Energy Efficient Design

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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 CO_2 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 CO_2

- CO_2 emissions from energy use are rising, most notably from the use of coal and natural gas.
- Residential energy-related CO_2 emissions grew 4.4% in 2006-2007, more than any other sector
- The largest growth in energy-related CO_2 emissions in homes is for electricity use.
- CO_2 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

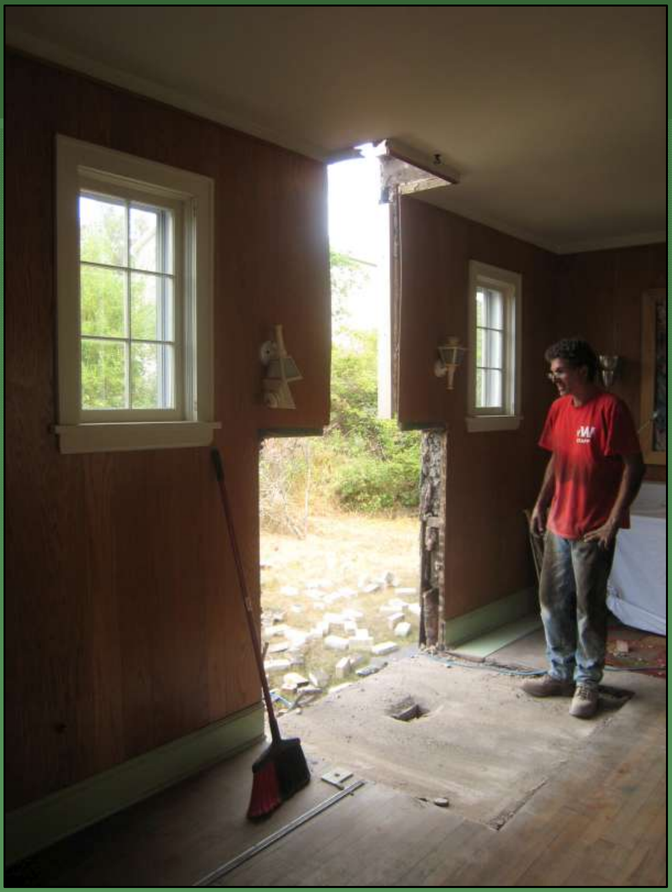
Source: U.S. Energy Information Administration www.eia.doe.gov

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

uilding 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."

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

efining Energy Efficiency

he Code itself states that it establishes minimum regulations for energy efficient uildings" …

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

efining 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

urrent Circumstances

04:

Oil $50/barrel

99-2006:

Price of residential natural gas doubles

07:

Oil hits $100/barrel

Biggest single-year increase in greenhouse gas emissions from U.S. Power Plants

08:

Oil $140/barrel

Rapid price increases in fuel oil and natural gas

Fuel switching stresses availability and infrastructure

nergy Efficiency – How Much?

n the face of current circumstances, Energy Star for buildings is not optimal.

5% 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.

efining Energy Efficiency Today

ndicators regarding climate change, uel scarcity, and rising costs suggest hat anything built today should use a naximum of ½ the energy of that vhich we built yesterday.

uilding 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

uilding with Regard to Energy

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

uilding 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

assive Solar Design Strategies

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

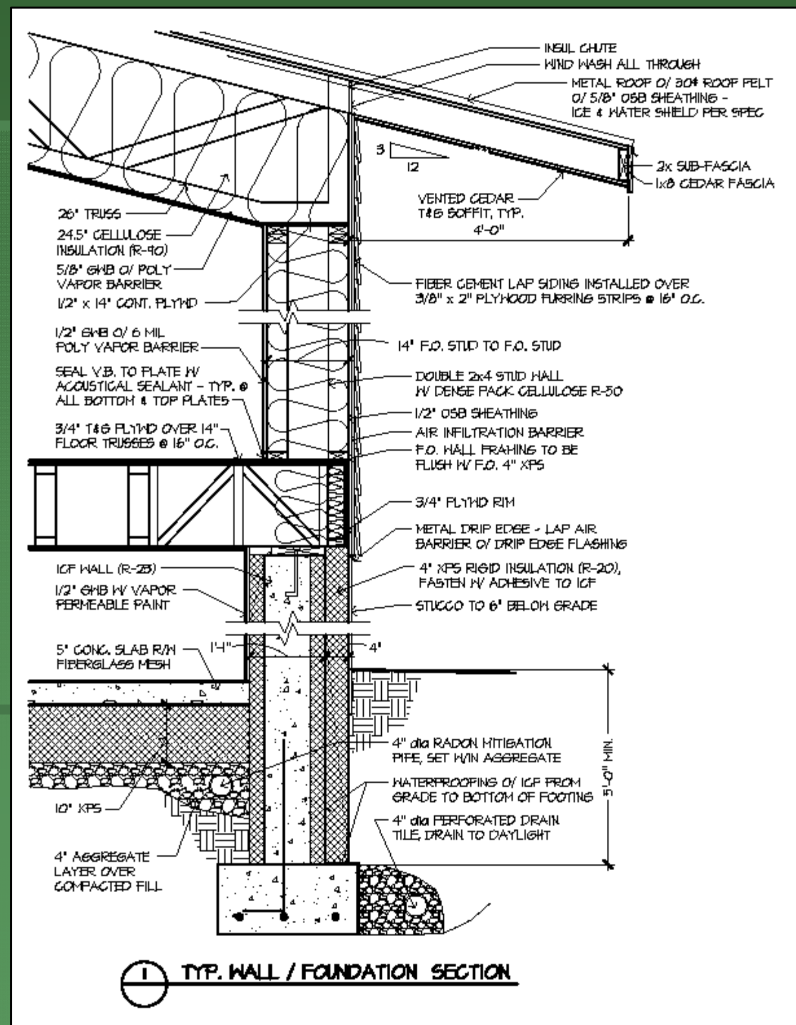
Passive Solar Design Strategies

- 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

uper-Insulated Building Envelope

- efining 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

uper-Insulated Building Envelope



uper-Insulated Building Envelope

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

uilding with Regard to Energy

umbing 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

ybrid Systems offer flexibility and integration

ybrid Mechanical Systems

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

ir 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

rgeting Energy Consumption

- Using percentages, i.e. 50% better, doesn't ell 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?"

uantifying Energy Consumption

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

lpg = 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)

lpg = 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

pace Heating Mpg = kBtu/sf ann

n 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

nproving Policy and Practice

Current Policy: IECC 2006

s 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.

ecommended Practice

UILDINGS 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.

nproving Policy and Practice

uluth 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%

ossible 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

ossible Drivers of Policy Change

. EPA Pilot Program:

mate Choice Advanced New Home Construction"

nalysis is climate specific

ompares construction to 2006 IECC and to urrent 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

chitecture 2030 Residential Targets – Midwest Region

ecommended 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

ecommended Practice

low 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.

ecommended Practice

ow 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.

ometimes 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.

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