20-23% for appliances and lighting

Source: U.S. Energy Information Administration www.eia.doe.gov

Where do houses lose energy?

- Thermal Bridges
- Lack of Insulation
- Air Leakage
- Inefficient Appliances

Reduced Loss = Reduced Use

- The biggest energy load is space heating
- The biggest energy losses are in the envelope
  - Thermal Resistance
  - Air Leakage
- Reduce the envelope losses and the result is to reduce the energy required for heating

Building Codes

- Establishing Guidelines for Energy Use
- Codes typically set a minimum standard to preserve something:
  - Occupant Life
  - Occupant Safety
  - Building Durability
  - Occupant Health
  - Operational Viability

Building Energy Codes - IECC

International Energy **Conservation** Code

"Internationally, code officials recognize the need for a modern, up-to-date energy conservation code addressing the design of energy-efficient building envelopes and installation of energy efficient mechanical, lighting and power systems through requirements emphasizing performance."

The IECC … "is designed to meet these needs through model code regulations that will result in the optimal utilization of fossil fuel and nondepletable resources in all communities, large and small."

Source:
2006 International Energy Conservation Code; Copyright 2006 by the International Code Council, Inc.

Building Energy Codes

IECC sets “code regulations that will result in the optimal utilization of fossil fuel and nondepletable resources in all communities”

But …

How is “optimal utilization” defined?

Defining Energy Efficiency

The Code itself states that it establishes "minimum regulations for energy efficient buildings" …

Can the code alone be both minimum regulations and also result in optimal utilization of resources?

Defining Long-term Energy Use

- 81 million buildings in the U.S.
- 107 million households
- Household needs regarding energy:
  - Ability to maintain comfort
  - Ability to cook and store food
  - Ability to wash
  - Affordable to do the above list

Current Circumstances

2004:

- Oil $50/barrel

1999-2006:

- Price of residential natural gas doubles

2007:

- Oil hits $100/barrel
- Biggest single-year increase in greenhouse gas emissions from U.S. Power Plants

2008:

- Oil $140/barrel
- Rapid price increases in fuel oil and natural gas
- Fuel switching stresses availability and infrastructure

Energy Efficiency – How Much?

- In the face of current circumstances, Energy Star for buildings is not optimal.
- 15% better than the 2004 IECC is not optimal.
- The 2006 IECC is not optimal.
- 30% better than the 2006 IECC is also not optimal.
- Or sustainable.

Defining Energy Efficiency Today

- Indicators regarding climate change, fuel scarcity, and rising costs suggest that anything built today should use a maximum of ½ the energy of that which we built yesterday.

Building with Regard to Energy

- Primary Impacts
  - Building Size and Form
  - Envelope design and construction
  - Climate
  - Energy Source/Fuel type chosen
- Secondary Impacts
  - Mechanical means to meet energy loads
  - Passive means to meet energy loads

Building with Regard to Energy

- Some pieces are more easily changed and modified over time than others
- Incremental improvements in energy efficiency make sense only in systems that can and will be changed in concert with the incremental planning:
  - Water heating
  - Heating and cooling equipment
  - Lighting and appliances

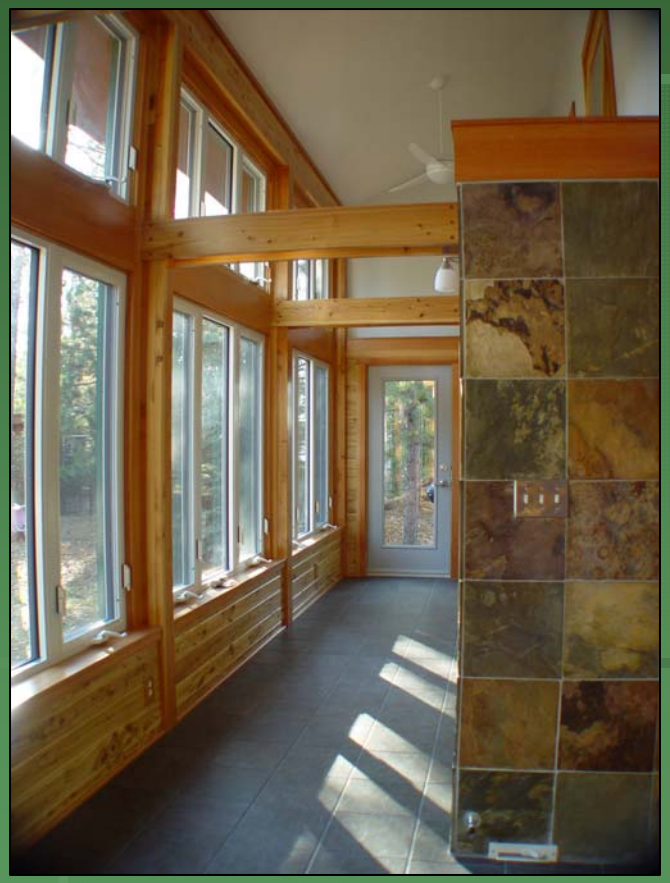
Building with Regard to Energy

Design Strategies to Maintain Comfort

minimize the need for non-renewable fossil fuels:

- Passive solar design
- Super-insulated building envelope
- Efficient plumbing/mechanical design
- An ability to heat and cook with wood or other renewable sources
- Air-tight construction
- High-efficiency mechanical ventilation
- Targets for energy consumption
- Energy modeling used to reach targets

Passive Solar Design Strategies



South Glazing calculated with regard to floor area, space plan, glazing type, and thermal mass.

Passive Solar Design Strategies

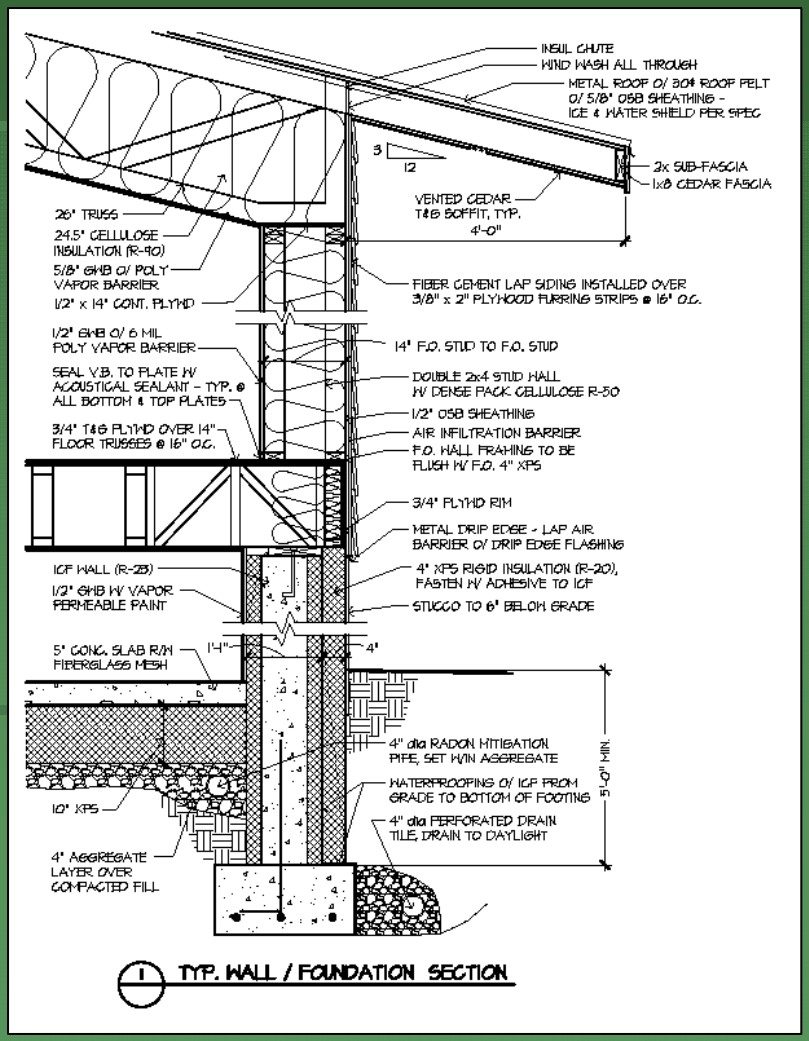
- Roof overhangs or awnings to let in winter sun and keep out summer sun
- Minimize north and west windows
- Place windows to facilitate cross ventilation
- South glazing with a relevant SHGC and U-value that allows retention of solar heat gained

Super-Insulated Building Envelope

Defining the Thermal Boundaries

- Ground Slab or Basement Slab
- Foundation Walls or Edges
- Exterior Walls
- Windows
- Rim Areas
- Ceiling/Roof
- Thermal Bridges
- Penetrations to the Envelope

Super-Insulated Building Envelope



Super-Insulated Building Envelope

Feature	Description
Foundation Walls	ICF with 8” total expanded polystyrene (R-40)
Lower Level Slab	5” poured concrete over 8-12” expanded polystyrene foam insulation
Floor Framing	14” parallel chord truss
Rim Insulation	9” spray urethane foam (2lb/cu. Ft.) or cellulose with XPS blocking
Framed Walls	Double 2 x 4 16” O.C. with 7” space between (14” total thickness)
Wall Insulation	Dense pack cellulose (R-53)
Windows	Triple Pane Double Low E Double Argon Fill w/ Fiberglass Frame
South glazing	Overall unit U-value 0.20, SHGC 0.5
North, east, west glazing	Overall unit U-value 0.17, SHGC 0.3
Roof Framing	26” parallel chord truss
Roof Insulation	24.5” blown cellulose with continuous vent chutes (R-88)
Interior Vapor Barrier	6 mil polyethylene with overlapped, caulked and taped seams
Exterior Air Barrier	House wrap with taped seams
Exterior Siding	5” lap fiber cement over furring strips
Finished Roof	Standing seam painted steel, vented

Building with Regard to Energy

Plumbing and Mechanical Systems Design

- Simplify plumbing layouts
- Minimize water runs
- Create a utility “core”
- Consider the life of the plant
- Consider the life of the distribution systems

Hybrid Systems offer flexibility and integration

Hybrid Mechanical Systems

- Fuel flexibility
- Integration of renewable and non-renewable
- Climate Specific
- Seasonally adjustable

Air Tightness and Ventilation

- Climate Specific
- Seasonally adjustable
- Natural Ventilation with controlled heat loss
- Air tight envelope construction
- Mechanical Ventilation Controls Air Quality and Energy Use

Targeting Energy Consumption

- Using percentages, i.e. 50% better, doesn't tell you how much energy a building uses
- The HERS Index doesn't tell you this either
- Energy Use needs to be measured like mpg
- Code (IECC) doesn't regulate energy consumption or air tightness
  - What is "optimal?"

Quantifying Energy Consumption

- Energy modeling software programs measure heat loss, heat gain, energy usage
- Energy loss or gain is quantified by envelope component and air tightness
- Targets are developed and verified
- Quantifies
  - Infiltration
  - Ventilation
  - Thermal resistance and thermal bridging
  - Passive Solar gain

Mpg = kBtu/sf annual energy

- Converts all energy consumed on the site to kBtu's per square foot annually
  - Can also use source energy
- Electricity is usually kWh
- Heating is usually kBtu or Therms
- Cooling with electricity is usually kWh
- Domestic hot water varies

- 1 kWh = 3.412 kBtu
- 1 Therm = 100 kBtu (or 100,000 Btu)

Mpg = kBtu/sf annual site energy

- According to the EIA average household mpg for detached single family homes is 44.7 kBtu/sf annually
- My house, c. 1906, has a total site energy mpg of 43.2 kBtu/sf annual

- According to the EIA, average household space heating mpg for detached single family home is 24.9 kBtu/sf annually
- My house, c. 1906, has a heating mpg of 29.6 kBtu/sf annual

Space Heating Mpg = kBtu/sf ann

- In heating dominated climates, heating alone will usually account for more than ½ the total household site energy used
- "Space Heating Mpg" gives a useful relative scale to compare the envelope and heating systems efficiencies

- Passive House heating mpg = 4.75 kBtu/sf annual (less than 20% of U.S. average mpg)

Heating Mpg

14.3 kBtu/sf ann

12.6 kBtu/sf ann

25.3 kBtu/sf ann

7.3 kBtu/sf ann

Improving Policy and Practice

- Current Policy: IECC 2006
- Is 30% better than IECC 2006 an appropriate response to current and predicted conditions?
- Do the math.
- Policymakers recommendations are not in line with experts' research and recommendations, and with recent legislative actions.

Recommended Practice

BUILDINGS LAST.

- Based on current knowledge and experts' predictions about climate change and resource availability, what we build now should use 50% less energy at a maximum, and fairly soon should use 80-90% less energy from non-renewable fossil fuel resources.

Improving Policy and Practice

Duluth Home Heating Energy Comparison

	heating mpg	% of code
Code	49 kBtu/sf ann	100%
Eco-Home	14.3 kBtu/sf ann	30%
Willard	12.5 kBtu/sf ann	26%
Skyline	7.3 kBtu/sf ann	15%
L-N Retrofit	22.6 kBtu/sf ann	46%
Passive House	4.75 kBtu/sf ann	10%

Possible Drivers of Policy Change

- Carbon Cap and Trade
- Legislative Actions
- architecture2030.org
- Passive House (www.passivehouse.us)
- Rigorous and honest governmental study and action
- Public Opinion and Outcry

Possible Drivers of Policy Change

U.S. EPA Pilot Program:

"Climate Choice Advanced New Home Construction"

- Analysis is climate specific
- Compares construction to 2006 IECC and to current Energy Star, including measurement of:
  - Associated CO2 emissions reductions
  - HERS Index
  - Total site energy in kBtu/sf annual
  - Modeled results show about half the total energy use (and emissions) of 2006 IECC construction

2030 CHALLENGE Targets: Residential Regional Averages

U.S. Regional Averages for Site Energy Use and 2030 Challenge Energy Reduction Targets by Residentail Space/Building Type (RECS 2001)[1]

From the Environmental Protection Agency (EPA): Use this chart to find the site fossil-fuel energy targets.

Residential Space/Building Type[2]	Average Source EUI[3,4] (kBtu/Sq.Ft./Yr)	Average Site EUI[3,5] (kBtu/Sq.Ft./Yr)	2030 Challenge Site EUI Targets (kBtu/Sq.Ft./Yr)				
			50% Target	60% Target	70% Target	80% Target	90% Target
Midwest							
Single-Family Detached	76.2	49.5	**24.7**	19.8	14.8	9.9	4.9
Single-Family Attached	66.6	44.8	**22.4**	17.9	13.4	9.0	4.5
Multi-Family, 2 to 4 units	104.8	74.0	**37.0**	29.6	22.2	14.8	7.4
Multi-Family, 5 or more units	93.3	50.9	**25.4**	20.4	15.3	10.2	5.1
Mobile Homes	168.9	103.3	**51.6**	41.3	31.0	20.7	10.3

Notes

1. This table presents values calculated from the Energy Information Administration in the Residential Energy Consumption Survey (RECS), conducted in 2001. The survey data is available on the EIA's website at http://www.eia.doe.gov/emeu/recs/recs2001/detailcetbls.html.
2. Space/Building Type use descriptions are taken from valid building activities as defined by the Energy Information Administration in the Residential Energy Consumption Survey (RECS), conducted in 2001.
3. The average Source EUI and Site EUI are calculated in kBtu/Sq.Ft./Yr as weighted averages across all buildings of a given space type in the RECS 2001 data set. Souce Energy is a measure that accounts for the energy consumed on site and the energy consumed during generation and transmission in supplying energy to the site.
   Converting Site to Source Energy:
   Source Energy values are calculated using a conversion for electricity of 1 kBtu Site Energy = 3.013 kBtu Source Energy; a conversion for natural gas of 1 kBtu Site Energy = 1.024 kBtu Source Energy; and a 1:1 conversion for fuel oil and district heat.
4. Energy Information Administration (EIA), U.S. Residential Energy Intensity Using Weather-Adjusted Primary Energy by Census Region and Type of Housing Unit, 1980-2001, Table 8c.
5. Energy Information Administration (EIA), U.S. Residential Energy Intensity Using Weather-Adjusted Site Energy by Census Region and Type of Housing Unit, 1980-2001, Table 6c.

EUI: Energy Use Intensity

Architecture 2030 Residential Targets – Midwest Region

Recommended Policy

Proposed New Code Requirements:

- Minimum building air tightness
  - Cfm/sf@50 Pascals or ACH @50 Pascals
- Performance Path with a maximum allowable modeled annual energy load for heating and cooling (kBtu/sf) and Prescriptive Path based on the same allowable modeled annual energy load

Recommended Practice

How should we build?

- Understand the building's function.
- Maximize use of the sun.
- Do the math.
- Know how much energy the building requires to maintain comfort.
- Design systems of Energy Flexibility.

Recommended Practice

How should we build?

- Maximize the efficiency of the things we know how to control for the long term (*the envelope*), keeping in mind the longevity of buildings and the certainty of changes in fossil fuel availability.

Sometimes you have to be BOLD

Dilbert, by Scott Adams 2007 www.dilbert.com

Climate change and resource depletion require conservation measures in all sectors unheard of in the history of our energy-intensive culture. Buildings are the one thing we know how to fix right now, with no new or undeveloped technologies.

We only need the will to do it.

Wagner Zaun
Architecture

17 N Lake Avenue
Duluth, MN 55802
218.730.0690
www.wagnerzaun.com